International Journal of Environmental Science and Toxicology Research (ISSN: 2408-7262) Vol. 2(5) pp. 108-118, May, 2014
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Full Length Research Paper

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. Total thirty two samples were collected including surface and ground water samples both from the study area and were analyzed for pH, EC, TDS, hardness, calcium, sodium, potassium, alkalinity (in terms of carbonates and bicarbonates), chloride, sulphate, phosphate, nitrate and silica. All the parameters were found well within the desirable and permissible limits of BIS (1991) and WHO (2006). The different irrigation parameters i.e. percent sodium, SAR, RSC, Magnesium ratio and Corrosivity ratio were calculated and further interpretation shows that the surface and ground water of Sukhna wetland and nearby areas is good for irrigation purpose. Ca^{2+}- Mg^{2+}- CO_3^{2-} - HCO_3^- is the dominant hydrochemical facies in the water chemistry of study area, which is identified through piper diagram. The water quality of Sukhna wetland and its adjoining ground water regime is almost similar and it is fit for the agricultural, industrial and domestic use.

Keywords: Hydrochemical, surface water, groundwater, irrigation, Sukhna wetland.

INTRODUCTION

Water is an important source of nutrients to the wetlands (Eser and Rasen, 1999). The water received by the wetlands is from the surface runoff (i.e. rivers, streams etc.), rainfall and groundwater (Mann and Wetzel, 2001; Somay and Filiz, 2002). 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 (Cowardian et al., 1979). These ecosystems plays very important role on earth surface, as they meet many crucial needs for life such as drinking water, water purification, nutrient recycling, fodder, biodiversity, floods, recreation, research education, sinks and climate stabilizers. So it is important to study the hydrochemistry of wetlands, in order to understand and maintain them (Malcolm and Soulsby, 2001). The present paper attempts to shed light on the hydrochemistry of surface and groundwater of Sukhna wetland and its surrounding areas.

Study Area

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. The lake is 1.52 km long and 1.49 km wide with initial storage capacity of 1,074 ha-m of water (Singh, 2002).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

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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 recreation.

Hydrogeology and Groundwater Regime around Sukhna Wetland

Union territories 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 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 (C.G.W.B., 2007). 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 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.

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 (Figure 1) and analyzed for different chemical parameters. 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 water and soil analysis 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. Sodium and potassium were analyzed by Flame Photometer.

RESULTS AND DISCUSSIONS

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.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 concentration of TDS ranges from 133 to 525 mg/l with an average of 257 mg/l in pre monsoon period whereas in post monsoon period ranges from 137 to 403 mg/l with an average of 225.4 mg/l. 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. 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 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 sodium concentration ranges from 4.2 to 6 mg/l with an average mean of

