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Hydro-Chemical Analysis of Ground Water for Irrigation and Drinking Purpose in Kolhapur, Maharashtra Region, India

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Abstract - **Multivariate statistical techniques and factor analysis were employed under this study to assess the ground water suitability for drinking as well as for agricultural purpose in Kolhapur region of Maharashtra State. Detailed analysis and the evaluated results with statistical approach indicated that overall ground water quality was satisfactory for the purpose although the some samples exceeded safe limit for some parameters. Electrical Conductivity for most of the samples found to be above the safe limit of 1500 µs/cm. Concentrations of cations Na+, K+, Ca+ and Mg+, varied from 102.4 to 184.2, 0.9 to 20.4, 56.7 to 112.4 and 13.6 to 28.2 ppm respectively, with mean values of 128.6, 8.7, 86.11 and 19.5 ppm with more than 90% falling under safe category. Chronological order of major cations were Na+ > Ca2+ > Mg2+ > K+, and major anions were HCO3- > Cl- > SO42- respectively. Na+ was found to be the dominant cation among the cations, and K+ was the lowest constituents, whereas bicarbonates was the most abundant and SO4 was the minor constituents under anions. Nearly 50% samples recorded below average values under WQI, and more than 80% samples falling in Class I category under Doneen's graph. All samples exhibited the SAR values less than 10, indicating high suitability for the irrigation purpose.**

Keywords: **Ground Water Quality, Statistical Analysis, Pearson's Correlation, Kelly's Ratio**

I. INTRODUCTION

Ground water is an important water source in many parts of India. Ground water is used areas where surface source is not available or too far to transport. Many of the resident areas, especially villages are situated in such areas where dependability on sub-surface water is more. As such ground water is used for both, drinking and agricultural purpose, it is important that the water is safe for the health of human beings and animals as well [18]. Compositional and contaminant controlling ground water quality depend not only on the hydrologic factors, geologic characteristics of aquifer lithology and interactions between water and aquifer, but also on human activities, such as agricultural practices, human population explosion and rapid industrialization [5]. Groundwater quality is being increasingly threatened bydifferent types of contaminants due to urbanization and industrialization [11]. Ground water quality is also affected by the anthropogenic factors, such as leaching of fertilizers, industrial waste-water, over withdrawal of ground water and accidental spillage [7]. Due to this ground water sources' quality is affected by the addition of toxic materials, nutrient substances and petroleum products which alter the ground water chemistry affecting the quality adversely. Natural factors, like rainfall, surface runoff and ground water flow are seasonal phenomenon that are mainly that are mainly affected by climate [12].

A linkage between evaporation, precipitation, chemical weathering and anthropogenic activities is required in order to have reliable information about inherent properties of water quality and to follow the variations in hydro-chemical and biological properties. Multivariate statistical techniques, like factor analysis (FA) and principle component analysis (PCA) are widely used for the evaluation of pollution sources and interpretation of large and complex water quality datasets. With above considerations, the main objective of this research study is to obtain deeper understanding about

1. The quality assessment with regard to drinking and agricultural purpose and hydro chemical characteristics in the study area of Kolhapur region.
2. Identifying possible pollution sources.

II. MATERIALS AND METHODS

A. Introduction to Study Area

Selected study area falls surrounding the area of Kala-Odha stream which is surrounded by many industrial units, viz., textiles. These include a good number of power looms, sizing units, spinning mills, shuttle looms and processing units. This study area is under the latitude 16.69 N to 16.67 N, and longitude 74.46 E to 74.47 E. Further, it is under the geological feature of Deccan trap of Upper Cretaceous to Lower Eocene in age. Fourteen ground water samples, 11 from bore-wells and three from open wells, were collected during the year 2019 – 20 for assessment of ground water quality for agricultural use. Although surface water is available, but most of the Ichalakaranji area depends on ground water source as the streams and rivers quickly dry up even before the summer.

