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A Groundwater Quality Assessment for Irrigation in Katthiwada Area, Alirajpur District, Madhya Pradesh

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Abstract:
An elaborate account of groundwater quality estimation for irrigation in Katthiwada area Alirajpur district Madhya Pradesh is presented in this paper. The selected 20 groundwater samples from open-dug wells have been subjected to chemical analysis by standard techniques of graphic representation in tabular form. The analysis of dug wells samples for determination of Physico-chemical parameters indicates that all groundwater samples are colourless, odourless, and tasteless with pH (7.0 -8.7), Electrical conductivity (238-1555), Total dissolved solids (450 -1180) mg/l. The chemical parameters involve the determination of the ionic concentration of cations - Calcium (0.89 to 3.04 mg/l), Magnesium (0.49 to 3.12 mg/l), potassium (0.01 to 0.13 mg/l) and sodium (0.95 to 10.35 mg/l) and anion - nitrate (0.56 to 1.45), Hco3 (1.19 to 3.85 mg/l), chloride (0.31 to 5.10) and sulphate (0.02 to 2.68 mg/l). The quality of groundwater for irrigational purposes depends on different chemical parameters such as sodium persent; Kelley's Ratio, Sodium Adsorption Ratio, Residual Sodium Carbonate, and Magnesium-Hazard. U. S. Salinity diagram shows that 19 samples belong to the C2 S1 type (medium salinity – low sodium water), 1 sample represents to C3 S1 type (high salinity – low sodium water) and 1 sample falls into C3 S2. Wilcox diagram shows that 16 samples of the groundwater fall under the excellent to good category, and 4 samples represent the good to permissible categories. The groundwater of the Katthiwada area is suitable for irrigation use.

Keywords: *Chemical Quality, Groundwater, Irrigation, Katthiwada, Madhya Pradesh.*

1. INTRODUCTION

Groundwater is a precious natural resource all over the globe. Groundwater quality assessment plays a noteworthy role in the planning the groundwater resource management. The physical analysis includes an examination of the colour, odour, taste, temperature, turbidity, pH, and specific or electrical conductivity. The occurrences of dissolved gases and radionuclide's in groundwater have been noticed in quality analysis (Walton 1970, Todd 1980). Physico–chemical interaction of groundwater and rocks results in the principal solubility of minerals of the parent rocks in the groundwater system. The mineral content increase in groundwater as it moves along until a balance or equilibrium of dissolved substance is obtained (Charlu and Dutt 1982). Groundwater contains higher concentrations of dissolved constituents than surface water. Changes in the concentration of certain constituents may be natural or anthropogenic. Groundwater quality characteristics are affected by the downward movement of water in the recharge areas and lateral movement through aquifers (Linsley, et. al, 1982). The existence of total dissolved salts in water is determined by

chemical analysis. These dissolved salts in water dissociate into electrically charged particles known as the ions having positive charge known as cations namely, Calcium, Potassium, and ions with negatively charged ions, which are identified as anions, Calcium carbonate (Johnsons, 1983). The type and concentration of the dissolved salts in the water of an aquifer system determine the suitability of groundwater for irrigation, domestic water supply, industrial purposes, livestock watering and other uses (Todd, 2001). The physical, chemical, and bacteriological properties of groundwater are delineated by quality envisage, field observation regarding the source and environment of groundwater occurrence, source, pollution and other related aspects that have a bearing on the quality of groundwater. A few properties such as the temperature and pH have been noted in the field (Karanth 2003).

1.1 Location of Study Area

The present study area situated in Katthiwada (latitude 22 °25'to 22°30 N and longitude 74°5' to 74°15'E) in Alirajpur district, Madhya Pradesh (Survey of India Toposheet No 46J/3). Physiographically, Katthiwada area is characterized by the hilly region revealing a typical undulating topography with plain area. The temperature ranges from 10° C to 50°C. The climate of the area is typical monsoon type. The area is approachable by the road throughout the year.

1.2 Geology of Study Area

In India, the Jhabua region reveals the presence of rocks, which range from the Archaean to Recent. Regional geology and geological set-up of the Katthiwada sector in the Alirajpur district comprise rocks of the Aravali group, Lametta and Bagh Beds, Deccan Traps, Alluvium and laterite. Katthiwada area is characterized by the presence of the Aravali group (Phyllites, Quartzes, Granites, Amphibolites, Dolomite limestone, volcanic lava flows, and Intrusive dolerite). The structural features include the presence of faults and joints.

