

Irrigational Suitability of Surface and Sub-Surface Waters Of the Area in and Around Bhopal City, District - Bhopal, (M.P.)



Manisha Singh

Chemistry Department, Govt. Motilal Vigyan Mahavidyalaya, Bhopal (M.P.)
Corresponding author - email: manisha.msingh@yahoo.com

D. K. Gupta

Chemistry Department, Govt. Motilal Vigyan Mahavidyalaya,
Bhopal (M.P.)

R. S. Raghuwanshi

Geology Department, Govt. Motilal Vigyan Mahavidyalaya, Bhopal (M.P.)

R. N. Saxena

Retd. Professor, Department of Applied Geology, Barkatullah University, Bhopal

ABSTRACT:-

The study area in and around Bhopal lies between Latitude 23°10'-23 °22'N and Longitude 77°15'-77°13'E on the Survey of India toposheet Nos. 55-E/7 and 55-E/8 covering an area of 550 km². In order to assess the quality of surface and sub-surface water of the study area, the physico-chemical character of water samples were studied at the sampling point in the field and the chemical characters have been determined in the laboratory.

On the basis of chemical character of natural waters an attempt has been made to evaluate the suitability of surface and sub-surface waters of the area for irrigational purposes and its possible effects on. plant growth. Important parameters like Kelley's ratio; Sodium Adsorption Ratio (SAR) ; Residual Sodium Carbonate (RSC) etc. were determined to evaluate the suitability of waters for irrigation purposes. On the basis of these parameters and specifications, it is proposed that the water is suitable for irrigation purpose.

Keywords : - Bhopal, Irrigation, Physico - chemical, Surface and Subsurface, Water.

1. INTRODUCTION

The study area in and around Bhopal lies between Latitude 23°10'-23°22'N and Longitude 77°15'-77°13'E on the Survey of India toposheet Nos. 55-E/7 and 55-E/8 covering an area of about 550 km².

In the present study quality of surface and sub-surface water have been worked out considering the geological formations namely Vindhya and Deccan trap lava flows which forms the geographical distinguishable area of Bhopal city.

In order to assess the quality of surface and sub-surface water of the study area for irrigation purpose, the physico-chemical character of water samples were studied at the sampling point in the field and the chemical characters have been determined in the laboratory.

Water has value only when its quality is suitable for which it is being sought or explored. The suitability of natural water for a particular purpose depend upon the criteria or standard of acceptable quality for that use.

In order to evaluate the suitability of surface and sub-surface waters for irrigational purposes, various specifications based on different standards have been proposed from time to time by various agencies and workers like A. G. Asgar, A.N. Puri and E.M. Taylor (1936), W.P. Kelly, S.M. Brown and G.F. Liebig (1940), L.V. Wilcox (1948), F.M. Eaton (1950), U.S. Salinity Laboratory Staff (1954) and many others.

In the present study, the specifications as proposed by Kellys *et al.* (1940), Eaton (1950), U.S. Salinity Laboratory Staff (1954), Wilcox (1948) and K.V. Paliwal (1972) have been used to assess the quality of water. These specifications are mostly based on the chemical characters of natural waters and their effects on plant growth. The calculated values of these specifications are given in Table 1 and 2.

2. METHODOLOGY

Base map of the study area has been prepared using Survey of India toposheet Nos. 55-E/7 and 55-E/8 to show the location of collected water samples. In all 50 water samples have been collected from various part of the area, by dividing the area into rectangular grid system.

These samples were taken from surface and sub-surface water bodies, collected samples were analyzed physically and chemically using pH meter, conductivity meter, flame photometer, spectrophotometer etc. Cations and anions were analysed using analytical techniques laid down by Rainwater and Thatcher (1960) and Greenburg *et al.* (1985) Table 1 and 2.

Qualitative and quantitative estimations were carried out for total alkalinity, total hardness, total dissolved solids, chemical oxygen demand, Biochemical oxygen demand, sodium, potassium, magnesium, chlorides, sulphate, nitrate, fluoride, phosphate, carbonate and bicarbonate.

3. RESULT AND DISCUSSION:

To understand the suitability of water for irrigation purpose, certain ratio and diagrams are of fundamental importance and described as :

The SAR is an important parameter for determination of suitability of irrigation water because it is responsible for the sodium hazard (U.S. Salinity Laboratory Staff, 1973).

Sodium Adsorption Ration (SAR) which is defined as

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

Where, all concentrations are expressed in equivalent per million. The SAR value of the surface and sub-surface water of the study area varies from 0.133 to 10.82 (Rose garden) in pre-monsoon periods while 0.622 to 9.845 in posttmonsoon period. (Table 3 and 4) The recommended water classification for SAR values are given below (Todd, 1959)

SAR water class

< 10 Excellent

10-18 Good

18-26

Fair

> 26 Poor

Water samples of the study area have SAR value less than 10 (Table 3 and 4) indicating their suitability for irrigation purposes.

