Hydrochemical Investigations of Sukhna Wetland and Adjoining Groundwater Regime

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ABSTRACT: *Hydrochemical investigations of Sukhna wetland and adjoining ground water regime have been carried out. The pH of Sukhna wetland water and its upper catchment area ranges from 6.50 to 8.20; electrical conductance ranges between 210 and 820 micromhos/cm at 25^0C; TDS values range between 130 and 550 mg/l; calcium values range between 7 and 69 mg/l ;total hardness ranges between 40 and 95 mg/l; magnesium values range between 3 and 19 mg/l; alkalinity in terms of bicarbonate ranges between 30 and 400 mg/l and carbonate was found to be absent; chloride ranges between 14 and 50 mg/l; sulphate ranges between 1 and 17 mg/l; phosphate ranges between 0.01 and 0.12 mg/l; nitrate ranges between 10 and 13 mg/l and silica values range between 0.10 and 12 mg/l. Similarly, all the parameters where determined for ground water samples collected from tubewells existing in adjoining areas of Sukhna wetland. The values of pH in ground water ranges from 6.70 to 7.80; electrical conductance ranges from 460 to 790 micromhos/cm at 25^0C; TDS values range between 303 and 510 mg/l; calcium value ranges between 8.41 and 75 mg/l ;total hardness ranges between 130 and 250 mg/l; magnesium value ranges between 20 and 45 mg/l; alkalinity in terms of bicarbonate ranges between 200 and 420 mg/l and carbonate was found to be absent; chloride ranges between 25and 50 mg/l; sulphate ranges between 1 and 11 mg/l; phosphate ranges between 0.01 and 0.09 mg/l; nitrate ranges between 10 to 14 mg/l and silica value ranges between 0.10 to 14 mg/l. The hydrochemical data have been processed by plotting the ratio 1 for cations and ratio 2 for anions against TDS on Gibbs Diagram. The results revealed the "rock dominance" as the major factor in controlling the chemistry of both surface and ground water. The water quality of Sukhna wetland water and its adjoining ground water regime is almost similar and it is fit for the agricultural, industrial and domestic use.*

Keywords: *Wetland, Hydrochemical investigations, Ground water and Surface water.*

1. Introduction:

Wetlands are among the most productive ecosystems in the world, comparable to rain forests and coral reefs, they are also known as "biological supermarkets". Wetlands are defined as areas "where water is the primary factor controlling the environment and the associated plant and animal life".They act as a transitional zone between land and water, where saturation with water is the dominant factor. This helps in determining the nature of soil and the types of plant and animal communities living there [1].These are also known as the areas of marsh, fen, peatland, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water, the depth of which at low tide does not exceed six meter. All the definitions of wetlands are based on hydrological conditions, but the degree of wetness is a major variable. Wetlands are wetter than uplands but not as wet as aquatic habitats [2]. These ecosystems plays very important role on earth surface, as they meet many crucial needs for life such as drinking water, water purification, fodder, biodiversity, floods, recreation, research education, sinks and climate stabilizers.

Sukhna wetland is a manmade freshwater lacustrine wetland. Sukhna lake is roughly kidney shaped, which is located at 32^0 42' N Latitude and 76^0 54' E Longitude within the city beautiful Chandigarh at the base of Siwaliks (Fig. 1). The lake is 1.52 km long

and 1.49 km wide with initial storage capacity of 1,074 ha-m of water [3].The climate of the study area is semi arid with mean maximum temperature of 42 ^{0}C during summers and minimum temperature of 5.11 ^{0}C during winters. The average rainfall is 1120 mm during monsoon season. The soil is predominantly alluvial sandy embedded with layers of clay and is highly susceptible to soil erosion by water runoff action. It is also an abode for large variety of plants, birds and animal species. This wetland is center of attraction among tourists, as people visit Sukhna wetland for recreational purpose and its scenic beauty .



Figure 1. Showing the location of Sukhna wetland.

