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Original Research Paper

Evaluation of Surface Water Quality and Its Suitability for Drinking and Agricultural Use in Jalgaon District, Maharashtra, India

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ABSTRACT

Only small amount of freshwater is available to us. Industrial, domestic and agricultural wastes are drained in surface water so the pollution of water increasing day by day. The present study area comes under semi arid climate zone. The physiography of study area is rugged and somewhere plain in central part. The area is covered by quaternary alluvial and underlain by Deccan basalt of cretaceous to eocene age. The area has major irrigation networks and water is used continuously for various purposes. The chemical quality of surface water is of great importance in determining the suitability of water for specific use. Surface water samples were collected from different irrigation projects for analysis and the parameters include pH, alkalinity, hardness, COD, BOD, TSS, chlorides, phosphate, nitrate, SAR, ESP, etc. It is observed that pH is significantly decreased with the increasing pollution load. Pollution load increases organic matter which is turn decreases DO and increases HCO_3^-. From the evaluation of carbonate hazards, it is clear that the surface water is safe from bicarbonate hazards and the water quality is suitable for Irrigation and domestic purposes.

INTRODUCTION

Of the total amount of global water only 2.4% is distributed on the main land of which only small portion can be utilized as freshwater (Kale 1995). The quality of water is of vital concern for mankind since it is directly linked with human welfare (Yogendra 2008). At present the dangers of waterborne diseases and epidemics still loom large on the horizons of developing countries, and polluted water is the culprit in all such cases (Nollet 2000). The major sources of water pollution are domestic wastes from urban and rural areas and industrial wastes, which are discharged into natural water bodies (Ahlawat & Kumar 2009).

The available freshwater to man is hardly 0.3-0.5 percent of the total water supply and therefore its judicious use is imperative (Jain 2011). Though lakes are the principal forms of inland standing surface waters, ponds and pools by their individual characteristics are also equally important to man, fish and water birds (Dixit et al. 2005). Growth in population and industries, and advanced agricultural practices have become a threat to these ecosystems which were once probably clean waters (Gupta 1989). Because of continuous usage of water of ponds and lakes, it has become necessary to evaluate the quality of surface water (Chhatwal et al. 1989). This study therefore attempts to evaluate the quality of surface water of Jalgaon district in Maharashtra State with respect to domestic and irrigational purposes.

STUDY AREA

Jalgaon district is situated in the east Khandesh district (subsequently known as a Jalgaon district) in northern part of Maharashtra state. The study area is entrapped between Satpuda and Ajanta Range, which lies between latitude 2°00’00" to 21°04’30" E and 75°41’00" to 75°50’00" N longitude. The study area comes under semiarid climatic zone. The Jalgaon district has average temperature of maximum 42.4°C to minimum 30.5°C. The high relative humidity values of 83.63% occur in rainy season. The average annual rainfall is around 670 mm.

Jalgaon district has major irrigation network with rivers Tapi, Purna, Bori, Girana and Waghur. Out of these networks Tapi is a major river which is flowing east to west direction, and all other rivers meet the Tapi at different places. From the last decade, the overexploitation of surface water for domestic and irrigation use is at peak level, and as a result the surface water and drinking water scarcity problems in this area are severe. The situation gets more paralysed, especially in the month of March to May. In the study area surface waters are polluted due to effluents from industries, washing, cattle, bathing and vehicle washing. Therefore, it is prime necessity to study the increasing deterioration of land and water pollution, and to suggest the control measures for irrigation and domestic water suitability.

Jalgaon urban centre is well surrounded by surface water reservoirs and lakes. Mehrun lake is 3 km from Jalgaon city in the south-east direction. Padmalay lake is situated near Erandol Taluka. Bahula project is situated in the Bahula River

