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The Influence of Seasonal Variations on Ground and Surface Water Quality at Southern Kordofan State, Sudan

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Abstract: *The aim of this study was to evaluate the seasonal variation effects on drinking water quality at Southern Kordofan state. Ground and surface water samples were collected from the same sources during autumn and winter seasons. The sampling covered the thirteen localities of the state. pH, EC, and TDS values were measured. The concentrations of* SO_4^{2-}, NO_3^- *and* F^- *were determined by UV-Vis spectrophotometer. Chloride content was titrimetrically measured. Minerals Inductively coupled plasma analysis was carried for measuring minerals content. The obtained results showed clear seasonal variations in TDS, EC, pH values,* F^-, Cl^-, SO_4^{2-} *and* NO_3^-. *Na and K concentrations were higher in winter. The concentrations of Ca and Mg in winter sometimes increase or decrease than that of autumn for ground water samples, but showed regular increasing in surface water samples. The trace minerals concentrations were significantly low in the two seasons and only Fe, Al and Cu showed minor seasonal variations. According to WHO SSMO guidelines values all the studied water sources may be good, suitable and safe as drinking water sources.*

Keywords: Southern Kordofan, Seasonal variations, Ground water, ICP.

Introduction

In Sudan about 75% of the population depends on ground water sources for human drinking and livestock watering (Gibla Omer A., 2007). Sudanese also obtain drinking water from some surface water sources known as hafeirs. The consumed ground and surface water are non-piped and untreated. Today there is an increasing demand for groundwater worldwide to meet human consumption for drinking, irrigation and industrial purposes. This increasing demand for ground water is due to rapid increasing rate of urbanization and population growth. Surface water resources near cities, towns and villages are converted into sites for construction of houses, buildings, offices, institutions, commercial areas, or industrial sites, which led to a decrease in surface water resources to a large extent and to more demand for ground water (Tylor, E.W, 1958). The increase in human population, rapid urbanization, rising living standards across the world, poor waste management, and environmental degradation put freshwater resources under increasing stress (Miriam J. A. et al., 2022). Ground water is not always safe for the different human uses (Fetter C. W, 1992). In Southern Kordofan State, drinking water is normally obtained from boreholes, hand dug wells, hand pumps and hafeirs, therefore drinking water quality may be seriously affected by climatic factors, seasonal variations, water source depth and human activities. The area remains under the influence of heavy rains from May to October in each year. During this period, the winds direction changes from south to north bringing dry air (FAO, 1976). Miriam Judith Adongo (2022) reported significant seasonal variations in ground water sources, which sometimes exceeded the WHO standards for drinking water quality including, pH, EC, turbidity, total hardness, dissolved oxygen, Na, K, Ca, Fe and fluoride levels.

Morshed H. M. et al., (2022), who studied the Seasonal variation of drinking water quality in urban water bodies, reported a clear indication of unfit and unsuitable water for drinking in the Rainy season, and of poor quality in winter seasons, where, EC, BOD, COD, turbidity and nitrate have exceeded the maximum permissible limit (MPL). Marcos F. S. Teixeira, (2021), observed seasonal variation in cadmium concentrations during the dry and rainy seasons, suggesting that, During the rainy season, there is a dilution effect due to the increase in the aquifer's water volume, whereas, during the dry season, the low water level in the aquifer causes the opposite process, when the cadmium concentration increases.

Afaf (2007), Madena (2012) and Ali (2018), reported high concentrations of fluoride, carbonate, bicarbonate, Calcium and sulphates in drinking water sources within Southern Kordofan State. Emily Kumpel et al., (2017) suggested several important implications for research on and monitoring of water quality in urban areas that are primarily served by non-piped water supplies and reported microbial deterioration of drinking water quality during the rainy season which, indicate high public health risks associated with drinking water quality. Fluctuation of groundwater levels and salinity during the wet and dry season was reported to be influenced by certain climate factors such as, precipitation events, seawater intrusion, and evaporation (Shao-feng Yan, 2015). By measuring the parameters, pH, EC, TDS, DO, COD, BOD, NO_3^-, Ammonium, Phosphate, Chloride and Coliform bacteria during the wet and dry seasons, ground water quality was found to be significantly influenced by seasonal variations and aquifer depth (J. M. Ishaku, 2012).

