Bulletin of Pure and Applied Sciences.
Vol.38 F (Geology), No.1, 2019: P.104-113

Print version ISSN 0970 4639
Online version ISSN 2320 3234
DOI 10.5958/2320-3234.2019.00007.6

Available online at www.bpasjournals.com

Original Article

Suitability of Groundwater Quality for Drinking and Irrigation Purposes in the Dheku River Basin, Maharashtra

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(Received on 21.02.2019, **Accepted on 07.05.2019**)

ABSTRACT

Groundwater quality in the Dheku River sub basin was estimated for its suitability for drinking and agricultural purposes by collecting thirty five groundwater samples spread over the basin area and analyzed for physico-chemical parameters (pH, electrical conductivity, total dissolved solids, and total hardness,), major ions (Ca, Cl, HCO_3, K, Mg, Na, K and SO_4) Based on the physicochemical analyses, irrigation quality parameters like sodium adsorption ratio (SAR), residual sodium carbonate (RSC), and sodium soluble percentage (SSP) was calculated. The suitability of the water from the groundwater sources for drinking purposes was evaluated by comparing the values of different water quality parameters with Bureau of Indian Standards and World Health Organization guideline values for drinking water. The result of the analysis shows that the Water chemistry of Dheku river sub basin is deteriorated at some places. The correlation of the analytical data has been attempted by plotting different graphical representations such as US Salinity Laboratory for the classification of water, and results show that almost samples are fit for irrigation. Groundwater quality in Dheku basin is impeded by natural geology and anthropogenic activities, and proper groundwater management strategies are necessary to protect sustainably this valuable resource.

KEYWORDS: Dheku River basin, Hydrogeochemistry, Groundwater pollution, Maharashtra, India.

INTRODUCTION

India is a vast country with a highly diversified hydro geologic set-up. The ground water behavior in the Indian sub-continent is highly complicated due to the occurrence of diversified geological formations with considerable lithological and chronological variations, complex tectonic framework, climatologically dissimilarities and various hydro chemical conditions. Quality of water is assuming great importance with the rising pressure on agriculture and rise in standard of living (Wijnen, 2012; Wani et al, 2014; Aher et al, 2015). The continuous growth in the world's population means more water is needed for industrial, domestic, environmental, recreational, and agricultural requirements. The increasing demand for water when water resources are limited requires proper water resource management and assessment, especially when the water is to be used for drinking (Niemczynowicz 1999; Aly, et al., 2015). Groundwater is an important source of drinking water due to its high-quality, small seasonal variations, storage, easy exploitation, and socio-economic development. Presently, 85% of the water requirement for domestic use in rural areas, 55% for irrigation, and over 50% for industrial and urban uses is met from groundwater sources (Ghosh and Sharma 2006; Vijay et al, 2011; Aher, K.R,2017). In India, sedimentary aquifers are the important source of groundwater. Changes in groundwater quality are due to rock–water interaction and oxidation–reduction reactions during the percolation of water through the aquifers. In addition to these processes, water-borne pathogens, toxic and nontoxic pollutants are the major water quality degradation parameters which are transported from recharge area to discharge area through aquifers by groundwater motion. Undesirable and soluble constituents in the water cannot be controlled after entering the ground (Johnson., 1979; Sastri, 1994; Krishna Kumar et al.,2009; Aher and Deshpande.,2015; Aher, 2012). Groundwater is the purest form of water sourced from natural resources and meets the overall demand of rural and semi-urban people. But the development of human societies and industry result in bioenvironmental problems; pollution puts the water, air and soil resources at risk (Milovanovic, 2007; Kathane & Aher, 2015).Groundwater is a primary source for human consumption, agriculture and industrial purposes in the country. However, inferior quality of groundwater is a major problem due to sources of geogenic origin (apatite, fluorite etc) and man-made activities (improper disposal of municipal wastes, leakage of septic tanks, dumping of industrial effluents, uncontrolled usage of agricultural fertilizers, pesticides and soil amendments for higher crop yields, etc). In the coastal region, over-exploitation of groundwater causes seawater influx into inland aquifer. Deterioration of groundwater quality is a main constraint for developmental activities in an area (Rao & Rao, 2015).Adverse quality conditions increase the investment in irrigation and health, as well as decrease agricultural production. This in turn, reduces agrarian economy and retard improvement in the living conditions of rural people (Deshpande and Aher, 2011). In recent decades, attention is being given to study the natural concentration of many ions and metals in groundwater in order to establish the anthropogenic and geogenic sources affecting groundwater quality as well as the reactions that take place within the aquifer (Ramesh and Elango, 2011; Aher & Deshpande, 2014).Water is essential to the existence of man and all living things. Groundwater occurs almost everywhere beneath the earth surface not only in a single wide spread aquifer, but also in thousands of local aquifer systems. Man's activities suchas food production, nutrition is dependent on water availability in adequate quantities and good quality (Howari, et al, 2005; Deshpande and Aher, 2012). Groundwater in the arid and semi-arid regions plays an important role as freshwater; it is the major source for different uses such as domestic, agricultural and industrial purposes. So, the groundwater quality needs to be given greater attention in these areas. It is estimated that approximately one third of the world's population uses groundwater for drinking (Nickson et al. 2005). Water quality analysis is one of the most important aspects in groundwater studies. The hydro chemical study reveals quality of water that is suitable for drinking, agriculture and industrial purposes. Chemical analysis forms the basis of interpretation of the quality of water in relation to source, geology, climate, and use. Water being an excellent solvent, it is important to know the geochemistry of dissolved constituents and methods of reporting analytical data. The normal groundwater have typically neutral to slightly alkaline pH dominated by base cations and bicarbonate (Frengstad and Banks 2000; Nagaraju, et al. 2014). In present investigation, the thirty-five groundwater samples collected from the Dheku basin and are subjected various laboratory analysis.

