International Journal for Multidisciplinary Research (IJFMR)
E-ISSN: 2582-2160 ● Website: www.ijfmr.com ● Email: editor@ijfmr.com

Assessment Of Selected Ground Samples Around A Sugar Factory, Shirol, Maharashtra, India

Ashwamegh Babaso Palakhe[1], Pratik shantinath Patil[2], Hrutvik Rajaram Shendge[3], Pratik Satish Shingade[4]

[1,2,3,4]B. Tech in Civil Engineering, Sharad Institute of Technology College of Engineering

Abstract
Ground water quality surrounding a sugar factory was studied for the impact of effluent discharged by the industry by applying multivariate statistical techniques. Although the samples recorded the EC values well within the permissible range and a close assessment of the analysis and the evaluated statistical approach disclosed that the overall quality of ground water was suitable for domestic purpose. Concentrations of cations Na^+, K^+, Ca^+, and Mg^+ varied from 67 to 43, 2.2 to 1.1, 70 to 106, and 25 to 37 ppm, respectively. Na^+, Ca^{2+}, Mg^{2+}, and K^+ were major cations in chronological order accompanied by HCO_3^-, Cl^-, and SO_4^{2-} for the major anions. Na^+ was the most widespread cation and K^+ was the lowest abundant, whereas bicarbonates were the most common and SO_4 was the least significant cation under anions. More than 95% of the samples fall under Doneen's Class I category, and every sample demonstrated SAR values below 10, which indicated high suitability for applying water domestic as well as for crops.

Keywords: Agglomerative hierarchical cluster analysis; Dindrogram; SAR index; Magnesium hazard; Kelly's Ratio; Doneen's chart

List of notations:
µs/cm is the microsiemens per centimetre
mg/L is the milligram per litre
TH is the Total Hardness
KR is the Kelly's Ratio/ index
MAR is the Magnesium Adsorption Ratio
RSBC is the Residual Sodium Bicarbonates
IWQ is the Irrigation Water Qualit

1. Introduction
One of the most essential elements of human existence is water. The development and sustainability of ecosystems depend heavily on the availability of water. Given the scarcity of surface water, groundwater is used as a backup source for surface water in the majority of India. It is regarded as a trustworthy alternative source for industrial, domestic, and agricultural activities in arid and semi-arid regions. Interactions between groundwater and the mineral properties of the aquifer the water flows through have always been the source of variations in groundwater chemistry. The sources' groundwater chemistry

variation is investigated, categorized, and assessed using a variety of techniques. Among the techniques that reveal the condition of water are the geo-statistical techniques, multivariate statistical methods, and the water quality index.

Aquifer boundaries, groundwater flow paths, and hydrochemical parameters can all be resolved using multivariate statistical techniques, factor analysis, and hierarchical cluster analysis (Qualid et al., 2019; Wang et al., 2001; Locsey and Cox, 2003; Belkhiri et al., 2011; Mostafaei, 2014; Mohamed et al., 2015; Teikeu et al., 2015). According to Love et al. (2004), these instruments are also employed in the distinction between uncontaminated groundwater, mining, sewage pollution, and agricultural practices. HCA was also widely used as an efficient multivariate statistical tool for classification of water and to create geochemical models based on the available data on factor scores (Meng and Maynard, 2001). The parameters that are chemical and physical can also be assessed by contrasting the global permissible limits to ascertain the groundwater quality (WHO 2011; Ayers and Westcot 1994). One of the best and most efficient ways to convey the quality of groundwater for drinking and irrigation is through the use of the water quality index. It is among the best techniques for condensing and presenting data on water quality (Tiri et al. 2018).

The present study prioritizes the use of the water quality index and multivariate statistical analysis of ground water chemistry data for the purpose of classifying ground water with an emphasis on domestic use.

Study Area:

The selected study area is situated in Shirol, a village in the state of Maharshtra, India which is a sugar industry with a crushing capacity of 3000 TPD. Effluent released from the process is treated and discharged. The study area lies between latitudes 16.69 and 16.67 N and 74.46 and 74.47 E. Additionally, it is beneath the Deccan Trap, a geological formation that dates from the Upper Cretaceous to the Lower Eocene. Location of the sugar factory is presented in Fig.1.

