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Assessment and Management of Underground Water Quality in North-West Gir Madhuvanti Toposequence of South Saurashtra Region of Gujarat

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Abstract

Underground water sample from existing wells / tube wells adjoining to selected profiles from the different land slopes of north-west Gir Madhuvanti toposequence of South Saurashtra region of Gujarat. The distribution of underground water for irrigation based on the semi-logarithmic USSL diagram, out of 110 wells / bore wells water samples reveals that 20, 25.45, 34.55 and 20 per cent water samples were placed in C_2S_1, C_3S_1, C_4S_1 and C_4S_2 water quality class, respectively. In general, the underground water of lower elevated area was placed under doubtful class or C_4S_1 that of higher elevated area. The weighted mean of permeability index, magnesium adsorption ratio, sodium to calcium activity ratio, Kelly's ratio and total permanent hardness were found to be 64.73, 55.56, 6.59, 1.05 and 48.07 mg l^{-1}, respectively.

Keywords: Land slopes, water resources, suitability and management, underground water quality

Introduction

Water is one of the most important natural resources vital for economic development of a nation. Planning for judicious use of fresh and poor quality water in agriculture has to consider important factors for agriculture like nutrient value, soil salinity / sodicity, heavy metals in soils and plants, crop yield and quality. Water is a natural resource, which is essential for crop production. The semi arid region is dependent on underground waters for irrigation. Irrigation water of good quality is usually not available in sufficient quantities to satisfy the water requirement of all the crops grown in the south Saurashtra region as there are limited canal water facilities. Under these conditions, the farmers are obliged to use underground water with high quantities of dissolved salts, invariably accompanied with yield reduction in most of the crops being grown. Indiscriminate use of such water often leads to crop failures and development of the saline or sodic soils, which in turn, require expensive treatment to make them productive again. On the other hand, judicious use of saline water can contribute to the sustainable production of various crops particularly in light textured well drained soils.

Materials and Methods

The study area (north-west Gir Madhuvanti toposequence) was located between $21^0 13'$ to $21^0 25'$ N latitudes and $69^0 57'$ to $70^0 32'$ E longitudes encompassing parts of the Mendarda, Vanthli, and Keshod tehsils of Junagadh district and Porbandar tehsil of Porbandar district of south Saurashtra at an elevation ranged from 5 to 190 above mean sea level. IRS IA LISS II FCC imagery on 1:50 000 scale in conjunction with Survey of India topographical (SOI) map referred above on 1:50,000 scale were used to select various land slopes of north-west Gir Madhuvanti toposequence of south Saurashtra region of Gujarat namely: hill slope (LS-1), upper piedmont (LS-2), lower piedmont (LS-3), plain area (LS-4), depression area (LS-5) and upper coast (LS-6) (Fig.1). The mean annual rainfall is 1120 mm and the climate of the area is semi-arid characterized by extremes of temperature and low wind velocity. 110 underground water sample from existing wells/tube wells adjoining to selected profiles from the different land slopes of north-west Gir Madhuvanti toposequence of South Saurashtra were collected in plastic bottle in the month of May before monsoon for maintaining proper records and the water table depth also measured. Different methods of analysis used to determine various parameters of water samples are enlisted as under: pH by pH meter (Richards, 1954), Electrical conductivity by EC meters

(Richards, 1954), Sodium and potassium by Flame photometer (Richards,1954), calcium and magnesium by Versenate titration (Richards,1954), Chloride by Silver nitrate titration (Richards,1954) and Carbonate & bicarbonate by Acid neutralization (Richards, 1954). The wells / Tube wells water categorized SAR, RSC and SSP for their salinity classes according to the USSL Staff (Richards, 1954). The permeability index, magnesium adsorption ratio, Kelly's ratio, sodium to calcium activity ratio and total permanent hardness assessment of the water samples was done as outline by Vadher *et al.* (2016). These guidelines are practical utility, in general, for irrigated agriculture. The water quality guidelines suggested cover a wide range of conditions in irrigated agriculture and incorporate the newer concepts in soil-water-plant relationship.