STUDY AREA

The study area is in the drainage basin of the Dheku River in Aurangabad district, Maharashtra, India. It cover an area of 410 km^2 and lies between latitudes 12^{0}152 N to 19^{0}552 N and longitudes 74^0 452 E to 75^0 002 E and falls in the Survey of India Toposheet 46L/16 and 47I/13. The climate is characterized by hot summer and general dryness throughout the year except the during the south west monsoon season which is from June to September while October and November constitute the post monsoon season with the temperature of 10.3^{0}C in winter and 39.8^{0}C in summer. The normal annual rainfall varies from about 500 mm to about 840 mm. most rainfall occurs during southwest monsoon (June to September) period. Agricultural is the main activity in the study area and groundwater is the major source for irrigation.

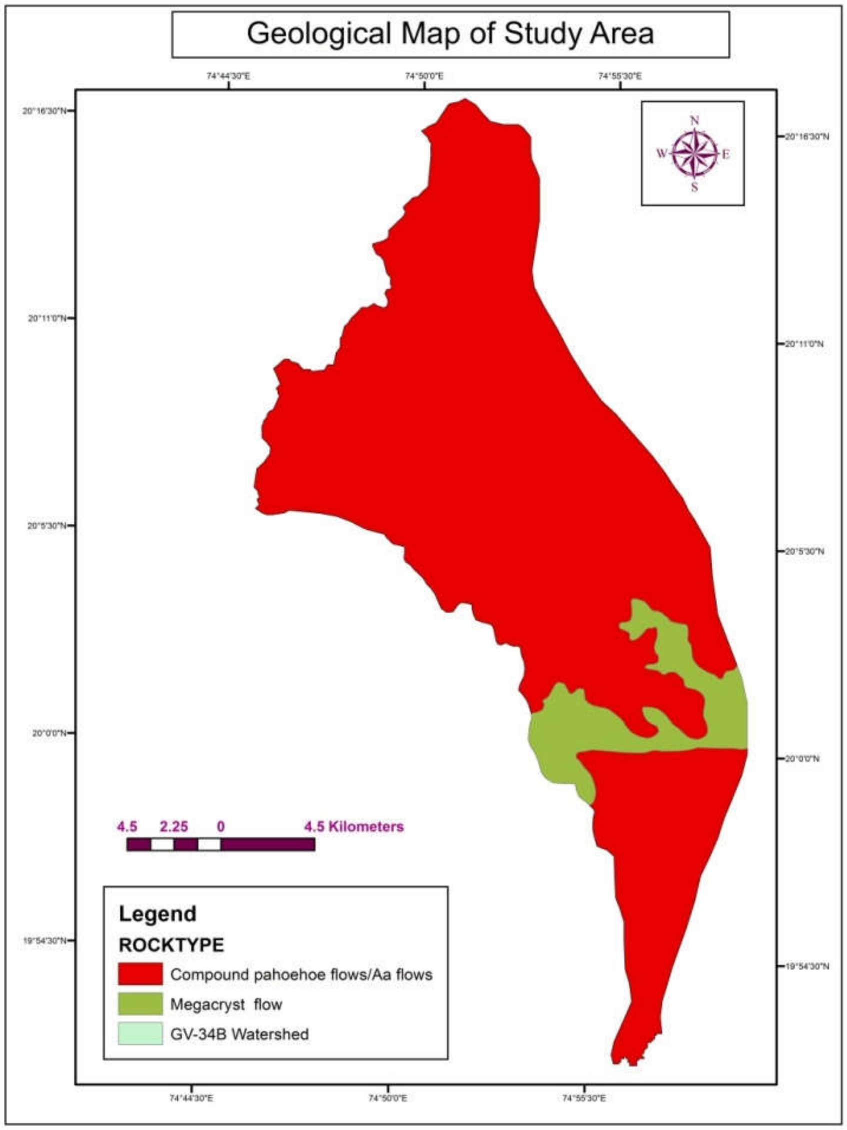

Figure 1: Geological map of the Dheku river basin (study area)

HYDROGEOLOGICAL SETUP

The study area consists of Deccan volcanic province (DVP). The flows of Upper Cretaceous to Eocene age. The traps are overlain by thin alluvial deposits along the river. The lava flows are the horizontal and each flows has distinct two units. The upper layers consist of vesicular and amygdule zeolitic basalt while the lower layer consist of massive basalt. A number of lineaments which are fractures zones have been identified from the satellite imagery. These lineaments are favorable for occurrence of groundwater. The soil is mostly formed from the igneous rocks. It is black and medium black in color shallow and calcareous. (Central Groundwater Board, 2010).

METHODOLOGY

