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Groundwater Quality Assessment of Arid Northern Gujarat (India)

R.K. Goyal* and Mukesh Sharma

ICAR-Central Arid Zone Research Institute, Jodhpur 342003, India

Abstract: Availability of groundwater and its quality has always been a major concern for developing irrigated agriculture particularly in arid regions where surface water resources are insufficient or meagre to meet irrigation demand. An assessment of groundwater quality has been done for arid northern Gujarat state (India) mainly consist of Banaskantha district. Based on EC, SAR and RSC values the quality of groundwater has been classified in Dhanera, Deesa, Tharad, Vav, Diyodhar and Bhabhar tehsils of Banaskantha district. The analysis of groundwater samples indicated that in majority of area (75%) groundwater has moderate sodicity with SAR<18. The SAR ranges from 0.1 to 89 with an average of 13.3. Highest SAR was found in Tharad (>18) tehsil followed by moderate in Vav and Bhabhar (10-18) and low(<10) in Dhanera, Deesa and Diyodhar tehsils. About 55% area has EC >3.0 dS m^{-1} reflecting moderate to high salinity whereas in about 97% of area RSC found to be <2.5 Me L^{-1}. Based on EC, SAR and RSC criterion, the irrigation quality of groundwater has been assessed for each tehsil and classified as C1S1R1, C2S2R1, C2S3R1, and C3S2R1.

Key words: Banaskantha, groundwater quality, salinity, sodicity, irrigation class.

The groundwater quality is a major constraint in developing irrigated agriculture (Oster and Jayawardane, 1998). To assess the groundwater quality a study was carried out in arid northern part of Gujarat state (India) lies at N 24°00´ to N24°45´; E71°15´ to E72°15 covering an area of 6367 km^2 in Banaskantha district (Fig. 1). The climate of the district is extreme and droughts are frequent. The average annual rainfall of the district is about 675 mm. Alluvium covers the entire study area belonging to Quaternary era.

It comprises of unconsolidated to semi consolidated sand, gravels, pebbles, boulders and clay at places, in varying proportions. These are windblown sand with fluvial deposits vary in thickness and also encountered at depths. Schist/phyllite/gneisses belonging to Aravalli super group occupy small portion on eastern part of the Dhanera tehsil. It does not expose anywhere but encountered at depth 50-55 m and more. These are argillaceous meta sediments, generally susceptible to weathering. The area is drained by ephemeral river Bargaon in the north and Sukal River which flow the entire length through centre of Dhanera tehsil from east to west. Another major ephemeral river in the area is Banas which flows from NE-SW through heart of Deesa tehsil. The chemical characteristics of groundwater are largely dependent on hydrogeological formations (Oster *et al.*, 1999; Saxena *et al.*, 2003) through which it circulates and depicts the chemical and physical behavior of the aquifer. Though the attempts to classify the water for agriculture have been made in the past by several researchers, these studies mostly emphasized the problem and distribution of salinity (Dhir, 1977; Gupta, 1979) and lack in providing detailed information regarding distribution pattern of Sodium Adsorption Ratio (SAR) and Residual Sodium Carbonate (RSC) which are considered as important sodicity and alkalinity criterion for irrigation water. The present study is therefore, an attempt to classify groundwater quality under different formations of the district on the basis of SAR and RSC along with salinity level. Since entire area is composed of singhle Alluvium aquifer, therefore tehsil wise groundwater classification has been adopted in the present study.

Material and Method

A total of 301 groundwater samples were collected from entire area from different locations during hydrogeological survey of the district conducted during 2010-2012. The samples collected were chemically analyzed for all major chemical constituents as per standard methods. SAR and RSC were determined to know the sodicity and alkalinity level in groundwater. Salinity, SAR and RSC maps were prepared using GIS ARC/INFO workstation.