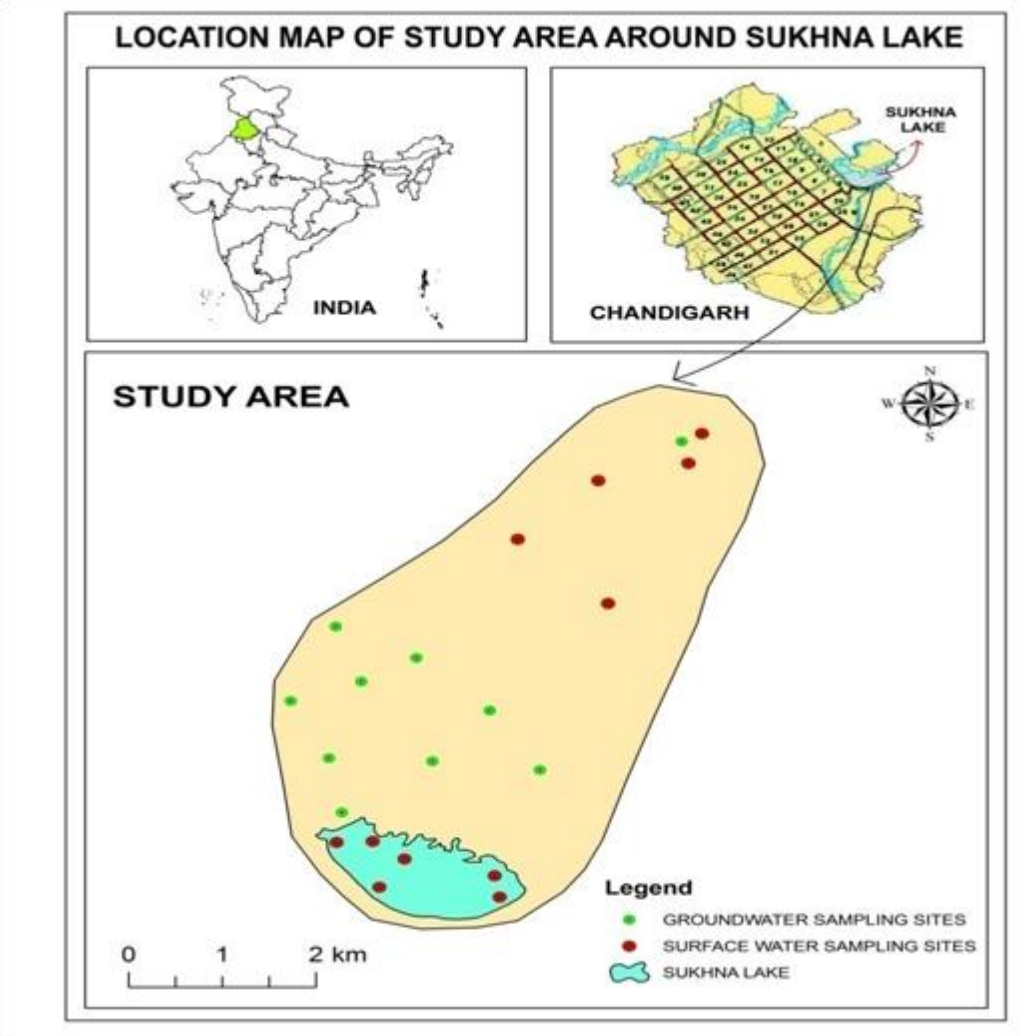

Figure 1. Showing the location of study area and the sampling sites of surface water and ground water samples.

Table 1 Major ion analysis of surface water samples of Sukhna wetland in pre-monsoon period (all parameters are in mg/l, except pH, EC (µmho/cm)

S. No.	Sample Location	pH	EC	TDS	TH	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	HCO_3^{-}	Cl^{-}	SO_4^{2-}	PO_4^{3-}	NO_3^{-}	SiO_2
1.	N 30^0 44' 43.3" E 76^0 48' 38.5"	6.68	261	170	56	15.9	9.72	5.6	1.1	115	21.3	5.27	0.02	12.4	1.76
2.	N 30^0 44' 49.0" E $76^0$48' 41.6"	7.03	253	164	44	15.2	6.99	4.8	1.2	100	23.1	16.55	0.05	10.5	0.12
3.	N 30^0 44' 41.9" E $76^0$48' 42.6"	7.37	228	149	50	12.6	9.08	6	1.2	85	14.2	2.01	0.03	12.2	0.24
4.	N 30^0 44'45.6" E 76 48' 53.3"	7.31	242	159	42	15.9	6.38	5.8	1.1	100	21.7	2.13	0.04	11.5	0.30
5.	N 30^0 44' 38.3" E 76^0 48'54.4"	8.3	205	133	38	15.1	5.55	5.1	1.2	70	22.1	1.22	0.08	11.8	0.12
6.	N 30^0 44' 19.9" E $76^0$48' 54.6"	7.44	310	201	66	52.1	3.36	5	0.6	30	25.6	1.56	0.1	11.9	0.18
7.	N 30^0 47' 41.7" E 76^0 50' 44.3"	6.7	289	188	84	18.5	15.9	4.2	2.6	125	21.2	1.62	0.05	12.7	8.56

Table 1. Continue

8.	N 30^{0}47' 29.0'' E 76^0 50'44.3''	7.03	818	525	90	21.8	16.5	5.1	1.9	375	28.4	1	0.09	11.0	10.3
9.	N 30^{0}47' 19.3'' E 76^0 50'23.3''	7.34	533	346	70	9.25	14.7	4.9	0.9	210	21.4	3.13	0.11	12.9	5.89
10.	N 30^{0}46' 57.5'' E 76^0 50'12.8''	6.58	573	370	92	7.57	20.5	4.3	0.5	250	27.9	5.12	0.03	10.5	7.65
11.	N 30^{0}46' 25.1'' E 76^{0}49' 58.2''	7.11	621	400	122	15.1	25.9	4.2	1.1	270	28.9	10.21	0.02	10.6	11.9

Table 2 Major ion analysis of surface water samples of Sukhna wetland in post monsoon period (all parameters are in mg/l, except pH, EC (µmho/cm)

S. No.	Sample Location	pH	EC*	TDS	TH	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	HCO_3^{-}	Cl^{-}	SO_4^{2-}	PO_4^{3-}	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	12.6	8.9	120	28.4	8.73	0.08	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	11.7	8	160	14.2	11.41	0.04	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	12.6	7.5	105	21.3	2.54	0.01	11.27	2.12
4.	N 30^0 44'45.6'' E 76 48' 53.3''	8.08	235	153	70	18	12.63	12.8	5	65	15	2.17	0.02	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	12	7.1	115	22.3	1.99	0.05	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	11.9	10.1	105	17	1.73	0.09	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	11.5	6.8	130	16.5	1.84	0.01	12.15	5.10
8.	N 30^{0}47' 29.0'' E 76^0 50'44.3''	7.9	568	365	95	25	17.01	12.2	5.3	310	21.3	3.06	0.02	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	12.7	6.6	300	35.5	7.85	0.01	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	12.4	6.7	160	42.6	15.12	0.11	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	11.8	6.9	230	28.4	9.91	0.06	10.43	4.37

