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Suitability of Groundwater Quality for Irrigational use between Silkanth and Kundgaon, North of River Narmada in the Upper Alluvial Plains of Narmada Valley, District Sehore and Dewas, M.P., India

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Abstract

Groundwater is one of the earth's most widely distributed resources and is consistently catering to the requirement of the agricultural irrigation. In the present study, an attempt has been made to understand the hydrochemistry and its agricultural water quality of groundwater between Silkhanth and Kundgaon, North of river Narmada, Madhya Pradesh. During the course of water quality studies of the area,17 groundwater samples were collected and chemically analysed. Results obtained from water chemistry were used in the determination of different irrigational specifications to appraise the agricultural quality of groundwater. Important specifications like Sodium Adsorption Ratio (SAR) Residual Sodium Carbonate (RSC), Soluble Sodium Percentage (SSP) and Kelly's Ratio (KR) are used for decisive the appropriateness of groundwater for the agricultural purposes. Result shows that the majority of groundwater belongs to Medium to -High Saline and Low sodium water. As per the magnesium ratio classification, the ground waters of the study area has no magnesium hazards. Kelly's ratio shows that majority of groundwater belongs to suitable class. As per the classification based on RSC the groundwater belongs to Safe class. As per the guidelines of Ayers and Westcot, majority of water have slight to moderate toxicity with respect to Nitrate and their use is restricted for semitolerant crops.

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Introduction

Groundwater is an important natural resource for the growth of any civilization and dependable and cost-effective condition of agricultural water supply in the country. It thus plays a imperative role in human being, aquatic and global ecosystems

Excellent quality of irrigation water is quite essential for achieving maximum crop efficiency. During recent past, studies on agricultural water quality have been reported by various workers in the alluvial plains of Narmada valley in India like Dhiman, (2014), Maghanga *et al.*, (2013), Jhariya *et al.*, (2012), Ravikumar *et al*, (2011), Sharma *et al*, (2011), Jayalakshmi Devi *et al*,(2009), Jain (1993) and Parashar, (1994, 2001)

Study Area

The study area lies between Silkhant to Kundgaon, North of river Narmada. The area covers parts of Sehore and Dewas districts of Madhya Pradesh, India. The study area lies between latitude 22°30'0" to 22°40'0" N and longitudes 77°0'0" and 77°20'0" East. The area of present investigation falls on the Survey of India toposheet Nos. 55F/2, 55F/6, 55B/14 and 55B/15.

Material and Methods

The hydrochemistry of collected groundwater samples from both during the pre- monsoon and post-monsoon period are presented in Table -1. The samples were collected in pre cleaned polyethylene containers of one liter capacity. The samples were collected from those wells only which are widely used for drinking and irrigational purposes. The study of water samples was carried out by using Flame photometer, Hach Spectrophotometer and titration methods. The physical properties like colour, temperature, odour, and taste of water samples were recorded at the sampling stations during field work. The pH of the water samples was determined by pH meter. Conductivity is measured in micro mohs per cm at 25 °C by conductivity meter. The carbonate alkalinity was determined by titrimetric method using phenolphthalein as indicator. The bicarbonate was determined by titrating sample with standard acid solution using methyl orange indicator. Total hardness as $CaCO_3$ was determined by EDTA titrimetric method using Erichrome Black-T indicator. Ca content was calculated from Ca hardness by multiplying with a factor 0.432 and the results were expressed in mg/l. Magnesium content was calculated from Mg hardness by using a formula and results expressed in mg/l. Chloride concentration was determined by titration method involving formation of reddish brown complex by adding potassium chromate which is titrated against silver nitrate solution. Nitrate is determined by phenol disulphuric acid method as per APHA (1995) using Hach DR-4000 UV-Vis Spectrophotometer.

Hydrochemistry of Study Area

The pH value of groundwater of the study area varies from 7.5 to 7.9 in pre-monsoon and 7.0 to 7.8 in post-monsoon period which shows that water is slightly alkaline in nature. The Electrical conductivity (EC) values in groundwater vary from 370 µmohs/cm to 910 µmohs/cm and 340 µmohs/cm to 880 µmohs/cm in pre-monsoon post-monsoon period respectively. Calcium content in groundwater varies from 32 mg/l to 70 mg/l in pre-monsoon and 27 mg/l to 55 mg/l in post-monsoon periods. The Magnesium concentration in groundwater varies from 10 mg/l to 26 mg/l in pre-monsoon and 08 mg/l to 24 mg/l in post-monsoon period. The sodium content in groundwater varies from 14 mg/l to 76 mg/l in pre-monsoon and 9 mg/l to 70 mg/l in post-monsoon period. The Potassium content in groundwater is varies from 1 mg/l to 7.3 mg/l in pre-monsoon and 0.6 mg/l to 6.7 mg/l in post-monsoon period. The total hardness in terms of $CaCO_3$ ranges from 140 mg/l to 233 mg/l in pre-monsoon and 125mg/l to 218 mg/l in post-monsoon period.

