Ethiopian Journal of Environmental Studies & Management 15(4): 532 – 545, 2022
ISSN:1998-0507 doi: https://ejesm.org/doi/v15i4.10
Submitted: June 16, 2022 Accepted: August 8, 2022

NITRATE AND NITRITE IN WATER WITHIN ANKA ARTISANAL MINING SITE, NIGERIA: CONTAMINATION AND HUMAN HEALTH RISK ASSESSMENT

ADEWUMI, A.J.
Department of Geological Sciences, Achievers University, PMB 1030, Owo, Ondo State, Nigeria
Email: adewumiadeniyi27@achievers.edu.ng

Abstract
This study evaluated the health risks associated with nitrate and nitrite in water of Anka artisanal mining area. 104 water samples were obtained in both the dry and rainy seasons using standard methods. Inductively Coupled Plasma-Optical Emission Spectrometer (ICP-OES) was used to estimate the concentrations of NO_3 and NO_2. The single pollution index (SPI) and the Nemerow Pollution Index (NPI) were used to evaluate the extent of contamination. The approach given by the USEPA was used to calculate non-carcinogenic health risks. During the dry season, the average concentrations of NO_3 and NO_2 in groundwater in the area were 298.70 mg/L and 0.87 mg/L, respectively, whereas during the rainy season, they were 64.34 mg/L and 9.16 mg/L. During the dry season, the mean values of NO_3 and NO_2 in surface water were 71.99 mg/L and 8.13 mg/L respectively, while during the wet season, they were 71.79 mg/L and 8.24 mg/L. Infants are more susceptible to non-carcinogenic health concerns linked with NO_3 and NO_2 in water from this area, according to a health risk assessment. To avoid health hazards connected with nitrate and nitrite, it is advised that mining activities in the vicinity be closely monitored.

Key Words: *Anka, Nitrate, Nitrite, Non-carcinogenic health risks, Water pollution*

Introduction

Water is important for the bulk of people living in developing nations like Nigeria (Adewumi and Anifowose, 2017). The growth of Africa have resulted in an increase in industry and a monetary flow (Mendes *et al.*, 2014). Minerals are the bedrocks of every country's conservative development (Dubiski 2013). Metals are important parts of these minerals, which are released into the environment either by human or natural processes, or both (Adewumi *et al.*, 2020a). Mineral exploitation are human activities that contribute to water contamination across the world which may pose serious health risk (Dubiski 2013; Adewumi *et al.*, 2020b; Laniyan and Adewumi, 2019).

Nitrate (NO_3) is naturally present as part of the nitrogen cycle, although increasing concentrations in water are linked to horticulture cycles (Rankinen *et al.*, 2007). Other sources are sewage frameworks, releasing sewers, creature care, and elevated air N testimonies (WHO 2017). Nitrate levels in water are rising on a global basis, particularly in periurban areas (Ducci *et al.,* 2017). Use of NPK manures is an important source of water NO_3 in Nigeria (Makinde *et al.*, 2011). Suhalite for example, have NH_3 in its mineral cross section, which may be microbially converted to NO_3 when degraded (Holloway and Smith, 2005).

Human health risk assessment is a method for determining the type and likelihood of negative health effects in persons who may be exposed to synthetic substances in polluted environmental media now or in the future. Many research have employed this technique to uncover the possible health concerns associated with toxic metals in water, including those in Iran (Alidadi *et al.*, 2019), Ethiopia (Meseret *et al.*, 2020), Nigeria (Adewumi and Laniyan, 2021), and China (Jiao *et al.,* 2018).

There has been no research conducted to establish the extent of pollution and health risks associated with nitrate and nitrite in water in several gold mining sites in the Anka area of northwest Nigeria. This research examines the dispersion and human risks associated with nitrate and nitrite, as well as the human health risks of various groups. The findings of this investigation will be used to alert government officials and residents in the mining region about nitrate pollution in water, as well as human health risks. It will also aid in the management of water and pollution prevention.

Materials and methods

Study Area

Anka is located in Zamfara State, Northwestern Nigeria on longitude 12°15'27.05"N and latitude 5°51'27.01"E (Figure 1). This district is characterized by high and undulating geography with elevation of 420m above sea level. The tropical climatic conditions common here (Adejuwon, 2012). The mean precipitation is 71.83mm (Figure 2). The chief rocks in this area are the Precambrian migmatitic-gneisses and metasediments of the Anka Schist Belt (Danbatta *et al.*, 2009) (Figure 1). The orientation of lineaments in this space were NNE–SSW, NE–SW, and NW–SE and are associated with the Pan-African Orogeny (Adewumi *et al.* 2017).