5mg/l in pre monsoon period whereas in post monsoon it ranges from 11.5 to 12.8 mg/l with an average mean of 12.2 mg/l. The potassium concentration ranges from 0.5 to 2.6 mg/l with an average mean of 1.21 mg/l in pre monsoon period whereas in post monsoon it ranges from 5 to 8.9 mg/l with an average mean of 7.13 mg/l. 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 concentration of chloride ion varies from 14.2 to 28.9 mg/l with an average of 23.2 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. The value of sulphate ranges from 1 to 16.5 mg/l with an average of 4.52 mg/l in pre monsoon period and it ranges from 1.73 to 15.1 mg/l with an average of 6.04 mg/l in post monsoon period. The phosphate concentration ranges from 0.02 to 0.11 mg/l with an average of 0.05 mg/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 nitrate concentration varies from 10.5 to 12.9 mg/l with an average of 11.6 mg/l in pre monsoon period whereas it varies from 10.38 to 16.7 mg/l with an average of 11.7 mg/l in post monsoon period. The silica value varies from 0.12 to 11.9 mg/l with an average of 4.27 mg/l in pre monsoon period and it varies from 2.12 to 5.70 mg/l with an average of 3.79 mg/l. All the samples were found between the desirable and permissible limits of BIS (1991) and WHO (2006) standards of drinking water (Table 3)

The results of chemical analysis of ground water samples are summarized in Table 4. In ground water samples pH varies from 6.96 to 7.73 with an average of 6.61. The electrical conductance varies from 469 to789 micromhos/cm at 25^0 C with an average of 813.1 micromhos/cm at 25^{0}C. The concentration of TDS varies

Table 3. Showing BIS (1991) standards and W.H.O. (2006) guideline for drinking water

S. No.	Parameters	BIS (1991)		W.H.O. (2006)
		Desirable Limit (mg/l)	Permissible Limit (mg/l)	Desirable Limit (mg/l)
1	pH	6.5 – 8.5	-	7.0 – 8.5
2	Electrical Conductance (EC)	100	2000	-
3	Total Dissolved Solids (TDS)	500	2000	500
4	Total Hardness (TH)	300	600	-
5	Calcium (Ca)	75	200	75
6	Magnesium (Mg)	30	100	30
7	Chloride (Cl)	250	1000	250
8	Sulphate (SO_4)	200	400	250
9	Nitrate (NO_3)	45	100	50

Table 4 Major ion analysis of ground water samples of Sukhna wetland (all parameters are in mg/l, except pH, EC (µmho/cm).

S. No.	Sample location	pH	EC*	TDS	TH	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	HCO_3^{-}	Cl^{-}	SO_4^{2-}	PO_4^{3-}	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	5.52	1.3	295	35.5	1.52	0.01	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	4.83	1.4	250	35.6	10.01	0.02	12.4	5.82
3.	N 30^0 44' 41.9'' E 76^0 48' 42.6''	7.28	584	378	160	40.39	29.06	8	2.5	305	35.1	1.96	0.01	13.3	9.41
4.	N 30^0 44'45.6'' E 76 48' 53.3''	7.39	596	385	212	46.28	40.26	3.9	1.9	275	28.4	2.74	0.03	11.8	6.98
5.	N 30^0 44' 38.3'' E 76^0 48'54.4''	6.98	585	378	216	24.4	46.55	8.9	1.1	295	35.7	3.09	0.04	13.6	7.22
6.	N 30^0 44' 19.9'' E 76^0 48' 54.6''	7.73	508	328	200	35.34	40.01	7.8	1.9	205	42.6	9.43	0.02	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	67.8	2.5	420	35.5	9.17	0.07	10.6	6.13
8.	N 30^0 47' 29.0'' E 76^0 50'44.3''	7.49	789	510	242	74.06	40.8	25.3	1.8	240	49.7	12.4	0.09	22.1	12.3
9.	N 30^0 47' 19.3'' E 76^0 50'23.3''	7.12	520	337	196	54.7	34.33	11.5	1.6	215	28.4	6.21	0.02	10.7	6.25
10.	N 30^0 46' 57.5'' E 76^0 50'12.8''	7.33	469	303	158	8.41	36.35	10.3	1.6	230	35.1	1.94	0.07	11.2	11.4

from 303 to 510 mg/l with an average of 349.2 mg/l. The total hardness varies from 130 to 246 mg/l with an average of 178.7 mg/l. The calcium concentration varies from 8.41 to 74.06 mg/l with an average of 39.01 mg/l. The magnesium value varies from 21.16 to 46.55 mg/l with an average of 33.94 mg/l. The concentration of sodium ranges from 15.3 to 17 mg/l with an average of 15.38 mg/l. The potassium value varies from 1.1 to 2.5 mg/l with an average of 1.75 mg/l. 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 chloride ion concentration varies from 28.4 to 49.7 mg/l with an average of 32.87 mg/l. The concentration of sulphate ranges from 1.52 to 10.01 mg/l with an average of 5.31 mg/l. The phosphate value ranges from 0.01 to 0.09 mg/l with an average of 0.03 mg/l. The nitrate ion values ranges from 10.6 to 22.1 mg/l with an average of 11.73 mg/l. The silica concentration ranges from 5.82 to 12.32 mg/l with an average of 7.10 mg/l. All the samples were found between the desirable and permissible limits of BIS (1991) and WHO (2006) standards of drinking water (Table 3).

