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Hydrochemistry and Quality Assessment of Ground water in Mann River Basin, Maharashtra, India

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Abstract

As the environmental problems are getting more serious day by day in different parts of the world, now a days, the problems of water quality have become more serious than the quantity. Many factors like soil, sewage disposal, effluents, geology and other environmental conditions in which the water tends to stay or move and interact with ground and biological characteristics greatly affects the groundwater quality of an area. The Mann river falls in Buldana and Akola district of Maharashtra, India. The study area falls under the tropical climate. It has high temperature in summer and very cold in winter. The mean annual rainfall is 625 mm. The major sources of water supply in the study area for drinking and industrial uses are surface water bodies and groundwater. In present situation, groundwater (wells and hand pumps) is the major source of irrigation. In present study, assessment of groundwater quality and hydro chemical evolution of groundwater has been taken into consideration. Hydrochemistry has been studied based on concentrations of Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, Cl^{-}, SO_4^{2-}, CO_3^{2-} and HCO_3^{-}. Sodium Adsorption Ratio (SAR), percent sodium (% Na), Permeability Index (PI), pH, Total Dissolved Solids (TDS), Total Hardness (TH) and trilinear diagrams have been studied. SAR value ranges from 6.78 mg/L – 30.32 mg/L. Percent sodium value ranges from 67.76 – 96.88%. Permeability Index ranges from 31.46 – 98.78%. pH values ranges from 7.67 – 8.73. The value of hardness ranges from 84 – 1113. Na and PI results indicate that the groundwater in the basin is suitable for irrigation use. Therefore, the present study concludes that the groundwater in the basin is of moderate to good quality and is suitable for uses.

Key words: Hydrochemistry, Groundwater, Sodium Adsorbtion Ratio (SAR), Total Dissolved Solids (TDS), Permeability Index (PI)

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1. Introduction

Earth is called as blue planet as it contain about 79% of water. Out of these resources much of water is saline and locked into huge glaciers. Therefore less than 1% water is only available to meet the agricultural, industrial and household requirements. Therefore it become quite eventual to preserve the quality and quantity of the valuable natural resource.[1-4]Groundwater is the main source of water which generally utilized to fulfill the said requirements.[5] The nature of rocks and their water preserving properties decides the availability of ground water. Worldwide, many workers have concentrated over groundwater and drainage morphometric analysis.[6-9] Groundwater is supposed to be a supportive function of human health, socio-economic development and positive growth of ecosystems.[10,11] In order to disclose the hydrochemistry of ground water, relevant factors such as mapping and structural interpretation,[12-14] lithostratigraphical study,[15] identification of unstable zone,[16] tectonics net erosion rate, land use/land cover change detection, etc are at the shoot end of geoscientists.[17] Anthropogenic activities are responsible for small to large scale changes on the hydrological cycle.[18] Agricultural production and standard of human health are the promoted factors by the importance of quality of water. The overexplotation of ground water is reflected through the detrimental affection of quality and quantity of the valuable universal solvent. Residential, municipal, commercial, industrial and agricultural activities are also responsible to play the role in affecting the groundwater quality.[19] Water quality data is utilized in the present study to analyze the chemistry of ground water. Hydro geochemical data are used in the analysis of Electrical Conductivity (EC), Total Dissolved Solids (TDS), Total Hardness (TH) and Sodium Adsorption Ratio (SAR), Percent sodium and Permeability Index (PI).

2. Materials and Methods

Study area

Mann river basin falls in Buldana and Akola district of Maharashtra, India. **(Fig. 1)**. It has tropical climate, high temperatures in summer and very cold in winters. The summers have a mean maximum of 43 ^{o}C and a mean minimum of 27.8 ^{o}C, while the winter mean maximum is 19.3^{o}C and the mean minimum is 9.3 ^{o}C. Monsoon arrives in the month of July heralded by thunderstorms. It annually receives around 713 mm of rainfall. This scanty amount of rainfall makes more humid. The humidity reaches to the extent of 87 percent during the month of monsoons.The Mann river originating from the Satpuda hills (about 45 kms from Buldana). Eleven types of geologic lithology namely, (1) biotite schist and calc biotite schist, (2) biotite schist and calc schist, (3) biotite schist and gneiss, (4) calc silicate rocks, (5) chloritic phyllites, (6) epiclastic conglomerate, (7) feldspathic schist, (8) hornblende schist, (9) meta siltstone and phyllite, (10) pegmatite (11)composite gneisses are found in the study area **(Fig. 2)**. Study of the lithofacies and bedding characteristics and groundwater of Akola and Buldana area, Maharashtra has been carried out. These litho units are moderate to highly hard. Gneiss is dark colored, medium to coarse grained rocks. Schist litho units are hard and compact,fine to medium grained and characterized by alternating bands of light and dark colored ferromagnesian minerals. Granite is grey colored, medium to coarse grained rock mainly composed of feldspar with biotite and hornblende as minor constituents.

