# 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 khud and nallahas 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 waters. Quality of surface waters 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,* $CO3^{2-}$, $HCO^{3-}$, $Cl^{-}$, $SO_4^{2-}$, $PO_4^{3-,}$ $F^{-}$, $Na^{+}$, $K^{+}$, $Ca^{2+}$ *and* $Mg^{2+}$ *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*

## 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 waters for agricultural purposes in India. Irrigation water available from various sources in agriculture is justified on agronomic and economic grounds but care must be taken to minimize its adverse environmental and health impacts. Quality of water is assuming great importance with the rising pressure on industries and agriculture and rise in standard of living. Quality of irrigation water depends on the amount of suspended sediment and chemical constituents in the water. 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 maintain the water quality for irrigation, pollution levels in surface waters have been detected by monitoring physico-chemical 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 [4]. The present study was mainly 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. The 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. Administratively, Solan town is the head quarter of the district. The temperature of the area fluctuates from $4^0$C to $34^0$C 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 khud and nallahas are an important source of irrigation in the study area.

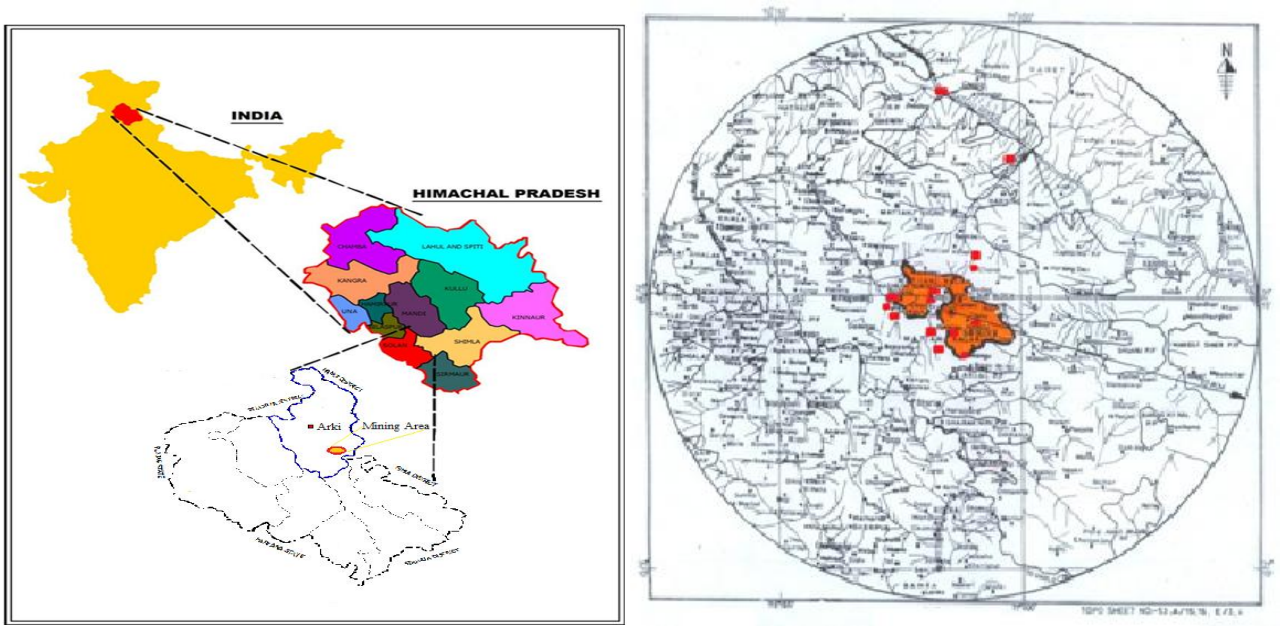



**Figure 1:** Map of the Study Area

### 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).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 mill equivalent/l. The different formulae were used to determine irrigation related parameters.

$\% Na = [(Na^+ + K^+)] \times 100 / (Ca^{2+} + Mg^{2+} + Na^+ + K^+)$

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

$PI = (Na^+ + \sqrt{HCO^{3-}}) \times 100 / (Ca^{2+} + Mg^{2+} + Na^+ + K^+)$

$RSC\ (meq/l) = (CO3^{2-} + HCO^{3-}) - (Ca^{2+} + Mg^{2+})$

% Na by Wilcox method consider the percentage ratio of cations $Na^+$ and $K^+$ to all other cations to classify water for irrigation. Sodium adsorption ratio (SAR) takes EC and relative proportion of $Na^+$ to other cations into consideration. The permeability index (PI) method also takes percentage ratio of $Na^+$ and $HCO3^-$ to all other cations where as Residual Sodium Carbonate (RSC) by Eaton takes values of calcium, magnesium, carbonate and bicarbonate into consideration for rating of water for irrigation purpose