*E-mail: rkgoyal24@rediffmail.com

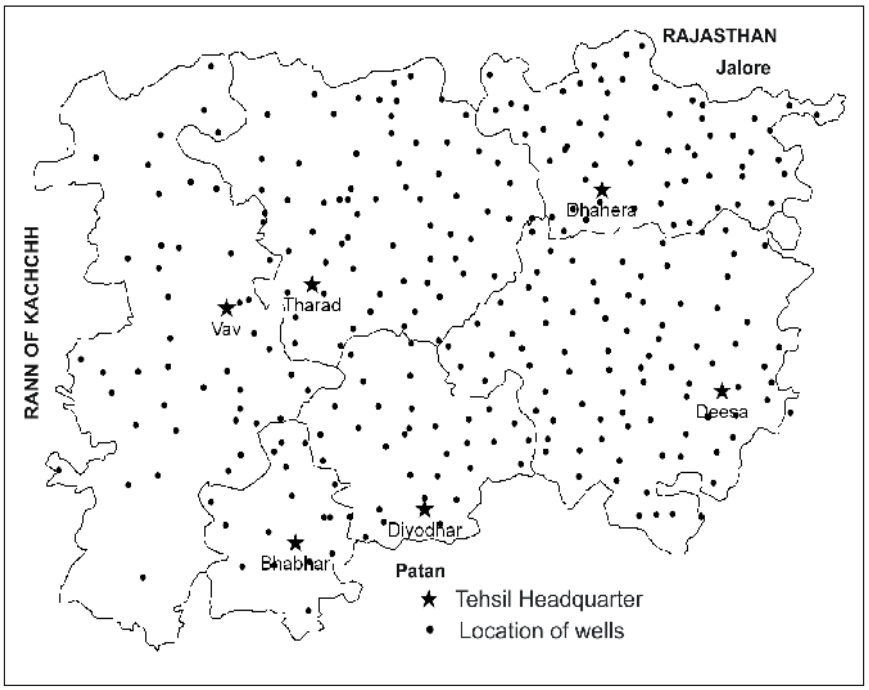

Fig. 1. Location of study area and groundwater samples.

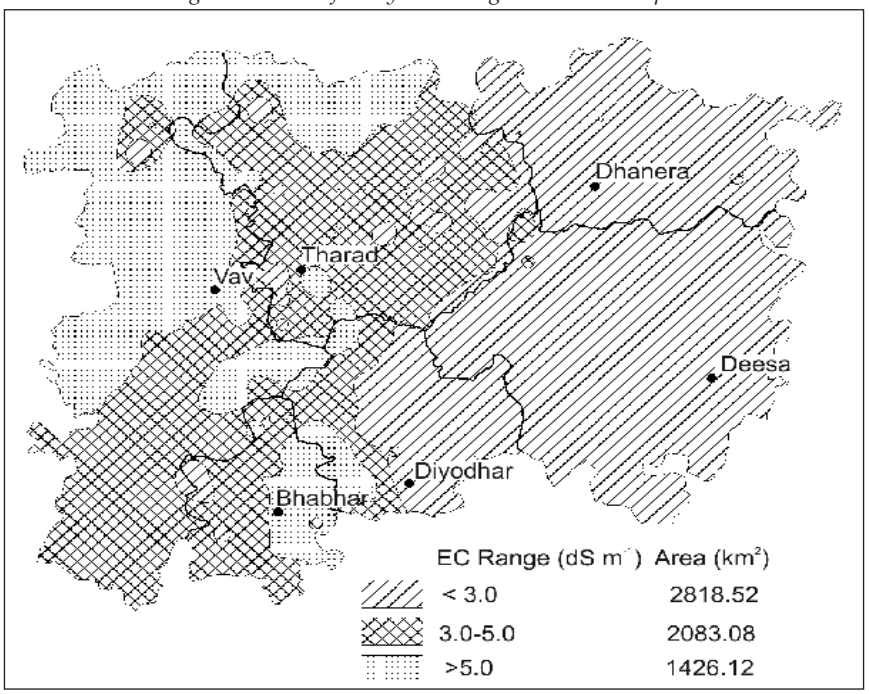

Fig. 2. Distribution of electrical conductivity in the study area.

Table 1. Parameters of classification

Classification	Parameters					
	Salinity		SAR		RSC	
	dS m^{-1}	Class	Value	Class	Me L^{-1}	Class
Low	<3	C1	<10	S1	<2.5	R1
Medium	3-5	C2	10-18	S2	-	-
High	>5	C3	>18	S3	>2.5	R2

On the basis of EC values groundwater was classified in to three salinity classes viz. Low (<3 dS m^{-1}), medium (3-5 dS m^{-1}) and high (>5 dS m^{-1}). Similarly three classes of SAR have been adopted as low (<10), medium (10-18) and high (>18). Following the groundwater quality standards of ICAR for arid and semi-arid regions (Gupta, 1979; Anonymous, 1986) the RSC in water is classified as low (<2.5 Me L^{-1}) and high (>2.5 Me L^{-1}) (Table 1).