2. Hydrogeology and Groundwater regime around Sukhna wetland:

Union territory Chandigarh is occupied by semi consolidated formations of upper Siwalik system of middle Miocene age and is exposed in the northeastern fringe. These rocks form the catchment area of Sukhna wetland. The rest of the area is occupied by the alluvium of Pleistocene age. The piedmont deposits at the foot of Siwaliks comprises of cobbles, pebbles and boulders associated with sand, silt and clay. The piedmont deposits are followed by alluvial plain comprised of clay, silt and sand [4]. The subsurface lithology of the area has been revealed through the exploratory drilling carried out by Central Ground Water Board. The results indicate that the top soil comprises clayey material varies in thickness from less than meter to 10 meters and is underlain by beds of clay, kankar, sand and gravel.

Along Sukhna choe, three prominent sand beds occur (inter-bedded with clay beds) within a depth of about 100 m. The upper sand beds are about 15 m thick and occur 8 m below land surface. Middle sand bed is about 18 m thick and occurs at depth varying from 21 to 38 mbgl. The deeper sand bed occurs at depth varying from 39 to 76 mbgl and is about 27 m thick. These beds are more persistent in the downstream direction of Sukhna lake. The upper aquifers are generally unconfined upto 80 m in Manimajra area as revealed by drilling data. In other areas, semi confined conditions prevail upto 20-30 m below the land surface. Deeper confined aquifers exist below 90 m in Manimajra which is close to Sukhna wetland. Depth to groundwater in upper unconfined aquifer system is about 10 m and more in Krishangarh, Manimajra and adjoining Mauli-Jagran villages. The regional groundwater flow is from north to southwest and southern direction. The water level in both shallow unconfined and deeper confined aquifers show falling water level trend due to over exploitation. The lake is contributing little recharge in upper aquifers due to top impermeable clay beds lying over the upper aquifer system.

3. Methodology:

In order to understand the hydrochemistry of Sukhna wetland and areas near to its vicinity, 11 surface water samples and 10 ground water samples were collected and analyzed for different chemical parameters (Fig. 2). The surface water samples were

collected during pre and post monsoon period of year 2012 from the ponded area of Sukhna lake and check dams constructed in the Sukhna wildlife sanctuary for the present study. To study the comparison of surface and ground water quality and to understand the ground water regime existing around Sukhna wetland, the groundwater samples were collected in the month of October 2012 from irrigation department tubewells and bore wells in the study area. The depth of tubewells and borewells varies from 200 to 600 mbgl. All the water samples (i.e. surface and ground water) were collected in one liter narrow mouthed pre washed polyethylene bottles. The pH, electrical conductivity and total dissolved solids were measured in the field by using a portable conductivity kit. The total hardness and calcium were estimated by EDTA titrimetric method and magnesium was calculated by the difference of total hardness and calcium. Total alkalinity in terms of carbonate and bicarbonate were estimated by titrimetric method. Chloride was also estimated by titrimetric method. Sulphate, phosphate, nitrate and silica were analyzed by the UV- spectrophotometer.