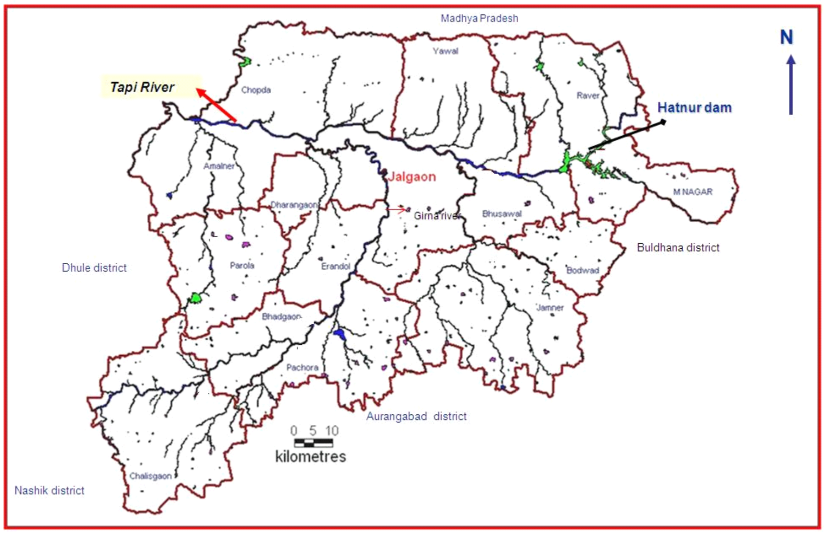

Fig.1: Map of study area.

near Pachora. Hiwara project is located in the southern part of Bahula project. Angawati is a medium project in the Pachora taluka. Manmad Dam is located in the south-west direction of the area, as shown in the Fig. 1.

Geology of the area: The area under the present investigation is covered by the Tapi-Purna alluvial, which is followed by Deccan basalts of cretaceous-eocene age. The entire area lies in region 1A. The Padmalay hill has best varieties of porphyritic basalt. The hydrothermal amygdaloidal basalts are exposed in some parts of the study area mainly at Amalner, Parola, Pachora and Erandol taluka places. On the north side of Tapi River there are thick layers of alluvial plains of more than 250 feet.

Compact basalt has prismatic joining in nature near the Pal in the Satpuda ranges. There are six lava flows which are recorded in the north eastern side of the Raver city. Some calcified soil also occurs in some patches towards the north side of the area.

MATERIALS AND METHODS

The field data were carried out from different irrigation projects in Jalgaon district. Surface water pilot study was carried out in order to achieve a clear knowledge of quality of surface water during the selection of sampling station. Care was taken to make sure that no other contaminant would interfere with the study.

For surface water quality monitoring, 25 representative sampling stations were selected in the present study area. Pre monsoon, post monsoon and winter sampling of surface water quality was carried out at each sampling location. The samples were collected in pre cleaned plastic cans of 1-L capacity. Samples were brought to the laboratory for the physico-chemical analysis. The surface water was analysed by the standard analytical procedures of APHA-AWWA-WPCF (2005) and Trivedy & Goel (1984). The parameters include pH, electrical conductivity, DO, organic matter, TDS, hardness, phosphate, nitrate, calcium, magnesium, sodium, potassium, sulphate, chloride, silica, carbonate and bicarbonate.

The water analysis data obtained in the present study have been utilized for understanding the suitability of water for the agricultural purposes. There are various parameters, which help in determining the quality of water for irrigation, such as sodium adsorption ratio (S.A.R.), Kelly's ratio (K.R.), residual sodium carbonate (R.S.C.), exchangeable sodium percentage (E.S.P.), soluble sodium percentage (S.S.P.), permeability index (P.I.) and sodium percentage (Na%) (U.S.D.A. 1954). All the concentrations are expressed in milliequivalent per litre (meq/L).

Sodium Adsorption Ratio (SAR): The sodium concentration is very important in classifying the irrigation water because sodium by the process of base exchange may replace calcium in the soil and thereby may reduce the permeability of soil to water, if this process continuous. It has an adverse effect on plant growth. The relativity at sodium ion in exchange reaction with soil is expressed in terms of ratio known as Sodium Adsorption Ratio. SAR is calculated by following formula:

