Human health risks assessment from arsenic (As) in groundwater around industrial gold mining area: a case study in northern Côte d'Ivoire, West Africa

Abstract

Human exposure to arsenic is a worldwide concern due to its toxicity, persistence and non-biodegradability.This study focused on assessing human health risks from arsenic in groundwater near Tongon industrial mining area. The approach consisted firstly to determine total As concentrations in groundwater. In the second step, groundwater quality was ascertained through water quality index. Finally, the health risks due to Aswere assessedusing carcinogenic and non-carcinogenic risks indices The results showed that total concentrations of As in the majority wells (14.46 - 32.04 µg/L) are above its WHO guideline value (10 µg/L). Water quality index values showed good water quality for the wells P2 and P5. While, waters from wells P1, P3 and P4 are poor quality. The non-carcinogenic indices indicated that children are the most exposed to adverse effects through the consumption of wells water around Tongon mining area.The total carcinogenic risk showed that children and adults can develop cancer.Therefore, it is important to treat wells waters before using for domestic purposes.

Keywords: Groundwater, gold mining, arsenic, human health risk

1. Introduction

Poverty reduction through the creation of jobs via mining activities has led to the massive population settling in the vicinity of these mining areas (Taiwo and Awomeso 2017, Traore et al. 2021, Traore et al. 2022). In most of the villages close to these mining areas, groundwater is used by population for various purposes. The quality of these groundwater can be impacted by releasing chemical pollutants via anthropogenic activities such as mining and agricultural activities (Solgi and Jalili 2021, Torrance et al. 2021, Traore et al. 2021).Among these pollutants, trace metals and metalloids are a world-wide concern due to their toxicity and bioaccumulation. Hence, trace metals and metalloids monitoring in water is necessary.

Arsenic ingestion by human can cause kidney, lungs, bladers, skin and liver cancers. In addition, respiratory issues, cardiovascular disorders and diabetes are associated to arsenic toxic effects (Kaur et al. 2024,Zhao et al. 2023).Furthermore, Human prolonged exposure via ingestion and dermal contact to arsenic-contaminated water can impact negatively their health. (Ogarekpe et al. 2023, Qaiser et al. 2023).Therefore, it is important to assess the contamination level of arsenic in groundwater.

In many countries such as Iran (Solgi and Jalili 2021), Turkey (Gemici et al. 2008), Mexico (Esteller et al. 2015), China (Li et al. 2021), and South Africa (Mudzielwana et al. 2020) high arsenic concentrations were found in groundwater around mining areas. The ingestion of these enriched arsenic water by Humans can lead to severe contamination. For example, high concentrations of arsenic were obtained in the urine of residents around Tarkwa miningarea (34 – 700 µg/L) in Ghana (Asante et al. 2007),Mongolia mining area (23.89 - 36.93 µg/L) in Korea (Surenbaatar et al. 2021), Akyem mining area (33.95 - 104.97 µg/L) in Ghana (Adu-Poku et al. 2019).

Côte d'Ivoire is a country located in west Africa. In this country, during the last two decades, mining activities are grown exponentially.Studies done on arsenic around the mining areas in Côte d'Ivoire were generally focused on soil, sediments and surface waters (Kinimo et al. 2018,Kone et al. 2019, Akpo et al. 2020,Kouakou et al. 2020, Kagbagnan et al. 2023,Kone and Kouakou 2023,N'goran et al. 2023). These studies reported high concentrations of arsenic in soils, sediments and water. For example, Kinimo et al (2018), and N'goran et al (2023) reported that sediments around mining areas in southeastern, and northern Cote d'Ivoire, respectively, were strongly contaminated by arsenic. Soils near the Tongon mining area in the northern Côte d'Ivoire, were extremely contaminated by arsenic (Kone and Kouakou 2023). In addition, Kone et al (2019) reported that surface water in the vicinity of the Tongon mining area were severely contaminated by arsenic.However, data related to Human exposure to arsenic through ingestion or dermal contact of groundwater around mining areas in Côte d'Ivoire are limited. The objectives of this study were to: (i) determine arsenic concentration in groundwater; (ii) assess the groundwater quality using water quality index, and (iii) estimate the health risks via non-carcinogenic risk and carcinogenic risk indexes. Data from this study will help in the implantation of groundwater management strategies around mining areas.