Methodology

Ground water samples were collected from forty two (42) sources, covering thirteen (13) Areas within Southern Kordofan State, including El-dalanj, Aldabibat, Alhamadi, Alfarshaya, Hbila, Kortala, Dalami, Alkorgol, Kadugli, Abujubaiyha, Alrashad, Alabassiya and Abukrshola. Equal volumes of ground water samples were mixed to form thirteen composite samples representing each area. The surface water samples were collected from five sources, representing, Aldalanj, Aldabibat, Hbila, Kortala and Alrashad. Each surface water samples was analyzed separately.

The samples were collected twice, during autumn season (September, 2017) and winter season (January, 2018). All chemicals used were of analytical grade. Standard analytical procedures were used for measuring, pH values, EC, TDS, F^-, Cl^-, SO_4^{2-} and NO_3^- ions. Na, K, Ca and Mg concentrations were measured by Inductively Coupled Plasma spectroscopy (ICP).

Results and discussion:

1. Ground water

The composite ground water samples showed clear seasonal variations in pH values, electrical conductivity, and total dissolved solids content (Fig. 1, and 2).

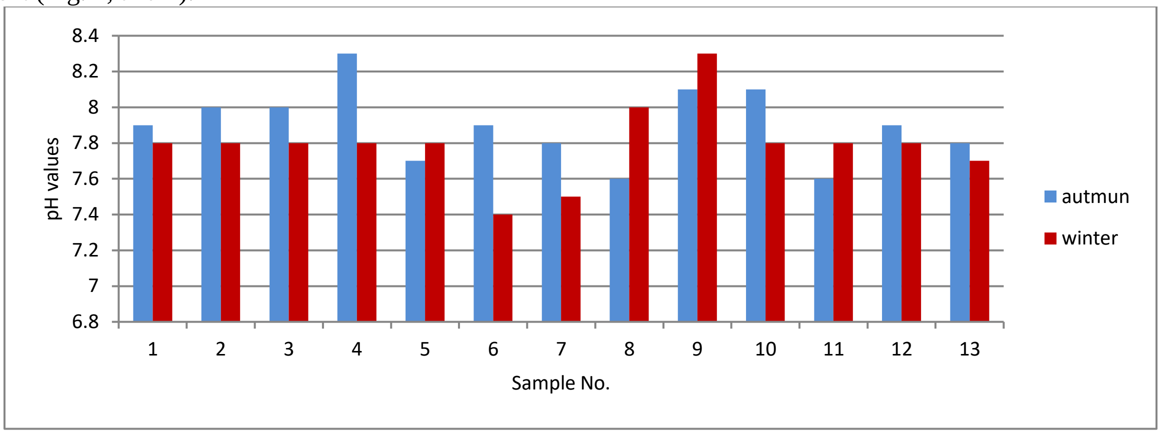

Fig.1: Seasonal variations of pH values in ground water

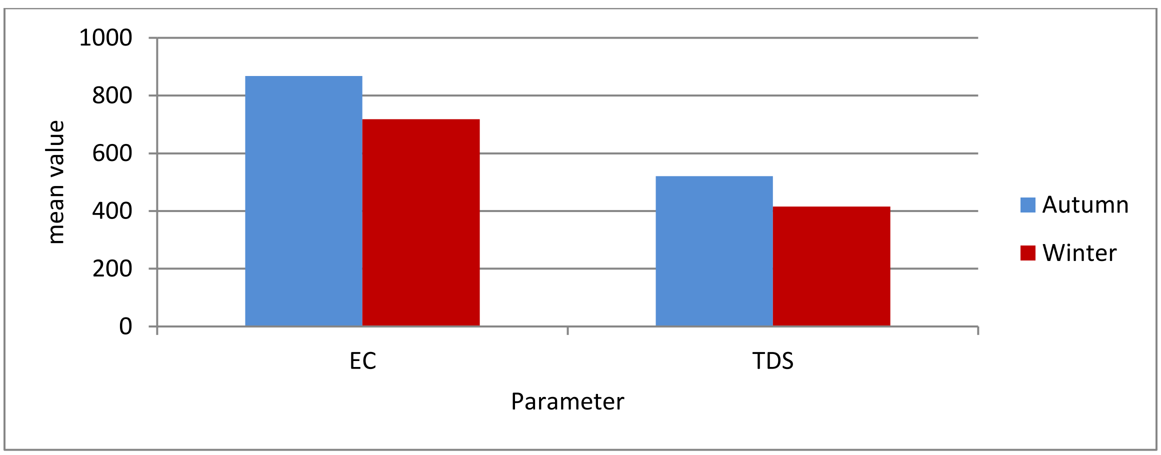

Fig.2: Seasonal variations of EC and TDS in ground water (mean)

