



<http://dx.doi.org/10.5455/sf.XXXXX>

Science Forum (Journal of Pure and Applied Sciences)

journal homepage: www.atbuscienceforum.com



Distribution of strontium in the groundwaters of parts of central Plateau, North central Nigeria

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ABSTRACT

Although the WHO has no guidance for the concentration of strontium in drinking water, consumption of strontium in drinking water and foods has received attention due to its adverse human- health effects. This study was carried out to determine the concentration and distribution of strontium in drinking water in parts of central Plateau State, Northcentral Nigeria. The 65 groundwater samples collected for this study showed no significant variation of strontium with regard to both rock types and drinking water sources. A significant correlation between strontium and the major cations indicates possible feldspar weathering as mineral leaching strontium into the waters. The highest value of strontium in the area was 1.06 mg/l. About 94% of drinking water sources in the area have strontium concentration below the global strontium in the freshwater level of 0.5–1.5 mg/l and 100% below the health-based screening level benchmark of 4 mg/l. It is clear that strontium in the waters of the study area is not adequate for bone development, especially for children. No literature has, however, reported bone-related problems in the area indicating that calcium may be adequate in the waters to supplement strontium in waters and foods. This has been confirmed by the 68% of water sources having calcium and strontium ratio of 100 and above.

ARTICLE INFO

Article history:

Received 28 November 2022
Received in revised form
28 November 2022
Accepted 28 November 2022
Published 31 December 2022
Available online
31 December 2022

KEYWORDS

Strontium
Groundwater
Central Plateau
North Central Nigeria

Introduction

Strontium is an alkaline-earth element with a similar ionic radius and the same charge as calcium. It is common in rocks, soils, sediments, and waters (Musgrove, 2021). Strontium in groundwater is the result of the dissolution of its compound strontianite and celestite (Hem, 1992). Although the WHO has not established a standard for strontium in groundwater as of 2017, studies on strontium and its effect on human health have been carried out (Duo et al., 2021; Hao et al., 2021; Liza et al., 2021). Strontium isotopes have also been used as a tracer in groundwater (Ojiambo et al., 2003; Philipe et al., 2004) studies. Strontium-rich water is

regarded as strontium mineral water (Duo et al., 2021) in China and is being distributed for use all over the country. This is because strontium is regarded as an element that contributes to the formation of bones and teeth and also functions in the human structure of blood vessels. Strontium has the ability to mask the absorption of excess sodium in the body, thereby preventing hypertension and cardiovascular diseases. The distribution of chemical elements in groundwater and its effects on health has been studied in different parts of Nigeria, especially on fluoride (Dibal and Lar, 2005; Lar et al., 2007; Wongdem et al., 2003) and on radon in groundwater (Akinagbe et al., 2018; Dibal

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et al., 2021; Garba et al., 2013; Gbadebo et al., 2021; Joseph et al., 2018; Kalip et al., 2018; Olise et al., 2016; Oni and Adagunodo, 2019; Pauline et al., 2021) but there is no mention of the distribution and importance of strontium in groundwater and its effect on human health. The aim of this study is to determine the distribution of strontium in groundwater in parts of central Plateau State, Nigeria, and draw inferences as to the likely effect of this distribution in the area.

Methodology

Description of the study area

This study area covers parts of Mangu and Pankshin with a total area of about 500 square kilometers (Fig. 1). Except for Abor Dyis which is at an altitude of below 900 m above sea level, the remaining area is at an altitude of above 1,000 m above sea level. Drinking water sources are obtained from hand-dug wells and springs, and in some localities, individuals and the

government have provided hand pumps for the locals. Spring water sources are common in areas covered with volcanic rocks, which issues out by hillsides of the volcanic piles. The discharge from the Punguk spring is about $0.234 \text{ m}^3/\text{second}$ (Longpia, 2020). It is located about 2 km from the popular Kerang volcanic Hill, known as the “Swan Water” which has a wide distribution all over Nigeria, used as “Table Water.” Two rock types characterized the study area: the basement rocks and the volcanic rocks. The basement rocks are of two types – the porphyritic biotite granites and the migmatites. The porphyritic biotite covers areas around Mangu, Gindiri, and Pushit and west and east of Bownpe where the volcanic piles have not buried them and the migmatite outcrops around Pankshin. Intruded into these rocks are fine to medium-grained biotite granite which outcrops between Mangu and Panyam in Deka village and syenite in Pankshin. The volcanic flows cover the area around Panyam, Kerang, Punguk, Niyes, and Abor Dyis. Hydrogeologically,

