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AN ANALYSIS OF SUITABILITY OF GROUNDWATER FOR AGRICULTURAL PRACTICES IN AMBALA CITY AND AMBALA CANTONMENT AREA, HARYANA, INDIA

Ritu Sarsoha

Assistant Professor, Post Graduate Govt. College Sector 46, Chandigarh, India.

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ABSTRACT

The world has witnessed great development in past decades but deterioration of natural resources is a side product of all this progress and achievement. India hosts 16% of the world's population but water available here is only 4%. Being a major agriculture country, the dependence on groundwater resources is high particularly in non-Himalayan states. The present study explores the quality of groundwater in the study area to cater the needs on agricultural front. In the present study, the groundwater quality for suitability in agriculture from Ambala City and Ambala Cantonment, has been evaluated. A total of 61 groundwater samples have been collected and analysed for pH, EC, TH, HCO_3^-, CO_3^{2-}, Cl^-, SO_4^{2-}, NO_3^-, Ca^{2+}, Mg^{2+}, Na^+ and K^+. To assess the groundwater quality for irrigation purpose, parameters like sodium adsorption ratio (SAR), residual sodium carbonate (RSC), permeability index (PI), values have been calculated. The values of SAR indicate that all of the samples were found in good water category. In USSL diagram, the groundwater in Ambala City and Ambala Cantonment for irrigation purposes is of C_3S_1, C_4S_1 and C_1S_1 type indicating that water in Ambala City and Ambala Cantonment exhibits high salinity and low sodium and very high salinity and low sodium hazard. On the basis of RSC, all groundwater samples were observed to be suitable for irrigation purpose.

Keywords: Agriculture, Groundwater, PI, KI, SAR, RSC, Wilcox

1. INTRODUCTION

Tukura *et al.* (2013) worked on the groundwater of Nasarawa State, Nigeria. As per their study, at some of the locations, NO_3^- was present above the acceptable limit of WHO (2005) but within the maximum limit. All other parameters were found within the acceptable limit owing to low level of industrialization. Continuous disposal of industrial effluents on land, which has limited capacity

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to assimilate the pollution load, has caused groundwater pollution (Mukherjee and Nelliyat, 2006). Two fifth of the total agricultural land in India is being irrigated by groundwater. Being an agriculture economy state, Haryana is heavily dependent on its water resources. Along with the agriculture, the water demands of urban areas are also increasing. As the surface water available in the state of Haryana is too less to cater the demands of its population, the dependency on the groundwater is very high leading to its overexploitation. The state has 55 overexploited blocks, 11 critical and 5 semi critical blocks (www.cgwb.gov.in). The harvesting of groundwater in an unscientific manner results into depletion of groundwater resources. The success of the Green Revolution in Punjab and Haryana brought with itself the adverse impact on the groundwater regime in the form of over draft. The effect is so pronounced that out of 36 districts in these two states, 25 districts have areas where decline in groundwater levels have set in.). Undoubtedly the use of groundwater has improved stability in cropping over the past few decades but it has resulted into rapidly falling water tables in some states due to aquifer depletion (Rodell *et al.*, 2009; Shah, 2009). Esteller and Andreu (2005) investigated the effect of intensive exploitation of the Valle de Toluca aquifer, located in the Highlands of Mexico. This aquifer was the main source of agricultural and industrial uses in the Valle de Toluca as well as in the city of Mexico. The study revealed that the overexploitation of groundwater has led to a change in its chemical characteristics. An increase in the concentration of NO_3^- and other heavy metals was also detected which might be due to the use of fertilizers in agricultural areas and discharge of wastewater. The abstractions have resulted in lowering of the water table in the aquifer, land subsidence as well as decrease of river flows and springs. Sarsoha, and Rishi (2015) carried out a study on the temporal variation on the groundwater quality of Ambala City and Ambala Cantonment, Haryana, India. They concluded that the groundwater quality of Ambala City and Ambala Cantonment can be used for drinking purpose but needs treatment for hardness at some places.

1.2 DESCRIPTION OF STUDY AREA

Ambala is a city and a municipal corporation in Ambala district in the state of Haryana, India, located on the border to the state of Punjab. Politically, Ambala has two sub-areas: Ambala Cantonment (Ambala Cantt) and Ambala City, approximately 3 kilometers apart from each other, therefore it is also known as "Twin City".

