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Evaluation of Surface Water Quality for irrigation purposes in Limestone Mining areas of District Solan, Himachal Pradesh, India

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ABSTRACT: Agriculture is a major sector in the economic development of India, as it is the source of livelihood for majority of population. Our food supply depends on precipitation collected in an irrigation system or falling directly on a field. The availability of water for irrigation is not ideally matched to the water needs. Therefore local surface water resources such as Satluj and its tributaries, small khads and nallas are used by inhabitants of the study area for irrigation. The functioning of an ecosystem and its stability to support life forms depend, to a great extent, on the physico-chemical characteristics of its water. Mining may have impact on the water resources of the surrounding areas. The water bodies, rivers, lakes, dams and estuaries are continuously subject to dynamic state of change with respect to the geological age and geochemical characteristics. Evaluation of water quality has been carried out in and around the Kashlog Limestone mine to determine the concentrations of different ions present in the surface water. Quality of surface water was evaluated for its suitability for irrigation purposes. The quality assessment was made through the estimation of various physico-chemical parameters like temperature, pH, EC, TDS, CO32-, HCO3-, Cl-, SO42-, PO43-, F-, Na+, K+, Ca2+ and Mg2+ for both pre monsoon and post monsoon season . A total of 15 surface water samples were collected from different sources of the Mining area and based on their analyses, some irrigation parameters like % Na, SAR, RSC and PI were calculated.

Key Words: Investigation, Satluj River, Irrigation, Ecosystem and Water Resources

1. Introduction :

India is rich in water resources, being endowed with a network of rivers and blessed with snow cover in the Himalayan range that can meet a variety of water requirements of the country. However, with the rapid increase in the population of the country and the need to meet the increasing demands of irrigation, human and industrial consumption, the available water resources in many parts of the country are getting depleted and the water quality has deteriorated. Indian rivers are polluted due to the discharge of untreated sewage and industrial effluents. Irrigation is one of the important uses of surface water for agricultural purposes in India. Quality of water is assuming great importance with the rising pressure on industries and agriculture and rise in standard of living. The concentration and composition of dissolved constituents in water determines its quality for irrigation use. The adequate amount of water is very essential for proper growth of plants but the quality of water used for irrigation purpose should also be well within the permissible limit otherwise it could adversely affect the plant growth. The water quality is degraded mainly due to natural reasons along with over withdrawal of water, insanitary conditions in rural and urban areas and increased application of fertilizers and discharge from industrial and mining areas. In order to assess the water quality for irrigation, pollution level in

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surface water have been detected by monitoring the parameters such as pH, Electrical Conductivity (EC), Sodium Adsorption Ratio (SAR), % Na, RSC and PI. For all practical purposes, pure water is considered as one which has low dissolved solids required only for drinking purposes while for other uses like agriculture and industry, the quality of water can be quite flexible and water polluted up to certain extent in general sense can be regarded as pure (*Joshi et al.,2009*). The present study was conducted to analyze the quality of water in the limestone mining areas of district Solan, Himachal Pradesh, India to determine its suitability for irrigation. The water being used for irrigation may contain many impurities which in turn maybe taken up by crops and is ultimately consumed by animals and human beings. This may pose a greater threat to bio-cycle and therefore calls for assessment of water quality for its sustainable management in the project area.

2. Study Area :

The Study area is located at the north latitude of 30°44’53” to 31°22’01” and east longitude of 76°36’10” to 77°15’14” and is covered by Survey of India topo-sheets 53A, 53B, 53E and 53F. The average elevation of the district ranges between 300-3000 m above mean sea level. District Solan is bordered by Shimla district in the north and Ropar district of Punjab and Ambala district of Haryana in the south, Sirmour district in the east and Bilaspur district in the west. Mandi touches the boundary in the north east (Fig. 1). Administratively, Solan town is the head quarter of the district. The temperature of the area fluctuates from 4^0C to 34^0C for winter season to summer season. The area receives the mean annual rainfall of 1450 mm with average of 64 rainy days. The district is surrounded by catchment area of three rivers Satluj, Yamuna and Ghagar. Soil is generally sandy loam in valley areas of the district and in rest of the hilly and mountainous areas soil is skeletal, soil depth is generally shallow except in areas having good vegetative cover. The area has sufficient irrigation facilities available, Satluj and its tributaries, small *khads* and *nallas* are an important source of irrigation in the study area. Figure 1 shows the location of study area.