The pH, EC and TDS values were generally high in autumn with few exceptions in winter (table. 1 and 2). This may reflect some differences in geological formation of water bearing rocks, aquifers recharge, wells depth or/and water withdrawing rate.

Table (1): Physicochemical properties of ground water samples in autumn

Sample No.	pH	ECµs/cm	TDS	F^-	Cl^-	SO_4^{-2}	NO_3^-	Na	K	Ca	Mg
1	7.9	1042	626.6	1. 28	52.1	36	23.28	7.654	2.966	8.407	36.81
2	8.0	768.5	459.5	0.795	34.7	65.5	47.45	1.637	3.07	17.89	6.493
3	8.0	856.5	512.5	0.82	32.2	17.5	24.8	2.142	3.767	42.54	39.41
4	8.3	738.7	443	0.93	37.96	10	33.7	4.186	1.588	13.94	33.63
5	7.7	1387	831	0.59	64.5	138	19.3	5.816	0.757	23.08	21.72
6	7.9	1547	930	1.5	81.9	58	66.2	2.834	2.683	12.29	3.565

7	7.8	947.7	569	3.41	80.24	23	49.6	6.681	9.763	11.97	15.25
8	7.6	431.5	259	1.34	31.3	12.66	8.4	0.732	4.647	24.79	13.17
9	8.1	788	471.6	1.56	51.6	15.8	18.92	6.392	1.798	39.67	16.46
10	8.1	585.3	351.5	0.82	36.6	13.75	6.87	2.87	1.819	28.9	19.47
11	7.6	1027	615.5	1.4	102.4	35.5	11.8	5.278	2.172	21.25	4.236
12	7.9	671	400.4	1.09	26.3	11.6	19.36	4.029	2.242	28.09	21.93
13	7.8	495	296.8	0.58	26.3	5.5	19.8	4.649	1.121	21.36	11.12

Table (2): Physicochemical properties of ground water samples in winter

Sample No.	PH	ECμs/cm	TDS	F^-	Cl^-	SO_4^{-2}	NO_3^-	Na	K	Ca	Mg
1	7.8	1125	674	1.1	41.18	19.34	9.68	7.53	6.56	11.9	31.11
2	7.8	846	518	0.29	48.4	18	15.8	7.53	6.56	11.9	25.06
3	7.8	750	448	0.34	33.5	18	6.05	2.72	5.02	47.44	27.91
4	7.8	644	387	1.92	26.46	4.66	3.7	3.98	1.94	13.57	14.32
5	7.8	253	151.5	1.22	77.4	235	11.6	6.02	0.76	11.488	4.97
6	7.4	1187	713	2.66	69.5	215	48.8	6.7	2.89	27.45	55.97
7	7.5	781	469	4.38	84.36	15.66	30.5	6.40	9.94	33.99	72.82
8	8.0	591	355	1.4	49.6	177.5	11.9	6.05	1.44	28.92	13.29
9	8.3	632	380	1.68	50.6	19.6	2.08	5.58	2.42	46.91	17.92
10	7.8	401	240	0.56	34.1	19.34	2.64	5.27	2.06	12.8	14.86
11	7.8	195.5	116.6	0.88	121.5	18	4.08	4.18	2.52	15.2	18.87
12	7.8	1668	887	0.99	27.36	18	2.32	9.33	1.25	20.39	13.45
13	7.7	259	154.8	0.52	28.26	4.66	2.84	5.11	0.94	18.15	22.53