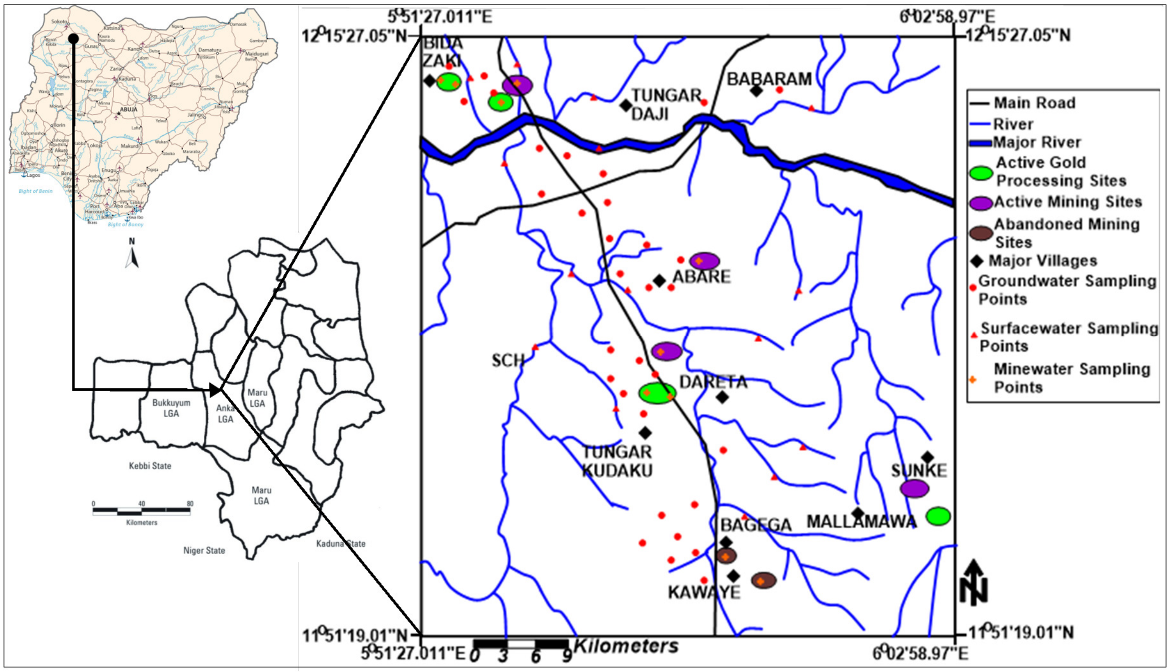

Fig. 1: Map of the Study Area

Sample Collection and Laboratory Analysis

All samples were collected following the method used by Naveedullah *et al.* (2014) during dry season and wet periods of 2017. For this study, a total of 64 groundwater, 30 surface water and 10 mine water were collected. (Figure 1). The pH, temperature and electrical conductivity (EC), total dissolved solids (TDS) and total hardness (TH) of water samples was recorded *in-situ* using PCS Fester TM35 series following Naveedullah *et al.* (2014). The amount of nitrate and nitrite in the samples were unravel employing Agilent 7700 series High Performance Liquid Chromatography–Inductively Coupled Plasma-Optical Emission Spectrometry (HPLC–ICP-OES) at the Institute of Geochemistry, Chinese Academy of Sciences, Guiyang, China.

Contamination Assessment

Single-factor pollution index (*SPI*) and Nemerow Pollution Index (NPI) for contamination assessment were calculated utilizing the Zhong *et al.* (2015) techniques.

Human Health Risk Assessment

Human health risk assessment of nitrate and nitrite in water of the study area are evaluated following the methods of Gao *et al.* (2020). Equations 1 and 2 were used to calculate the chronic daily intake (CDI) and daily absorbed dose (DAD). Table 1 show the reference doses for nitrate.

$$CDI = \frac{C_W \times DI \times EF \times ED}{BW \times AT} \quad (1)$$

where CDI is the chronic daily intake, mg/kg per day; CW is the contaminant concentration in the water, mg/L; DI is the daily intake of water, L/day; EF is the exposure frequency, days/year; ED is the average exposure duration in a lifetime, a/lifetime; BW is the average body weight, kg; and AT is the averaging time (AT = EF ∗ ED), days.

$$DAD = \frac{C_W \times K_i \times SA \times EF \times ED \times EV \times CF}{BW \times AT} \qquad (2)$$

where DAD is the everyday consumed portion, mg/kg each day; Ki is the dermal adsorption boundary, cm/h; SA is the skin surface region accessible for contact, cm^2/occasion; EV is the washing recurrence, times/day.

The danger rest of the drinking water pathway can be dictated by equations 3.

$$HQ_0 = \frac{CDI}{Rf_o} \qquad (3)$$

where HQ_0 is the non-cancer causing hazard remainder which is unitless and Rfo is the nitrate reference part, mg/kg day. The equation for the danger remainder of the dermal contact pathway is according to equation 4.

$$HQ_d = \frac{DAD}{Rf_d} \qquad (4)$$

where HQ_d is the non-cancer-causing peril remainder of the dermal contact pathway, unitless; RfDd is the nitrate reference portion of the dermal contact pathway, mg/kg/day. Equation for surveying the all danger remainder for the health risk assessment presented in equation 5.

$$HD = HQ_0 + HQ_d \qquad (5)$$

Table 1: Parameters utilized for the human health risk assessment

Parameter	**Group Value**				**Units**
	Adult Males	Adult Females	Children	Infants	
DI	2.75[a]	2.50[a]	1.50[a]	0.65[b]	L/day
EF	365[c]	365[c]	365[c]	365[c]	Days/Year
ED	30[b]	30[b]	16.50[c]	0.50[c]	Years
BW	72.42[d]	62.26[d]	36.66[d]	92.70[d]	kg
BH	169.22[d]	157.66[d]	132.22[d]	70.44[d]	cm
AT	10950[c]	10950[c]	6023c	183c	Days
K	0.001[e]	0.001[e]	0.001[e]	0.001[e]	cm/h
SA	17900[c]	16000[c]	11400[c]	4200[c]	cm^2
EV	1.00[e]	1.00[e]	1.00[e]	1.00[e]	times/day
CF	0.001[e]	0.001[e]	0.001[e]	0.001[e]	L/cm^3

[a]Zhai *et al.* (2017); [b] Su *et al.* (2013); [c]Gao *et al.* (2020); [d] CHNS (2014); [e]Yang *et al.* (2012)

Gatherings and Dataset

As indicated by the diverse conduct and physiological attributes of individuals in the study region, individuals were isolated into four gatherings: babies (age ≤ a half year), kids (a half year < age ≤ 17 years of age), grown-up guys (> 18 years of age), and grown-up females (> 18 years of age). Meanwhile, the EFs of the wet and dry seasons were secluded into 125 days/year and 240 days/year, independently (Gao *et al.,* 2020). Table 1 shows the limits used to register the danger remainders of the drinking water and dermal contact pathways.