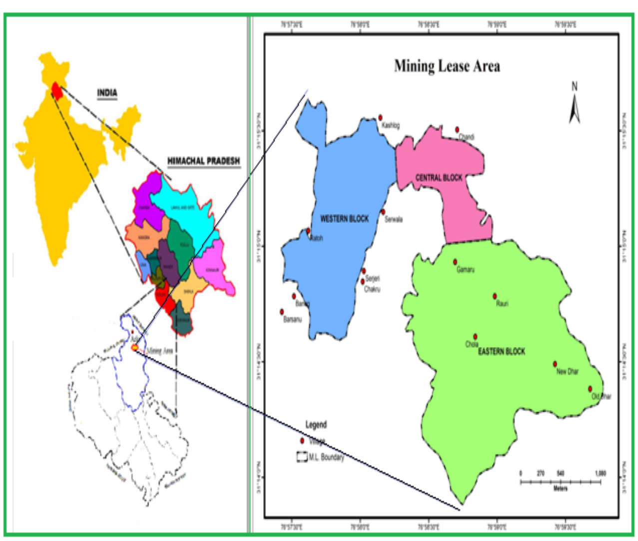

Fig. 1 Location Map of the Study Area

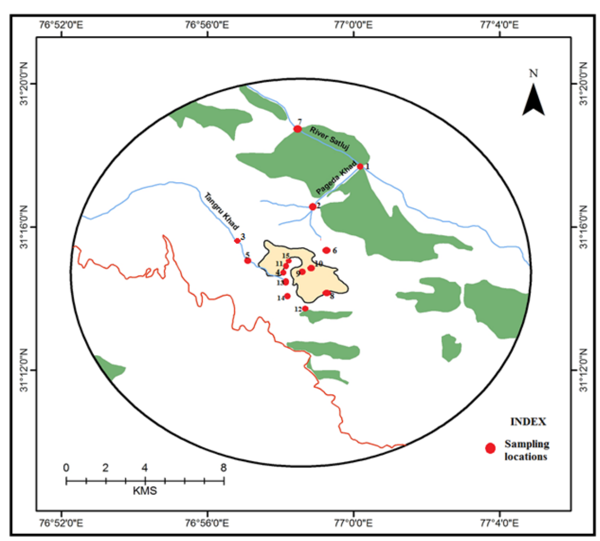

Fig. 2 Surface Water Sampling Locations in Study area

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3. Materials and Methods :

Surface water samples were collected from15 different locations situated in Kashlog limestone mining area in the month of May and October, 2011 (Fig. 2). These samples were collected in clean polythene bottle of two-liter capacity. Bottles were thoroughly rinsed two to three times with water to be sampled at the time of sampling. The physical parameters such as pH, electrical conductivity (EC), total dissolved solids (TDS) and temperature were measured in the field using water and soil analysis kit. All other characteristics of water samples were measured in the laboratory immediately after bringing the water samples to the laboratory. Sodium (Na^+), potassium (K^+), calcium (Ca^{2+}), magnesium (Mg^{2+}), total hardness (TH), chloride (Cl^-), sulphate (SO_4^{2-}), phosphate (PO_4^{3-}), fluoride (F^-), carbonate (CO_3^{2-}), and bicarbonate (HCO_3^-), were estimated using standard procedures. Water quality of the study area was assessed for suitability to irrigation in terms of critical pollutants such as pH, Electrical Conductivity, Percent Sodium, Sodium Adsorption Ratio (SAR), PI and Residual Sodium Carbonate (RSC). Ionic balance was calculated by converting the mg/l value to milli equivalent/l. The different formulae were used to determine irrigation related parameters.

- $\% Na = [(Na^+ + K^+)] \times 100 / (Ca^{2+} + Mg^{2+} + Na^+ + K^+)$
- $SAR = Na^+ / \sqrt{Ca^{2+} + Mg^{2+}/2}$
- $PI = (Na^+ + \sqrt{HCO_3^-}) \times 100 / (Ca^{2+} + Mg^{2+} + Na^+ + K^+)$
- $RSC\ (meq/l) = (CO_3^{2-} + HCO_3^-) - (Ca^{2+} + Mg^{2+})$

4. Results and Discussion:

The suitability of groundwater for irrigation purposes depends upon the effect of mineral constituents of water on both plants and soils. The general criteria for assessing the irrigation water quality are: total salt concentration as measured by EC, relative proportions of Na^+ as expressed by %Na, SAR and RSC. Water quality criteria can be used as guidelines by farmers for selecting appropriate management practice to overcome potential salinity hazard, if the quality of available water would pose any problem for irrigation. EC and Na^+ are very important in classifying irrigation water. High salt content in irrigation water causes osmotic pressure in soil solution (Thorne and Peterson, 1954). The salt besides affecting growth of plant directly also affects soil structure, soil permeability, aeration, texture and makes soil hard (Trivedy and Geol, 1984).

