Sodicity and Salinity Hazards in Water Flow Processes in the Soil

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Abstract: Groundwater is one of the natural resource with the potential for domestic, agricultural and industrial consumption. This paper presents the results of the distribution of salinity characteristics (electrical conductivity and sodium adsorption ratio) of groundwater and based on the results, the evaluation of the sodicity and salinity hazards or in the processes if such groundwater is used for such purposes has been restrictive. This is because of the salinization of aquifers generated by rock salt present below the aquifers. The issue was studied for the groundwater environment in the Karha river basin area, Baramati, Pune, (M.S.) India, for the period of September 2009 to August 2010. The measured data were presented in the form of graphical attachments. The average annual values of the electrical conductivity of groundwater ranged from 490 to 8920 $\mu\text{S}/\text{cm}$ in the examined period. Data obtained from analysis signifies the salinity of groundwater in study area is high to very high salinity and can't be used for crops in a soil with restricted drainage but it can be used under very special circumstances. The sodium adsorption ratio values indicate low, medium to high sodium salinization of the groundwater.

Keywords: Groundwater, Electrical conductivity, Sodium adsorption ratio, Salinity hazard, Sodicity hazard

Introduction

Water is a valuable resource on which all life is dependent. Water is a basic necessity of life, not only for people but for every type of plant and animal as well¹.

The present study aims at the assessment of sodicity and salinity hazard of groundwater of drought prone Karha river basin area, Baramati, Pune, (Maharashtra), India. Leaching of rock is a natural process and ion concentration in soil and water becomes higher, such groundwater when used for irrigation it leads to the accumulation of salts in the soil profile². Groundwater is drawn by evapotranspiration, and soluble salts coagulate on the surface of soil particles and sodium ions are adsorbed into the soil colloidal system³ (Figure 1).

Figure 1. Soil surface contaminated with excess of salts

When such water is used for agricultural purposes, the suitability of water depends on how it can be used under specific conditions. These conditions include the tolerance of crops to salts, various physical and chemical properties of soil, management of irrigation methods and climatic conditions in the given region⁷.

The total water mineralization is defined as the sum of mass concentrations of solid inorganic substances dissolved in water, electrolytes (cations and anions) and non-electrolytes. The term salinity relates to the total concentration of the main dissolved inorganic ions, *i.e.* Na^+ , K^+ , Ca^{2+} , Mg^{2+} , HCO_3^- , SO_4^{2-} and Cl^- in groundwater⁴. The total concentration of salts (*i.e.* the salinity) is expressed as the sum of the individual cations and anions in mmol/L, or in mg/L. For reasons of analytical simplification the real salinity indicator is the electrical conductivity of water (EC) expressed in $\mu\text{S}/\text{cm}$. Electrical conductivity is always expressed at a standard temperature of 25 °C in order to allow for the comparison of electrical conductivity in various climatic conditions. The adverse effect of irrigation water quality on the physical properties of soil is associated with the accumulation of sodium ion on the soil exchange complex which imparts instability to the soil aggregates and whose disruption is followed by dispersion of clay particles resulting in clogging of soil pores⁵⁻⁹.

The objective of the present paper was to obtain groundwater salinity characteristics and to use them to determine the sodicity and salinity hazard within the aforementioned processes in the water of the Karha river basin area.

Experimental

Ground water samples from different seventeen wells of Karha river basin area are selected randomly and by considering the topography of the study area (Figure 2).

Figure 2. Location map of the study area

Sample collection

Water samples from the selected sites were collected in a good quality polyethylene bottle of one liter capacity during period September 2009 to May 2010 (winter and summer season respectively).

Chemical analysis

The concentration of salting ions was determined in groundwater samples. This concerns the anions: carbonates, bicarbonates, chlorides, sulphates and cations: calcium, magnesium, sodium, potassium. The pH and EC were measured and the SAR values calculated by using standard methods recommended by APHA⁴.

Results and Discussion

Chemical properties of ground water samples from different locations of karha river basin area are shown in Table 1 and 2 pH value of water samples were varying from 6.75 to 8.6. Electrical conductivity (EC) of the groundwater is varying from 490 to 8920 $\mu\text{S}/\text{cm}$ at 25 °C in summer while 540 to 8650 $\mu\text{S}/\text{cm}$ in winter season. The salinity hazard in the groundwater is considerable. 30% samples are with EC up to 750 $\mu\text{S}/\text{cm}$ (minimum value 540 $\mu\text{S}/\text{cm}$). In the rest of the area (70%) salinity hazard is classified as high to very high with EC values up to 8650 $\mu\text{S}/\text{cm}$ (Figure 3).