Bicarbonate is the predominant anion in the groundwater of the study area. Bicarbonate concentration in the groundwater varies from 105 mg/l to 255 mg/l in pre-monsoon and 90 mg/l to 240 mg/l in post-monsoon period. The carbonate content is found to be absent in all the samples of groundwater, collected during the pre-monsoon and post-monsoon periods.

The chloride concentration in groundwater varies from 46 mg/l to 96 mg/l in pre-monsoon and 41 mg/l to 90 mg/l in post-monsoon period. The Sulphate concentration in the groundwater of the study area

Table 1: hydrochemistry of Groundwater of the study area between Silkhant and Kundgaon.

		Concentrations in mg/l (Pre monsoon)													Concentrations in mg/l (Postmonsoon)										
Well no.	Name of the village	pH	EXC10^6 at 25^{0}c	CATIONS Na^+	K^+	Ca^{++}	Mg^{++}	T.H. as $CaCo_3$	ANIONS HCO_3	CO_3--	Cl^-	NO_3	SO_4	PO_4	pH	EXC1 10^6 at 25^{0}c	CATIONS Na^+	K^+	Ca^{++}	Mg^{++}	T.H. as $CaCo_3$	ANIONS HCO_3	CO_3--	Cl^-	NO_3	SO_4	PO_4
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
1	Silkhanth	7.6	830	76	3.5	42	25	208	186	Abs	53	60	62	0.18	7.3	810	70	2.7	37	24	192	170	Abs	47	56	57	0.16
2	Dholpur	7.5	450	70	3.9	50	18	201	255	Abs	49	37	25	0.19	7.3	420	63	3	45	17	184	240	Abs	44	30	21	0.16
3	Ranipura	7.5	720	37	5	58	20	228	138	Abs	88	36	18	0.17	7.3	690	31	4.2	55	18	212	125	Abs	84	31	13	0.16
4	Khera	7.8	750	53	5.2	48	12	170	146	Abs	67	24	39	0.29	7.5	730	48	4.6	44	11	155	130	Abs	63	16	33	0.27
5	Kolari	7.7	370	20	4	40	10	140	150	Abs	75	28	24	0.26	7.5	340	14	3.1	36	8	125	90	Abs	71	24	19	0.24
6	Pipalneria	7.7	840	14	2.8	42	21	192	116	Abs	80	34	48	0.31	7.8	810	9	2.3	37	21	179	100	Abs	75	30	42	0.29
7	Bijalgaon	7.8	720	16	4.9	47	20	200	162	Abs	60	57	29	0.21	7.3	700	11	4.2	43	18	184	150	Abs	54	49	23	0.19
8	Karond	7.7	650	26	3.5	38	16	160	212	Abs	46	18	24	0.27	7.2	630	21	2.4	33	15	147	160	Abs	41	12	20	0.25
9	Pipliya	7.9	710	18	4.1	40	14	157	110	Abs	71	59	18	0.31	7.6	680	13	3.4	36	13	143	96	aBS	66	52	13	0.28
10	Akawliya	7.5	590	15	5.2	36	23	186	162	Abs	76	40	12	0.28	7.2	570	10	4.3	32	22	172	130	Abs	72	36	7	0.26
11	Murjal	7.8	630	33	3.9	32	18	154	122	Abs	80	62	20	0.2	7.1	600	27	3.4	27	17	140	110	Abs	76	57	15	0.18
12	Jamner	7.8	690	45	7.3	47	18	160	180	Abs	50	34	19	0.28	7.3	650	40	6.7	30	17	145	169	Abs	44	28	14	0.26
13	Dait	7.5	910	36	1.8	70	21	206	165	aBS	89	29	25	0.28	7.2	880	31	1.3	43	20	190	144	Abs	83	22	21	0.26
14	Rehtai	7.4	850	27	1	40	26	207	136	Abs	46	39	27	0.21	7	820	22	0.6	36	24	189	121	Abs	41	32	24	0.19
15	Tigali	7.6	620	15	2.9	34	25	190	105	Abs	94	40	27	0.23	7.5	590	10	2	30	24	195	92	Abs	80	34	23	0.21
16	Guraria	7.6	730	37	5.6	58	21	233	140	Abs	90	41	52	0.22	7.3	690	31	4.8	54	20	218	125	Abs	83	37	46	0.18
17	Kundgaon	7.5	700	20	3.6	40	19	178	106	Abs	96	31	25	0.32	7.1	670	14	2.7	36	18	163	95	Abs	90	26	20	0.29
	Min.	**705**	**370**	**14**	**1**	**23**	**10**	**140**	**105**	**Abs**	**46**	**18**	**12**	**0.17**	**7**	**340**	**9**	**0.6**	**27**	**8**	**125**	**90**	**Abs**	**41**	**12**	**7**	**0.16**
	Max.	**7.9**	**910**	**76**	**7.3**	**70**	**26**	**233**	**255**	**Abs**	**96**	**62**	**62**	**0.32**	**7.8**	**880**	**70**	**6.7**	**55**	**24**	**218**	**240**	**Abs**	**90**	**57**	**57**	**0.29**