Data Analysis

Data Analysis of data was carried out using SPSS 21.0 version. Descriptive analysis including minimum, maximum, average and standard error mean (SEM) and coefficient of variance were used to analyze all the data. T-test were carried out to understand the significance of data obtained from physico-chemical parameters.

Results and Discussion

Physicochemical Parameters in Water

Physicochemical properties in water of the study are presented in Table 2. During the dry season, the average concentration of pH, temperature, EC, TDS, TH, NO_3 and NO_2 in groundwater of the area are 6.84, 24.84ºC, 566.53 µS/cm, 550.28 mg/L, 67.37 mg/L, 298.70 mg/L and 0.87 mg/L respectively while during the wet season it was 7.05, 26.58ºC, 696.41 µS/cm, 739.78 mg/L, 52.47 mg/L, 64.34 mg/L and 9.16 mg/L. During the dry season, the average concentration of pH, temperature, EC, TDS, TH, NO_3 and NO_2 in surfacewater of the area are 6.58, 26.00ºC, 656.80 µS/cm, 707.33 mg/L, 28.81 mg/L, 71.99 mg/L and 8.13 mg/L respectively while during the wet season it was 6.68, 26.80ºC, 657.92 µS/cm, 622.15 mg/L, 35.46 mg/L, 71.79 mg/L and 8.24 mg/L (Figures 2 and 3). For minewater, the concentration of pH, temperature, EC, TDS, TH, NO_3 and NO_2 it was 6.73, 26.30ºC, 644.20 µS/cm, 626.30 mg/L, 36.21 mg/L, 72.92 mg/L and 7.74 mg/L respectively (Table 2). Groundwater around Kawaye had more than 300 mg/l of nitrate during the dry season while surface water around Bida Zaki have nitrate concentration higher than 300 mg/l during the same season (Figure 2). Nitrate in water samples were above the recommended limit, while it was lesser than the recommended limits in groundwater during the dry season. NO_2 in water during the wet season and surface water during the dry season were above the acceptable limits (Table 2).

Table 2: Descriptive Statistics of Physicochemical Parameters in Groundwater, Surfacewater and Minewater in the Study Area

		Dry Season							**Wet Season**						
		pH	Temp. (°C)	EC (µS/cm)	TDS (mg/L)	TH (mg/L)	NO_3 (mg/L)	NO_2 (mg/L)	pH	Temp. (°C)	EC (µS/cm)	TDS (mg/L)	TH (mg/L)	NO_3 (mg/L)	NO_2 (mg/L)
Ground water	Minimum	6.33	22.00	210.00	212.00	8.87	12.11	0.19	6.12	22.00	534.00	560.00	12.80	20.68	6.54
	Maximum	7.65	28.00	980.00	957.00	147.08	845.00	6.40	7.87	28.78	872.00	980.00	288.62	357.36	12.49
	Avg.	6.84	24.84	566.53	550.28	67.37	298.70	0.87	7.05	26.58	696.41	739.78	52.47	64.34	9.16
	±SEM	±0.06	±0.24	±34.14	±5.05	±0.06	±43.09	±0.28	±0.09	±0.31	±16.81	±20.73	±10.29	±0.06	±0.06
	CV	4.78	5.42	34.09	37.58	42.44	135.41	37.67	7.29	6.58	13.65	15.85	108.89	90.47	1588
	P-Value	p<0.01	p<0.01	p<0.01	p<0.01	p<0.01	p<0.01	p<0.01	p<0.01	p<0.01	p<0.01	p<0.01	p<0.01	p<0.01	p<0.01
Surface water	Minimum	6.12	24.00	543.00	489.00	12.14	18.37	6.91	6.29	25.70	458.00	497.00	6.29	54.08	6.55
	Maximum	6.89	29.00	880.00	875.00	66.74	115.79	9.64	7.38	29.70	804.00	784.00	95.83	93.16	9.61
	Avg.	6.58	26.00	656.80	707.33	28.81	71.99	8.13	6.68	26.80	657.92	622.15	35.46	71.79	8.24
	±SEM	±0.06	±0.42	±25.37	±27.93	±3.47	±6.32	±0.24	±0.10	±0.42	±25.46	±25.93	±6.14	±3.01	±0.66
	CV	4.08	6.01	14.96	15.29	46.66	33.99	11.53	5.42	4.74	13.95	15.02	62.42	15.14	11.69
	P-Value	p<0.01	p<0.01	p<0.01	p<0.01	p<0.01	p<0.01	p<0.01	p<0.01	p<0.01	p<0.01	p<0.01	p<0.01	p<0.01	p<0.01
Mine water	Minimum	-	-	-	-	-	-	-	6.00	24.00	348.00	457.00	15.14	54.97	6.58
	Maximum	-	-	-	-	-	-	-	8.00	28.00	876.00	869.00	75.14	102.14	8.65
	Avg.	-	-	-	-	-	-	-	6.73	26.30	644.20	626.30	36.21	72.92	7.74
	±SEM								±0.17	±0.44	±54.19	±35.55	±0.44	±4.68	±0.23
	CV	-	-	-	-	-	-	-	8.86	5.39	26.59	17.95	50.51	20.31	9.54
	P-Value	-	-	-	-	-	-	-	p<0.01	p<0.01	p<0.01	p<0.01	p<0.01	p<0.01	p<0.01
	WHO (2018)	6.5-8.5	-	1000.00	447.90	-	50.00	1.00	6.5-8.5	-	1000.00	447.90	-	50.00	1.00
	NSDWQ (2008)	6.5-8.5	-	-	500.00	-	50.00	0.20	6.5-8.5	-	-	500.00	-	50.00	0.20
	Nigeria[a]						44.00							44.00	
	China[b]	-	-	-	-	-	66.55	-	-	-	-	-	-	58.13	-
	India[c]	7.42	-	1406.00	954.00	-	83.45	-	7.42	-	1406.00	954.00	-	83.45	-
	Jordan[d]	7.65	-	790.83	593.12	345.40	45.75	-	7.65	-	790.83	593.12	345.40	45.75	-
	Iran[e]	7.79	14.50	496.66	435.33	-	14.32	-	7.79	14.50	496.66	435.33	-	14.32	-
	South Africa[f]	-	-	-	940.00	-	92.93	-	-	-	-	940.00	-	92.93	-