2. Material and methods

2.1. Study area, sampling and laboratory analysis

The Tongonindustrial mining area is located in the northern Côte d'Ivoire, West Africa (Fig. 1). The geology of this zone is dominated by feral soils which are derived from felsic or parent rocks such us granitic, gneiss, phyllite and schist (N'goran et al. 2022). This industrial mine is located from 2.5 km to the Tongon village.The wells P1, P2, P3 and P4 are located around the village of Tongon. While, P5 is located in the village. The agricutural activities namely cotton, cashew, yam, corn, and vegetables crops are carried out around the wells P1 and P3. The well P3 is located in an artisanal gold mining zone. The well P4 is closest to the Tongon mining area. Also, the wood coal production and cattle rearing activities are carried out in the vicinity of the well P4. The sampling was done from May 2023 to July 2023. After water collection according the protocol described by Traore et al (2021), samples were acidified with 1 mL of nitric acid HNO_3 (65% suprapur, E.Merck, Germany). Before acidification, the pH of water and the total dissolved solids (TDS) were determined *in situ* using a multiparameter HI.9828. The major cations (Na^+, Mg^{2+} and Ca^{2+}) and arsenic(As) concentrations were determined through an Inductively Couple Plasma Mass Spectrometer (ICP-MS). The analysis was done in triplicate with an error less than 5%.

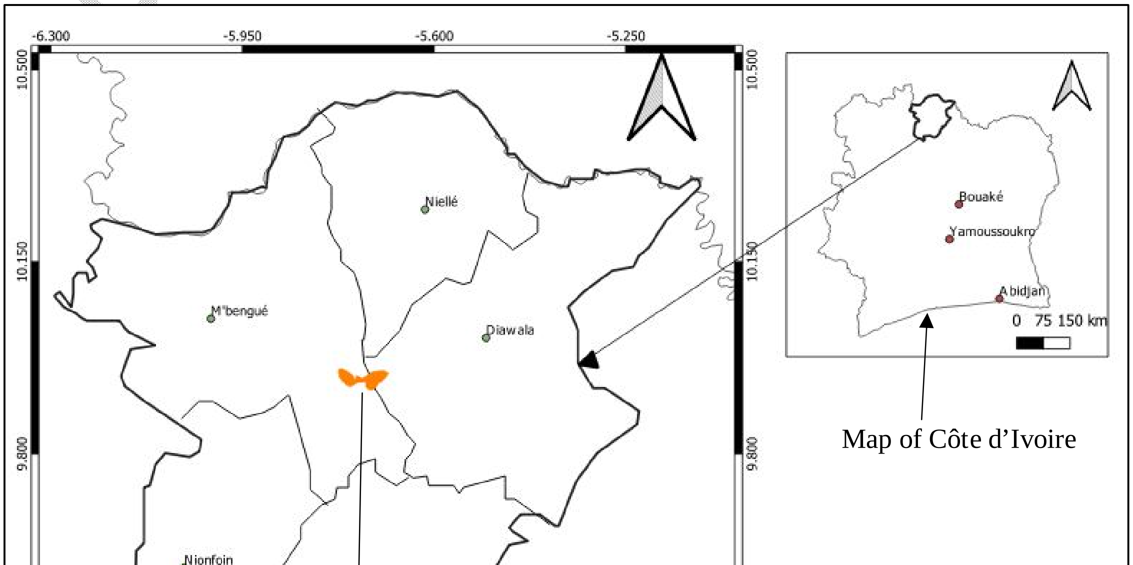

Fig.1. Study area and sampling stations

2.2. Groundwater quality and human health risks assessment

2.2.1. Groundwater quality assessment

The water quality index (WQI) proposed by Sener et al (2017) and Traore et al (2021) was used to assess the quality of the groundwater. WQI is calculated using the Eq.(1):

$$\mathbf{WQI} = \sum\left(\mathbf{W_i} \times \frac{C_i}{S_i} \times \mathbf{100}\right)(1)$$

$$\mathbf{W_i} = \frac{w_i}{\sum w_i}(2)$$

With :

