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EVALUATION OF GROUNDWATER QUALITY FOR IRRIGATION SUITABILITY IN THIMMAJIPET MANDAL, MAHABUBNAGAR DISTRICT

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ABSTRACT

Georeferenced groundwater samples collected from Thimmajipet mandal, Mahabubnagar district were analyzed and evaluated for their suitability for irrigation. Out of 49 samples, 12 per cent samples recorded pH > 8.5 and electrical conductivity varied from 500 to 5130 µS cm^{-1}. All the samples have high Mg^{2+} content and 92 and 94 per cent samples have high Ca^{2+} and Na^{+}, respectively. Among the total groundwater samples 59 per cent have high sodium hazard, 80 per cent with high magnesium hazard, 7 per cent with high Mg/Ca ratio and 100 per cent with very high permeability index. Water samples were classified as C3S1 (29%), C3S2 (39%), C2S2 (2%) and C2S1 (4%). In general, the groundwater in Thimmajipet mandal is unsafe for long-term irrigation use.

KEYWORDS: Groundwater quality, Irrigation suitability, Permeability index, Sodium hazard.

INTRODUCTION

Groundwater is one of the prime sources for irrigation especially in arid and semi-arid regions of India. Tube wells are major source of irrigation and their share has increased from 1 per cent in 1960–61 to 37 per cent in 1999–2000 (MoRD, 2006). Telangana, located in the southern Deccan plateau region receives very less mean annual rainfall (MAR) with uneven distribution and the agriculture sector registered a mixed growth rate varying from 25.2 to -10.0 per cent during the period 2005-06 to 2013-14 due to frequent droughts. The cropping intensity has increased from 109 per cent in 1993-94 to 127 per cent in 2013-14 with a major shift in irrigation pattern making it more costly for the farmers, highly uncertain and unsustainable (Rao, 2014). The vagaries of climate change have put the seasonal agricultural system and agriculture dependent economy of Telangana in jeopardy.

The occurrence and behavior of groundwater is an outcome of combined interplay of hydrological, geological, structural and climatological factors. The composition of groundwater is determined by their source and the type of strata over which they flow (Rengaraj, 1996) and the kinds of salts found in them depends on the laws of dissolution. The suitability of water for irrigation is influenced by many factors such as quality of water, soil type, salt tolerance characteristics of the plants, climate and drainage characteristics of the soil (Michael, 1990). The potential evapo-transpiration largely exceeds precipitation in the semi-arid regions, thereby increasing the probability of soil salinity or sodicity development if the groundwater used for irrigation is poor in quality. Telangana is now facing both depleting groundwater table and deficit rains and allocation of natural resources like groundwater to different sectors *viz*., agriculture, industry and drinking water use has become a challenging task for policy makers. The steady decline in groundwater level warrants immediate attention on both quantity and quality of groundwater. The groundwater quality is deteriorating particularly with high salt content and limits its use for agriculture in Mahabubnagar district (CWGB, 2013). In the context of above scenario, several studies need to be conducted to assess the potential threat of poor quality groundwater. The present study is one such type, which attempts to evaluate the groundwater for its quality and suitability for irrigation in Thimmajipet mandal, Mahbubnagar district.

MATERIALS AND METHODS

Description of the Study Area

Thimmajipet mandal is part of Mahabubnagar district, located between 16°55' N latitude and 78°20' E longitude with on elevation of 481 m above mean sea level in southern Telangana plateau, (Agro Ecological Sub Region 7.2).The total geographical area is 200.90 km^2

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and covered by granite, peninsular gneiss, basalt, and mixed granite and basaltic rocks. The MAR varies from 450-550 mm. Gross cropped and irrigated areas are 14,020 and 1,960 ha respectively. Major crops grown during *kharif* are cotton (*Gossypium hirsutum*), maize (*Zea mays*) followed by paddy (*Oryza sativa*), red gram (*Cajanu scajan*) and castor (*Ricinus communis*). In *Rabi* groundnut (*Arachis hypogaea*) is the major crop followed by paddy and maize. The length of growing period (LGP) is 90-120 days. Tube wells are the major sources of water irrigating more than 90 per cent of the irrigated area.