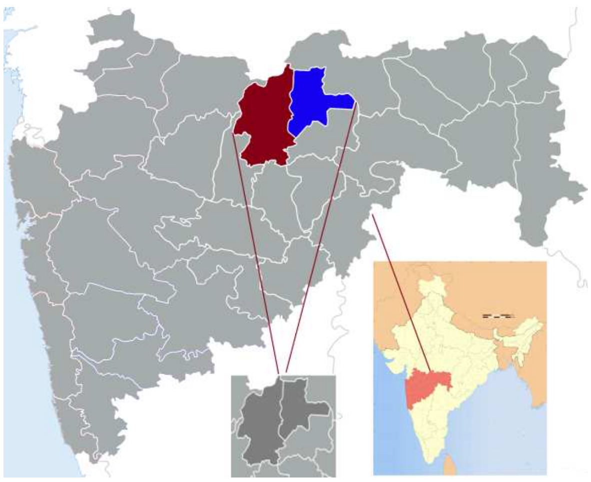


Figure 1. Location map of the study area

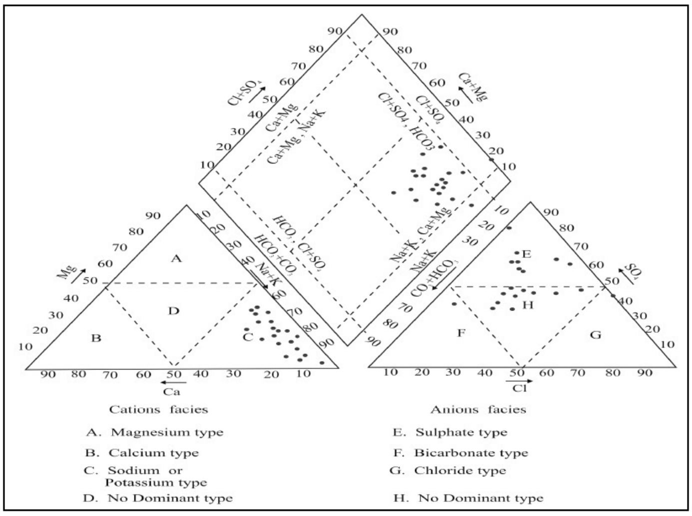
The water samples were collected from the field at different locations.16 samples were collected in glass bottles that had been thoroughly washed with chromic acid solution and rinsed with distilled water. The glass bottles were closed tightly to avoid any spillage during transportation. Samples were analyzed for various physical parameters and chemical constituents following standard methods. Hardness and calcium was calculated by complexation titrating agent i.e. EDTA.

Hardness (mg/L) =EDTA used x 1000/mL of sample
Calcium(mg/L) = EDTA used x 400.8/mL of sample
Chloride was calculated by titration against silver nitrate(by using Mohr's method)
Chloride(mg/L) =(mL x N of AgNO3) 1000 X 35.5/mL of sample
Magnesium was calculated by-
Magnesium(mg/L) = (b-a) 400.8/Vol. of sample x 1.645
Where, b = EDTA used in hardness and
a = EDTA used in calcium
Sulphate was calculated by gravimetric method
Sulphate(mg/L)=(BaSO4 in mg) 411.5 /mL of sample

Sodium and potassium was calculated by using Flame Photometer. The whole analysis was carried out in the Department of Chemistry, G.S. Science, Arts and Commerce College, Khamgaon, District. Buldana, M.S., INDIA.