$\mathbf{C_i}$: the determined value of ith parameter

$\mathbf{S_i}$: WHO standard value

$\mathbf{W_i}$: the relative weight to the element i

$\mathbf{W_i}$: the attributed weight to the element i

The WQI < 50 indicates excellent quality. The water quality is good when 50 ≤ WQI< 100. The quality is poor for 100 ≤ WQI< 200. When 200 ≤ WQI < 300, the water quality is very poor. The WQI ≥300 shows that the water is undrinkable (Şener et al. 2017, Traoré et al. 2021). The Table1gives the S_i, W_i and w_i values.

Table 1. WHO standard values, and, relative and attributedweights values

Parameters	**WHO standard (2017)**	**Attributedweight (w_i)**	**Relative weight (W_i)**
pH	6.5-8.5	4	0.2105
Total dissolvedsolid (TDS)	1000 (mg/L)	4	0.2105
Ca^{2+}	300 (mg/L)	2	0.1053
Mg^{2+}	30 (mg/L)	2	0.1053
Na^{+}	200 (mg/L)	2	0.1053
As	0.01 (mg/L)	5	0.2632
		$\sum \boldsymbol{w_i} = \mathbf{19}$	$\sum \boldsymbol{W_i} = \mathbf{1}$

2.2.2. Human health risks assessment

The hazard index (HI) expressed by the Eq. (3) is used to estimate the total non-carcinogenic risk (Zhang et al. 2017).

$$\mathrm{HI} = \mathrm{HQ}_{\mathrm{ing}} + \mathrm{HQ}_{\mathrm{der}} (3)$$

With :

$\mathrm{HQ}_{\mathrm{ing}}$: hazard quotient via ingestion

$\mathrm{HQ}_{\mathrm{der}}$: hazard quotient through dermal contact

When HI < 1, human is exposed to low adverse effects; HI > 1 shows adverse effects (Zhang et al. 2017, Traore et al. 2022).

$$\mathbf{HQ_{ing}} = \frac{\mathbf{C_i \times IR \times EF \times ED}}{\mathbf{BW \times AT_{nc} \times RfD_{ing}}} \quad (4)$$

$$\mathbf{HQ_{der}} = \frac{\mathbf{C_i \times SA \times K_P \times ET \times EF \times ED \times CF}}{\mathbf{BW \times AT_{nc} \times RfD_{der}}} \quad (5)$$

$$\mathbf{RfD_{der}} = \mathbf{RfD_{ing}} \times \mathbf{ABS_g} (6)$$

$\mathrm{RfD}_{\mathrm{ing}}$ and $\mathrm{RfD}_{\mathrm{der}}$ are reference dose via ingestion and dermal contact, respectively.

The total carcinogenic risk (TCR) was computed using the Eq.(7) (Zhang et al. 2017)

$$\mathrm{TCR} = \mathrm{CR}_{\mathrm{ing}} + \mathrm{CR}_{\mathrm{der}} (7)$$

$\mathrm{CR}_{\mathrm{der}}$ and $\mathrm{CR}_{\mathrm{ing}}$represent the carcinogenic risks via dermal contact and ingestion, respectively.

$\mathrm{CR}_{\mathrm{der}}$ and $\mathrm{CR}_{\mathrm{ing}}$ are computed as follows:

$$\mathbf{CR_{ing}} = \frac{\mathbf{C_i \times IR \times EF} \times \mathrm{ED} \times \mathrm{SF_{ing}}}{\mathrm{BW \times AT_{ca}}} (8)$$

$$\mathbf{CR_{der}} = \frac{\mathbf{C_i \times SA \times K_P \times ET \times EF} \times \mathrm{ED \times CF \times SF_{der}}}{\mathrm{BW \times AT_{ca}}} \quad (9)$$

$$\mathbf{SF_{der}} = \frac{\mathbf{SF_{ing}}}{\mathbf{ABS_g}} (10)$$

The carcinogenic risk is acceptable when for TCR range of $10^{-6} – 10^{-4}$. When TCR $\leq 10^{-6}$, the risk is no significant. While, TCR $\geq 10^{-4}$ indicates the possibility for human to develop cancer (Zhang et al., 2017, Traore et al. 2022)

The exposure parameters used to compute the carcinogenic and non-carcinogenic risks indexes are summarized in the Table 2.