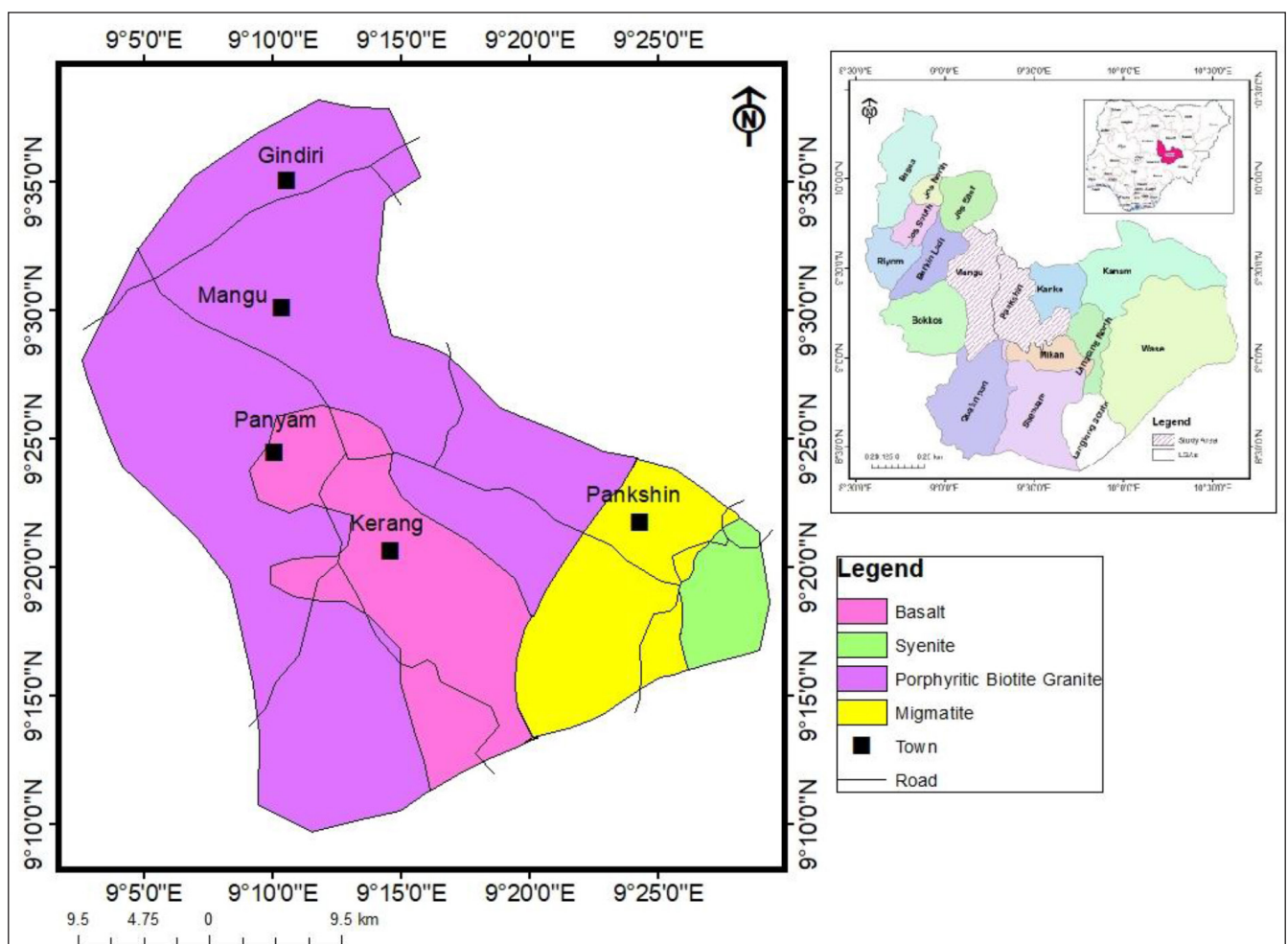


Figure 1. Location and geological map of the study area.

water occurs in the sub-basalt aquifers in areas covered by the flows and in overburdened, weathered, and in fractures in the basement rocks.

Field sampling of groundwater

Waters were sampled from hand-dug wells (45), hand pumps (13), and springs (7). The sampling points are shown in Figure 2. The hand-dug wells were sampled according to the method described by Davies 1994. Hand pumps were pumped for at least 2–3 minutes, with the view that stagnant waters in the column of pipes are removed so as to sample waters from the formation, this was not done for pumps that were already in use. Spring waters were sampled close to issuing point to minimize contact with the atmosphere. Two water samples were collected in 250 ml plastic bottles

which were prewashed with HCl acid and rinsed with distilled water before the sampling exercise. In the field, the bottles were rinsed again with water to be sampled three times before it was collected. One of the samples was acidified to a pH of < 2 to preserve the ions in the water for samples to be analyzed for cations.

Sampling preparation and laboratory analysis

In the laboratory, the acidified samples were transferred into 60 ml bottles, packaged, and sent to Bureau Veritas Mineral Laboratories Canada for analysis. The cations including strontium were analyzed with the Inductively Coupled Plasma Optical Emission Spectrophotometer.

The anions (HCO_3 , SO_4 , and Cl) were analyzed at the University of Jos, Department of Geology. Bicarbonate

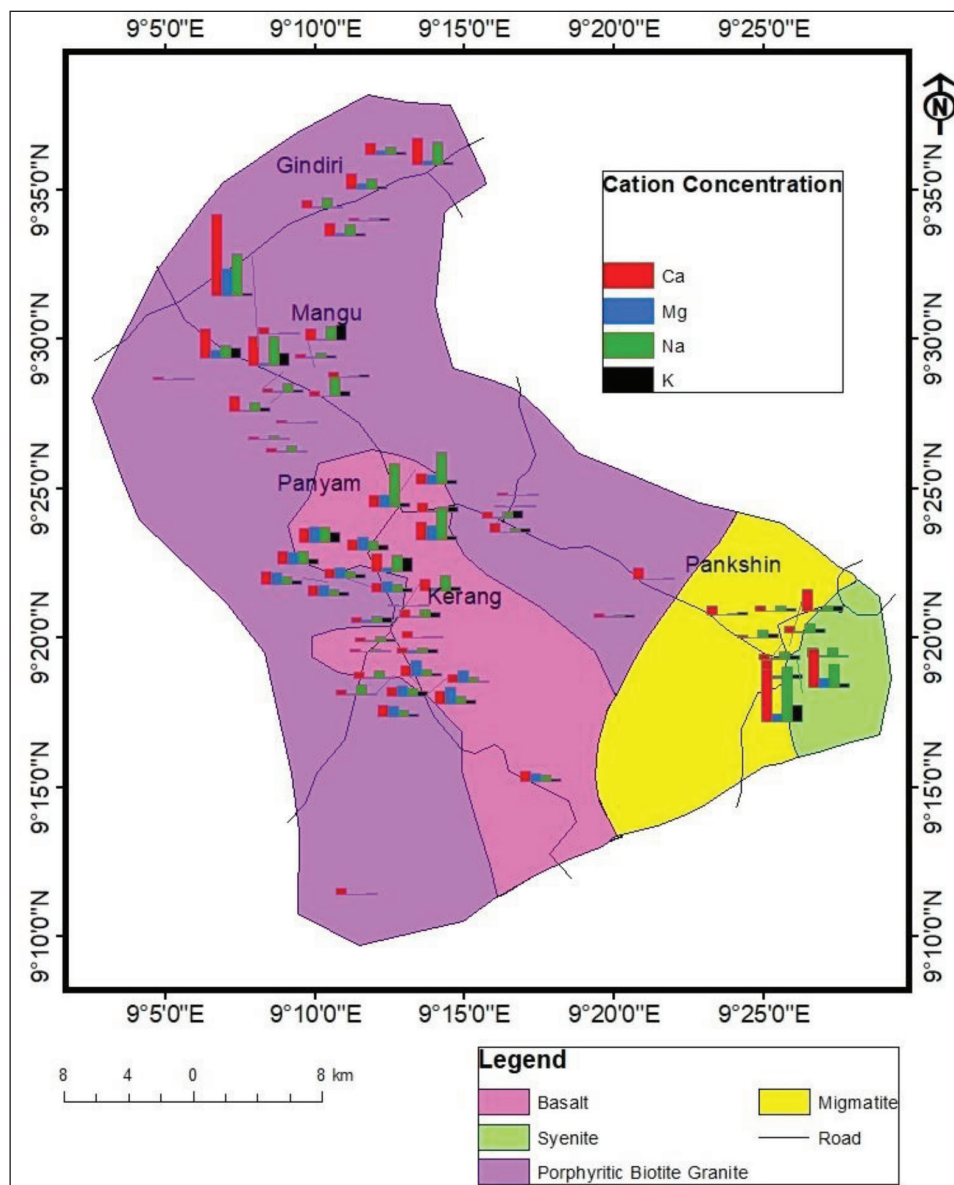


Figure 2. Distribution of cations (Ca, Mg, Na, and K) in the study area.

and chloride were analyzed by titration methods and sulfate by the UV Multi Ion Parameter Model 2000.

