International Journal of Multidisciplinary Research and Development
Online ISSN: 2349-4182, Print ISSN: 2349-5979, Impact Factor: RJIF 5.72
www.allsubjectjournal.com
Volume 3; Issue 9; September 2016; Page No. 79-86

Chemical quality delineation of groundwater for irrigation purpose in Datana-Palkhanda sector of Ujjain district, Madhya Pradesh, India

[1] Pankaj Barbele, *[2] Pramendra Dev

[1] School of studies in Earth science, Vikram University, Ujjain, Madhya Pradesh, India
[2] Adarsh Vikram Nagar, Ujjain, Madhya Pradesh, India

Abstract
The present paper deals with the chemical quality delineation of groundwater of the Datana-Palkhana Sector, Ujjain district of Madhya Pradesh. The groundwater samples collected from 40 open dug wells, during the post-monsoon season have been analyzed by adopting standard methods of chemical analysis. The physical parameters of groundwater indicate that all samples are colourless, odourless, and tasteless. The other physical parameters include the pH (7.00 - 8.60), Electrical conductivity (398 - 2090) and Total Dissolved Solids (352 - 1432 ppm). The chemical analysis involves determination of ionic concentration of Ca (38 - 170 ppm), Mg (21- 84 ppm), K (0.9 – 62.24 ppm), Na (20 – 193 ppm), Cl (42- 368 ppm), SO_4 (11- 223 ppm), HCO3 (207 - 497 ppm), NO_3 (0.9 – 39.90 ppm), and F (0.3 – 1.36 ppm). The suitability of groundwater for irrigation use evaluated based on sodium percent; Kelley's Ratio, Sodium Adsorption Ratio, Residual Sodium Carbonate, and Magnesium-Hazard. The plots of chemical parameters on U. S. Salinity diagram indicate that 09 samples belong to the C_2 S_1 type (medium salinity – low sodium water) and 31 samples represent to C_3 S_1 type (high salinity – low sodium water). Wilcox diagram exhibits that most 09 samples of the groundwater characterize the excellent to good, 30 samples represent the good to permissible and 1 sample is preferable to doubtful to unsuitable categories. In general, the groundwater of the study area is suitable for the irrigation application.

Keywords: Chemical Quality, Groundwater, Irrigation, Datana-Palkhanda, Ujjain, Madhya Pradesh

Introduction

The groundwater is an important natural resource; which occurs in most of the geological formations under the earth surface. In tropical regions, groundwater plays a significant role in context of the fluctuating and increasing contamination of groundwater. The agriculture is the main source of livelihood of the population and groundwater is the major source of irrigation. Groundwater gets contaminated with a variety of pollutants generated from varied sources such as agriculture, domestic, and industrial. The availability of this important natural resource has been taken for granted increasing groundwater use and pollution generation has crossed the sustainable limits in many parts, due to fast changing land use pattern. There has been tremendous increase in demand for fresh water due to population growth and intense agriculture activities. With rapid increase in population and growth of industrialization, groundwater quality is being increasingly vulnerable by disposal of urban and industrial solid waste (Raju *et al*., 2011) [14].

The quality of groundwater is resultant of all the processes and reactions that have operated on the water from the moment it condensed in the atmosphere to the time it is discharged by a well. Hence, the quality of groundwater differs from place to place, with the depth of water table, and from season to season and is principally controlled by the extent and composition of dissolved solids. The worldwide, aquifers are experiencing an increasing threat of pollution from urbanization, industrial development, agricultural activities and mining enterprises. In recent years, an increasing threat to groundwater quality due to human activities has become of great importance (Reddy *et al*, 2012; Deshpande and Aher, 2012) [15, 6].

The rapidly increasing trend of population is generating a number of environmental problems including the degradation of groundwater quality. The presence of any ion in groundwater in excess of prescribed limits is harmful for human health. In the present work, the chemical analysis of groundwater has been carried out with the main objective to delineate the suitability of groundwater for the irrigation purpose.

Location of Study Area

The present study area constitutes a part of the Kshipra River Basin in the vicinity of South -Western part of Ujjain district of Madhya Pradesh, which is one of the holy religious cities of ancient India. The study area is confined to the latitudes - 23°00' and 23°07' N and longitudes 75°45' and 76°00 E (Survey of India Toposheet No. 46M/16). The climate of the study area is tropical to sub-tropical. The temperature ranges from 4°C to 45°C, with the average of 29° C, The rainfall data indicate a range from 563.8 mm. to 2019.0 mm, with an annual average value of 1010.4 mm. soil is of three types such as red soil, black cotton soil, and alluvial soil.