$$SAR = \frac{Na}{\sqrt{\frac{Ca + Mg}{2}}}$$

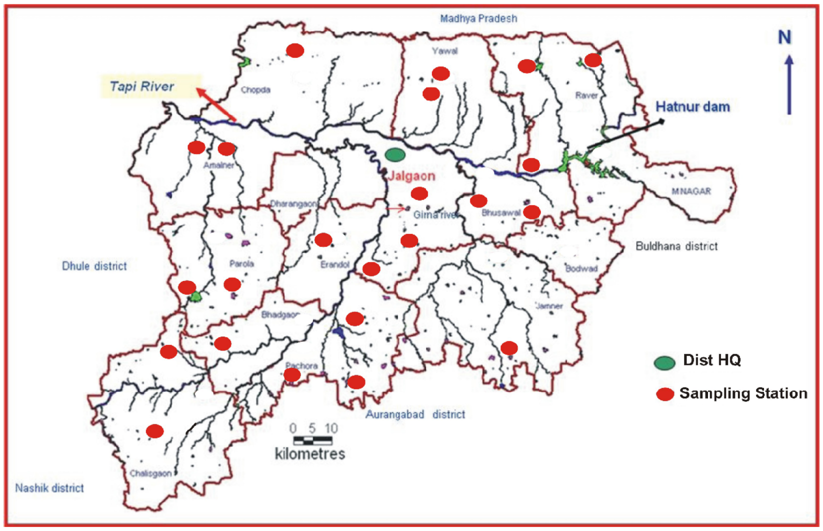

Fig.1: Location map of study area and sampling stations.

Kelly's Ratio (KR): Kelly's ratio represents the alkali hazards of water and it is calculated from the following formula.

$$K.R. = \frac{Na^{+}}{Ca^{2+} + Mg^{2+}}$$

If the Kelley's ratio is unity or less than one, it indicates that the water is good for irrigation (Karanath 1989).

Exchangeable Sodium Percentage (E.S.P.): The exchangeable sodium percentage is of the special interest in irrigation. Higher E.S.P. levels are generally associated with soils with slowly permeable nature, which causes major problem with the crop production (Mc Neal 1966). The E.S.P. is calculated by using the equation (U.S. Salinity Laboratory Staff 1954).

$$E.S.P. = \frac{100(-0.0126+0.01475 \times SAR)}{1+(0.0126+0.01475 \times SAR)}$$

Soluble Sodium Percentage (S.S.P.): Another parameter that has been taken into consideration for determination of quality of irrigation water is soluble sodium percentages (SSP). The SSP in water is calculated as follows.

$$S.S.P. = \frac{Na \times 100}{Ca + Mg + Na}$$

Values of S.S.P. less than 50 indicate good quantity of water and higher values show unsatisfactory quality of water (U.S. Salinity Laboratory Staff 1960).

Residual Sodium Carbonate (R.S.C.): The carbonate and bicarbonate hazards on water quality can be determined in terms of residual sodium carbonate which is defined by the following equation (Eaton 1950).

$$R.S.C. = (HCO_3^{-} + CO_3^{-2}) - (Ca^{2+} + Mg^{2+})$$

RESULTS AND DISCUSSION

In the present study atmospheric and water temperatures have shown similar gradients. Maximum temperature fluctuations occurred when the water table rises to the ground surface levels. In present study area the temperature of surface water ranges between 27°C and 32°C.

The physico-chemical characteristics of the surface waters are given in Table 1. It is observed that the pH values range from 7.4 to 8.4. Some of the reservoirs have very high pollution since they receive the sewage i.e., Meharun reservoir. So it is clear that pH is significantly decreased with the increasing pollution load. The electrical conductivity is the indicator of cations and anions in waters. In the present study, the electrical conductivity varied between 623 and 1105 micromhos/cm. Highest value was recorded in sample location Panzara with 1105 micromhos/cm, and lowest in sample location Vitner with 623 micromhos/cm.

The dissolved oxygen regulates the distribution of flora and fauna (Yogendra 2008). The present investigation indicated that the concentration of dissolved oxygen fluctuated between 3.2 and 5.0 mg/L.

The TDS values fluctuated between 65.9 and 718 mg/L. Lower values were recorded at station No. 1, 3, 4, 7 and 10 whereas high values were recorded at station No. 5 and 12 due to the presence of bicarbonates, sulphates and chlorides of calcium and magnesium. Natural hardness of water depends upon the geological nature of the drainage basin and mineral levels in natural water. The total hardness ranges from 102 to 384 mg/L. The lowest total hardness was in

Table 1: Physico-chemical characteristics of surface water.