Table 1: Analysis of Water Samples for Irrigation

S. No.	Parameters → Locations	EC		% Na		SAR		PI		RSC	
		Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
1	Pazeena Khad (US)	382	283	3.48	3.33	0.023	0.021	60.42	55.22	4.31	4.83
2	Pazeena Khad (DS)	398	385	4.68	4.07	0.032	0.029	70.49	61.18	4.15	12.81
3	Dumla Khad	298	286	3.49	3.83	0.025	0.026	83.51	81.66	6.90	5.49
4	Gyana Khad (US)	560	540	5.85	5.57	0.063	0.058	34.28	38.56	-2.53	4.40
5	Gyana Khad (DS)	772	755	6.04	4.72	0.063	0.051	39.07	36.57	-1.30	-1.41
6	Chandi Nalla	352	362	3.75	4.82	0.034	0.045	60.48	55.49	3.63	23.16
7	Satluj River	354	372	4.43	5.72	0.039	0.047	56.62	75.44	1.95	4.39
8	Mangu Nalla (US)	389	360	8.88	8.32	0.086	0.077	61.44	71.29	2.77	3.86
9	Mangu Nalla (DS)	412	390	8.43	7.13	0.084	0.070	61.38	53.35	2.44	1.34
10	Patti	302	300	7.04	6.95	0.056	0.054	68.25	69.53	3.25	12.38
11	Chakru	298	310	7.89	8.67	0.068	0.067	79.78	89.01	7.04	17.28
12	Ali Khad Barsanu(US)	488	455	8.83	6.26	0.084	0.064	70.26	59.79	3.54	3.97
13	Ali Khad Barsanu(DS)	780	760	8.70	7.19	0.084	0.072	77.16	70.77	6.24	5.58

14	**Banog Nalla**	812	760	6.14	5.38	0.049	0.046	62.81	65.55	1.98	8.87
15	**Serjeri**	362	350	6.48	4.66	0.062	0.048	57.99	51.97	1.78	5.88

*UP-Upstream *DS-Downstream

The electrical conductivity values of water samples from the study area, for pre monsoon season were 298 to 812 µmhos/cm and 283 to 760 µmhos/cm for post monsoon season. Eighty percent water samples for pre monsoon as well as post monsoon season were found in the C_2 class representing good quality of water where as 20% water samples for both the seasons were of C_3 class, which are still within the permissible limit, therefore suitable for agriculture.

Table 2: Salinity Hazard Classification based on EC values of Surface Water Samples

EC in micro mhos/cm at 25^o C	Salinity Hazard Class	Pre monsoon	Post monsoon
< 250	Excellent C_1	Nil	Nil
250-750	Good C_2	80 %	80 %
750-2,250	Permissible C_3	20 %	20 %
>2,250	Unsuitable C_4	Nil	Nil

4.1 $\%Na^+$

Percentage sodium ($\%Na^+$) is widely used to evaluate suitability of water for irrigation purpose (Wilcox, 1948). It is computed with respect to relative proportions of cations present in water, where the concentrations of ions are expressed in meq/l.

$\%Na^+$ ranged from 3.33 to 8.88 % with an average value of 6.27 % in pre monsoon season and 5.854 % in post monsoon season. Analytical data of the irrigation water samples collected in pre monsoon and post monsoon season was plotted on the Wilcox's diagram (Wilcox, 1948). In the Wilcox's diagram EC is plotted against $\%Na^+$ (Fig. 3). In pre monsoon season 80 % samples were of excellent to good Category and 20 % samples were of good to permissible class where as in post monsoon season 100 % of the samples were excellent to good, showing suitability of water for irrigation