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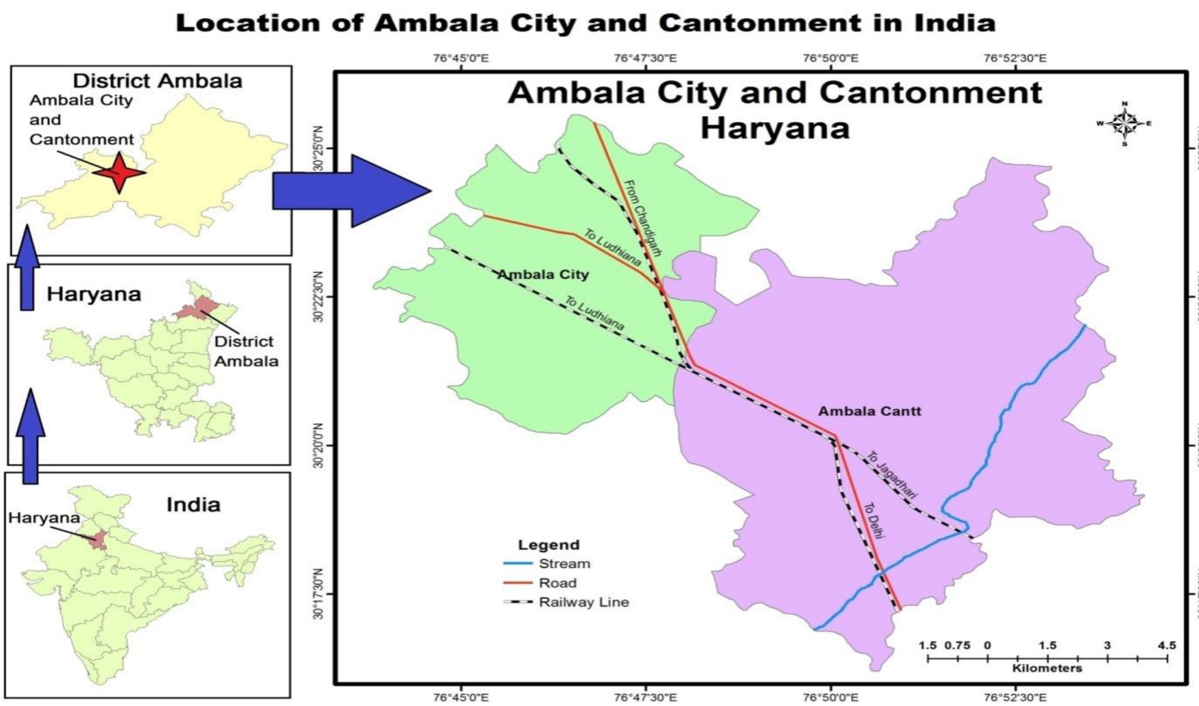

Fig. 1.1: Base map of Study Area

2. METHODOLOGY

For performing the present study, a systematic, well tested and technically sound methodology was adopted. The field and laboratory investigations carried out for the present study are discussed below.

2.1 FIELD INVESTIGATIONS

Reconnaissance survey of the area was carried out to get familiarize with the research area and to collect the preliminary baseline data pertaining to groundwater resources and meteorological parameters.

- A systematic random sampling was done to collect the groundwater samples from the area selected. The locations of the groundwater samples are shown in Fig 2.1.
- Water samples were then collected in hard polythene bottles of two litre capacity, which were thoroughly rinsed with distilled water to ensure compositional originality of water samples from hand pumps (HP) and tube wells (TW) in the months of May (pre monsoon) and October (post monsoon), 2014 and 2015.

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- A total of 61 samples were collected from different locations from the Ambala City and Ambala Cantonment area.
- To ensure that the representative water samples were collected from the respective aquifer, tube wells and hand pumps were initially pumped for 10-15 minutes so that the water in contact with the metallic well casing could be removed.
- The sampling bottles were washed and rinsed three times with the water samples and thereafter, filled to the capacity, sealed and labeled accordingly.
- The physical parameters like temperature; pH, electrical conductivity (EC) and total dissolved solids (TDS) were measured in the field with the help of soil and water analysis kit. To ensure accuracy in the data the values were repeated thrice and mean value was taken in case of variation.

2.2 SAMPLE COLLECTION AND DIGITAL DATA BASE CREATION

The sites of water sources from where water samples were collected in terms of latitude and longitude were used for generating point location map, using MapInfo Professional 6.5 (Fig. 2). Each source of water sample was assigned with the serial number and structured field data was linked to their respective locations. The sites marked by A1 to A30 and C1 to C31 in the figure 1.2 are the sampling sites in Ambala City and Ambala Cantonment respectively.