Hydrochemical Facies

Hydrochemical facies helps to know the chemical reactions taking place between the minerals within the lithologic framework and groundwater of the area (Back,

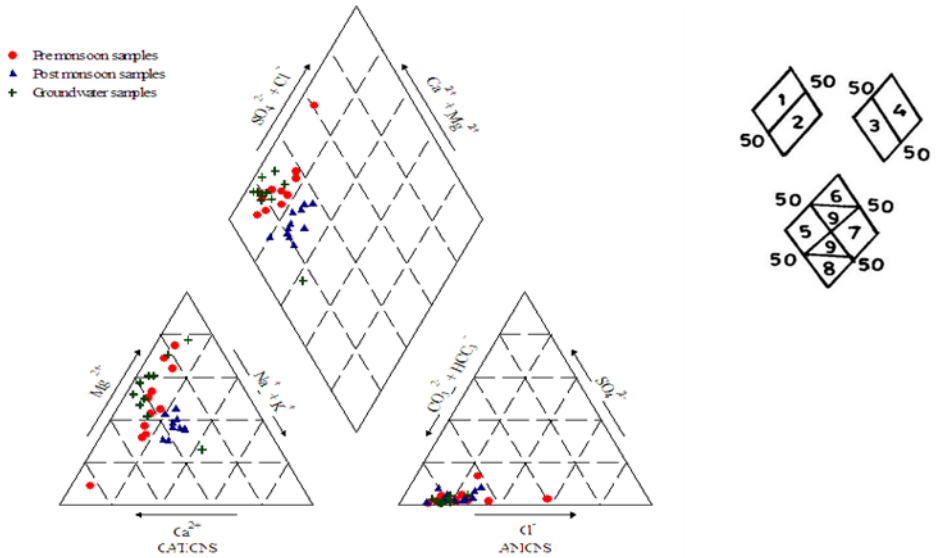

Figure 2. Piper trilinear diagram showing the relative cation and anion composition of surface and ground water samples in Sukhna wetland

Table 5. The characterization of surface and ground water of Sukhna on the basis of Piper Trilinear diagram

Subdivision of the diamond shape field	Characteristics of corresponding subdivision of diamond shaped field	Number of samples in different fields
1	Alkaline earth (Ca+Mg) exceeds alkalies (Na+K)	32
2	Alkalies exceeds alkaline earths	0
3	Weak acids (CO_3+HCO_3) exceeds strong acids (SO_4+Cl)	31
4	Strong acids exceeds weak acids	1
5	Carbonate hardness (secondary salinity) exceeds 50%	31
6	Non-carbonate hardness (secondary salinity) exceeds 50%	0
7	Non-carbonate alkali (primary salinity) exceeds 50%	0
8	Carbonate alkali (primary salinity) exceeds 50%	0
9	None of the cation or anion pairs exceeds 50%	0

1960). The hydrochemical facies is used to explain the chemical composition of water in different hydrologic systems. In order to understand the chemical characteristics of ground water many researchers (Back, 1960; Seaber, 1962; Morgan and Winner, 1962; Hanshaw et al., 1965; Davis and Dewiest, 1970; Walton 1970) have used the concept of hydrochemical facies. The hydrochemical facies are a function of flow patterns, solution kinetics and lithology (Raju et al., 2009).

Piper trilinear diagram (Piper, 1944), is a very common graphical approach which explains the dominance of ions in the different water samples. Piper diagram is the combination of three distinct fields i.e. two triangular fields at lower left and lower right, in between diamond shaped field. The lower left triangular field represents cation facies (Ca^{2+}, Mg^{2+}, Na^{+}). The lower right triangular field represents anion facies (SO_4^{2-}, HCO_3^{-}, Cl^{-}).The diamond shaped field between the two triangles represents the chemical composition of water with respect to cations and anions (Raju et al., 2009).

The concentration of major ions of surface and groundwater of Sukhna wetland were plotted in the Piper trilinear diagram to determine the water type. The diamond shaped field of piper diagram (Figure 2) shows that majority of samples (including pre-post and groundwater samples) fall in fields 1, 3 and 5 as shown in table 5, which indicates that alkaline earths exceeds alkalis, weak acids exceeds strong acids and ions representing carbonate hardness (secondary alkalinity) exceeds 50 %. The chemical composition obtained from

Table 6. Classification of irrigation water (Wilcox, 1955)

Percent Sodium	Water Class
< 20	Excellent
20 - 40	Good
40 - 60	Permissible
60 - 80	Doubtful
> 80	Unsuitable