Results

Concentration and distribution of the elements in the groundwater

The concentration of the elements is presented in [Table 1](#) and distributions of some of the cations and anions are shown in [Figures 2](#) and [3](#). The concentration is in the order of $\text{Ca} > \text{Na} > \text{Mg} > \text{K}$ for the cations and among the anions $\text{HCO}_3^- > \text{Cl}^- > \text{SO}_4^{2-}$. There are no clear variations in the distributions of the cations with regard to the rock types. However, elevated values of calcium have been recorded in the northern as well as the southern areas. Sodium is elevated in a few points in the north, central, and southern parts of the study area. The distribution of magnesium is more uniform across the study area and so is potassium, but the low concentration of potassium in the waters makes them hardly seen ([Fig. 2](#)). The anions show the central areas to have a high concentration of bicarbonate. In the northern and southern areas, only a few points have this high concentration. Chloride concentration is generally low across the study area, but the lower concentration is obtained more in the northern areas compared to the central and southern areas.

3.2. Concentration and distribution of strontium and calcium/strontium ratio

Strontium in the waters ranges from 0.01 to 1.06 mg/l in the study area ([Table 1](#)). Although the number of water samples collected within each rock type varies, different host rocks vary in concentration of strontium. The concentration of strontium in the syenite host rock ranges from 0.12 to 0.88 mg/l, with three out of the four samples having a concentration > 0.50 mg/l. In the migmatite host rock, the concentration of strontium ranges from 0.07 to 0.22 mg/l. About 80% of the water in this host rock has a concentration > 0.10 mg/l of strontium in water. Waters in the basalts and porphyritic biotite granite host rocks range from 0.02 to 0.35 mg/l and 0.01 to 1.06 mg/l, respectively. About 70% of water in the basalt has a strontium concentration > 0.10 and 39% of the water in the porphyritic biotite granite has strontium < 0.10 mg/l. The concentration of strontium also varies with different sources. The hand-dug wells have strontium in the range of 0.01–1.06 with 37% of the sources having strontium in water < 0.10 mg/l. Strontium level in the waters of the hand pumps ranges from 0.05 to 0.16 mg/l with 23% having strontium in waters < 0.10 mg/l. About 100%

of the spring sources have > 0.10 mg/l of strontium in water, with a range of 0.10–0.20 mg/l. It appears that the spring sources have higher strontium concentration than the other two sources (hand-dug wells and hand pumps).

The distribution of strontium shows that around the Gindiri area in the northern part, only one point has a concentration in the range of 0.00–0.09 mg/l of strontium in water. Two sample points have a concentration ranging from 0.10 to 0.19 mg/l of strontium and the three remaining points have greater than 0.20 mg/l. In Mangu and its environs, all the sample points except one have a concentration of strontium in the water of greater than 0.20 mg/l in water. The outskirts areas have lower concentrations of strontium in water.

The concentration of strontium in the range of 0.10–0.19 dominates the central areas. The areas are characterized by basaltic rocks and the contact between the basaltic and the porphyritic biotite granite rocks. The same distribution in concentration is obtained in the southern portion of the study area ([Fig. 4](#)).

Ca/Sr ratio in waters of the area ranges from 17.23–553.00. the lowest of 17.23 is obtained in a hand-dug well at Kurgwam 2 and the highest in a hand-dug well at Kurgwam 1 within the porphyritic biotite granite. About 32% of sample points in the study area have a Ca/Sr ratio of less than 100 and 68% of sample points have greater than 100. All sources in the Gindiri area have a Ca/Sr ratio greater than 100, but on a general note, the greater than 100 values dominate and are fairly distributed across the area.

Correlation of strontium with some ions in water

The cations (Ca, Na, Mg, and K) show some significant level of correlation with strontium ([Fig. 6](#)). This correlation is stronger, especially with calcium. But, no clear correlation between the anions was exhibited with strontium.

Water type in the area

The piper diagram ([Fig. 7](#)) shows two dominant water types; Ca-Mg-HCO₃-Cl and Na-HCO₃-Cl water types in the area.

Discussion

4.1. Occurrence of strontium in the study area

But for the uniform concentration in the springs which are located in the basaltic environment, similar values in concentration have been obtained in the different rock types as well as in the different sources from which the waters were obtained. Control on the

Table 1. Concentration of major elements and Ca/Sr ratio in the study area.