It is necessary to express the total concentration of dissolved salts in irrigation waters in terms of the electrical conductivity of water for diagnostic and classification purposes.

Table 1. Water analysis data of Karha river basin area (post monsoon) winter 2009

S. No	Sampling sites	pH	Salinity	TDS	Sodium	RSC	SAR	Ca	Mg	TH	Na	K
			$\mu\text{S/cm}$	mg/L	%	meq/L		mg/L	mg/L	mg/L	mg/L	mg/L
1	Ambi	7.71	540	346	23.81	2.7	0.76	14.03	34.05	175.2	25.3	0.8
2	Morgaon	8.04	570	365	22.97	2.3	0.61	28.06	19.46	150.2	20.7	0.7
3	Tardoli	8.5	1700	1088	55.40	0.4	2.56	30.06	19.46	155.2	89.24	0.9
4	Baburdi	7.56	1650	1056	55.15	0.8	2.97	22.04	29.18	175.2	103.5	6.2
5	Karhati	6.75	8650	5536	7.98		0.71	116.23	391.55	1902.5	75.9	2.4
6	Jalgaon KP	7.1	6400	4096	19.31		1.70	242.48	268.74	1711.9	188.6	2.3
7	Jalgaon Supe	7.16	3800	2432	27.48		1.93	168.34	125.25	935.9	163.3	1.4
8	Anjangaon	7.49	1200	768	24.54		0.96	22.04	49.86	260.3	39.1	1.1
9	Karhawagaj	7.25	1900	1216	29.49		1.30	54.11	48.64	335.4	64.63	0.7
10	Nepatwalan	7.88	7100	4544	33.43		3.20	721.44	35.26	1945.9	450.8	5.2
11	Barnanpur	7.58	1100	704	27.35	2.3	0.85	20.04	27.97	165.2	28.75	0.8
12	Medad	8.38	7600	4864	33.58		3.55	248.50	256.58	1676.8	391	4.6
13	Baramati	7.3	1250	800	96.02	9.15	27.64	9.02	2.43	32.5	471.5	7.8
14	Malad	8.11	1100	704	91.23	10.5	18.21	11.02	13.38	82.6	439.3	7.3
15	Gunawadi	7.4	600	384	48.08	3.5	1.83	34.07	15.81	150.1	64.4	0.9
16	Dorlewadi	8.19	650	416	66.24	0.85	5.02	9.02	37.70	177.7	163.3	2.7
17	Songaon	7.76	810	518	56.03	4.75	2.49	17.03	19.46	122.6	73.6	2.4
	Min	6.75	540	347	7.98	0.4	0.61	9.02	2.43	32.5	20.7	0.7
	Max	8.5	8650	5536	96.02	10.5	27.64	721.44	391.6	1945.9	471.5	7.8

Table 2. Water analysis data of Karha river basin area (pre monsoon) summer 2010

S.No	Sampling sites	pH	Salinity	TDS	Sodium	RSC	SAR	Ca	Mg	TH	Na
			$\mu\text{S/cm}$	mg/L	%	meq/L		mg/L	mg/L	mg/L	mg/L
1	Ambi	7.8	580	371	25.9	3.1	0.83	12.02	32.83	165.2	26.68
2	Morgaon	8.12	580	371	23.3	2.4	0.64	30.06	20.67	160.2	22.54
3	Tardoli	8.55	1800	1152	52.3	0.4	2.37	32.06	21.89	170.2	86.25
4	Baburdi	7.7	1700	1088	56.3	0.7	3.07	20.04	30.40	175.2	105.8
5	Karhati	6.8	8920	5709	7.7		0.70	118.24	420.74	2027.7	77.97
6	Jalgaon KP	7.3	6500	4160	15.9		1.41	264.53	297.92	1887.1	163.8
7	Jalgaon Supe	7.5	4000	2560	24.8		1.75	172.34	138.62	1001.0	152
8	Anjangaon	7.6	1150	736	22.3		0.87	24.05	52.29	275.4	36.57
9	Karhawagaj	7.65	1850	1184	27.4		1.19	60.12	49.86	355.4	61.64
10	Nepatwalan	7.85	7890	5056	33.70		3.31	761.52	36.50	2051.1	478.4
11	Barnanpur	7.7	800	512	25.4	2.5	0.78	18.04	29.18	165.2	25.99
12	Medad	8.6	8050	5152	31.2		3.28	262.52	271.17	1771.9	371.2
13	Baramati	7.6	1350	864	96.1	9.6	26.62	10.02	1.22	30.0	454
14	Malad	8.5	1150	736	91.2	11	17.61	12.02	12.16	80.1	424.8
15	Gunawadi	7.7	490	314	45.4	3.6	1.69	36.07	17.02	160.1	61.64
16	Dorlewadi	8.3	730	467	63.4	0.9	4.50	10.02	38.91	185.3	150
17	Songaon	7.85	910	582	53.0	4.56	2.24	20.04	20.67	135.2	69.92
	Min	6.8	490	314	7.7	0.4	0.64	10.02	1.22	30.0	22.54
	Max	8.6	8920	5709	96.1	11	26.62	791.52	420.7	2051.1	478.4