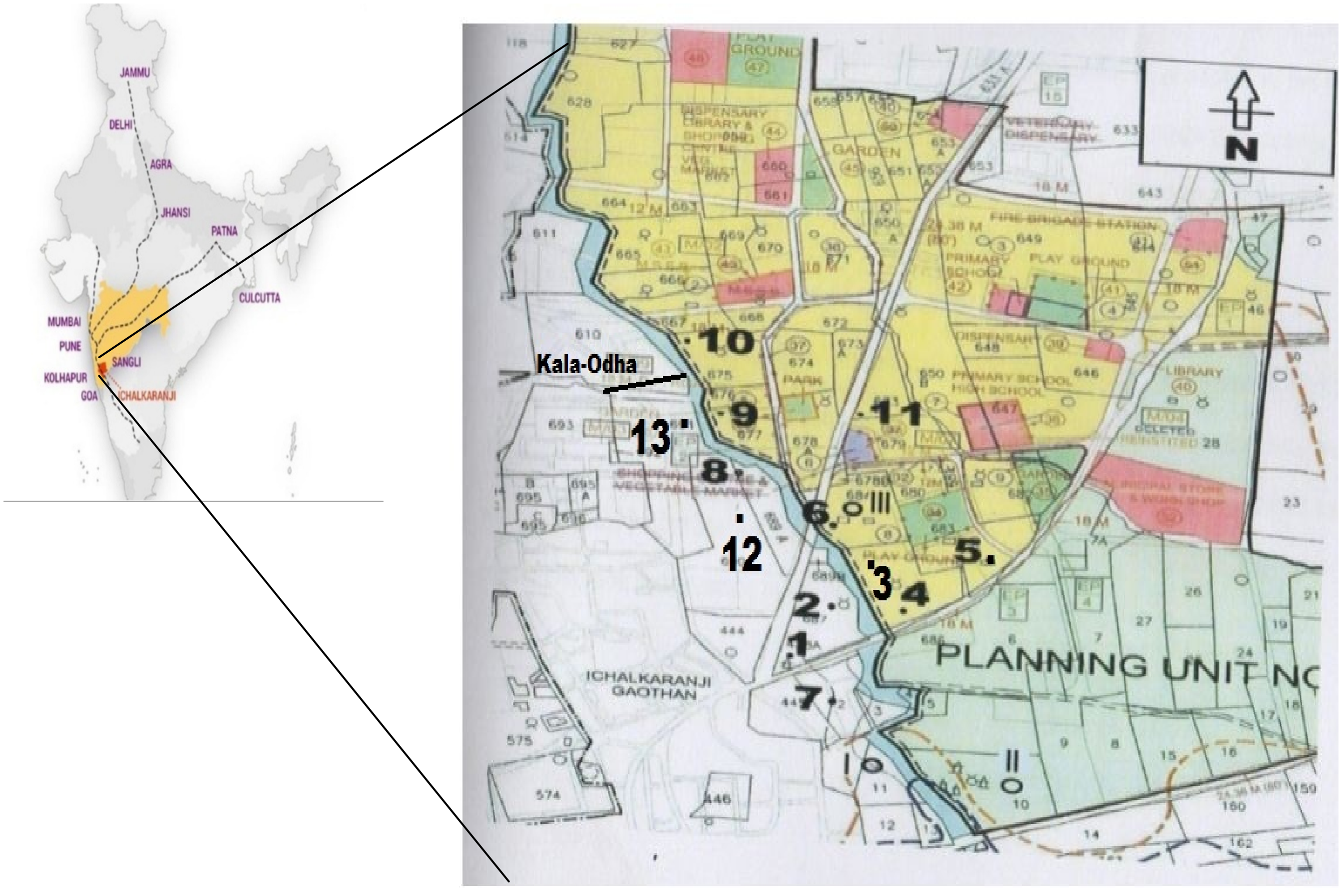

Fig. 1 Location map for the study area

B. Method

A total of 14 samples, as indicated in Fig. 1 were collected in clean polythene bottles of each 2 liter capacity. Depth of bore-wells ranged from 60 to 80 meters. pH value, EC and TDS were measured in situ with multi-parameters monitoring instruments, and DO was fixed at site. All other parameters were analyzed by titration, except Na, K where flame photometer was used for the analysis. Standard methods and procedures were followed as per the guidelines under APHA.

III. RESULTS AND DISCUSSIONS

A. Hydro Chemical Data Analysis

Summary of the hydro chemical data for the selected region is presented in Table I. Minimum pH value of 7.2 was recorded at SW-06 and maximum of 7.9 at SW-01 and BW-06, with an average pH of 7.61. Average pH value was to be lower than those reported by Loni *et al.*, 2010 [14] in the region, but in line with the values reported by Vyas and Sawant, 2007 [16] Safe limit for pH is 6.5 to 8.5 as per the WHO guidelines and all samples in the study area recorded the pH value in this range. Abrupt variation in pH value in a water body can have adverse effect on the aquatic life. Variation in pH value can also affect the solubility and toxicity of chemicals and heavy metals in the water. Most of the aquatic creatures survive in the pH range of 6.5-9.0, though some can live in water with pH levels outside of this range. However, pH in the outside range of optimum value of 6.5 to 9 would not pose detrimental effects. Apart from biological effects, extreme pH levels usually increase the solubility of elements and compounds, making toxic chemicals more active and increase the risk of absorption by aquatic life. Overall, the variation in pH value affects the water chemistry including solubility, alkalinity and speciation. Electrical conductivity is one of the important water quality parameters indicating the measure of dissolved salts and salinity. Average EC value was 1967 µS/cm, with minimum EC of 1582 µS/cm for SW-3 and maximum of 2375 µS/cm for SW-05 as presented in Table I. Present study recorded higher values of EC as found by Vyas and Sawant, 2007 [16], while working on ground water study in Kolhapur region, Maharashtra, and lower than [9]. High EC of the water samples reflect leaching or dissolution of the aquifer materials or mixing of other sources such as saline water. Recorded values for EC under the present study were found to be slightly on the higher side compared to WHO guidelines. Maximum TDS was found to be 1950 mg/L. Mean value for alkalinity was found to be 166.2 mg/L with maximum of 316 mg/L for SW-02 and minimum of 110 mg/L for BW-01, as presented in Table I.

TABLE I LABORATORY TEST RESULTS FOR THE SAMPLES COLLECTED IN THE STUDY AREA

Sample Type	Sample No.	pH value	EC µS/cm	T. Hardness	T. Alkalinity	TDS	Calcium	Magnesium	Sodium, Na	Potassium, K	Bicarbonates, HCO_3	Sulfates, SO_4	Chlorides, Cl	Nitrates, NO_3
SW1	1	8.2	1904	384	182	1180	104.2	21.4	144.6	19.7	470	122.2	170	5.4
SW2	2	7.8	2286	309	316	1320	90.4	20.6	117.5	20.4	520	77.1	147	3.6
SW3	3	8.4	1582	356	118	1090	89.2	18.6	184.2	6.9	510	92.6	139	4.3
SW4	4	8.2	1986	407	156	1650	86.4	22.4	115.4	4.3	436	93.9	116	2.8
SW5	5	8.3	2375	315	216	1880	56.7	14.6	164.4	17.4	409	117.2	124	3.2
SW6	6	8.6	1929	288	206	1430	108.6	25.4	124.5	4.9	420	163.4	133	4.1
DW1	7	7.4	2076	344	168.5	1720	98.5	17.8	148.6	8.3	412	158.6	152	5.6
DW2	8	7.8	2069	418	162	1810	90.2	14.2	116.2	0.9	407	91.2	107	4.7
DW3	9	7.9	2040	294	212	1350	112.4	28.2	132.8	3.2	398	187.8	135	2.6
BW1	10	8.1	1936	304	112	1120	71.4	21.8	125.3	11.3	330	149.4	120	2.8
BW2	11	8.1	1782	448	144	1260	86.4	20.5	138.9	8.5	410	146.3	132	3.4
BW3	12	8.3	1784	318	119	1280	69.5	16.4	104.3	4.7	360	74.6	102	2.9
BW4	13	8.4	2095	336	142	1550	82.3	12.3	120.4	8.9	374	82.4	129	3.4
BW5	I	8.6	1850	292	138	1050	78.4	13.6	108.2	7.6	312	69.2	142	4.6
BW6	II	7.9	2125	317	152	1950	84.5	23.4	110.6	6.8	374	80.5	149	4.1
BW7	III	7.8	1655	352	116	960	68.6	20.3	102.4	5.4	346	98.2	103	1.8