Y	X	LOCATION	SOURCE	Ca	Mg	Na	K	Cl	HCO ₃	SO ₄	Sr	Ca/Sr	ROCK TYPE	
L1	9.32091	9.43526	YILTU (PANKSHIN)	HAND-DUG WELL	88.8	14.07	94.56	28.05	10.00	276.00	16.00	0.88	100.88	sy
L2	9.3225	9.44814	KURUM (PANKSHIN)	HAND-DUG WELL	15.9	2.6	15.73	2.07	14.00	242.00	18.00	0.12	131.89	sy
L3	9.32586	9.44814	ANGWAN MISSION(PANKSHIN)	HAND-DUG WELL	65.1	14.41	38.76	6.91	21.00	32.30	12.00	0.62	105.02	sy
L4	9.32869	9.43153	UBA (PANKSHIN)	HAND-DUG WELL	37.4	1.01	7.38	7.29	49.00	36.30	10.00	0.21	178.76	mig
L5	9.33629	9.42935	VWEL(PANKSHIN)	HAND-DUG WELL	10.4	1.57	14.00	6.45	77.00	80.80	10.00	0.20	52.36	mig
L6	9.34788	9.42187	DUK (PANKSHIN)	HAND-DUG WELL	9.61	0.83	8.62	4.23	35.00	44.40	10.00	0.10	97.71	mig
L7	9.32953	9.42703	NEW MARKET (PANKSHIN)	HAND-DUG WELL	30.9	3.76	15.69	7.39	49.00	44.40	17.00	0.22	143.79	mig
L8	9.32146	9.42591	ANG. TAZUK (PANKSHIN)	HAND-DUG WELL	7.31	2.15	12.87	5.03	49.00	78.70	14.00	0.13	57.49	mig
L9	9.33308	9.41359	GENERAL HOSP (PANKSHIN)	HAND PUMP	4.65	1.39	12.91	7.39	42.00	80.80	11.00	0.09	52.09	mig
L10	9.34581	9.39685	GERR (PANKSHIN)	HAND-DUG WELL	15	0.20	3.51	4.14	49.00	76.70	10.00	0.07	203.70	mig
L11	9.34424	9.33356	FCE (PANKSHIN)	HAND PUMP	7.30	2.39	6.35	5.49	56.00	84.80	17.00	0.14	51.19	PBG
L12	9.3658	9.35526	COCIN (FIER)	HAND-DUG WELL	20.1	0.86	1.03	3.38	14.00	72.70	11.00	0.05	441.69	PBG
L13	9.4008	9.27779	MUTHIR (PUSHIT)	HAND-DUG WELL	2.23	0.28	2.09	2.67	35.00	70.70	10.00	0.01	196.13	PBG
L14	9.40325	9.27549	ANG PASTOR (PUSHIT)	HAND-DUG WELL	14.8	0.73	6.07	6.18	7.00	46.40	17.00	0.09	158.33	PBG
L15	9.41238	9.2794	PWASKOP (PUSHIT)	HAND-DUG WELL	4.73	0.33	1.15	2.34	18.00	157.00	34.00	0.02	242.56	PBG
L16	9.4002	9.27126	ANG SARKI (PUSHIT)	HAND-DUG WELL	9.03	2.24	9.77	11.56	49.00	82.80	26.00	0.12	77.43	PBG
L17	9.40322	9.23479	JUWAK (PANYAM)	HAND-DUG WELL	16.2	3.35	8.72	9.78	85.00	58.50	16.00	0.18	88.38	bas
L18	9.40275	9.21132	MISSION COMP (PANYAM)	HAND-DUG WELL	28.8	22.56	53.26	6.24	49.00	70.70	11.00	0.29	99.84	bas
L19	9.40596	9.20808	ANG. POULTRY (PANYAM)	HAND PUMP	17.5	17.2	56.47	6.53	14.00	105.00	27.00	0.14	126.75	bas
L20	9.34036	9.20992	SHAMSOHO (KERANG)	HAND-DUG WELL	19.8	4.75	26.15	5.98	21.00	10.10	10.00	0.35	56.77	bas
L21	9.333	9.21463	DUMBIN (KERANG)	HAND-DUG WELL	11.6	0.99	2.38	2.67	14.00	26.20	24.00	0.06	188.85	bas
L22	9.33512	9.20186	KURGWAN (KERANG)	HAND-DUG WELL	7.51	3.17	7.87	6.56	7.00	50.50	11.00	0.10	76.44	bas
L23	9.33303	9.197	FUVU SWAN (KERANG)	HAND-DUG WELL	3.52	0.38	4.49	1.21	21.00	64.60	9.40	0.02	231.88	bas
L24	9.34705	9.21049	DUNGRAR (KERANG)	HAND-DUG WELL	11.7	2.02	11.47	7.36	21.00	62.60	11.00	0.18	66.45	bas
L25	9.47449	9.15345	DAWO (MANGU)	HAND-DUG WELL	24.7	2.51	13.76	5.11	7.00	20.20	10.00	0.13	195.25	PBG
L26	9.48053	9.15616	BUNGA (MANGU)	HAND-DUG WELL	9.62	0.80	33.68	8.20	14.00	62.60	11.00	0.08	120.78	PBG
L27	9.48442	9.16611	JWAKGASS (MANGU)	HAND-DUG WELL	21	2.77	24.52	26.74	7.00	22.20	11.00	0.42	50.38	PBG
L28	9.48162	9.14829	HIGH COURT (MANGU)	HAND-DUG WELL	6.31	3.36	15.45	4.56	7.00	30.30	11.00	0.05	127.19	PBG
L29	9.48958	9.14621	ANG.SARKI (MANGU)	HAND PUMP	4.67	0.96	8.26	4.58	7.00	58.50	8.50	0.09	49.68	PBG
L30	9.47862	9.1851	POST OFFICE (MANGU)	HAND-DUG WELL	9.12	0.26	1.21	4.97	10.00	76.70	8.00	0.05	188.04	PBG
L31	9.48925	9.13465	DENGDENG (MANGU)	HAND-DUG WELL	140	45.98	72.12	4.15	14.00	74.70	9.50	1.06	132.52	PBG
L32	9.48752	9.12848	CHINCHIN (MANGU)	HAND-DUG WELL	48.6	12.9	21.02	16.02	7.00	58.50	9.00	0.38	128.49	PBG
L33	9.48474	9.14016	ANG MISSION (MANGU)	HAND-DUG WELL	50.7	6.35	52.21	23.25	14.00	48.40	11.00	0.52	97.15	PBG