[a]Adelana *et al.* (2003); [b]Gao *et al.* (2020); [c]Adimalla *et al.* (2020); [d]Obeidat *et al.* (2012); [e] Fathi *et al.* (2018); [f] Bosman (2009)

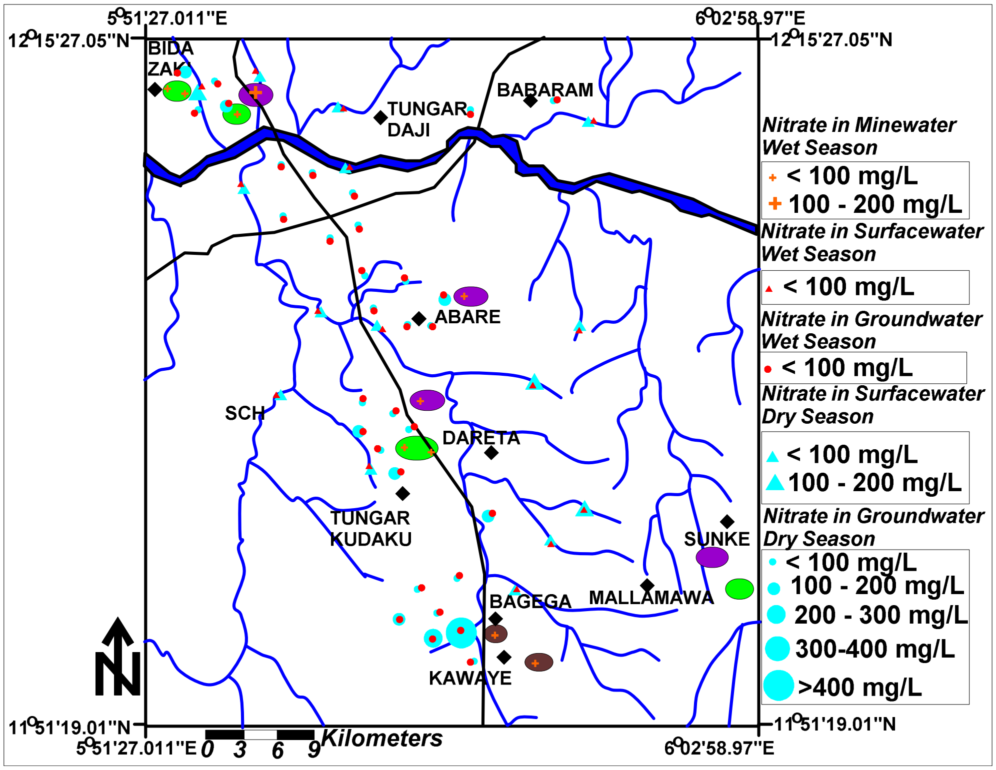

Fig. 2: Distribution of nitrate in water

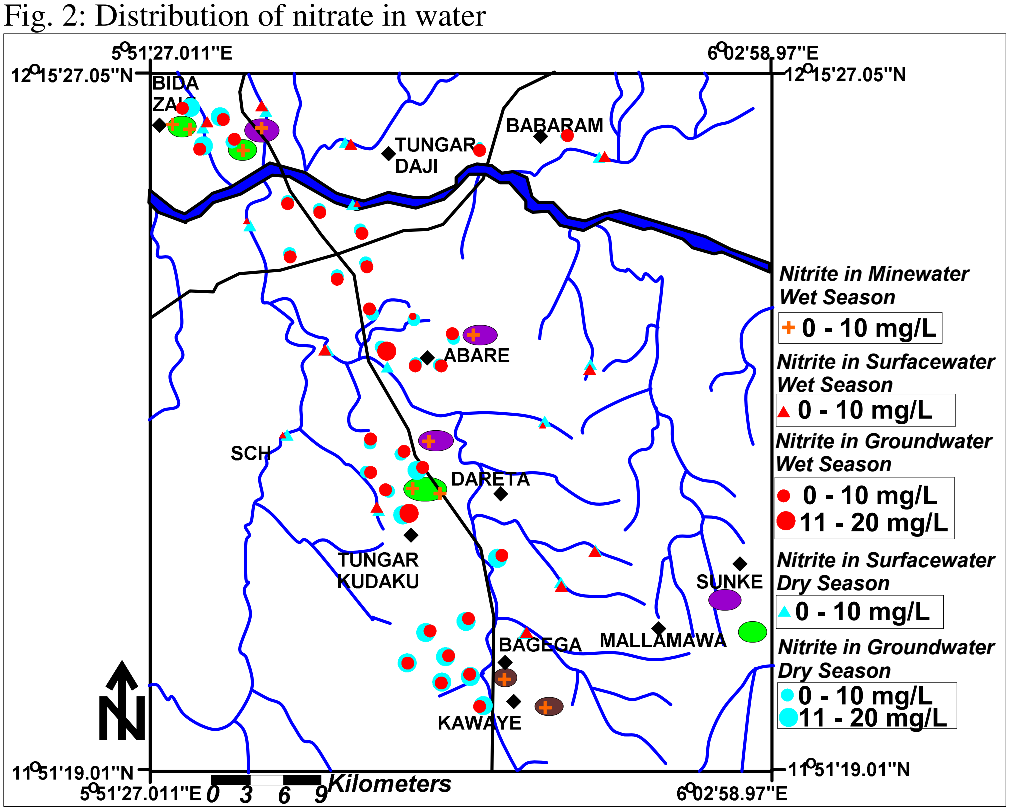

Fig. 3: Distribution of nitrite in water

Results of pollution assessment for nitrate and nitrite in water in the area is presented in Figure 4. SPI values for nitrate in groundwater for both the dry and wet seasons were 2.26 and 1.29 while for surfacewater, they were 1.44 each. For minewater during the wet season, the SPI value was 1.46. The SPI values for nitrite in groundwater for both the dry and wet seasons were 10.41 and 9.17 while for surfacewater, they were 8.13 and 8.24 respectively. For minewater during the wet season, the SPI value for nitrite was 