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Evaluation of Seasonal Variation in Groundwater Quality and its Suitability for Irrigation Purpose in Selected Blocks of Rupnagar District, Punjab, India

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Abstract: ***In the study area, groundwater is highly exploited by over abstraction for irrigation. Agriculture is the main source of income of the area and irrigation is mainly done using groundwater. Considering the present scenario of the district, it was found significant to assess the seasonal variation of groundwater quality and suitability for irrigation purpose. 60 groundwater samples were collected and analyzed for both pre and post monsoon seasons. Analytical results show that in few sample salinity was above the desirable limit prescribed by Bureau of Indian Standard. Depth to water level in the study area ranges from 5 to 40 mbgl, whereas, Chamkaur Sahib and Morinda Blocks fall in the over-exploited category with groundwater development being more than 100%. The suitability of the groundwater for agricultural use in the study area has been assessed using USSL classification, RSC, %Na, SAR, and PI. An evaluation is made in present study to determine any change in the quality of groundwater due to seasonal variation in the study area.***

Keywords: Groundwater Quality, Irrigation, SAR, USSL Classification, RSC, %Na, PI.

1. Introduction

Groundwater is the largest source of usable, fresh water in the world. Fertile land, moderate temperature, average humidity, periodic monsoon, availability of usable water resources has made the Indian sub continent a perfect agricultural land. In India, agriculture has played and still has a massive role in its economic development. Agriculture contributes about 13.9% to the GDP of India [1]. Sengupta in an article claimed, with the right technology and policies, India could contribute to feeding not just itself but the world [2]. Until the mid 1960's India heavily counted on imports and other food assistance for domestic needs. Condition further declined with the droughts in 1965 and 1966. This lead to India's Green Revolution which started in Punjab giving food and fodder to the entire nation, hence the name "Bread basket of India" was flagged by the state. Accounting for 1.5% of the country's land area, Punjab is home to 2.3% of the country's population. It is the largest contributor of wheat (around 55%) and second largest of paddy (around 42%) after Andhra Pradesh to the central pool of the country; though its relative contribution in central pool of food grains both for wheat and paddy has been declining during the last few years [3][4]. Sustainability of agriculture in Punjab is thus important for the state's economy and also for food security in India. Punjab contributes 13-14% towards the total food grain production of the country. On an average there are 28 tube wells per sq. km. of net sown area in Punjab alone. Punjab is a predominantly agricultural state having 85% of its area under cultivation with an average cropping intensity of 188% [5]; therefore the demand for water in the state is very high.

The consequences of intensive water resource mobilization, in the absence of systematic groundwater management backed by robust water governance mechanisms, have been extreme depletion of groundwater resources on one hand and a rising water level, leading to water logging and soil salinity on the other [6]. In the tube-well irrigated areas, water table is depleting and water-logging is the problem in canal irrigated areas which can degrade the quality of groundwater. Studies have been carried out on chemical quality of groundwater which showed that the groundwater quality has been deteriorated due to its over-exploitation [7] [8].

2. Literature Review

Various studies have been conducted to evaluate the groundwater quality for irrigation use around the globe. Musah Salifu (2015) assessed the groundwater quality for irrigation in selected districts of Upper West Region of Ghana. The results showed that the groundwater is suitable for irrigation. Based on KR, 34% of the samples were unfit for irrigation which require special careful application [9]. Groundwater quality of Karonga and Rumphi districts, Northern Malawi was evaluated by Wanda et al. (2013) to check its suitability for agricultural use. The study found that groundwater has low mineralization, is neutral to alkaline and mostly fresh water of Ca-HCO_3 type. SAR, KR and %Na indicated good and permissible irrigation water quality. But some samples with high salinity hazard limits the suitability of groundwater for irrigation [10]. Subba Rao (2006) studied the seasonal variation of groundwater quality and its suitability for drinking and agricultural use in a part of Guntur district, Andhra Pradesh, India. He concluded that water quality degraded in post monsoon season making it unfit for drinking and irrigation use. It is caused due to leaching of salts by infiltrating recharge waters [11].