Sampling and Analysis

Forty nine geo-referenced groundwater samples were collected from 19 villages of the Thimmajipet mandal (Fig.I) during February 2015 from tube wells in stopper fitted plastic bottles and stored at a temperature below 4°C prior to analysis in the laboratory. The samples were analyzed for pH, electrical conductivity, cations (Ca^{2+}, Mg^{2+}, Na^+ and K^+) and anions (Cl^-, CO_3^{2-}, HCO_3^-, SO_4^{2-} and BO_3^{3-}) using standard procedures (APHA, 2005). Important indicators of water quality for irrigation were derived using the guidelines given by Ayers and Westcot (1985). Parameters such as pH, electrical conductivity (EC), soluble sodium percentage (SSP), residual sodium carbonate (RSC), potential salinity (PS), magnesium hazard (MH) and permeability index (PI) were used to assess the suitability of water for irrigation purposes.

SSP was calculated by the following equation (Todd, 1995).

$$SSP = \frac{Na^+}{Ca^{2+} + Mg^{2+} + Na^+ + K^+} \times 100$$

RSC was calculated according to Gupta and Gupta (1987):

$$RSC = (CO_3^{2-} + HCO_3^-) - (Ca^{2+} + Mg^{2+})$$

PI was calculated according to Doneen (1964) employing the following equation:

$$PI = \frac{Na^+ + HCO_3^-}{Na^+ + Ca^{2+} + Mg^{2+}} \times 100$$

MH was calculated using the following equation (Raghunath, 1987):

$$MH = \frac{Mg^{2+}}{Ca^{2+} + Mg^{2+}} \times 100$$

PS was calculated based on the formula (Hammet, 1992) as:

$$PS = \frac{1}{2} SO_4^{2-} + Cl^-$$

RESULTS AND DISCUSSION

Hydrochemistry

pH ranged between 6.91 and 8.91. Among the 49 samples studied, 12% showed pH > 8.5 and may be harmful for plant growth by (Table 1) inducing alkalinity in soils. Electrical conductivity (EC) varied from 500 to 5130 µS cm^{-1} with a mean value 1897 µS cm^{-1} (Table 1) and 20 per cent of water samples have EC more than 2500µS cm^{-1} which is unsafe for irrigation and may induce strong salinity in irrigated soils (Ayers and Westcot, 1985).Total dissolved solids (TDS) varied from 320 to 3283 mg L^{-1} with a mean value of 1214 mg L^{-1}. According to FAO standards (Table 2), irrigation water with more than TDS > 1500 mg L^{-1} are classified with severe limitation for its use and 20 per cent of the water samples are unsafe for irrigation.

Ionic concentration

The concentration of cations and anions in groundwater depends on the geology, weathering of rocks and soil and water management practices. Calcium (Ca^{2+}) contributes to the hardness of the water and the sources of Ca^{2+} in ground water especially in sedimentary rocks such as calcite, aragonite, gypsum and anhydride. In the present study, Ca^{2+} varied from 11 to 114 me L^{-1} and Mg^{2+} from 14 to 129 me L^{-1}. The usual range of Ca^{2+} and Mg^{2+} in irrigation water is 0-20 and 0-5 me L^{-1}, respectively and 92 per cent of water samples have Ca^{2+} more than 20 me L^{-1} and all the samples have high Mg^{2+}. The high concentration of Ca^{2+} and Mg^{2+} results in alkalinity of water and induces osmotic stress to the plants. K^+ ranged between 0.13 and 1.97 me L^{-1} while Na^+ varied between 35.65 and 117 me L^{-1} (Table 1). The safe range of Na^+ is 0-40 me L^{-1} and 94 per cent of water samples have high sodium content. Cl^- varied from 5 to 18 me $L^{-1}$and 39 per cent samples are with moderate Cl^- toxicity, 53 per cent with high toxicity and 8 per cent with very high toxicity according to FAO standards (Ayers and Westcot, 1985). CO_3^{2-} varied from 0 to 10 me L^{-1}, HCO_3^- from 0.3 to 17.5 me L^{-1}, SO_4^{2-} from 0 to 63 me L^{-1} and BO_3^{3-} from 0.2 to 1.25 me L^{-1}.