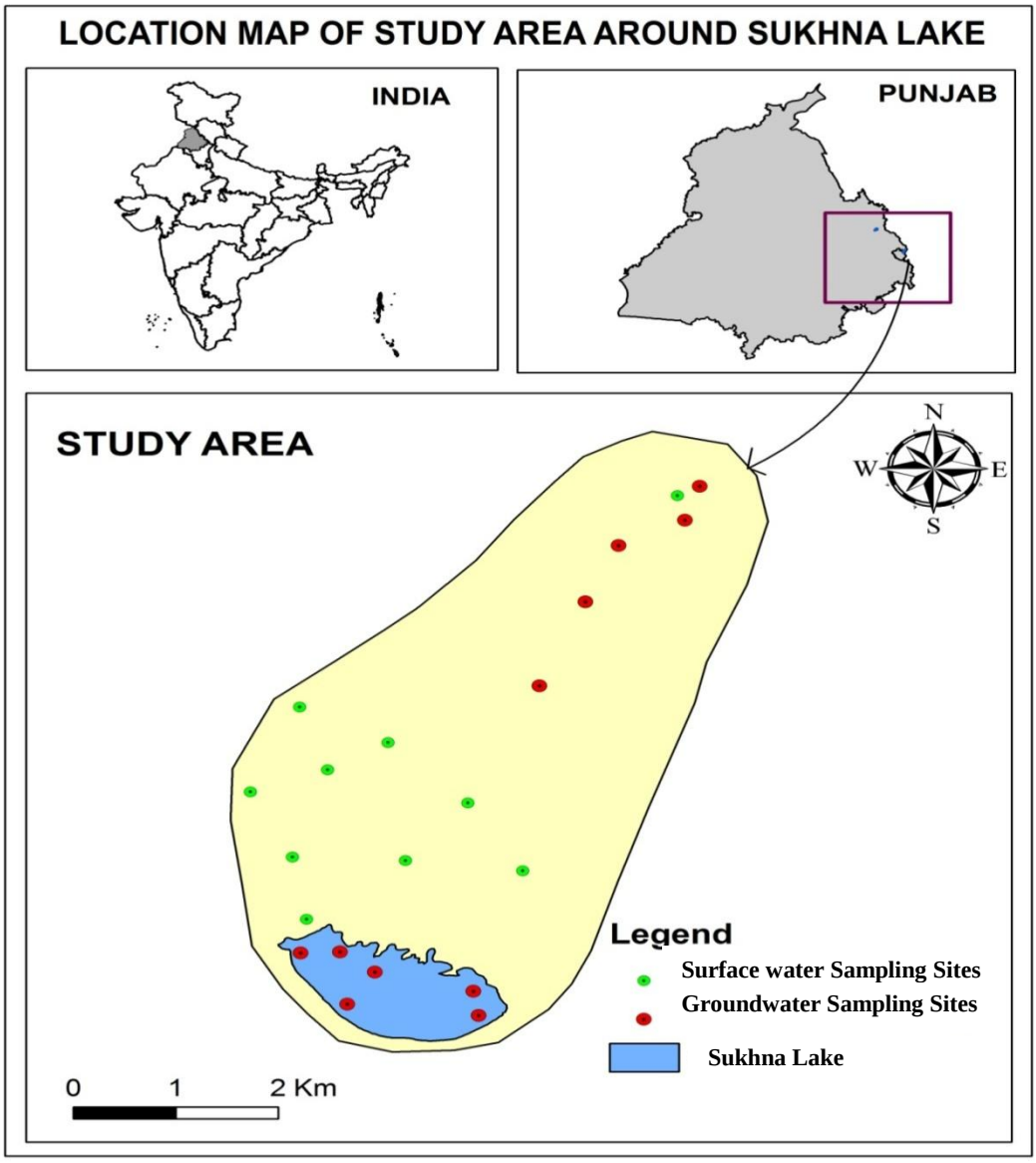


Figure 2. Showing the location of study area and the sampling sites of ground water and surface water samples.