Four of the sixteen samples, i.e 25% samples exceeded the concentration for alkalinity as set by WHO guidelines. Higher concentrations of alkalinity generally occur due to the presence of salts such as carbonates, bicarbonates and silicates. The leaching process through surface water during rainy season can also add to higher value of alkalinity. The natural sources of HCO_3^- in the water are carbonated rocks. Alkalinity in groundwater exceeded >200 mg/L give unpleasant taste and thus limits the acceptance as potable water. Surface sources generally contain less alkalinity. TDS recorded a maximum concentration of 1950 mg/L at BW-06 location, minimum of 960 mg/L at BW-07, with an average concentration of 1412.5 mg/L. Concentrations of TDS were found to be higher than those recorded by Vyas and Sawant (2007) [16], and lower than recorded by [9]. High level of TDS may be responsible for reduction in palatability of water.

In the present study TDS concentrations recorded for the study area were more than the desirable limit, but well within the maximum limit of IS: 10500; 2012. High concentrations of TDS and EC can be attributed to rainwater infiltration, sediment dissolution, evaporation and ion exchange. TDS concentrations in ground water generally depend on the water chemistry and the aquifer materials solubility through which the water is flowing. High levels of TDS could lead to laxative effects and gastrointestinal irritations. Further TDS and EC exhibited a strong relation as there was increase in TDS with the increase of EC and decrease of EC when TDS recorded decreased values [21] found the same relation working on “Assessment of physicochemical properties of water and their seasonal variation in an urban river in Bangladesh”. Among the cations, Ca^{2+} and Mg^{2+} recorded the values well within the permissible limit of IS: 10500: 2012 and WHO guidelines. Maximum concentration of Ca^{2+} of 112.4 mg/L was recorded for DW-03 location and minimum of 56.7 mg/L for SW-05 open well with average of 86.11 mg/L. Calcium is an abundant cation in groundwater, which is mainly contributed by carbonate minerals (calcite and dolomite) and plagioclase feldspar. High concentration of calcium impairs the quality of ground water by causing kidney or bladder stone formation and irritation in urinary passage in human beings. Concentrations of Mg^{2+} were also recorded below the desirable limit of WHO.

Average value for Mg^{2+} was 19.47 mg/L, with maximum of 28.2 mg/L for DW-03 and minimum recorded value was 12.3 mg/L for BW-04 as presented in Table 1. Mg^{2+} is essential as an activator of many enzyme systems but it is cathartic and diuretic. Concentrations of Mg^{2+} recorded were found to be well below the WHO and IS guidelines of 150 mg/L. Most common sources for Mg^{2+} are dolomites and mafic minerals in the bedrocks. Na^+ and K^+ recorded maximum concentrations of 184.2 mg/L and 20.4 mg/L respectively at SW-03 and SW-02, as presented in Table I. Minimum values were found at locations BW-07 and at DW-02 with concentrations of 102.4 mg/L and 0.9 mg/L respectively. Average concentrations for Na^+ and K^+ were found to be 128.6 mg/L and 8.7 mg/L respectively. Average values were found to be higher than those recorded by Vyas and Sawant (2007) [16] and less than those reported by Varadarajan and Purandare (2010) [9]. The suggested guideline value for Na^+ is (200 mg/L) recommended by WHO, as Na^+ level greater than this limit may affect taste of drinking water. Na^+ is one of the most commonly found cation in water. Associated anion with Na^+ is the major cause for the taste threshold concentration in water and the temperature of the solution. Natural salt deposit erosion, improper sewage treatment, water treatment chemicals and the ion exchange softening units are the most common sources of Na^+ in drinking water.

High Na^+ concentration in drinking water may pose a risk to the persons suffering from cardiac, renal and circulatory diseases (WHO, 2011). Concentrations of K^+ were found to be higher than WHO guidelines at SW-01, SW-02 and SW-05 locations, with maximum value of 20.4 mg/L at SW-02 and minimum of 0.9 mg/L at DW-02. K^+ concentration exceeded by 64.17%, 66.67% and 45% at SW-01, SW-02 and SW-05 respectively against the maximum permissible value of 12 mg/L. K^+ is an essential nutrient but if ingested in excess may have laxative effect (Jehan *et al.*, 2019). Orthoclase, microcline and clay minerals are the chief sources for this element and it also results through ion exchange process. Mean concentration of HCO_3^- was found to be on higher side for all the locations, with minimum concentration of 312 mg/L at BW-05 and maximum of 520 mg/L at SW-02 with an average value of 405.5 mg/ L, as presented in Table I. Minimum variation was recorded 24.8% higher than the WHO limit of 250 mg/L and maximum variation at 108% of the limit. HCO_3^- is generally associated with pH value over 7.5 and is helpful in neutralizing the acidic condition of the human body. Concentrations of sulfates recorded higher values although 87.5% of samples indicated lesser values than IS: 10500 - 2020 (BIS, 2020) permissible limit. Maximum value recorded for SO_4^- was187.8 mg/L at DW-03 location. All recorded values were found to be below the WHO, EPA and IS 10500-2020 permissible limits of 400, 250 and 200 mg/L, respectively.