Table 1. Summary statistics of groundwater properties in study area

Characteristics	Minimum	Maximum	Mean	Standard Deviation
pH	6.91	8.91	7.82	0.46
EC (µs cm^{-1})	500	5130	1897	1194
TDS (mg L^{-1})	320	3283	1214	764
K^+ (me L^{-1})	0.13	1.97	0.41	0.28
Na^+ (me L^{-1})	35.65	117	69	21.70
Ca^{2+} (me L^{-1})	11	114	32.47	15.57
Mg^{2+} (me L^{-1})	14	129	41.67	22.56
Cl^- (me L^{-1})	5	18	8.65	2.59
CO_3^{2-} (me L^{-1})	0	10	0.73	2.18
HCO_3^- (me L^{-1})	0.3	17.5	10.96	4.09
Boron (mg L^{-1})	0.2	1.25	0.52	0.25
SO_4^{2-} (me L^{-1})	0	63	11.96	11
RSC (me L^{-1})	-89.00	-5.00	-25.38	17.62
SSP (%)	19.74	71.54	48.96	11.38
PS (me L^{-1})	7	40	14	6.93
Magnesium Hazard	26.42	76.09	55.40	9.84

Table 2. Evaluation Criteria of water samples (USSL, 1954 and Ayers and Westcot, 1985)

Water Quality Classes for irrigation				
Salinity Hazard				
Parameters	**Classification**			
	Excellent	**Good**	**Permissible**	**Unsuitable**
EC (dSm^{-1})	<0.25	0.25-0.75	0.75-2.25	>2.25
TDS (mg L^{-1})	<200	200-500	500-1500	>1500
Soil Water infiltration (Evaluation using EC and SAR together)				
EC (uS cm^{-1})	**Class**		**SAR**	**Class**
<250	C1		>10	S1
250-750	C2		10-18	S2
750-2250	C3		18-26	S3
2250	C4		>26	S4
Specific Ion Toxicity				
Boron (me L^{-1})	**Class**		**Chloride (me L^{-1})**	**Class**
<0.5	Low		<4	Good
0.5-10	Medium		4-7	Medium
1.0-2.0	High		7-12	Unsafe
>2.0	Very high		>12	Very Unsafe

Table 3. Water quality indices of groundwater in the study area

Sample ID	[a] SAR	[b] RSC	[c] SSP	[d] PS	[e] MH	[f] PI
W1	17.90	-35.5	58.29	26	70.37	59
W2	15.77	-12.0	59.72	8	73.21	71
W3	9.97	-12.0	50.79	13	76.09	63
W4	13.10	-15.5	55.43	10	60.00	60
W5	4.73	-64.0	21.97	20	62.77	25
W6	4.86	-89.0	19.74	20	64.95	23
W7	6.57	-41.0	31.41	40	52.94	38
W8	8.06	-22.0	41.60	17	52.38	51
W9	8.56	-17.5	44.16	16	48.28	55
W10	7.08	-84.5	26.20	16	42.42	32
W11	18.43	-19.4	62.21	21	74.19	63
W12	13.26	-13.0	55.75	33	30.91	67
W13	11.30	-13.5	53.66	10	46.81	64
W14	12.44	-17.0	52.87	11	52.46	63
W15	7.53	-22.0	39.78	11	65.63	49
W16	19.54	-13.0	64.37	14	56.90	74
W17	13.47	-13.5	56.83	21	50.00	67
W18	10.08	-25.0	45.02	10	53.33	54
W19	11.37	-11.5	56.45	12	44.74	65
W20	9.94	-27.0	44.70	13	46.67	53
W21	20.10	-12.0	65.99	8	26.42	75
W22	14.82	-22.5	54.90	9	43.84	64
W23	8.30	-31.0	38.09	9	52.22	48
W24	6.74	-36.5	33.31	8	51.11	40
W25	13.92	-24.0	52.61	23	55.13	62
W26	6.48	-26.5	34.84	8	57.53	44
W27	14.80	-16.0	57.10	17	59.02	67
W28	11.99	-23.5	49.18	15	48.68	59
W29	12.73	-71.0	40.69	32	75.88	46
W30	9.69	-29.7	45.51	9	50.00	46
W31	13.24	-20.0	54.97	12	62.07	62
W32	23.15	-5.0	71.54	11	57.14	77
W33	8.68	-24.5	43.47	11	58.73	50
W34	6.30	-25.0	35.70	11	62.50	43
W35	11.81	-28.0	47.90	14	58.54	56
W36	12.87	-23.5	50.45	9	60.76	61
W37	10.55	-22.0	48.64	14	55.74	53
W38	10.43	-28.0	46.03	18	60.81	53
W39	15.56	-9.0	62.60	12	52.38	74
W40	11.01	-21.0	47.65	7	56.94	59
W41	18.89	-12.5	63.21	9	51.67	74
W42	8.62	-15.5	44.97	8	52.73	57
W43	12.18	-20.5	52.14	9	58.06	60
W44	19.31	-8.5	67.44	10	44.19	77
W45	16.40	-27.0	56.79	12	59.74	63
W46	10.64	-18.5	49.12	12	53.33	59
W47	8.93	-35.5	39.41	13	58.06	47
W48	11.55	-19.5	49.47	12	50.72	61
W49	14.11	-19.5	54.34	9	55.71	64