The Kelly's Ratio (KR) for the water samples of the area was estimated by using the following formula:

$$KR = \frac{Na^+}{Ca^{2+} + Mg^{2+}}$$

The water having $KR \leq 1$ is considered to be of good quality for irrigation, on the other hand KR of more than 1 is considered to be unsuitable for irrigation and it causes alkali hazard in the soil (Kamath, 1987). The KR values for the surface and sub-surface water samples of the study area for both the seasons are less than 1 which indicates good quality of water for irrigation purpose (Table 3 and 4).

The Soluble sodium percentage (SSP) for the samples of the area and calculated by the following formula:

$$KR = \frac{Na^+ \times 100}{Ca^{2+} + Mg^{2+} + Na^+}$$

The SSP values of ≤ 50 indicate good quality water for irrigation and if it is more than 50, it indicates the unsuitable nature of water for irrigation. The SSP values for the surface and sub-surface water of study area are less than 50 indicating that the surface and sub-surface waters are suitable for irrigation purpose (Table 3 and 4).

The excess of bicarbonate and carbonate of water is denoted as residual sodium carbonate (U.S. Salinity Laboratory Staff, 1973). It is calculated by the following formula:

$$RSC = (HCO_3^- + CO_3^{2-}) - (Ca^{2+} + Mg^{2+})$$

If the RSC values are ≤ 1.25 it indicates safe quality of water for irrigation, 1.25 to 2.5 indicates marginally suitable water and if it is more than 2.5 then the water is unsuitable for irrigation purpose. The RSC values for the surface and sub-surface water of study area are less than 1.25 which indicate that the water is safe for irrigation purpose (Table 3 and 4).

Graphical Representation and Classification:

In the previous section, the classification and chemistry of waters are discussed based on the criteria which only incorporate the individual or paired ionic concentrations. However, by considering the combined chemistry of all ions rather than individual or paired ionic concentrations, better results regarding the classification, geochemical studies and suitability standards of waters for different purposes can be obtained (Hem, 1959; Handa, 1964, 1965; Romani, 1981).

Hence, with a view to bring out the similarities and differences in chemical composition of waters of different geochemical characteristics, and for a simpler, quicker visual inspection, several graphical methods have been suggested by different workers. Collin's (1923) bar diagram, Stiffs (1951) horizontal pattern diagram, pie diagram, logarithmic diagram of Schoeller (1962) and Taussig's (1961) zigzag diagram are widely used to demonstrate the proportion of ionic concentrations in individual water analysis. In the present investigation, Stiffs (1951) horizontal pattern diagram, USSL diagram and Gibb's (1970) diagram are used for their simplicity and inherent advantages.