Results and Discussion

Characterization and Classification of Water resources

Underground water table, pH, EC, water soluble cations (Ca^{2+}, Mg^{2+}, Na^{+} and K^{+}), anions (CO_3^{2-}, HCO_3^{-} and Cl^{-}) and quality of underground water from different wells / bores adjoining to pedons P_1 to P_6 in different land slopes of north-west Gir Madhuvanti toposequence were presented in Table 1. The results reveal that the water table depth ranged from 11.5 to 52.14 m with the overall mean of 26.65 m. The depth of underground water table of north-west Gir Madhuvanti toposequence was found in the order of Lower piedmont > Hill slope > Upper piedmont> Plain area >Depression area> Upper coast. It is observed that the availability of ground water was scare and at greater depth in Lower Piedmont as compared to coastal area. The pH of underground water of well / bores of north-west Gir Madhuvanti toposequence ranged between 7.45 and 8.26 with the overall mean of 7.86. The EC ranged between 0.68 and 5.85 dSm^{-1} with the overall mean of 3.06 dSm^{-1}. The pH and EC increased with decreasing elevation from hill slope to upper coast of north-west Gir Madhuvanti toposequence. This can be ascribed to the accumulation of soluble salts at the lower elevation carried by the percolating water (Patel, 2010 and Gandhi, 2013).

Among the cations, Na^{+} was dominant throughout the north-west Gir Madhuvanti toposequence varied from 2.14 to 37.55 me l^{-1} followed by Mg^{2+}, Ca^{2+} and K^{+} with a range of 1.90 to 15.00, 2.21 to 9.19 and 0.00 to 0.71 me l^{-1}, respectively. The corresponding mean values of these cations were 17.12, 8.47, 5.33 and 0.25 $meql^{-1}$. The total water soluble cations ranged from 6.26 to 60.94 me l^{-1} with a mean value of 31.18 $meql^{-1}$, which increased with decreasing elevation from 6.26 me l^{-1} in the hill slope to 60.94 me l^{-1} at upper coast. Similar results were also reported by Savalia *et al.* (2006), Patel (2010) and Gandhi (2013). The concentration of Na^{+} increased with an increase in EC (Gupta, 1986 and Savalia *et al.,* 2006).

Among the anions, CO_3^{2-}, HCO_3^{-} and Cl^{-} ranged from 0.00 to 0.74, 4.02 to 6.39 and 3.33 to 54.76 me l^{-1} with the mean values of 0.42, 4.98 and 26.69 me l^{-1}, respectively. The Cl^{-} was the dominant anion followed by HCO_3^{-} and CO_3^{2-}. Similar observations have been made by Savalia *et al.* (2006), Patel (2010) and Gandhi (2013). The total water soluble cations as well as anions were highest in upper coast area. This might be due to very high ingress of sea water (Patel *et al*., 1982) caused as a result of over exploitation of groundwater for irrigation, in areas near to the sea.

Underground water quality

Table 1: Chemical composition of irrigation water collected during month of May from the area adjoining to selected profile of north-west Gir Madhuvanti toposequence of south Saurashtra (weighted mean)

No.	Source of water	Water table depth (m)	pH	EC (dSm^{-1})	Cations (mel^{-1}) Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	Total cations (mel^{-1})	Anions (mel^{-1}) CO_3^{2-}	HCO_3^{-}	Cl^{-}
Pedon-1	Well / Tube well	32.71	7.45	0.68	2.21	1.90	2.14	0.0	6.26	0.0	4.58	3.33
Pedon-2	Well / Tube well	27.40	7.62	0.73	2.23	2.32	2.86	0.01	7.42	0.35	4.02	3.34
Pedon-3	Well / Tube well	52.14	7.77	1.15	3.36	2.45	6.96	0.03	12.79	0.48	5.50	6.73
Pedon-4	Well / Tube well	23.54	7.85	4.39	9.19	14.35	19.88	0.23	43.65	0.41	4.68	40.83
Pedon-5	Well / Tube well	12.63	8.21	5.54	7.32	14.83	33.32	0.50	55.98	0.74	6.39	51.13
Pedon-6	Well / Tube well	11.5	8.26	5.85	7.67	15.00	37.55	0.71	60.94	0.55	4.74	54.76
Overall Mean	26.65	7.86	3.06	5.33	8.47	17.12	0.25	31.18	0.42	4.98	26.69	