7.74. The NIPI for minewater during the wet seasons was 3.96. In this study, it was uncovered by SPI and NIPI that water from this area were polluted by NO_3 and NO_2. This supported by findings from New York (Gelberg *et al.,* 1999), India (Suthar *et al.,* 2009), Argentina (Costa *et al.,* 2002) and China (Hu *et al.,* 2005; Feng *et al.*, 2020) are polluted by nitrate and nitrite and are generally released into the environment via human exercises including agricultural activities (Atafar *et al.,* 2010) and mining activities (Bosman, 2009). In this area, artisanal mining and use of NPK fertilizers for agricultural activities are the major sources of nitrate and nitrite in the water bodies.

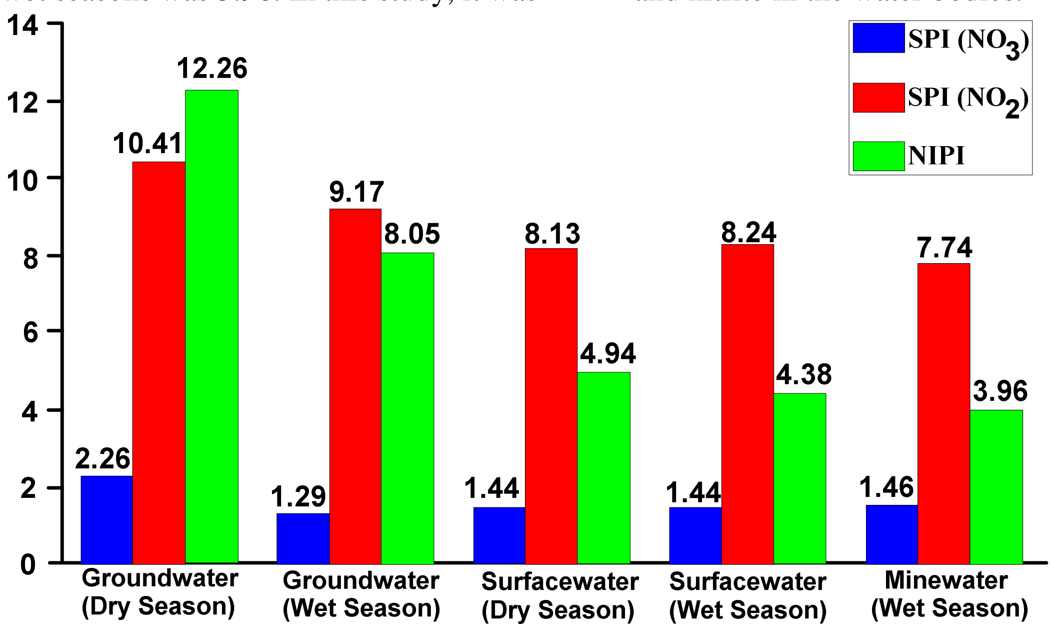

Fig. 4: Single Pollution Index (SPI) and Nemerow Integrated Pollution Index (NIPI) of NO_3 and NO_2 in Water