However, most of the concentrations recorded values higher than NSDWQ which is 100 mg/L. Accumulation of sulfate in water may lead to increase in water pH causing acidosis. Any other health implication and side effects have not been recorded so far for excess sulfate concentration in water. Concentration of chloride varied from a maximum of 170 mg/L at SW-01 sampling site to a minimum of 102 mg/L at BW-03 site, with an average reports that diarrhea, catharsis, dehydration and gastrointestinal irritation may be associated with the ingestion of water containing higher levels of sulfate. Sulfates concentrations recorded in the study area ranged from a maximum of 187.8 mg/L at DW-03 to a minimum of 69.2 mg/L at BW-05 with an average of 112.8 mg/L as presented in Table I. All values recorded were well below the permissible limit of 400 mg/L as per WHO guidelines. Vyas and Sawant (2007) [16] recorded slightly higher concentrations than the present study in the Kolhapur region. Nitrates recorded a maximum of 5.6 mg/L at location DW-01, minimum of 1.8 mg/L at BW-07 and with an average of 3.7 mg/L. All the samples exhibited concentrations well below the maximum limit of BIS and WHO guidelines. Concentrations of nitrate recorded during the present study exhibited lesser values than those found by Patil and Bhosale (2019) [20]. Decaying organic matter domestic wastes and fertilizers are major source of NO_3^- in ground water. Major health 131 mg/L. All recorded concentrations were below the maximum permissible values of 250 mg/L, 250 mg/L and 600 mg/L as per NSDWQ, IS: 10500 and the WHO guidelines, respectively. Chloride has been found to exist naturally in the form of sodium and potassium salts and its concentration varies from types of water. Chloride concentration is uninterrupted by both physico- and bio-chemical processes which makes it as a stable water component. Erosion and watering of crystalline rocks are the processes responsible for chloride in groundwater. Hornblende sodalities, micas and apatite are chief minerals that contribute chloride to groundwater. Seawater, sewage and saline residues in soil are responsible for high concentration of chloride in natural water. Excessive chlorides concentration in water could lead to laxative effect, damage to metallic pipes and water becomes unsuitable for agricultural application. Activities of bacteria, such as chlorothiobacteria and rhodothiobacteria, carry oxidation of sulfates' bearing ores and H_2S, which results in sulfates. Wastes resulting from domestic activities, feedlots and agricultural runoff (fertilizers) also add excess SO_4^{-2} concentrations to groundwater. Health concerns regarding SO_4^{-2} in drinking water have been raised because of the reports that diarrhoea, catharsis, dehydration and gastrointestinal irritation may be associated with the ingestion of water containing higher levels of sulphate. Implications of excess nitrate in water are hypertension in adults and methaemoglobinaemia in infants. NO_3^- is prone to leaching through soils with infiltrating water as it is soluble and mobile.

B. Statistical Correlation of Groundwater Contaminants

Existing interaction between minimum of two continuous variables with values ranging between − 1 and +1 is exhibited by Pearson's correlation (r). This correlation statistical tool was used to correlate the groundwater contaminants in study area. A positive value indicates positive correlation between variables, while negative value implies negative correlation. Negligible connection between parameters is indicated by $r = 0$. In most cases, strong correlation exists within parameters when $r > 0.7$, while moderate correlation exists when r ranges between 0.5 and 0.7. Pearson correlation results assessed for physicochemical parameters of water samples in the study area is presented in Table II. The results indicated that approximately 21%, 57% and 22% of the physicochemical parameters to be strongly ($r \geq 0.7$), moderately ($0.5 < r < 0.7$) and poorly ($r < 0.5$) correlated.

TABLE II PEARSON’S CORRELATION FOR THE SAMPLES COLLECTED IN THE STUDY AREA

Parameters	pH	EC	TH	T Alk	TDS	Ca	Mg	Na	K	HCO_3	SO_4	Cl	NO_3
pH	1												
EC	0.13	1											
TH	0.04	0.25	1										
T Alk	0.16	0.69	0.25	1									
TDS	0.06	0.73	0.1	0.26	1								
Ca	0.01	0.02	0.05	0.35	0.01	1							
Mg	0.19	0.09	0.14	0.25	0.12	0.56	1						
Na	0.39	0.01	0.13	0.08	0.05	0.14	0.02	1					
K	0.15	0.42	0.13	0.53	0.08	0.14	0.09	0.32	1				
CO_3	0.22	0.13	0.41	0.02	0.34	0.07	0.32	0.15	0.36				
HCO_3	0.12	0.13	0.27	0.57	0.07	0.44	0.21	0.55	0.41	1			
SO_4	0.13	0.03	0.07	0.14	0.02	0.50	0.59	0.34	0.07	0.01	1		
Cl	0.07	0.20	0.12	0.38	0.03	0.54	0.22	0.39	0.54	0.42	0.18	1	
NO_3	0.11	0.11	0.13	0.12	0.23	0.45	0.23	0.34	0.19	0.31	0.00	0.68	1