Fluoride concentrations were ranging from (0.58 to3.41ppm) in autumn and from (0.29 to 4.38ppm) in winter. Some ground water sources showed fluoride content greater than the maximum permissible guideline values (1.5ppm) according to (WHO, 2011). This may indicate some differences in geographical and/or geological backgrounds of the sources. Chloride ions content was found to range from (26.3 to102.4ppm) in autumn and from (26.4 to121.5ppm) in winter. The highest chloride concentrations were shown by sample (No. 11) and the lowest concentrations by samples (No.12 and 13) in the two seasons. This may also be attributed to significant differences in bedrock formations (table 1 and 2). Nitrate ion concentrations were significantly high, ranging from (6.87 to 66.2ppm) in autumn and from (2.08 to 48.8ppm) in winter. All autumn samples showed high nitrate content, except sample (No.8). Samples (No.2, 6 and 7) showed higher nitrate content in the two seasons (table. 1 and 2). According to the (WHO, 2011) guidelines the maximum permissible concentrations of nitrate in drinking water is 50mg/l as nitrate ion (NO_3^-) or 11 mg/l as nitrate-nitrogen ($NO_3^- - N$), to protect against methaemoglobinaemia in bottle-fed infants (short-term exposure). Sulfate ion concentrations were relatively low in all samples during autumn and winter, although clear variations were shown by samples (2, 5, 6 and 8). Chloride and sulfate mean concentrations were higher in winter, whereas nitrate concentration mean was higher in autumn and fluoride mean concentrations were almost similar in the two seasons (Fig. 3).

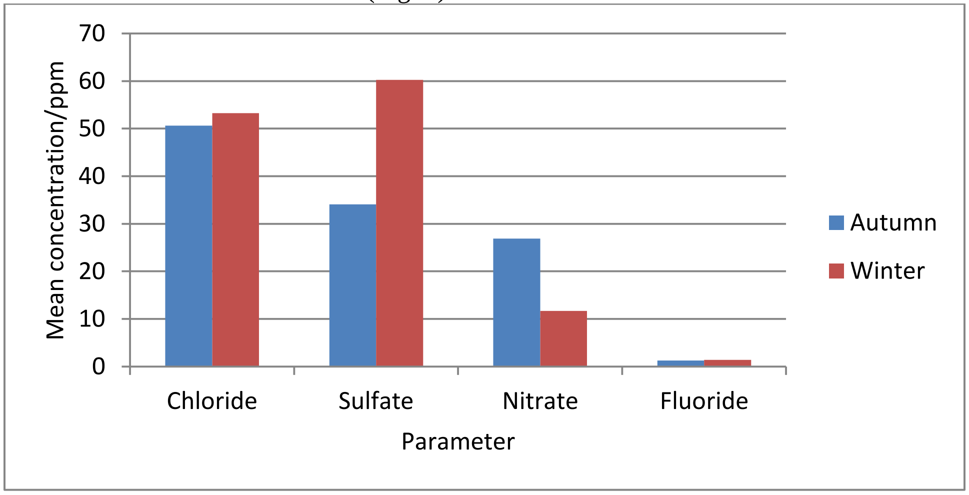

Fig.3: Seasonal variations in Cl^-, SO_4^{2-} NO_3^- and F^- content of ground water samples

The macro minerals, Na, K, Ca, and Mg mean concentrations were generally high in ground water samples during winter (Fig. 4). As shown by tables (No. 1 and 2), the highest seasonal variations in Na content were shown by samples (No.2, 6, 8 and 12). Clear variations for K, were shown by samples (No. 1, 2 and 8), and almost similar concentrations by samples (No. 5, 6, 7 and 10). Significantly high seasonal variations in Ca concentrations were shown by samples (No. 5, 6, 7 and 10), whereas sample (No. 4) showed almost similar, Ca content in the two seasons. On the other hand samples (No.2, 4, 5, 6 and 7) showed significant seasonal variations in Mg content and sample (No. 8) showed almost similar Mg concentrations in the two seasons (table. 1 and 2).