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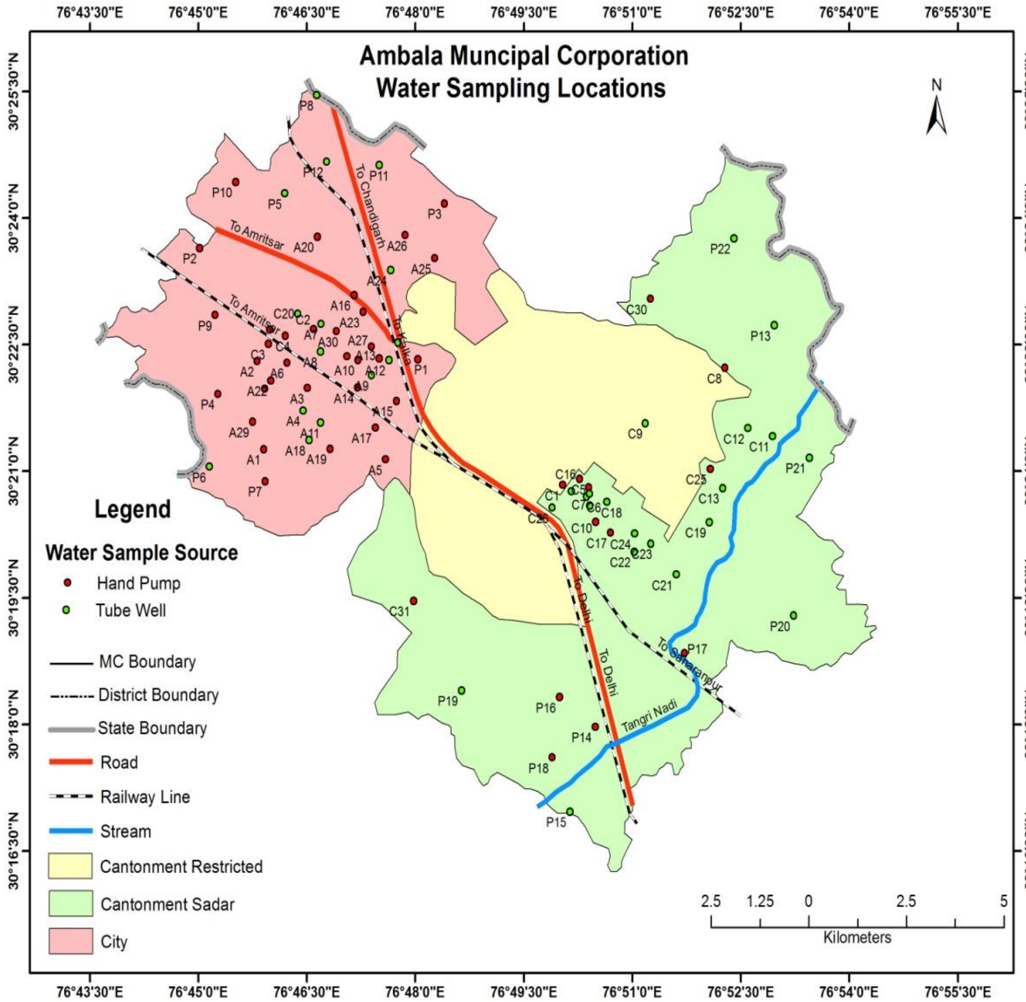

Fig. 2.1: Location of sampling points in the study area

2.3 LABORATORY INVESTIGATIONS

The water samples so collected were analyzed in the geochemical laboratory of the Department of Geology, Panjab University, Chandigarh according to the standard methodology outlined by APHA, 2005.

3. RESULTS AND DISCUSSION

Salinity, relative proportion of sodium to calcium and magnesium (SAR), relative proportion of bicarbonate to calcium and magnesium (RSC) are the important parameters to determine the suitability of water for irrigation, which was calculated using Table 3.1 and 3.2 for Ambala City and Table 3.3 and 3.4 for Ambala Cantonment, respectively. All the parameters for calculating

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groundwater suitability for irrigation were taken in meq/l. The suitability of water for irrigation depends upon the effect of chemical constituents in water on plant growth and soil. The important parameters are salinity, relative proportion of sodium to calcium and magnesium (SAR), relative proportion of bicarbonate to calcium and magnesium (RSC). The majority of groundwater in the area has high salt contents and high RSC which poses many health hazards and rendered many areas unproductive. The chemical analysis values are given in Table 3.1 to 3.4 for Ambala City and Ambala Cantonment respectively for both pre and post monsoon season. All the parameters for calculating groundwater suitability for irrigation were taken in meq/l.

Table 3.1: Statistical analysis of groundwater samples with respect to agricultural practices in Ambala City (Pre- monsoon)

S. No.	Location	T. W./H. P.	RSC	%Na	SAR
1	Satsang bhawan	H. P.	0.04	55.73	0.08
2	District Court	H. P.	0.46	46.81	0.05
3	Sector 8	H. P.	1.59	57.74	0.09
4	Sector 8	T. W.	0.19	65.94	0.13
5	New Grain Market	T. W.	1.59	58.85	0.09
6	New Grain Market	H. P.	2.56	64.88	0.12
7	ITI Chowk	T. W.	2.55	66.97	0.12
8	Peer Baba,Sector 7	T. W.	2.07	68.27	0.14
9	Sector 1	T. W.	0.99	59.63	0.09
10	Sector-1	H.P.	2.64	60.35	0.09
11	Sector 9	T. W.	0.20	73.27	0.17
12	Jail Campus	T. W.	1.46	73.94	0.16
13	Jail Campus	H.P.	3.27	62.45	0.10
14	Prem Nagar	H.P.	0.76	60.71	0.10
15	Model Town	H. P.	2.84	62.56	0.10
16	Kalka Modd	H.P.	1.04	68.70	0.13
17	Laxmi Nagar	H.P.	1.30	71.07	0.14
18	Sector 10	T. W.	2.37	57.06	0.08