Sr. No	Station	pH	EC	DO	CO_3	HCO_3	Cl	SO_4	NO_3	PO_4	Ca	Mg	Na	K	TDS	TH	SI
1	Meharun	7.4	639	3.5	11	210	72	11	25	0.03	81	68	5	01	415.35	230.2	22
2	Padmalya	8.1	982	4	10	310	90	08	26	0.40	49	15	18	01	338.3	184.07	21
3	Bahula	7.8	1003	3.2	15	270	108	07	18	0.73	69	28	19	02	63.9	287	13
4	Hiwara	8.0	932	4	18	310	80	09	14	0.68	28	08	14	01	605.8	102	16
5	Aganwati	8.4	861	5	19	210	103	19	16	0.70	60	18	16	01	559.6	233	12
6	Mangad	8.3	642	4.6	14	230	80	18	18	0.06	61	17	21	02	417	222	18
7	Jamda	8.3	789	4.6	21	310	81	21	30	0.08	79	22	19	01	512	287	28
8	Warkhedi	8.0	841	4	10	230	100	21	27	0.09	77	11	18	01	546	237	37
9	Dahigaon	8.3	912	4.3	08	260	80	16	30	0.17	71	35	22	01	542.8	321	25
10	Vitner	8.1	623	4.3	14	210	78	16	30	0.63	60	18	14	02	404.9	223	24
11	Shirsawani	7.9	824	3.6	14	240	60	17	30	0.54	55	19	13	01	535.6	215	24
12	Bori	8.0	731	4	08	260	81	16	32	0.83	43	23	19	01	475.15	202	28
13	Bhokarwari	8.4	908	4.5	06	260	60	07	39	0.92	47	22	28	01	590	207	25
14	Kakraj	8.1	1023	4	12	310	108	16	30	0.83	85	21	48	02	664	298	32
15	Panzara	8.0	1105	4	10	360	102	14	40	0.23	98	24	59	02	718	343	35
16	Patonda	8.2	902	4.3	14	270	82	26	26	0.09	79	26	17	01	586	304	26
17	Gul	7.9	616	3.9	08	270	42	22	25	0.06	80	28	21	01	530	314	26
18	Mangrul	8.3	732	5	08	220	81	06	30	0.13	65	30	29	03	475	285	32
19	Hatnur	8.3	945	3.7	10	260	62	16	50	0.73	71	19	33	01	614	255	32
20	Suki	8.4	832	4.6	08	210	81	12	26	0.84	87	18	14	02	540	291	26
21	Wadri	7.9	783	3.6	08	230	62	11	22	0.63	82	16	12	01	508	270	26
22	Waghur	8.3	854	4.3	08	270	41	14	30	0.72	85	17	21	01	551	282	35
23	Tondapur	7.9	989	3.9	10	210	36	12	32	0.32	78	25	10	02	642	297	32
24	Khandala	8.4	932	4.5	06	190	70	12	22	0.82	75	48	15	01	605	384	24
25	Mor	7.9	780	3.9	06	200	30	08	20	0.72	65	29	09	01	512	281	30

All the values are average of three samplings and expressed in mg/L expect pH, EC.

Hiwara reservoir (102 mg/L), while highest in Khandala reservoir (384mg/L). WHO (1971) and ISI (1983) give the maximum permissible hardness limit of 500 mg/L and 600 mg/L respectively (Patil et al. 2010). So the total hardness of the water samples of the reservoir is below the limit. The calcium values ranged between 28 and 98 mg/L. The magnesium values were in the range of 8 and 68 mg/L. The highest value of magnesium was recorded at Mehrun, while lowest value at Hiwara. The chloride content increases normally as the mineral content increases. The chloride level ranged between 30 and 108 mg/L. The highest value of chloride was recorded at Bahula and Kakraj, while lowest value was recorded at Mor. Two factors are responsible for the scarcity of potassium in groundwater, one being the resistance of potassium minerals to decomposition by weathering and the other is fixation of potassium in clay minerals formed due to weathering. The values of potassium varied from 0 to 3 mg/L. The highest value of potassium was found at Mangrul, while lowest value at Padmalay.

