



# Assessment of nitrate and its health risk capability in groundwater used by residents around a dumpsite in Lagos, Nigeria

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## Abstract

Anthropologic activities in our environment had been continuously associated with the release of nitrate a contaminant that has been linked with some dangerous health effects. This study assessed the concentration and health risk of nitrate in groundwater used by residents around a dumpsite. For this study groundwater samples were obtained randomly from 12 sampling sites near the Solos dumpsite at Igando, Alimosho local government area, Lagos, Nigeria. The water samples were analyzed for nitrate and some other physic-chemical parameters. The water quality index of the water samples was calculated to determine the suitability for consumption purposes. The non-carcinogenic hazard health risk associated with the nitrate level in the water samples was also assessed. The relationship between the nitrate in the water samples and the drinking water quality index (DWQI) was a positive one with r= 0.21 at p=0.517. The hazard index for ingestion (oral) route (HIoral) range were 0.024-0.962, 0.028-1.136 and 0.033-1.3 for male, female and children respectively. The dermal hazard index (HIdermal) shows range of 0.001-0.026 for male, 0.001-0.027 for female and 0.002-0,071 for children. Sample 6 had Total hazard index (HItotal) greater than 1 for both female adult and children as 1.163 and 1.371 respectively. All water samples on this study had the presence of nitrate that were positive correlated with water quality index and only one of the samples nitrate concentration was associated with high health non-carcinogenic risk effect especially in children and women.

## 1. Introduction

With a lot of contaminants been released into our surrounding daily through anthropogenic activities, nitrate cannot be ignore as it is one of the most important contaminants released into the environment (Darvishmotevallia et al., 2019). Contamination of groundwater by Nitrate (NO3-) has become prevalent and leading to reduction in the viability and quality of groundwater in the universe (Adimalla et al. 2018b; Adimalla and Venkatayogi 2018; Chica-Olmo et al. 2017). Nitrate as a pollutant, is believed to be a byproduct from livestock manure and inorganic fertilizer used in agricultural activities. Waste water treatment, motor vehicles and wastewater effluents from industries had been identified as some of the contributors of nitrate as a pollutant into the environment (Alimohammadi et al., 2018; Asghari et al., 2018; Khosravi et al., 2018). Leaching and nitrogenous substances oxidation taking place in rocks and leguminous floras and microbes, are some natural sources through which groundwater could be polluted with nitrate (Chica-Olmo et al. 2017; Elisante and Muzuka 2017). Groundwater nitrate contamination and the associated health danger has been well noted and discuss in some studies around the globe (Adimalla et al., 2018b; Chen et al., 2017; Chica-Olmo et al., 2017; Zhang et al., 2018).

It has been reported that groundwater has the tendency of being contaminated by nitrate (**Wongsanit** *et al.*, **2015**). Some studies

(Cheong *et al.*, 2012; Pennino*et al.*, 2020). Groundwater nitrate value is positively correlated with ammonia increase (Shamsuddin *et al.*, 2016). Conductivity of groundwater can be affected by nitrate. Nitrate as a dissolved inorganic solids has also be found to correlate with salinity and total dissolved solid (TDS) (Annapoorani *et al.*, 2014; Igboekwe *et al.*, 2011; Yan *et al.*, 2015). Some adverse health conditions such as Age-related Macular

had reported high nitrate concentration in groundwater

Degeneration (AMD), diabetes, gastric and thyroid dysfunction had been linked to increase nitrate level in drinking water (Aschebrook-Kilfoy *et al.*, 2012; Klein *et al.*, 2013).

Methemoglobinemia (blue baby syndrome) especially in infants had been documented as one of the dangerous health effect that results from continuous exposure to nitrate as a pollutant in groundwater (Jaliliet *al.*, 2018; Radfard *et al.*, 2018a; Soleimani *et al.*, 2018).