Thirty five groundwater samples were collected from Dug wells and Bore Wells of the Dheku river basin. The groundwater samples were collected in good quality polythene bottles of one liter capacity. Prior to sampling all thesampling containers were to washed and rinsed with the groundwater. Sampling was carried in the month of May 2016 in a year. In case bore wells and dug wells samples have been taken which are in continuous use. The Dug wells, in general, have a depth range 13-19 m bgl whereas; bore wells of 80-90 m bgl. The chemical characteristics were determined as per the standard methods for examination of water and wastewater (APHA, 2002; Trivedi and Goel, 1984). All results are compare with standard limit recommended by the Bureau of Indian Standard (BIS, 2003), and (WHO, 1993). Physical parameter like Potentiahydrogenii (pH), and electric Conductivity were measured using digital portable meter. Alkalinities (Al), calcium (Ca), chloride (Cl), total Hardness (TH) were determined by respective volumetric titration methods. Magnesium is measured by using Calcium hardness value subtracting from the Total hardness. Sodium (Na) and Potassium (K) were determines by using flame photometer, whereas sulphate (SO_4) by using VIS spectrophotometer. Total Dissolved Solids (TDS) concentration was calculated from EC value.The further step involve is to process the data for irrigation related parameters i.e., Sodium Absorption Ratio (SAR), Residual Sodium Carbonate (RSC), Kelly's Ratio (KR), Sodium Soluble Percentage (SSP).

RESULTS AND DISCUSSION

Understanding the groundwater quality very important, because it is the main factor which decides its suitability for purpose like drinking, domestics and agricultural. The chemical composition of groundwater is result of the geochemical processes occurring due to the reaction of water and geologic materials (aquifer) through which it flows. It is also influenced by other natural and anthropogenic factors that affect the quality of groundwater. The result physicochemical analysis is present in Table 1 and 2.