4. Results and discussion:

4.1. Major Ion Chemistry:

The chemical analyses of surface water samples for pre and post monsoon are summarized in Table 1 and 2. The pH of surface water samples in the pre monsoon varies from 6.58 to 8.3 with an average around 7.17 and in the post monsoon varies from 7.24 to 8.13 with an average around 7.87. All the samples were found between the permissible limits of WHO [5] drinking standards in pH .The electrical conductance values are found to be within the range of 205-818 micromhos/cm at 25^0 C with an average of 393.9 micromhos/cm at 25^0 C in the pre monsoon period and ranges from 211-623 micromhos/cm at 25^0 C with an average of 348.7 micromhos/cm at 25^0 C in post monsoon period. The electrical conductance values for all samples in pre-post monsoon period are well within the permissible limit of WHO [5] standards of drinking water.
The concentration of TDS ranges from 133 to 534 mg/l with an average of 257 mg/l in pre monsoon period whereas in post monsoon period it ranges from 137 to 403 mg/l with an average of 225.4 mg/l. The TDS value is within the desirable limits of WHO [5].The total hardness varies from 38 to 122 mg/l in pre monsoon with an average of 68.54 mg/l and in the post monsoon varies from 55 to 95 mg/l with an average of 69.81 mg/l. All the samples are found within the desirable limits of WHO standards of drinking water. The concentration of calcium ranges from 7.57 to 21.88 mg/l with an average of 18.15 mg/l in pre monsoon and in post monsoon it ranges from 15.10 to 23.70 mg/l with an average of 19.78 mg/l. The calcium concentration is found well within the desirable limits of WHO standards of drinking water. The value of magnesium was calculated from the difference of total hardness and calcium. The magnesium values ranges from 3.36 to 25.96 mg/l with an average of 12.25 mg/l in pre monsoon period and in post monsoon period it ranges from 8.85 to 17.01 mg/l with an average of 12.15 mg/l. The magnesium concentration is also found within the desirable limits of WHO standards of drinking water. The bicarbonate varies from 30 to 375 mg/l with an average of 157.27 mg/l in pre monsoon period whereas in post monsoon it varies from 65 to 310 mg/l with an average of 163.63 mg/l. The carbonate was found to be absent in pre and post monsoon respectively. The value of sulphate ranges from 1 to 16.55 mg/l with an average of 4.52 mg/l in pre monsoon period and it ranges from 1.73 to 15.12 mg/l with an average of 6.04 mg/l in post monsoon period. The sulphate concentration is also found to be well within the desired limits of WHO standards of drinking water. The phosphate concentration ranges from 0.02 to 0.11 mg/l with an average of 0.05mg/l in pre monsoon period and in post monsoon period ranges from 0.01 to 0.11 mg/l with an average of 0.04 mg/l. The concentration of chloride ion varies from 14.2 to 28.9 mg/l with an average of 23.25 mg/l in pre monsoon period whereas in it varies from 14.2 to 42.6 mg/l with an average of 23.86 mg/l in post monsoon period. All the samples are within the desirable limit of WHO standards of drinking water. The nitrate concentration varies from 10.56 to 12.93 mg/l with an average of 11.63 mg/l in pre monsoon period whereas it varies from 10.38 to 16.7 mg/l with an average of 11.70 mg/l in post monsoon period. The nitrate concentration is found within the desirable limits of WHO standards of drinking water. The silica value varies from 0.12 to 11.90 mg/l with an average of 4.27mg/l in pre monsoon period and it varies from 2.12 to 5.70 mg/l with an average of 3.79 mg/l.

Table 1*. Major ion (mg/l) analysis of surface water samples of Sukhna wetland in pre-monsoon period.*

S. No.	Sample Location	pH	EC*	TDS	TH	Ca^{2+}	Mg^{2+}	HCO_3	CO_3^{2-}	SO_4^{2-}	PO_4^{3-}	Cl^-	NO_3^-	SiO_2
1.	N 30^0 44' 43.3'' E 76^0 48' 38.5''	6.68	261	170	56	15.99	9.72	115	0	5.27	0.02	21.3	12.45	1.76
2.	N 30^0 44' 49.0'' E $76^0$48' 41.6''	7.03	253	171	44	15.21	6.99	100	0	16.55	0.05	23.1	10.56	0.12
3.	N 30^0 44' 41.9'' E $76^0$48' 42.6''	7.37	228	152	50	12.62	9.08	85	0	2.01	0.03	14.2	12.25	0.24
4.	N 30^0 44'45.6'' E 76 48' 53.3''	7.31	242	159	42	15.99	6.38	100	0	2.13	0.04	21.7	11.56	0.30
5.	N 30^0 44' 38.3'' E 76^0 48'54.4''	8.3	205	133	38	15.14	5.55	70	0	1.22	0.08	22.1	11.81	0.12

6.	N 30^{0}44' 19.9'' E 76^{0}48' 54.6''	7.44	310	201	66	52.17	3.36	30	0	1.56	0.1	25.6	11.93	0.18
7.	N 30^{0}47' 41.7'' E 76^{0}50' 44.3''	6.7	289	188	84	18.51	15.91	125	0	1.62	0.05	21.2	12.77	8.56
8.	N 30^{0}47' 29.0'' E 76^{0}50'44.3''	7.03	818	534	90	21.88	16.55	375	0	1	0.09	28.4	11.02	10.32
9.	N 30^{0}47' 19.3'' E 76^{0}50'23.3''	7.34	533	346	70	9.25	14.76	210	0	3.13	0.11	21.4	12.93	5.89
10.	N 30^{0}46' 57.5'' E 76^{0}50'12.8''	6.58	573	370	92	7.57	20.51	250	0	5.12	0.03	27.9	10.59	7.65
11.	N 30^{0}46' 25.1'' E 76^{0}49' 58.2''	7.11	621	403	122	15.14	25.96	270	0	10.21	0.02	28.9	10.65	11.90