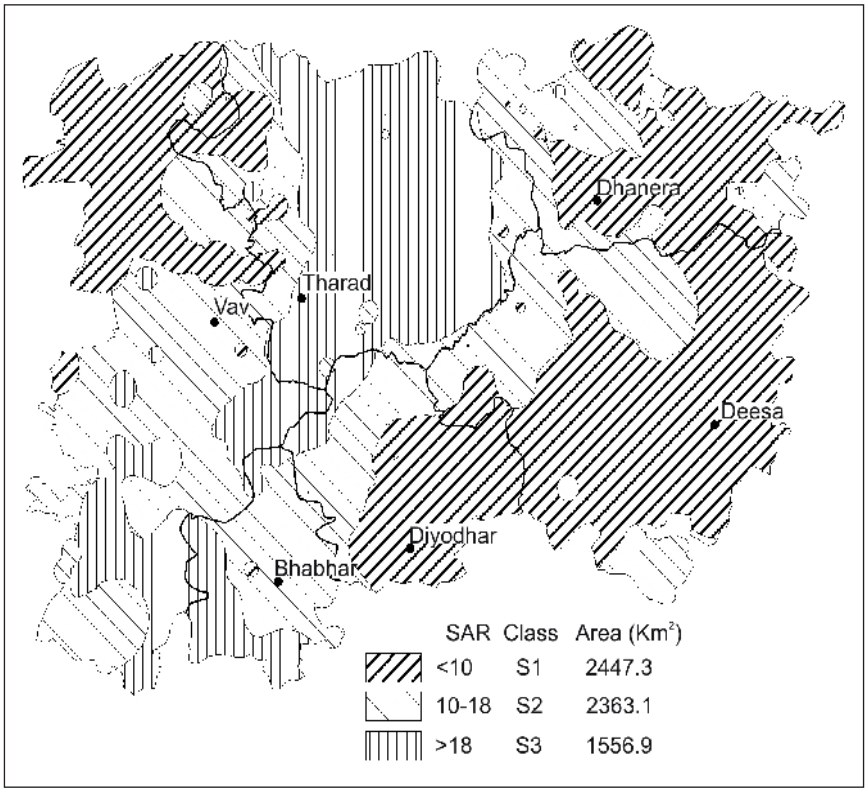

Fig. 3. Distribution of SAR.

Table 2. Salinity distribution in groundwater of Banaskantha district

Tehsil	EC (dS m^{-1}) range and per cent area in tehsil						Category
	Min.	Max.	Ave.	<3.0	3.0-5.0	>5.0	
Dhanera	0.445	4.675	2.028	79.31	20.69	-	C1
Deesa	0.519	4.626	1.571	96.47	3.53	-	C1
Tharad	1.134	12.232	4.137	23.88	50.75	25.37	C2
Vav	0.555	10.830	5.543	6.98	37.21	55.81	C3
Diyodhar	1.012	7.857	2.803	66.67	20.00	13.33	C1
Bhabhar	2.102	10.116	4.870	27.78	38.89	33.33	C2

Table 3. SAR distribution in groundwater of Banaskantha district

Tehsil	SAR range and per cent area in tehsil						Category
	Min.	Max.	Ave.	<10.00	10.0-18.0	>18.00	
Dhanera	1.96	20.74	8.52	65.52	31.00	3.48	S1
Deesa	2.91	17.27	8.28	69.41	30.59	0.00	S1
Tharad	2.09	89.89	24.08	8.96	17.91	73.13	S3
Vav	0.1	47.26	14.10	30.23	39.54	30.23	S2
Diyodhar	4.13	22.11	9.56	63.33	30.00	6.67	S1
Bhabhar	8.43	29.16	16.61	5.56	61.11	33.33	S2

Table 4. RSC distribution in groundwater of Banaskantha district

Tehsil	RSC range and percent distribution					Category
	Min.	Max.	Ave.	<2.5	>2.5	
Dhanera	-	6.8	1.10	70.69	29.31	R1
Deesa	-	4.6	1.13	64.71	35.29	R1
Tharad	-	16.8	1.29	76.12	23.88	R1
Vav	-	3.2	0.27	93.02	6.98	R1
Diyodhar	-	4.2	0.37	86.66	13.34	R1
Bhabhar	-	2.08	0.38	83.33	16.67	R1

The classification in vogue (Richards, 1954; Dhir, 1977) has been taken for evaluating distribution of SAR and RSC.