The characteristic ratios of the water samples are given in Table 2. It is evident that the water quality is, in general, good for irrigation purpose. The values of SAR vary from 0.022 to 0.060. The average Kelly's ratio is less than 1. The Na% is less than 15%. The ESP values are all negative varying between -13.79 and -14.79. The high values of ESP indicate that cations-anions of soil are not in steady state, which is due to concentration of salts by evaporation of water from plant root zones and selective precipitation of Ca, Mg salts during evaporation process.

Salinity hazard: The U.S. salinity laboratory staff has proposed the standard diagram for water quality classification, which takes in to account SAR and electrical conductivity of water to evaluate the inner relationship as shown in Fig. 2.

These data plotted on this diagram clearly indicate the classification of water for agricultural and irrigation purposes. In the diagram four classes C1, C2, C3 and C4 are used for salinity classification and S1-S4 for sodium classification.

The plot shows that surface water falls in the C3-S1 and C2-S1 class, which means that the water can be used for all types of irrigation.

Wilcox diagram: Wilcox (1995) has classified irrigation water on the basis of soluble sodium percentage (SSP) and electrical conductivity (EC). A better classification of irrigation water with respect to EC and SSP is obtained with the help of the Wilcox diagram (Fig. 3).

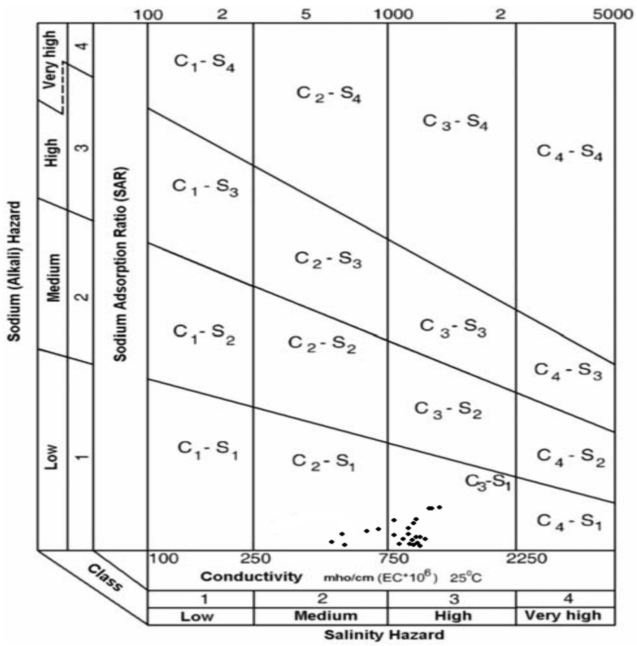

Fig. 2: Salinity hazard diagram.

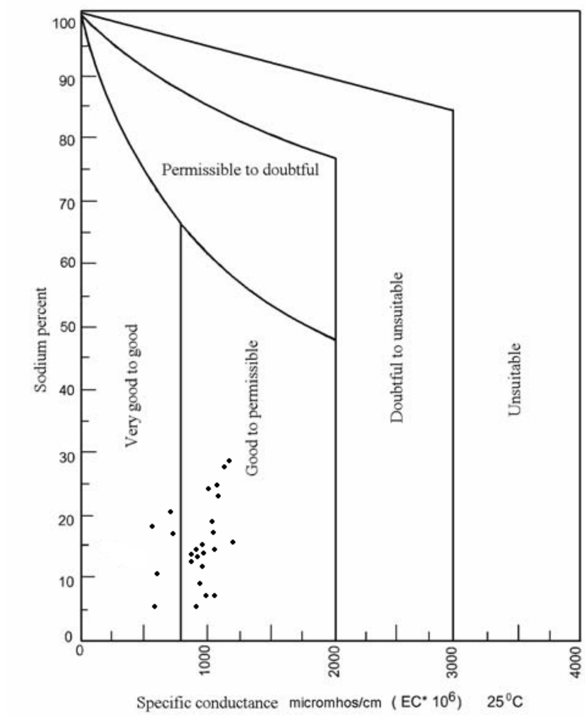

Fig. 3: Wilcox diagram.