Table 2: Water quality evaluation of irrigation water collected during month of May from the area adjoining to selected profile of north-west Gir Madhuvanti toposequence of south Saurashtra (weighted mean)

No.	SSP	SAR	Permeability index	MAR	SCAR	Kelly's ratio	Total permanent hardness (mg l^{-1})	Water quality class
Pedon-1	34.23	1.49	68.48	46.18	1.44	0.52	13.32	C_2S_1
Pedon-2	38.62	1.94	65.67	50.98	1.92	0.63	15.09	C_2S_1
Pedon-3	54.24	4.09	72.87	42.13	3.79	1.19	18.44	C_3S_1
Pedon-4	48.16	6.20	50.76	60.96	6.55	0.84	81.83	C_4S_1
Pedon-5	59.66	10.11	64.63	66.96	12.31	1.50	79.10	C_4S_2
Pedon-6	61.95	11.36	65.97	66.17	13.56	1.65	80.69	C_4S_2
Overall Mean	49.4	5.86	64.73	55.56	6.59	1.05	48.07	C_4S_1

SSP- Soluble Sodium Percentage, SAR- Sodium Adsorption Ratio, MAR- Magnesium Adsorption Ratio, SCAR- Sodium to Calcium Activity Ratio and RSC (Residual Sodium Carbonate - absent in all water samples)

Table 3: Evaluation of underground water USSL EC classes in the different land slope of north-west Gir Madhuvanti Toposequence of south Saurashtra

Salinity class	Salinity hazard	EC (dSm^{-1})	% of samples	No. of samples	Guideline for suitability with management
C_2	Medium salinity	0.25-0.75	20	22	1) Water can be used for all soils with little danger of harmful salinity level development.2) The salinity sen sitive crops might be affected
C_3	High salinity	0.75-2.25	25.45	28	1) Water cannot be used on soils with restricted drainage. Even with adequate drainage, special management for irrigated crops may be required. 2) Plants with good salt tolerance should be selected.
C_4	Very high salinity	> 2.25	54.55	60	1) Water is not suitable for irrigation under ordinary conditions, but may be used occasionally under very special circumstance. The soil must be permeable, drainage must be adequate and irrigation water must be applied in excess to provide considerable leaching. 2) Very salt tolerant variety should be selected.

Table 4: Evaluation of underground water USSL SAR classes in the different land slope of north-west Gir Madhuvanti toposequence of south Saurashtra

Salinity class	Sodicity hazard	SAR range	% of samples	No. of samples	Guideline for suitability with management
S_1	Low	< 10	80	88	1) Water can be used for all soils with little danger of harmful Na level development. 2) The Na sensitive crops might be affected
S_2	Medium	10 - 18	20	22	1) Sodium hazard likely to occurr in fine textured soil. 2) Water can be used on soil having high permeability.

The SSP of underground water ranged from 34.23 to 61.95 me l^{-1} with a mean value of 49.48 me l^{-1} indicating the irrigation water is not harmful (< 60 SSP) with respect to Na^+ ion. The SAR of underground water ranged from 1.49 to 11.36 with a mean value of 5.86 indicating the irrigation water of north-west Gir Madhuvanti toposequence have low sodium hazard. The SAR and SSP increased with increasing pH and EC (Savalia *et al*., 2006, Patel, 2010 and Gandhi, 2013). The RSC was absent in all water samples. These results are in conformity to those reported by Savalia (2005) Patel (2010) and Gandhi (2013).

The permeability index ranged from 50.76 to 72.87 with a mean value of 64.73 indicating not suitable for irrigation (< 65). Magnesium adsorption ratio ranged from 42.13 to 66.96 with a mean value of 55.56 indicating no harmful effect of magnesium hazards (> 50). Sodium to calcium activity ratio ranged from 1.44 to 13.56 with mean value of 6.59 indicating normal water (5-10). Kelli's ratio ranged from 0.52 to 1.65 with mean value of 1.05 indicating not suitable for irrigation (> 1) and total permanent hardness ranged from 13.32 to 81.83 mg l^{-1} with mean value of 48.07 mg l^{-1} indicating not hazardous for irrigation (< 150 mg l^{-1}) in the north-west Gir Madhuvanti toposequence (Vadher *et al.,* 2016). In general, the underground water of lower elevated area was placed under doubtful class or C_4S_1 than that of higher elevated area. Similar results were also reported by DACS (2001), Savalia *et al*. (2006) Patel (2010) and Gandhi (2013).