2. MATERIALS AND METHODS

The general methodology includes groundwater sample collection in the study area, and the procedure of physico–chemical analysis of collected water samples in the laboratory has been elaborated and described herein. The method of groundwater sample collection for the determination of quality depends on the nature of the problem. The common procedure of collection of water samples, in practice, involves the following steps:

1. Selection of sampling site
2. Frequency sampling
3. Sampling equipment
4. Instruction of sampling

Twenty dug well water samples have been collected in bottles of 1-liter capacity. Bottles were properly rinsed prior to sampling and tightly sealed after the collection of water. Labels indicating the location of samples, type of well, no. of sample and date of collection, have been placed on the respective bottles. A few drops of acetic acid were added to all sampling bottles n order to avoid contamination. Sampling bottles were placed in a container and transported to a laboratory for chemical analysis.

Techniques for collection, preservation, analysis and interpretation described by Thatcher (1968), Wolton (1970), Brown et. al. (1970), I.C.M.R. (1975), Hem (1959), Todd (2001), Karanth (2003) and others have been employed in present work. Determination of different cations (Ca, Mg, Na, and K) and anions (Cl, So4, Co3, Hco3) in groundwater samples of the study area have been conducted by following the standard procedure of the chemical analysis of water samples. Values of sodium and potassium were determined by using a flame photometer. The method of volumetric analysis has been carried out for the determination of calcium, magnesium, carbonate, bicarbonate, chloride and total hardness. pH and electrical conductivity values were determined by using a pH meter and conductivity meter respectively.

Ionic concentrations (cations and anions) of groundwater are generally measured in ppm (parts per million) or mg/l (milligrams per liter). These values are also expressed as epm (equivalent per million) or meq/l (mili equivalent per liter).

Table 1: Physical Parameters of Dug Well Water Samples of study Area

S No.	Location	Colour	Odour	Taste	Turbidity	EC	pH	TDS
1	Indlawat	Colourless	Odourless	Tasteless	8.5	349	8.5	610
2	Wadoi C	Colourless	Odourless	Tasteless	4.9	418	8.2	490
3	Wadoi B	Colourless	Odourless	Tasteless	5.2	340	8.7	840
4	Jetpur	Colourless	Odourless	Tasteless	5.5	549	7.8	630
5	Bej	Colourless	Odourless	Tasteless	6	472	8.5	800
6	Golamba	Colourless	Odourless	Tasteless	8	401	8.2	710
7	Kastpani	Colourless	Odourless	Tasteless	9	429	7.5	900
8	Want	Colourless	Odourless	Tasteless	10	412	8.2	930
9	Rampura	Colourless	Odourless	Tasteless	8	307	8.0	1010
10	Keory	Colourless	Odourless	Tasteless	7	449	7.0	1020
11	Kaucha	Colourless	Odourless	Tasteless	9	1014	7.5	1180
12	Nimbriwat	Colourless	Odourless	Tasteless	8	326	8.1	510
13	Bhokria	Colourless	Odourless	Tasteless	6.7	489	7.2	530
14	Ghodiyadara	Colourless	Odourless	Tasteless	8	446	7.8	525
15	Dhayana	Colourless	Odourless	Tasteless	8.1	238	7.9	910
16	Bholwat	Colourless	Odourless	Tasteless	8.7	362	8.2	730
17	Kusumba	Colourless	Odourless	Tasteless	8.1	584	8.2	450
18	Lakhawat	Colourless	Odourless	Tasteless	8.2	1555	8.5	910
19	Havelikheda	Colourless	Odourless	Tasteless	9.2	396	8.5	950
20	Koutharmahura	Colourless	Odourless	Tasteless	8.0	366	8.0	930

Table 2: Chemical Quality Parameters of Groundwater Samples of Dug Wells in study Area. (Value Expressed in ppm)