Table 2: Indices of water samples characteristics ratios of study area.

Sr. No	Station	SAR	K.R.	E.S.P.	S.S.P.	% Na	R.S.C.
1	Meharun	0.145	0.048	101.067	0.046	5.077	- 0.88
2	Padmalya	0.463	0.137	100.586	0.121	12.243	- 0.274
3	Bahula	0.489	0.145	100.547	0.126	13.30	- 0.818
4	Hiwara	0.603	0.298	100.375	0.230	23.696	3.632
5	Aganwati	0.462	0.154	100.587	0.132	13.806	- 0.399
6	Mangad	0.611	0.205	100.363	0.170	17.155	2.059
7	Jamda	0.489	0.144	100.547	0.126	12.96	0.031
8	Warkhedi	1.282	0.164	99.366	0.141	14.52	- 0.646
9	Dahigaon	0.535	0.150	100.477	0.130	13.317	- 0.1887
10	Vitner	0.408	0.136	100.67	0.120	12.882	- 0.569
11	Shirsawani	0.382	0.130	100.708	0.115	11.986	0.09
12	Bori	0.585	0.206	100.402	0.171	17.516	0.49
13	Bhokarwari	0.849	0.293	100.012	0.227	23.053	0.302
14	Kakraj	1.204	0.349	99.48	0.258	26.325	- 0.487
15	Panzara	1382	0.373	99.219	0.272	27.557	- 0.634
16	Patonda	0.424	0.122	100.645	0.108	11.19	- 1.183
17	Gul	0.513	0.145	100.510	0.126	12.95	- 1.608
18	Mangrul	0.734	0.217	100.179	0.178	18.74	- 1.842
19	Hatnur	0.895	0.28	99.939	0.219	22.2	- 0.512
20	Suki	0.357	0.15	100.746	0.095	10.19	- 2.119
21	Wadri	0.316	0.096	99.22	0.088	9.17	- 1.377
22	Waghur	0.542	0.161	100.467	0.139	14.23	- 0.953
23	Tondapur	0.249	0.072	100909	0.067	7.484	- 2.175
24	Khandala	0.332	0.085	100784	0.078	8.083	- 4.353
25	More	0.232	0.069	100.935	0.065	6.886	- 2.127

All values are in epm

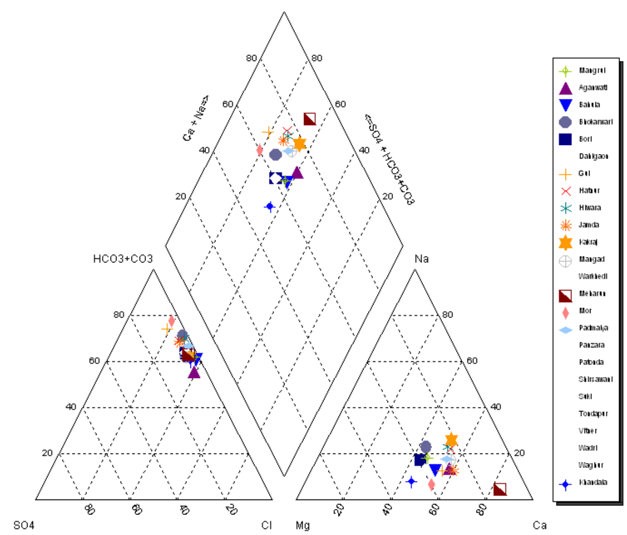

Fig. 4: Piper trilinear diagram.

The various types of water samples from the area plotted on the Wilcox diagram indicate that the waters fall into the classification "Very Good to Good" and "Good to Permissible" (Fig. 3). Thus, these waters can easily be used for irrigation.

Piper trilinear diagram: Piper (1953) diagram uses a multiple trilinear plot to depict the water analysis and this quaternary diagram shows the chemical composition of water

Table 3: Inter elemental coefficient correlation matrix of water samples.