Table 1: Physico-chemical composition* and irrigation specification values of groundwater of study area

Well No.	pH	EC	TDS	TH	Ca	Mg	Na	K	H CO3	Cl	SO4	SAR	SSP	RSC	KR
1	6.8	950	617.5	146	56.91	25.87	90	0	60	183.2	65.9	2.48	52.1	-3.99	0.79
2	7.6	1050	682.5	396	50.5	7.16	58	0	50	93.72	37.2	2.02	50.2	-2.29	0.81
3	7.6	1120	728	362	53.71	11.12	57	0	65	113.6	57	1.85	47	-2.53	0.69
4	7.7	1890	1228.5	670	123.5	35.17	67	4	55	203.1	63	1.37	29.7	-8.15	0.32
5	7.7	2010	1306.5	698	139.5	43.24	63	9	50	222.9	72.7	1.19	25.7	-9.7	0.26
6	7.8	1410	916.5	544	99.4	28.05	48	0	450	153.4	41.4	1.1	27.4	0.11	0.29
7	8.2	200	130	224	48.1	15.9	51	0	40	45.44	22.8	1.63	44.4	-3.05	0.6
8	7.5	2610	1696.5	624	233.3	104.5	132	0	45	424.6	100	1.8	28.1	-19.5	0.28
9	7.8	1430	929.5	490	72.95	15.21	58	0	50	164.7	47.3	1.61	39.7	-4.07	0.52
10	7.5	3130	2034.5	866	145.9	37.17	132	0	45	529.7	82.1	2.53	41.9	-9.6	0.56
11	7.9	860	559	278	54.51	16.59	56	1	40	71	29.8	1.7	44.1	-3.43	0.6
12	7.6	1500	975	520	89.78	23.64	57	0	50	288.3	53.7	1.38	33.4	-5.61	0.39
13	7.8	1350	877.5	474	60.92	8.86	62	0	40	200.2	53.7	1.96	47.1	-3.11	0.72
14	7.8	1610	1046.5	516	67.33	10.26	83	0	40	278.3	60.7	2.49	51.7	-3.55	0.86

15	7.3	600	390	224	38.48	10.06	51	1	40	36.92	15.6	1.89	51.2	-2.09	0.81
16	8.3	610	396.5	202	32.06	7.48	50	0	45	36.92	16.8	2.07	55.7	-1.48	0.98
17	7.6	750	487.5	280	49.7	13.55	49	1	40	44.02	24.3	1.59	43.7	-2.94	0.59
18	7.4	5190	3373.5	2800	417.6	87.37	184	0	60	969.9	91	2.14	26.7	-27	0.29
19	7.8	1380	897	398	68.14	17.74	90	0	50	180.3	57.5	2.51	51.2	-4.04	0.81
20	7.7	2160	1404	622	71.34	6.41	128	0	75	288.3	90.9	3.89	62.2	-2.86	1.36
21	7.8	900	585	282	34.47	4.19	67	0	55	46.86	25.8	2.87	63.4	-1.16	1.41
22	8	1640	1066	466	54.51	5.44	109	1	85	129.2	72.4	3.77	64.7	-1.77	1.5
23	7.9	2480	1612	336	45.69	7.8	180	1	65	142	116	6.48	77.1	-1.86	2.68
24	7.7	1320	858	438	36.07	8.76	126	0	55	48.28	96.4	4.88	73.8	-1.62	2.17
25	8.3	3460	2249	176	19.24	1.24	600	0	120	90.88	117	35.8	96.3	0.9	24.6
26	8.3	1370	890.5	128	24.05	7	146	0	60	38.34	82.2	6.74	82.5	-0.79	3.58
27	7.7	4090	2658.5	760	100.2	15.73	600	6	105	343.6	111	14.7	83.8	-4.57	4.15
28	7.5	1460	949	556	115.4	37.07	35	0	40	119.3	38.2	0.73	18.7	-8.15	0.17
29	7.5	1840	1196	730	157.1	52.04	44	0	40	194.5	48.3	0.78	17.4	-11.5	0.16
30	7.4	1340	871	566	106.6	31.12	31	0	45	78.1	39.9	0.68	18.4	-7.14	0.17
31	8.4	2080	1352	624	94.59	20.39	114	0	45	167.6	98.8	2.77	49.6	-5.66	0.78
32	7.6	3810	2476.5	1552	148.3	22.04	157	1	35	494.2	114	3.18	48	-8.64	0.74
33	7.9	1660	1079	670	114.6	29.82	69	0	45	153.4	87.4	1.48	32.3	-7.44	0.37
34	7.5	1190	773.5	428	124.3	50	34	0	35	62.48	39.2	0.65	16.3	-9.74	0.14
35	7.8	2370	1540.5	236	78.56	33.67	170	1	40	154.8	101	4.04	60.2	-6.03	1.11
Min	6.8	200	130	128	19.24	1.24	31	0	35	36.92	15.6	0.65	16.3	-27	0.14
Max	8.4	5190	3373.5	2800	417.6	104.5	600	9	450	969.9	117	35.8	96.3	0.9	24.6
Avg	7.7	1843.51	1198.28	600.3	99.03	25.88	126.5	1	74.19	210.8	65	4.41	47.8	5.95	2.19