Well no	Location	Ca	Mg	K	Na	No_3	Co_3	Hco_3	Cl	So_4
1	Indlawat	48	30	1.1	28	28	-	122	28	O2
2	Wadoi ©	22	9	1.7	37	21	-	122	53	05
3	Wadoi (B)	32	19	2.3	30	27	-	146	25	03
4	Jetpur	33	13	1.8	37	35	-	235	50	02
5	Bej	24	06	3.6	32	40	-	134	78	15
6	Golamba	61	12	3.4	22	45	-	165	21	12
7	Kasatpani	38	38	1.2	44	50	-	165	35	07
8	Want	32	36	0.3	23	41	-	165	35	09
9	Rampura	20	27	0.7	23	42	-	146	18	02
10	Keory	21	16	1.2	36	43	-	207	28	05
11	Kaucha	90	11	2.3	76	35	-	73	181	129
12	Nimbriwat	24	18	2.0	35	48	-	128	21	05
13	Bhokria	28	10	0.6	37	58	-	226	28	02
14	Ghodiyadara	50	12	1.1	25	50	-	177	25	01
15	Dhyana	20	12	2.3	24	40	-	85	14	02
16	Bholwat	26	21	5.4	36	48	-	134	18	Nil
17	Kusumba	30	11	0.6	28	90	-	165	46	03
18	Lakhawat	46	24	0.9	238	70	-	92	404	72
19	Havelikheda	18	11	0.7	28	75	-	159	18	02
20	Koutharmahura	22	13	0.4	35	80	-	140	11	01

Groundwater Quality for Irrigation Purpose

The suitability of groundwater for irrigation is dependent on the effects of the mineral constituents of water on both the plant and soil (Richards, 1954, Wilcox, 1955). Several chemical constituents affect the suitability of water for irrigation and important features are described by Karanath (2003) as.

1. Total concentration of soluble salts (which is generally associated to the specific conductance of water)
2. The comparative proportion of sodium to calcium and magnesium.
3. The concentration of boron
4. The comparative proportion of bicarbonate to calcium and magnesium.

Particular water can be used without harmful effects such as water table, topography, climate, type of crop, and others. When present beyond a certain limits, salts in water useful for irrigation can harm the growth of plants by toxicity, or by varying soil properties. The Soil with low permeability, shallow water table, flat topography and arid climates favour increase of salts within the root zones of plants. Total dissolved solids contents are measured in terms of specific electrical conductance give the salinity hazard of irrigation water. Besides the salinity hazards ,excessive sodium content in water renders it unsuitable for soils containing exchangeable C^{++} and Mg^{++} ions. if percentage of Na^{+} to Ca^{+++} Mg^{+++} Na^{+++} is considerably above50 in irrigation waters, soils containing exchangeable calcium and magnesium take up sodium and permeability of soils (Karanth, 2003). An elaborate account of groundwater quality estimation for irrigation in the Katthiwada area of Alirajpur district Madhya Pradesh is presented in this paper.

The purpose of this paper is to provide an in-depth study of groundwater quality estimation in the Katthiwada area of Alirajpur district Madhya Pradesh for irrigation use.

Sodium Percent (Na %)

Sodium concentration plays an essential role for classifying water to determine feasibility for irrigation water. Sodium percentage is expressed by using equation (Todd, 2010).

$$\text{Sodium Percent (Na \%)} = \frac{(Na + K) \times 100}{(Ca + Mg + Na + K)}$$

Excessive sodium percentage in irrigation water will reduce its Base Exchange reaction with soil, where Calcium and Magnesium in soil are replaced by sodium. So appropriate predictions of this exchange reaction are possible and then effect does not become important until the percent sodium exceeds 50%. Wilcox (1948, 1955) has classified water for agriculture utility based on percent sodium (Na %) as well as electrical conductivity (Ec) as expressed in table 3.

The Sodium percentage values ranges from 11.18 to 70 (Table 3). The value of Sodium percentage was not exceeding 60% in irrigational waters. The sodium percentage of 19 groundwater samples in study area is under 60%. Only one groundwater sample in Lakhawat village was found under higher value of sodium percentage.

Residual Sodium Carbonate (R.S.C.)

The Residual Sodium Carbonate (R.S.C.) is known as “Eaton Index and is used to express carbonate and bicarbonate hazards on water quality. It is represented by the following expression:

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

Concentration of all ions is expressed in equivalent per million (epm). It has been recorded as water having excess ions of carbonate and bicarbonate than calcium and magnesium will yield much greater alkali formation as compared to its sodium absorption ratio and as a result permeability of soil is decreased (Eaton, 1950).

Sodium Adsorption Ratio (S.A.R)

In irrigated water, Sodium hazard is denoted by determining sodium absorption ratio (SAR) by use of following expression -

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

The concentration is exhibited in milli equivalents per liter .Classification of irrigation water in respect to salinity and sodium hazards are described by Richards (1954). The SAR values range from 0.438 to 10.19 representing that all the 20 groundwater samples are suitable for irrigation uses (Table 3).