***Micromhos/cm at 25^{0}C**

Table 2. *Major ion (mg/l) analysis of surface water samples of Sukhna wetland in post-monsoon period.*

S. No.	Sample Location	pH	EC*	TDS	TH	Ca^{2+}	Mg^{2+}	HCO_3	CO_3^{2-}	SO_4^{2-}	PO_4^{3-}	Cl^-	NO_3^-	SiO_2
1.	N 30^{0}44' 43.3'' E 76^{0}48' 38.5''	7.93	223	144	75	21.98	12.88	120	0	8.73	0.08	28.4	11.13	3.58
2.	N 30^{0}44' 49.0'' E 76^{0}48' 41.6''	7.86	249	161	69	20.01	11.90	160	0	11.41	0.04	14.2	11.29	3.46
3.	N 30^{0}44' 41.9'' E 76^{0}48' 42.6''	7.8	229	148	56	15.35	9.87	105	0	2.54	0.01	21.3	11.27	2.12
4.	N 30^0 44'45.6'' E 76 48' 53.3''	8.08	235	153	70	18	12.63	65	0	2.17	0.02	15	11.43	3.40
5.	N 30^{0}44' 38.3'' E 76^0 48'54.4''	8.01	231	150	86	19.21	16.22	115	0	1.99	0.05	22.3	11.95	3.58
6.	N 30^{0}44' 19.9'' E 76^{0}48' 54.6''	8.1	224	145	80	22.01	14.09	105	0	1.73	0.09	17	16.7	3.52
7.	N 30^{0}47' 41.7'' E 76^{0}50' 44.3''	7.24	211	137	57	20.55	8.85	130	0	1.84	0.01	16.5	12.15	5.10
8.	N 30^{0}47' 29.0'' E 76^{0}50'44.3''	7.9	568	367	95	25	17.01	310	0	3.06	0.02	21.3	10.61	5.70
9.	N 30^{0}47' 19.3'' E 76^{0}50'23.3''	7.83	623	403	55	15.10	9.69	300	0	7.85	0.01	35.5	11.09	4.31
10.	N 30^{0}46' 57.5'' E 76^{0}50'12.8''	8.13	523	337	60	16.75	10.50	160	0	15.12	0.11	42.6	10.38	2.55
11.	N 30^{0}46' 25.1'' E 76^{0}49' 58.2''	7.77	520	335	65	23.70	10.03	230	0	9.91	0.06	28.4	10.43	4.37

***Micromhos/cm at 25^{0}C**

The results of chemical analysis of ground water samples are summarized in Table 3. In ground water samples pH varies from 6.96 to 7.73 with an average of 6.61.The pH values is within the desirable limits of WHO standards of drinking water. The electrical conductance varies from 469 to 789 micromhos/cm at

25^0 C with an average of 813.1 micromhos/cm at 25^0C. The electrical conductance is within the desirable limits of WHO standards of drinking water. The concentration of TDS varies from 303 to 510 mg/l with an average of 349.2 mg/l. The TDS value for all the samples is within the desired limit of WHO standards of drinking water. The total hardness varies from 130 to 246 mg/l with an average of 178.7 mg/l, which is within the desired limits of WHO standards of drinking water. The calcium concentration varies from 8.41 to 74.06 mg/l with an average of 39.01mg/l. The calcium is found within the desired limit of WHO standards of drinking water. The magnesium value varies from 21.16 to 46.55 mg/l with an average of 33.94 mg/l. All value of magnesium falls within the desired limit of WHO standards of drinking water. The concentration of bicarbonate ion ranges from 205 to 305 mg/l with an average of 248.18 mg/l. The carbonates were found to be absent. The concentration of sulphate ranges from 1.52 to 10.01 mg/l with an average of 5.31mg/l; all the values are found within the desired limits of WHO standards of drinking water. The phosphate value ranges from 0.01 to 0.09 mg/l with an average of 0.03mg/l. The chloride ion concentration varies from 28.4 to 49.7 mg/l with an average of 32.87 mg/l; all values are within the desirable limit of WHO standards of drinking water. The nitrate ion values ranges from 10.65 to 22.11 mg/l with an average of 11.73mg/l; the nitrate values are within the desirable limits of WHO standards of drinking water. The silica concentration ranges from 5.82 to 12.32 mg/l with an average of 7.10mg/l.