Four ground water samples, all from bore-wells were collected during the year 2023–24 to assess the ground water quality for domestic and agricultural use, as shown in Fig. 1. Although surface water source is available, river Panchaganga is 2 km away from the village.

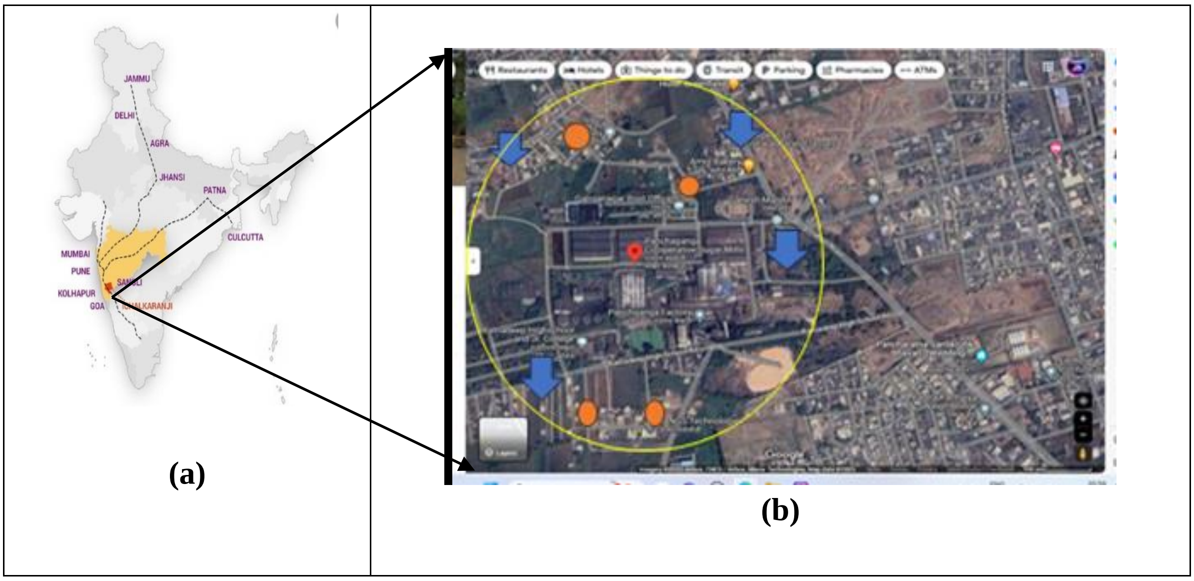

Fig.1: (a) Location of Ichalkarnji. b) Sugar factory

2. Materials and Methods

In order to collect the samples from the location clean polythene bottles of 2 liters' capacity were used. Bore-well depth varied from 20 to 30 meters. With a multi-parameter monitoring device, pH,, EC, and TDS were measured in situ, and the DO was fixed at the site. With the exception of Na and K, which were obtained using a flame photometer, all other parameter values were recorded by titration and the procedures as in Standard Methods for the Examination of Water and Wastewater, APHA were followed.

3.1 Water Quality Assessment

Water quality for irrigation is based on a relationship between the four components that comprise the IWQ parameters, which are linked to form a single index value for assessing the suitability of water for irrigation in the study area. The four components are permeability hazards, specific ion toxicity, salinity uncertainty, and other i impacts as per Ayers and Westcot (1985). imsek and Gunduz's (2007) assessment and methodologies for the IWQI were adjusted. From the lowest (1) to the highest (4) points in the technique, all parameters were fixed utilizing the weight coefficient. The salinity hazard is the highest priority factor in the assessment of the IWQ, whereas other effects on sensitive crops are the least significant components. The other two factors, which are listed in decreasing order of importance for irrigation water quality, are permeability threat and specific ion toxicity.

3.2 Water Quality Parameters:

Equations 1 to 7 were being used to find the values for irrigation water quality.