3. Results and Discussion

Assessment of groundwater quality for irrigation use and hydrochemical evolution of groundwater has been evaluated. Hydrochemical analysis has been carried out based on concentrations of Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, Cl^{-}, SO_4^{2-}, CO_3^{2-} and HCO_3^{-}. Sodium Adsorbtion Ratio (SAR), Percent sodium (% Na), Permeability index (PI) and Trilinear diagram have been studied **(Table 1).** The Piper Trilinear diagram **(Fig. 3)** is commonly used in water chemistry studies, which can show the percentage composition of different ions. By grouping Na^{+} and K^{+} together, the major cations are displayed on the trilinear diagram. Likewise, $CO3^{2-}$ and $HCO3^{-}$ are grouped, resulting in 3 groups of the major anions. The cations and anions were plotted in left and right triangles.The concern points are then assumed to be projected into the central diamond shaped area parallel to the upper edges of the central area. All these assumed points in the diamond shaped area represent the total ionic distribution. For each water sample, a single point could be imagined in the diamond shaped area, which represents the total ionic distribution. In cation studies, all the samples are of sodium or potassium type. In anion fancies 4 samples are of sulphate type, 1 sample is of bicarbonate type, 1 sample is of chloride type and 5 samples are of no dominant type.



Source : Data obtained from American geophysical union, Washington DC, USA
Figure 4. Chemical facies of groundwater of study area in Piper diagram

SAR **(Fig. 4)** USSL value ranges from 6.78 mg/L – 30.32 mg/L. Percent sodium value ranges from 67.76 – 96.88%. Permeability Index ranges from 31.46 – 98.78%. pH values range from 7.67 – 8.73. The value of hardness ranges from 84 – 1113. In USSL diagram, C3 – S2, indicates high salinity – medium sodium type. This type of water can be used to irrigate salt tolerant and semi tolerant crops under favorable drainage conditions. In Wilcox diagram **(Fig. 5)**, 6 water samples falls in permissible to doubtful category, 3 water samples falls in doubtful to unsuitable category whereas 2 samples falls in unsuitable category.

Permeability Index (PI)

Permeability index has been used as an important parameter for determination of suitability for groundwater in irrigation use **(Table 2)**. It can be calculated as:

PI (%) = Na+ + ΓHCO3- X 100 (meq/L)/(Ca2+ + Mg2+ + Na+)

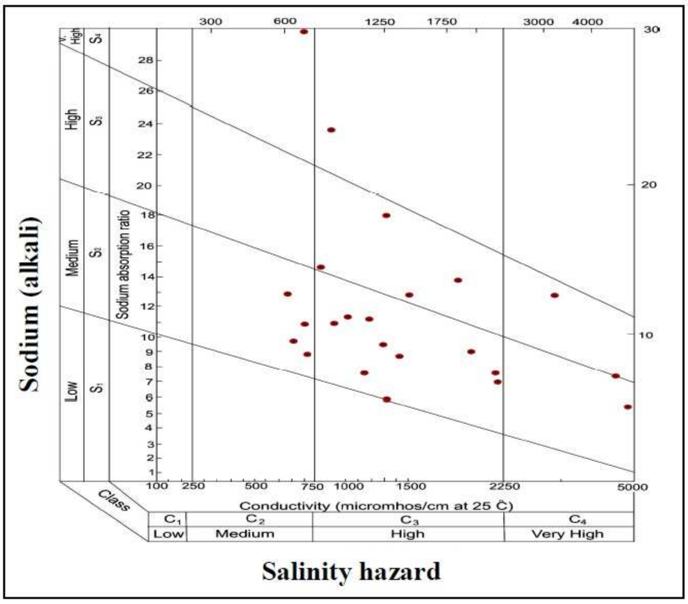
Percent sodium
Another method for determination of suitability for agricultural use in groundwater by calculating sodium percentage **(Table 3)** because sodium concentration reacts with soil to reduce its permeability. Todd Percent Sodium is calculated as-
Percent Sodium (%) = (Na^+ + K^+) 100 (meq/L)/(Ca^{2+} + Mg^{2+} + Na^+ + K^+)
Sodium Adsorption Ratio (SAR)
To determine the suitability for irrigation use, the sodium or alkali – hazard expressed in terms of Sodium Adsorption Ratio (SAR) **(Table 4)**. If the SAR value is greater than 6 to 9, the irrigation water **(Table 5)** will cause permeability problems on shrinking and swelling types of clayey soils.
SAR = Na^+ / ΓCa2+ + Mg2+/2
Residual Sodium Carbonate (RSC) Classification
If there is high concentration of HCO3 in water, there will be a tendency for Ca and Mg to precipitate as CO3. The excess sum of CO3 and H CO3 in groundwater over the sum of Ca and Mg also influences the suitability of the groundwater for irrigation, which is evaluated based on residual sodium carbonate **(Table 6)**. Complete precipitation takes place, when sum of carbonate and bicarbonate is in excess of calcium and magnesium.
RSC = [CO3- + H CO3-] – [Ca2+ + Mg2+] and is expressed in epm.