Table 2. Exposureassessmentparameters

Parameters	Meaning	Unit	Value		Reference
			Adult	**Children**	
IR	Ingestion rate	L/day	2.2	1	USEPA (2013)
ED	Exposure duration	years	30	10	USEPA (2013)
EF	Exposurefrequency	days/year	365	365	USEPA (2013)
BW	Average body weight	kg	70	15	USEPA (2013)
SA	Exposure skin area	cm^2	5700	2800	USEPA (2013)
K_P	Permeability coefficient	Cm/h	0.001	0.001	USEPA (2013)
ET	Exosure time	h/day	0.58	1	USEPA (2013)
AT_{nc}	Average time for non-carcinogenic	day	ED×365	ED×365	Coulibaly et al., (2022)
AT_{ca}	Average time for carcinogenic	day	LE×365	LE×365	Coulibaly et al., (2022)
CF	Conversion factor		0.001	0.001	USEPA (2013)
RfD_{ing}	Reference dose of arsenic through ingestion	mg/kg/day	0.3	0.3	USEPA (2013)
SF_{ing}	Slop factor of arsenic through ingestion	mg/kg/day	1.5	1.5	USEPA (2013)
ABS_g	Gastrointestinal absorption factor		1	1	USEPA (2013)

Life expectancy in Ivory Coastis 58 years (LE = 58 years) (**Word Bank, 2019)**

3. Results and discussion

3.1. Physicochemical parameters of groundwater

The pHvalues and the concentrations of TDS, Na^+, Mg^{2+} and Ca^{2+} are given by the Fig. 2. The mean values of pH (Fig. 2e)were 7.63 ± 0.03, 7.88 ± 0.29, 7.88±0.15, 7.06±0.36, and 7.60±0.74, in stations P1, P2, P2, P4, and P5, respectively. These values are in the WHO guideline value (6.5 – 8.5), indicating that these waters could be used for domestic purposes (Traoré et al. 2021). The TDS values (Fig.2d) were below the permissible value (1000 mg/L) of WHO. Indeed, TDS average values varied between 23.33 ± 5.77 and 213.33 ± 11.54 mg/L. Sodium (Na^+) concentrations (Fig. 2a) varying from 2.28 mg/L to 19.79 mg/L did not exceed the limit of 200mg/L, showing low decomposition of igneous rocks (Sunitha and Reddy

2019). These finding corroborate those of Traore et al (2021) in the groundwater near the artisanal mining areas in the central-western Côte d'Ivoire. Magnesium (Mg^{2+}) concentrations (Fig.2b) in the stations P2 (16.00±17.62 mg/L), P4 (14.26±15.86 mg/L), and P5 (7.68 ±6.90 mg/L) were below 30 mg/L (WHO guideline value). Whereas, those in the stations P1 (57.46±88.58 mg/L) and P3 (70.87±113.50 mg/L) exceeded 30 mg/L. According to Singh et al (2012) and Sunitha et al (2019), the decomposition of the ferromagnesia, minerals, the metamorphic rock and the magnesium carbonate in sedimentary rock may release an important amount of Mg^{2+} in the environment. Hence these phenomenon could explained the high concentrations Mg^{2+} obtained in stations P1 and P3. Calcium (Ca^{2+}) concentrations (Fig. 2c)varying from 11.23±10.74 mg/L to 59.34±82.93 mg/Lin all the sampling stations were below the WHO limit value of 300 mg/L, indicating low dissolution of calcite and dolomite (Şener et al. 2017).

