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Assessment of Water Quality of Lakes for Drinking and Irrigation Purposes in Raipur City, Chhattisgarh, India

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Abstract
Lake water is an important source for drinking, domestic and irrigation purposes in rural and urban India. The present study aims at evaluating the water quality of various lakes in Raipur city, Chhatisgarh. There existed 154 lakes in the city but it shrinked to 85 in number due to encroachment or drying up of lakes. Twenty seven prominent lakes are selected to study and evaluate the water quality for drinking and irrigation purposes. The water samples were collected and analysed for pH, Turbidity, Electrical Conductivity (EC), Total Dissolved Solids (TDS), Alkalinity, Hardness, Sodium(Na^+), Potassium(K^+), Calcium(Ca^{2+}), Magnesium(Mg^{2+}), Bicarbonate($HCO3^-$), Sulphate (SO_4^{2-}), Nitrate (NO_3^-),Phosphate(PO_4^{3-}) Fluoride(F^-), Chloride (Cl^-), Chemical Oxygen Demand (COD), Biochemical Oxygen Demand (BOD), Dissolved Oxygen (DO), Total Coliform (TC) and Fecal Coliform (FC). There are variations for pH (6.59-8.29), EC (382-2330µS/cm), Turbidity (1-232 NTU), TDS (244-1491 mg/L), Alkalinity (120-600 mg/L), Hardness (66-330mg/L), Na^+(37-430 mg/L), K^+ (8-253 mg/L), Ca^{2+} (9-90 mg/L), Mg^{2+}(3-26 mg/L), SO_4^{2-} (5-200 mg/L), NO_3^-(0-19 mg/L), PO_4^{3-}(0.19-5.3 mg/L), F^-(0.18-1.41 mg/L) and Cl^- (46-388 mg/L), DO(1-8.6 mg/L), BOD (0.1-11.3 mg/L), COD (8-118 mg/L), Total Coliform(15-3600 MPN/100ml) and Fecal Coliform (4-240 MPN/100 ml). The results have been compared with the drinking water standard prescribed by Bureau of Indian Standard (BIS). All the physiochemical parameters are within the prescribed limit except turbidity, fecal & total coliform. The Sodium Adsorption Ratio (SAR) and salinity hazards are studied to classify the water for irrigation uses. It is found that lake water is suitable for irrigation purposes.
Keywords – Lake, water quality, drinking, irrigation, Raipur

I. Introduction

Fresh water is one of basic needs for survival of human being. Most of fresh water bodies all over the world are getting polluted, thus decreasing the potability of water [1]. Lakes are the surface water bodies which provide fresh water on Earth's surface. Lakes play an important role in maintaining ecology and have a great significance on environment such as (i) sources of water: surface water and groundwater recharge, (ii) food and nutrition for many organisms, (iii) act as flood control and stream flow maintenance, (iv) recreation—education, boating, swimming, walking and jogging on the lake bund, (v) wildlife habitat, especially fish and birds, (vi) rain water harvesting and, (vii) others.

Lakes, being stagnant water bodies, are more prone to pollution than the rivers as in lakes self purification process are less effective than rivers. Any contamination or pollution of lakes affects greatly the flora and fauna and also the human health if the water is used for domestic supply. The environmental health of any lake system depends upon the nature of that lake and its exposure to various environmental factors such as temperature, depth of water, wind speed, soil types and land uses of the catchment. Hence, lake water quality depends not only on natural processes such as precipitation inputs, erosion, and weathering of crustal material, etc. but also on anthropogenic influences like urban, industrial, and agricultural activities [2]. In recent decades, population growth, agricultural practices and sewage runoff from urban areas have increased nutrient inputs many fold to the level of their natural occurrence, resulting in accelerated eutrophication[3,4]. The lakes and reservoirs, all over India without exception, are in varying degrees of environmental degradation, might be due to encroachments, eutrophication (from domestic and industrial effluents) and silting. There has been a quantum jump in population during the preceding century without corresponding expansion of civic facilities due to which the lakes and reservoirs become the sink of contaminants especially in urban areas. Most urban and rural lakes have been vanished under the population pressure with worldwide environmental concerns [5, 6]. Raipur city was blessed with 154 lakes locally called "Talabs" but 85 Talabs are in existence. The present work has been carried out with a focus to evaluate the prevailing water quality of 27 prominent lakes of the city by analysing different parameters to know the suitability of water for drinking and irrigation purposes.