Continued

Y	X	LOCATION	SOURCE	Ca	Mg	Na	K	Cl	HCO ₃	SO ₄	Sr	Ca/Sr	ROCK TYPE
L34	9.50244	9.14623	HAWWA MEM.(MANGU)	12.1	2.10	2.20	2.86	14.00	84.80	19.00	0.05	268.19	PBG
L35	9.57755	9.1953	SABON BARKI (GINDIRI)	12.5	1.89	16.86	2.01	7.00	131.00	11.00	0.15	83.81	PBG
L36	9.58381	9.1953	COCIN COMPD (GINDIRI)	26.1	7.32	16.06	4.59	42.00	119.00	12.00	0.27	95.59	PBG
L37	9.603	9.21859	DECHEINJE (GINDIRI)	18.9	5.04	12.07	3.59	35.00	105.00	16.00	0.24	79.83	PBG
L38	9.59691	9.23195	ANG MAGAJI (GINDIRI)	45.8	6.58	39.05	6.00	77.00	64.60	14.00	0.40	114.88	PBG
L39	9.56594	9.19648	COE (GINDIRI)	4.96	0.73	3.38	4.70	28.00	44.40	32.00	0.04	135.67	PBG
L40	9.55765	9.18292	KASUWAN ALI (GINDIRI)	21.7	3.99	18.65	3.50	21.00	34.30	12.00	0.19	116.67	PBG
L41	9.4062	9.208	PANYAM 1	19.6	19.83	74.42	6.04	53.60	243.40	4.60	0.11	177.82	bas
L42	9.3419	9.1981	KURGWAM 1	9.34	4.64	10.9	7.72	3.89	19.19	6.50	0.02	467.00	bas
L43	9.351	9.2184	KURGWAM 2	2.24	0.17	0.56	1.39	1.99	12.20	9.20	0.13	17.23	bas
L44	9.2965	9.2316	AJING BWONPE 1	21.8	28.48	12.12	6.44	14.89	157.56	5.50	0.11	197.82	bas
L45	9.3056	9.2255	AJING BWONPE 2	19.20	26.32	11.14	4.62	12.90	135.34	7.50	0.11	174.55	bas
L46	9.2528	9.2921	ABWOR DYIS	17.7	13.59	11.75	4.19	5.96	120.19	6.00	0.16	110.69	bas
L47	9.3017	9.2283	AJING	14.60	19.70	8.90	4.20	7.63	250.47	1.33	0.08	182.50	bas
L48	9.3008	9.2181	BWONPE 3	14.20	17.50	11.90	8.60	5.10	264.96	5.33	0.10	142.00	bas
L49	9.3314	9.2	KURGWAM 3	4.70	2.20	9.00	2.50	2.28	78.66	<0.03	0.20	23.50	bas
L50	9.3642	9.1728	PUNGUK	22.00	18.30	12.40	6.90	9.24	333.27	3.38	0.21	104.76	PBG
L51	9.3667	9.1831	AMSHAL 1	14.90	18.20	12.90	8.10	3.88	279.45	3.05	0.10	149.00	PBG
L52	9.3567	9.1739	KONJI	17.90	18.40	10.90	7.60	4.27	262.89	3.58	0.17	105.29	PBG
L53	9.3747	9.1733	UGUT	21.60	20.50	22.20	8.60	6.18	382.95	7.00	0.18	120.00	PBG
L54	9.3667	9.1831	AMSHAL 2	14.50	16.20	11.50	7.10	4.79	225.63	3.35	0.10	145.00	bas
L55	9.3014	9.1994	SHIPANG	10.60	2.90	14.40	2.80	8.91	117.99	<0.03	0.15	70.66	PBG
L56	9.1897	9.1897	PYEP	10.70	0.40	1.40	2.10	8.96	70.38	0.70	0.02	535.00	PBG
L57	9.3822	9.1969	NIVES	29.80	7.10	28.40	24.30	8.81	178.02	23.90	0.12	248.33	PBG
L58	9.4386	9.1503	MILLET	6.00	1.80	11.20	2.40	0.33	93.15	3.80	0.05	120.00	PBG
L59	9.4528	9.1564	POHOL	4.70	0.40	0.90	2.50	0.21	41.40	0.22	0.01	470.00	PBG
L60	9.2892	9.2128	KOPI	19.20	17.40	10.80	3.80	10.50	221.49	8.65	0.19	101.05	PBG
L61	9.3014	9.1897	AMPANG WEST	7.90	1.10	17.70	2.00	5.01	55.89	0.19	0.06	131.67	PBG
L62	9.3822	9.1867	PANG	16.80	21.10	16.20	9.00	8.52	298.80	2.95	0.10	168.00	bas
L63	9.3861	9.1692	JWAKMANG	24.60	26.40	28.20	18.60	0.20	461.61	1.86	0.16	153.75	bas
L64	9.4769	9.0875	BUNGHA	6.20	0.40	3.20	2.10	1.18	49.68	0.60	0.02	310.00	PBG
L65	9.4436	9.1403	JWAKMILLET	5.80	1.10	7.40	3.50	0.20	84.87	0.16	0.06	96.66	PBG

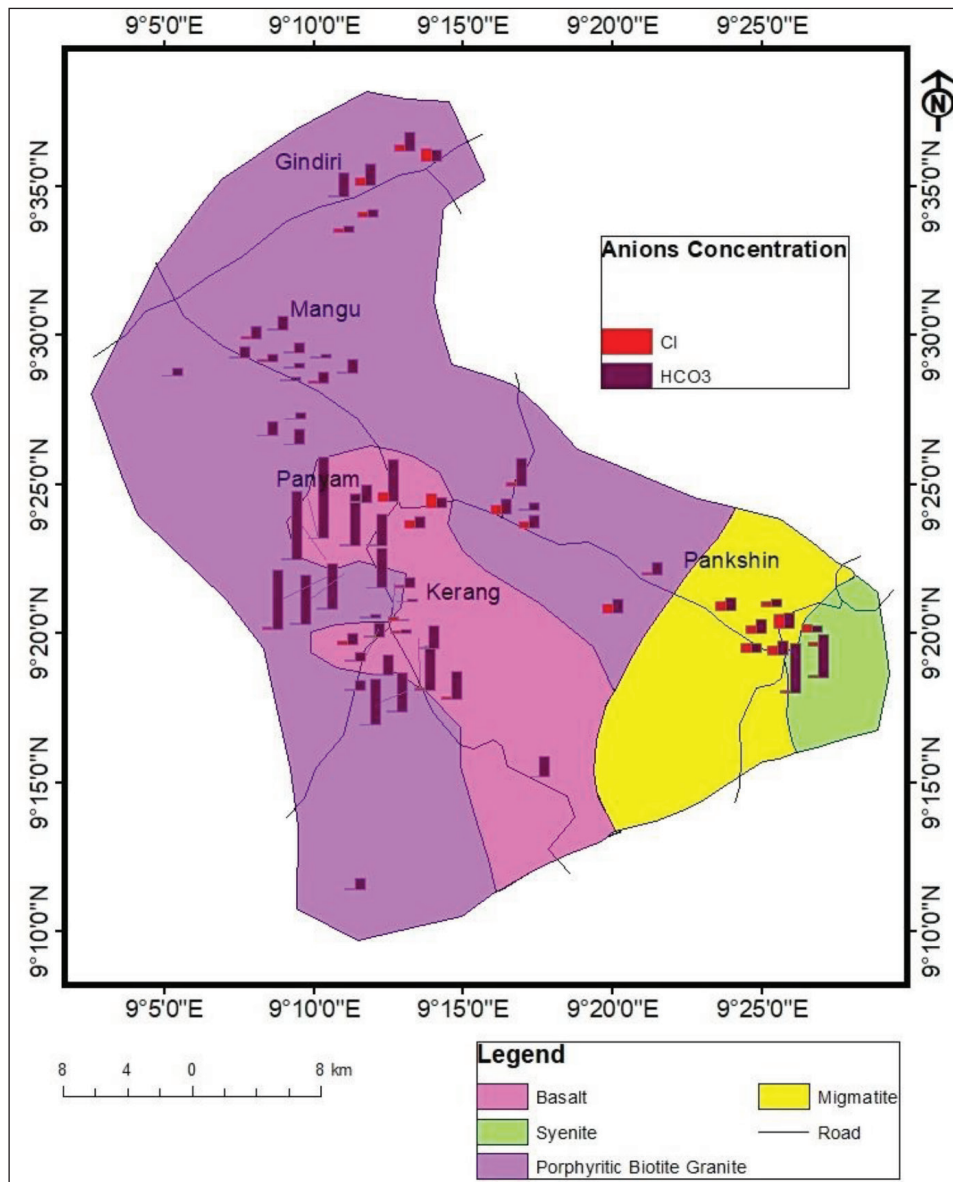


Figure 3. Distribution of HCO₃ and Cl in the study area.