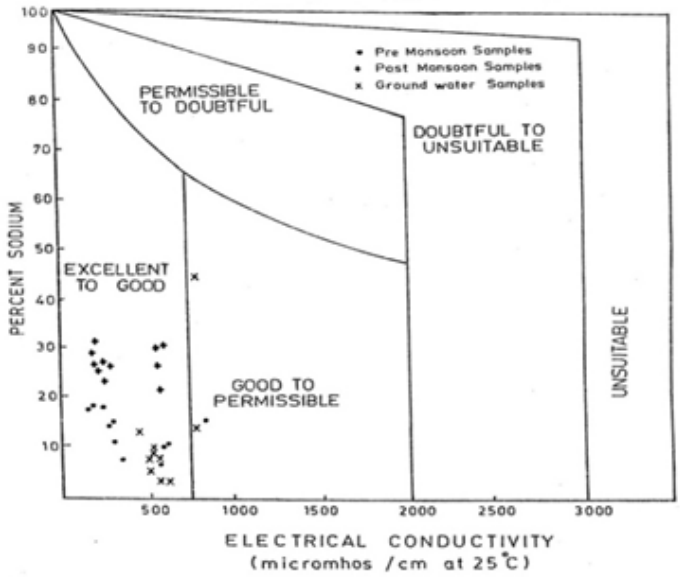

Figure 3. Wilcox diagram for classification of surface and ground water samples of Sukhna wetland based on EC and Na%

figure 2 reveals that the major cations dominating in the study area are Ca^{2+} and Mg^{2+} whereas the major anions dominating are CO_3^{2-} and HCO_3^- in the study area. Hence, hydrochemistry of Sukhna wetland is controlled by dominance of alkaline earth metals (Ca^{2+}- Mg^{2+}) and weak acids (CO_3^{2-} - HCO_3^-).

Sodium Percent (% Na)

Sodium concentration is important in classifying irrigation water because excess of sodium concentration in water replaces calcium and magnesium ions in the soil and leads to deterioration of the soil properties and reduces soil permeability (Kelly, 1951). So, it is important to assess the sodium concentration in water for its suitability for irrigation purpose. In all natural water percent of sodium content is a parameter which is needed to be examined for its suitability for agricultural purposes (Wilcox, 1948).

Sodium content in water is expressed as percent sodium (% Na) and is obtained by the following equation:

Sodium Percent (% Na) = $Na^+ + K^+ / Ca^{2+} + Mg^{2+} + Na^+ + K^+ \times 100$

(All the values are expressed in epm)

Wilcox (1955) has given a classification of water for the irrigation purposes, based upon electrical conductivity and percent sodium as mentioned in table 6. According to which percent sodium in surface and ground water samples of Sukhna wetland ranges from 3.39 to 29.82 meq/l as mentioned in table 7, majority of surface and ground water samples of Sukhna wetland fall in excellent to good water class indicating that water is fit for irrigation.

In figure 3, majority of the samples (i.e. pre monsoon , post monsoon and ground water samples) falls in the excellent to good class except one pre monsoon and two ground water samples which falls in good to permissible class in Sukhna wetland. This indicates that the surface and ground water of Sukhna wetland is good for irrigation purposes.

Sodium Adsorption Ratio (SAR)

The process of cation exchange reaction in soil which is

Table 7. Showing the values of different irrigation parameters (meq/l) in Sukhna wetland

Sample No.	Parameters														
	% Na			SAR			RSC			MR			CR		
	Pre	Post	GW	Pre	Post	GW	Pre	Post	GW	Pre	Post	GW	Pre	Post	GW
1	14.5	26.2	5.42	0.27	0.53	0.14	0.30	-0.1	-0.4	50.6	49.0	63.3	0.31	0.40	0.70
2	13.6	26.3	3.39	0.23	0.52	0.11	0.31	0.66	-2.7	42.8	49.4	53.2	0.52	0.19	0.24
3	17.3	31.6	8.52	0.31	0.62	0.23	0.01	0.15	0.58	54.3	51.5	54.1	0.25	0.31	0.16
4	17.2	26.2	3.77	0.31	0.55	0.10	0.34	-0.8	-1.0	40	53.6	58.8	0.32	0.34	0.15
5	16.9	23.3	7.48	0.28	0.48	0.24	-0.1	-0.4	-0.2	37.7	58.3	75.8	0.44	0.27	0.18
6	7.08	25.4	7	0.18	0.49	0.21	-2.3	-0.5	1.83	9.72	51.3	65.1	1.22	0.20	0.34
7	10.0	27.8	43.6	0.17	0.53	2.12	-0.2	0.39	3.00	58.7	41.3	44.8	0.25	0.16	0.14
8	14.1	21.2	13.9	0.20	0.46	0.58	4.06	2.45	-1.6	55.5	52.8	47.5	0.10	0.10	0.34
9	12.0	29.8	8.88	0.23	0.63	0.30	1.77	3.37	-3.5	72.4	80.5	50.9	0.15	0.19	0.21
10	7.97	29.0	12.3	0.18	0.58	0.17	2.03	0.93	0.36	81.6	50.8	87.6	0.18	0.47	0.22
11	8.89	25.28		0.17	0.51		2.27	1.77		64.6	41		0.18	0.21	

Pre - Pre monsoon samples **Post** - Post monsoon samples **GW**- Groundwater samples

expressed in terms of ratio is known as sodium adsorption ratio (SAR). The excess concentration of sodium is undesirable in water because it leads to adsorption of sodium on the soil cation exchange sites, leading soil aggregates to break down (deflocculating) sealing pores of the soil and making soil impermeable to water flow. Sodium adsorption ratio is an important parameter for determining the suitability of water for irrigation purposes, as it is a measure of alkali/ sodium hazard for the crops. It is expressed as:

Sodium Adsorption Ratio (SAR) = $Na^+ / \sqrt{Ca^{2+} + Mg^{2+}} / 2$

(All the values are expressed in epm)

The SAR values for all samples are mentioned in table 7. Based upon these values, figures 4 (USSL, 1954) indicates that majority of pre and post monsoon surface water samples fall in S_1 - C_1 class and $S_1 – C_2$ class whereas majority of ground water samples fall in $S_1 – C_3$ class except three samples which fall in $S_1 – C_2$ class in Sukhna wetland which indicates that sodium hazard is low and salinity hazard is little high in few ground water samples while in surface water samples the salinity hazard is low and medium.

