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Research Paper

Assessment of ground water quality of lahar block, Bhind district in Madhya Pradesh

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Abstract

In sustainable groundwater study, it is necessary to assess the quality of groundwater in terms of irrigation purposes. The present study attempts to assess the groundwater quality through Irrigation Water Quality Index (IWQI) in hard-rock aquifer system and sustainable water use in Lahar block, Bhind of district, Madhya Pradesh, India. The quality of ground water in major part of the study area is generally good. In order to understand the shallow groundwater quality, the water samples were collected from 40 tube wells irrigation water. The primary physical and chemical parameters like potential Hydrogen (pH), Total Dissolved Solids (TDS), calcium (Ca^{2+}), magnesium (Mg^{2+}), sodium (Na^{+}), potassium (K^{+}), bicarbonate (HCO_3^{-}), carbonate (CO_3^{2-}), chloride (Cl^{-}), and nitrate (NO_3^{-}) were analyzed for (irrigation water quality index) IWQI. The secondary parameters of irrigation groundwater quality indices such as Sodium Adsorption Ratio (SAR), Sodium Soluble Percentage (SSP), Residual Sodium Carbonate (RSC), Permeability Index (PI), and Kellies Ratio (KR) were also derived from the primary parameter for irrigation water quality index (IWQI). The IWQI was classified into excellent to unfit condition of groundwater quality based on their Water Quality Index (WQI). The IWQI (82.5%+15.0%) indicate that slightly unsustainable to good quality of ground water. Due to this quality deterioration of shallow aquifer, an immediate attestation requires for sustainable development.

Keywords: *Groundwater Quality; Irrigation Water Quality Indices; Permeability Index and Arrange Kallies Ratio etc.*

1. Introduction

Groundwater is considered as the major source of usable water, so that quality of water is the main key factor in management of groundwater in a sustainable manner. In the past few decades, reports of ground water contamination have increased public concern about ground water quality (Yanggen and Born, 1990). Since groundwater is the primary source of water for domestic, agricultural and industrial uses in many countries and its contamination has been recognized as one of the most serious problems in India. Due to rapid growth of population, urbanization, industrialization and agriculture activities, ground water quality is depleted; it is also influenced by a contribution from the atmosphere and surface water bodies.

Approximately 70% of freshwater is consumed by agriculture. (Baroni et al., 2007). Fresh water is a finite resource, essential for agriculture, industry and even human existence, without fresh water of adequate quantity and quality; sustainable development will not be possible. The ground water resources are being utilized for drinking, irrigation and industrial purposes. Ground water contains a wide variety of dissolved inorganic chemical constituents in various concentrations, resulting from chemical and biochemical interactions between water and the geological materials. Inorganic contaminants, including salinity, chloride, nitrate, iron and arsenic are important in determining the suitability of ground water for irrigation and drinking purposes.

Quality of water is an important consideration in any appraisal of salinity or alkali conditions in an irrigated area. All irrigation water contains some salts, but the concentration and nature of salts vary. The quality of irrigation water depends primarily on the total amount of salt present and the proportion of Na^{+} to other cation and certain other parameters. Rajankar et al. (2009) calculated WQI for different groundwater sources, viz., dug wells, bore wells, and tube wells at Khaperkheda Region, Maharashtra. The problems of water quality are more acute in areas that are densely populated thickly industrialized and have shallow water set (Shivran et al. 2006). Keeping view above facts, present study is undertaken to assess the shallow groundwater quality of Lahar block in Bhind district, Madhya Pradesh for irrigation purposes through different ground water quality indices and generate WQI.

2. Study area

Bhind district is situated in the northern part of the Madhya Pradesh and covers an area of about 4459 sq. km. It lies between N Latitude 25° 55’ and 26° 45’ and E longitude 78° 12’ and 79° 05’. It is bounded in the North and east by Uttar Pradesh, in the south by the Gwalior and Datia districts in the west by the district Datia. Bhind district is divided into seven tehsils and six blocks. Lahar tehsil is one of the seven tehsil of Bhind district, Madhya Pradesh India. It is located in the east-southern area of the district.