Sodium Adsorption Ratio: Eq. 1 represents SAR as per the US Salinity Laboratory (Richards, 1954). Higher SAR values in the water increase the risk of Na+, which leads to the development of alkaline soil that is unfriendly to crop production.

$$SAR = \frac{Na^+}{\sqrt{(Ca^{2+}Mg^{2+})/2}} \qquad (1)$$

Residual Sodium Bicarbonate: This is calculated using Eq. (2) (Gupta 1983).

$$RSBC = HCO_3^- - Ca^{2+} \qquad (2)$$

Magnesium hazard: This is Magnesium Adsorption Ratio (MAR) (Raghunath 1990) which is calculated by Eq. (3)

$$MAR = \frac{Mg^{2+}}{Ca^{2+} + Mg^{2+}} \times 100 \qquad (3)$$

Kelley's Ratio: Kelly's ratio is obtained by using Eq. (4) (Kelley 1963), as below:

$$KR = \frac{Na^+}{Ca^{2+}Mg^{2+}} \qquad (4)$$

Total Hardness: Total hardness (TH) in milligrams per liter is estimated using Eq. (5) *(Todd 1980; Raghunath 1987)*.

$$TH = 2.497\ Ca^{2+} + 4.11\ Mg^{2+} \qquad (5)$$

Percentage of Sodium: Sodium concentration in irrigation water is generally denoted by percentage sodium, i.e. Na%. Concentration of Na% can be found by using Eq. (6) (Todd 1980).

$$Na\% = \frac{Na^+}{Na^+ + Ca^+ + Mg^+} \times 100 \qquad (6)$$

Permeability Index: WHO (2004) and Doneen (1964) developed a criterion to test the suitability of groundwater for irrigational uses based on soil permeability, which is influenced by the presence of cations and anions in irrigation water. The permeability index (PI) has been characterized by the authors as follows:

$$PI = \frac{Na^{+} + \sqrt{HCO_3^{-}}}{Ca^{+} + Mg^{+} + Na^{+}} \times 100 \qquad (7)$$

3.

4. Results and discussions:

Characterization of Ground water:

The general quality of ground water for the study area is represented by the physicochemical parameters as presented in Table 1. pH values varied from 7.2 to 7.5, with an average value of 7.4, indicating a normal range of values. Values higher than the permissible value of 8.5 indicate carbonate content in the bedrock.

Table 1: Recorded concentrations of parameters for the collected samples in the study area.

SAMPLE NO	pH	EC μs/cm	TH	T. Alk	TDS	Ca	Mg	Na	K	$HC0_3$	Cl^-	DO
BW1	7.4	1200	165	230	960	96.8	36.5	58	2	296	124	6.4
BW2	7.5	980	139	265	740	74.8	27	46	1.4	220	86	6.8
BW3	7.5	1120	175	185	840	71	26	44	1.3	280	71	6.2
BW4	7.2	1490	122	210	1210	106	35	66	2.1	320	106	6.6

Note: BW – Bore-well sample.

Electrical conductivity for the samples varied from 980 μs/cm to 1490 μs/cm, with an average value of 1197.5 μs/cm, which is close to BIS standards of 1500 μs/cm. TDS ranged from 740 ppm to 1210 ppm, with an average of 937.5 ppm. Ground water in the study area may be classified as brackish water with a TDS > 1000 ppm (Selvam et al., 2013). However, in the present study no sample recorded more than 1000 ppm, except at BW4. Hence all bore-wells appeared to be safe except BW4. N, K, Ca, and Mg cation concentrations varied from 44 to 66, 1.3 to 2.1, 71 to 106, and 26 to 36.5 ppm, respectively, with mean values of 53.5, 1.7, 87.15, and 31.13 ppm as presented in Table 1. Dissolved anions' (Cl^-, and HCO_3) concentration varied from 71 to 124 and 220 to 320 ppm, with average recorded concentrations of 96.75 ppm and 279 ppm respectively (Table 1). Major cations in chronological order were $Ca^{2+} > Na^{2+} > Mg^{2+} > K^+$, whereas major anions were $HCO_3^- > Cl^-$. Ca^+ is the most prevalent and K^+ is the least relevant cation, whereas bicarbonates are the most widespread and Cl^- is the least major cation under anions. Further, dissolution of carbonate minerals was suggested with high concentrations of HCO_3^- and Ca^{2+} ions (Safiur et al., 2017)

Ground water quality assessment: WQI is an important index to find the suitability of ground water for human consumption and agricultural use (Avvannavar & Shrihari, 2008; Mishra & Patel, 2001). The

WQI was determined based on the weight values of the groups. This study to assess the water quality for domestic and agriculture purpose is presented graphically in Fig. 2 for WQI variations among the sampling points. Ground water was classified into three classes, i.e., low, medium, and high suitability water, based on the WQI (Simsek and Gunduz, 2007), as shown in Table 2. Present study revealed that all of the groundwater samples recorded as suitable for domestic and agriculture purpose. WQI values more than 25 were not observed in any location, whereas medium suitability was found at the BW2 location and the rest of the locations were found to be of high suitability. This clearly demonstrated that 100% of ground water in the study region was classified as having high suitability for domestic and agriculture (Table 2, GW classification). Utilization of the ground water for all the bore-wells can be done safely.