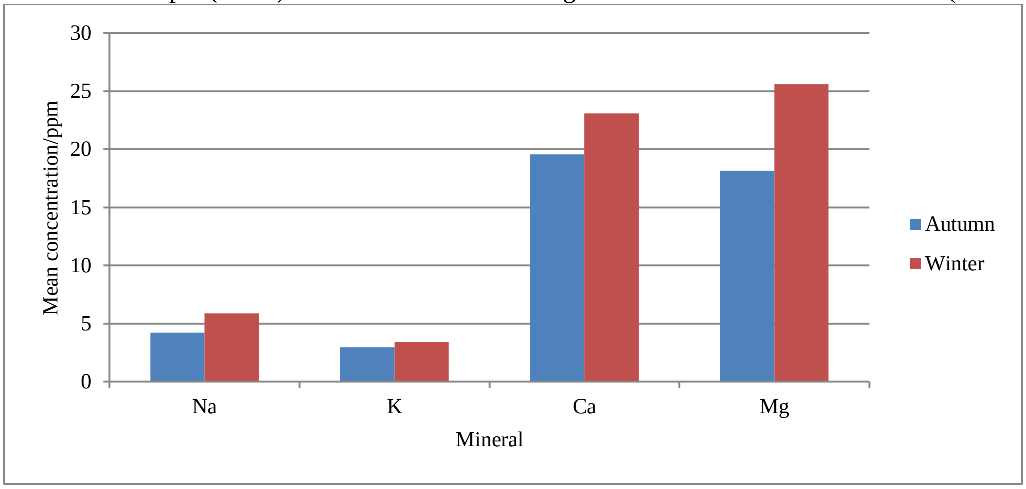

Fig.4: Seasonal variations of Na, K, Ca and Mg content in ground water (mean)

2. Surface water

The surface water samples showed pH values, within the acceptable guideline ranges, as (6.9 to 7.9) in autumn and (7.1 to 7.9) in winter, with relatively small seasonal variations (Fig.5). The TDS content of surface water samples was ranging from (63.8 to 831ppm) in autumn and (139.8 to 797ppm) in winter. The EC range was (106 to 1378µs/cm) in autumn and (233 to 1328µs/cm) in winter. Sample (No.2) showed the highest TDS and EC values in the two seasons (table. 3 and 4). The increase of mean values for TDS and EC was significant, as shown by (Fig. 6).

Table (3): Physicochemical properties of Surface water samples, Autumn season

Sample No	PH	EC	TDS	Na	K	Ca	Mg	F	Cl	SO_4	NO_3
1	6.9	106	63.8	0.03	4.697	10.9	2.566	0.35	22.3	4	19.8
2	7.7	1387	831	8.231	2.522	17.53	6.493	0.59	64.5	138	19.3
3	7.6	1027	615.5	8.383	1.826	17.84	3.565	1.4	102.4	35.5	11.8
4	7.8	428	257	2.657	1.98	26.42	4.745	0.58	26.3	5.5	19.8
5	7. 9	146.8	87.9	0.125	3.506	19.7	13.52	0.73	25.3	5	17.3

Table (4): Physicochemical properties of Surface water samples, winter season

Samp le No	PH	EC	TDS	Na	K	Ca	Mg	F	Cl	SO_4	NO_3
1	7.1	233	139.8	1.813	6.558	21.54	5.299	0.14	32.2	2.4	3.5
2	7.8	1328	797	2.781	3.316	38.46	30.71	1.58	24.8	1.6	7.1
3	7.9	404	242	1.485	5.099	18.36	4.77	0.98	19.8	3.2	2.0
4	7.6	695	417	1.218	5.68	31.21	7.018	0.26	29.8	1.0	5.2
5	7.8	1229	738	5.556	3.339	44.39	7.337	0.50	66.5	0.7	15.0

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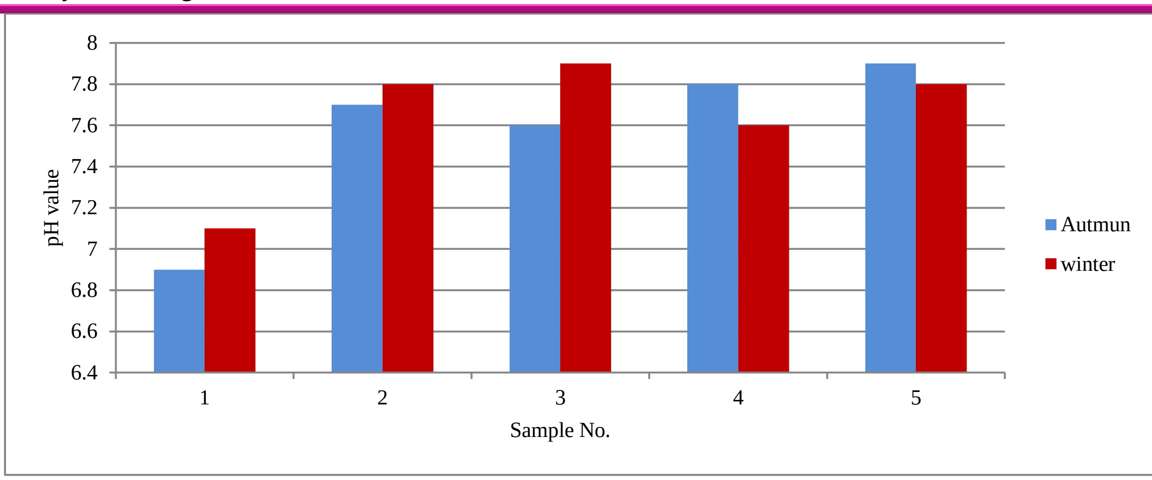