3. Materials and method

Groundwater quality data and World Health Organization (WHO) water quality standards were utilized in the present study. Sampling was carried out during pre-monsoon season (April) for the year 2015. Total 40 water samples were collected from the selected locations throughout the study area. Water quality secondary parameters name SAR, RSC, SSP; KR and PI were analyzed for IWQI. The statistical analysis of various quality parameters IWQI was classified into excellent to unfit condition of groundwater quality based on their Water Quality Index (WQI). Based on their severity of WQI the sub-basin further classified into good to pour good state of groundwater quality for sustainable development. The physio-chemical analysis was performed following standard methods (APHA, 1992). The brief details of analytical methods and equipment used in the study are given in Table 1. Electrical conductivity and pH were measured using EC and pH meters. Total dissolved solids were estimated by ionic calculation method. CO_3^{2-} and HCO_3^- were estimated by titrating with concentration H_2SO_4. Ca^{2+}+Mg^{2+} were analyses titrimetrically using standard EDTA. Na^+ and K^+ were measured by a flame photometer. Cl^- was estimated by standard $AgNO_3$ titration. Nitrate was estimated by using an ion selective electrode with 720 pH/ISE meter.

Table 1: Methods of Physico-Chemical Analysis of Water and Equipment Used in the Study (APHA, 1992)

S.N.	Parameters	Method followed	Equipment
1	pH	Electrometric	pH Meter
2	Conductivity	Electrometric	Conductivity Meter
3	Chloride	Titration by $AgNO_3$ (0.01N)	Titration
4	Nitrate	Direct ion selective electrode	Electrochemically
5	Sodium	Flame emission spectroscopy	Flame photometer
6	Potassium	Flame emission spectroscopy	Flame photometer
7	Ca^{2+}+Mg^{2+}	Titration by EDTA (0.01 N)	Titration
8	CO_3^{--} / HCO_3^-	Titration by Std. H_2SO_4 (0.01 N)	Titration
9	SAR	Calculation	-
10	RSC	Calculation	-
11	KR	Calculation	-
12	SSP	Calculation	-
13	PI	Calculation	-

4. Irrigation water quality indices (IWQI)

The various irrigation water quality indices were derived from the primary parameter of drinking water quality.

i) Sodium adsorption ratio (SAR)

SAR is an important parameter for determining the suitability of ground water for irrigation because it is a measure of alkali/sodium hazard to crops. SAR is calculated using the following formula where the concentration of all ions is in meq L^{-1}.

$$SAR = \frac{Na+}{\sqrt{\frac{Ca2++Mg2+}{2}}}$$

ii) Soluble sodium percentage (SSP)

Wilcox (1955) has proposed classification scheme for rating irrigation water on the basis of soluble sodium percentage (SSP). The SSP was calculated by using following formula where the concentration of all ions is in meq L^{-1}.

$$SSP = \frac{Na \times 100}{Ca+Mg+Na}$$

The values of SSP less than 50 indicate good quality of water and higher values (i.e.>50) show that the water is unsafe for irrigation (USDA, 1954).

iii) Residual sodium carbonate (RSC)

Water containing carbonate plus bicarbonate concentration greater than the calcium plus magnesium concentration, referred as "residual sodium carbonate" and calculated as (Raghunath, 1987).

$$RSC = (CO_3 + HCO_3) - (Ca + Mg)$$

iv) Permeability index (PI)

Permeability index is calculated by using the following formula:

$$PI = \frac{Na+\sqrt{HCO3}}{Ca+Mg+Na} \times 100$$

Where, all the values are in meq^{-1}. The PI values >75 indicate excellent quality of water for irrigation. If the PI values fall in between 25 and 75, they indicate good quality of water for irrigation. However, if the PI values are <25, they reflect unsuitable nature of water for irrigation.

v) Kelly's ratio (KR)

Kelly's ratio was calculated by using the following expression

$$KR = \frac{Na+}{Ca2+ + Mg2+}$$

Where, concentrations are expressed in meq L^{-1}. The Kelly's ratio of unity or less than one is indicative of good quality of water for irrigation where as above one is suggestive of unsuitability for agricultural purpose due to alkali hazards (Karanth, 1987).

vi) Corrosively ratio index (CRI)

The magnitude of the corrosiveness of water can be assessed by using a perimeter known as corrositivity ratio Index (CRI), which can be determined by using the following formula.

$$CR = \frac{\frac{Cl}{25.5+2so4}}{2(CO2+\frac{HCO3}{100})}$$

The water having the corrositivity ratio less than one is safe and non corrosive. Corrositivity ratio greater than two is suggestive of corrosiveness.

vii) Magnesium adsorption ratio (MAR)

The Magnesium Adsorption Ratio (MAR) was calculated using the following equation (Raghunath, 1987):

$$MAR = \frac{Mg \times 100}{Mg+Ca}$$

Where, all the ionic constituents are expressed in $meqL^{-1}$.