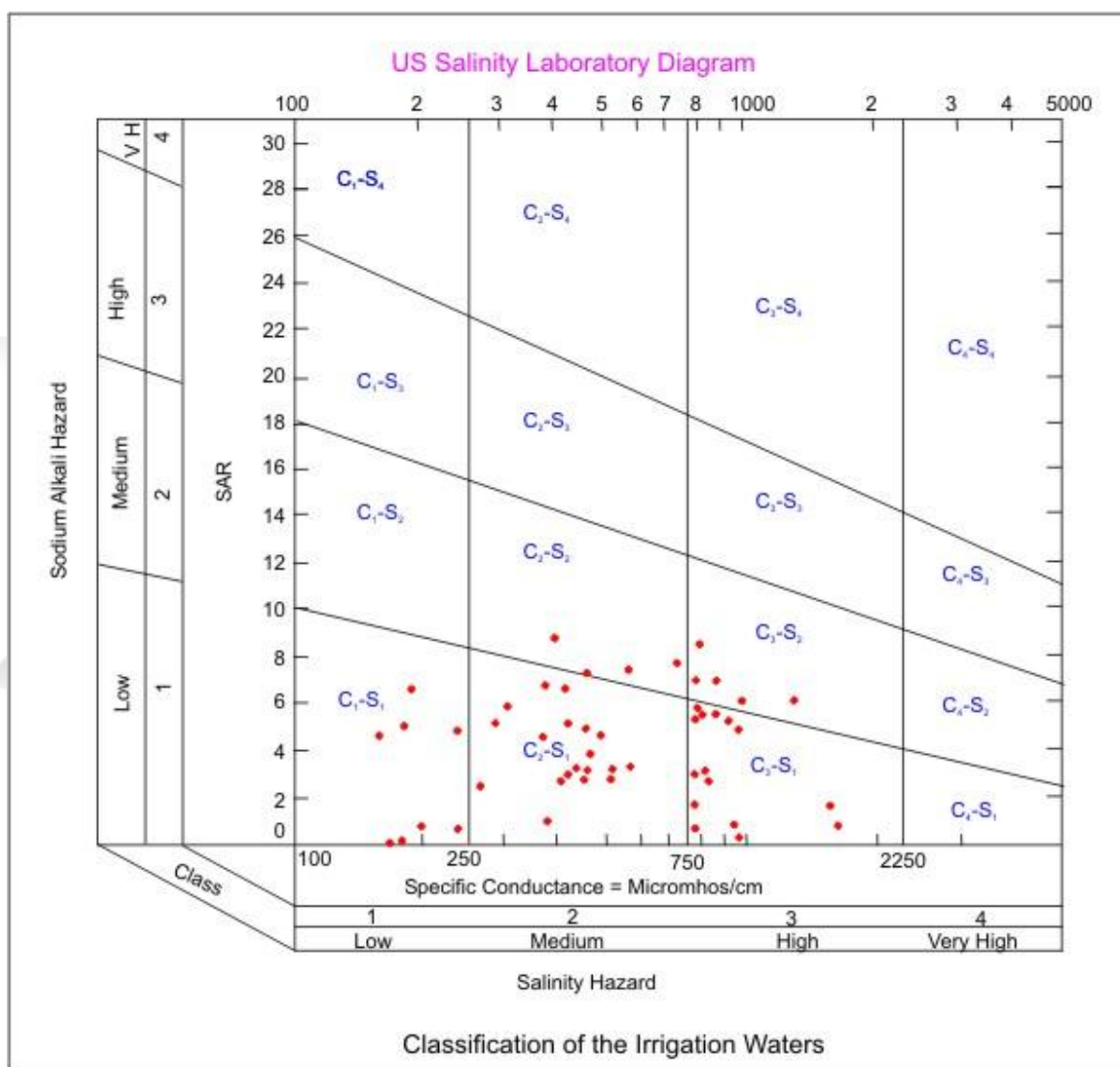


FIGURE 1 a

U.S. Salinity Laboratory Diagram of Natural Water of Bhopal City for Post-Monsoon Season
(2008)