### 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 to maintain existing soil productivity with the benefit of high crop yield under irrigation. EC and $Na^+$ are very important in classifying irrigation water. High salt content in irrigation water causes osmotic pressure in soil solution [9]T.he salt besides affecting growth of plant directly also affects soil structure, affecting soil permeability, aeration, texture and makes soil hard[10]

Because plants can only transpire "pure" water, usable plant water in the soil solution decreases dramatically as EC increases. A maximum limit of 2,500 µmhos/cm has been adopted for "Class E" water in the Primary Water Quality Criteria. However, electrical conductivity levels have been suggested as per guidelines for evaluation of irrigation water quality is given in table 3 [6].

**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 Khud (upstream) | 382 | 283 | 3.48 | 3.33 | 0.023 | 0.021 | 60.42 | 55.22 | 4.311 | 4.827 |
| 2 | Pazeena Khud (downstream) | 398 | 385 | 4.68 | 4.07 | 0.032 | 0.029 | 70.49 | 61.18 | 4.152 | 12.81 |
| 3 | Dumla Khud | 298 | 286 | 3.49 | 3.83 | 0.025 | 0.026 | 83.51 | 81.66 | 6.900 | 5.495 |
| 4 | Gyana khud (upstream) | 560 | 540 | 5.85 | 5.567 | 0.063 | 0.058 | 34.28 | 38.56 | -2.533 | 4.403 |
| 5 | Gyana khud (downstream) | 772 | 755 | 6.04 | 4.72 | 0.063 | 0.051 | 39.07 | 36.57 | -1.300 | -1.407 |
| 6 | Chandi Nalla | 352 | 362 | 3.75 | 4.82 | 0.034 | 0.045 | 60.48 | 55.49 | 3.634 | 23.16 |
| 7 | Satluj River | 354 | 372 | 4.43 | 5.72 | 0.039 | 0.047 | 56.62 | 75.44 | 1.947 | 4.389 |
| 8 | Mangu Nalla (upstream) | 389 | 360 | 8.88 | 8.32 | 0.086 | 0.077 | 61.44 | 71.29 | 2.774 | 3.862 |
| 9 | Mangu Nalla (downstream) | 412 | 390 | 8.43 | 7.13 | 0.084 | 0.070 | 61.38 | 53.35 | 2.439 | 1.342 |
| 10 | Patti (Spring water) | 302 | 300 | 7.04 | 6.95 | 0.056 | 0.054 | 68.25 | 69.53 | 3.246 | 12.38 |
| 11 | Chakru Village (spring water) | 298 | 310 | 7.89 | 8.67 | 0.068 | 0.067 | 79.78 | 89.01 | 7.039 | 17.278 |
| 12 | Ali Khud Barsanu (upstream) | 488 | 455 | 8.83 | 6.26 | 0.084 | 0.064 | 70.26 | 59.79 | 3.536 | 3.9713 |
| 13 | Alikhud Barsanu (downstream) | 780 | 760 | 8.70 | 7.19 | 0.084 | 0.072 | 77.16 | 70.77 | 6.244 | 5.575 |
| 14 | Banog Nalla | 812 | 760 | 6.14 | 5.38 | 0.049 | 0.046 | 62.81 | 65.55 | 1.975 | 8.873 |
| 15 | Serjeri (Tap water) | 362 | 350 | 6.48 | 4.66 | 0.062 | 0.048 | 57.99 | 51.97 | 1.781 | 5.881 |

The electrical conductivity values of water samples for premonsoon season are 298 to 812 µmhos/cm and 283 to 760 µmhos/cm for post monsoon season from the study area. Eighty percent water samples for premonsoon as well as postmonsoon season falls in the category of good (C2) class where as 20 % water samples for both the seasons are of C3 class, which are still within the permissible limit.