II. Study Area

Present study is focussed on the lakes existing in the municipal boundaries of Raipur City, Chhatisgarh, India. Raipur city is situated in the fertile plains of the Mahanadi River basin in Chhattisgarh state. The city has a population of 11, 22,555 [7] and experienced a growth rate of 34.65% during decade 2001-2011. Raipur city and its sprawling area comprising of about 147 sq. km have hydrogeological formations comprising mainly of either limestone or sandstone/shale layer in different parts. The city experiences the average annual rainfall of 1200 mm. Once, Raipur was blessed with 154 Talabs, which had either been built by nature or by human intervention, has presently only 85 Talabs survived. These 85 surface water bodies of varying sizes (2800 - 402000 sq.m) occupying a total surface area of 2.83 sq.km [8], which is about 2% of the city's area. Twenty seven prominent Talabs were chosen for water quality assessments which are shown in Fig. 1.

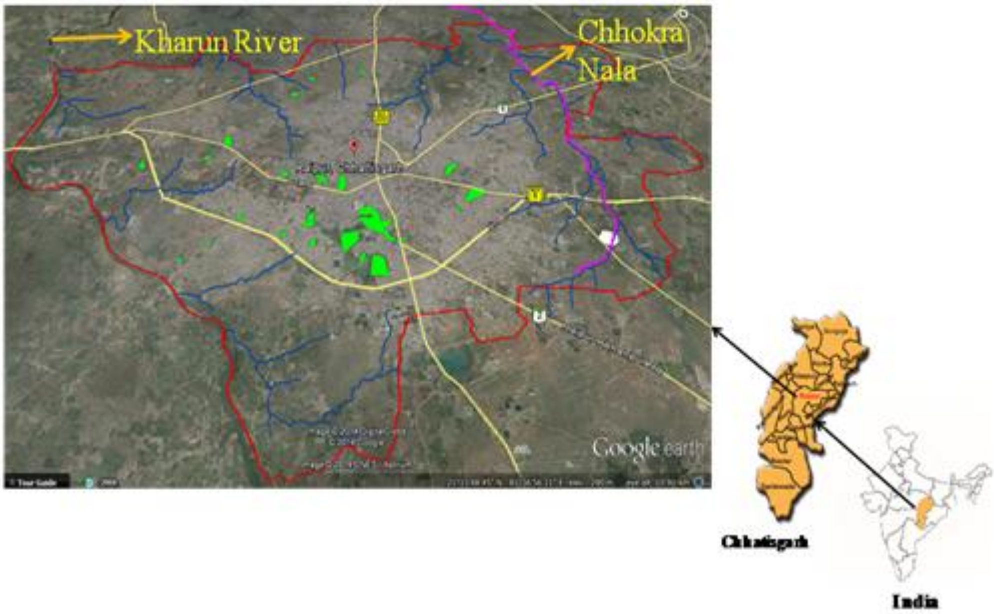

Fig. 1 Location map of the study area (Raipur municipal area in red boundary)

III. Methodology

The water samples were collected in the month of June, 2014 before onset of the monsoon from twenty seven Talabs (Fig.2) and sample number is labelled as L1, L2, ...L27 (Table 3). The samples were analysed for physicochemical parameters, organic load viz. BOD, COD and bacteriological parameters. Electrical Conductivity (EC) and pH were measured in the field. The standard analytical procedures as recommended by the American Public Health Association [9] were followed for the sample analyses. Based on the results of physicochemical analyses, irrigation quality parameters like sodium adsorption ratio (SAR), were also calculated. The suitability of lake's water for drinking and irrigation purposes was evaluated by using Bureau of Indian standards [10] and USSL classification [11], respectively. The BIS guideline provides the acceptable and permissible limits to know the suitability of water for drinking purposes. In the present study the permissible limits have been used for the intended purpose.