Water resources constraints

Hill slope

High runoff, low surface water reservoir condition, low availability of ground water and deep water table were the major water resources constraints found on hill slope area.

Upper piedmont

The moderate runoff, moderate availability of ground water, moderate surface reservoir condition, and deep water table were the major water resources constraints found on upper piedmont area.

Lower piedmont

The moderate availability of ground and deep water table water resource constraint were observed in lower piedmont.

Plain area

The moderate to high salinity water and temporary water logging were the major water constraints observed in plain area.

Depression area

The very high salinity & sodic water and temporary water logging were the major water constraints observed in depression area.

Upper coast

Temporary water logging, very high saline and sodic ground water area of seacoast were the major water constraints observed in coast area.

Evaluation of underground water resource

The evaluation of underground water was carried out based on EC classes, SAR classes and combined effect of EC and SAR classes (as per semi-logarithmic USSL diagram, Richard, 1954), which are presented in Table 3, 4 and 5, respectively. Out of 110 wells / tube wells water samples 20, 25.45 and 54.55 per cent were facing the medium, high and very high salinity hazard problem (Table 3), respectively, while the 80 and 20 per cent samples were facing the low and medium sodicity hazard problems (Table 4). The guideline for the management of different well / tube well water samples of respective EC classes and SAR classes are presented in Table- 3 and 4, respectively. The distribution of underground water for irrigation of the different land slopes of north-west Gir Madhuvanti toposequence (based on semi-logarithmic USSL diagrams) are presented in Table 5. The results reveals that out of 110 well / tube well water samples 20, 25.45, 34.55 and 20 were placed in C_2S_1, C_3S_1, C_4S_1 and C_4S_2 water quality class, respectively. The guideline for its suitability and management are given in Table 5.

Suitability of underground water resource

For ongoing discussion, the different quality of irrigation water was not suitable directly to the field. It is only just for guideline to use for as irrigation. The suitability of particular quality class of irrigation water is determined by the following five factors (f): SI = f (QSPCM) Where,

SI = Suitability of irrigation water

Q = Quality of irrigation water: Water quality class, amount, nature and proportion of cations and anions present in water.

S = Soil property: Depth of soil, texture, structure, drainage, permeability, hard pan, depth of water table, chemical composition of the soil pH, EC, ESP and $CaCO_3$ content will determine the suitability of irrigation.

P = Nature of plants to be grown: Water, which may not be suitable for sensitive crop, it may be suitable for tolerant crops. The information on salt tolerant crops and their varieties would decide the suitability of poor quality of underground water.

C = Climatic condition: High temperature with less humidity will require more number of irrigation of prevailing water quality for irrigation to use in appropriate crop selection, considering the soil type and climate *e.g.* High rainfall area has the sufficient amount of rainfall to leach out the salts to use high saline water quality as compare to arid climatic condition in study area at the same soil type. Thus, the climatic condition determined the suitability of poor quality of underground water.

M = Management: Farmers to judge the suitability of poor quality of underground water, e.g. some of the farmers add the seashore sand in the soil which provide the high infiltration rate, a good soil physical environment and also act as mulch which helps in suitability.

Conclusion

Based on the present study it can be concluded that the soils of study area were underground water quality for irrigation based on semi-logarithmic USSL diagram, in observed that 20, 25.45, 34.55 and 20 per cent water samples were placed in C_2S_1, C_3S_1, C_4S_1 and C_4S_2 water quality class, respectively, indicating the majority of water samples fall in C_4S_1 class. The pH, EC, cations and SAR increased with decrease in elevation from higher topography to lower topography, whereas the SSP and anions was found irregular trend with respect to elevation. The strategies for its suitability and management were discussed in the text.

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