3.2. Arsenic distribution in groundwater

The mean total concentrations of As were 32.04 ± 54.63 µg/L, 14.46 ± 21.67 µg/L, 15.93±20.34 µg/L, 26.92±44.90 µg/L, and 9.75±14.34 µg/L in the groundwater from the stations P1, P2, P3, P4, and P5, respectively (Fig. 2f). The total As concentrations in wells P1, P2, P3 and P4 were higher than the WHO standard (10 µg/L) (2017), indicating thatAs may impact negatively human health. In addition, As high concentrations obtained in the wells can be explained by the high infiltration of water and leachates from tongon mine due to rainfall (Abiye and Bhattacharya 2019, Shams et al. 2020). During the study period, As concentrations did not varied significantly ($p < 0.05$) among the stations. However, station P1 has registered the highest concentrations. Data(9.75 – 32.04 µg/L) from this study were compared to those from the literature.As total concentrations from the present study were lower than those obtained by Mudzielwana et al(2020)(32.21µg/L) in South Africa, and by Gemici et al (2008) (33 -911 µg/L) in Turkey. Whereas, data found in Indiaby Reddy and Sunitha(2023) (10.3 µg/L), by Sahoo and Khaoash(2020)(0.3 µg/L) and by Singh et al (2018)(2.4 µg/L), in China by Qiao et al (2020)(0.0027 – 0.003µg/L) and by Pan et al(2022)(1.3 µg/L), in Iran by Solgi and Jalili,(2021)(30.16 µg/L), and in South Africaby Erdogan et al(2020) (10 – 20 µg/L)were lower than ours.

3.3 Groundwater qualityand human health risks assessment

As reported on Fig. 2g, the mean values of thewater quality index WQIwere 161.20±221.93, 86.13±64.98, 117.08±62.88, 122.25±143.13, and 65.76±45.61 in stations P1, P2, P3, P4 and

P5, respectively, thereby suggesting poor quality of waters from the wells P1, P3, and P4. Whereas,waters from wells P2 and P5 qualitiesaregood.