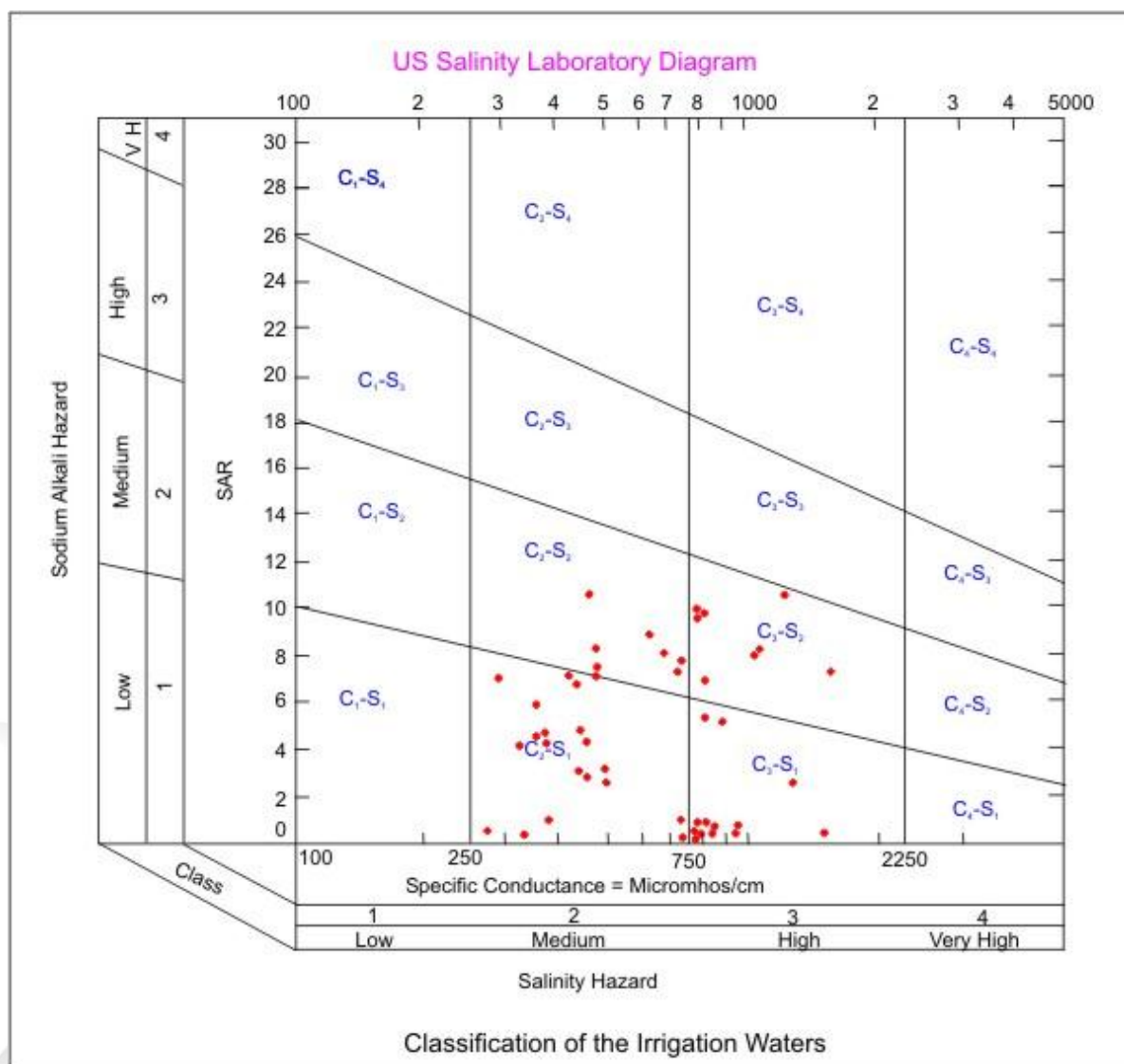


FIGURE 1 b

U.S. Salinity Laboratory Diagram of Natural Water of Bhopal City for Pre-Monsoon Season (2008)

The U.S. Salinity Laboratory proposed a salinity diagram (Fig. 1a and 1b) for the classification of irrigation waters with respect to salinity and sodium hazards (Richards, Ed. 1954). On the basis of specific conductance and SAR values the diagram gives the classification of water samples into C_1 , C_2 , C_3 , etc., which represent water classes with increasing salinity hazards. Also S_1 , S_2 , S_3 , etc., represent water classes with increasing hazards of exchangeable sodium. Good quality waters are taken as those falling into C_1S_1 and C_2S_1 groups. Water samples falling into C_1S_2 , C_2S_2 , C_3S_2 and C_3S_1 are considered

as of moderate quality; whereas waters belonging to groups other than these, generally are considered as poor quality waters. In the present investigation, all the plots fall in good to moderate water zone.