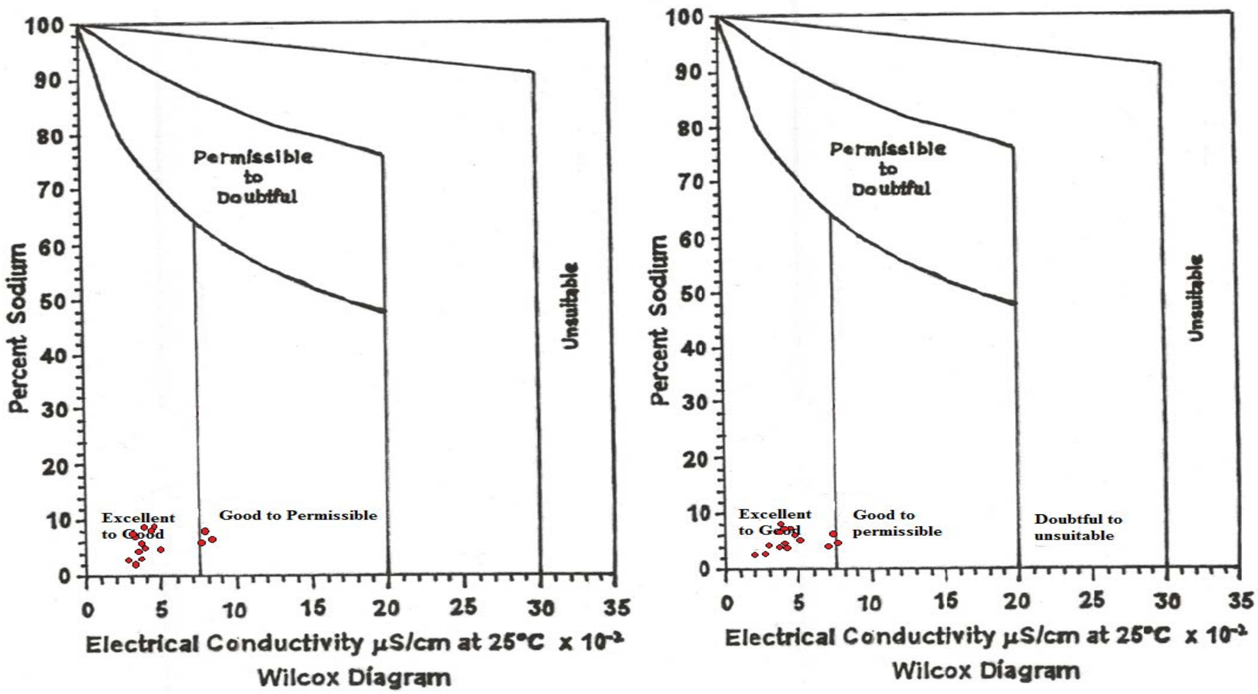

Fig. 3 Wilcox's Diagram Plot of the Surface Water Samples for Pre monsoon and Post monsoon

4.2 SAR:

Sodium Adsorption Ratio (SAR) is an important parameter for the determination of suitability of irrigation water because it is responsible for the sodium hazard to crops. The degree to which irrigation water tends to enter into cation-exchange reactions in soil can be indicated by the sodium adsorption ratio. Sodium replacing adsorbed calcium and magnesium is hazard as it causes damage to the soil structure and soil becomes compact and impervious. The waters were classified in relation to irrigation based in the ranges of SAR values.

Water having medium SAR levels of 10 to 18 requires amendments (such as Gypsum) and leaching to avoid sodium hazard. Water generally are unsuitable for continuous use with high SAR values ranging from 18 to 26 whereas, irrigation water having >26 SAR indicate very high sodium hazard. These levels have been defined as, excellent, good, medium, bad and very bad as per Indian guideline for evaluation of irrigation water quality (IS2296, 1992). However, continuous use of irrigation water having low SAR levels of 1 to10 may cause sodium hazard on sodium sensitive crops (Sakthivel, 2007).

In the study area all the water samples for pre monsoon and post monsoon season were of excellent category i.e. all the values of SAR for water samples are less than 10.USSL plot (Fig. 4) for SAR and EC shows that all the waters fall in C_2-S_1 and C_3-S_1 Salinity Hazard Class which indicates low sodium levels with medium to high salinity Hazard.