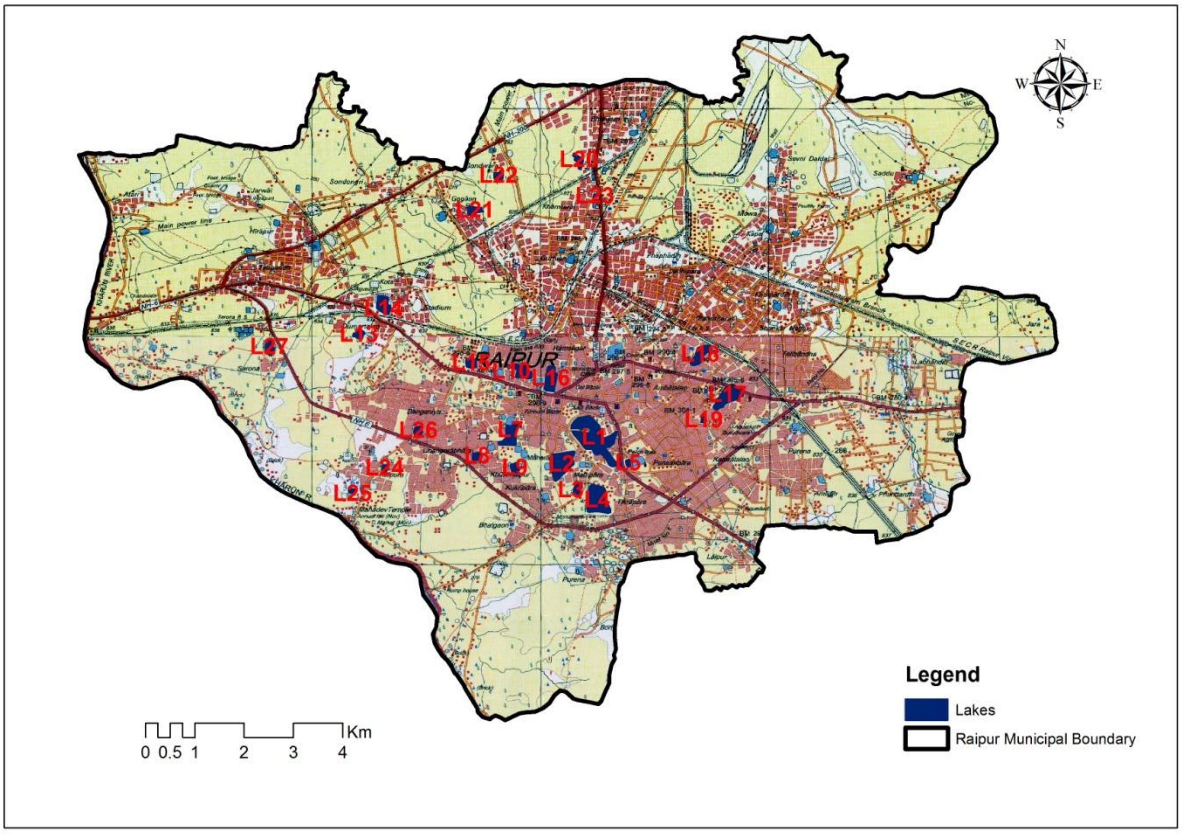

Fig. 2 Location of the lakes selected for water sampling

IV. Results and Discussion

The water samples are analysed for pH, Turbidity, Electrical Conductivity (EC), Total Dissolved Solids (TDS), Alkalinity, Hardness, Sodium(Na^+), Potassium(K^+), Calcium(Ca^{2+}), Magnesium(Mg^{2+}), Bicarbonate($HCO3^-$), Sulphate ($SO4^{2-}$), Nitrate (NO_3^-), Fluoride(F^-), Chloride (Cl^-), Chemical Oxygen Demand (COD), Biochemical Oxygen Demand (BOD), Dissolved Oxygen (DO), Total Coliform (TC) and Fecal Coliform (FC) and the analytical results are summarized in Table 1. The results are discussed for drinking and irrigation purposes separately.

4.1 Drinking Purposes

pH is measure of the intensity of acidity or alkalinity of water assessed on the basis of hydrogen ion concentration. pH has no direct adverse effects on health; however, higher values of pH hasten the scale formation in water heating apparatus and also reduce germicidal potential of chloride. Water with pH below 6.5 corrodes the pipes, thereby releasing toxic metals such as Zn, Pb, Cd and Cu etc. [12]. The pH values of water samples of present study ranges from 6.59 to 8.29 where as permissible range is 6.5-8.5.

EC is a function of its total dissolved salts [13] and is used as an index to represent the total concentration of soluble salts in water. The results show that EC values of lakes vary from 382 µs/cm to2330 µs/cm. The maximum value of EC is observed in Ama Talab.