[a]: Sodium Adsorption Ratio; [b]: Residual Sodium carbonate;
[c]: Soluble Sodium Percentage; [d]: Potential Salinity;
[e]: Magnesium Hazard; [f]: Permeability Index

Water quality indices

The sodium adsorption ratio (SAR) indicates relative proportion of sodium to calcium and magnesium, which influences soil physical properties especially hydraulic conductivity. Results indicated that 6 per cent of water samples have high (SAR > 18), 53 per cent with medium (SAR 10-18) and 41 per cent with low (SAR < 10) sodium hazard. Also, soluble sodium in irrigation water is an important parameter influencing the soil properties and crop performance. High concentration of sodium in irrigation water may stunt the plant growth and reduces soil permeability (Joshi *et al.* 2009). The soluble sodium percentage (SSP) varied from 19.74 to 71.54 per cent and 17 per cent of water samples are unsafe for irrigation with SSP > 60 per cent.

The concentration of HCO_3^- and CO_3^{2-} influences the suitability of water for irrigation purpose. The water with high residual sodium carbonate (RSC) will increase the pH in soils. Since the calcium and magnesium content were proportionately high, effect of HCO_3^- and CO_3^{2-} through RSC index is low as the RSC varied from -89 to -5 (Table 3). Potential salinity (PS) is an indicator of ability of water to cause salinity in soils and the suitability of water for safe use in different textured soils. PS varied from 7 to 40 me L^{-1} and the groundwater is unsuitable for irrigating fine textured soils (PS > 3). However, 71% samples are suitable for medium textured soils (PS 3 – 15 me L^{-1}) and 84 per cent suitable for sandy soils.

Generally calcium and magnesium maintain a state of equilibrium in most waters. High level of Mg^{2+} usually promotes increase in Na^+ concentration in irrigated soils. Results showed that 80 per cent of water samples are above the acceptable limit of 50 per cent MH (Ayers and Westcot, 1985). The Mg/Ca ratio for analyzed water samples varied from 0.36 to 3.18. Among the groundwater samples 73 per cent is safe (Mg/Ca < 1.5), 20 per cent is moderately safe (Mg/Ca 1.5-3.0) and 7 per cent is unsafe (Mg/Ca >3.0) for irrigation. According to U.S. Salinity Laboratory (USSL, 1954) classification, 29 per cent are grouped in C3S1, 39 per cent in C3S2 and 2 per cent in C2S2 (Fig. 2) indicating their unsuitability for long term irrigation with moderate to high salinity and sodium hazard.