Figure 3. Salinity of ground water of Karha river basin area

Based on electrical conductivity, waters are classified into four classes according to Richards³. The boundary values between the individual classes are 250, 750 and 2250 $\mu\text{S/cm}$. These limit values were determined on the basis of the relationship between the electrical conductivity of waters.

Low salinity water ($\text{EC} < 250 \mu\text{S/cm}$) can be used for irrigation of most crops on Probability that soil salinity will develop. Medium-salinity water ($250 < \text{EC} < 750 \mu\text{S/cm}$) can be used if the soil is washed with a moderate amount of water. In most cases crops with a moderate salt tolerance can grow without applying special methods of salinity regulation.

High salinity water ($750 < \text{EC} < 2250 \mu\text{S/cm}$) cannot be used on soils with restricted drainage. Special management of salinity regulation and choice of crops with good salt tolerance are required even for soils with adequate drainage.

Very high salinity water ($\text{EC} > 2250 \mu\text{S/cm}$) is not suitable for irrigation under ordinary conditions, but it can be used under very special circumstances. The soils must be permeable, drainage must be adequate, water must be applied in excessive amounts in order to ensure high soil leaching to be able to grow crops that are very salt tolerant.

The SAR value ranges from 0.61 to 27.64 in winter season while in summer season it ranges from 0.64 to 26.62, indicating low, medium to high sodium salinization of the groundwater. In the winter season salinity of water slightly decreases, it may be due to dilution of water by rain.

The sodicity hazard is determined by absolute and relative cation concentrations. If the content of sodium is high, the sodicity hazard is high and vice versa. If calcium and magnesium

are dominant, the hazard is low. The introduction of water quality classes with regard to the sodicity hazard is even more complicated than with regard to the salinity. The classification of irrigation water with respect to SAR is mainly based on the effect of exchangeable sodium on the physical condition of the soil. Sodium sensitive crops can be damaged due to the accumulation of sodium in plant tissues.

Low sodium water ($SAR = 0-10$) can be used for irrigation on almost all soils with low risk of the emergence of harmful levels of exchangeable sodium. However, sodium sensitive crops can accumulate harmful concentrations of sodium.

Medium sodium water ($SAR = 10-18$) represents an obvious sodium hazard in fine textured soils having high cation-exchange capacity, especially in the case of low soil leaching if gypsum is not present. Such water can be used in coarse-grained soils or in organic soils with good permeability.

High sodium water ($SAR = 18-26$) can produce a harmful amount of exchangeable sodium, and will therefore require special soil management – good drainage, high soil leaching, and the addition of organic substances. Very high sodium water ($SAR > 26$) is generally unsuitable for irrigation purposes.

Conclusion

Groundwater in the study area, Karha river basin area is classified as highly mineralized water with a high hazard of salinization of the subsurface environment. In the period from September 2009 to May 2010 the average EC concentrations in groundwater ranged from 490 to 8920 $\mu S/cm$ at 25°. The plotted maps of the of salinity hazard (Figure 3) complement appropriately the knowledge of the hydrogeochemical composition of groundwater indicating, it can't be used on soils with restricted drainage and water is not suitable for irrigation under ordinary conditions but it can be used under very special circumstances. Seasonal fluctuations are observed in the water flow processes. The study of salinity serve as a reference basis when assessing alterations in its development in the period.

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