Kelley' S Ratio

Sodium level is measured as against the Calcium and Magnesium as Kelley's ratio. This ratio helps in rating irrigation water (Kelley, 1946, Paliwal, 1967). Kelley's ratio is represented as –

$$\text{Kelley's Ratio} = \frac{Na}{Ca+Mg}$$

The determine values of Kelley's ratio range from 0.219 to 2.45 the vales exhibiting that the all groundwater samples are safe for irrigational application.

Mg –Hazards

The magnesium ratio is an expression of the excess quantity of Magnesium over Calcium and Magnesium amount where otherwise normally stage of Calcium and Magnesium will be in a state of balance. The excess concentration of Magnesium affects the quality of soil resulting in poor development of crops. The impact of Magnesium hazard on irrigation water is calculated by adopting the procedure proposed by Paliwal (1972). Mg hazard is estimated by the use of the following expression-

$$\text{Mg –hazards} = \frac{Mg \times 100}{(Ca+Mg)}$$

Generally, the Mg hazard value in irrigational water was not exceeding 50%. The observed value of 20 groundwater samples ranges from 16.75 to 68.99. The 14 groundwater samples were under the safe category and 6 groundwater samples show a higher Mg hazard ratio. The higher Mg hazard ratio in groundwater is unsafe for plants' health. Thus the groundwater should be used after adding up some amount of lime powder.

Table 3: Indices computation by using ionic concentration values for calculation of chemical parameters of dug wells

S. No	Kelly's Ratio	Sodium Percent (Na %)	Sodium Adsorption Ratio	Residual Sodium Carbonate	Mg Hazards
1	0.250	20.39	0.438	-2.863	50.740
2	0.875	56.11	1.135	0.162	40.283
3	0.413	30.14	1.46	-0.766	49.461
4	0.592	37.87	1.95	1.136	39.373
5	0.832	46.75	2.14	0.506	29.171
6	0.237	20.55	0.95	-1.326	24.491
7	0.381	27.92	1.70	-2.317	62.238
8	0.219	18.09	0.94	-1.853	64.976
9	0.310	24.00	1.11	-1.853	68.996
10	0.662	40.59	2.03	1.029	55.691
11	0.612	38.40	2.84	-4.199	16.756
12	0.568	37.01	1.86	-0.58	55.285
13	0.725	42.25	2.16	1.485	37.043
14	0.312	24.38	1.16	-0.581	28.345
15	0.525	35.69	1.49	-0.592	49.722
16	0.517	36.04	1.80	-0.828	57.109
17	0.507	33.92	1.57	0.303	37.650
18	2.425	70.85	10.19	-2.762	46.240
19	0.675	40.66	1.81	0.804	50.166
20	0.702	11.18	2.07	0.128	49.353

4. RESULTS AND DISCUSSION

U.S. Salinity Diagram

U.S. Salinity diagram has been proposed by U. S. Salinity Laboratory Staff (1954), specifically, by Wilcox (1955). Total dissolved solids are measured as specific/electrical conductivity in micro–mhos/cm at 25 C and indicate the salinity hazards. Sodium hazards are expressed in terms of the Sodium Adsorption Ratio (SAR). The plots of S.A.R. and EC on the U.S. Salinity diagram exhibit sodium and salinity hazards (Figure 1).

The plots on U.S. Salinity diagram (Figure.1) indicate that 18 groundwater samples are belonging to C2 S1, 1 sample refers to C3 S1 and 1 sample represents C3 S2 class. In general, groundwater is suitable for irrigation purposes in the study area.