concentration of strontium in the area is the rock types that constitute the study area. This is confirmed in the positive correlation exhibited between strontium and the major cations, especially calcium. A positive correlation of strontium with these ions has also been confirmed by (Duo et al., 2021; Musgrove, 2021). However, a weak correlation between strontium and these ions in water was confirmed by (Health Canada, 2018; Scott et al., 2020). Because, strontium substitutes for calcium in plagioclase feldspars (Krauskopf and Bird, 1995), the weathering of plagioclase feldspars which are a major constituent of all the rocks (Lekmang, 2020; Longpia, 2020) may be responsible for the concentration in the waters. The weak

correlation between SO₄ and HCO₃ ruled out celestine and strontianite as minerals responsible for strontium in the waters. Moreover, these minerals are normally associated with the carbonate environment than with the crystalline environment (Musgrove, 2021). Also, the concentration of strontium in the waters could not be from industrial activities, nuclear atmospheric fallout, and or fertilizers (Watts and Howe, 2007; Böhlke and Horan, 2000) as these activities are not practiced in the area. The water types in the area do not seem to be ones that may support the concentration of strontium in waters being HCO₃-Cl type as the concentration of strontium in waters used as mineral waters are of the HCO₃ type waters (Duo et al., 2021). Here, we

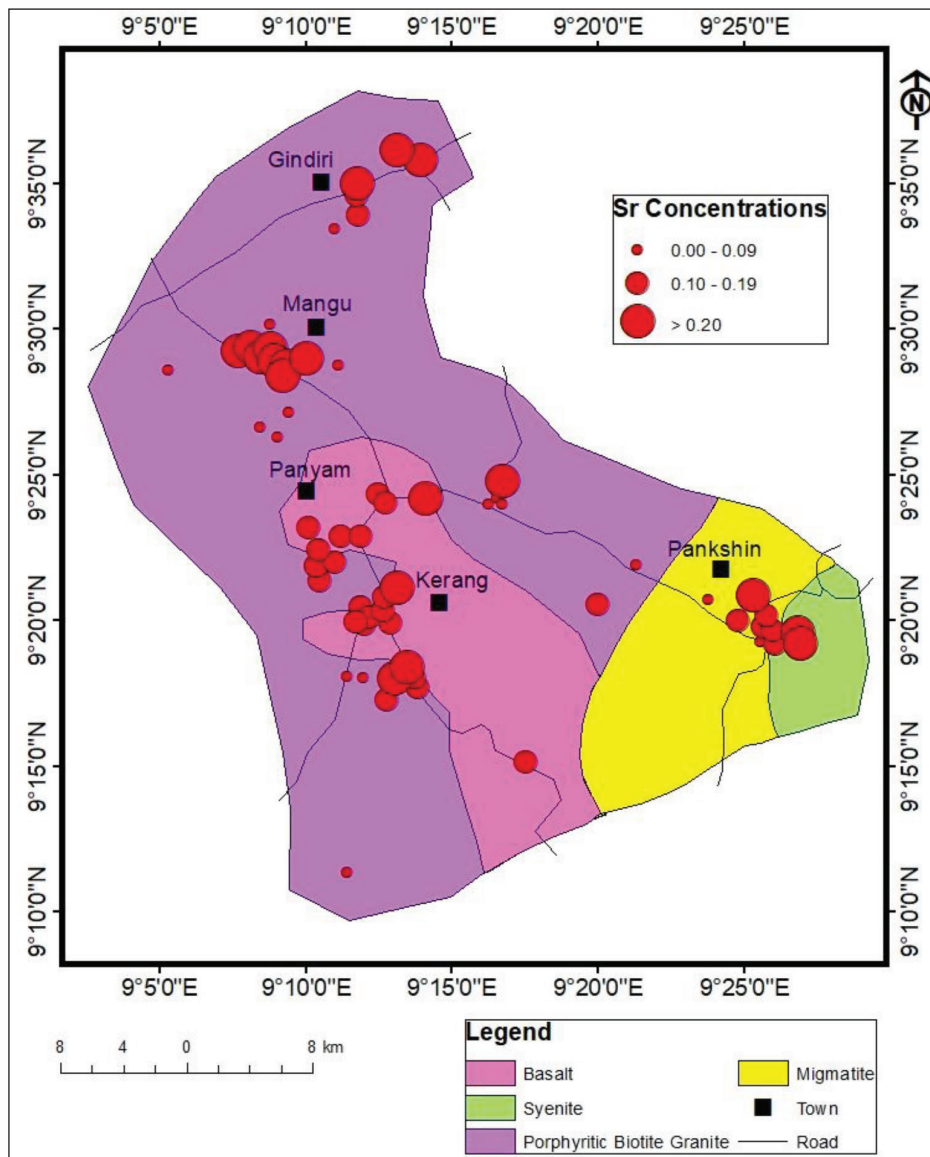


Figure 4. Distribution of strontium in waters of the study area according to rock types.

believe the presence of chloride to be a contribution from anthropogenic activities as most of the wells are in residential and public environments.

The concentration of strontium in the waters of the study area shows that 94% of the sources fall far below the strontium global freshwater average of 0.5–1.5. However, the concentration compares well to different ranges of strontium in waters in countries like China – 0.005–3.11 (Hao et al., 2021); USA – <0.5–32,000 ug/l. In Canada, concentration was determined for different sources and our waters have been found to compare well with them.