Residual Sodium Carbonate (RSC)

Residual Sodium Carbonate is used to find the suitability of water for irrigation purpose and helps to indicate the alkalinity hazard in the soil. The water having excess of carbonate and bicarbonate may lead to calcium and magnesium carbonate precipitation in the soil as water is concentrated by evapo- transpiration. This results into the increase of sodium proportionate which exerts same adverse effect as high amount of sodium in irrigation water. The sum of carbonate and bicarbonate in water over the sum of calcium and magnesium influences the suitability of water for irrigation (Brindha and Elango, 2011; Joshi et al., 2009 and Raju et al., 2009). This is termed as residual sodium carbonate (RSC).It is expressed by the relationship:

Residual Sodium Carbonate (RSC) = $(CO_3^{2-} + HCO_3^-) – (Ca^{2+} + Mg^{2+})$

(All the values are expressed in epm)

If RSC < 1.25 meq/l the water falls in safe category, if RSC lies between 1.25 – 2.5 meq/l then water is marginally suitable and if RSC > 2.5 meq/l the water is unsuitable for irrigation. In Sukhna wetland RSC values ranges from - 0.1 to 3 meq/l (table 7). Table 8 shows that in Sukhna wetland during pre monsoon 7 samples fall in safe category, 3 in marginally suitable and 1 in unsuitable category, in post monsoon 8 samples fall in safe category, 2 in marginally suitable and 1 in unsuitable category and in groundwater samples 8 falls in safe category, 1 in marginally suitable and 1 in unsuitable category. This indicates that surface and ground water of Sukhna wetland is suitable for irrigation purpose.

Magnesium Ratio (MR)

Magnesium ratio (MR) is generally described as the high amount of magnesium over the calcium. Normally calcium and magnesium are in the condition of equilibrium (Brindha and Elango, 2011; Pandian and Sankar, 2007). If magnesium is in excess amount, it leads to adverse effects on the soils which results into poor crop yield. It is expressed as:

Magnesium Ratio (MR) = $Mg^{2+} / Ca^{2+} + Mg^{2+} \times 100$

(All the values are expressed in epm)

The value of magnesium ratio greater than 50 percent is considered as suitable for irrigation purposes (Palliwal, 1972 and Tripathi et al., 2012). In Sukhna wetland, magnesium ratio of pre monsoon samples