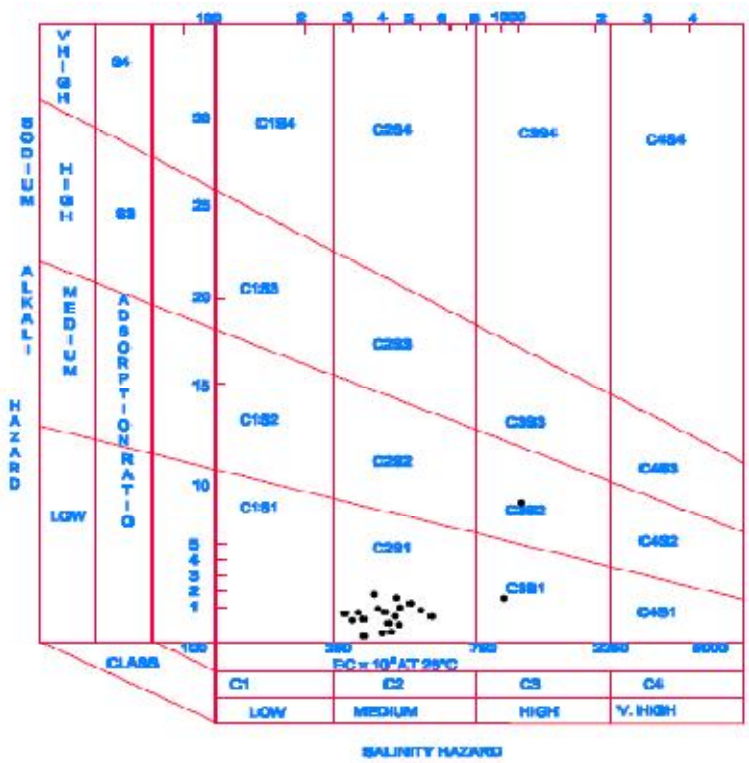

Figure 1: U.S. Salinity diagram representing plots of Sodium Absorption and Electrical Conductivity indicating groundwater suitability for irrigation. (After Richards, 1957)

Wilcox diagram

The diagram is used to determine the classification of water for irrigation purposes. Wilcox (1955) suggested that groundwater may be classified into five types:

(a) Excellent to good
(b) Good to permissible
(c) Permissible to doubtful
(d) Doubtful to unsuitable and
(e) Unsuitable.

Wilcox diagram indicates that 16 samples belong to the excellent to a good category, 3 samples are preferable to the category good to permissible and 1 sample is indicating permissible to doubtful category.

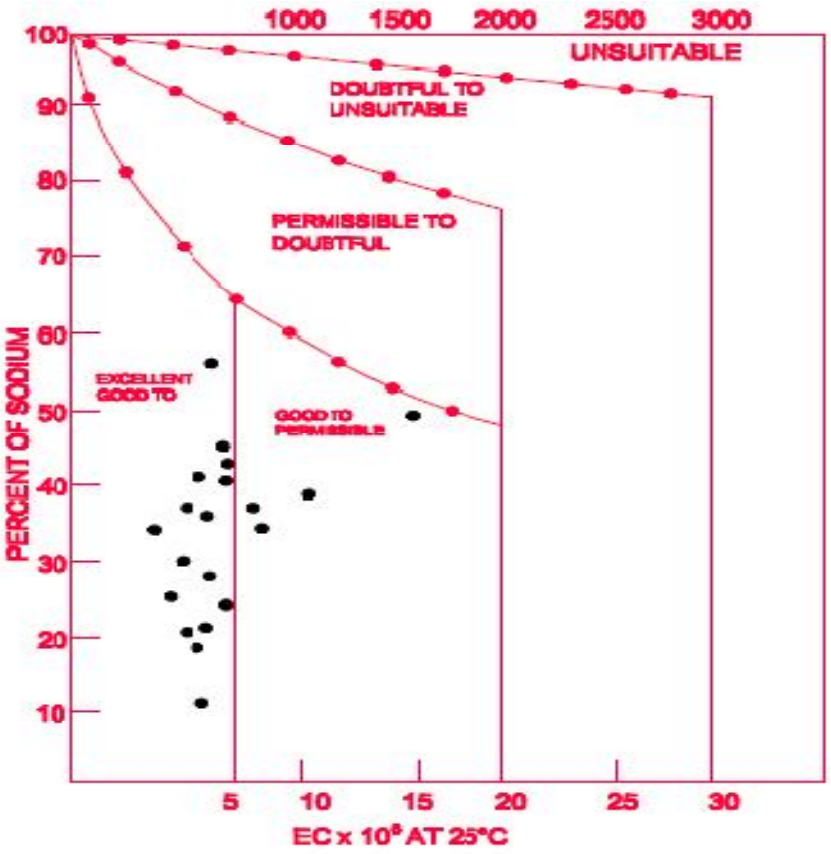

Figure 2: Wilcox diagram exhibiting plots of Sodium Percent and Electrical Conductivity values for determination of Irrigation quality (After Wilcox 1955).

5. CONCLUSION

The calculated values of chemical parameters such as, sodium percent; Kelley's Ratio, Sodium Adsorption Ratio, Residual Sodium Carbonate, and Magnesium-Hazard have been determined and these values have been plotted on U S Salinity diagram specify that 19 samples belong to the C2 S1 type (medium salinity – low sodium water), 1 sample represents to C3 S1 type (high salinity – low sodium water) and 1 sample fall in C3 S2. Wilcox diagram shows that 16 samples of the groundwater are fallen under the excellent to good category, and 4 samples represent the good to permissible categories. Based on chemical analysis of the groundwater sample of the Katthiwada area is suitable for irrigation use.

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