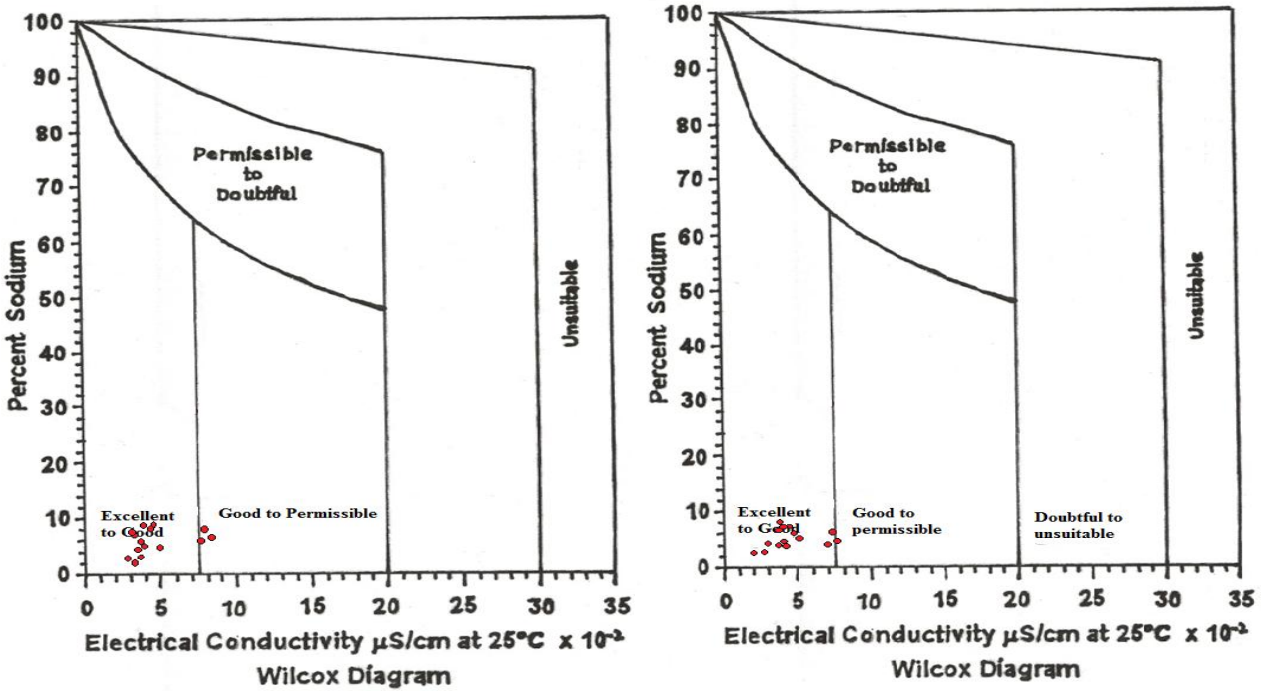
**Table 2 :** Salinity Hazard Classification based on EC values of Surface Water Samples

| EC in micro mhos/cm at 25° 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 $^+$) in irrigation water samples is also widely used to evaluate suitability of the sample for the purpose [13].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 6.274 % in premonsoon season and 5.854 % in postmonsoon season. Analytical data of the irrigation water samples collected in premonsoon and postmonsoon season was plotted in the Wilcox's diagram [13]. In the Wilcox's diagram EC is plotted against %Na $^+$ Figure 2 (a & b). In premonsoon season 80 % samples were of excellent to good Category for irrigation and 20 % samples were good to permissible for irrigation where as in postmonsoon season 100 % of the samples were excellent to good.




**a** **b**

**Figure 2. (a &b) :** Wilcox's diagram plot of the surface water samples for Pre monsoon and Post monsoon

**4.2 SAR**

SAR is an important parameter for the determination of suitability of irrigation water because it is responsible for the sodium hazard to crops. Sodium Adsorption Ratio (SAR) gives the concentration of sodium, relative to the concentrations of calcium and magnesium and is a guide to judge the sodium hazards of irrigation water. 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 an 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. Maximum limits of SAR of 26 have been recommended for water bodies used for irrigation purposes in Class "E" of Primary Water Quality Criteria. However, continuous use of irrigation water having low SAR levels of 1 to10 may cause sodium hazard on sodium sensitive crops [7].

Water having medium SAR levels of 10 to 18 requires amendmends (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 .

In the study area all the water samples for premonsoon and post monsoon season are of excellent category ie all the values of SAR for water samples are less than 10.USSL plot Figure 3. (a & b) for SAR and EC shows that all the waters fall in C2-S1 and C3-S1 Salinity Hazard Class which indicates medium to high salinity Hazard.