Geological Setup of Study Area

The present study area forms a part of the Malwa plateau exhibiting terraced or strap like structures with irregular isolated hills and represents uneven to undulating topography with a gentle slope towards North. The minimum elevation is 490 m a. m.s.l. and the maximum elevation of the area is noted as 532 m a.m.s.l. Deccan Trap group covers an extensive area consisting of 02 basaltic lava flows with thickness of 32 m. The study area belongs to Middle division of the Deccan Trap.

The low lying plains are restricted to the major river valleys in the northern parts, and the rise in elevation is very gradual. The first geological account has been given by Blanford (1869) and followed by several workers. Barbele (2012) [3] carried out hydrogeological studies in Narwar– Palkhanda area.

Materials and Methods

The 40 water samples were collected from dug wells in the study area for analysis of various physical-chemical parameters. One liter of water samples were collected in polyethylene bottles from various wells during the month of November-December. The pH was measured by using portable pH meter and EC was measured by EC meter in the field. The ionic concentrations of sodium, calcium, magnesium, potassium, carbonate, bicarbonate, chloride, sulphate and nitrate were determined by using the standard laboratory methods. The standard methods of ground water quality analysis have been given by the American Public Health Association (APHA, 2005) [2], and other workers. The analytical data can be used for the classification of water for utilitarian purposes and for ascertaining various factors on which the chemical characteristics of water depend.

Table 1: Physical Parameters of open Dug Well Water Samples of Study Area.

S. No.	Location	Colour	Odour	Taste	pH	TDS	Sp. Cond.(EC)
1	Datana	Colourless	Odourless	Tasteless	7.6	1011	951
2	Matana Bhuj.	Colourless	Odourless	Tasteless	7.3	824	979
3	Chandesra	Colourless	Odourless	Tasteless	7.4	671	1209
4	Chandesri	Colourless	Odourless	Tasteless	7.2	885	1196
5	Kithodo rao	Colourless	Odourless	Tasteless	8.0	694	1085
6	Kithodo rao	Colourless	Odourless	Tasteless	7.5	654	480
7	Matana khurd	Colourless	Odourless	Tasteless	7.8	771	398
8	Narwar	Colourless	Odourless	Tasteless	8.3	799	549
9	Narwar	Colourless	Odourless	Tasteless	7.9	398	516
10	Piplodadwaricadhish	Colourless	Odourless	Tasteless	7.6	370	531
11	Chainpura	Colourless	Odourless	Tasteless	8.4	541	557
12	Madhopura	Colourless	Odourless	Tasteless	8.3	748	1022
13	Madhopura	Colourless	Odourless	Tasteless	8.1	698	1090
14	Piplodadwaricadhish	Colourless	Odourless	Tasteless	7.5	812	1009
15	Palkhanda	Colourless	Odourless	Tasteless	7.1	738	1002
16	Palkhanda	Colourless	Odourless	Tasteless	7.4	1094	1710
17	Kachanaria	Colourless	Odourless	Tasteless	8.2	717	992
18	Kachanaria	Colourless	Odourless	Tasteless	7.9	718	1122
19	Harnaoda	Colourless	Odourless	Tasteless	8.1	863	984
20	Bolasa	Colourless	Odourless	Tasteless	7.3	974	967
21	Bolasa	Colourless	Odourless	Tasteless	7.7	1050	1640
22	Bhanwari	Colourless	Odourless	Tasteless	7.8	826	625
23	Bhanwari	Colourless	Odourless	Tasteless	7.9	594	928
24	Munjakheri	Colourless	Odourless	Tasteless	7.5	789	659
25	Munjakheri	Colourless	Odourless	Tasteless	8.3	764	1194
26	Samadi	Colourless	Odourless	Tasteless	7.4	848	1041
27	Gamri	Colourless	Odourless	Tasteless	7.6	943	1520
28	Tigrria sancha	Colourless	Odourless	Tasteless	7.3	1009	1460
29	Chimli	Colourless	Odourless	Tasteless	7.8	1105	1005
30	Kalyanpura	Colourless	Odourless	Tasteless	7.5	821	995
31	Kalyanpura	Colourless	Odourless	Tasteless	8.5	649	973
32	Khokaria	Colourless	Odourless	Tasteless	7.0	530	978
33	Dewarkheri Khurd	Colourless	Odourless	Tasteless	7.7	953	1502
34	Alampur	Colourless	Odourless	Tasteless	7.3	998	1432
35	Alampur	Colourless	Odourless	Tasteless	8.6	352	550
36	Kasampura	Colourless	Odourless	Tasteless	7.2	911	1017
37	Kasampura	Colourless	Odourless	Tasteless	7.6	878	1372
38	Karcha	Colourless	Odourless	Tasteless	7.5	879	989
39	Karcha	Colourless	Odourless	Tasteless	7.6	1432	2090
40	Khajuria Rewari	Colourless	Odourless	Tasteless	7.1	622	973