TDS indicates the general nature of the water salinity. Water with high TDS have salty taste and produce scales on cooking vessels and boilers. TDS value of the samples lie in the range of 244 to 1108 mg/l which are within permissible limit (2000 mg/l). The salts dissolved in water, affect soil structure, permeability, aeration, and indirectly the plant growth.

Turbidity is an optical characteristic or property of a liquid, which generally describes the clarity, or haziness of the liquid. Turbidity is not colour related, but relates rather to the loss of transparency due to the effect of suspended particulate, colloidal material, or both. Turbidity of the water ranges from 4 to 232 NTU. In most of the Talabs turbidity values are higher than permissible limit (5 NTU).

Alkalinity is due to the presence of bicarbonates, carbonates and hydroxides. The weathering of rocks is the potential source of alkalinity. High alkalinity imparts a bitter taste, harmful for irrigation as it damages soil and hence reduces crop yields [14]. The alkalinity ranges from 130 mg/l to 600 mg/l as $CaCO_3$ which is within the permissible limits (600 mg/l).

High chloride content in water may be due to the pollution from chloride rich effluent of sewage and municipal waste. However chloride in excess imparts salty taste to water and people who are not accustomed to high chloride are subjected to laxative effect [15]. The chloride content of the samples is in the range of 46 to 388 mg/l which is well within the permissible limits (1000 mg/l).

Hardness is mainly due to Ca, Mg and eutrophication [16]. The water containing excess hardness is not desirable for potable water as it forms scales on water heater and utensils when used for cooking and consume more soap during washing of clothes. The total hardness value of sample of the samples was in range of 66 to 330 mg/l as $CaCO_3$ is well within the permissible limits (600 mg/l).

Table1 Physicochemical characteristics of Talabs' water of Raipur City, Chhatisgarh

Sampling Location (Talab)	pH	EC µs/cm	TDS mg/l	Turb NTU	Alk mg/l	Hard mg/l	Na mg/l	K mg/l	Ca mg/l	Mg mg/l	HCO3 mg/l	Cl mg/l	SO4 mg/l	NO3 mg/l	F mg/l	PO4 mg/l	DO mg/l	BOD mg/l	COD mg/l	TC MPN /100 ml	FC MPN /100 ml
Budhha	8.15	583	373	4	130	90	81	20	14	13	159	90	13	12	0.35	0.81	3.2	4.1	31	210	9
Maharajbandh	7.75	607	388	16	150	120	69	21	26	14	183	82	17	15	0.38	1.44	4.6	4.4	55	3200	210
Chironji	7.51	1140	730	61	350	152	202	22	16	27	427	162	3	2	0.57	0.9	5	2.1	39	3200	210
Naya	7.92	678	434	37	166	86	100	23	18	10	203	102	17	16	0.42	1.72	7.6	6.5	87	460	23
Naraya	7.47	666	426	24	170	126	80	24	22	17	207	94	19	16	0.43	0.68	4.8	7.7	24	210	15
Kho Kho	8.29	1494	956	186	210	66	232	85	20	4	256	214	200	15	0.46	1.1	5.1	6.9	118	3600	240
Bandhua	8.17	843	540	11	150	142	71	16	28	17	183	100	18	4	0.66	0.92	2	6.5	55	21	15
Paharai	7.86	978	626	232	130	140	115	16	45	7	159	150	22	5	0.54	1.3	7	4.5	55	93	43
Malsai	7.99	1571	1005	86	284	100	233	59	18	13	346	274	5	6	0.94	0.86	4.1	3.7	79	28	20
Ama	7.91	2330	1491	12	600	88	430	31	9	16	732	388	6	2	0.6	0.78	5.6	6.9	71	28	9
Dhobi	7.47	896	573	44	300	132	210	37	24	17	366	162	22	3	0.18	1.21	6.5	11.3	39	20	15
Shetla	8.03	677	433	6	164	120	98	10	22	16	200	100	24	2	0.53	0.81	8.6	1.3	24	1100	93
Ghorai	7.68	816	522	10	202	144	99	38	24	20	246	116	49	0	0.41	0.53	7.6	0.9	24	28	15
Mahan	6.59	1719	1100	7	420	330	137	45	90	26	512	230	162	19	0.97	5.3	4.1	9.3	47	23	9
Karbala	7.94	638	408	33	140	96	67	23	18	12	171	86	32	16	0.51	0.45	2.8	4.5	31	28	7
Handi	8.10	1464	937	29	320	122	211	27	18	19	390	234	34	4	0.63	0.91	6.5	4.9	63	240	28
Telibandha	7.63	563	360	21	134	94	60	20	22	10	163	80	25	1	0.57	0.65	3.5	0.5	8	28	15
Raja	7.05	993	636	4	300	220	77	15	40	29	366	84	12	8	0.65	0.77	6.2	0.5	31	45	9
Katora	7.46	511	327	13	154	82	50	13	28	3	188	60	5	1	0.48	0.86	1	5.7	24	150	43
Bandha	7.72	1255	803	1	250	106	188	27	20	14	305	210	25	2	1.41	0.23	3	2.9	31	460	23
Gogaon	8.05	1450	928	17	338	104	196	51	17	15	412	238	10	0	0.84	0.52	6.4	6.1	39	1100	150
Gondwara	8.10	649	415	112	120	94	86	11	24	8	146	94	38	11	0.62	0.19	1.2	3.7	24	15	4
Khamtarai	8.19	1160	742	7	180	98	96	17	24	9	208	150	18	0	1.03	0.48	6.8	2.9	87	210	75
Sitala Mata Mandir	7.39	1342	859	39	275	104	194	253	21	13	336	245	57	4	0.78	0.61	3	5.7	39	460	93
Pankhatiya	7.10	1732	1108	9	484	242	198	78	69	17	590	232	29	1	0.74	0.55	2.1	0.1	31	23	7
Rohinpura	7.52	481	308	16	122	114	49	8	26	12	149	68	22	1	0.94	0.43	3.5	3.7	31	21	4
Sarona	7.86	382	244	51	130	96	37	12	18	12	159	46	16	3	0.91	0.27	3.1	1.7	47	93	43