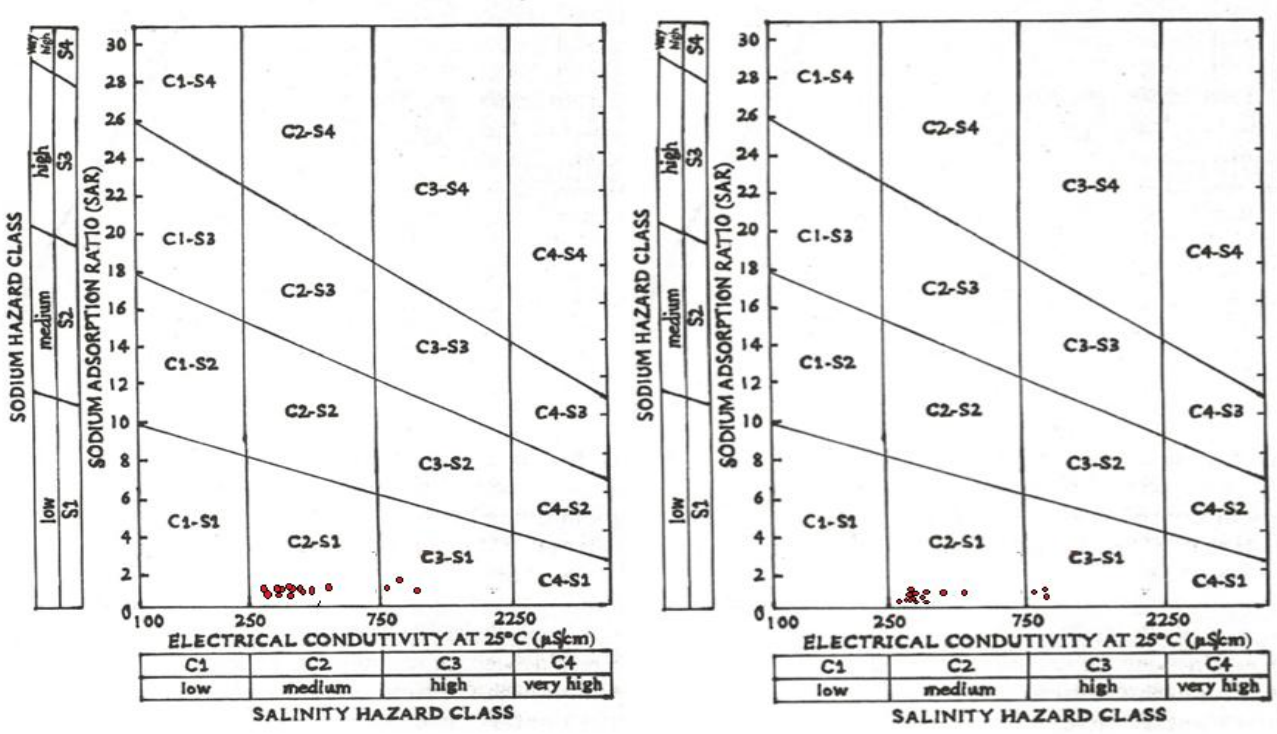



**Figure 3. (a & b) :** USSL Salinity hazard for Pre monsoon and Post monsoon Seasons

**4.3 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) and WHO (1989) gave a criterion for assessing the suitability of water for irrigation based on the PI, where concentrations are in meq/l. PI values varied from 34.28 % to 89.01 %. Based on PI values, 80% samples fall in class (25-75%) in premonsoon season and 87 % in postmonsoon season which 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 [12] for modifying water quality classification based on RSC. RSC level less than 1.25meq/l is considered safe, where as water with RSC of 1.25 – 2.50meq/l is within marginal range and RSC value of water sample 2.50meq/l or greater is considered too high making the water unsuitable for irrigation use. In premonsoon and postmonsoon seasons 20% and 13% samples respectively had RSC value less than 1.25meq/l. In premonsoon season 27% samples had RSC value in between 1.25-2.5 meq/l. In post and premonsoon seasons 87% and 53% water samples had RSC values greater than 2.5 meq/l indicating that waters samples are unsuitable for irrigation.

**Table 3: Surface Water Quality based on RSC**

| RSC meq/l | Water Class | Premonsoon | Postmonsoon |
|---|---|---|---|
| **<1.25** | **Safe** | **20 %** | **13 %** |
| **1.25-2.5** | **Moderate** | **27 %** | **Nil** |
| **>2.5** | **Unsuitable** | **53 %** | **87 %** |

## 5. Conclusion

According to the EC values eighty percent water samples for premonsoon as well as postmonsoon season falls in the category of good (C2) class where as 20 % water samples for both the seasons are of C3 class, which are still within the permissible limit and 80 % samples were of excellent to good Category for irrigation in premonsoon season and 20 % samples were good to permissible for irrigation where as in postmonsoon season 100 % of the samples were excellent to good based on Wilcox Method. SAR values for all water samples are 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
C2-S1 and C3-S1, indicating high salinity and low sodium water, which can be used for irrigation on almost all type of soil with little danger of exchangeable sodium. However, permeability index values indicate that almost all the surface water samples are suitable for irrigation. According to the overall assessment based on the parameters mentioned above, of the surface water quality was found suitable for irrigation.

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