varies from 12 mg/l to 62 mg/l in pre-monsoon and 7 mg/l to 57 mg/l in post-monsoon period. In the present investigation, the Nitrate content in the groundwater varies from 18 mg/l to 62 mg/l in pre-monsoon and 12 mg/l to 57mg/l in post-monsoon period. The Phosphate concentration in groundwater of the study area varies from 0.17mg/l to 0.32 mg/l in pre-monsoon and 0.16mg/l to 0.29 mg/l in post-monsoon period.

Irrigational Water Quality

Various specifications have been proposed from time to time by different workers to evaluate the agricultural water quality. In the present study the specifications as proposed by Kelley *et al.*, (1940); Eaton, (1950); US Soil Salinity Laboratory Staff (1954); Wilcox (1955); Paliwal, (1972) and Ayers and Westcot (1994) have been used to assess the suitability of groundwater for agricultural purposes.

Table 2: Tabulated Computed data of various Irrigational Specification of Groundwater

Well No.	Name of Village	Agricultural Utility (Per Monsoon) R.S.C	K.R	Mg%	Salt Index	Na%	SAR	Agricultural Utility (post Monsoon) R.S.C	K.R.	Mg%	Salt Index	Na%	SAR
1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Silkhanth	-1.11	1.13	17.06	5.18	51.87	2.29	-1.03	1.15	17.95	3.13	52.35	2.2
2	Dholpur	0.2	1.03	12.68	0.9	49.33	2.15	0.28	1.01	13.28	-1.38	49.21	2.04
3	ranipura	-2.27	0.47	16.66	-6.48	30.83	1.07	-2.17	0.42	16.63	-8.92	28.65	0.93
4	Khera	-1	0.88	10.15	-5.65	44.84	1.76	-0.97	0.87	10.22	-7.41	44.6	1.68
5	Kolari	-1.1	0.4	13.51	-14.97	27.02	0.73	-0.99	0.31	13.09	-17.4	22.91	0.55
6	Pipalneria	-1.93	0.22	26.31	-12.28	17.54	0.44	-1.94	0.15	30.3	-13.61	12.98	0.29
7	Bijalgaon	-1.34	0.24	22.75	-11.89	18.2	0.49	-1.17	0.18	23.62	-14.05	14.43	0.35
8	Karond	0.25	0.98	19.16	-11.12	31.13	0.89	0.26	0.44	21	-12.9	29.41	0.75
9	Pipliya	-1.35	0.33	18.39	-13.89	23.65	0.62	-1.3	0.26	19.87	-15.61	19.87	0.47
10	Akawliya	-1.04	0.25	29.04	-10.85	18.94	0.48	-1.28	0.18	32.21	-12.7	14.64	0.33
11	Murjal	-1.08	0.66	20.71	-8.5	37.97	1.15	-0.95	0.61	22.84	-10.46	36.29	1
12	Jamner	-0.88	0.69	15.34	-5.02	38.36	1.42	-0.13	0.85	18.14	6-74	42.68	1.45
13	Dait	-2.52	0.39	16.3	-6.76	27.95	0.97	-1.43	0.49	20.98	-8.53	32.52	0.98
14	Rehtai	-1.91	0.41	27.65	-7.21	28.72	0.81	-1.79	0.36	29.05	-9.31	26.63	0.7
15	Tigali	-2.04	0.25	32.5	-10.4	19.5	0.47	-1.96	0.18	36.36	-12.16	15.15	0.32
16	Guraria	-2.33	0.47	17.26	-6.05	30.42	1.06	-2.28	0.42	18.21	-8.05	28.23	0.92
17	Kundgaon	-1.82	0.34	23	-11.43	24.21	0.65	-1.72	0.26	25.45	-13.48	19.8	0.47