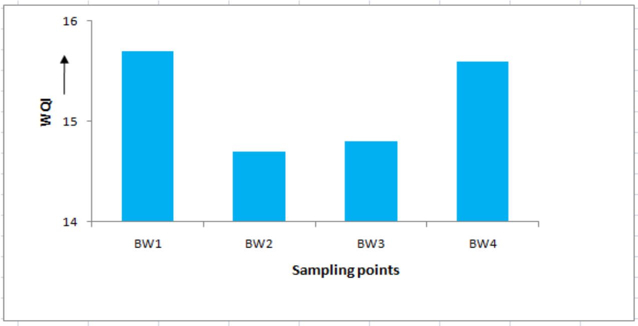

Fig. 2: WQI variation among the sampling locations.

Table 2: Calculated values of different indices.

Sample	Na%	SAR	KR	MAR%
BW1	26.07	1.43	0.042	35.85
BW2	25.79	1.40	0.042	35.42
BW3	26.07	1.41	0.042	33.88
BW4	26.07	1.43	0.042	35.84

Table 2: Classification of Ground water quality

Index Method	Reference	Range	Class of water	No. of locations	% of samples
Na%	Ramesh & Elango 2012	< 20	Excellent	0	0
		20 - 40	Good	4	100
		> 40 - 60	Permissible	0	0
		> 60 - 80	Doubtful	-	
		> 80	Unsuitable	-	
EC (µs/cm)	Wilcox, 1948	< 250	Excellent (C1)	0	0
		250 - 750	Good (C2)	1	25
		750 - 2250	Fair (C3)	3	75
		> 2250	Poor (C4)	-	-
SAR	Todd, 1980	< 10	Excellent (S1)	4	100

		10 - 18	Good (S2)		
		> 18 - 26	Fair (S3)		
		> 26	Poor (S4)		
TH (ppm)	Swayer and McCarthy, 1967	< 75	Soft	0	0
		75 - 150	Moderately Hard	4	100
		150 - 300	Hard	0	0
		> 300	Very Hard	-	-
KR	Kelly, 1963	< 1	Excellent	4	100
		> 1	Excess level of Na^+ in water	-	-
MAR	Gupta and Gupta, 1987	< 50	Excellent	4	100
		> 50	Harmful to soil	-	-
WQI	Brown *et.al*, 1972	0 - 25	Excellent	4	100
		26 -50	Good		
		51 - 75	Poor		
		76 - 100	Very poor		
		> 100	Unfit for consumption		

Electrical Conductivity and sodium content are the prime factors for IWQ classification. The growth of plants is restricted by the excess concentration of sodium and high values of EC as the soil becomes hard. It also affects the structure, texture, and permeability of the soil (Trivedy and Geol 1984). A high concentration of salt in irrigation water can also result in osmotic pressure in the soil (Thorne and Peterson, 1954). Further, High Na^+ content in water increases the Na^+ content of the cropland, adversely affecting the soil permeability and resulting in the soil becoming inapt for seed germination (Jeevanandam et al., 2012). The values of EC under the present study of ground water samples fall under the C3, i.e., the fair (85.7%) to poor category (14.3%) for irrigation purposes (Table 2). The variation in Na% was found to be from 21.11% to 53.86%, with a mean value of 36.49%. As per the classification of ground water based on Na% (Table 2), 64.3% agreed to the good category, while the rest, i.e., 35.7%, fell under the permissible category. Lole et al. (2018) and Wagh (2014) also arrived at similar groundwater quality around the Ichalkaranji area.

Another important groundwater quality assessment index is the SAR, which is the measure of sodium or alkali hazards to crops (Todd, 1980). High SAR values indicate Ca^{2+} or Mg^{2+} substitution for Na^+ in soil through the cation exchange process. Soil permeability is reduced, and air and water circulation are restricted in the soil due to this exchange process. SAR values calculated for the samples in the study area recorded around 1.4 for all samples, indicating high suitability for domestic and agriculture purpose.