4.2. Effects on health

Only a few studies have documented the adverse effect of strontium on bones, compared to the many on animals which showed ingestion of high doses of strontium has adverse effects (Health Canada, 2018). Humans are exposed to strontium mainly from foods and drinking water. Canada, for example, has set a maximum allowable concentration level of 7.0 mg/l to protect infants, since the highest sensitivity to adverse bone effects occurs during the first year of life. The WHO as of now does not have guidance for strontium

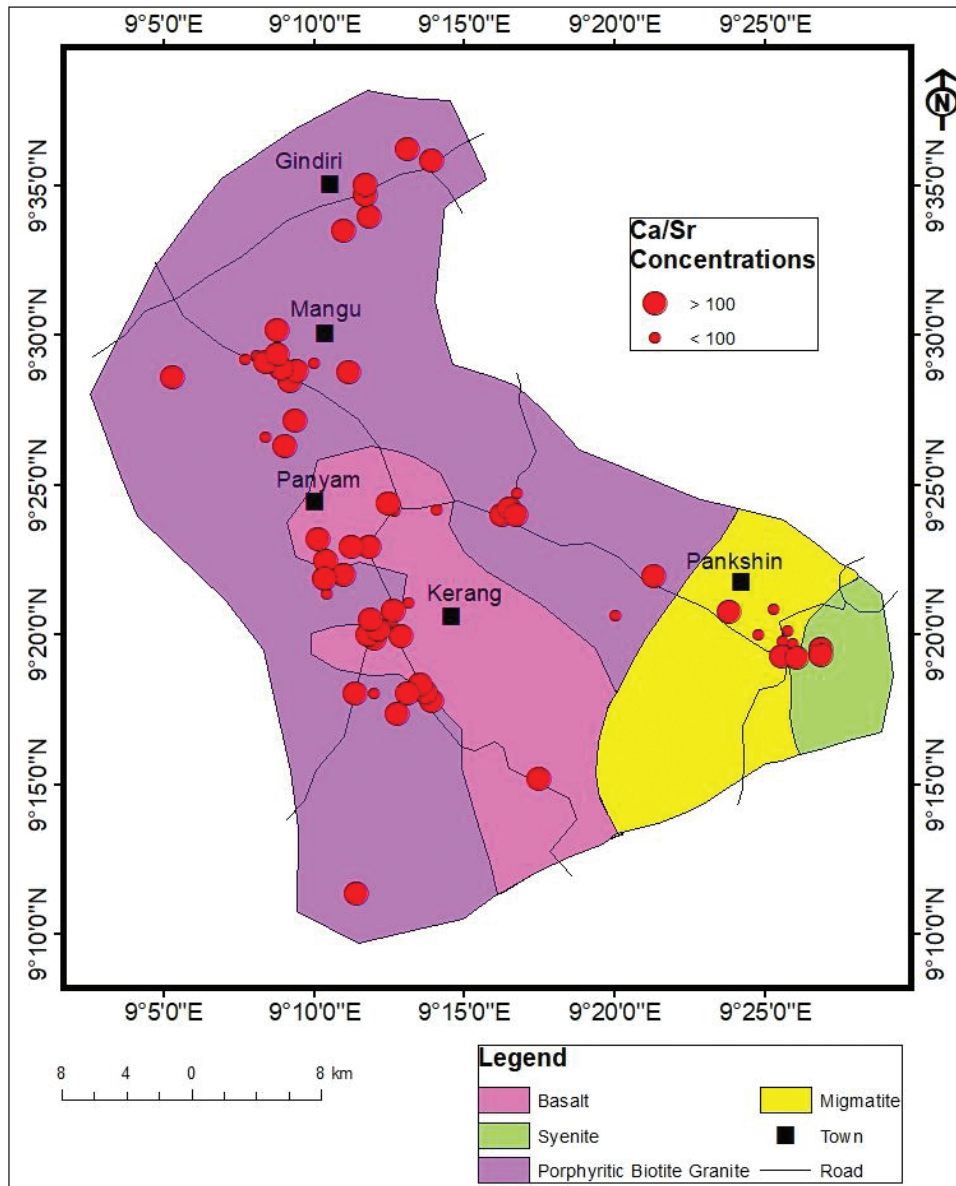


Figure 5. Ca/Sr ratio map of the study area.

concentration in drinking water. However, a health-based screening level (HBSL) of 4.0 mg/l, a non-enforceable water quality standard benchmark designed to supplement the United State Environmental Protection Agency regulatory standard to assess potential human health concerns for the contaminant in drinking water has been proposed.

With over 96% of water sources having less than the global 0.5–1.5 mg/l for strontium in fresh water and 100% of all sources below the HBSL of 4.0 mg/l, waters in the area may probably not be meeting the need for bone development, especially for children. But since no incidence of bone problems has been reported in the area, supplements from other elements such as

calcium which are critical for bone development may be adequate in foods and waters. This is confirmed in the calcium and strontium ratio in the waters of the area with 68% of sample points having above 100 which may be adequate for bone development (Hao et al., 2021). Gusikit, 2007, however, reported a loss of teeth, especially in adults ages between 40 years and above in the area, and attributed these losses to the low concentration of fluoride in the waters. Since strontium has also been reported as a component of teeth (Duo et al., 2021) and to strengthen the enamel (Wang et al., 2019), the low content of both fluoride and strontium may be responsible for the loss of teeth in the area.