Health Risk Assessment

Health risk of nitrate and nitrite in water are presented in Table 3. ADI of NO_3 and NO_2 for grown-up males through ingestion and dermal contact with water nearby are presented in Table 3. ADI of NO_3 through ingestion and dermal contact with groundwater during the dry and wet seasons were 4.33 mg/kg/day and 2.46 mg/kg/day each while for surfacewater, it was 2.76 mg/kg/day and 2.75 mg/kg/day each. For minewater ADI through ingestion and dermal contact was 2.79 mg/kg/day. Likewise, ADI of NO_2 for adult males through ingestion and dermal contact with groundwater during the dry and wet seasons were 0.40 mg/kg/day and 0.36 mg/kg/day each while for surfacewater, it was 0.32 mg/kg/day each. The outcome showed that the complete ADI of NO_3 through oral ingestion and dermal contact with groundwater during the dry and wet seasons were 4.58 mg/kg/day and 2.61 mg/kg/day each while for surfacewater, it was 2.91 mg/kg/day each. For mine water, the complete ADI through oral ingestion and dermal contact was 2.95 mg/kg/day. ADI of NO_2 for grown-up females through oral ingestion and dermal contact with groundwater during the dry and wet seasons were 0.43 mg/kg/day and 0.38 mg/kg individually while for surfacewater, it was 0.34 mg/kg/day each. For mine water, the complete ADI through oral ingestion and dermal contact was 0.32 mg/kg/day. ADI of NO_2 for adult females through oral ingestion and dermal contact with groundwater during the dry and wet seasons were 0.74 mg/kg/day and 0.65 mg/kg respectively while for surfacewater, it was 0.58 mg/kg/day and 0.59 mg/kg/day each. For mine water, ADI through oral ingestion and dermal contact was 0.55 mg/kg/day. For kids, ADI of NO_3 through ingestion and dermal contact with groundwater during the dry and wet seasons were 4.67 mg/kg/day and 2.66 mg/kg/day each while for surfacewater, it was 2.97 mg/kg/day and 2.96 mg/kg/day separately. For newborns, ADI of NO_3 through ingestion and dermal contact with groundwater during the dry and wet seasons were 7.97 mg/kg/day and 4.53 mg/kg/day each while for surfacewater, it was 5.07 mg/kg/day and 5.06 mg/kg/day respectively. For mine water, the total ADI through oral ingestion and dermal contact was 5.14 mg/kg/day. These were above the recommended limits of daily consumption of nitrates by USEPA (2004). For both nitrates and nitrites, ADIs were aggravated mainly through oral ingestion of water contaminated by nitrates and nitrites HI for NO_3 in water and NO_2 in both seasons through ingestion and dermal contact for adult males, females, kids and infants are >1. This nitrate and nitrite in water in this area may contribute to high non-carcinogenic health risks for adult males, adult females, children and infants. Non-carcinogenic health risks associated with nitrate and nitrite exposure are increased heart rate, nausea, headaches, and abdominal cramps (MDH, 2021). It has been suggested that exposure to water contaminated by nitrate and nitrite may cause an increased risk of cancer, especially gastric cancer, associated with dietary nitrate/nitrite exposure (MDH, 2021). Additionally, high substance of nitrate might prompt methaemoglobinaemia, which results from association of nitrite with hemoglobin in the red platelets to frame methaemoglobin, which ties oxygen firmly and doesn't deliver it, accordingly obstructing oxygen transport (Ducci 2018). Significant degrees of methaemoglobin in babies can bring about cyanosis, alluded to as blue child disorder (Knobeloch *et al.* 2000). In this area, infants are most affected by nitrate and nitrite contamination, studies have shown that toxic substance bioaccumulate in infants than adults, because of their underdeveloped immune system (Adewumi and Laniyan, 2020). Nitrate and nitrite may cross through the placenta during pregnancy have been raised concerns because research shows nitrites and potentially increase methemoglobin levels in the developing foetus (Zhou, 2015).

Table 3: Average Daily Intake for NO_3 and NO_2 in water

		NO_3 (mg/kg/day)				NO_2 (mg/kg/day)			
		Adults Male	**Adults Female**	**Children**	**Infants**	**Adults Male**	**Adults Female**	**Children**	**Infants**
Groundwater Dry Season	Oral Ingestion	4.30	4.55	4.63	7.92	0.40	0.42	0.43	0.73
	Dermal Contact	0.03	0.03	0.04	0.06	0.01	0.01	0.01	0.01
	Total	**4.33**	**4.58**	**4.67**	**7.97**	**0.40**	**0.43**	**0.43**	**0.74**
Groundwater Wet Season	Oral Ingestion	2.45	2.59	2.64	4.50	0.35	0.37	0.38	0.65
	Dermal Contact	0.02	0.02	0.03	0.03	0.01	0.01	0.01	0.01
	Total	**2.46**	**2.61**	**2.66**	**4.53**	**0.36**	**0.38**	**0.38**	**0.65**
Surfacewater Dry Season	Oral Ingestion	2.74	2.90	2.95	5.04	0.31	0.33	0.34	0.57
	Dermal Contact	0.02	0.02	0.03	0.04	0.01	0.01	0.01	0.01
	Total	**2.76**	**2.91**	**2.97**	**5.07**	**0.32**	**0.33**	**0.34**	**0.58**
Surfacewater Wet Season	Oral Ingestion	2.73	2.89	2.94	5.03	0.32	0.34	0.34	0.58
	Dermal Contact	0.02	0.02	0.03	0.04	0.01	0.01	0.01	0.01
	Total	**2.75**	**2.91**	**2.96**	**5.06**	**0.32**	**0.34**	**0.34**	**0.59**
Minewater Wet Season	Oral Ingestion	2.77	2.93	2.99	5.10	0.30	0.32	0.32	0.55
	Dermal Contact	0.02	0.02	0.03	0.04	0.01	0.01	0.01	0.01
	Total	**2.79**	**2.95**	**3.01**	**5.14**	**0.30**	**0.32**	**0.32**	**0.55**
	ADI (JECFA, 2002)	**3.70**	**3.70**	**3.70**	**3.70**	**0.07**	**0.07**	**0.07**	**0.07**