To achieve maximum crop productivity, water used for irrigation should be of good quality. Chemical parameters play a significant role for classifying and evaluating the groundwater quality. Therefore, to assess water quality for different uses, with specific reference to irrigation, water quality indices such as SAR, RSC, Mg-hazard (MAR), permeability index (PI), Kelly's ratio (KR), hardness and sodium percentage (Na%) were calculated from the chemical analyses of 16 groundwater samples collected in the study area. Permeability of soil is reduced due to the reaction of sodium ions with soil, and sodium concentration is important in the classification of irrigation water quality. Clay particles in the soil adsorb the sodium ions when the concentration is high in the irrigation water, thereby exchanging Na^+ ions in water and displacing Ca^{2+} and Mg^{2+} from the soil. Soil permeability is severely affected due to this, and decreases with poor internal drainage which results in limited air and water circulation during wet conditions. Wilcox (1955) proposed a classification based on sodium percentage. As per the classification, Na% with <60 in groundwater is suitable for irrigation purpose. In the present study Na% ranged from 37.8% to 65.2%. As presented in Table III, 12.5% samples fall under good category, 81.25% under permissible and whereas 6.25% fall under doubtful to unsuitable category. Although more than 80% fall in the permissible range, Na% is near to the doubtful range indicating higher sodium concentration. High Na^+ may be attributed to long residence time of water, addition of chemical fertilizers and dissolution of minerals from lithological.

Magnesium hazard as indicated by MAR should be less than 50 for good irrigation water whereas higher than 50 is unsuitable for irrigation purpose. Higher values of magnesium decreases the crop yield and makes soil more alkaline, also large amount of water is absorbed between magnesium and clay particles reducing the infiltration capability of soil adversely affecting the crop yield and growth. Value of MAR varied from 40.8 to 65.7 in the present study, with only 37.5% samples under 50 and the rest recording MAR > 50 indicating unsuitability for irrigation purpose as in Table III.

TABLE III DIFFERENT CALCULATED INDICES FOR THE GROUNDWATER IN THE STUDY AREA

Sample	SW-01	SW-02	SW-03	SW-04	SW-05	SW-06	DW-01	DW-02	DW-03	BW-01	BW-02	BW-03	BW-04	BW-05	BW-06	BW-07
No. on map	1	2	3	4	5	6	7	8	9	10	11	12	13	I	II	III
Na%	46.5	47.7	59.3	41.8	65.2	37.8	45.5	45	43.9	48.8	48.4	39.7	40.8	41.5	40.4	40.9
MAR	49.6	41.4	40.8	58.7	48.2	59.4	61.7	48.9	45.6	57.7	54.3	67.6	64.9	61	60.8	65.7
PI	54.6	62.7	70.2	50.9	77.7	42.9	47.8	55.9	51.9	55.9	56.1	45.7	46.5	49.6	46.9	47.8
RSC	-2.6	0.8	1.1	-2.4	1.3	-6.4	-5.4	-1.7	-3.8	-3.1	-2.7	-4.6	-4.6	-3.3	-4.6	-4.2
KR	0.6	0.7	1.1	0.5	1.3	0.4	0.5	0.6	0.6	0.6	0.6	0.4	0.4	0.5	0.4	0.5
SAR	3.4	2.9	4.6	2.9	5.1	2.8	3.6	3	2.9	3.4	3.5	2.9	3.3	3	2.7	2.8

Similarly PI indicated the water quality can be categorized as 'good' with the values of all samples falling in the range 25 to 75 (category III). Further, KR is< 1 for 87.5% samples exhibiting that most of the samples collected are suitable for the irrigation purpose as in Table III. Only 12.5% samples exceeded unity, and are unsuitable. Whisker plots are drawn for comparing different data sets. Fig. 2 (a) presents the box plot for Na%, RSBC, PI and WQI. The plot exhibits the nature of distribution of these properties for the study area. Na% concentrations mostly clustered at the lower values, RSBC values dispersed at the lower level, most PI values clustered at the middle range and the WQI values slightly wider dispersed at the higher values. Similarly, data set distribution for EC, total hardness and TDS is exhibited in Fig. 2 (b). Data set values are clustered at higher range for EC, indicating increased values of EC for the samples total hardness clustered at lower level and Total dissolved solids with, dispersed values. Soluble sodium content of the ground water is indicated by Na% and is used to assess the sodium hazard under irrigation application. EC and Na^{2+} concentrations play the important role in classifying irrigation water.