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19	Sector 10	H. P.	3.46	54.22	0.07
20	Manmohan Nagar	H. P.	3.73	67.16	0.11
21	Kapda M arket	H. P.	4.53	71.36	0.13
22	Manav Chowk	H. P.	3.64	70.65	0.13
23	Near Curch	H. P.	4.89	71.89	0.15
24	Baldev Nagar	T. W.	1.37	77.88	0.23
25	Baldev nagar	H. P.	3.95	70.79	0.15
26	Baldev Nagar	H. P.	4.28	70.66	0.16
27	Police Lines Chowk	H. P.	4.67	74.47	0.18
28	Police Lines Chowk	T. W.	1.61	64.01	0.11
29	Durga Nagar	H. P.	3.15	69.30	0.15
30	Civil Hospital	T. W.	0.77	58.01	0.09

Table 3.2: Statistical analysis of groundwater samples with respect to agricultural practices in Ambala City (Post- monsoon)

S. No.	Location	Source	RSC	%Na	SAR
1	Satsang bhawan	H. P.	-3.1	44.45	0.03
2	District Court	H. P.	-1.8	47.62	0.02
3	Sector 8	H. P.	-3.4	47.973	0.03
4	Sector 8	T. W.	1.11	57.14	0.04
5	New Grain Market	T. W.	-0.8	51.41	0.03
6	New Grain Market	H. P.	-1	68.19	0.08
7	ITI Chowk	T. W.	-0.8	67.88	0.07
8	Peer Baba, Sector 7	T. W.	-0.6	61.60	0.06
9	Sector 1	T. W.	0.54	53.32	0.04

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10	Sector-1	H.P.	-0.1	56.94	0.05
11	Sector 9	T. W.	-1.1	67.88	0.07
12	Jail Campus	T. W.	-0.2	68.80	0.06
13	Jail Campus	H.P.	-0.1	64.50	0.05
14	Prem Nagar	H.P.	-3.8	57.43	0.09
15	Model Town	H. P.	-2.7	65.85	0.06
16	Kalka Modd	H.P.	0.97	62.70	0.05
17	Laxmi Nagar	H.P.	-0.3	59.24	0.07
18	Sector 10	T. W.	-0.5	56.92	0.04
19	Sector 10	H. P.	-3.3	60.11	0.11
20	Manmohan Nagar	H. P.	-0.7	70.53	0.13
21	Kapda M arket	H. P.	-0.8	73.83	0.07
22	Manav Chowk	H. P.	-1.6	65.14	0.12
23	Near Curch	H. P.	-4.4	72.17	0.07
24	Baldev Nagar	T. W.	2.1	77.03	0.12
25	Baldev nagar	H. P.	-1.1	75.39	0.11
26	Baldev Nagar	H. P.	1.05	76.21	0.09
27	Police Lines Chowk	H. P.	-1.7	53.16	0.03
28	Police Lines Chowk	T. W.	-0.2	58.39	0.04
29	Durga Nagar	H. P.	-1.5	67.20	0.10
30	Civil Hospital	T. W.	0.77	56.11	0.04

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Table 3.3: Statistical analysis of groundwater samples with respect to agricultural practices in Ambala Cantonment (Pre- monsoon)

S. No.	Location	T.W./H.P.	RSC	%Na	SAR
1	Ram Nagar Colony	H.P.	1.03	56.87	1.30
2	Alaxandra road	H.P.	1.63	61.58	1.59
3	Railway Road	H.P.	3.48	60.45	1.52
4	Bus stand	H.P.	2.40	57.08	1.32
5	BC Bazar	H. P.	3.31	52.50	1.08
6	Gandhi Ground	T.W.	2.91	65.60	1.89
7	Rangia Mandi	T.W.	1.45	60.48	1.51
8	Anand nagar	H. P.	3.02	50.27	0.98
9	Patel Park	T.W.	2.62	61.42	1.56
10	Dalipgarh	H. P.	2.62	59.18	1.43
11	Babiyal	T.W.	3.87	65.84	1.90
12	Babiyal village	T.W.	4.31	72.04	2.54
13	Dayal Bagh	H. P.	2.90	55.67	1.23
14	Indira Park	T.W.	5.23	73.07	2.63
15	PWD office	T.W.	1.98	73.18	2.71
16	P.W.D. Office	H. P.	5.33	70.33	2.31
17	Grain Market	H. P.	1.06	58.94	1.43
18	Supply Depot	T.W.	0.91	52.90	1.11
19	Mahesh Nagar	H. P.	3.07	58.18	1.38
20	Dushehra Ground	T. W.	5.92	72.94	2.68
21	Aggarsain Nagar	T. W.	5.34	67.41	2.05