Practically all sodium compounds are water soluble and tend to remain in aqueous solution. Water in contact with igneous rocks will dissolve sodium from its natural source. Higher concentration of Na^+ ion in drinking water may cause heart problems. Higher Na^+ ion in irrigation water may cause sodicity problems. The range of Na^+ ions in water samples varies from 5.25 to 35.49 mg/l. The range of K^+ ions in water samples varies from 8 to 78 mg/l except Sitla Mata Mandir Talab where it is 253 mg/l.

The sources of Ca and Mg in natural water are various types of rocks, industrial waste and sewage. There is evidence that hard water plays a role in heart diseases. The Ca and Mg concentration in the lakes's water ranges from 9 to 50 and 3 to 27 mg/l, respectively which are within permissible limits (200 & 100 mg/l).

Fluoride content is essential for the development of normal bones and teeth. Excessive fluoride gets deposited on teeth causes dental flurosis, deposited on bones cause skeletal flurosis and Cripping flurosis. In Present samples fluoride content varies from 0.18 to 1.41 mg/l which is within the permissible limit (1.5 mg/l).

Nitrate concentration in groundwater and surface water is normally low but can reach high levels as a result of agricultural runoff, refuge dump runoffs, or contamination with human or animal wastes[17].When nitrate concentration is above 45 mg/l, it may lead to a disease called Methamoglobinemia" or "blue baby" in children. The nitrate value varies from traces to 19 mg/l which is in within the permissible limit (45 mg/l).

Sulphate is a substance that occurs naturally in drinking water. Health concerns regarding sulphate in drinking water have been raised because of reports that diarrhea may be associated with the ingestion of water containing high levels of sulphate. The concentration of Sulphate varies from 3 to 57 mg/l except for the Mahan and Kho Kho Talabs where the values are 162 and 200 mg/l respectively but these values are also within the permissible limit (400 mg/l).

Phosphorus is an essential nutrients for the plants and animals that make up the aquatic food web. Phosphorus is an essential element for plant life, but when there is too much of it in water, it can accelerate eutrophication. There are many forms of phosphorus that can be measured, we have analysed ortho phosphate as an indicator for phosphorus enrichment. Ortho phosphate content of lake water samples ranges from 0.19 mg/l to 1.72 mg/l, except for Mahan Talab where it is 5.3 mg/l.

BOD is the measure of the extent of pollutant in the water body. The untreated discharge of municipal and domestic wastes in water bodies increases the amount of organic content. Therefore the microbes present in water require more amount of oxygen for its degradation. Thus the BOD of water gets increased. In the present study the BOD level of water was varies from 0.1 to 11.3 mg/l.