Fig.5: Seasonal effects on surface water pH values

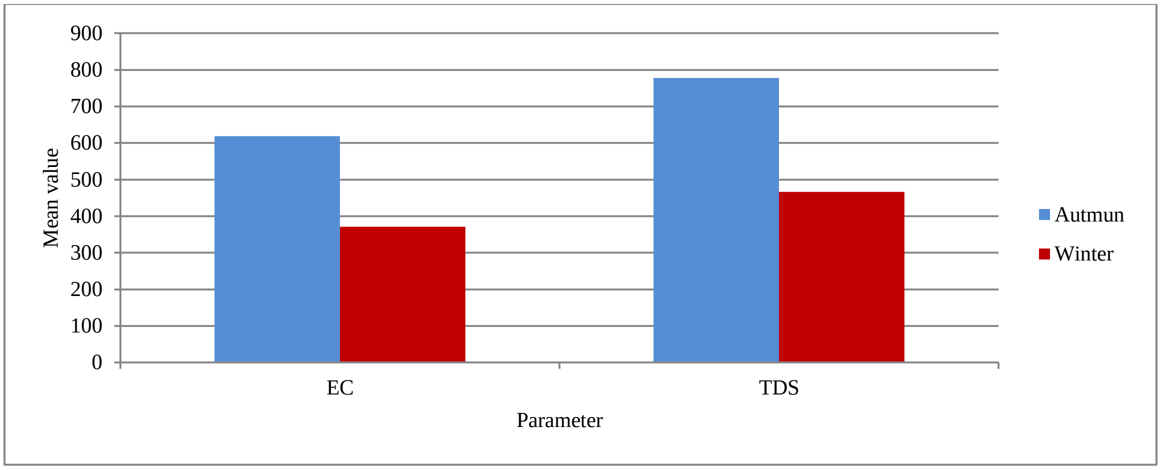

Fig.6 Seasonal effects on surface water EC and TDS values.

Fluoride ion concentrations were increased in four surface water sources, during autumn (table.3 and 4). Sample (No.2) showed significantly high fluoride content in winter as (1.58ppm), which exceeds the highest permissible guideline value (0.5 to 1.5ppm). The five surface water sources showed general concentration increase in the specific ions, Cl^-, SO_4^{2-} and NO_3^- content during autumn (table. 3). The concentrations of the three ions were within the permissible guideline values according to WHO, (2011).