5. Results and discussions

Water quality is good and suitable for irrigation every crop. Irrigation water quality analysis is important in understanding current water quality and to making more informed decisions. Irrigation water testing provides regarding minerals present in water. Lahar block is one of the developing block in Bhind, district of Madhya Pradesh. The observed over all pH values ranging between 7.4 to 8.1 (Table 1) in different water sampling condition in which they are taken and 100% water sample suitable for irrigation which was within maximum permissible limit. EC values ranging from 0.33 to 1.65 dSm^{-1} in the reported. TDS range from 211 to 1056 mg L^{-1}. NO_3^- values ranged between 0.01 to 210.6 mg L^{-1}. Chloride ranges from 1.90 to 15.30 meq L^{-1}. Carbonate and bicarbonate range from 0.0 to 1.1 and 2.10 to 8.30 meq L^{-1}. Potassium value ranged 0.00 to 0.70 meq L^{-1}. Sodium values ranged between 1.50 to 42.70 meq L^{-1}. Calcium plus magnesium recorded between 2.5 to 32.0 meq L^{-1}. The rock water interaction and aquifer material played major role in evolution of water chemistry, which was further influenced by the evaporation process. Geological location is one of the most important factors affecting ground water quality (Becket et al., 1985). The calculated value of SAR in the study area has been shown about 82.50% of area under suitable. The 17.50% of study areas fall under high to very high SAR for irrigation. When SAR values are greater than 18, irrigation water will cause permeability problems on shrinking and swelling in clay soil (Saleh et al., 1999). The higher the SAR values in the water, the greater the risk of Na which leads to the development of an alkaline soil (Todd, 1980), while a high salt concentration in water leads to formation of saline soil. The average Sodium Absorption Ratio (SAR) of ground water in the study area range is 0.87-26.22meq L^{-1}. In ground water sodium absorption ratio becomes >18-26 ppm, it is called exchangeable sodium percentage. In the study area, RSC varies between -28.2 ppm to 5.1 ppm. Hazards from RSC are low to medium and only at two locations RSC are in the high hazard category. Where, the concentrations of ions are expressed in meq L^{-1}. The values of SSP less than 50 indicate good quality of water and higher values (i.e. > 50) show that the water is unsafe for irrigation (USDA, 1954). It is observed from (Table1) that, majority of the groundwater samples have SSP values greater than 50, which can be graded as unsuitable for irrigation. On the basis of PI, the groundwater in the study area can be classified as good (67%) for agricultural use. Most of the groundwater sample in the study area falls in the corrosively ratio index zone less than 1 and so they are safe, suitable and less corrosive and hence can be used for domestic or industrial purposes. The corrositivity of the groundwater in the study area ranges between 0.14 and 8.05. Where, concentrations are expressed in meq L^{-1}. The Kelly's ratio of unity or less than one is indicative of good quality of water for irrigation whereas above one is suggestive of unsuitability for agricultural purpose due to alkali hazards (Karanth, 1987). It is observed from (Table 1), the majority of the samples in the study area fall more than one. This suggests that, the samples from study area are unsuitable for irrigation.

Table 2: Cations and Anions in Ground Water of Lahar Block in Bhind District

Water characteristics	Range	Mean	S.D.±	C.V. (%)
pH	7.40-8.10	7.75	0.18	2.36
EC	0.33-1.65	0.82	0.38	46.29
TDS	211.00-1056.00	546.05	239.35	43.83
NO_3^- (meq L^{-1})	0.01-210.60	16.72	41.59	248.77
Cl^- (meq L^{-1})	1.90-15.30	4.92	2.95	59.97
CO_3^{2-} (meq L^{-1})	0.00-1.10	0.36	0.33	90.24
HCO_3^- (meq L^{-1})	2.10-8.30	4.44	1.47	33.04
K^+ (mg L^{-1})	0.00-0.70	0.08	0.12	141.43
Na (mg L^{-1})	1.50-42.70	10.89	8.50	78.10
Ca^{2+} Mg^{2+}(mgL^{-1})	2.50-32.00	7.37	5.16	70.06

In order to assess the irrigation water quality in Lahar block of Bhind district Madhya Pradesh. An attempt has been made to develop a model on Irrigation Water Quality Index (IWQI). The various irrigation water quality indices such as SAR, SSP, RSC, PI, and KR were considered to assess the ground water quality for irrigation. The indices value summed, then classified into excellent to unfit ground-water quality (Table 4). The output has shown only 82.50% of water slightly unsustainable for irrigation, whereas some parts of the area (15%) good quality found in water sample and only 2.50% found in very poor quality these findings are in close conformity with those reports by (Anbazaghan, 2014).