COD test measures the oxygen demand of biodegradable pollutants plus the oxygen demand of non biodegradable oxidisable pollutants.COD is a water quality measure used not only to measure the amount of biologically active substances such as bacteria but also biologically inactive organic matter in water. [18] related higher values of COD with increased anthropogenic pressures on lakes and it is evident from the results that COD values of the lakes are very high (8-118 mg/l), an indication of flooded organic matter.

Dissolved oxygen (DO) is the maximum concentration of oxygen that can dissolve in water. As a function of water temperature, it may vary from place to place and time to time. DO is an important parameter to assess the waste assimilative capacity of the waters It fluctuate seasonally, daily and with variation in water temperature [19], mainly due to consumption of DO owing to respiration by aquatic animals, decomposition of organic matter, and various chemical reactions. Dissolved oxygen concentration ranges from 1 mg/l to 8.6 mg/l.

Total and fecal coliform are used as indicators of possible sewage contamination because they are commonly found in human and animal feces. Although they are generally not harmful themselves, they indicate the possible presence of pathogenic (disease-causing) bacteria, viruses, and protozoans that also live in human and animal digestive systems. Therefore, their presence in lakes suggests that pathogenic microorganisms might also be present. The range of total coliform varies from 15 to 3600 MPN/100ml and for fecal coliform the range varies from 4 to 240 MPN/100ml.

4.2 Irrigation Purposes

Sodium Adsorption Ratio (SAR) is a measure of the suitability of water for use in agricultural irrigation. In general, higher the sodium adsorption ratio, the less suitable the water is for irrigation(Table 2). The SAR values for each water sample were calculated using the following equation.

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

Table 2 Classification of irrigation water based on SAR

S.No.	Types of water and SAR value	Quality	Suitability for irrigation
1	Low sodium water (S1) SAR value: 0–10	Excellent	Suitable for all types of crops and all types of soils, except for those crops, which are sensitive to sodium
2	Medium sodium water (S2) SAR value: 10–18	Good	Suitable for coarse textured or organic soil with good permeability. Relatively unsuitable in fine textured soils
3	High sodium water (S3) SAR value: 18–26	Fair	Harmful for almost all types of soil; Requires good drainage, high leaching gypsum addition
4	Very high sodium water (S4) SAR value: above 26	Poor	Unsuitable for Irrigation

From Table 3 it can be observed that SAR value ranges from 1.64 to 19.95 which indicate that Talabs'water is suitable for irrigation. Most of the Talabs are having SAR values less than 10 which mean low sodium water (Table 3) and quality is excellent for irrigation of all types of crops and all types of soils.

Table 3 Classification of Talabs' water for irrigation purposes based on SAR value

Sample No.	Lake/Talab name	SAR Values	SAR based classification of water
L1	Budhha Talab	3.74	Excellent
L 2	Maharajbandh Talab	2.76	Excellent
L 3	Chironji Talab	7.13	Excellent
L 4	Naya Talab	4.69	Excellent
L 5	Naraya Talab	3.11	Excellent
L 6	Kho Kho talab	12.41	Good
L 7	Bandhua Talab	2.60	Excellent
L 8	Paharai Talab	4.83	Excellent
L 9	Malsai Talb	10.15	Good
L 10	Ama Talab	19.95	Fair
L 11	Dhobi Talab	8.43	Excellent
L 12	Shetla Talab	3.91	Excellent
L 13	Ghorai Talab	3.60	Excellent
L 14	Mahan Talab	3.28	Excellent
L 15	Karbala Talab	2.99	Excellent
L 16	Handi Talab	8.30	Excellent
L 17	Telibandha Talab	2.69	Excellent
L 18	Raja Talab	2.26	Excellent
L 19	Katora Talab	2.41	Excellent
L 20	Bandha Talab	7.93	Excellent
L 21	Gogaon Talab	8.37	Excellent
L 22	Gondwara Talab	3.87	Excellent
L 23	KhamtaraiTalab	4.22	Excellent
L 24	Sitala Mata Mandir Talab	8.29	Excellent
L 25	Pankhatiya	5.55	Excellent
L 26	Rohinpura Talab	2.01	Excellent
L 27	Sarona Lake	1.64	Excellent

US salinity laboratory (USSL) classification evaluates the irrigation water quality on the basis of its electric conductivity (EC) as the indicator of its salt concentration, and SAR as the indicator of its relative sodium activity. Electrical conductivity therefore becomes a satisfactory measure of the salinity hazard involved in the use of water for irrigation. Waters are divided into 4 groups (C1, C2, C3, C4) with respect to conductivity, the dividing points between classes being at 250,750, and 2,250 micromhos/cm. SAR is a measure of sodium hazard and is divided into four groups(S1, S2, S3, S4), the dividing points between classes being at 10,18, and 26. All the water samples falls in C2 & C3 category which implies salinity hazard is medium to high. As far as sodium hazard is concerned all samples were falls under S1 & S2 category implying low to medium sodicity (Fig. 3).