Therefore, assessing and consistently evaluating the groundwater resources and study of the potential health risk of groundwater contaminants can be said to be vital for health awareness programs. Two major routes of exposure to risk in the environmental water contamination are skin absorption and ingestion routes (Li and Zhang, 2010; Wu *et al.*, 2009). Comparing the analyzed level of health impacts with the standard and permissible limits, is an old fashion techniques, which could be said not to be adequate in the provision of valid

apprehensive hazard levels and discovering contaminants (Hashmi *et al.*, 2014). Likely health effect that could be caused by some contaminants in water environment is best estimated by important procedures called Health risk assessment (Radfardet *al.*, 2018b; Xiao *et al.*, 2017).

Identification of the nitrate and the factors influencing its concentration in the groundwater can be evaluated by risk assessment models and spatial analysis (Bianet al., 2016; Jamaludin et al., 2013; Rojas Fabro et al., 2015; Saidiet al., 2011; Shrestha et al., 2016).

This study set out to evaluate the concentration and health risk of nitrate in groundwater used by residents around a dumpsite.

## 2. Material and methods

#### 2.1 Study Location

This study covers some residential around Solous dumpsite; situated within the longitude 3°26 E to 3°25 E and latitude 6°56N to 6°57N within Ikotun/Igando Local Council Development Area of Alimosho Local Government in Lagos State, Nigeria

#### 2.2 Sample Collection

In an effort to study the extent of the groundwater contamination 12 sampling sites were selected near the dumpsite from where the samples were taken. The samples were collected in 60 cl capacity polythene bottles. Prior to the collection, bottles were thoroughly washed and rinsed with sample to avoid any possible contamination in bottling and other precautionary measures were taken.

#### 2.3 Sample Analysis

The samples were transferred to Biochemistry Drug laboratory and stored in cold room ( $4 \cdot C$ ). All the samples were analyzed for selected relevant physico-chemical parameters which include colour, pH, Electrical conductivity (EC), Total hardness (TH), nitrates and phosphates.

## 2.4 Drinking water quality index (DWQI)

In order to determine the suitability of the groundwater for consumption purposes, the water quality index was calculated. Hence, for calculating the DWQI, results of the physico-chemical parameters like pH, electrical conductivity, total hardness, nitrate and phosphate were used. The steps abduct for computing DWQI were

- i. Weight (wi) assignment
- ii. Calculation of relative weight (Wi)
- iii. Calculation of quality rating scale (qi), and
- iv. Calculation of sub-index (SI).
- v. Calculation of DWQI

(a) Weight (wi) was assigned to each of the physico-chemical parameters with referenced to perceived relative influence in quality of groundwater for drinking generally. Nitrate was the highest weight of 5, pH, Electrical conductivity (EC) and phosphate were assigned the value of 3 and Total hardness (TH) was assigned the lowest value of 2 since it is believed to show less effect (Table 1).

(b) The following equation was used in calculating the relative weight (wi)

$$Wi = \frac{Wi}{\sum_{i=1}^{n} Wi}$$

Equation 1

Wi connote the relative weight, the assigned weight of each parameter is wi and parameter numbers is n.

(c) To calculate the quality rating (qi) for the parameters; the concentration (Ci) (mg/dL) of each parameters in the groundwater sample was divided by the permissible standard (Si) (WHO 2011), and multiplied by 100. The following equation was used in calculating qi:

$$qi = \frac{Ci}{Si} \times 100$$

Equation 2

(d) The sub-index (SI) was computed by using

SIi= Wi x qi

Equation 3

. (e) DWQI was computed by using

$$DWQI = \sum_{i=1}^{n} SIi$$
Equation 4

Sub-index of the ith parameter is SIi, relative weight is Wi, quality rating is qi, and n is the parameters number

#### 2.5 Human health risk assessment

To evaluate the health risk associated with water contaminated four methods such as identification of hazard, evaluation of dose response, assessment of exposure and risk (**Adimallaet al., 2018a; Li et al., 2016; Narsimha and Rajitha 2018**) were computed. Humans can be exposed to NO<sub>3</sub>- contaminated water via consumption of the water and skin popularly known dermal contact. Therefore, the chronic daily intake (CDI: mg/kg/day), and dermal absorbed dose (DAD: mg/kg day) were calculated to evaluate the doses gotten via the individual route.