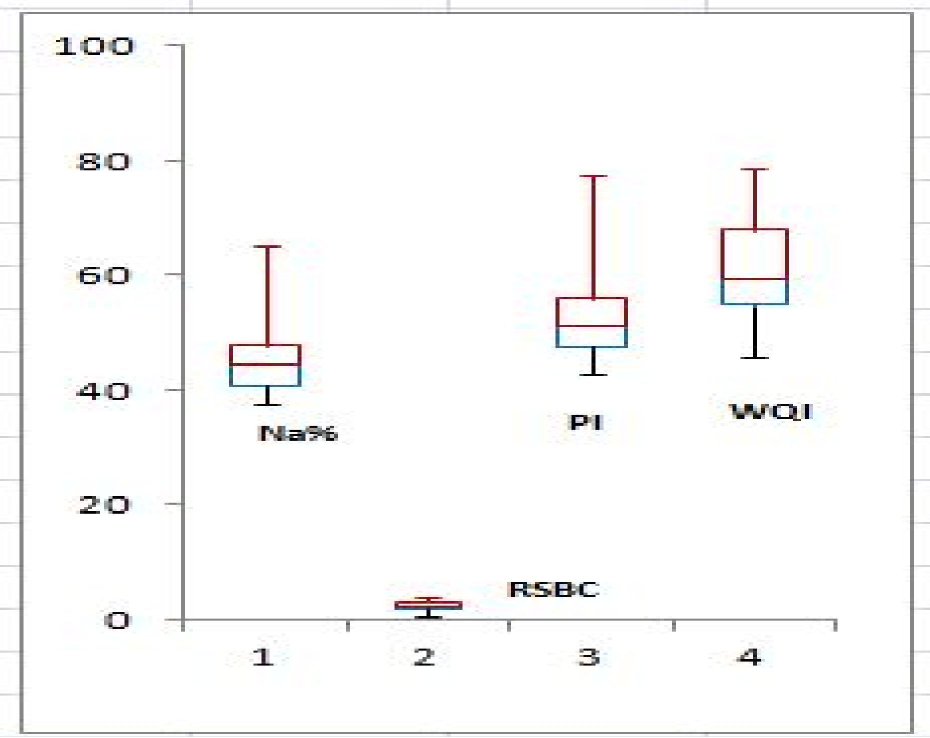

Fig. 2 (a) Whiskar plot for Na%, RSBC, PI and WQI

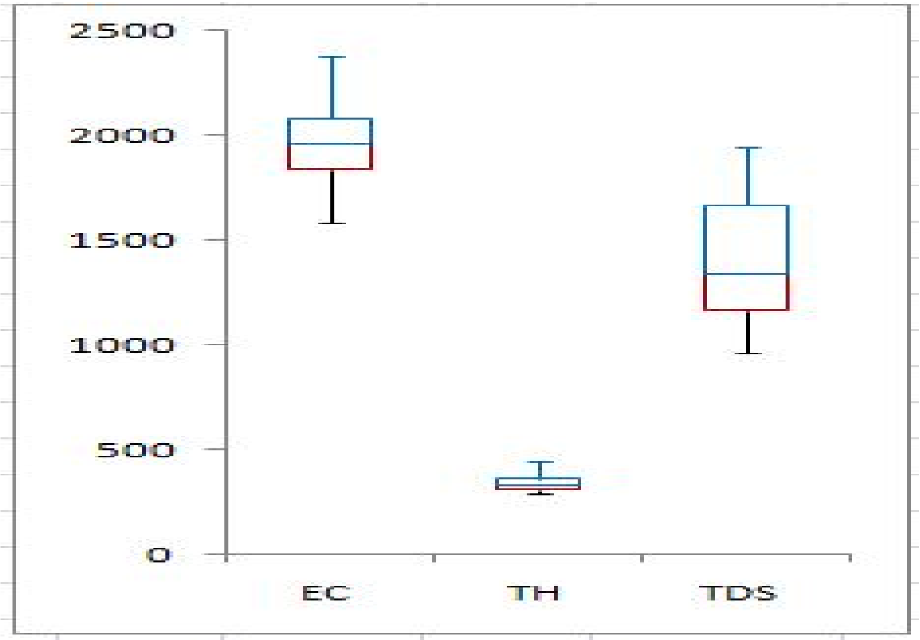

Fig. 2 (b) Whiskar plot for EC, TH and TDS

High salt content as indicated by high EC, in irrigation water leads to formation of saline soil. Salinization, on the irrigated lands, is the major cause of loss of production, and it has adverse environmental impacts on irrigation. Crop germination and yield is adversely affected and also the choice of crops becomes limited due to saline condition of irrigating land. It is important that all evaluations regarding irrigation water quality are linked to the evaluation of the soils to be irrigated [3]. Since sodium reacts with soil reducing its permeability, it is important to classify irrigation water based on sodium concentration. In all natural waters, percent sodium is a parameter to evaluate its suitability for agricultural purposes (Wilcox, 1984); sodium combining with carbonate forms alkaline soils, while sodium combining with chloride forms saline soils. Either type of sodium-enriched soil will support little or no plant growth.

The chemical quality of groundwater samples was studied by plotting analytical data relating EC and sodium percent that show that most of the samples belonging to “Good to permissible”. This is presented in the form of Wilcox diagram as in Fig. 3.

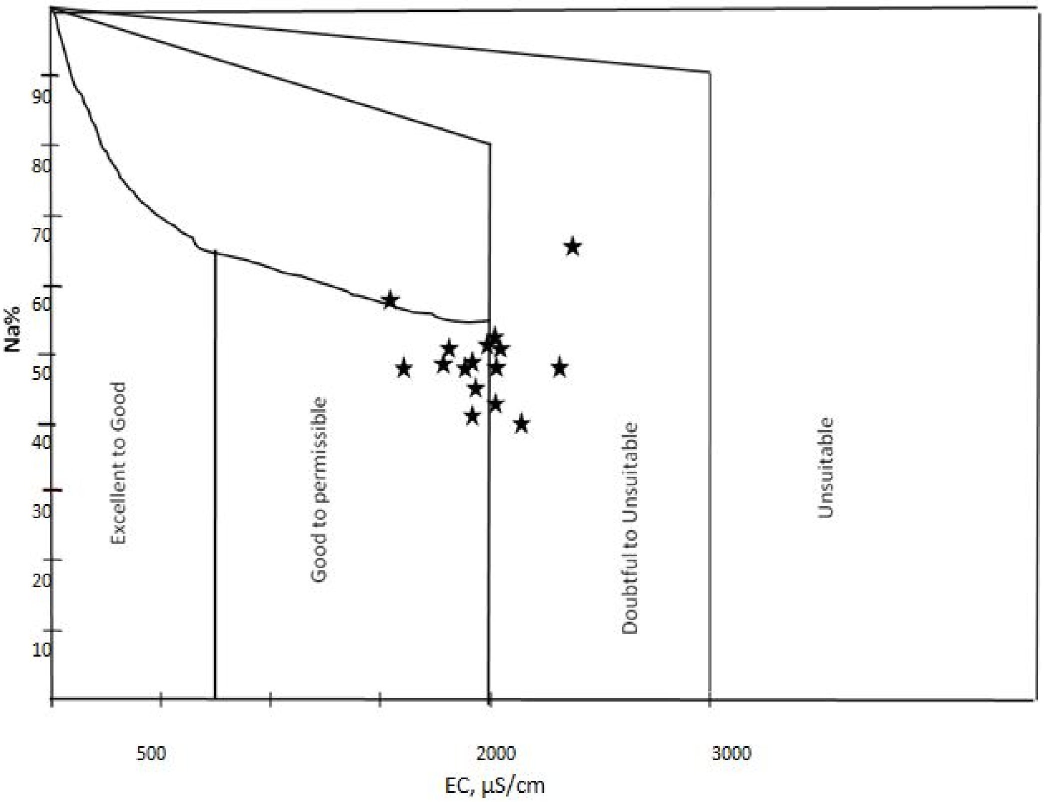

Fig. 3 Classification of groundwater samples on the basis of electrical conductivity and Na^{2+}

The figure reveals that 56.5% of samples fell under good to permissible class and the rest of the samples under doubtful to unsuitable.