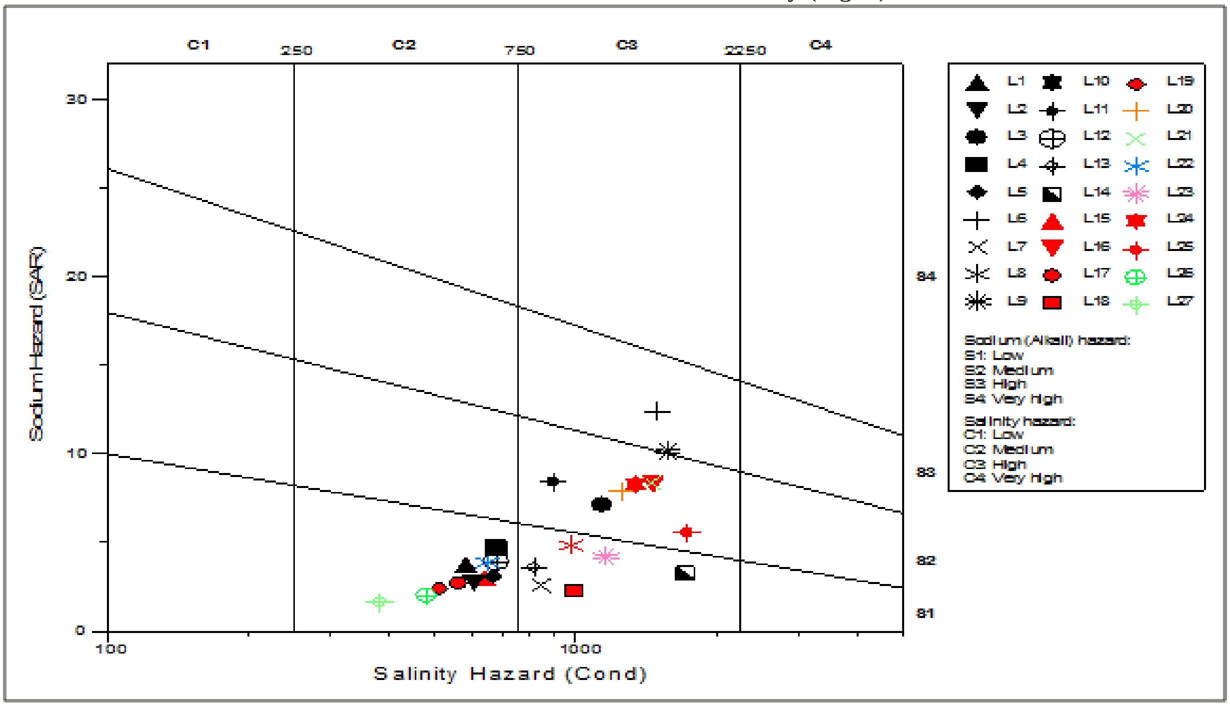

Fig. 3 USSL classification for irrigation water

V. Conclusion

In this study characterization of the physicochemical, BOD, COD and bacteriological parameters of twenty seven lakes' water from different locations in Raipur city area has been carried out. To assess the quality of lake water each parameter was compared with the standard permissible limits prescribed by Bureau of Indian Standard (BIS, 2012). From the study it is concluded that lake water is not safe for drinking purposes from the point of view of levels of turbidity, TC and FC mainly. The irrigation water quality was also assessed by estimating Salinity and Sodium hazards. All the samples fall in S1 and S2 classes which implies low to medium sodium hazard. For Salinity hazards, all the samples fall in C2 and C3 classes implying medium to high salinity. It may be concluded that lake water is good for irrigation purposes. The lake water quality may be improved by bans the activities that cause pollution and diversion of sewerage water by abstaining it to drain into lake.

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