#### 2.6 Ingestion route

The amount of chemical substance consumed via drinking per kilogram of body weight per day (mg/kg day) can be computed using CDI. A Non-carcinogenic danger via drinking water route in terms of CDI is computed using the below Equation 5 (**US EPA 1989; 2001**):

$$CDI = \frac{CPW \times IR \times ED \times EF}{ABW \times AET}$$

#### Equation 5

CDI- Is the chronic daily intake (mg/kg day);

CPW- Is the concentration (mg/L) of the contaminant in view (which is nitrate for this study in groundwater)

IR- Is the ingestion rate for humans (L/day: 0.78 L/day for children and 2.5 L/day for adults)

ED- Is the exposure duration (years: 12, 64 and 67 for children, men and women respectively)

EF- Is the exposure frequency (days/years: 365 days for both children and adults)

ABW- Is the average body weight (Kg: 65, 55, and 15 for males, women, and children respectively)

AET- Is the average exposure time (days: 4380, 23360 and 24455, for children, males and women respectively).

## 2.7 Skin contact route

In order to assess the health risk of exposure, skin contact route was calculated using the following equation:

## DAD= [Tc x Kp x Cw x Ev x ED x EF x SSA x CF] / ABW x AET

Equation 6

DAD- Is the dermal absorbed dose (mg/kg day)

TC- Time of contact i.e. duration (h/d: 0.4 h per day for both adults and children)

Kp - Is the skin adsorption parameters (cm/h: 0.001cm/h);

Cw- Concentration of the substance in water

Ev- Is the frequency of bath taken (times/day: taken as 1 time in a day)

SSA- Is the skin surface area for contact (cm2: 12,000 cm and 16,600 for children and adults respectively)

CF- Is the conversion factors (0.001 according to Li *et al.*, 2016; Wu and Sun 2016)

ED- Is the exposure duration (years: 12, 64 and 67 for children, men and women respectively)

EF- Is the exposure frequency (days/years: 365 days for both children and adults)

ABW- Is the average body weight (Kg: 65, 55, and 15 for males, women, and children respectively).

AET- Is the average exposure time (days: 4380, 23360 and 24455, for children, males and women, respectively)

2.8 Hazard quotient for oral and skin routes

Hazard quotient for oral and skin for nitrate health risk assessment is calculated by

$$HQ_{Oral} = \frac{CDI}{RfD}$$

Equation 7

$$HQ_{Dermal} = \frac{DAD}{RfD}$$

#### **Equation 8**

HQoral and HQskin- Is the non-carcinogenic for oral and skin hazard quotient, respectively.

DAD and CDI show the dermal absorbed dose (mg/kg/day) and chronic daily intake (mg/kg/day), respectively

RfD- Is the reference dose of a particular contaminant (**US EPA 2001**).

The oral reference doses of nitrate-nitrogen is 1.6 mg/kg/day (Integrated Risk Information System, US Environmental Protection Agency 1989) and the reference dose of skin nitrate nitrogen intake was 0.18 mg/kg.d (**Yang et al., 2012**)

2.9 Total hazard index (HItotal)

The total hazard index (HItotal) which represents the cumulative non-carcinogenic risk is estimated by summing up hazard quotients (HQoral and HQdermal) and are calculated by Equations (9) and (10):

 $HI_i = HQ_{oral} + HQ_{Dermal}$ 

Equation 9

$$HI_{total} = \sum_{i=1}^{n} HI_i$$

Equation 10

According to **Li** *et al.*, **(2016)**; **US EPA (2001)** HItotal values lesser than one (HItotal<1), indicate no significant risk of non-carcinogenic effects while if HItotal value exceeds one (HItotal>1), then there is exposure to non-carcinogenic danger.