Table3: Water Quality Classification Based on Water Quality Index Value

Sample No.	SAR	RSC	KR	SSP	PI	MAR	CR	IWQI
W_1	5.40	-5.1	1.28	56.25	15.11	36.2	0.8	110.03
W_2	6.11	-1.6	1.96	66.32	17.15	32.9	1.2	124.04
W_3	1.57	-6.5	0.36	26.82	16.24	29.7	1.6	69.79
W_4	7.67	-1.2	2.12	67.97	09.62	41.1	1.8	129.08
W_5	4.86	0.5	1.55	60.80	23.89	23.5	3.2	118.3
W_6	4.62	-1.8	1.33	57.14	52.22	28.6	2.6	144.71
W_7	12.3	0.7	3.32	77.69	18.55	31.8	2.7	147.05
W_8	4.74	-4.0	1.30	56.66	17.01	33.5	3.1	112.31
W_9	2.46	-2.1	0.68	40.74	41.10	51.8	1.9	136.58
W_{10}	11.7	-0.7	3.88	79.54	45.78	57.8	2.4	200.37
W_{11}	11.2	0.1	3.31	76.82	38.20	48.6	2.9	181.11
W_{12}	9.26	-2.3	2.24	69.15	34.89	44.5	2.7	160.44
W_{13}	4.24	-7.6	0.86	46.42	43.15	36.5	4.1	91.17
W_{14}	1.15	-28.2	0.14	12.56	31.18	32.1	4.5	53.43
W_{15}	1.30	-17.6	0.20	16.66	27.00	32.8	4.9	65.26
W_{16}	2.70	-5.0	0.56	36.11	21.63	38.5	4.7	99.20
W_{17}	1.86	-1.0	1.11	52.75	27.10	26.4	5.4	113.62
W_{18}	5.03	-3.5	1.34	57.31	30.51	24.9	5.6	121.19
W_{19}	7.16	0.9	2.25	71.42	18.88	28.1	5.7	134.41
W_{20}	2.76	0.6	0.91	47.72	18.05	25.9	5.8	101.74
W_{21}	4.66	-3.3	1.12	52.97	13.18	52.8	6.1	127.53
W_{22}	2.45	-7.4	0.46	31.70	19.88	54.6	6.4	108.09
W_{23}	5.47	-2.5	1.53	60.48	29.24	51.7	6.8	152.72
W_{24}	3.22	0.1	1.12	52.94	12.92	49.6	6.3	126.20
W_{25}	5.46	1.2	2.44	70.93	23.65	45.6	0.9	150.18
W_{26}	0.87	1.8	0.25	20.00	15.83	42.2	1.2	82.15
W_{27}	4.12	-4.0	1.09	52.34	13.91	47.1	1.8	116.36
W_{28}	3.51	-1.7	1.72	47.55	14.29	46.5	1.4	113.27
W_{29}	4.89	0.3	1.14	63.30	10.44	38.5	7.1	125.67
W_{30}	3.59	0.3	6.90	53.13	64.12	34.3	7.4	169.74
W_{31}	21.82	-0.8	8.05	87.34	08.50	36.8	7.6	169.31
W_{32}	26.22	0.0	2.28	88.95	24.53	33.6	7.5	183.08
W_{33}	7.39	-1.8	2.98	69.54	33.22	24.5	0.9	136.73
W_{34}	9.86	0.0	3.06	74.88	57.27	26.8	1.4	173.27
W_{35}	13.25	-3.4	1.86	75.39	22.29	29.7	1.6	140.69
W_{36}	6.40	-2.5	0.97	65.08	09.59	28.6	1.8	109.94
W_{37}	3.00	-0.2	1.67	49.46	11.76	35.4	3.2	104.29
W_{38}	4.79	1.4	1.88	62.60	19.22	31.8	3.6	125.29
W_{39}	5.92	-0.2	1.25	65.27	08.90	33.4	3.5	118.04
W_{40}	3.16	5.1	2.54	55.55	16.22	32.5	2.8	117.87
Mean	6.2	-2 .58	1.88	56.91	24.41	37.04	3.67	126.61
Range	0.87-26.22	-28.2-5.10	0.14 -8.05	12.56 -88.95	8.50-64. 12	23.50-57.80	0.80-7.60	53.43- 200.37
SD±	5.19	5.51	1.59	18.07	13 .72	9.49	2.15	32.15
CV (%)	83.63	-214 .05	84.95	31.75	56.21	25.62	58 .46	25.39

Note- SAR=Sodium adsorption ratio RSC=Residual sodium carbonate KR= Kelly,S ratio
SSP= Soluble sodium percentage PI= Permeability index MAR= Magnesium adsorption ratio CR=corrosively ratio IWQI=Irrigation water qwality index.