Table 2: Assessment of groundwater quality for drinking purpose

Parameter	<DL	>DL<MPL	>MPL
TDS	11.42	74.28	14.28
TH	28.57	40	31.42
Ca	54.28	40	2.85
Mg	71.42	25.71	2.85
Cl	77.14	22.85	-
HCO_3	97.14	2.85	-
SO_4	100	-	-

Groundwater Quality for drinking purpose

Groundwater in the study area is generally alkaline in nature with pH ranging from 6.8 to 8.4, averaging 7.7. The pH in the study area is influenced by infiltration of rain water, surface water. The EC ranged from 200 to 5190 µs/cm, with an average of 1843.51 µs/cm. The TDS, which is in accordance with the sum of dissolved ionic concentrations, varied between 130 and 3373.5 mg/l, with an average of 1198.25, 14.88% samples exceeding maximum permissible limit given by (BIS, 2003), and (WHO, 1993). Total hardness values varied from 128 to 2800 mg/l with an average of 600.3 mg /l, 31.42 % samples exceeding maximum permissible limit given by (BIS, 2003), and (WHO, 1993). Chloride concentration varied from 36.92 to 969.9 mg/l with an average of 210.8 mg/l. Sulphate values varied from 15.6 to 117 mg/l with an average of 65 mg /l. HCO3 concentration varied from 35 to 450 mg/l with an average of 74.19 mg/l. Na concentration varied from 31 to 600 mg/l with an average of 126.5 mg/l. Ca concentration varied from 19.24 to 417.6 mg /l with an average of 99.03 mg/l. 2.85 % samples exceeding maximum permissible limit given by (BIS, 2003), and (WHO, 1993). Mg concentration varied from 1.24 to 104.5 mg/l with an average of 25.88 mg/l. 2.85 % samples exceeding maximum permissible limit given by (BIS, 2003), and (WHO, 1993). K values varied from 0 to 9 mg/l with an average of 1 mg/l. Dominance of cations in the study area is as follows; Na>Ca>Mg>K. The minimum, maximum and average values of physical and chemical parameters of groundwater samples are present in Table (1). Groundwater quality in Dheku basin is impeded by natural geology and anthropogenic activities, and proper groundwater management strategies are necessary to protect sustainably this valuable resource.

Groundwater quality for Irrigation purpose

The water for irrigation used is an imperative aspect in taking productivity of crops, its yield and quality the continuous use of poor-quality water without drainage and soil management may lead to saline and sodic soil particularly in clayey soils.

Sodium Absorption Ratio (SAR)

The sodium Absorption Ratio (SAR) is an appearance pertaining to cations make up of water and soil solution and is used for characterizing the sodium hazard of irrigation water. Sodium absorption ratio value is used to calculate the degree to which irrigation water tend to enter into cation exchange section in the soil. The main problem with the high sodium concentration is its effect on soil permeability. Sodium also contributes directly to the total salinity of the water and may be toxic to sensitive crops such as fruit trees. The higher value of Sodium absorption ratio indicates soil structure damage. The sodium Absorption ratio values for each water samples were calculated by using equation by Richard (1954).

As shown in Table 1, the SAR values of the groundwater samples varied from 0.65 to 35.8 with an average value of 4.41. The SAR values of the 33 water samples of the studied area to be <10 and are classified as excellent for irrigation, 1 water sample of the studied area to be 10-18 and are classified as good for irrigation, and 1 sample is unsuitable for irrigation, (Table 3). (Richards 1954).

Table 3: Classification of groundwater on the basis SAR, SSP, RSC & KR

Parameter	Range	Water Class	Samples
	<10	Excellent	33
SAR	10-18	Good	1
	18-26	Doubtful	-
	>26	Unsuitable	1
SSP	<50	Good	19
	>50	Bad	16
RSC	<1.25	Good	4
	1.25-2.5	Doubtful	6
	>2.5	Unsuitable	25
KR	<1	Suitable	26
	>1	Unsuitable	9

Soluble Sodium Percentage (SSP)

The SSP values less than 50 or equal to 50 indicates good quality water and if it is more than 50 indicates the unsuitable water quality for irrigation. As per the SSP values 19 of wells are falls in good quality and remaining 16 of wells falls in bad quality of water for irrigation purpose (Table 3).