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22	Housing Board	T. W.	2.42	56.86	1.31
23	Subhash Nagar	T.W.	4.85	67.03	2.02
24	Subhash Park	T.W.	3.15	77.54	3.42
25	Shyam Nagar	H. P.	2.51	63.43	1.71
26	MES	T.W.	4.67	76.46	3.22
27	Mall Road	H. P.	2.51	59.73	1.46
28	Guru Nanak Marg	H. P.	3.05	61.48	1.57
29	Preet Nagar	T. W.	2.76	63.04	1.69
30	Harinagar	H. P.	2.64	58.40	1.38
31	Town Park	H. P.	2.35	53.62	1.13

Table 3.4: Statistical analysis of groundwater samples with respect to agricultural practices in Ambala Cantonment (Post- monsoon)

S. No.	Location	T.W./H.P.	RSC	%Na	SAR
1	Ram Nagar Colony	H.P.	0.74	43.46	0.68
2	Alaxandra road	H.P.	0.96	49.33	3.00
3	Railway Road	H.P.	1.51	60.38	3.83
4	Bus stand	H.P.	1.47	59.93	3.23
5	BC Bazar	H. P.	1.52	60.66	3.87
6	Gandhi Ground	T.W.	1.97	66.54	3.30
7	Rangia Mandi	T.W.	1.93	66.17	2.14
8	Anand nagar	H. P.	1.27	56.63	3.50
9	Patel Park	T.W.	1.75	63.89	3.17
10	Dalipgarh	H. P.	1.26	55.89	2.99

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11	Babiyal	T.W.	3.29	76.80	4.98
12	Babiyal village	T.W.	3.44	77.59	4.04
13	Dayal Bagh	H. P.	0.26	21.78	-0.87
14	Indira Park	T.W.	3.10	75.74	5.80
15	PWD office	T.W.	1.36	57.83	1.70
16	P.W.D. Office	H. P.	1.23	55.28	3.15
17	Grain Market	H. P.	1.30	56.66	3.57
18	Supply Depot	T.W.	0.94	48.78	0.74
19	Mahesh Nagar	H. P.	1.15	53.85	2.69
20	Dushehra Ground	T. W.	1.77	64.02	5.24
21	Aggarsain Nagar	T. W.	2.02	67.17	4.52
22	Housing Board	T. W.	1.75	63.82	3.81
23	Subhash Nagar	T.W.	1.84	65.01	4.02
24	Subhash park	T.W.	5.13	83.81	6.46
25	Shyam Nagar	H. P.	1.57	61.47	4.05
26	MES	T.W.	2.94	74.75	4.17
27	Mall Road	H. P.	1.67	62.89	4.22
28	Guru Nanak Marg	H. P.	1.74	63.76	4.31
29	Preet Nagar	T. W.	1.22	55.15	2.28
30	Hari Nagar	H. P.	1.71	63.35	4.12
31	Town park	H. P.	1.20	55.09	2.52

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3.1 SALINITY HAZARD

The index used is the Sodium Adsorption Ratio (SAR) that expresses the relative activity of sodium ions in the exchange reactions with the soil. This ratio measures the relative concentration of sodium to calcium and magnesium.

SAR is defined by the following equation:

$$SAR = \frac{Na^{+}}{\sqrt{Ca^{2+} + Mg^{2+}/2}}$$

The salinity and sodium hazard classes of salinity viz. $\mathbf{C_1}$, $\mathbf{C_2}$, $\mathbf{C_3}$ and $\mathbf{C_4}$. Classes $\mathbf{C_1}$and $\mathbf{C_2}$of the water are considered suitable for irrigation purpose (no problem) $\mathbf{C_3}$and $\mathbf{C_4}$classes of the water are not suitable for irrigation purpose (severe problem). Low sodium water **(S_1)** presents the little danger of exchangeable sodium; medium sodium water **(S_2)** can present appreciable hazard; whereas high **(S_3)** and very high **(S_4)** sodium water are considered unsatisfactory as they can cause harmful levels of exchangeable sodium in soils. Table 3.5 and 3.6 exhibit the classification of irrigation water and the groundwater samples falling in a particular category.