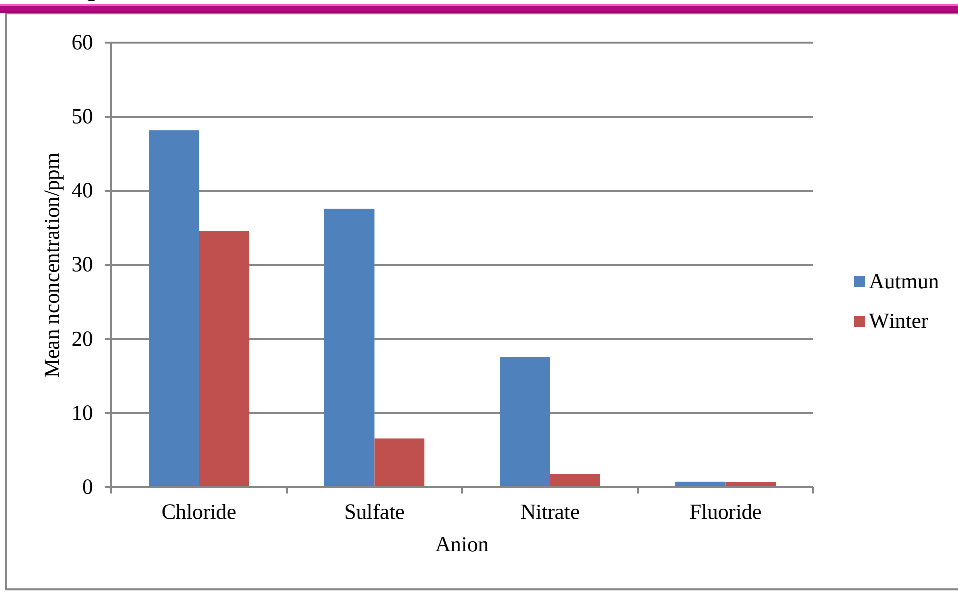

Fig.7: Seasonal variations of Cl^- , SO_4^{2-} NO_3^- and F^- in surface water.

The macro nutrients, Na, K, Ca and Mg showed very clear seasonal variations in the five surface water sources. The minerals K, Ca and Mg showed high mean concentrations in autumn (Fig. 8). The concentration of Na was very low in samples (No. 1 and 5), medium in sample (No.4) and relatively high in samples (2 and 3), when compared with its concentrations during winter (table.4). High K content was shown by four surface water samples during winter and one sample have almost similar K content in the two seasons, as (3.506ppm) in Autumn and (3.339ppm) in winter (table 3 and 4).

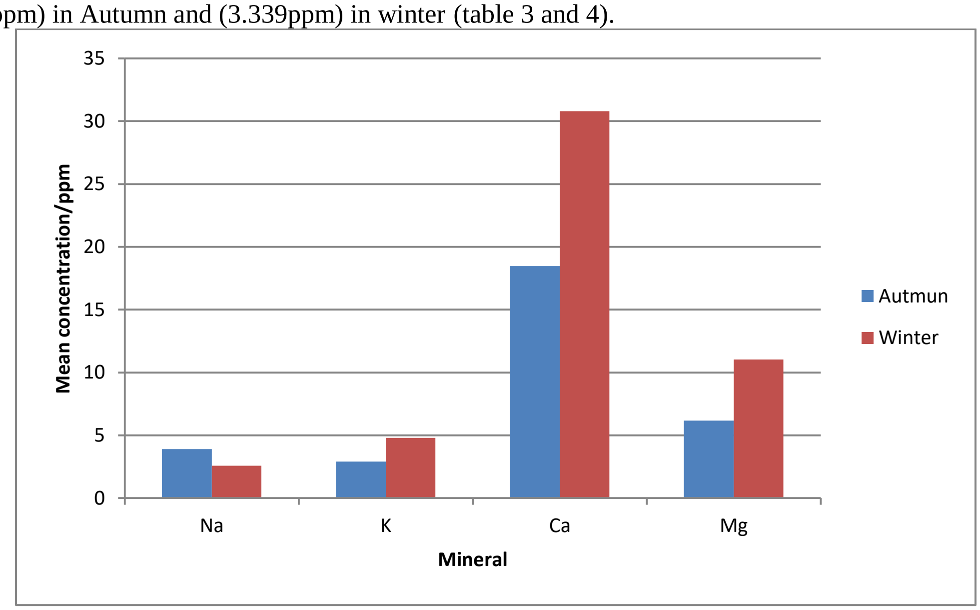

Fig.8: Seasonal variations of Na, K, Ca and Mg in Surface water

Clear seasonal variations were shown by Ca and Mg in the five surface water samples, with relatively high concentrations in winter (Fig. 8). The highest variations were shown by Ca in samples (No. 1, 2 and 5), whereas the highest variation in Mg content was shown by sample (No.2). The obtained results of this study strongly agree with some previous findings reported by J. M. ISHAKU, (2012), Shao-feng Yan, (2015), Marcos F. S. Teixeira, (2021) and M. H. Molla, (2022).

Conclusion

All the measured parameters showed clear seasonal variations in ground and surface water samples. Seriously high fluoride concentrations were shown by some ground water samples. From standard guideline values sight of view all the analyzed ground and surface water samples may be suitable and safe for human consumption.

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