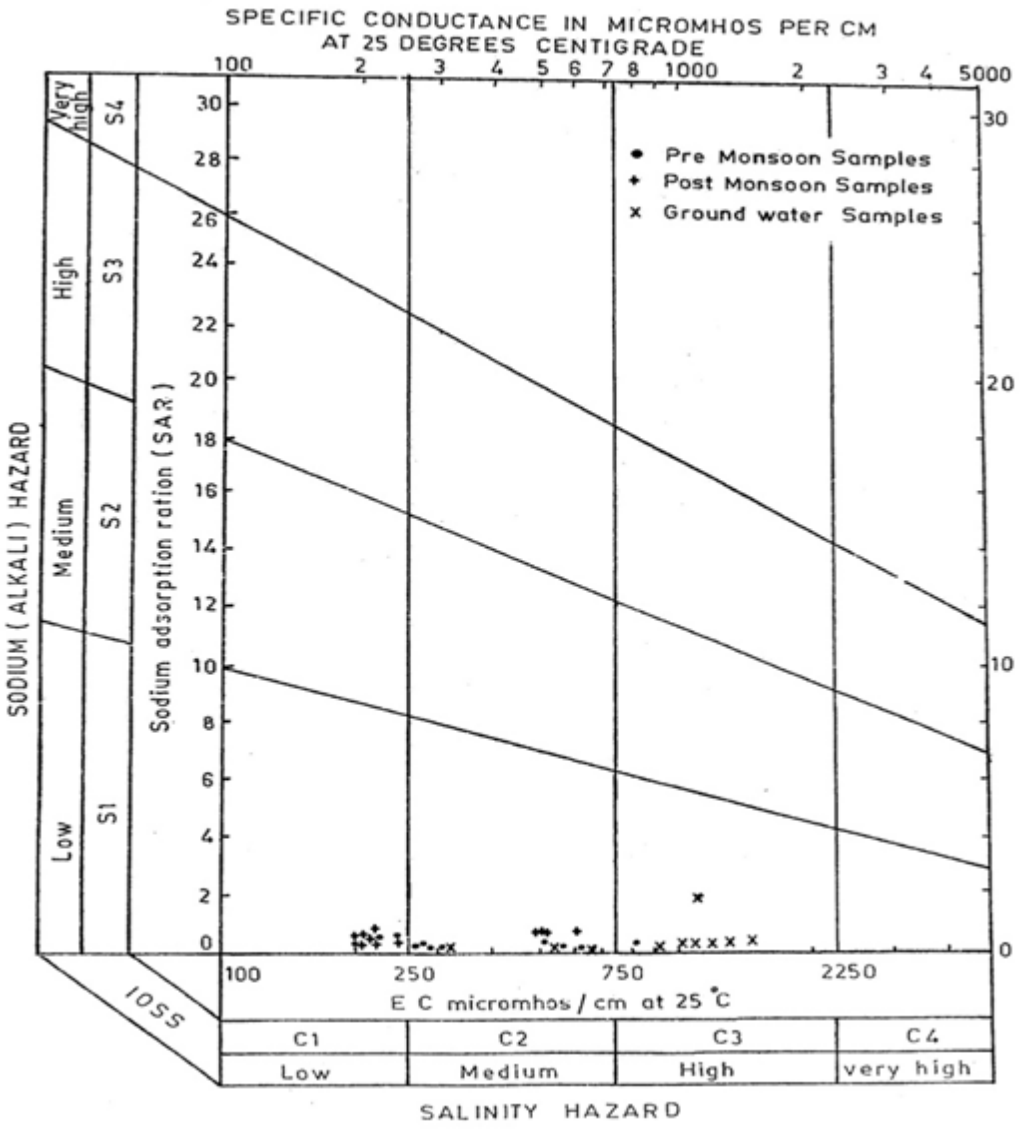

Figure 4. U.S. Salinity diagram for surface and groundwater samples of Sukhna Wetland

Table 8. Showing residual sodium carbonate classification in Sukhna wetland

RSC (epm)	Water Category	Number of Pre-monsoon samples	Number of Post-monsoon samples	Number of Ground water samples
< 1.25	Safe	7	8	8
1.25 – 2.5	Marginally suitable	3	2	1
> 2.50	Unsuitable	1	1	1

varies from 9.72 to 81.64 meq/l, post monsoon samples varies from 41 to 80.57 meq/l and in groundwater samples it varies from 44.84 to 87.68 meq/l as mentioned in table 8. The study reveals that out of total 32 samples (including pre monsoon, post monsoon and ground water) the magnesium ratio of 22 samples is higher than 50 percent which indicate it is suitable for irrigation and 10 samples are unsuitable for irrigation as magnesium ratio is less than 50 percent in Sukhna wetland.

Corrosivity Ratio (CR)

Corrosivity ratio (CR) helps to know whether water can be transported in the metallic pipes or not (Mahadevaswamy, et al, 2001). It describes the susceptibility of water to corrosion and is expressed as ratio of alkaline earths to saline salts in water (Pandian and Sankar, 2007). The intensity of corrosion depends on many factors such as pressure, temperature and velocity of water flow (Ayer and Westcot, 1985). The corrosivity ratio is calculated by the formula:

Corrosivity Ratio (CR) = $(Cl^- / 35.5) + 2 (SO_4^- / 96) / 2 (HCO_3^- + CO_3^{2-} /100)$

(All the values are expressed in epm)

The water with corrosivity ratio less than one is considered to be safe for transport of water in any pipes (Balasumbramanian, 1986; Pandian and Sankar, 2007) and if the corrosivity ratio is more than one, only non-corrosive pipes such as Polyvinyl Chloride (PVC) pipes should be used. In Sukhna wetland, all the water samples (i.e. pre monsoon, post monsoon and ground water) have corrosivity ratio less than one (safe zone) except one pre monsoon sample whose corrosivity ratio is 1.22 meq/l which is more than one (unsafe zone) as mentioned in table 7.

CONCLUSION

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, sodium, potassium, carbonates, bicarbonates, sulphate, phosphate, chloride, nitrate and silica for surface and groundwater analysis are found well within the desirable and permissible limits of BIS (1991) and WHO (2006). Moreover, different irrigation parameters i.e. percent sodium, SAR, RSC, Magnesium ratio and Corrositivity ratio were calculated and further interpretation shows that the surface and ground water of Sukhna wetland and nearby areas is good for irrigation purpose. This reflects that the water quality of Sukhna wetland and adjoining groundwater regime is fit for drinking, agricultural and industrial use. Ca^{2+}- Mg^{2+}-CO_3^{2-} - HCO_3^- is the dominant hydrochemical facies. This results in similarities in geochemistry of ground water and surface water of Sukhna wetland.

ACKNOWLEDGEMENTS

The authors are grateful to the Head, Department of Geology and Department of Environment Studies, Panjab University, Chandigarh for providing the necessary facilities for our research work. The authors are also thankful to Kuldeep Singh for rendering his help during the chemical analysis.

REFERENCES

Ayers RS, Wescot DW (1985). Water quality for irrigation. FAO Irrigation and Drainage Paper No.20., Rev.1,FAO, Rome.

Back W (1960). Origin of hydrochemical facies of ground water in the Atlantic Coastal Plain. Proc.21st Inter. Geol. Cong. Copenhagen, 87-95.