**Figure 1** Map showing the water sample collection sites (as an extraction from Alimosho Local Government, Lagos where the Solous dumpsite is situated)

#### 2.10 Statistical Analysis

The data obtain for the nitrate and other physic-chemical parameters were analyzed using SPSS version 22 and Graphad prism 8

#### 3. Results and Discussion

Table 1 shows the summary of the pyshco-chemical parameter and DWQI values obtained in this study with the minimum, mean, maximum, coefficient of variation, kurtosis, skewness and the World Health Organization permissible limits. The pH in this study has minimum, mean and maximum value of 6.15, 7.53 and 8.55 respectively. The coefficient of variation of the pH 9.0%. The water samples were weakly acidic to weakly alkaline. The quantity of substances that dissolved in water are indicated by electrical conductivity (EC), in this study, the minimum, mean and maximum values were 78.2, 1185 and 6570 respectively, has indicated in Table 1.

The nitrate across the 12 sites from which water samples were obtained, the nitrate (mg/L) ranged from 1.00 to 40.00 with site 6 having the highest value as indicated in Table 1. The Nitrate has a coefficient of 160.6%, kurtosis vale of 9.57 and 3.01 for the skewness value

The drinking water quality index (DWQI) were within the ranged 211.15 to 671.22. According to **Adimalla (2020**), quality of groundwater can be grouped into five (5) on the criteria of DWQI values as, excellent water (<50), good water (50–100),

poor water (100–200), very poor water (200–300), and water unsuitable for drinking (>300). It could be said from this study that 41.67% of the water samples were classified as very poor water, while 58.33% of the water samples fall in the category of unsuitable for oral consumption.

DWQI has used in this study to evaluate the quality of the water samples has also been utilized in study by **Adimalla and** 

Venkatayogi (2018), Effendi *et al.*, (2015), Gupta *et al.*, (2017), Houatmia*et al.*, (2016) to assess the quality of water for the sole aim of drinking.

The relationship between the nitrate in the water samples and the DWQI was a positive one with r= 0.21 at p=0.517 as indicated in Fig. 2.

Table 1 Physico-chemical parameters of the water samples collected									
Sample Color		рН	E.C	T.H	Nitrate	Phosphate	DWQI		
		(Mean±S.D)	(µS/cm)	(ppm)	(mg/L)	(mg/L)			
Site 1	Colorless	6.15±0.08	83.1	17.8	2.5	1.00	211.15		
Site 2	Colorless	6.50±0.01	187.0	53.4	2.5	1.00	217.91		
Site 3	Cloudy	7.46±0.06	122.5	17.8	1.5	1.00	216.13		
Site 4	Colorless	7.18±0.03	153.5	17.8	2.5	1.00	217.42		
Site 5	Cloudy	7.83±0.04	1406.0	124.6	10	2.00	472.87		
Site 6	Colorless	8.02±0.01	1676.0	89.0	40	1.50	387.73		
Site 7	Colorless	7.89±0.02	288	35.6	5.0	1.50	410.23		
Site 8	Brownish yellow	7.51±0.01	359	720	2.5	1.00	244.80		
Site 9	Colorless	7.49±0.01	353	530	1.5	1.50	333.60		
Site 10	Colorless	7.55±0.03	78.2	17.8	1.0	1.50	307.78		
Site 11	Yellow	8.55±0.00	6570	356	2.5	1.75	671.22		
Site 12	Light yellow	8.23±0.00	2940	267	10	1.00	361.98		
Minimum		6.15	78.2	17.8	1	1	211.2		
Mean		7.53	1185	187.2	6/79	1.31	337.7		
Maximum		8.55	6570	720	40	2	671.2		
COV		9.0%	161.3%	125.3%	160.6%	27.1%	40.6%		
Kurtosis		0.52	6.11	1.14	9.57	-9.86	2.06		
Skewness		-0.75	2.41	1.44	3.01	0.61	1.39		
WHO, 2011	Colorless	6.5-8.5	400	500	50	0.1			