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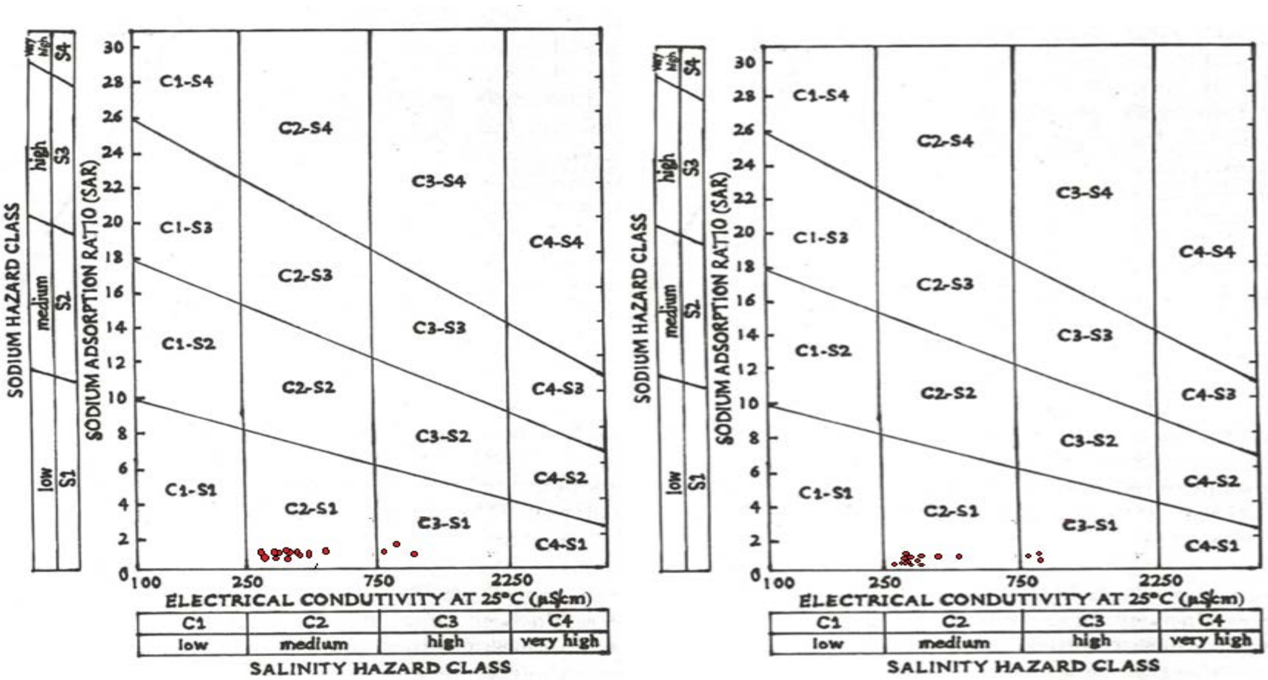

Fig. 4 USSL Salinity Hazard for Pre monsoon and Post monsoon Seasons

4.3 Permeability Index (PI):

The soil permeability is affected by the long term use of irrigation water as it is influenced by Na^{+}, Ca^{2+}, Mg^{2+} and HCO_3^{-} content of the soil. Doneen (1964) gave a criterion for assessing the suitability of water for irrigation based on the PI, where concentrations are in meq/l. PI values of surface water samples varied from 34.28 % to 89.01 %. Based on PI values, 80% samples in pre monsoon season and 87 % in post monsoon season fall in class II (25-75%) which indicates, water is good for irrigation.

4.4 RSC:

RSC is a measurement that compares the concentration of Ca^{2+} and Mg^{2+} to HCO_3^{-} and CO_3^{2-} . Where, all the cations and anions are expressed in meq/l. It also determines when Ca^{2+} and Mg^{2+} (macro nutrients) precipitation can occur in the soil and results in additional Na^{+} dominance of soil cation exchange sites.

The USDA (United States Department of Agriculture) has established guidelines for modifying water quality classification based on RSC given in table 3. In pre monsoon and post monsoon seasons 20% and 13% samples respectively had RSC value less than 1.25meq/l. In pre monsoon season 27% samples had RSC value in between 1.25-2.5 meq/l. In post and pre monsoon seasons 87% and 53% water samples had RSC values greater than 2.5 meq/l indicating that water samples are unsuitable for irrigation.

Table 3: Surface Water Quality based on RSC

RSC meq/l	Water Class	Pre monsoon	Post monsoon
<1.25	Safe	20 %	13 %
1.25-2.5	Moderate	27 %	Nil
>2.5	Unsuitable	53 %	87 %

5 Conclusions:

According to the EC values eighty percent water samples for pre monsoon as well as post monsoon were of C_2 class where as 20 % water samples for both the seasons were of C_3 class. 80 % samples in pre monsoon season were of excellent to good Category and 20 % samples were of good to permissible class where as in post monsoon season 100 % of the samples were excellent to good based on Wilcox Method. SAR values for all water samples were less than 10. Therefore water is of excellent category. The US salinity diagram illustrates that most of the surface water samples fall in the field of C_2-S_1 and C_3-S_1, indicating low sodium hazard with medium to high salinity. However, permeability index values indicate that almost all the surface water samples were of good quality. Based on the overall assessment of the parameters mentioned above, it can be concluded that surface water samples from the study area are suitable for irrigation.

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