3. Statement of the Problem

The study area is predominantly an agricultural zone, with dense agricultural activities. Majority of the people in this region depend on agriculture. Further intensive study of the concerned area is required to have a detailed examination of groundwater quality in both the seasons for agricultural use.

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4. Methodology

Rupnagar district, formerly known as Ropar, included in the Patiala Division of Punjab falls between North latitude 30°-32' and 31°-24' and East longitude 76°-18' and 76°-55' (Fig. 1). The Sutlej river passes close (2 to 5 km) to the towns of Nangal, Rupnagar and Anandpur Sahib. The district is divided into

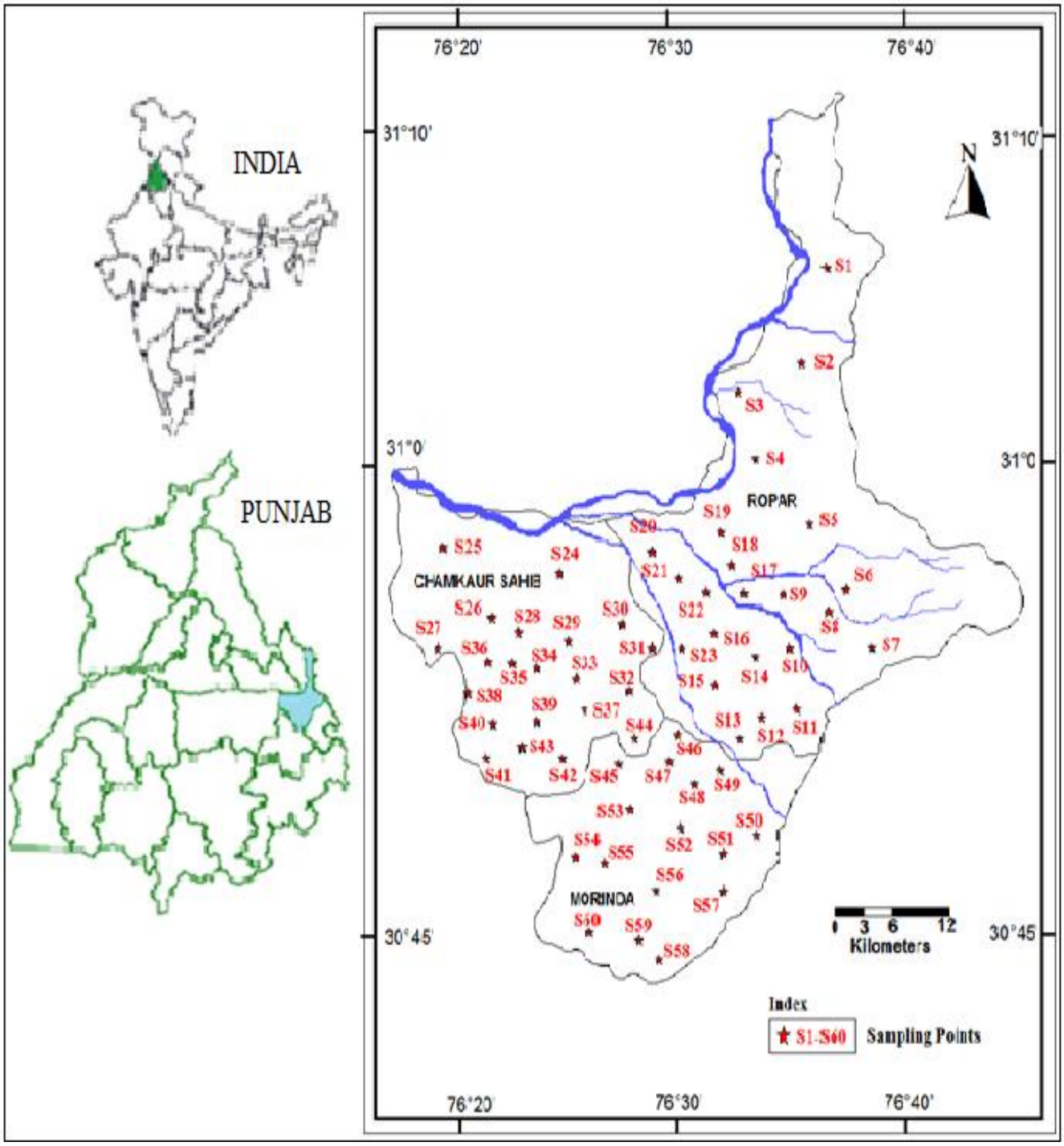


Figure 1: Location map and sampling points in Rupnagar District, Punjab, India

five blocks – Anandpur Sahib, Chamkaur Sahib, Morinda, Nurpur Bedi and Rupnagar. Rupnagar town, the district headquarters is 42 kms from Chandigarh (U.T.), the state capital. Agriculture is the main source of economy in these blocks, and the main crops grown are paddy, jowar, bajra, maize, wheat, barley, sugarcane, gram, oil seeds and cotton. Groundwater samples were collected for two different seasons. A total of 60 samples were taken in the months of May (Pre monsoon) and October (Post monsoon), 2013 from Ropar, Morinda and Chamkaur Sahib blocks of Rupnagar district. The samples were collected from tube wells and hand pumps ranging in depth between 20 m to 100 m below ground level. Water samples were collected after pumping the water for 10 minutes from hand pumps in order to have minimum effect of iron pipes through which the water was pumped out. Samples were collected in pre rinsed 1 L polyethylene bottles. Plastic bottles were filled up to the brim and immediately sealed to prevent any exposure to the