Table 3. *Major ion (mg/l) analysis of ground water samples of Sukhna wetland.*

S.No.	Sample location	pH	EC*	TDS	TH	Ca^{2+}	Mg^{2+}	HCO_3	CO_3^{2-}	SO_4^{2-}	PO_4^{3-}	Cl^-	NO_3^-	SiO_2
1.	N 30^0 44' 43.3'' E 76^0 48' 38.5''	7.21	513	331	206	38.71	40.65	295	0	1.52	0.01	35.5	10.9	6.37
2.	N 30^0 44' 49.0'' E $76^0$48' 41.6''	6.96	601	389	246	63.96	44.23	250	0	10.01	0.02	35.6	12.45	5.82
3.	N 30^0 44' 41.9'' E $76^0$48' 42.6''	7.28	584	378	160	40.39	29.06	305	0	1.96	0.01	35.1	13.36	9.41
4.	N 30^0 44'45.6'' E 76 48' 53.3''	7.39	596	385	212	46.28	40.26	275	0	2.74	0.03	28.4	11.86	6.98
5.	N 30^0 44' 38.3'' E 76^0 48'54.4''	6.98	585	378	216	24.4	46.55	295	0	3.09	0.04	35.7	13.63	7.22
6.	N 30^0 44' 19.9'' E $76^0$48' 54.6''	7.73	508	328	200	35.34	40.01	205	0	9.43	0.02	42.6	12.2	6.19
7.	N 30^0 47' 41.7'' E 76^0 50' 44.3''	7.22	780	503	130	42.92	21.16	420	0	9.17	0.07	35.5	10.65	6.13
8.	N 30^0 47' 29.0'' E 76^0 50'44.3''	7.49	789	510	242	74.06	40.8	240	0	12.4	0.09	49.7	22.11	12.32
9.	N 30^0 47' 19.3'' E 76^0 50'23.3''	7.12	520	337	196	54.7	34.33	215	0	6.21	0.02	28.4	10.72	6.25
10.	N 30^0 46' 57.5'' E 76^0 50'12.8''	7.33	469	303	158	8.41	36.35	230	0	1.94	0.07	35.1	11.2	11.47

***Micromhos/cm at 25^0C**

4.1.1. Gibbs Diagram:

To understand the hydrochemistry of surface and ground water and their relationship with respective aquifers such as chemistry of the rock types, chemistry of precipitated water, and rate of evaporation, Gibbs [6] has suggested a diagram in which ratio of dominant anions and cations are plotted against the value of TDS. Gibbs diagrams,

representing the ratio 1 for cations [$(Na^+ + K^+)/(Na^+ + K^+ + Ca^{2+})$] and ratio 2 for anions [$Cl^-/(Cl^- + HCO_3^-)$] as a function of TDS are widely employed to assess the functional sources of dissolved chemical constituents, such as precipitation, rock, and evaporation dominance [7-10].The chemical data of surface water samples for pre and post monsoon period and for ground water samples are plotted in Gibbs diagram (Fig. 3a and 3b). It shows that surface water samples in pre and post monsoon period for both the Gibbs ratio i.e. ratio 1 for cations and ratio 2 for anions against relative values of total dissolved solids, point towards rock dominance. In the ground water samples also it results towards rock dominance. This reflects the influence of rock dominance in the hydrochemistry of both surface and ground water samples of Sukhna wetland.