Balasubramanian A (1986). Hydrogeological investigations in the Tambraparani River Basin, Tamil Nadu, Unpublished Ph.D. Thesis, University of Mysore, Mysore.

BIS, (Bureau of Indian Standards) (1991). BIS: Indian standard drinking water - specification (First Revision) IS-10500:1991. BIS, New Delhi, India.

Brindha K, Elango L (2011). Hydrochemical characteristics of groundwater for domestic and irrigation purposes in Madhuranthakam, Tamil Nadu, India. Earth Sci. Res. SJ. 15:101 - 108.

C.G.W.B. (2007). Ground Water Information Booklet Chandigarh, Central Ground Water Borad, India.

Cowardin LM, Carter V, Golet FC, La Raoe ET (1979). Classification of Wetlands and Deepwater Habitats of United States, US Fish and Wildlife Service, pp103.

Davies S N, Dewiest RJM (1970). Hydrology, John Wiley and Sons, Inc., New York, pp 463.

Eser P, Rasen MR (1999). The influence of groundwater hydrology and stratigraphy on the hydrochemistry of Stump Bay, South Taupo Wetland, New Zealand. J. Hydrol. 220: 27– 47.

Hanshaw B B, Back W, Rubin M (1965). Carbonate equillibria and radiocarbon distribution related to the ground water flow in the Floridian Limestone aquifer, USA Proc Duronille Symp., Inter. Asso. of Sci. Hydrol. 601-614.

Joshi DM, Kumar A, Agrawal N (2009). Assessment of the irrigation water quality of river Ganga in Haridwar District. Rasayan J. Chem. 2: 285-292.

Kelley WP (1951). Alkali soils-their formation properties and reclamation. Reinold Publ. Corp., New York.

Mahadevaswamy G, Nagaraju D, Siddalingamurthy S, Lakshmamma, Mohammad S, Nagesh PC, Rao K (2011). Groundwater quality studies in Nanjangud Taluk, Mysore District, Karnataka, India. Int. J. of Environ. Sci. 1(7):1582 -1591.

Malcolm R, Soulsby C (2001). Hydrochemistry of groundwater in coastal wetlands: implications for coastal conservation in Scotland. Sci Total Environ. 265: 269 –280.

Mann CJ, Wetzel RG (2000). Hydrology of an impounded loticwetland – wetland sediment characteristics. Wetlands 20: 23–32

Morgan CO, Winner MD (1962). Hydrochemical facies in the '400 feet' and '600 foot' sands of the Baton Rouge area, Louisiana. U.S. Geol. Surv. Prof. Paper 450-B, 120-121.

Palliwal KV (1972). Irrigation with saline water, ICARI Monograph No.2, New Delhi, pp 198.

Pandian K, Sankar K (2007). Hydrochemistry and groundwater quality in the Vaippar River Basin, Tamil Nadu. Journal Geological Society of India 69; 970-982.

Piper AM (1944). A Graphical Procedure in the Chemical Interpretation of Groundwater Analysis. Trans. Amer. Geophy. Union 25:914-923.

Raju NJ, Ram P, Dey S (2009). Groundwater quality in the lower Varuna River Basin, Varanasi District, Uttar Pradesh. Journal Geological Society of India 73:178-192.

Seaber DR (1962). Cation hydrochemical facies of ground water in the English town Formation, New Jersy, in short paper in geology, hydrology, and topography: U.S. Geol. Surv. Prof. Paper 450-B, 124-126.

Singh Y (2002).Siltation Problems in Sukhna Lake in Chandigarh, NW India and Comments on Geohydrological Changes in the Yamuna-

Satluj Region, ENVIS Bulletin: Himalayan Ecology and Development 10(2):18-31.
Somay AM, Filiz S (2001). Current hydrogeological problems of Lower Gediz Basin. International Earth Sciences Colloquium on the Aegean Region (IESCA-2000). Proceedings 169 –176, Izmir.
Tripathi AK, Mishra UK, Mishra A, Tiwari S, Dubey P (2012). Studies of hydrogeochemical in groundwater quality around Chakghat area, Rewa District, Madhya Pradesh, India. International Journal of Modern Engineering Research 2(6): 4051-4059.
U.S. Salinity Laboratory (1954). Diagnosis and Improvement of Saline and Alkaline Soils. U.S. Agriculture H and Book- 60, Washington, D.C., pp 160.
Walton WC (1970). Classification and use of irrigation waters, U.S. Dept. Agri. Cir. No.969, pp 19.
WHO, (World Health Organization) (2006). Guidelines for Drinking Water Quality. Third Edition. Ist Addendum to Vol. 1. WHO Press, 20 Avenue Appia, 1211 Geneva 27, Switzerland.
Wilcox LV (1948). The quality of water for irrigation, use, U.S. Deptt. of Agriculture, Technical Bulletin, 1962, Washington D.C., pp19.
Wilcox LV (1955). Classification and use of irrigation waters. U.S. Dept. Agri. Circ. No. 969, pp 19.

How to cite this article: Taak JK, Singh KP (2014). Hydrochemical Investigations of Sukhna Wetland and Adjoining Groundwater Regime. Int. J. Environ. Sci. Toxic. Res. Vol. 2(5):108-118