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air. pH, EC and TDS were measured at the sampling site using portable field kit. Major ionic concentration was measured using standard analytical procedures recommended by APHA [12]. Carbonates, bicarbonates and total hardness were determined using EDTA titrimetric method. Chloride was measured using Argenetometric method, sodium and potassium using Flamephotometric method, phosphate and nitrate by UV Spectrophotometric method whereas sulphate and fluoride were determined using Turbidity and SPADNS method respectively.

5. Results and Discussions

Major ionic concentrations (Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, CO_3^{2-}, HCO_3^{-},) were computed which was further used to calculate SAR, RSC, %Na and give the USSL classification and Wilcox diagram in order to evaluate the suitability of groundwater for irrigation in the study area.

Salinity Hazard: The measurement of electrical conductivity is directly related to the concentration of ionized substance in water and may also be related to problems of excessive hardness and/or other mineral contamination. Salinity hazard can be measured by computing the conductance of the water samples. Higher salt content in irrigation water causes an increase in soil solution osmotic pressure [13]; in other words higher the EC, less water is available to plants as they become incapable to compete with the ions present in soil for water. The US Salinity Laboratory categorized groundwater on the basis of Electrical Conductivity (Table 4) [14]. Perusal of US Salinity diagram illustrates that most of the groundwater samples fall in the field of C_2S_1 and C_3S_1, indicating medium to high salinity and low sodium water, thereby concluding that the groundwater of the study area can be used for irrigation on almost all types of soil with little danger of exchangeable sodium (Fig. 2).