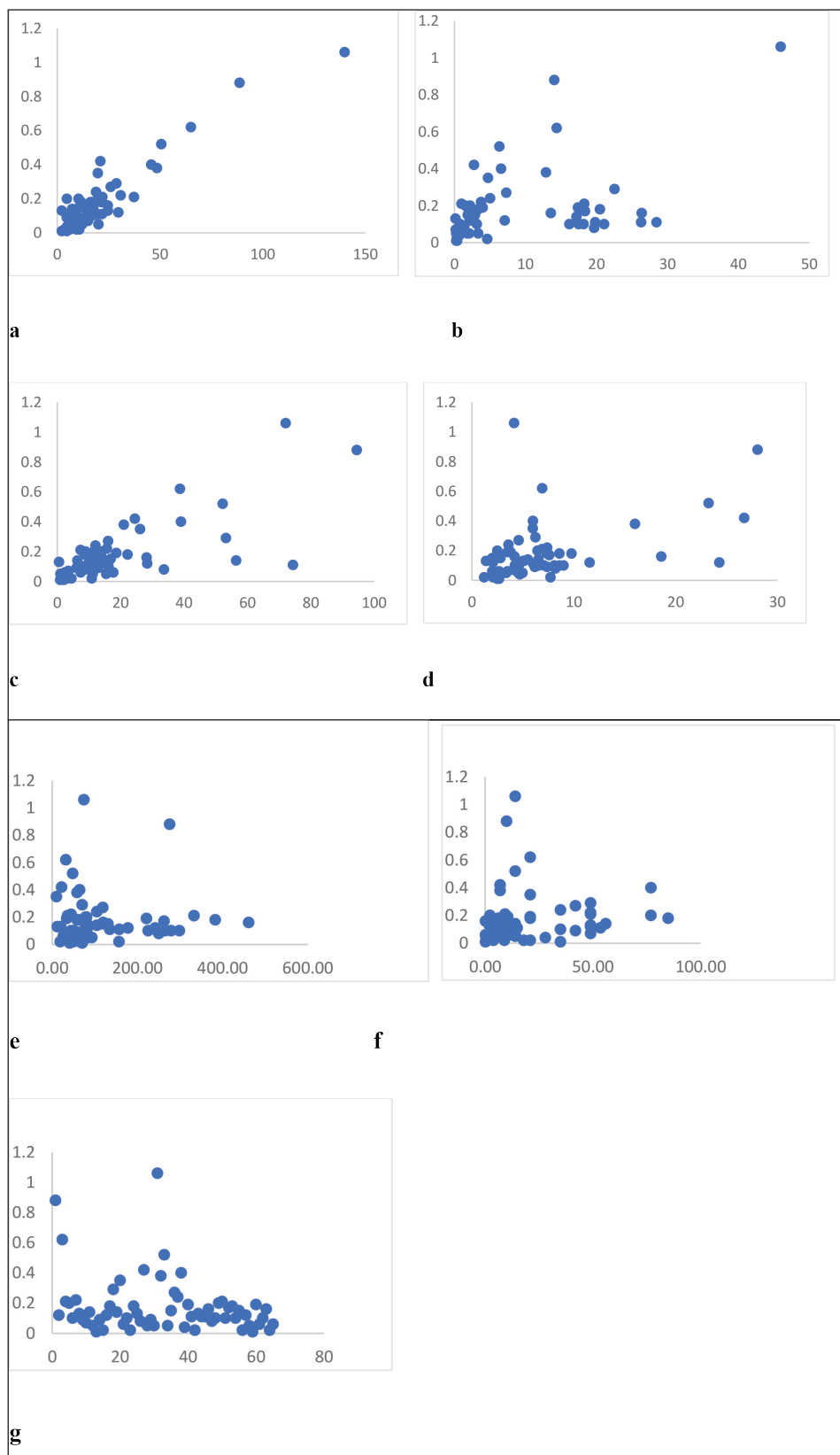


Figure 6. Relationship between strontium and major cations and anions in waters of the area. (a) Sr versus Ca (b) Sr versus Mg (c) Sr versus Na (d) Sr versus K (e) Sr versus HCO₃ (f) Sr versus Cl (g) Sr versus SO₄.

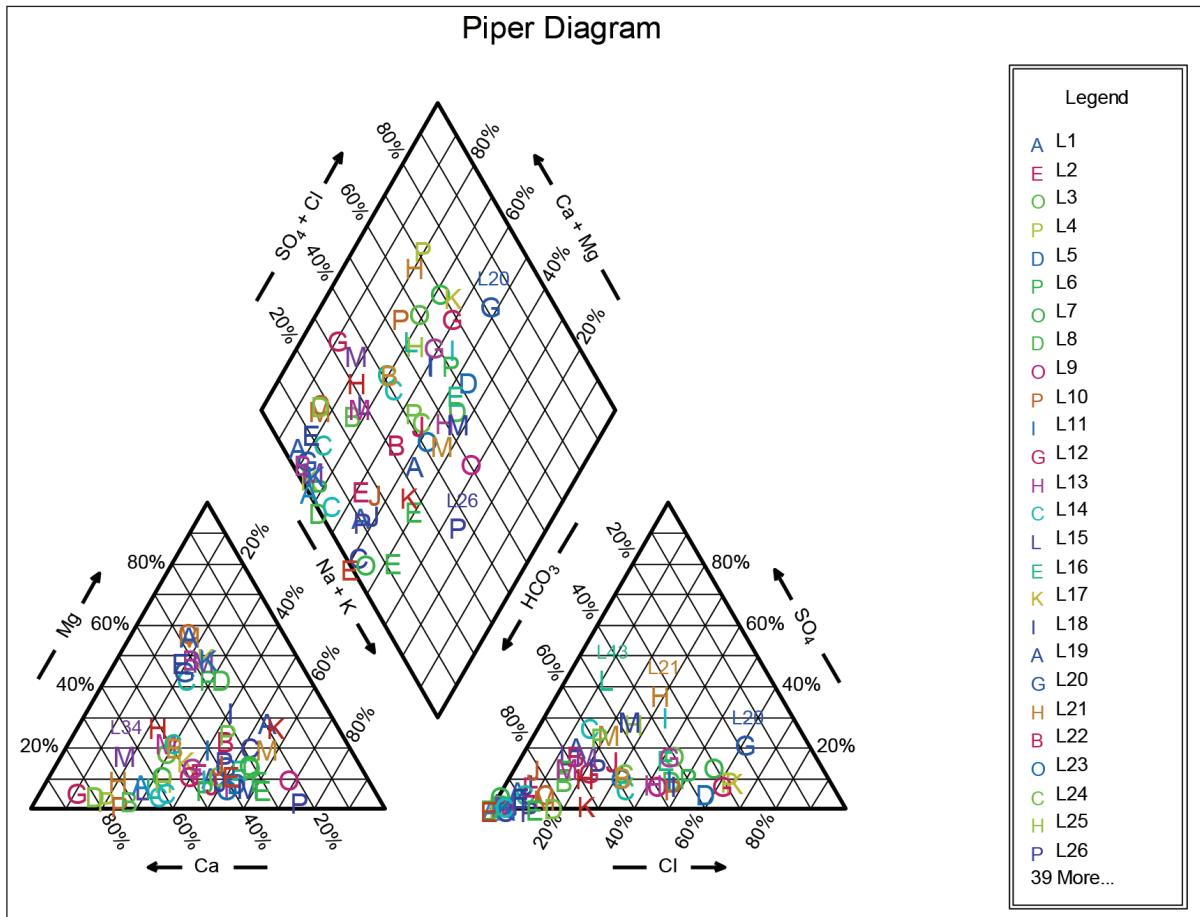


Figure 7. Water type in the study area.

Conclusion

The distribution of strontium and concentration of other elements in the waters of the study area was studied. There are no clear variations in distributions of the cations and strontium with regard to the rock types. However, the spring sources located within the volcanic rocks have been found to have a similar concentration of strontium. The weathering of feldspars may be the principal mineral leaching strontium in the waters. This is exhibited in the significant correlation between strontium and the cations. Chloride being a component of the water type in the area, may be contributed from anthropogenic sources.

About 94% of water sources fall far below the strontium global freshwater average of 0.5–1.5 mg/l. However, the concentration compares well to different ranges of strontium in waters in countries like China and the USA.

Waters in the area may probably not be meeting the need for bone development, especially for

children with 100% of all sources below the HSBL of 4.0 mg/l. But since no incidence of bone problems has been reported in the area, supplements from other elements such as calcium which are critical for bone development may be adequate in foods and waters. This is confirmed in the calcium and strontium ratio in waters of the area having 68% of sample points above 100 which may be adequate for bone development.

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