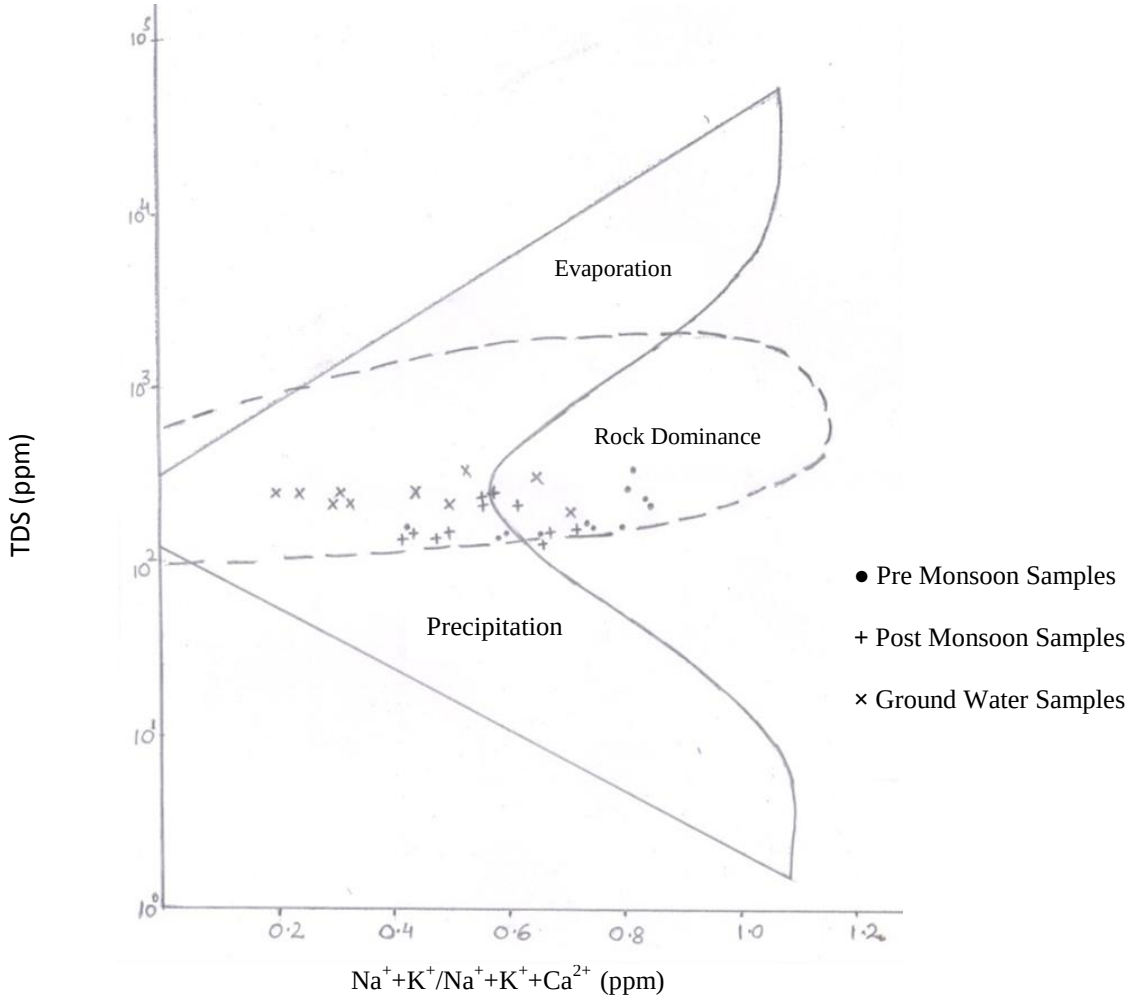


Figure 3a. Gibbs plot for cations showing the geochemistry of surface water samples (pre and post monsoon period) and ground water samples in Sukhna wetland and adjoining areas.