Table 3.5: Classification of irrigation water based on SAR values after (Ayers and Westcott, 1985), Ambala City and Ambala Cantonment

Water Class	**SAR Value**	**Remarks**	**%age of Samples**	
			Pre- monsoon	
			Ambala City	**Ambala Cantonment**
S_1 Low hazard	0-10	Good	100%	100%
S_2 medium hazard	10-18	Medium	NIL	NIL
S_3 high hazard	18-26	Appreciable hazard	NIL	NIL
S_4 very high hazard	>26	High hazard	NIL	NIL

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Table 3.6: Classification of irrigation water based on SAR values after (Ayers and Westcott, 1985), Ambala City and Ambala Cantonment

Water Class	**SAR Value**	**Remarks**	**%age of Samples**	
			Post- monsoon	
			Ambala City	**Ambala Cantonment**
S_1 Low hazard	0-10	Good	100%	100%
S_2 medium hazard	10-18	Medium	NIL	NIL
S_3 high hazard	18-26	Appreciable hazard	NIL	NIL
S_4 very high hazard	>26	High hazard	NIL	NIL

A diagram has been proposed for the classification of irrigation water by US salinity staff (1954). This diagram is being used widely to classify the irrigation water with reference to salinity and sodium hazard. On a semi-logarithmic paper, the Electrical Conductivity (EC) and Sodium Absorption Ratio (SAR) values of water are plotted against each other. The high concentration of sodium in water makes the soil impermeable to water by blocking its pores due to adsorption of sodium on the cation exchange process.

The analytical data plotted on US salinity diagrams shows that during pre-monsoon (Fig. 3), the groundwater in Ambala City and Ambala Cantonment for irrigation purposes are of C_3S_1, C_4S_1 and C_1S_1 type indicating that water in Ambala City and Ambala Cantonment exhibits high salinity and low sodium and very high salinity and low sodium hazard. This indicates that high salinity and low sodium water which can be used for irrigation for almost all types of soils.

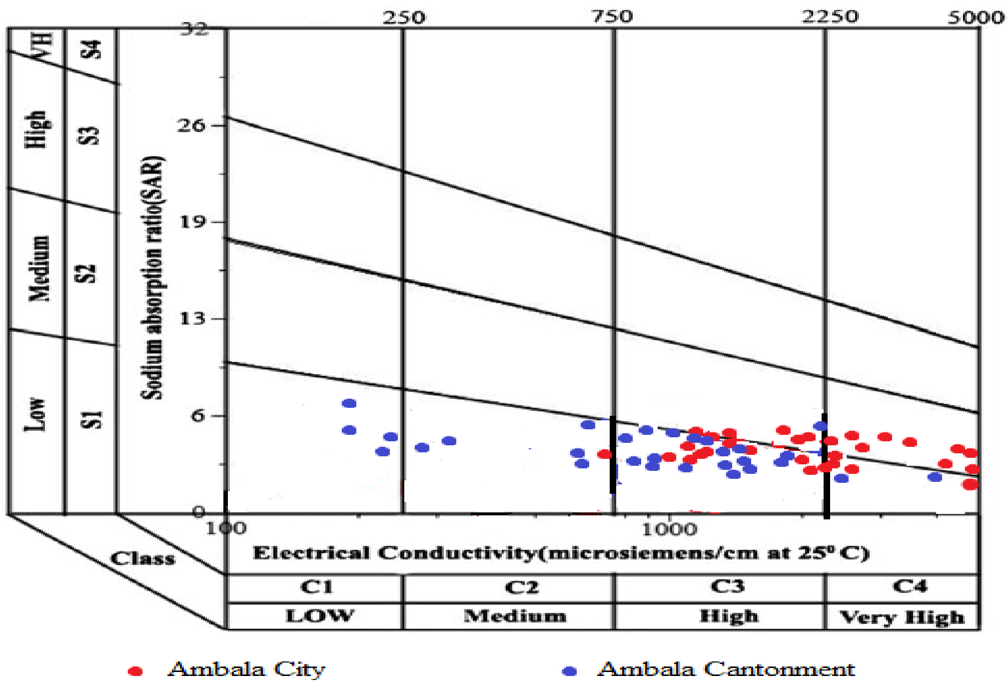

Fig. 3: USSL diagram showing classification of water in Ambala City and Ambala Cantonment (Pre- monsoon)