Table 4: Hazard quotient (HQ) and Hazard Index (HI) for NO_3 and NO_2 in water

		NO_3				NO_2			
	Pathway	**Adults male**	**Adults female**	**Children**	**Infants**	**Adults male**	**Adults female**	**Children**	**Infants**
Groundwater Dry Season	HQ Oral Ingestion	2.69	2.85	2.90	4.95	1.20	1.27	1.30	2.21
	HQ Dermal Contact	0.02	0.02	0.03	0.04	0.01	0.01	0.01	0.02
	Hazard Index (HI)	**2.71**	**2.86**	**2.92**	**4.98**	**1.21**	**1.28**	**1.31**	**2.23**
Groundwater Wet Season	HQ Oral Ingestion	1.53	1.62	1.65	2.82	1.06	1.12	1.14	1.95
	HQ Dermal Contact	0.01	0.02	0.02	0.02	0.01	0.01	0.01	0.02
	Hazard Index (HI)	**1.54**	**1.63**	**1.66**	**2.84**	**1.07**	**1.13**	**1.15**	**1.96**
Surfacewater Dry Season	HQ Oral Ingestion	1.71	1.81	1.85	3.15	0.94	0.99	1.01	1.73
	HQ Dermal Contact	0.02	0.02	0.02	0.03	0.01	0.01	0.01	0.02
	Hazard Index (HI)	**1.72**	**1.82**	**1.86**	**3.17**	0.95	**1.00**	**1.02**	**1.74**
Surfacewater Wet Season	HQ Oral Ingestion	1.71	1.81	1.84	3.14	0.95	1.01	1.03	1.75
	HQ Dermal Contact	0.02	0.02	0.02	0.03	0.01	0.01	0.01	0.02
	Hazard Index (HI)	**1.72**	**1.82**	**1.85**	**3.16**	0.96	**1.01**	**1.03**	**1.76**
Minewater Wet Season	HQ Oral Ingestion	1.74	1.84	1.87	3.19	0.90	0.95	0.96	1.65
	HQ Dermal Contact	0.02	0.02	0.02	0.03	0.01	0.01	0.01	0.02
	Hazard Index (HI)	**1.75**	**1.85**	**1.88**	**3.21**	0.90	0.95	0.97	**1.66**

Conclusion

This study was completed to decide the degree of nitrate and nitrite defilement and wellbeing hazards related with them in water in Anka mining region, Northwest Nigeria. Nitrate and nitrite in water from the region were over the reasonable global cutoff. Discoveries revealed that water from this area were exceptionally sullied by both nitrate and nitrite. The discoveries uncovered that the oxides of nitrogen in water of the region may have begun from anthropogenic sources particularly mining and agrarian practices. Occupants of this space ought to be illuminated with regards to the effect of nitrate defilement of water nearby. This will extraordinarily decrease the effect of nitrate and nitrite on the health of the general population. It will help policy makers in settling on choices that will alleviate their effect on the environment.

Acknowledgement

This study was sponsored by the State Key Laboratory of Environmental Geochemistry (SKLEG), Institute of Geochemistry, Chinese Academy of Science, Guiyang, China. The grant number is SKLEG2017910.

References

Adejuwon, J.O. (2012). Rainfall seasonality in the Niger Delta Belt, Nigeria. *Journal of Geology and Regional Planning*, 5(2): 51-60.

Adewumi, A.J. and Anifowose, Y.B., 2017. Hydrogeologic characterization of Owo and its environs using remote sensing and GIS. *Applied Water Science*, 7(6): 2987-3000.

Adewumi, A.J. and Laniyan, T.A. (2020). Contamination, Sources, and Risk Assessments of Metals in Media from Anka Artisanal Gold Mining Area, Northwest Nigeria. *Science of the Total Environment*, 718: 137235.

Adewumi, A.J., Laniyan, T.A. and Ikhane, P.R. (2020a). Distribution, contamination, toxicity, and potential risk assessment of toxic metals in media from Arufu Pb–Zn–F mining area, northeast Nigeria. *Toxin Reviews,* 40(4): 1-22.

Adewumi, A.J., Laniyan, T.A. and Omoge, O.M. (2017). Paleostress analysis of joints in part of basement complex area of Southwestern Nigeria. *Journal of Geography, Environment and Earth Science International*, 11(2): 1-16.

Adewumi, A.J. and Laniyan, T.A. (2021). Ecological and Human Health Risks Associated with Metals in Water from Anka Artisanal Gold Mining Area, Nigeria. *Human and Ecological Risk Assessment*, 26(1): 35-53.

Adewumi, A.J., Laniyan, T.A., Xiao, T., Liu, Y. and Ning, Z. (2020b). Exposure of children to heavy metals from artisanal gold mining in Nigeria: evidences from bio-monitoring of hairs and nails. *Acta. Geochimica*., 39(4): 451-470.

Alidadi, H., Sany, S.B.T., Oftadeh, B.Z.G., Mohamad, T., Shamszade, H. and Fakhari, M. (2019). Health risk assessments of arsenic and toxic heavy metal exposure in drinking water in northeast Iran. *Environmental Health and Preventive Medicine*, 24: 59.

Atafar, Z., Mesdaghinia, A., Nouri, J., Homaee, M., Yunesian, M., Ahmadimoghaddam, M. and Mahvi, A.H. (2010). Effect of fertilizer application on soil heavy metal concentration. *Environmental Monitoring and Assessment*, 160(1): 83-89.

Bosman, C. (2009). The hidden dragon: nitrate pollution from open-pit mines–a case study from the Limpopo province, South Africa. *Carin Bosman Sustainable Solutions, Pretoria, Gauteng, Republic of South Africa*. Available at https://www.imwa.info/docs/imwa_2009/IMWA2009_Bosman.pdf

Costa, J.L., Massone, H., Martınez, D., Suero, E.E., Vidal, C.M. and Bedmar, F. (2002). Nitrate contamination of a rural aquifer and accumulation in the unsaturated zone. *Agricultural Water Management*, 57(1): 33-47.

Danbatta, U.A., Abubakar, Y.I. and Ibrahim, A.A. (2009). Geochemistry of gold deposits in Anka Schist Belt, Northwestern, Nigeria. *Nigerian Journal of Chemical Research*, 14: 19-29.

Dubiski, J. (2013). Sustainable development of mining mineral resources. *Journal of Sustainable Mining*, 12 (1): 1-6.