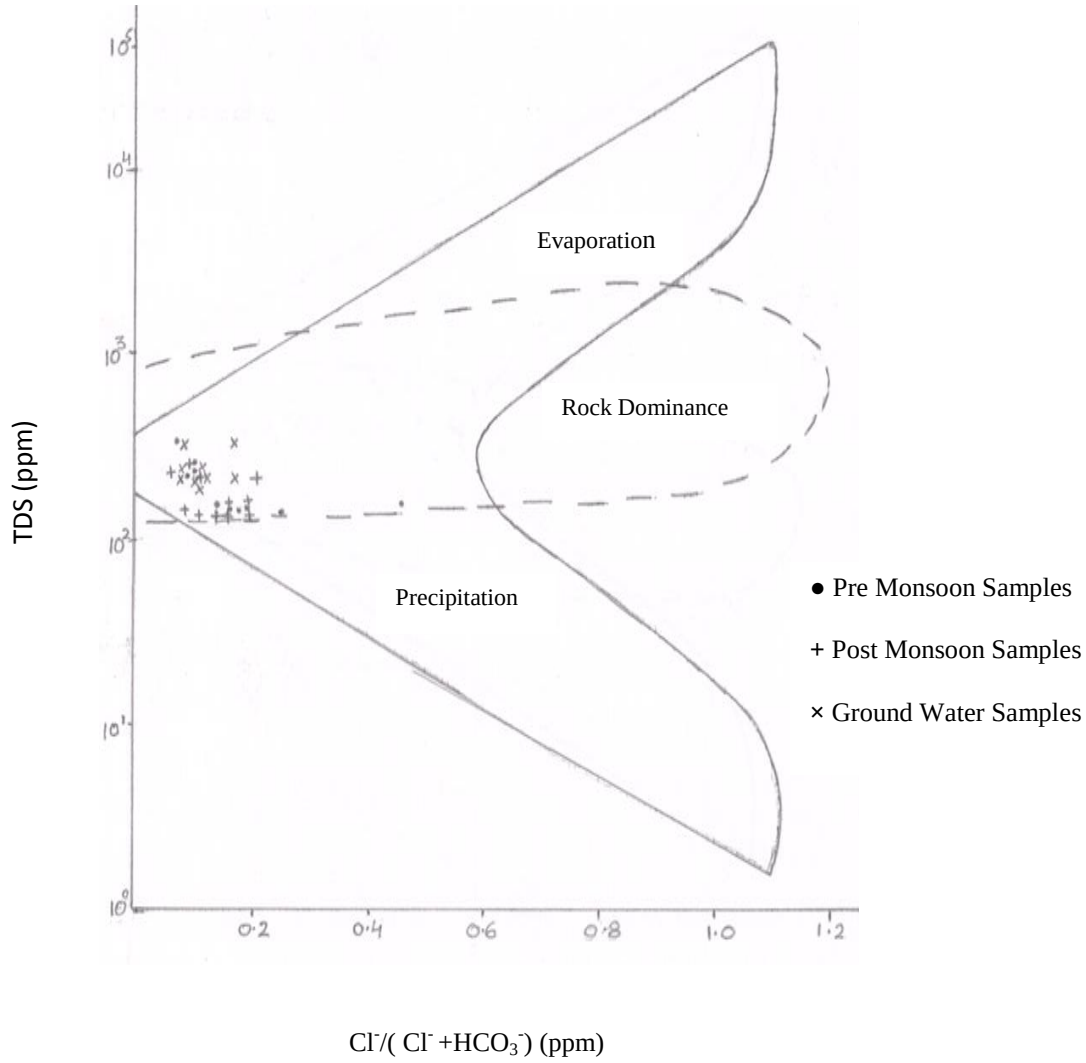


Figure 3b. Gibbs plot for anions showing the geochemistry of surface water samples (pre and post monsoon period) and ground water samples in Sukhna wetland and adjoining areas.

5. Conclusions:

The results of hydrochemical studies of surface water samples for pre and post monsoon periods show limited seasonal variations. The values of pH, electrical conductance, TDS, total hardness, calcium, magnesium, bicarbonates, sulphate, chloride, nitrate and silica for surface water analysis are found well within the permissible limits of WHO [5] standards of drinking water. During ground water analysis, all the chemical parameters were found within the desirable limits of WHO [5] standards of drinking water. This reflects that the water quality of Sukhna wetland and adjoining groundwater regime is fit for drinking, agricultural and industrial use. The hydrochemical data processed by plotting the ratio 1 for cations $[(Na^+ + K^+)/(Na^+ + K^+ + Ca^{2+})]$ and ratio 2 for anions $[Cl^-/(Cl^- + HCO_3^-)]$ against TDS on Gibbs Diagram revealed the "rock dominance" as the major factor in controlling the chemistry of both surface and ground water, as all the samples fall in the rock dominance field. This shows that the surface water geochemistry is controlled by the rocks of the catchment area which mainly comprises of loose sandstones and clays belonging to Siwaliks. The ground water geochemistry is influenced by the Quaternary sediments comprising shale, sand stones, clay, silt, pebbles and boulders. Lithologically, catchment area rocks and sediments forming aquifers are similar. This results in similarities in

geochemistry of ground water and surface water of Sukhna wetland.

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