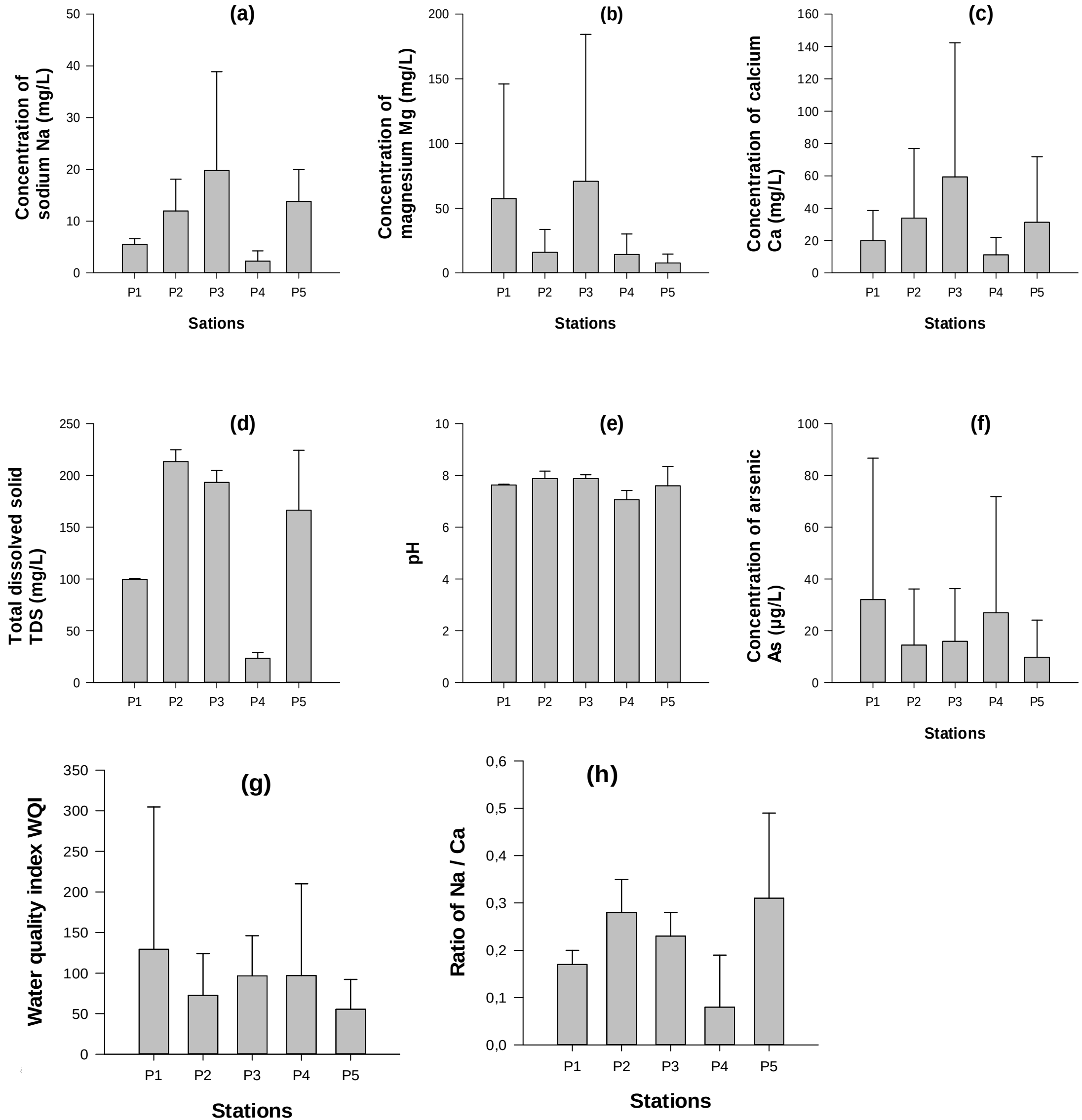

Fig. 2.Spatial variations of sodium (a), magnesium (b), calcium (c), total dissolved solids (d) and arsenic (f) concentrations, and spatial variations of pH (e), water quality index(g) and ratio of Na/Ca (h)

Table 3 indicates the computed values of non-carcinogenic risk (HQing, HQder, HI) and carcinogenic risk (CRing, CR der, TCR) indexes. The HI values for adults and children were ranged from 0.44 to 1.44, and from 2.17 to 7.14, respectively. All HI values for children were above 1. For adults, the HI value obtained at stations P1 (1.44) and P4 (1.21) werehigher than

1. These results showed potential adverseeffects for children, and adults.The results also revealed that the values of HQing (above 1 for children at all stations, and for adults at stations P1 and P4) were higher than those of HQder, showing that arsenic induced adverse effects through ingestion. In addition, children are the most exposed to adverse effects due to their low body weight compared to that for adults, and to their rapid growing (Slogi and Jalili 2021). Indeed, the adults's HI values were lower than those of children. The mean values for CRing varied between 2.38×10^{-4} and 7.81×10^{-4} for adults, and, between 1.68×10^{-4} and 5.52×10^{-4} for children. Those for CRder ranged from 6×10^{-7} to $10^{-6}$for adults, and from $4.7\times10^{-}$to $^{7}10^{-6}$ for children. The values of TCR, varied from 2.38×10^{-4} and 7.82×10^{-4} for adults, and from 1.69×10^{-4} and 5.52×10^{-4} for children. The values of CRing and TCR both for children and adults were above 10^{-4}, suggesting that children and adults can develop cancer.