Gibbs plot, as presented in Fig. 4 (a) and (b) for the study area showed that the ion composition is controlled by evaporation-crystallization close to the boundaries and by rock weathering in the center of the plain. This exhibits the fact that water-rock interaction is the mechanism responsible for the chemistry of the ground water. Ca^{2+} and HCO_3^- are the dominant ions near the boundaries while Na^+ and Cl^- are the dominant ions in the center of the plain.

Permeability Index is also an important index to assess the suitability of ground water for irrigation purpose. It indicates the relationship between bicarbonates and major cations in hydrochemistry. Irrigation water quality is classified in to three categories as suggested by Doneen (1964). Value of PI ranged from 42.92 to 77.69%, with an average of 53.94% as presented in Table III.

As suggested by Doneen, most suitable ground water under Class I with more than 75% permeability, moderately suitable 25% to 75% under Class II, and not suitable for those falling below 25% permeability, as Class III. In the present study, more than 90% of samples fall under Class I exhibiting good water quality for irrigation application. Only one sample fell under Class II with moderate suitability for irrigation purpose, as in Fig.5.

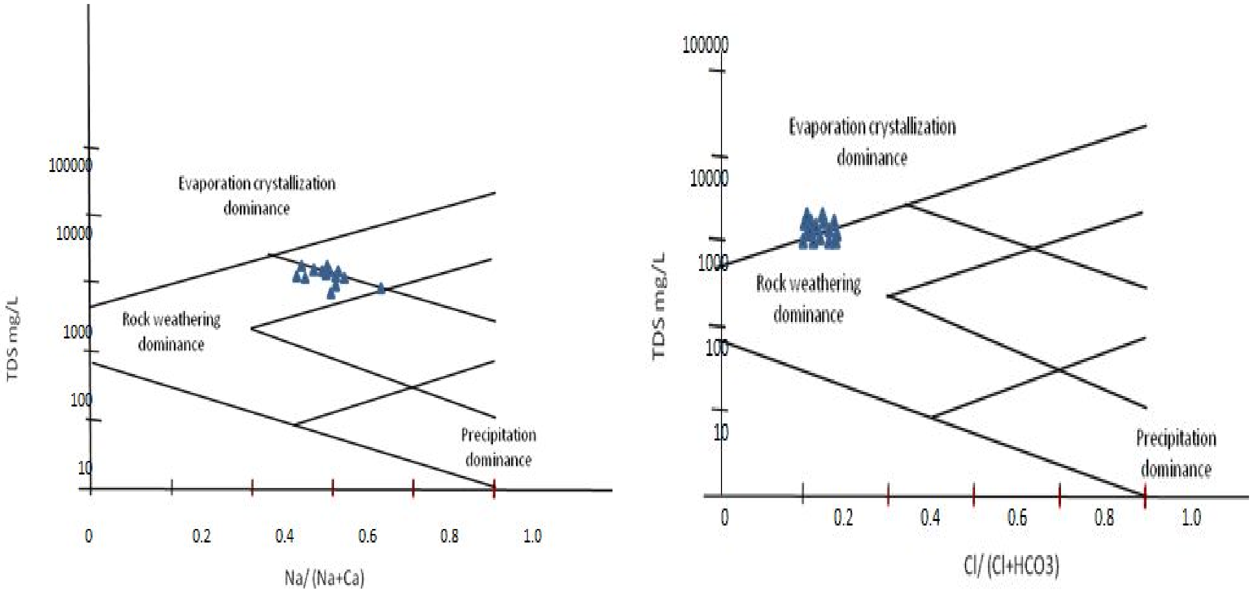

Fig. 4 Classification of groundwater samples on the basis of Gibbs plot

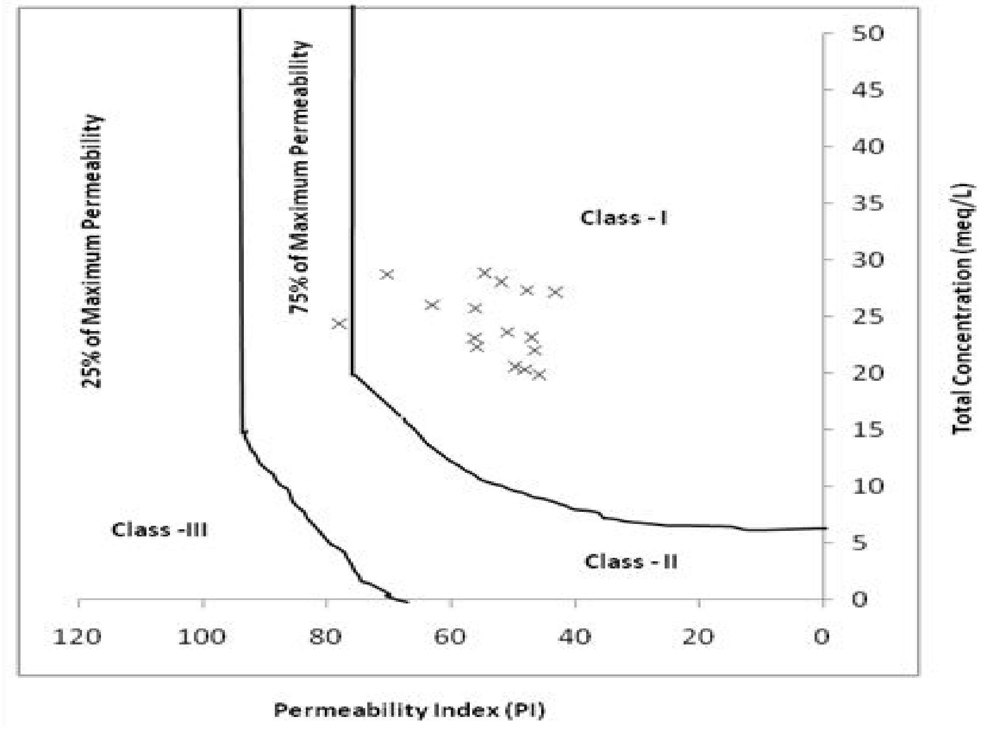

Fig. 5 Classification of groundwater samples on the basis Doneen's chart

The Piper-trilinear plot shows the classification of water samples from various lithological environments. It also demonstrates the chemical character of the water samples using the dominant cation and anion to describe the dissimilarities and similarities of the groundwater samples. The study area water analysis result is plotted in piper diagram (Fig. 6). Piper-trilinear diagram is classified into