Table 2: Quality Parameters of open Dug Well Water Samples of Study Area. (Value expressed in ppm)

S. No.	Location /Ions	Cations					Anions					
		Na	K	Ca	Mg	Fl	Cl	SO_4	CO_3	HCO_3	NO_3	TH
1	Datana	153	2.9	98	66	1.22	128	127	Nil	410	18.75	690
2	Matana Bhuj.	171	2.29	108	62	0.90	124	139	Nil	322	26.27	422
3	Chandesra	91	4.89	105	48	0.89	166	128	Nil	319	19.38	617
4	Chandesri	98	1.91	110	44	0.72	149	134	Nil	322	14.99	665
5	Kithodo rao	58	1.3	112	31	0.60	106	120	Nil	314	11	408
6	Kithodo rao	179	3.03	100	51	0.68	172	88	Nil	217	35.09	428
7	Matana khurd	145	1.06	118	60	0.82	118	19	Nil	343	22.91	495
8	Narwar	58.1	39.91	144	33	0.63	138	113	Nil	389	31.93	477
9	Narwar	96.10	48.08	129	47	0.99	135	182	Nil	333	29.07	562
10	Piploda dwa.	89.15	62.24	116	43	1.19	106	234	Nil	443	20.98	458
11	Chainpura	76	31.29	96	32	0.47	42	117	Nil	425	11.39	405
12	Madhopura	59.88	34.14	148	27	0.52	54	68	Nil	339	22.11	464
13	Madhopura	63	1.5	111	34	0.5	111	110	Nil	332	10	428
14	Piploda dwa.	41.15	20.81	120	29	0.71	47	77	Nil	269	25.04	436
15	Palkhanda	97.11	10.66	124	61	1.36	117	122	Nil	407	19.21	578
16	Palkhanda	143	3.2	106	60	0.8	258	132	Nil	410	18	515
17	Kachanaria	105	3.27	139	48	0.88	130	126	Nil	302	26.26	352
18	Kachanaria	66	1.1	90	48	0.9	109	83	Nil	368	12	419
19	Harnaoda	163	3.81	106	39	0.39	129	131	Nil	314	24.08	395
20	Bolasa	165	2.00	126	73	0.43	123	93	Nil	299	20.26	459
21	Bolasa	92	0.9	150	54	0.5	162	168	Nil	440	24	600
22	Bhanwari	186	1.72	94	66	0.51	188	97	Nil	207	28.02	433
23	Bhanwari	81	2.7	45	41	0.7	116	34	Nil	300	5.6	301
24	Munjakheri	170	1.39	98	67	0.49	143	90	Nil	329	23.30	299
25	Munjakheri	71	1.6	101	47	0.9	129	72	Nil	320	3.9	449
26	Samadi	172	3.18	89	59	0.40	209	88	Nil	316	21.50	248
27	Gamri	178	2.99	91	50	0.53	178	71	Nil	213	39.70	416
28	Tigrria sancha	184	2.22	101	70	1.19	119	78	Nil	223	18.10	441
29	Chimli	169	3.46	105	65	0.95	127	69	Nil	318	22.20	465
30	Kalyanpura	158	1.68	122	58	0.86	116	15	Nil	348	28.50	445
31	Kalyanpura	193	3.5	170	80	0.8	368	191	Nil	432	29	760
32	Khokaria	20	1.41	112	52	0.93	120	110	Nil	327	21.90	423
33	Dewarkherikh.	188	1.77	127	68	1.12	168	116	Nil	368	15.61	637
34	Alampur	194	2.27	114	54	1.27	137	123	Nil	497	18.29	624
35	Alampur	77	2.4	38	21	0.9	106	11	Nil	216	0.9	184
36	Kasampura	154	2.81	93	60	1.16	121	129	Nil	404	14.91	605
37	Kasampura	104	8.3	86	56	1.0	176	58	Nil	424	3.1	448
38	Karcha	177	1.80	110	75	0.90	133	134	Nil	417	38.21	629
39	Karcha	198	2.6	141	84	1.0	363	190	Nil	462	38	696
40	Khajuria Rewari	160	2.07	120	45	1.08	138	120	Nil	378	18.59	474