Generally, calcium and magnesium ions in ground water exhibit a state of equilibrium (Raju *et al*., 2011). The presence of a higher concentration of Mg^{2+} in groundwater results in alkaline irrigation soil, which adversely affects the crop yielding capacity of the soil. Values greater than 50% MAR are considered harmful for irrigation (Gupta and Gupta, 1987; Raghunath, 1990). The present study revealed that 35.7% of samples showed 'excellent' application for irrigation, whereas 64.3% samples were in the harmful' group (Table 2). Hence, the ground water falling under this must be used with caution for irrigation purposes. The study indicated Na^+**:**Ca^+ and Mg+:Ca+ values less than the maximum value of 3, as shown in Table 3. Values for Na^+**:**Ca^+ varied from 0.85 to 2.885, with an average of 1.565, and for Mg+:Ca+ values were 4.42 to 1.37, with an average of 0.79, as represented in Fig. 2b with a whisker plot.

5. Conclusion

Different available water quality indices and statistical methods were used to explore the groundwater's suitability for agricultural purposes in the Ichalkaranji area. The order of abundance of major ions in the samples was HCO_3^- > Cl^- > and for cations, it was Ca^{2+} > Na^{2+} > Mg^{2+} > K^+. As observed from WQI, all 100% of the samples belonged to the high-suitability water category for domestic and agricultural purposes. Results of the EC, Na%, and SAR index displayed that the majority of the ground water was in the good to acceptable' class for agricultural use, as was evident from the Whiskar plot, trilinear, and water classification charts. Interpretation of the samples based on MAR, KR, TH, and RSBC exhibited that more than 90% of groundwater samples were classified as 'safe' for agricultural use. An overall conclusion can be drawn that the decision-makers can safely suggest the use of groundwater for agriculture and domestic purposes to maintain the existing fertility and increase crop yield.

References:

1. Ayers, R.S., & Westcot, D.W. (1985). Water quality for agriculture,FAO Irrigation and Drainage Paper 29, Rev. I, UN Food and Agriculture Organization, Rome.
2. Ayers RS, Westcot DW (1994) Food, Agriculture Organization of the United Nations (FAO), water quality for agriculture, irrigation and drainage, Rome, Paper No. 29. Rev1, M-56. ISBN 92-5-102263-1
3. Avvannavar, S.M., & Shrihari, S. (2008). Evaluation of water quality index for drinking purposes for river Netravathi, Mangalore, South India. *Environmental Monitoring and*
4. Belkhiri L, Boudoukha A, Mouni L, Baouz T (2011) Statistical categorization geochemical modeling of groundwater in Ain Azel plain (Algeria). J Afr Earth Sci 59:140–148 *Assessment, 143*(1–3), 279–290.
5. Eaton, F.M. (1950). Significance of carbonate in irrigation water. *Soil Science, 69*(2), 123–133.
6. Gupta, S. K. (1983). Variations of water table in Yamuna drainage basin of Haryana-implications andmanagement strategies. In Seminar on Strategies for Irrigation Water Management, Patna Google Scholar.
7. Gupta, S. K., & Gupta, I. C. (1987). Management of saline soils and waters. New Delhi: Oxford and IBH Publishing Company.