1. Sulfated or chlorinated waters of calcic or magnesian waters,
2. Calcium or magnesium bicarbonated waters,
3. Bicarbonated sodic waters and
4. Sulfated or chlorinated sodic waters.

In the presented study 11 of 16 samples fall under the 1st category exhibiting sulfated or chlorinated waters of calcic or magnesium characteristics.

Three samples under the 2nd category of calcium or magnesium bicarbonated waters, and rest under the sulfated or chlorinated sodic waters, as presented in Fig. 6.

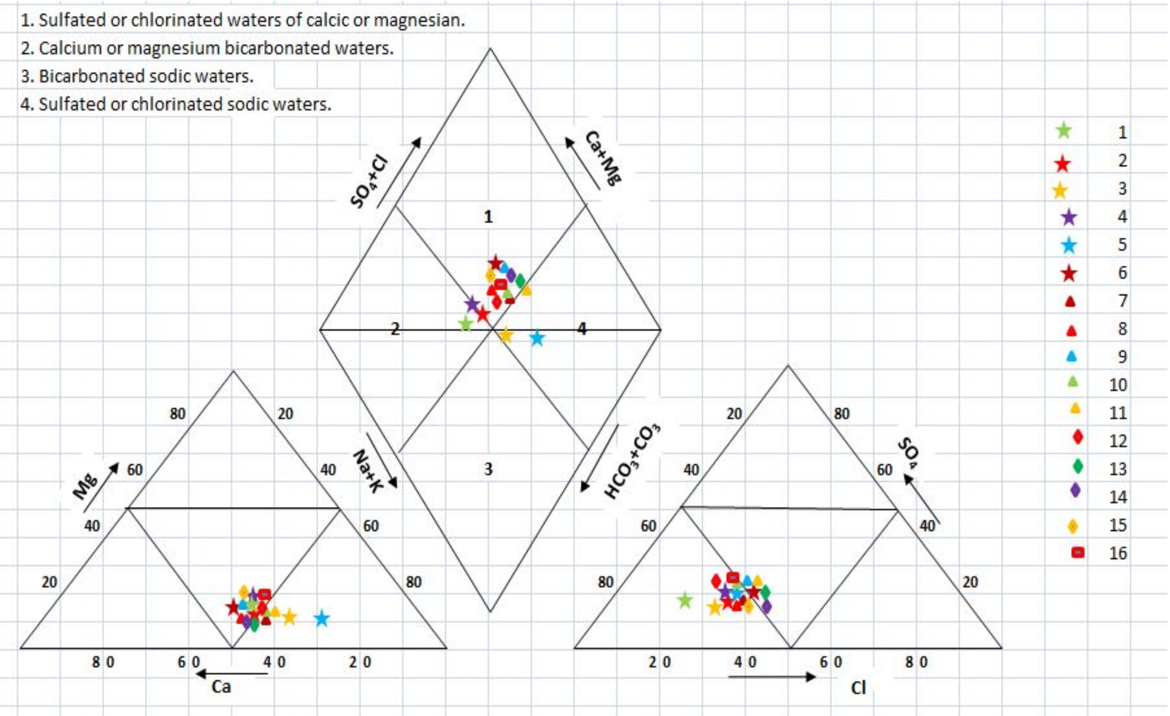

Fig. 6 Piper trilinear diagram for groundwater samples in the study area

IV. CONCLUSION

Present study was carried out for the assessment of ground water quality for irrigation and drinking purpose in Kolhapur region of Maharashtra State. The study was conducted in accordance with standard procedures and guidelines. Overall outcome of the study revealed that ground water was predominantly slightly acidic in nature, with EC values indicating high salinity for all the samples. More than 90% samples recorded high TDS, but well below the maximum limit exhibiting high saline category for irrigation purpose. SAR index recorded values well below 10 indicating excellent water quality for irrigation application. Further, all water samples, except one, fell under Class I of Doneen's plot which indicates excellent water quality for irrigation purpose. Only 12.5% samples exceeded unity for Kelly's ratio whereas all other samples recorded less than unity, exhibiting suitability for the agricultural purpose. Wilcox diagram in the classification of EC revealed that 9 out of 16 samples fell under good to permissible class and remaining under doubtful to unsuitable class.

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