Table 3. Values of non-carcinogenicrisk and carcinogenicrisk indices

			P1	P2	P3	P4	P5
Non-carcinogenic	Adult	HQing	1.44 ± 2.45	0.65 ± 0.97	0.72 ± 0.91	1.21 ± 2.02	0.44 ± 0.65
		HQder	$2.16\times10^{-3} \pm 3.69\times10^{-3}$	$9.75\times10^{-4} \pm 1.46\times10^{-3}$	$1.08\times10^{-3} \pm 1.37\times10^{-3}$	$1.82\times10^{-3} \pm 3.03\times10^{-3}$	$6.58\times10^{-4} \pm 9.7\times10^{-4}$
		HI	1.44 ± 2.46	0.65 ± 0.97	0.72 ± 0.91	1.21 ± 2.02	0.44 ± 0.65
	Children	HQing	7.12 ± 12.14	3.21 ± 4.83	3.54 ± 4.52	5.98 ± 9.98	2.17 ± 3.20
		HQder	$1.99\times10^{-2} \pm 3.4\times10^{-2}$	$9.00\times10^{-3} \pm 1.35\times10^{-2}$	$9.91\times10^{-3} \pm 1.27\times10^{-2}$	$1.67\times10^{-2} \pm 2.79\times10^{-2}$	$6.1\times10^{-3} \pm 8.9\times10^{-3}$
		HI	7.14 ± 12.17	3.22 ± 4.83	3.55 ± 4.53	6.00 ± 10.01	2.17 ± 3.20
Carcinogenic	Adult	CRing	$7.81\times10^{-3} \pm 1.33\times10^{-3}$	$3.53\times10^{-4} \pm 5.3 \times10^{-4}$	$3.88\times10^{-4} \pm 4.95\times10^{-4}$	$6.56\times10^{-4} \pm 1.1\times10^{-4}$	$2.38\times10^{-4} \pm 3.5\times10^{-4}$
		CRder	$1.20\times10^{-6} \pm 2.00\times10^{-6}$	$5.00\times10^{-7} \pm 7.94\times10^{-7}$	$5.83\times10^{-7} \pm 7.45\times10^{-7}$	$9.86\times10^{-7} \pm 1.64\times10^{-6}$	$3.57\times10^{-7} \pm 5.26\times10^{-7}$
		TCR	$7.81\times10^{-3} \pm 1.33\times10^{-3}$	$3.53\times10^{-4} \pm 5.3 \times10^{-4}$	$3.88\times10^{-4} \pm 4.95\times10^{-4}$	$6.57\times10^{-4} \pm 1.1\times10^{-4}$	$2.38\times10^{-4} \pm 3.5\times10^{-4}$
	Children	CRing	$5.52\times10^{-4} \pm 9.41\times10^{-4}$	$2.49\times10^{-4} \pm 3.73\times10^{-4}$	$2.75\times10^{-4} \pm 3.5\times10^{-4}$	$4.64\times10^{-4} \pm 7.74\times10^{-4}$	$1.68\times10^{-4} \pm 2.48\times10^{-4}$
		CRder	$2.00\times10^{-6} \pm 2.64 \times10^{-6}$	$6.97\times10^{-7} \pm 1.04\times10^{-6}$	$7.69\times10^{-7} \pm 9.81\times10^{-7}$	$1.29\times10^{-6} \pm 2.16\times10^{-6}$	$4.70\times10^{-7} \pm 6.97\times10^{-7}$
		TCR	$5.54\times10^{-4} \pm 9.41\times10^{-4}$	$2.49\times10^{-4} \pm 3.73\times10^{-4}$	$2.75 \times10^{-4} \pm 3.5\times10^{-4}$	$4.65\times10^{-4} \pm 7.74\times10^{-4}$	$1.68\times10^{-4} \pm 2.48\times10^{-4}$