Ducci, D. (2018). An easy-to-use method for assessing nitrate contamination susceptibility in groundwater. *Geofluids*, 2018: 1-12.

Feng, W., Wang, C., Lei, X., Wang, H. and Zhang, X. (2020). Distribution of nitrate content in groundwater and evaluation of potential health risks: a case study of rural areas in northern China. *International Journal of Environmental Research and Public Health*, 17(24): 9390.

Gao, S., Li, C.S., Jia, C., Zhang, H.L., Guan, Q. and Wu, X.C. (2020). Health risk assessment of groundwater nitrate contamination: a case study of a typical karst hydrogeological unit in East China. *Environmental Science and Pollution Research*, 27: 9274–9287.

Gelberg, K.H., Church, L., Casey, G., London, M., Roerig, D.S., Boyd, J. and Hill, M. (1999). Nitrate levels in drinking water in rural New York State. *Environmental Research*, 80(1): 34-40.

Holloway, J.M. and Smith, R.L. (2005). Nitrogen and carbon flow from rock to water: Regulation through soil biogeochemical processes, Mokelumne River watershed, California, and Grand Valley, Colorado. *Journal of Geophysical Research: Earth Surface*, 110 (F1).

Hu, K., Huang, Y., Li, H., Li, B., Chen, D. and White, R.E. (2005). Spatial variability of shallow groundwater level, electrical conductivity and nitrate concentration, and risk assessment of nitrate contamination in North China Plain. *Environmental International*, 31(6): 896-903.

Jiao, Z., Li, H., Song, M. and Wang, L. (2018). Ecological risk assessment of heavy metals in water and sediment of the Pearl River Estuary, China. *In IOP Conference Series: Material Science and Engineering*, 394(5): 52-55.

Laniyan, T.A. and Adewumi, A.J. (2019). Health Risk Assessment of Heavy Metals Pollution in Groundwater around an Exposed Dumpsite in Southwestern Nigeria. *Journal of Health Pollution*, 9(24): 191-210.

Makinde, E.A., Ayeni, L.S. and Ojeniyi, S.O. (2011). Effects of organic, organomineral and NPK fertilizer treatments on the nutrient uptake of *Amaranthus cruentus* (L) on Two Soil Types in Lagos, Nigeria. *Journal of Central European Agriculture*, 12(1): 114-123.

MDH, (2021). Nitrate in Drinking Water. Minnesota Department of Health. Accessed at https://www.health.state.mn.us/communities/environment/water/contaminants/nitrate.html#:~:text=Natural%20processes%20can%20cause%20low,septic%20systems%2C%20or%20urban%20drainage, (Accessed on the 13th of November, 2021).

Mendes, A.P.F., Bertella, M.A. and Teixeira, R.F. (2014). Industrialization in Sub-Saharan Africa and import substitution policy. *Brazilian Journal of Political Economics*, 34: 120-138.

Meseret, M., Ketema, G. and Kassahun, H. (2020). Health risk assessment and determination of some heavy metals in commonly consumed traditional herbal preparations in Northeast. *Ethiopian Journal of Chemistry*, 2020: 8883837.

Naveedullah, N., Hashmi, M.Z., Yu, C., Shen, H., Duan, D., Shen, C., Lou, L. and Chen, Y. (2014). Concentrations and Human Health Risk Assessment of Selected Heavy Metals in Surface Water of the Siling Reservoir Watershed in Zhejiang Province. *China Political Journal of Environmental Studies*, 23(3): 801-811.

Rankinen, K., Salo, T., Granlund, K. and Rita, H. (2007). Simulated nitrogen leaching, nitrogen mass field balances and their correlation on four farms in south-western Finland during the period 2000–2005. *Agricultural Food Science*, 16: 387–406.

Su, X.S., Wang, H. and Zhang, Y.L. (2013). Health risk assessment of nitrate contamination in groundwater: a case study of an agricultural area in Northeast China. *Water Resource Management*, 27: 3025–3034.

Suthar, S., Bishnoi, P., Singh, S., Mutiyar, P.K., Nema, A.K. and Patil, N.S. (2009). Nitrate contamination in groundwater of some rural areas of Rajasthan, India. *Journal of Hazardouz Material*, 171(1-3): 189-199.

USEPA (2004). Risk assessment guidance for Superfund, Volume I: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment) Final. US Environmental Protection Agency, Washington DC. EPA/540/R-99/005 (Accessed on the 25th of October, 2021)

WHO (2017). Guidelines for drinking-water quality, 4th edition, incorporating the 1st addendum. Accessed on 15th November, 2021

Zhai, Y.Z., Zhao, X.B., Teng, Y.G., Li, X., Zhang, J.J. and Wu, J. (2017). Groundwater nitrate pollution and human health risk assessment by using HHRA model in an agricultural area, NE China. *Ecotoxicology and Environmental Safety*, 137: 130–142.

Zhong, S., Geng, H., Zhang, F., Liu, Z., Wang, T. and Song, B. (2015). Risk assessment and prediction of heavy metal pollution in groundwater and river sediment: a case study of a typical agricultural irrigation area in Northeast China. *International Journal of Analytical Chemistry*, 2015: 1-11.

Zhou, Z. (2015). A global assessment of nitrate contamination in groundwater. *International Groundwater Resources Assessment Center; Internship report; Wageningen University: Wageningen, The Netherlands*. 27 pp. Available at https://www.un-igrac.org/sites/default/files/resources/files/A%20Global%20Assessment%20of%20Nitrate%20Contamination%20in%20Groundwater.pdf, 2015. (Accessed on the 15th of October, 2021)