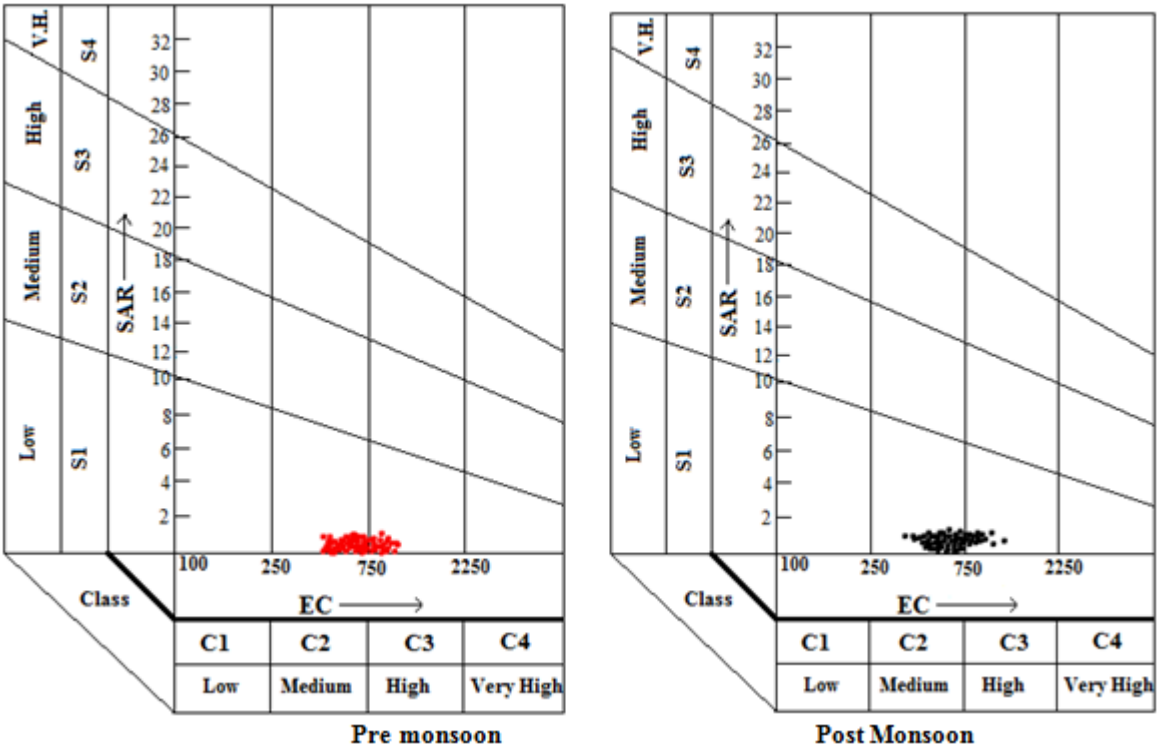


Figure 2: USSL classification of groundwater quality for irrigation (USSL, 1954)

Sodium Hazard: 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 [15]. It demonstrates the impact of relative cation concentration on sodium accumulation in soil, thus sodium adsorption ration (SAR) is a more reliable method for determining this effect than sodium percentage [16]. This index quantifies the proportion of Na^{+} to Ca^{2+} and Mg^{2+} ions in a sample. If irrigating water is high in sodium and low in calcium, the ion-exchange complex may become saturated with sodium which breaks down the soil structure, due to the dispersion of clay particles [17] and ultimately affects the plant growth. Hem (1991) gave the following equation to calculate SAR value of water sample [18]:

$$SAR = \frac{Na^{+}}{\left(\frac{\sqrt{Ca^{2+} + Mg^{2+}}}{2}\right)}$$ (all units in meq/l)

SAR values computed were very low in the study area which ranged from 0.07 to 1.26 meq/l in pre monsoon and from 0.12 to 1.56 meq/l in post monsoon season. Without any possibility of sodium exchange [19], groundwater is of excellent quality for irrigation (i.e. S1 category). Classification of groundwater from the study area with respect to SAR is given in Table 1 [20].

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Residual Sodium Carbonate: Apart from SAR and %Na, the excess sum of carbonate and bicarbonate in groundwater over the sum of calcium and magnesium influences the suitability of groundwater for irrigation. This is represented as RSC which is calculated using equation [21]:

$$RSC = \left(CO_3^{2-} + HCO_3^{-}\right) - \left(Ca^{2+} + Mg^{2+}\right)$$ (all units in meq/l)

RSC computed for the study area ranged from -3.16 to 1.45 meq/l and from -2.6 to 2.08 meq/l in pre monsoon and post monsoon season respectively. On the basis of RSC values, according to Richard's classification (1954) all the groundwater sample of the study area except for one sample have RSC values less than 1.25 meq/l and therefore, the groundwater is of good quality. At one location the groundwater sample (Sample no.8) with RSC value of 1.45 meq/l in pre monsoon and 2.08 meq/l in post monsoon was in the doubtful category (Table 1).