Groundwater Quality for Irrigation

The concentration of dissolved constituents in groundwater determines its quality for irrigation use. The suitability of groundwater for irrigation depends on the effects of the mineral constituents in water on both the plants and soils (Richards, 1954) [16]. The higher salt concentration in irrigation water causes an increase in soil solution osmotic pressure (Thorne, and Peterson, 1954) [17]. The effects of salts concentration on soil causing changes in soil structure, permeability and aeration in directly affect plants growth. Since plant roots extract water osmosis, the water uptake of plants decreases. The salts also affect the soil structure, permeability and aeration, which indirectly affect the plants growth (Todd, 1980, 2001) [18, 19]. The quality of water, type of soil, and cropping practices play an important role for a suitable irrigation practice. Presence of excessive amounts of dissolved ions in irrigation water affects plants and agricultural soil, reducing the productivity. The physical effect of these ions is to lower the osmotic pressure in the plant structural cells, thus preventing water to reach the branches and leaves of the plant. The chemical effect disrupt plant metabolism. Water quality problems in irrigation include indices for salinity, chlorinity, sodicity, and alkalinity (Mills 2003) [11].

The parameters such as Sodium Percentage**,** Kelly's ratio, Sodium Adsorption Ratio (SAR), Residual Sodium Carbonate (RSC), and Magnesium Hazard, have been determined and plotted on Wilcox diagram and U. S. Salinity hazard diagram for delineation of groundwater suitability for the irrigation purpose.

Sodium Percentage

Sodium percentage is widely utilized for evaluating the suitability of water quality for irrigation (Wilcox, 1948) [21]. Excess sodium concentration in groundwater produces the undesirable effects because Na reacts with soil to reduce its permeability and support little or no plant growth (Raju, Ram and Dey, 2009) [13]. The Sodium percentage is computed with respect to relative proportions of cations present in water, where the concentrations of ions are expressed in meq/l, using the following formula:

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

The calculated values of Sodium percentage range from 9 to 48 (Table 3). Generally, Sodium percentage should not exceed 60% in irrigation waters. The sodium percentage of all 40 groundwater samples in study area is less than 60% of Sodium percentage. All samples are safe for irrigation purpose. The higher sodium percentage may be due to the dissolution of minerals from lithological composition, and addition of chemical fertilizers by the irrigation waters (Subba Rao and *et al*. 2002).

Sodium Absorption Ratio (SAR)

The important chemical parameters for estimating the quantity of suitability of water for irrigation as sodium content or alkali hazard for crops, which is expressed in sodium adsorption ratio (SAR). SAR is calculated from the ratio of sodium to calcium and magnesium. Calcium and magnesium ions are important since they are tending to counter the effect of sodium. The higher concentration of SAR leads to breakdown in the physical structure of the soil. Sodium is adsorbed and become attached to soil particles. The soil then become hard and compact when dry and impervious to water penetration. Sodium replacing adsorbs calcium and magnesium is a hazard as it causes damage to the soil structure. The degree to which irrigation water tends to enter into cation exchange reaction in soil can be indicated by the SAR. The SAR recommended by the salinity laboratory of the U. S. Department of Agriculture (Wilcox, 1948) [21] is calculated by using the formula:

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

There is a close relationship between SAR values in irrigation water and the extent to which Na is absorbed by soils. If water used for irrigation is high in Na and low in Ca, the ion-exchange complex may become saturated with Na, which destroys soil structure, because of dispersion of clay particles. As a result, the soils tend to become deflocculated and relatively impermeable. Such soils can be very difficult to cultivate. The sodium hazard is expressed in terms of classification of irrigation water as low (S_1: <10), medium (S_2: 10 to 18), high (S_3: 18 to 26) and very high (S_4: >26).

The SAR values in groundwater samples of the study area range from 0.39 to 3.74 indicating that all the groundwater samples are suitable for irrigation purposes (Table 3).

Magnesium Hazard (MH)

Magnesium is essential for plant growth; however at high content it may associate with soil aggregation and friability (Khodapanah *et al*., 2009) [10]. More Mg+ present in waters affects the soil quality converting it to alkaline and decreases crop yield (Joshi *et al*., 2009) [7]. Mg hazard calculated using the formula.

$$Mg - Hazards = \frac{Mg}{(Ca + Mg)} \times 100$$

Mg hazard values >50 % are considered harmful and unsuitable for irrigation purposes. In the analyzed groundwater samples, the Mg hazard ranges from 23.12 to 53.61 % (Table 3). Out of 40 samples, 9 samples have Mg hazard <50% in the villages of Karcha (52.92), Kasampura (51.51, 51.77), Tigria sancha (53.34), Chimli (50.52), Samdhi (50.52), Munjakheri (52.98), Bhanwari (53.61), Datana (52.57). This high Mg hazard ratio causes harmful effects on plants growth. Therefore the water should be used for irrigation after reducing the Mg hazard ratio by adding suitable amount of lime.