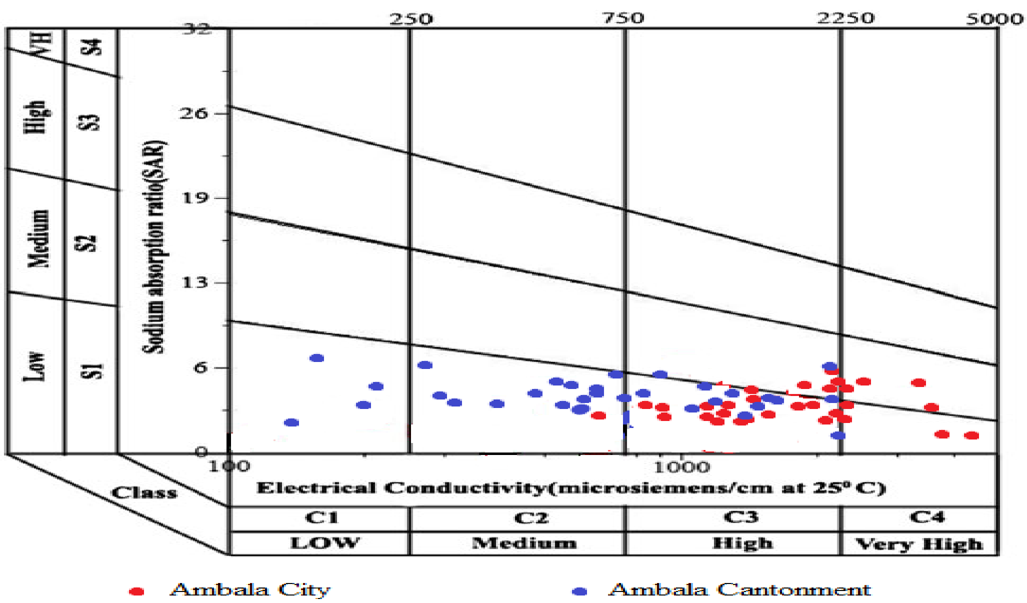

Fig. 4: USSL diagram showing classification of water in Ambala City and Ambala Cantonment (Post- monsoon)

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The analytical data plotted on US salinity diagrams shows that during post monsoon (Fig. 3), the groundwater in Ambala City and Ambala Cantonment for irrigation purposes is mainly of C_2S_1, $C_3S_1$and C_4S_1. 4 samples of Ambala City fall in C_4S_1, and C_4S_2 type (high hazard) It indicates that water in Ambala City and Ambala Cantonment is mainly of high salinity and low sodium and very high salinity and medium sodium hazard This indicates that high salinity and low sodium water which can be used for irrigation for almost all types of soils (Fig. 4).

3.2 SODICITY HAZARD

High sodium ions in water affects the permeability of soil and causes infiltration problems. This is because sodium when present in the soil in exchangeable form replaces calcium and magnesium adsorbed on the soil clays and causes dispersion of soil particles. This dispersion results in breakdown of soil aggregates. The soil becomes hard and compact when dry and reduces infiltration rates of water and air into the soil affecting its structure. This problem is also related with several factors such as the salinity rate and type of soil. Table 3.7 shows the classification of irrigation water based on Wilcox criteria.

Sodium content is usually expressed in terms of %Na and is given by the following equation:

$$\%Na = \frac{Na^{+} + K^{+}}{Ca^{+2} + Mg^{+2} + Na^{+} + K^{+}} X100$$

Where, all soluble cations are expressed in meq/l.

In Ambala City, the groundwater samples varied from a range of 46.81 meq/l to 77.88 meq/l during pre-monsoon, whereas during post monsoon it ranged from 44.45 meq/l to 77.03 meq/l. In Ambala Cantonment, the pre monsoon samples varied from 50.47 meq/l to 77.54 meq/l, whereas during post monsoon, the variation among water samples was from 43.46 meq/l to 77.59 meq/l.

3.3 WILCOX CLASSIFICATION

Wilcox (1955) diagram is adopted for classification of irrigation, wherein the EC is plotted against the percentage of Na. During pre-monsoon, based on Wilcox classification, (Table 3.7), in Ambala City, 10% of the samples were under unsuitable category, 46.6% of the samples were under permissible to doubtful category, 60% of the samples belonged to good to permissible category, 3.3% of the samples belong to the excellent to good category, whereas in Ambala Cantonment, 16.1% of the samples were under permissible to doubtful category, 38.7% of the samples belonged to good to permissible category and 45.1% of the samples were under excellent to good category (Fig. 5 and Fig. 6). During post monsoon, none of the sample fell in unsuitable category. Only 3 samples from Ambala City were at border line. Figure 5 and Figure 6 reveals that the quality of water samples from Ambala Cantonment was better than Ambala City.

Table 3.7: Classification of irrigation water, based on Electrical Conductivity after Wilcox (1955)

Water Class	EC Values (µS/cm at 25°C)
Excellent	<250
Good	250-750
Permissible	750-2000
Doubtful	2000-3000
Unsuitable	>3000