Table 1: Suitability of groundwater for irrigation based on several classifications

EC (µS/cm) (USSL, 1954)	Water class	% age of samples Pre-monsoon	Post-monsoon
Up to 250	Excellent	-	-
250–750	Good	71.7%	76.7%
750-2250	Fair	28.3%	23.3%
	Poor	-	-
Based on SAR (Todd, 1959)			
<10	Excellent	100%	100%
10-18	Good	-	-
18-26	Doubtful	-	-
>26	Unsuitable	-	-
Based on % Na (Wilcox, 1955)			
<20	Excellent	76.7%	18.3%
20-40	Good	23.3%	76.7%
40-60	Permissible	-	5%
60-80	Doubtful	-	-
>80	Unsafe	-	-
Based on RSC (Richard, 1954)			
<1.25	Good	98.3%	98.3%
1.25-2.5	Doubtful	1.7%	1.7%
>2.5	Unsuitable	-	-

Percent Sodium (%Na): Another important parameter used widely for evaluating the suitability of water quality for irrigation is Percent Sodium (%Na). Sodium reacts with soil to reduce its permeability as it tends to get absorbed by clay particles, displacing Mg^{2+} and Ca^{2+} ions and thus inhibits the supply of water required by the plants. The percent sodium (%Na) is calculated using the formula given below:

$$\%Na = \frac{Na^{+} + K^{+}}{Ca^{2+} + Mg^{2+} + Na^{+} + K^{+}} * 100$$ (all units in meq/l)

Calculated percent sodium for groundwater in the study area is plotted against electrical conductivity (EC) in Wilcox diagram [22]. Figure 3 shows that samples range from excellent to permissible category. According to the range given by Wilcox, 76.7% belongs to the excellent category and 23.3% belongs to good category in pre monsoon season; wherein post monsoon season, 18.3% samples belongs to excellent category, 76.7% samples are in good category and 5% belongs to the permissible category (Table 1).

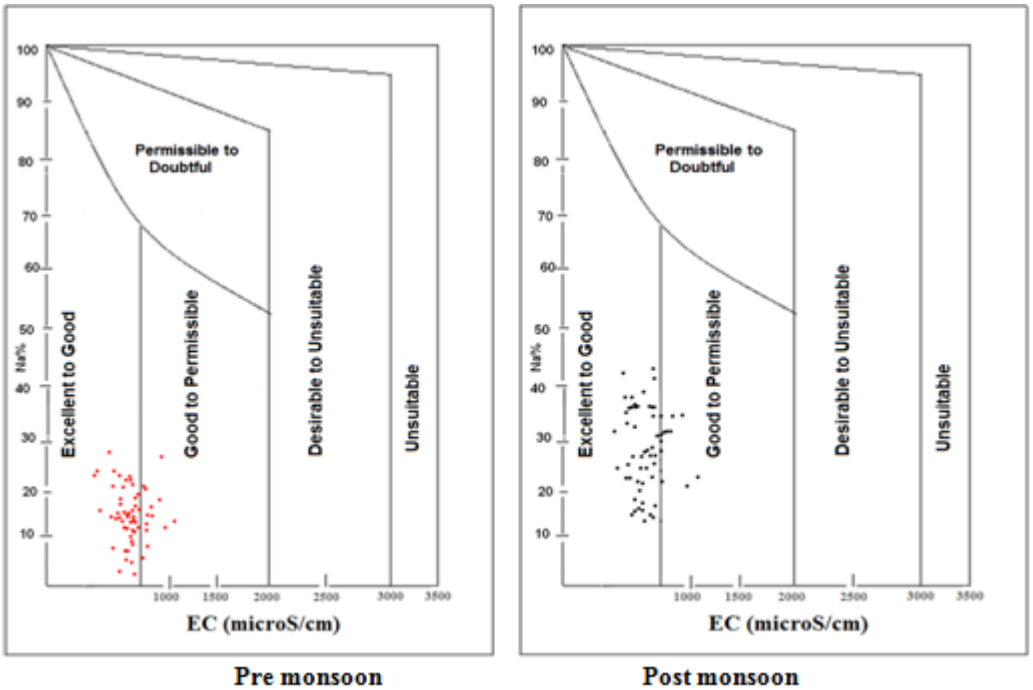


Figure 3: Classification of groundwater quality for irrigation (Wilcox, 1955)