Soluble Sodium Percentage(SSP), Sodium Adsorption Ratio(SAR), Residual Sodium Carbonate(RSC), Kelly's Ratio and Magnesium hazard are the distinguished specifications for determining the suitability of groundwater for agricultural purposes and are presented in Table-2. The suggested classification of irrigation water quality with respect to EC, SAR, Kelly's Ratio, Mg. Ratio, RSC and Na% are presented in Table -3.

Sodium concentration is very important in classifying the irrigation waters because sodium by the process of base exchange may replace calcium in the soil and thereby reduce the permeability of soil to water. Sodium or alkali hazard is measured on the basis of SAR. The relativity of sodium ion in the exchange reaction with soil is expressed in terms of a ratio known as Sodium Adsorption Ratio (SAR). As per the classification based on SAR, the sodium hazard is Low, if SAR content is less than 10; Medium, if SAR content is in between 10 to 18; High, if SAR content is in between 18 to 26 and Very High if SAR content is more than 26. The SAR values of the groundwater of the study area varies from 0.44 to 2.29 and 0.320to 2.2 in pre and post-monsoon period respectively. When the groundwater samples compared with this classification as shown in Table-3, it clearly indicates that the groundwater belongs to Low Sodium waters.

Kelly *et al*., (1940) have proposed that the potential sodium problem in irrigation water is evaluated on the basis of the following ratio:

Kellys Ratio = Na/ Ca+ Mg (where all the conc. expressed in epm)

Kellys *et al*., (1940) that if this ratio is less than unity, the water is suitable; more than two the water is unsuitable and in between one and two the water is marginal for irrigational purposes. It is seen from the Table 2, the Kelly's ratio varies from 0.22 to 1.13 in pre-monsoon and 0.15 to 1.15 in post-monsoon period. Table-3 shows that 88% of groundwater in pre and post monsoon belongs to suitable class and 12% belongs to marginal class in pre and post monsoon period. Thus the majority of groundwater is suitable for agricultural purposes.

Wilcox (1955) has proposed a classification based on specific Electrical Conductance, Soluble Percentage and Boron Concentration. Soluble Sodium Percentage is calculated by the following formula:

Na % = (Na+ K) x 100/ Ca+ Mg+Na+K(where all the conc. are expressed in epm)

Table 2 shows that, the Na% varies from 17.54 to 51.87 in pre-monsoon and 12.98 to 52.35 in post-monsoon period. Table-3 shows that 59% of groundwater in pre-monsoon period and 41% in post-monsoon period belong to Good class and 17% of groundwater in pre-monsoon period and 24% in post-monsoon period belongs to Permissible class which shows that the majority of groundwater is quite suitable for agricultural purposes.

Salinity hazard is assessed on the basis of Electrical conductivity (EC) and it also reflects the total dissolved solids (TDS) in groundwater. Soil structure, permeability and plant growthis affected by high salt content in irrigation water. On the basis of Richards (1954) classification, the water is low (if EC below 250 µmohs /cm), the water is medium (if EC between 250 to 750 µmohs/cm), the water is high (if EC content between 750 to 2250 µmohs/cm), the water is very high (if EC is more than 2250 µmohs/cm) with respect to salinity in water. When the groundwater samples compared with this classification, Table-1 clearly indicates that the groundwater varies from 370 to 910 µmohs/cm in pre monsoon period and 340 to 880 µmohs/cm in post monsoon period respectively and thus they belongs to Medium to High Salinity class. Table-3, further shows that 76% of groundwater in pre-monsoon and post-monsoon period belongs to Medium salinity class.

Paliwal (1972) has proposed the ratio Mgx100/ Ca+Mg as an index of magnesium hazards to irrigation waters. As per the classification, if the Mg Ratio less than 50% the water issuitable and if Mg ratio is more than 50% the water is unsuitable. It is seen from the Table-2, magnesium ratio of groundwater of the study area varies from 10.15 to 32.50 in pre-monsoon and 10.22 to 36.36 in post-monsoon period respectively. Table-3 indicates that

Table 3: Tabular Classification of Groundwater of the study area.