3.4. Sources of arsenic in groundwater

To know the possible sources of As in the groundwater, principal component analysis was performed. The results are shown in Table 4. Three PC loadings accounted for 44.25 % (PC1), 35.99 % (PC2) and 12.28 % (PC3) were selected. The major cations Na^+, Mg^{2+}, and Ca^{2+}were bound strongly on PC1 with loading values of 0.96, 0.86, and 0.96, respectively.This implies that these elements could have a common origin.According to Rakotondrabe et al. (2018), low concentrations of major cations compared to their WHO guidelines values are due to the natural processes such us silicate rocks and carbonate minerals dissolution. In this study, Na^+, Mg^{2+}, and Ca^{2+} concentrations are below to their WHO permissible levels. Therefore, these elements are naturally released in the groundwater. Hence, PC1 can be interpreted as a lithological contribution to the groundwater around Tongon mining area chemistry. The parameters pH and TDS, as well as arseniccontribute to the PC2. The loading values were 0.94 for pH, 0.89 for TDS and (-0.68) for As.It has been reported that, when the solubility of trace metal decresed under basic pH, the trace metal is measured in low concentration (Brindha et al., 2020). In the present study, the majority groundwaters pH are alkaline and the As total concentration are higher the WHO permissible level. Therefore, the pH not influence As distribution in the groundwater.That may explain the negative contribution of As on the PC 2. On the PC 3, only As was bound with loading value of 0.69, indicating that As in groundwater may derived from anthropogenic activities.This can be explained by the lack loading of Na^+ and Ca^{2+} on the PC3. Indeed, an exchange of Na^+ and Ca^{2+} lead to high As concentration in groundwater. This exchange occur when the ratio of Na^+/Ca^{2+} is above to 1 (Sako et al., 2016). The Na^+/Ca^{2+} ratios in the all groundwater around the tongon mining area varied between 0.08 and 0.31 (Fig.2h). Therefore, there is no exchange of Na^+ for Ca^{2+}. Hence the high concentrations of Ascan not be explained by the exchange of Na^+ for Ca^{2+}. Na^+ and Ca^{2+} not play an important role in the distribution of As in the groundwater. That confirm the anthropogenic sources of As. In the study area, industrial and artisanal gold mining activities are well developed. In addition, population use pesticides and phosphate fertilizers to improve the production of the cotton, cashew, yam, corn, and vegetables crops. These agrochemicals release an important amount of As in the environment (Jayasumana et al. 2015, Patel et al. 2023). Therefore, the agricultural and gold minining activities can be potential sources of As in the groundwater. The results of pearson correlation analysis (table S.1in the supplementary material) indicates that Mg^{2+} and Ca^{2+} are correlated (r = 0.72), Na^+

is correlated with Ca^{2+} (r = 0.97) and with Mg^{2+} (r = 0.71). In addition, pH and TDS are correlated (r = 0.84). Whereas, no correlation was found between As and the major cations (Mg^{2+}, Ca^{2+}, and Na^{+}), and between the parameters (pH and TDS). These results are in accordance with those of PCA analysis

Table 4. Principal component analysis (PCA) results

	PC 1	PC 2	PC 3
As	0.17	**-0.68**	**0.69**
Na	**0.96**	0.09	-0.22
Mg	**0.86**	-0.03	0.23
Ca	**0.96**	-0.11	-0.16
pH	0.002	**0.94**	0.26
TDS	0.18	**0.89**	0.26
Eigen value	2.65	2.16	0.74
Total variance (%)	44.25	35.99	12.28
Cumulative variance (%)	44.25	80.24	92.52

4. Conclusion

This study focused on assessing health risks from arsenic in groundwater near Tongon industrial mining area. The results indicated that pH values are in the WHO guideline value (6.5 – 8.5). Sodium (Na^{+}) and calcium (Ca^{2+}) concentrations were lower than thier WHO guideline values (200 mg/L for Na^{+} and 300 mg/L for Ca^{2+}). Magnesium (Mg^{2+}) concentrations exceeded its guideline value of 30 mg/L in the wells P1 and P3. The results also showed that As concentrations did not varied significantly ($p < 0.05$) among the wells. The total As concentrationsin the wells P1 (32.04 ± 54.63 µg/L), P2 (14.46 ± 21.67 µg/L), P3 (15.93±20.34 µg/L), and P4 (26.92±44.90 µg/L) were above the WHO standard (10 µg/L). Water quality index values showed good water quality for the wells P2 and P5. While, waters from wells P1, P3 and P4 are poor quality.The results of non-carcinogenic risk indices showed potential adverse effects for children through the water from all the wells, and adults through the water from the wells P1 and P4. The total carcinogenic risk suggested that children and adults can develop cancer.Complementary studies including arsenic concentrations assessment in the urine, blood and hair must be done to better understand the deleterious effects on the residents around the Tongon mining area.

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