Result and Discussion

A detailed classification on the basis of EC, SAR and RSC is presented in Table 2, 3 and 4, respectively. On the basis of detailed classification and GIS mapping it is revealed that about 45% of the area has EC <3.0 dS m^{-1} (average EC 3.03 dS m^{-1}). The average EC is slightly on the lower side in the Schist/ phyllite aquifer (2.21 dS m^{-1}). Average EC in Alluvium aquifer is 3.14 dS m^{-1}. Salinity level of groundwater in Dhanera, Deesa and Diyodhar tehsils is comparatively better. The average EC in Dhanera, Deesa and Diyodhar tehsils is 2.028, 1.571 and 2.803 dS m^{-1}, respectively. While average EC is almost 2-2.5 times in Tharad (4.14 dS m^{-1}), Vav (5.54 dS m^{-1}) and in Bhabhar (4.87 dS m^{-1}) tehsil (Fig. 2).

Sodium absorption ratio in the area is medium with average of 13.3. About 37% area is having low SAR (<10) and in about 75% area SAR is <18. Dhanera, Deesa and Diyodhar tehsils show comparatively low SAR with an

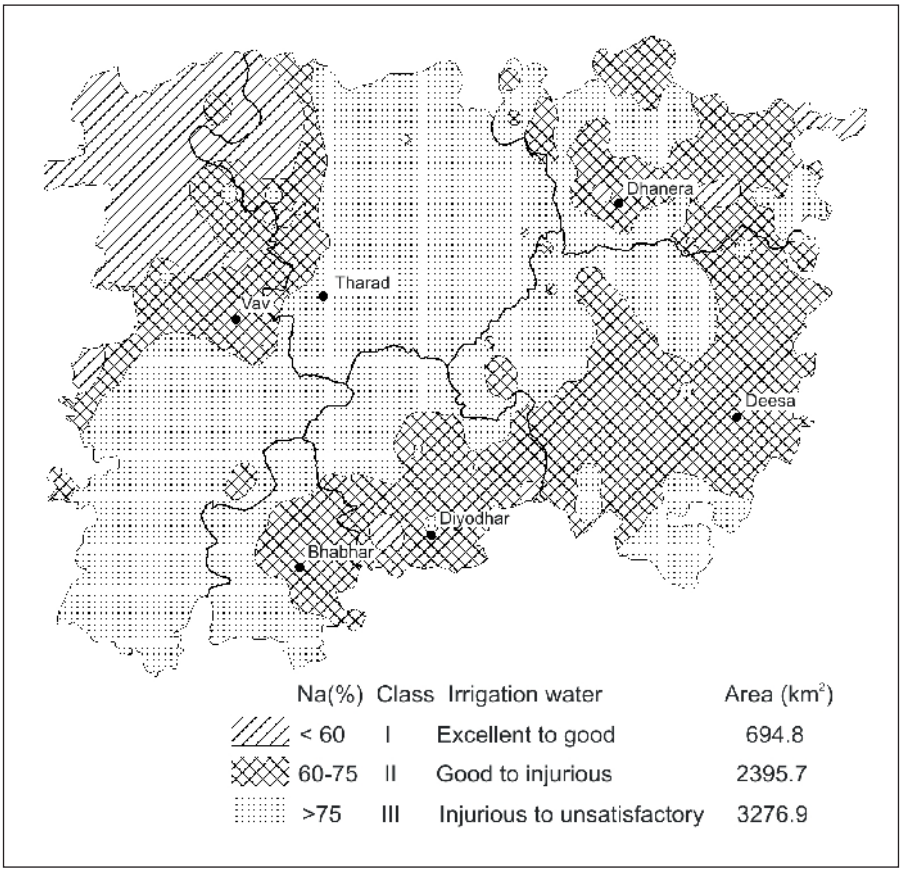

Fig. 4. Distribution of sodium (Na) in groundwater.