Residual sodium carbonate (RSC)

The Residual sodium carbonate index of irrigation water and soil water is used to indicate the alkalinity hazards for soil. Residual sodium carbonate (RSC) is considered to be superior to SAR as a measure of sodicity particularly at low salinity levels. The quantity of bicarbonate and carbonate in excess of alkalis (Ca^{2+} and Mg^{2+}) also influence the solubility of water for irrigation purposes. When the sum of carbonates and bicarbonates is in excess of calcium and magnesium there may be possibility of complete precipitation of calcium and magnesium (Raghunath, 1987).The solubility of groundwater based on residual sodium carbonate (RSC) was made into values (<1.25) good for irrigation purposes, then the water having RSC values in between (1.25 to 2.5) it is marginally suitable for irrigation purposes and water having RSC values (>2.5) is unsuitable for irrigation purposes. On the basis of RSC values Four (4) Samples fall in good for irrigation quality, six (6) for doubtful for irrigation and Twenty five (25) samples having unsuitable for irrigation purposes (Table 3).

Kelly's Ratio (KR)

The sodicity problem is evaluated based on Kelly's ratio (KR) (Kelly et al. 1940). A Kelly's rationmore than one indicates an excess level of sodium in water. Hence the water samples as the KR values for irrigation is less than one (1) are suitable for irrigation and more than one (1) are unsuitable for irrigation. As per the KR values 26 samples is suitable for irrigation and 9 samples are unsuitable for irrigation purposes (Table 3).

Hydrogeochemical facies

On thebasis of major cation and anion the groundwater the concept of hydrogeochemical facies of the investigated area are used in piper trilinear diagram (1953) for graphical analysis (Figure 2). This diagram reveals similarities and differences among water samples (Todd 1980). The facies mapping approach applied to the present study shows dominance of (Fig.2) week acid exceed strong acid and it is appearance that majority samples fall in the Ca^{2+} - Cl^{-} - Na^{+}type (77.15%), Na^{+} - Cl^{-} type (22.86%) and Mg^{2+} - HCO^{-}_{3} type(2.86%) remaining samples fall in the field of Na^{+}-Cl^{-} type. The results suggest that the mixed types dominance of the hydrogeochemical facies for the surveyed groundwater.

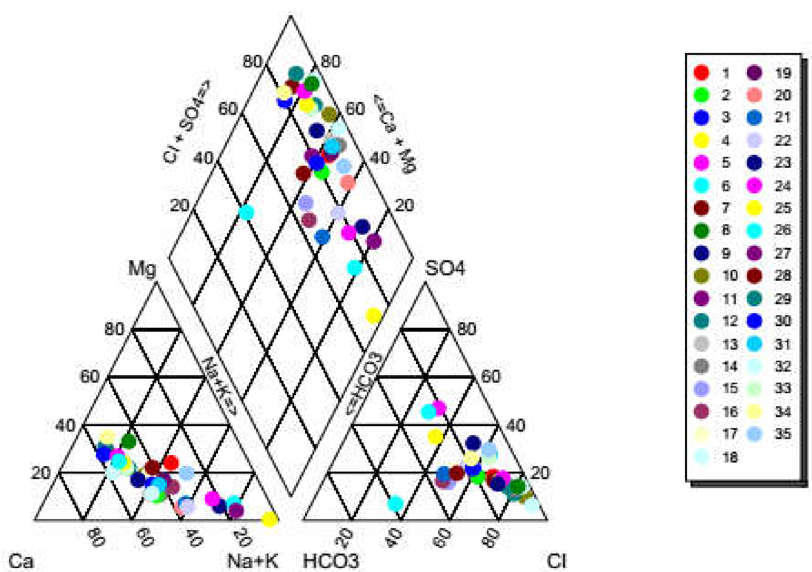

Figure 2: Piper trilinear diagram for representing the analysis groundwater samples.