Table 4: Water Quality Classification Based on WQI Value

Water value range	Water quality	No. of samples (IWQI)	(%)	Sustainable state
<50	Excellent	0	0	Sustainable
51-100	Good	6	15	Sustainable
101-200	Poor	33	82.50	Slightly Unsustainable
201-300	Very poor	1	2.50	Unsustainable
>301	Very bad	Nil	Nil	Highly Unsustainable

Correlation between water quality parameters

In the ground water, pH shows significant positive correlation with CO_3^{2-} (r=0.324*) and non-significant negative correlation with EC (r= -0.098), NO_3^-(r=-0.082), K^+ (r=-0.121) and Cl^- (r=-0.259). Reported by have also similar result that Khanna (2012) pH significant correlated carbonate (r=0.336).

In the ground water, EC shows negatively significant correlation with TDS (r=0.512**) and non-significant positive correlation with NO_3^- (r=0.220) and TDS (r=0.151) Yadav, R.K. (2012) Ground

Water have also reported the similar result in of Jaipur City (Rajasthan, India)

SAR shows significant negative correlation with Cl^- (r=-0.362*) and Ca + Mg^{2+} (r=-0.972**) and non-significant negative correlation with NO_3^-, K^+, and TDS in ground water. In addition to the RSC, the excess sum of carbonate and bicarbonate in ground water over the sum of calcium and magnesium also influences the suitability of ground water for irrigation. Continued usage of high residual sodium carbonate water affects the yields of crops. RSC shows significant negative correlation with Cl^- (r= -0.362*) and Ca^{2+}+Mg^{2+} (r= -0.972**) and non-significant negative correlation with NO_3^-, K^+, and TDS in the ground water. Yadav K. K., (2011) similar result given in Agra city.

Table 5: Correlation between Water Quality Parameters.

	pH	EC	NO_3^-	TDS	Cl^-	K^+	CO_3^{2-}	HCO_3^-	Na^+	Ca^{2+} + Mg^{2+}	SAR	RSC
pH	1											
EC	-0.004	1										
NO_3^-	-0.269	0.123	1									
TDS	0.151	-0.375*	0.220	1								
Cl^-	0.064	0.173	0.214	0.363*	1							
K^+	-0.140	0.144	0.618**	0.081	0.208	1						
CO_3^{2-}	0.324*	-0.098	-0.082	0.066	-0.259	-0.121	1					
HCO_3^-	-0.070	0.250	-0.102	-0.132	-0.035	-0.107	-0.534**	1				
Na^+	-0.049	-0.263	-0.062	-0.115	-0.105	0.138	-0.203	0.114	1			
Ca^{2+}+Mg^{2+}	-0.182	0.002	0.038	-0.020	0.362*	0.116	-0.321*	-0.061	-0.156	1		
SAR	-0.061	-0.268	-0.089	-0.175	-0.195	0.083	-0.125	0.081	0.979**	-0.262	1	
RSC	0.171	0.057	-0.068	-0.012	-0.363*	-0.144	0.219	0.290	0.165	-0.972**	0.260	1

Note: '*' represents significant at 0.05 level and '**' represents significant 0.01 level.

6. Conclusion

In the ground water, pH shows significant positive correlation with CO_3^{2-} (r=0.324*) .In the ground water, EC shows negatively significant correlation with TDS (r=1.00**) and non-significant positive correlation with NO_3^- (r=0.220) and TDS (r=0.151). SAR shows significant negative correlation with Cl^- (r=-0.362*) and Ca + Mg^{2+} (r=-0.972**). RSC shows significant negative correlation with Cl^- (r=-0.362*) and Ca^{2+}+Mg^{2+} (r=-0.972**) and non-significant negative correlation with NO_3^-, K^+, and TDS in the ground water.

The present study may help to improve groundwater resource assessment management, achieves social, economic and environmental benefits to support governance and policy. The results have shown that the ground water of study area has been in good in IWQI and maximum samples (82.5%) fall under slightly unsustainable for irrigation. This study can offer the requisite information for the authority to pursue the sustainable approaches on groundwater management and contamination prevention. As the poor quality of irrigation water of restricted for selection of the crops for study area, and only resistant crops can grow successfully. Therefore, it is strongly needed to improved irrigation practices and develops resistant varieties of crop that can grow without any yield loss in study area.

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