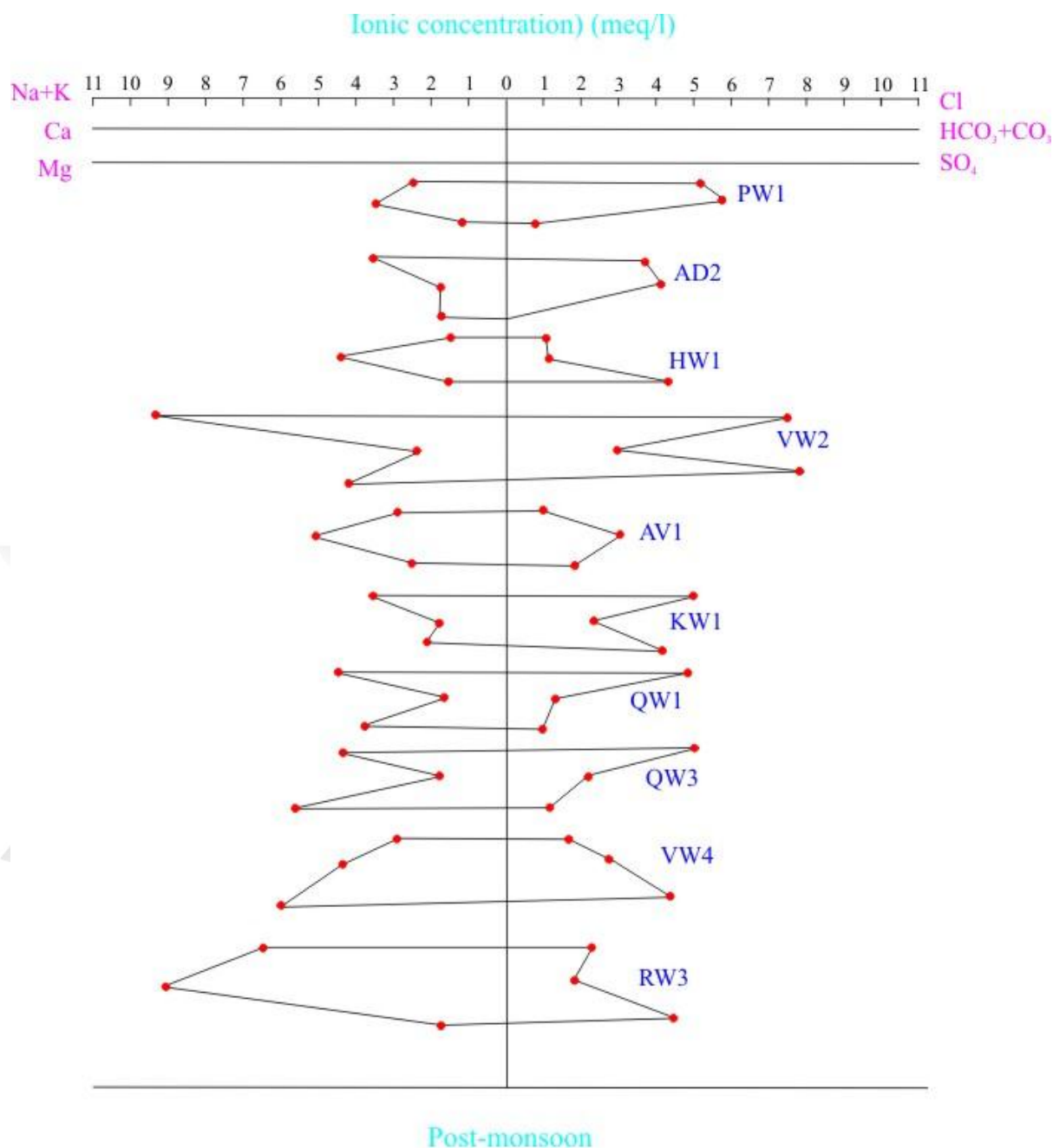


Fig. 2a : Stiff's diagram for post-monsoon - 2008

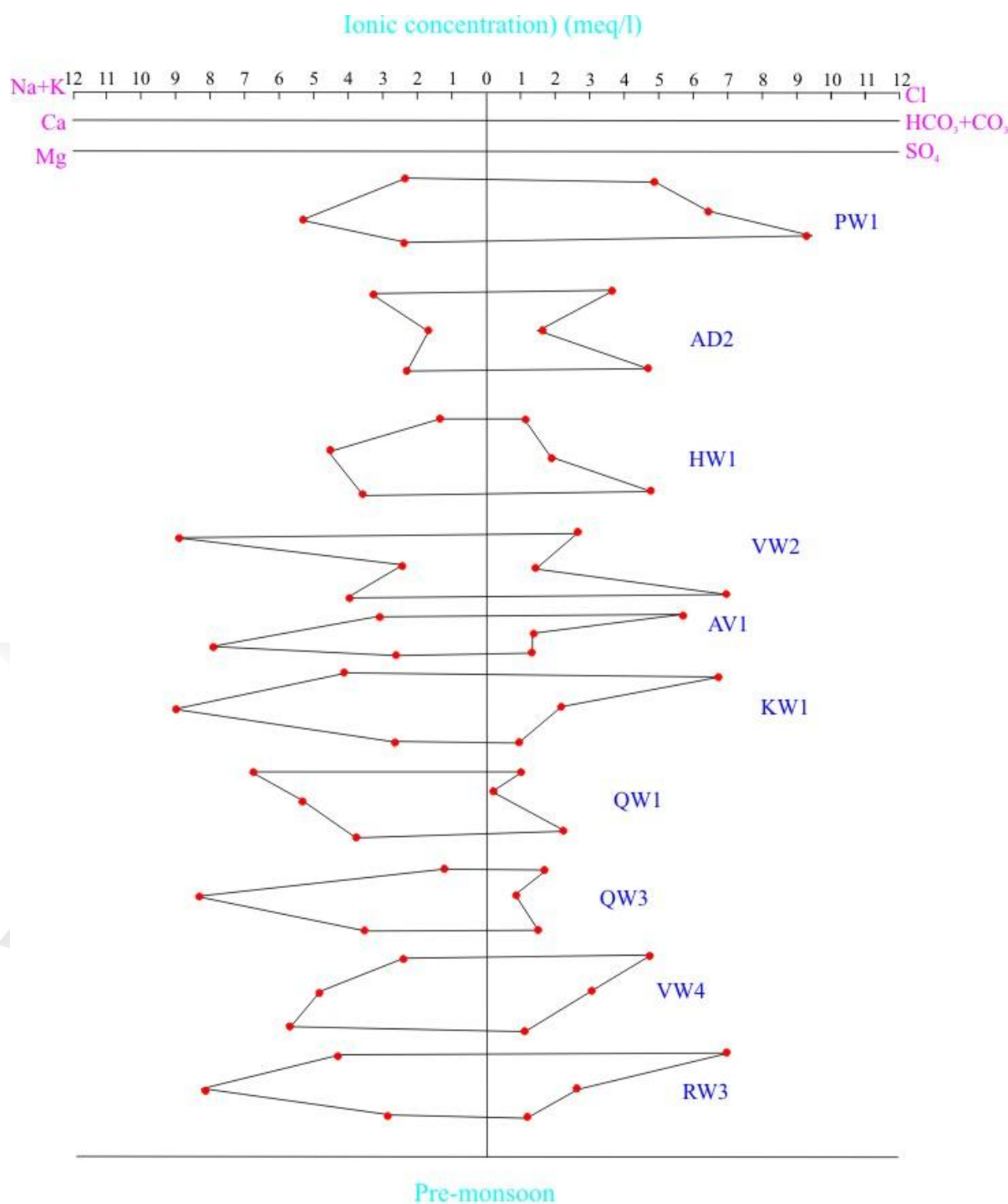


Fig. 2b : Stiff's diagram for pre-monsoon - 2008

Stiffs (1951) proposed a graphical method using four parallel horizontal axis and one vertical axis used in making comparisons of water, especially highly mineralized ones. Four cations are plotted along axis to the axis to the left of the zero point and four anions on the right. Concentrations are expressed in equivalent per liter, connecting points representing anions and cations give a closed figure, whose shape is more or less characteristic of a given kind of water (Fig. 2a i-ii and 2b i - ii).

The mechanisms that significantly control the chemical composition of the dissolved salts of the waters of the earth in major proportion have been discussed by Conway (1942); Gorham (1961); Mackenzie and Garrels (1965, 1966); Sillen (1967); Gibb's (1970) and Ramesam et al. (1973).