USSL Classification

The analytical data plotted on the US salinity diagram (USSL, 1954) (Figure 3) shows that the suitability class of groundwater for irrigation. As per this classification the study areas water samples majority fall in the (C_3S_1) having the salinity high and Low sodium(25 samples). In C_1S_1 low salinity with low sodium (1 sample). In C_2-S_1 Medium Salinity with low sodium (2 samples). C_4S_1 Very high Salinity with low sodium (2 samples). And the rest in C_3S_2 high salinity with medium sodium (1 sample) and C_4S_2 very high salinity with medium sodium (3 samples) and the C_4S_4 having very high salinity with very high sodium (1 sample) categories. A water sample in the study area uses of this high salinity water for irrigation is advocated for salt tolerant crops. Use of an irrigation water containing the high proportion of sodium as compare to other cations will increase the exchangeable sodium content of the soil. The affect soil permeability and texture, and lead to pudding and reduce rate of water intake. Such soil become hard to plough and unsuitable for seedling emergence.

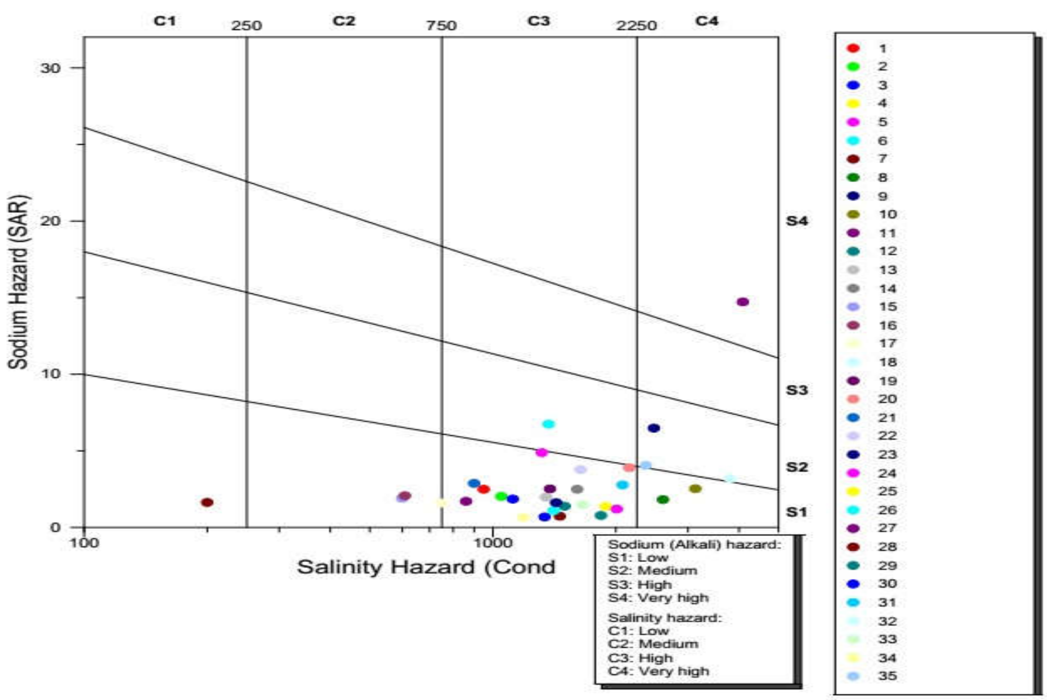

Figure 3: Salinity and sodium hazard of irrigation of water in US salinity diagram

CONCLUSION

The result of the analysis shows that the water chemistry of Dheku river sub basin is deteriorated at some places. Groundwater quality is impeded by natural geology and anthropogenic activities, and proper groundwater management strategies are necessary to protect sustainably this valuable resource. Irrigation quality parameters like sodium adsorption ratio (SAR), residual sodium carbonate (RSC), sodium soluble percentage (SSP), Kelly's Ratio (KR), indicate that except few samples most of the groundwater samples are suitable for irrigation. The values of EC and SAR of groundwater samples have been plotted in U.S. salinity diagram indicating that majority of samples fall in C_3 S_1 based on this following recommendation should be taken into account that in agricultural excessive use of chemical fertilizers should be avoided so that it does not leach down to ground water and deteriorate its quality; Rainwater harvesting techniques should be implemented to augment the groundwater resources and reduce salinity, protect soils and increase crop yields.

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