Irrigational Specifications	Range	Class	Type of Water			
			Pre Monsoon		Post Monsoon	
			No. of Samples	%	No.of Samples	%
	<250	Low	0	Nil	0	Nil
	250-750	Medium	13	76%	13	76%
EC	750-2250	High	4	24%	4	24%
	>2250	Very HIGH	0	Nil	0	Nil
	Total		**17**	**100%**	**17**	**100%**
	<10	Low	17	100%	17	100%
	10-18	Medium	0	Nil	0	Nil
SAR	18-26	High	0	Nil	0	Nil
	>26	Very High	0	Nil	0	Nil
	Total		**17**	**100%**	**17**	**100%**
	<1	Suitable	15	88%	15	88%
Kelly's Ratio	1-2	Marginal	2	12%	2	12%
	>2	Unsuitable	Nil	Nil	Nil	Nil
	Total		**17**	**100%**	**17**	**100%**
	<50	Suitable	17	100%	17	100%
Magnesium Ratio	>50	Unsuitable	Nil	Nil	NIl	Nil
	Total		**17**	**100%**	**17**	**100%**
	<1.25	Safe	17	100%	17	100%
Residual Sodium	>2.50	Unsuitable	Nil	Nil	Nil	Nil
Carbonate(RSC)	**Total**		**17**	**100%**	**17**	**100%**
	<20	Excellent	4	24%	6	35%
	20-40	Good	10	59%	7	41%
Soluble Sodium	40-60	Permissible	3	17%	4	24%
Percentage(SSP)	60-80	Doubtful	0	Nil	0	Nil
	>80	Unsuitable	0	Nil	0	Nil
	Total		**17**	**100%**	**17**	**100%**

all the groundwater of the study area belongs to suitable class and there is no magnesium hazard in groundwater of the study area.

Eaton(1950) has suggested that water having carbonate and bicarbonateions in excess of calcium and magnesium will lead to much greater alkali formation and thereby decreas the soil permeability. The carbonate and bicarbonate hazards in agricultural water quality are calculated in terms of Residual Sodium Carbonate (RSC):

$RSC = (CO_3 + HCO_3) - (Ca + Mg)$ (where all the conc. are expressed in epm)

Based on RSC, the irrigation waters are classified as Safe (if RSC is less than 1.25), Marginal (if RSC is in between 1.25–2.5) and Unsuitable (if RSC is more than 2.5).Table 2 indicates that RSC values of groundwater of the study area varies from -2.52 to 0.25 in pre-monsoon and -2.28 to –0.28 in post-monsoon period respectively. After imperative examination of Table 2 and 3, it reveals that all the

groundwater of the study area belongs to Safe class and thus they are suitable for agricultural purposes.

Ayers and Westcot(1994), proposed a modified water quality guidelines to assess the agricultural water quality. In the proposed guidelines, the water has been grouped into four classes mainly Salinity, Water Infiltration, Specific ion toxicity and Miscellaneous effects which have been further subdivided into three categories as None Restriction category, Slight to Moderate Restriction category and Severe Restriction category based on the degree of restrictions on their use. A comparison of EC, SAR, TDS, Sodium, Bicarbonate, Chloride and Nitrate concentration of groundwater of the study area with the values proposed in Ayers and Westcot water quality guidelines reveals that the groundwater belongs to None restriction category with respect to EC,TDS,SAR, Sodium, Bicarbonate, and Chloride and may be safely used for surface and sprinkler irrigation.

Conclusions

Agricultural water quality have been evaluated on the basis of Salinity hazard, Sodium hazard, Magnesium hazard and Bicarbonate hazard. According to the classification of groundwater with respect to SAR and EC, the majority of groundwater of the study area belongs to belongs to medium to high salinity class and Low sodium water. Kelly's ratio shows that 88% of groundwater in pre and post monsoon belongs to suitable class. Classification based on RSC clearly indicates that all the groundwater of the study area belongs to Safe class and thus they are suitable for agricultural purposes. As per the magnesium ratio classification, all the groundwater of the study area belongs to suitable class and there are no magnesium hazards in groundwater of the study area. As per Ayers and Westcot water quality guidelines the groundwater belongs to None restriction category with respect to EC, TDS, SAR, Sodium, Bicarbonate, and Chloride and may be safely used for surface and sprinkler irrigation. However, there is slight to moderate restriction with respect to nitrate and their use is restricted for sensitive crops.

From the above mentioned discussion and interpretation of the hydrochemistry and irrigational specifications, it can be concluded that the groundwater of the study area is quite suitable for irrigational purposes.

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