Parameters	pH	EC	DO	CO_3	HCO_3	Cl	SO_4	NO_3	PO_4	Ca^{2+}	Mg^{2+}	Na^+	K^+	TDS	TH	SI
pH	1.00															
EC	0.17	1.00														
DO	0.80	-0.16	1.00													
CO_3	-0.01	0.01	0.09	1.00												
HCO_3	0.00	0.50	-0.17	0.27	1.00											
Cl	0.12	0.31	0.13	0.45	0.36	1.00										
SO_4	0.15	-0.21	0.15	0.36	0.11	0.12	1.00									
NO_3	0.18	0.25	-0.06	-0.32	0.27	-0.13	0.07	1.00								
PO_4	0.24	0.30	-0.06	-0.19	-0.11	-0.05	-0.42	0.04	1.00							
Ca^{2+}	-0.06	0.12	-0.07	-0.20	0.02	-0.01	0.29	0.23	-0.29	1.00						
Mg^{2+}	0.34	0.19	0.22	-0.37	-0.16	-0.14	-0.04	0.06	0.08	0.19	1.00					
Na^+	0.25	0.49	0.09	-0.08	0.66	0.41	0.05	0.54	0.02	0.31	0.14	1.00				
K^+	0.08	0.03	0.23	-0.01	-0.05	0.27	-0.29	0.06	-0.10	0.21	0.13	0.36	1.00			
TDS	0.30	0.27	0.29	-0.17	0.14	-0.22	0.29	0.39	0.03	0.23	0.07	0.38	-0.15	1.00		
TH	0.17	0.20	0.10	-0.35	-0.09	-0.08	0.18	0.19	-0.15	0.80	0.74	0.29	0.22	0.21	1.00	
SI	0.04	0.12	-0.01	-0.50	0.12	-0.28	0.14	0.64	-0.14	0.51	0.09	0.40	0.12	0.53	0.39	1.00

in terms of cations and anions (Fig. 4).

From the Piper trilinear diagram, it is evident that 19 samples show (Ca + Mg) cation facies and 2 well samples show (Na + K) anion facies. Further, it is observed that 18 samples show ($Cl + SO_4$) facies and only one shows (CO_3 + NO_3) anion facies.

The correlation coefficient matrix of average values of physico-chemical parameters of surface water samples is given in Table 3. The correlation matrix indicates that almost all the analysed parameters are negatively and positively correlated. The concentration of the nutrients like PO_4, SO_4, NO_3, and Cl, Na, K, Mg are negatively correlated to each other. TH shows the negative correlation with most of parameters like Cl, PO_4, CO_3 and HCO_3. This indicates that the presence of Ca in water is in less soluble forms, more likely in the form of carbonate, which indicates high values of hardness in water samples (Ravindra & Kaushik 2003). DO shows a significantly positive correlation with Cl, SO_4, Mg, Na, K, which indicates that there will be contamination of sewage water in the surface water resources in the study area. In this case the DO values show the strong correlation with chlorides and pH which may indicate the strong source of sewage water in the surface waters in the study area.

CONCLUSION

The results of the study show that the surface water of the study area is somewhat suitable for the both domestic and irrigation purposes. Very few of the reservoirs are significantly contaminated having some problems regarding irrigation and domestic purposes. The concentration and composition of dissolved constituents in water determine its quality for irrigation. Quality of water is an important consideration in an appraisal of salinity or alkali condition in an irrigated area.

Amongst cations, sodium dominated in of the reservoirs, and amongst anions, bicarbonate dominated in most of the reservoirs. Not many open reservoir waters in Jalgaon district are used for irrigation, washing and bathing. Most of the reservoirs are constructed for the conservation of ground water. Some of the reservoirs have very high degree of pollution since they receive sewage, i.e., Meharun reservoir. Pollution load increases organic matter which is turn decreases DO and increases HCO_3^-. From the evaluation of salinity and sodium hazard, it is clear that the surface water is less than unity so it is suitable for irrigation and free from salinity hazards. From the evaluation of carbonate hazards, it is clear that the surface water is safe from bicarbonate hazards.

The water contamination is harmful for the human beings and soil quality. The water of this region requires remediation and regular monitoring. The preventive measure of the contaminated reservoirs is necessary.

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