E.C- Electrical Conductivity, T.H- Total Hardness, COV- Coefficient of variation



Figure 2 Correlation heat map between Nitrate and DQWI

Sites	Nitrate	HQoral			HQderm	HQdermal			HItotal		
	(mg/L)	Male	Female	Children	Male	Female	children	Male	Female	children	
1	2.5	0.060	0.071	0.081	0.001	0.002	0.004	0.061	0.073	0.085	
2	2.5	0.060	0.071	0.081	0.001	0.002	0.004	0.061	0.073	0.085	
3	1.5	0.036	0.043	0.049	0.001	0.001	0.003	0.037	0.044	0.046	
4	2.5	0.060	0.071	0.081	0.001	0.002	0.004	0.061	0.073	0.085	
5	10	0.240	0.284	0.325	0.006	0.007	0.018	0.246	0.291	0.343	
6	40	0.962	1.136	1.3	0.023	0.027	0.071	0.985	1.163	1.371	
7	5.0	0.120	0.142	0.163	0.003	0.003	0.009	0.123	0.145	0.172	
8	2.5	0.060	0.071	0.081	0.001	0.002	0.004	0.061	0.073	0.085	
9	1.5	0.036	0.043	0.049	0.001	0001	0.003	0.037	0.044	0.046	
10	1.0	0.024	0.028	0.033	0.001	0.001	0.002	0.025	0.029	0.062	
11	2.5	0.060	0.071	0.081	0.001	0.002	0.004	0.061	0.073	0.085	
12	10	0.240	0.284	0.325	0.006	0.007	0.018	0.246	0.291	0.343	

It has been reported that nitrate at higher concentration in the body create risk to health by hindering the bond between oxygen and hemoglohin as a result of the nitrite produced from its breakdown and this lead to methemoglobinemia and this could kill infants and children (Huang et al., 2011). This study focus on non-carcinogenic health risk that can be associated from contamination of groundwater used by residents around a dumpsite. The range for the hazard index for ingestion (oral) route (HIoral) was 0.024-0.962, 0.028-1.136 and 0.033-1.3 for male, female and children respectively. The dermal hazard index (HIdermal) shows from Table 2 a range of 0.001-0.026 for male adult, 0.001-0.027 for female adult and 0.002-0,071 for children According to Li et al., (2016); US EPA (2001) HItotal values lesser than one (HItotal<1), indicate no significant risk of noncarcinogenic effects while if HItotal value exceeds one (HItotal>1), then there is exposure to non-carcinogenic danger. From Table 2, all other sites where water samples were taken except site 6 fell below 1, which indicate that they do not pose non-carcinogenic risk to both adults and children. But the site 6 with HItotal for both female adult and children as 1.163 and 1.371 respectively show significant risk of non-carcinogenic effects when exposed to the nitrate in the water sample from the site.

In a study by **Su** *et al.*, (2013), 91.4% samples had nitrate in them and they were about 34.3% higher than the permissible limit and drinking such groundwater is dangerous and pose risk to human health. The nitrate hazard index (HI) in groundwater was found to be 0.75 in South Korea (Cheong et al., 2012). **Tenget al.**, (2019) in a study reported that nitrate HI for both adult and children in 46.4% parts of the area where the study was conducted in northern China were higher than 1 and children have a higher susceptibility of exposure to nitrate contaminants. Children having a higher level of susceptibility in terms of the health risk from the HItotal value were also observed in this study.

**Sadler** *et al.*, **(2016)** reported that the ingestion of nitrate contaminated water with the first trimester of pregnancy was associated with high risk of birth defects in susceptible populace in Indonesia. In rural part of China, **Zhaiet** *al.*, **(2017)** discovered that groundwater nitrate concentration is higher than permissible limit and that in terms of exposure to risk, children> female> male are at higher risk of health hazards from oral route. This was also reported in this study as shown in Table 2.

## 4. Conclusion

It has been proven that a dumpsite is one of the sources of leachate which do increase nitrate level in groundwater when it percolates into groundwater around the environment which a landfill is located. This study therefore made the following:

- All water samples on this study had the presence of nitrate that were positive correlated with water quality index
- Of all the water samples, 41.67% of them were classified as very poor water, while 58.33% of them fall in the category of unsuitable for oral consumption
- Only one of the water samples nitrate concentration is associated with high health non-carcinogenic risk effect especially in children and women.

## **Declaration of interest**

There is no conflict of interest in this work.

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