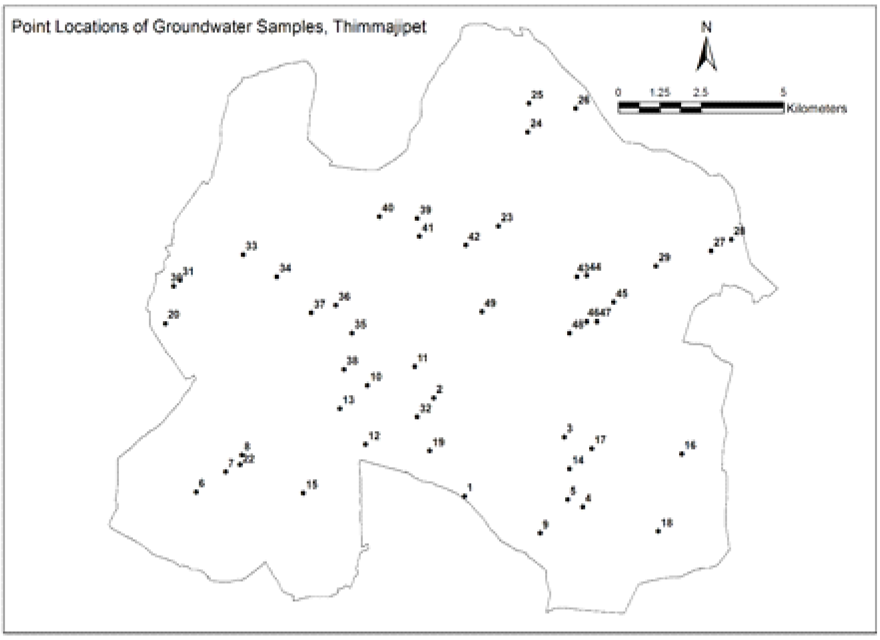

Fig. 1. Map showing point locations of collected groundwater samples in study area

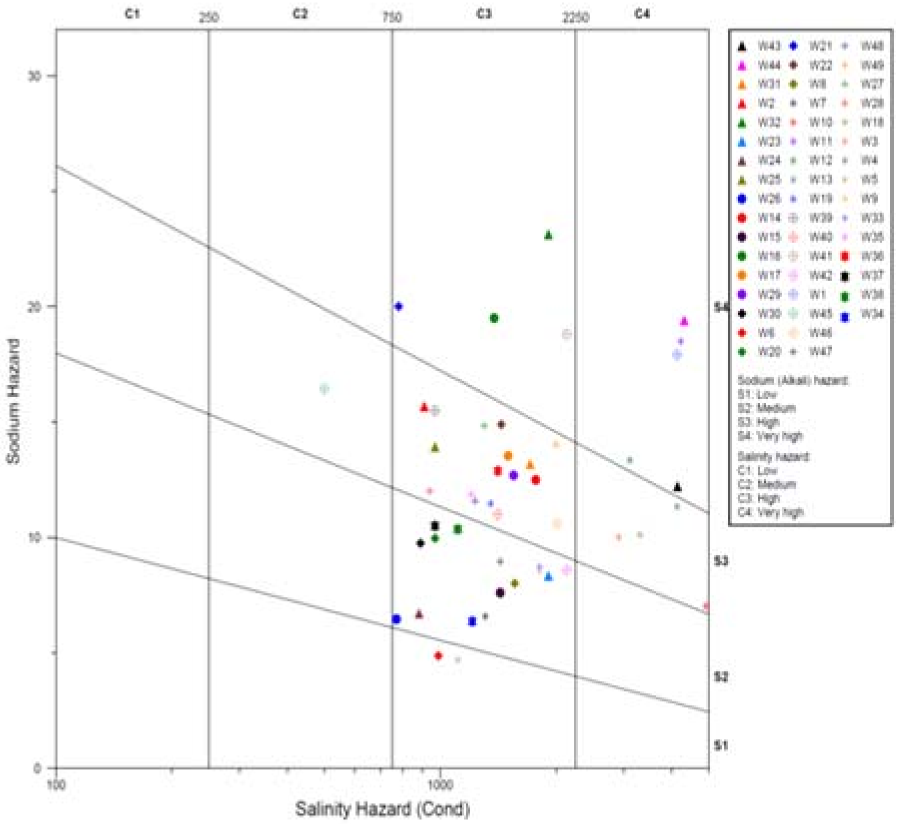

Fig. 2. Salinity diagram showing the classification of groundwater samples

CONCLUSION

The groundwater samples of Thimmajipet mandal were moderate to high in sodium hazard, highly saline and medium in chloride toxicity. The ground water is dominated by Na^+, Mg^{2+} and Ca^{2+} and have the potential to cause damage to the cultivated crops by inducing soil salinity and alkalinity. Since most of the water samples were classified as highly saline, use of groundwater blended with fresh water for irrigation could be an option to minimize the potential of soil salinity. Upon long term use for irrigation the sodium dominated waters may force the accumulation of sodium in soils and may impede the hydraulic properties of soils. Hence, leaching methods need to be improvised to remove salts from irrigated soils.

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