8. Jeevanandam, M., Senthilkumar, M., Nagarajan, R.,Srinivasalu, S., Manikandan, M., & Prasanna, M.V. (2012). Hydrogeochemistry and microbial contamination of groundwater from Lower Ponnaiyar Basin, Cuddalore District, Tamil Nadu, India. *Environmental Earth Sciences, 67*, 867–887.
9. Kelley, W. P. (1963). Use of saline irrigation water. Soil Science,95, 355–391.
10. Locsey KL, Cox ME (2003) Statistical and hydrochemical methods to compare basalt and basement rock-hosted groundwaters: Atheron Tablelands, northeastern Australia. Environ Geol 43(6):698–713.
11. Lole A.A., Bharamgunde S.S., Adam V.S., Bankar D.B., Patil V.V., 'Effect of Industrial Effluent on Groundwater: A Case Study of Kala Nala, Ichalkaranji, Kolhapur,
12. Maharashtra, India 'International Journal for Research in Applied Science & Engineering Technology, Volume 6 Issue IV, April 2018.
13. Love D, Hallbauer D, Amos A, Hranova R (2004) Factor analysis as a tool in roundwater quality management: two Southern African case studies. PhysChem Earth 29(15–18):1135–1143
14. Meng SX, Maynard JB (2001) Use of statistical analysis to formulate conceptual models of geochemical behavior: water chemical data from the Botucatu aquifer in Sa˜o Paulo state. Braz J Hydrol 250:78–97.
15. Mohamed I, Othman F, Ibrahim AIN, Alaa-Eldin ME, Yunus RM (2015) Assessment of water quality parameters using multivariate analysis for Klang River basin, Malaysia. Environ Monit Assess 187:4182
16. Mostafaei A (2014) Application of multivariate statistical methods and water quality index to evaluation of water quality in the Kashkan River. Environ Manag 53:865–881
17. Oualid Bouteraa1, Azeddine Mebarki, Foued Bouaicha1, Zeineddine Nouaceur, Benoit Laignel, "Groundwater quality assessment using multivariate analysis, geostatistical modeling, and water quality index (WQI): a case of study in the Boumerzoug-El Khroub valley of Northeast Algeria", Jr. of Acta Geochim (2019) 38(6):796–814.
18. Raghunath, H. M. (1990). Ground water. Wiley eastern limited (2nd ed.p. 563). New Delhi.
19. Raju, N.J., Shukla, U.K., & Ram, P. (2011). Hydrogeochemistry for the assessment of groundwater quality in Varanasi: a fast-urbanizing center in Uttar Pradesh, India.
20. *Environmental Monitoring and Assessment*, *173*, 279–300. 1387-6
21. Richards, L.A. (1954). Diagnosis and improvement of saline and alkaline soils, US Salinity Laboratory, US Department of Agriculture Hand Book, pp 60.
22. Safiur R M., Narottam Saha, Towfiqul A.R.M., Shuanghe Shen, Bodrud-Doza, 2017, 'Evaluation of Water Quality for Sustainable Agriculture in Bangladesh', Springer International Publishing AG 2017.
23. Selvam S, Manimaran G., Poovalingam S. 'GIS-based Evaluation of Water Quality Index of groundwater resources around Tuticorin coastal city, south India', Jr. of Environmental Earth Sciences, Jul., 2013.
24. Simsek, C., & Gunduz, O. (2007). IWQ index: a GIS-integrated technique to assess irrigation water quality. Environmental Monitoring and Assessment, 128, 277–300.
25. Srinivasamoorthy, K., Gopinath, M., Chidambaram, S.,Vasanthavigar, M., & Sarma, V.S. (2014). Hydrochemical characterization and quality appraisal of groundwaterfrom Pungar sub basin, Tamilnadu, India. *Journal of King Saud University - Science, 26*, 37–52.

26. Teikeu WA, Meli'i JL, Nouck PN, Tabod CT, Nyam FEA, Aretouyap Z (2015) Assessment of groundwater quality in Yaounde´ area, Cameroon, using geostatistical and statistical approaches. Environ Earth Sci. https://doi.org/10.1007/s12665-015-4779-7
27. Tiri A, Belkhiri L, Mouni L (2018) Evaluation of surface water quality for drinking purposes using fuzzy inference system.Groundw Sustain Dev 6:235–244
28. Thorne, D.W., & Peterson, H. B. (1954). Irrigated soils. London: Constable and Company.
29. Todd, D. K. (1980). Groundwater hydrology (2nd ed.). New York:Wiley.
30. Trivedy, R. K., & Geol, P. K. (1984). Chemical and biological methods for water pollution studies. Karad: Environ Publications.
31. Wagh C.H.,' To Study the Groundwater Quality this is affected Due to Industrial Area (Ichalkaranji-Kolhapur)', International Journal of Science and Research (IJSR) Volume 3 Issue 7, July 2014
32. WHO (2011) Guidelines for drinking-water quality, 4th edn. World Health Organization, Geneva
33. Wang Y, Ma T, Luo Z (2001) Geostatistical and geochemical analysis of surface water leakage into groundwater on regional scale: a case study in the Liulin karst system, northwestern China. J Hydrol 246(1–4):223–234.