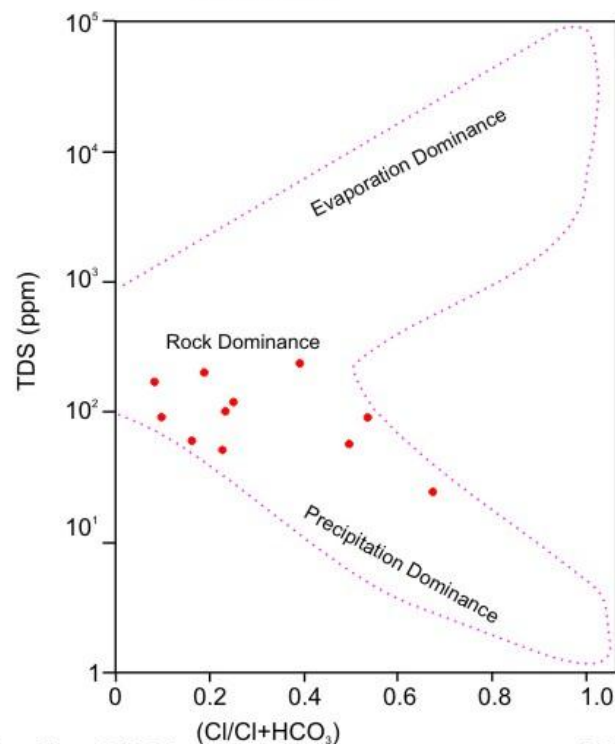
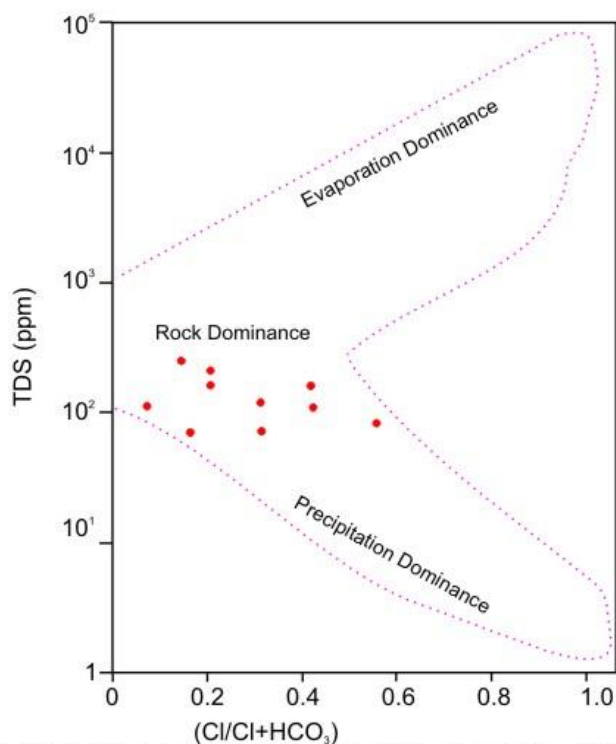
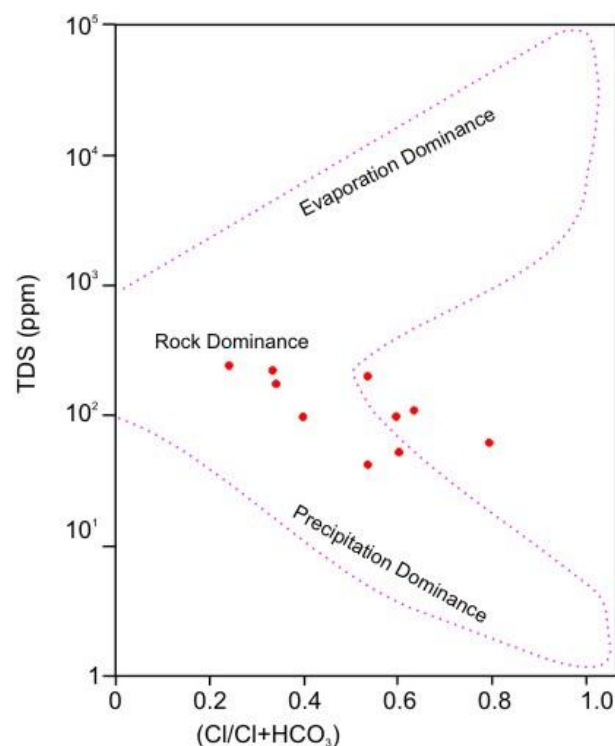
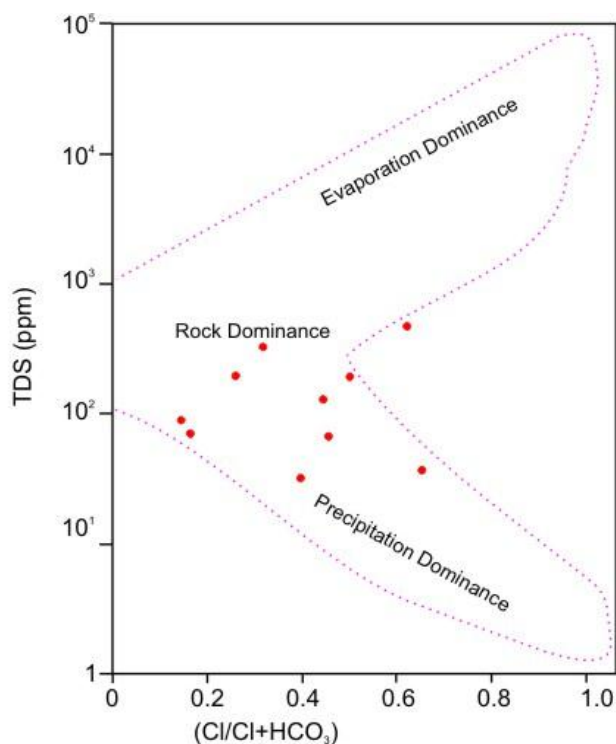


Fig. 3a : Gibb's diagram for post-monsoon - 2008

Fig. 3b : Gibb's diagram for pre-monsoon - 2008

Among all the investigators the contribution of Gibbs (1970) in describing the mechanisms of controlling the chemistry of different types of waters happens to be most appropriate. He proposed a diagram in which the domain of each of the three major controlling mechanisms and factors i.e., atmospheric precipitation, rock dominance and evaporation-crystallization process has clearly been demonstrated. Following the method given by Gibbs (1970) the ratios $(Na+K)/(Na+K+Ca)$ and $Cl/(Cl+HCO_3)$ against TDS are plotted (Fig. 3a and 3b). In both the diagrams, the plotted points of analyses of water fall within the rock dominance zone indicating the geological control, followed by the precipitation dominance control in the study area.

CONCLUSIONS :

The suitability of natural water for irrigation is contingent upon the effects of mineral constituents of the water on both the plant and soil (Todd, 1959). The important factors that influence the water quality for irrigation are TDS concentration (which is broadly related to the specific conductance of water), percent sodium and relative proportion Ca & Mg of sodium to calcium and magnesium. Salts may harm and interfere with plant growth by toxicity or by changing soil properties. Excessive amount of salts in general and sodium in particular affect the soil permeability, soil structure and create toxic conditions for plants, particularly those sensitive to sodium. Sodium toxicity is evidenced by leaf burn, defoliation and stunted growth. On the basis of aforesaid discussion the quality of surface and sub-surface waters of the study area may be concluded as under:

1. The pH value of water varies from 6.5 to 8.4 ppm in post monsoon and 7.0 to 8.62 in pre monsoon session. These values of pH shows that the water is slightly alkaline in its nature.
2. The Kelly's ratio is less than unity in all the surface and sub-surface water samples of the area; while the sodium adsorption ratio (SAR) is less than 10 in all water samples indicating their suitability for irrigational purposes.
3. All water samples have less than 1.25 RSC values, which clearly indicate their suitable nature for irrigational purposes.
4. Soluble sodium percentage (SSP) value for all the water samples of the area is less than 50% which indicates their suitability for irrigational purposes.