Table 5. Classification of Aquifer

Tehsil	Saline-sodic zone	Category
Dhanera	Zone-1	C1S1R1
Deesa	Zone-1	C1S1R1
Diyodhar	Zone-1	C1S1R1
Bhabhar	Zone-2	C2S2R1
Tharad	Zone-3	C2S3R1
Vav	Zone-4	C3S2R1

average of 8.52, 8.25 and 9.26, respectively (Fig. 3)

Sodium hazard is high in the Tharad tehsil (SAR 24.08) while it is moderate in Vav and Bhabhar tehsils with average SAR of 14.10 and 16.61 respectively. RSC is low in the study area with an average of 0.92 Me L^{-1}. About 97% of the area has RSC <2.5 Me L^{-1} out of which about 85% area has RSC <1.5 Me L^{-1}. Average Na% in the groundwater is 77.61%. About 89% of the area shows Na% >60% and out of which 51% area has Na% more than 75% which reflects Na% in the area remains a point of concern from irrigation water point of view (Fig. 4).

Classification of Saline-Sodic Zones

The continuous use of groundwater with high RSC and SAR for irrigation leads to soil degradation and reduction in crop productivity. Joshi and Dhir (1989) have observed that the continuous use of the water having RSC more than 15 Me L^{-1} for 8-10 years on sandy soils in Barmer district have turned the soil completely barren. However, the classification of irrigation water on the basis of EC, SAR and RSC values taken together depicts their inherent salinity and sodium hazard more distinctly than any individual or combination of two parameters inspite of certain limitations (Bajwa and Manchanda, 1986; Gupta, 1991). Thus, in the present case saline-sodic zones have been worked out considering the above chemical constituents. As such the district has been divided in to four saline-sodic zones each representing more than 60% area (Table 5; Fig. 5).