The parameters for delineation of irrigation quality assessment have been determined in the groundwater samples of the study area. The computed values of irrigation parameters for quality delineation of groundwater have been displayed (Table 3).

Table 3: Indices derived from the geochemical parameters of study area.

S. No.	Location Name	Sodium Percent	Sodium Adsorption Ratio	Kelly's Ratio	Residual Sodium Carbonate	Mg Hazards
1	Datana	39	2.92	0.645	-3.6	52.57
2	Matana Bhuj.	43	3.25	0.708	-5.21	48.66
3	Chandesra	30	1.84	0.43	-3.95	42.96
4	Chandesri	32	1.99	0.468	-3.82	39.71
5	Kithodo rao	24	1.25	0.31	-2.992	31.33
6	Kithodo rao	46	3.63	0.847	-5.63	45.64
7	Matana khurd	37	2.71	0.584	-5.16	45.73
8	Narwar	26	1.13	0.254	-3.52	27.4
9	Narwar	34	1.84	0.406	-4.84	37.51
10	Datana	37	1.79	0.415	-2.05	37.91
11	Chainpura	36	1.71	0.444	-0.46	35.44
12	Madhopura	27	1.18	0.27	-4.05	23.12
13	Madhopura	25	1.342	0.329	-2.895	33.55
14	Piplodadwaricadhish	22	0.87	0.214	-3.96	28.46
15	Palkhanda	29	1.78	0.377	-4.52	44.77
16	Palkhanda	38	2.75	0.608	-3.506	48.27
17	Kachanaria	30	1.95	0.419	-5.93	36.24
18	Kachanaria	25	1.397	0.34	-2.408	46.78
19	Harnaoda	46	3.44	0.836	-3.34	37.73
20	Bolasa	37	2.89	0.583	-7.38	48.85
21	Bolasa	25	1.638	0.335	-4.715	37.24
22	Bhanwari	42	3.18	0.709	-6.72	53.61
23	Bhanwari	39	2.102	0.627	-0.701	39.96
24	Munjakheri	42	3.24	0.71	-5.01	52.98
25	Munjakheri	26	1.463	0.347	-2.327	43.41
26	Samadi	45	3.47	0.805	-4.12	52.2
27	Gamri	47	3.72	0.894	-5.16	47.51
28	Tigrria sancha	43	3.44	0.742	-7.13	53.33
29	Chimli	41	3.19	0.695	-5.36	50.52
30	Kalyanpura	39	2.94	0.633	-5.15	43.96
31	Kalyanpura	38	3.218	0.586	-6.517	43.68
32	Khokaria	9	0.39	0.088	-4.5	43.35
33	DewarkheriKhurd	41	3.34	0.685	-5.89	46.89
34	Alampur	46	3.74	0.83	-1.98	43.87
35	Alampur	48	2.488	0.924	0.758	47.66
36	Kasampura	41	3.05	0.699	-2.95	51.51
37	Kasampura	35	2.145	0.508	-1.948	51.77
38	Karcha	40	3.18	0.66	-4.81	52.92
39	Karcha	38	3.262	0.618	-6.373	49.54
40	Khajuria ewari	43	3.28	0.745	-3.49	38.22

The chemical analysis of groundwater of Ujjain study area, indicates that the ground water is suitable for irrigation applications

U S Salinity Laboratory's Diagram

Richards (1954) [16] adopted U S Salinity Laboratory's diagram for assessment of irrigation water, where the value of SAR is plotted against E C. The plots of chemical data of the groundwater samples in the U S Salinity Laboratory's diagram are illustrated (Figure 1). The total concentrations of soluble salts in irrigation water can be classified into low (C_1), medium (C_2), high (C_3) and very high (C_4) salinity classes. The zones (C_1 - C_4) have the value of E C less than 250, 250 - 750, 750 - 2250 µs / cm and more than 2250 µs / cm, respectively. Higher Electric Conductivity in irrigation water creates a saline soil (Richards, 1954) [16].

The 31 groundwater sample points belong to C_3 S_1 class (77.5 %), which exhibits high salinity hazard and low alkali hazards. 9 samples represent C_2 S_1 class (22.5 %) indicating medium salinity and low alkali water (Figure1). The groundwater is favourable for irrigation purpose.