Permeability Index: Another important parameter to measure the suitability of groundwater for irrigation is the permeability index (PI). The permeability of soil is affected by long-term use of irrigation water and is also influenced by Na^{+}, Ca^{2+}, Mg^{2+} and HCO_3^{-}contents in soil. Doneen (1964) developed a standard for assessing the suitability of water for irrigation based

on PI which is calculated by using the following equation [23]:

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$$PI = \frac{\left(Na^{+} + \sqrt{HCO_3^{-}}\right) * 100}{Ca^{2+} + Mg^{2+} + Na^{+}}$$ (all units in meq/l)

PI values for the groundwater samples of the study area varied from 7 to 14% in pre monsoon season and from 6 to 14% in post monsoon season. The computed values of PI plotted on Doneen's chart showed that all the groundwater samples were in Class 1 category, i.e. 100% permeability of the soil (Fig. 4) [24].

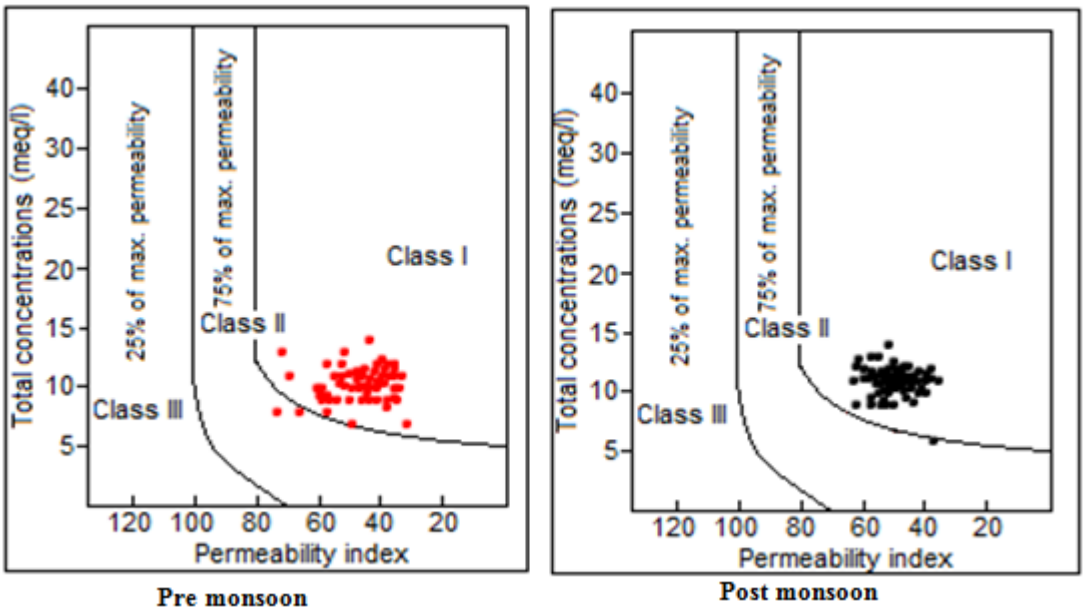


Figure 4: Doneen classification of irrigation water based on the permeability index (Domenico and Schwartz, 1990)

6. Conclusion

After analyzing all the data used in the study we can deduce that groundwater in the study area is fit for irrigation purpose. Large variations in few parameters suggest that water chemistry is not homogenous and regulated by various geochemical processes. All the classifications suggested that groundwater is in safe zone for irrigation use. Wilcox diagram shows that few samples fall in good to permissible category, therefore it is required that these samples be assessed time and again to keep a check on groundwater quality. Perusal of USSL classification, SAR, RSC and %Na indicate that groundwater is suitable for agricultural practices. Over-exploitation of aquifers lead to mixing of groundwater with agricultural return flow waters which is responsible for generating groundwater of various compositions in its lateral stretch. Though the groundwater is of good quality but periodic examination of the area is required as many samples have shown variations after the monsoons.

The prolonged agricultural activities prevailing in an area may directly or indirectly influence mineral dissolution in groundwater [25]. For sustainable development an integrated water management can be suggested for maintaining water quality and better crop production. Agricultural practices should be well managed to secure safe use of the water resource for a sustainable development of the region. Awareness and knowledge about irrigation water can help the farmers keep a check on water quality as well as its quantity.

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