5. In some parts of the study area, the hardness of water is very high, exceeding permissible limit. This may be due to sluggish movement of water in calcium and magnesium rich rocks like basalts.
6. It is evident from the US Salinity Staff diagram that the majority of surface and sub-surface waters fall in C_2-S_1 class followed by C_2-S_1 class which reveal low alkali hazard and moderate salinity hazard of surface and sub-surface waters from irrigational point of view.
7. As per the Gibbs (1970) diagram, water samples fall within the rock dominance zone indicating the geological control followed by the precipitation dominance control in the study area.

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IGNITED MINDS
Journals

BIBLIOGRAPHY

- Asgar, A.G., Puri, A.N. and Taylor, E.M. (1936) Soil determination in irrigated areas of Punjab, part I-III, Irrigation Research. Memoirs, Amritsar
- Collins, W.D. (1923) Graphic representation of analyses, Ind. and Eng. Chem., Vol. 15, 394 p.
- Conway, E.J. (1942) Mean geochemical data in relation to oceanic evolution, proc. Irish acad., sci B,V. 48, pp. 119-59.
- Eaton, F.M. (1950) Significance of Carbonate in Irrigation Water. Soil Sci., Vol. 69, No.2, pp. 123-133.
- Gorham, E. (1961) Factors influencing supply of major ions to inland waters with special references to the atmosphere, Bull, Geol. Soc. Amer., V. 72, pp. 795-840.
- Gibbs, R.J. (1970) Mechanisms, Controlling world water chemistry, science, V. 170, pp. 1080-1090.
- Handa, B.K. (1964) Modified classification procedure for rating irrigation waters, Soil. Sci., V. 98, pp. 264-69.
- Hem, J.D. (1959) Study and interpretation of the chemical characteristic of natural water, U.S. Geol. Surv. water supply paper 1473.
- Karanth, K.R. (1987) Role of Hydrogeology in integrated water resources development and management, environment context. Groundwater News. pp. 23-30.
- Kelly's, W.P. Brown, S.M. and Liebig, G.F. (Jr) (1940) Chemical effects of saline irrigation water on soil sci, Vol. 49, pp. 95-107.
- Mackenzie, F.T. and Garrels, R.M. (1965) Silicates reactivity with sea water, Science, V. 150, pp. 57-58.
- Mackenzie, F.T. and Garrels, R.M. (1966) Chemical mass balance between rivers and ocean Amer. Jour. Sci., V. 264, pp. 507-25.
- Paliwal, K.V. (1972) Irrigation with Saline water. I.A.R.I., Monograph No.2, (New Sereis), New Delhi, 198 p.

Ramesam, V. and Barna, S.K. (1973) Preliminary studies on the mechanisms controlling salinity in the northwestern acid region of India, Ind. Geohydrology, Vol. 9, pp. 10-18.

Rechard, L.A. (Ed.) (1954) Diagnosis and improvement of saline and alkali soils, U.S. Dept. of Agrl. hand book, No. 60, 160 p.

Romani (1981) A new diagram for the classification of natural waters and interpretation of chemical analysis data. In quality of groundwater (Van Deijvenbooden. P. Globergen and H. Van, eds.) Proc. Internat. Symp. Naardwi - Kerhout, Netherlands, pp. 743-48.

Schoeller, H. (1962) Les Eaux souterraines, Masson, Paris, pp. 257-384.

Stiffs, H.A. Jr. (1951) The interpretation of chemical water analysis by means of patterns, Jour. Petrol. Tech., V. 3, pp. 15-17.

Sillen, L.G. (1967) The Ocean as a chemical system, science, Vol. 156, pp. 1189997.

Taussig, K. (1961) Natural groups of groundwater and their origin, P.N. 205, Tahal. Water Plann., Tel Aviv, Israel.

Todd, P.K. (1959) Groundwater hydrology, John Wiley and Sons, New York, 336 p.

U.S. Salinity Laboratory Staff (1954) Diagnosis and improvement of saline and alkaline soils, U.S.D.A. Handbook No. 60, 160 p.

Wilcox, L.V. (1948) The quality of water for irrigation use., V.S.D.A. Tech. Bull. 962, Washington, D.C., p. 40.