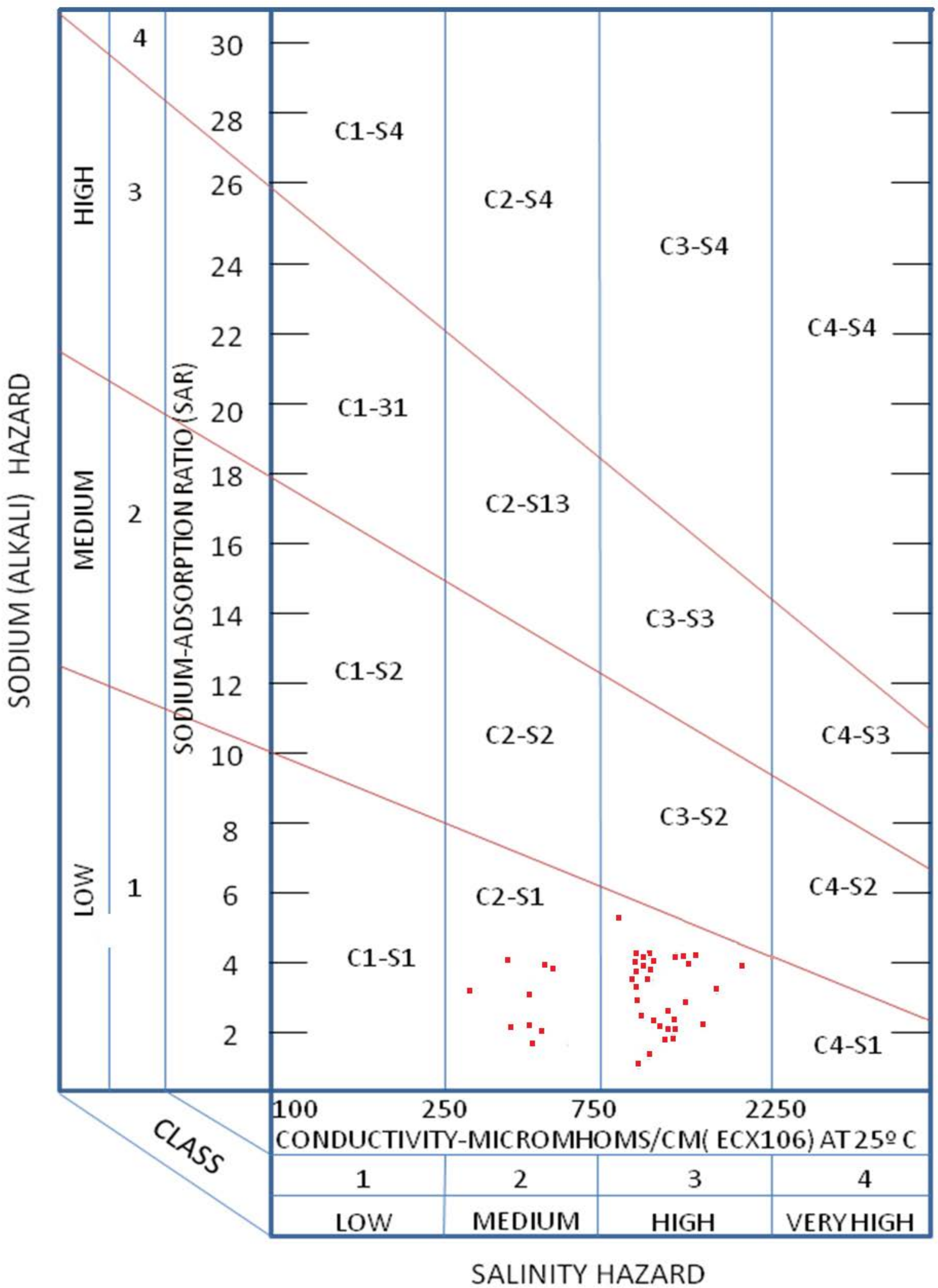

Fig 1: US Salinity Hazard diagram of the Ujjain study area.

Wilcox's Diagram

Wilcox's (1955) classified groundwater for irrigation purposes by correlating percent sodium and electrical conductivity. The groundwater quality for agricultural purpose is mainly depends on percentage of sodium and Electric conductivity. When the concentration of sodium is high in irrigation water, sodium ions tend to be adsorbed by clay particles, displacing Mg and Ca ions by base-exchange process. This exchange process of Na in water for Ca and Mg in soil reduces permeability and eventually results in soil with poor internal drainage. Hence, air and water circulation is restricted during wet conditions, and such soils are usually hard when dry (Collins and Jenkins 1996) [5].