Table 1A. Hydrogeochemical characteristics of the water samples of the Banas river basin in mg/L

S.No	Location	Water type	pH	Hardness (mg/L)	TDS (mg/L)	SAR	% Na (%)	PI (%)	Na^+ (mg/L)	K^+ (mg/L)
1	A	HP	8.1	255	1870	8.5	85.23	65.23	550	85
2	B	HP	7.5	300	1250	9.5	55.24	75.32	350	52
3	C	Well	7.1	365	1	10.2	64.62	68.562.50	255	35
4	D	HP	7.5	400	1	5.2	92.47	65.52	545	52
5	E	HP	8.0	215	1	4.5	68.25	84.23	245	60
6	F	SW	7.4	155	1	10.5	55.63	69.65	560	21
7	G	HP	7.3	180	2	30.2	68.45	58.65	230	35
8	H	HP	7.4	200	2	15.2	98.52	45.23	1080	38
9	I	HP	7.1	245	2	12.2	45.26	64.56	550	65
10	J	HP	7.1	954	1	14.2	36.54	70.25	365	91
11	K	HP	8.2	265	1	4.5	58.75	74.54	650	54
12	L	SW	8.1	156	1	8.9	64.58	78.15	630	56
13	M	SW	8.3	332	2	9.5	62.36	77.55	620	32
14	N	SW	7.8	380	2	15.2	70.80	74.56	600	32
15	O	SW	7.9	248	1520	5.3	55.87	80.55	680	58
16	P	SW	7.5	168	2	6.5	80.56	70.40	235	52

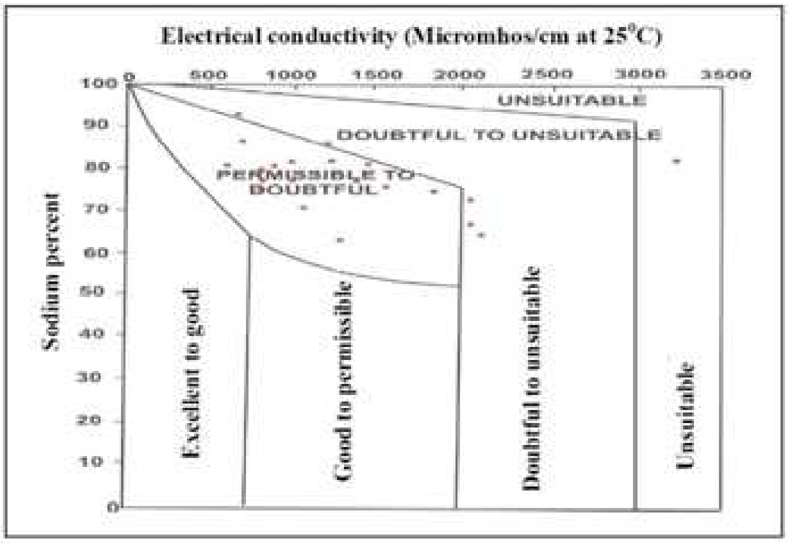
Table 1B. Hydro geochemical characteristics of the water samples of the Banas river basin in mg/L