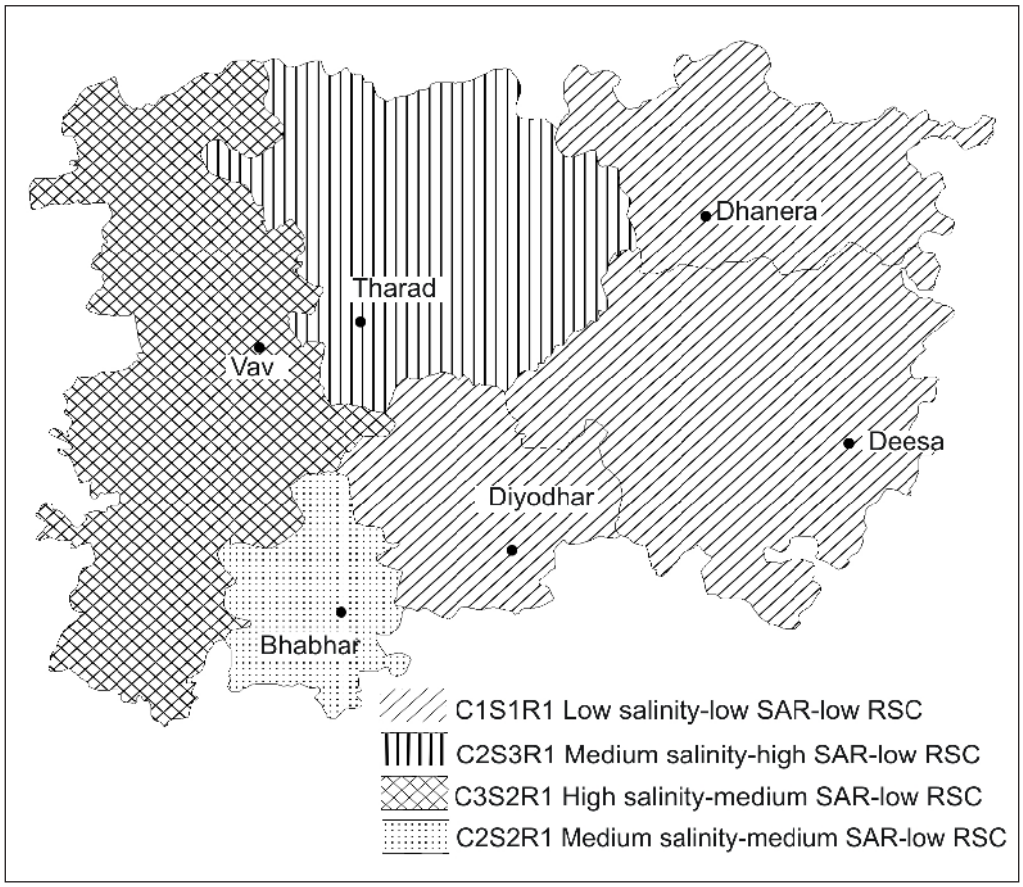

Fig. 5. Saline-sodic zones.

Zone-1: Low salinity, low SAR and low RSC water (C1S1R1): Such water occurs in the Dhanera, Deesa and Diyodhar tehsils covering an area of 2885.39 km^2 and in eastern margin of the district. In this zone the average salinity in ground water is 1.938 dS m^{-1}, SAR is <10 and RSC is <2.5 Me L^{-1}. Thus, the groundwater is classified as good quality and suitable for irrigated agriculture on sustainable basis.

Zone-2: Medium salinity, medium SAR and low RSC water (C2S2R1): This particular class of water is observed in the Bhabhar tehsil located in the southern part of the district covering an area of 429.27 km^2. The average salinity of ground water is 4.87 dS m^{-1}, SAR <18 and RSC is <2.5 Me L^{-1}. This water could be used for irrigating semi-tolerant crops without any harmful sodic effect.

Zone-3: Medium salinity, high SAR and low RSC water (C2S3R1): This class of water is encountered in the Tharad tehsil covering an area of 1357.98 km^2. In this zone about 76% of water has EC >3.0 dS m^{-1} with an average of 4.137 dS m^{-1}, 73% of samples have SAR >18 with an average of 24.08 and about 76% samples have RSC <2.5 Me L^{-1}. Therefore, continuous use of groundwater for longer period may cause high sodicity. In this zone semi-tolerant crops with soil amelioration is recommended.

Zone-4: High salinity, high SAR and low RSC water (C3S2R1): The Vav tehsil contains this class of water and occupies the 1694.68 km^2 area. Such waters have high salinity and moderate SAR values. About 56% of the samples have EC >5.0 dS m^{-1} with an average value of 5.543 dS m^{-1}, whereas 30% samples have SAR >18 with an average value of 14.10, reflecting moderate sodicity in the soil. In almost 93% area of the zone the RSC is low (<2.5 Me L^{-1}).

Conclusion

The present study revealed that salinity in the groundwater, in general, is low to medium and about 82% water have EC <5.0 dS m^{-1}. In general, the groundwater in parts of Banaskantha district contains medium to high sodium causing problems of sodicity with nearly 23% samples have SAR > 18. About 93% of the area has RSC <2.5 Me L^{-1}, as such RSC is not a quality problem in the district. However, Dhanera, Deesa and Diyodhar tehsils have best water-bearing formations in the district which containing water having an average EC <3.0 dS m^{-1}, SAR <10 and RSC <2.5 Me L^{-1}. However, these formations cover only about 45% of the district area. While, groundwater is poor in Tharad, Vav and Bhabhar tehsils. Groundwater in this aquifer has average EC of 4.17 dS m^{-1}, SAR 19.68 and RSC 0.82 Me L^{-1}.

Therefore, soil amelioration is a pre-requisite for practicing well irrigation. The use of saline and/or sodic ground waters, if made for irrigation without scientific management may render the irrigated soils as saline and or sodic and consequently crop production may reduced. Appropriate technological interventions like *in situ* conservation of rainwater in precisely levelled fields; blending saline/alkaline and fresh water to keep the resultant salinity below threshold or to achieve its amelioration; and, if residual sodium carbonate cannot be brought down to acceptable levels, dilution-blending or cyclic application and scheduling irrigation with salty water at less salt-sensitive stages (Tyagi, 2003). In spite of the technological advances that mitigate salinity damage and the likely economic advantages, there is always a need to exercise caution while practising irrigation with salty water for maintaining sustained productivity.

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