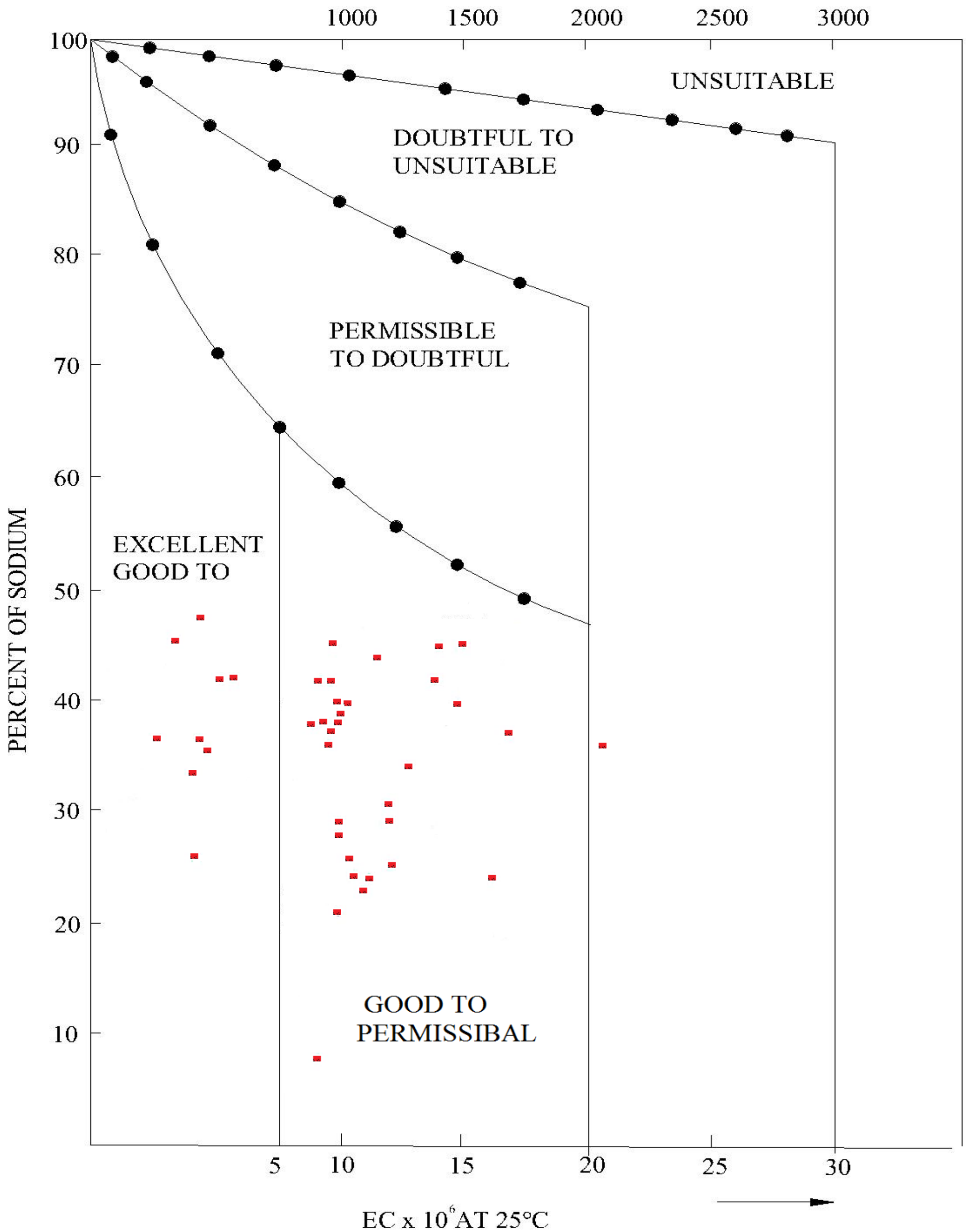

Fig 2: Wilcox's diagram of the study area.

Wilcox's diagram has been is adopted for the classification of groundwater for irrigation purpose, wherein the Electric Conductivity is plotted against Sodium percentage. The data of ground water samples of the study area are plotted on Wilcox diagram (Figure 2). Out of the 40 groundwater samples, 22.5 % of the groundwater samples belong to excellent to good category namely Kithodonrao, Matana Khurd, Narwar, Datana, Bhanwari, Munjakheri and Alampura and 75 % of groundwater samples belong to good to permissible category, for irrigation use. Only one groundwater sample of Karcha village belongs to the doubtful to unsuitable category for irrigation purpose

.