S.No	Location	Water type	Ca^{2+} (mg/L)	Mg^{2+} (mg/L)	$CO3^{2-}$ (mg/L)	HCO^- (mg/L)	Cl^- (mg/L)	$SO4^{2-}$ (mg/L)	EC micromhos /cm	RSC (epm)
1	A	HP	21.25	55.32	210	100	55.23	255.3	450	0.12
2	B	HP	10.02	48.25	30.	130	45.23	123.4	255	3.25
3	C	Well	14.09	45.23	52	230	22.63	568.2	420	2.36
4	D	HP	9.23	45.65	190	50	41.25	244.8	690	1.23
5	E	HP	18.25	25.78	160	90	56.23	45.9	1560	5.69
6	F	SW	14.65	84.25	250	320	85.75	450.7	1350	4.8
7	G	HP	11.02	25.45	30	540	95.45	280.5	250	-0.68
8	H	HP	20.06	21.21	70	230	130.23	530.6	580	9.56
9	I	HP	21.88	32.56	120	580	450.25	321.2	255	5.78
10	J	HP	14.10	65.45	50	60	450.58	223.8	1063	-5.86
11	K	HP	5.60	25.46	60	90	147.25	345.5	264	-2.13
12	L	SW	2.03	65.48	130	80	150.65	249.3	360	6.45
13	M	SW	30.55	12.45	450	140	70.26	278.5	90	8.73
14	N	SW	20.35	10.23	0	50	155.65	245.7	550	4.87
15	O	SW	55.50	12.32	40	210	140.25	211.2	689	-9.56
16	P	SW	10.50	45.21	120	280	21030	209.5	280	4.74



Source : USDA, Agr. Handbook No. 60, Washington DC, USA

Figure 5. USSL diagram



Source : U.S. Dept. Agri. Circular No 969, USA

Figure 6. Wilcox diagram

Table 2. Quality of groundwater based on permeability index

Water class	Sample location	Type of water
Class - I	1,2,3,4,5,12,13,15,16	Very good water quality >75% of maximum soil permeable.
Class - II		Good water quality 75% of maximum soil permeable.
Class - III	6,7,8,9,10,11	Moderate water quality <75% of maximum permeable.
Class - IV		Bad water quality <25% of maximum permeable.

Source : Data obtained from Wiley Eatern Ltd., Delhi, India

Table 3. Quality of groundwater based on percent sodium

% Sodium	Water class	Sample location
<20	Excellent	
20 - 40	Good	**10**
40 - 60	Permissible	2,6,9,11,15
60 - 80	Doubtful	3,5,7,12,13,14
>80	Unsuitable	1,4,8

Table 4. Quality of groundwater based on SAR

SAR	Water Class	Number of samples
Less than 10	Excellent	1,2,4,5,11,12,13,15,16
10 to 18	Good	3,6,8,9,10,14
18 to 26	Permissible	
Greater than 26	Unsuitable	7

Source: Data obtained from Agr. Handbook 60, ARS-US

Table 5. Classification of irrigation water based on electrical conductivity

Water Class	EC	No. of samples	Salinity Significance
Excellent	<250	13	Water of low salinity is generally composed of higher proportions of calcium, magnesium and bicarbonate ions.
Good	250 - 750	1,2,3,4,7,8,9,11, 12,14,15,16	Moderately saline water, having varying ionic concentrations
Permissible	750 -2250	5,6,10	High saline waters consist mostly of sodium and chloride ions
Doubtful	>2250		Water containing high concentration of sodium, bicarbonate and carbonate ions have high pH.

Source: Data obtained from Agr. Handbook 60, ARS-US

Table 6. Quality of groundwater based on RSC

RSC	Category	Number of samples
<1.25	Safe	1,4,7,10,11,15
1.25 – 2.5	Moderately suitable	
>2.5	Unsuitable	2,5,6,8,9,12,13,14,16

Source : Data obtained from Wiley Eatern Ltd., Delhi, India

4. Conclusion

In USSL Diagram, majority of the water samples fall in the moderate water class. few of the water samples fall in poor water class and very few of the water samples fall in the bad water class. In Piper trilinear diagram Na-K-SO4 type facies predominate the study area. The present study shows that groundwater quality is greatly influenced due to rapid urbanization. It has also been observed that poor sanitation system, washing and cleaning activities near the wells, water logging around the wells, open defacation, and animal sheds near the wells and a general lack of awareness contribute deterioration in the groundwater quality. In Wilcox diagram sample no.12 and 14 falls in the unsuitable category. Higher value of EC is an indication of salinity. The classification of groundwater for irrigation purpose according to RSC value indicates that more than 50% of the water samples are safe for agricultural purpose remaining of the water samples are of moderately suitable and unsuitable for agricultural purposes.

5. Acknowledgement

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