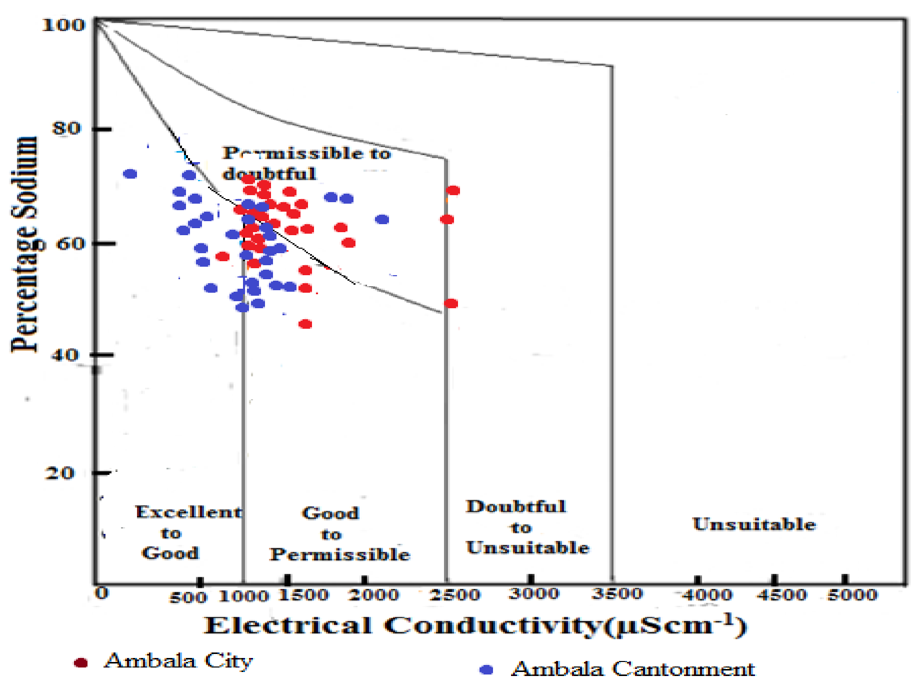

Fig. 5: Wilcox Classification for suitability of groundwater (Pre- monsoon)

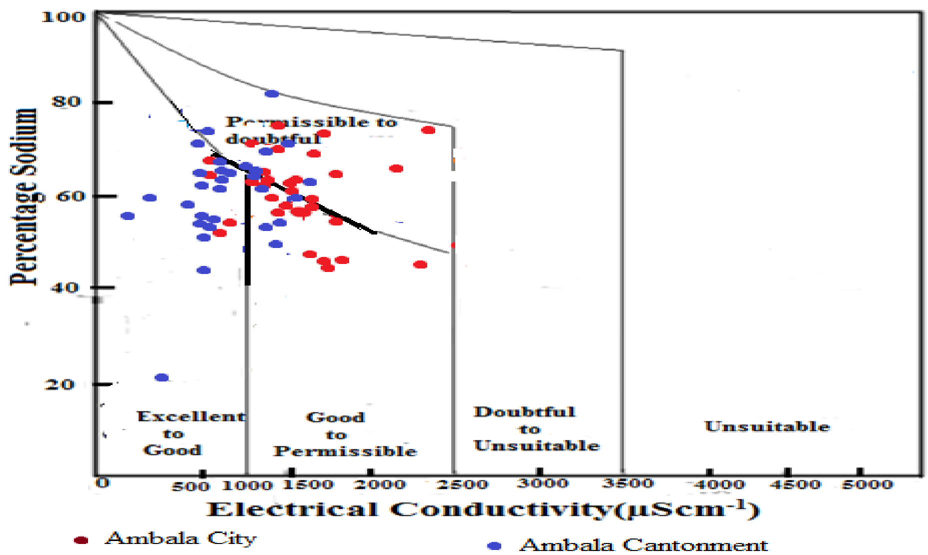

Fig. 6: Wilcox Classification for suitability of groundwater (post-monsoon)

If there is high percentage of sodium in the water, there will be less permeability for Ca^{2+} and Mg^{2+}. Such situation can lead to drainage problem (Kumar *et al.*, 2007). If there is water logging condition in the study area, then these above discussed problems may get enhanced. The high concentration of sodium reduces the permeability for Ca^{2+} and Mg^{2+} resulting in poor drainage. This may also attribute to water logging condition in the area.

4. CONCLUSION

The analysis of US salinity diagrams shows that the water in the study area is of high salinity and low sodium type which can be used for irrigation for almost all types of soils. The Wilcox diagram indicates that the water during pre-monsoon season was found in mixed category while during post monsoon, the most water samples fell into suitable category. The results indicate that the quality of water samples from Ambala Cantonment was better than Ambala City. It might be due to the fact that Ambala Cantonment is a well-planned city while Ambala City is a haphazardly grown city. Pre and post monsoon analysis indicates towards a better water quality during post monsoon season. This might be attributed to the dilution of pollutants in monsoon season. Since the study area is an urban area, the causes of poor water quality in some of the sampling locations might be due to sewage contamination and discharge of untreated industrial effluents. The suggested way to improve the water quality is to increase the number and efficiency of the sewage treatment plants and the effluent treatment plants. This might lead to a uniform and consistent availability of good quality water.

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