Conclusion

Based on the chemical analysis of groundwater samples of Ujjain study sector, the parameters like, sodium percent; Kelley's Ratio, Sodium Adsorption Ratio, Residual Sodium Carbonate, and Magnesium-Hazard have been determined and the values have been plotted on U S Salinity diagram indicate that 09 samples belong to the C_2 S_1 type (medium salinity – low sodium water) and 31 samples represent to C_3 S_1 type (high salinity – low sodium water). 75% of data are in C_3 S_1 class that iis indicator of moderate quality for the irrigation. The plots on Wilcox diagram exhibit that 09 samples of groundwater characterize the excellent to good class, 30 samples represent the good to permissible and 1 sample refers to the doubtful to unsuitable categories for the irrigation quality. In general, the groundwater of the study area is suitable for the irrigation application.

Acknowledgement

The authors are thankful to Prof. K.N. Singh, Professor and

Head, School of Studies in Earth Science Vikram University Ujjain for providing research facilities. Sincere appreciation is recorded to Mr. Vikas Barbele, Assistant Director, Central Water Commission for his kind help and encouragement.

References

1. Aher KR. Groundwater Quality Studies of Chikalthana area of Aurangabad, Dr. B.A. Marathwada University, Aurangabad (MS) India, Ph.D. Thesis, 2012.
2. American Public Health Association (APHA) Standard method for examination of water and wastewater (21st Ed.). Washington: APHA, AWWA, WPCF. 2005.
3. Barbele P. Hydrogeological Analysis of Deccan Trap Basaltic Flows of Narwar-Palkhanda area, Ujjain District, Madhya Pradesh. Vikram University, Ujjain, Unpubl. M. Phil. Thesis. 2012, 57.
4. Blandford WT. Geology of Tapti and lower Narmada Valley and some adjoining districts. Mem. Geol. Sur. India 1869; 6(3):162-222.
5. Collins R, Jenkins A. The impact of agricultural land use on stream chemistry in the middle hills of the Himalayas, Nepal. J Hydr. 1996; 185:71-86.
6. Deshpande SM, Aher KR. Evaluation of Groundwater Quality and its Suitability for Drinking and Agriculture use in Parts of Vaijapur, District Aurangabad, MS, India, Res. J Chem Sci. 2012; 2(1):25-31.
7. Joshi DM, Kumar A, Agrawal N. Assessment of the irrigation water quality of River Ganga in Haridwar District. Rasayan journal of chemistry. 2009; 2(2):285-292.
8. Kelly WP. Permissible composition and concentration of irrigation waters. Proceedings of ASCE. 1940; 66:607.
9. Kelly WP. Alkali soils—their formation, proper-ties and reclamation. New York: Reinhold. 1951.
10. Khodapanah L, Sulaiman WNA, Khodapanah N. Groundwater Quality Assessment for different Purposes in Eshtehard District, Tehran, Iran. European Journal of Scientific Research. 2009; 36(4):543-553.
11. Mills B. Interpreting water analysis for crop and pasture, file No. FS0334, DPI’s. 2003.
12. Agency for Food and Fiber Sciences, Toowoomba.
13. Raju NJ, Ram P, Dey S. Groundwater Quality in the Lower Varuna River Basin, Varanasi District, Uttar Pradesh, India. Journal of the Geological Society of India. 2009; 7**:**178-192.
14. Raju NJ, Shukla UK, Ram P. Hydrogeochemistry for the Assessment of Groundwater Quality in Varanasi: A Fast-Urbanizing Center in Uttar Pradesh, India. Environmental Monitoring and Assessment, 2011; 173:279-300.
15. Reddy L, Chandra Sekhar, Deshpande SM, Reddy KV Ramana, Aher KR. Hydro Geochemical Processes in the Groundwater Environment of Vemula area, Kadapa District, South India, International Journal of Recent Trends in Science and Technology. 2012; 3(1):18-24.
16. Richards, LA (US Salinity Laboratory) Diagnosis and improvement of saline and alkaline soils US Department of Agriculture hand book. 1954, 60.
17. Thorne DW, Peterson HB. Irrigated Soils. Constable and Company, London, UK. 1954.
18. Todd DK. Groundwater hydrology. (2nd ed.,). New York: Wiley. 1980, 315.
19. Todd DK. Groundwater hydrology. John Wiley and Sons Publication, Canada. 2001, 280-281.
20. Wilcox LV. Classification and use of irrigation waters, US Department of Agriculture, Washington D.C., 1955, 19.
21. Wilcox LV. The quality water for irrigation use. US Department of Agriculture, Washington D.C. 1948, 40.