Research Paper

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Variation and Evaluation of Ground Water Levels and Water Quality in Kandi and Sirowal Belts of Jammu District, Jammu and Kashmir, India

Environment

KEYWORDS : Ground Water, Kandi, Sirowal, Dtwl, NHNS, BIS.

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ABSTRACT

This study was conducted to analyse the variations and evaluate the ground water levels and quality in Kandi and Sirowal belts of Jammu district of Jammu and Kashmir State. The Kandi and Sirowal belts form the major aquifer systems in the district of which Sirowal belt is more prolific. The two belts comprised of the sediments deposited by the streams. Ground water in these belts occurs under both unconfined and confined conditions in Sirowal and under unconfined to semi-confined conditions in Kandi belt. Detailed hydrogeological investigation associated with periodic ground water levels and water quality monitoring helped in generating the overall idea of the variation in these two parameters in the aquifer system of the area.

The dtwl was measured in 41 designated NHNS for pre-monsoon as well as post- monsoon seasons of 2012. The variation in ground water quality of Kandi-Sirowal belt of Jammu district was evaluated using chemical quality results of 54 water samples collected from NHNS during pre monsoon season viz., May 2012. The chemical parameters like specific conductance, pH, Ca, Mg, Na, K, Cl, SO4, HCO3, NO3, F, TH and Fe were determined and were compared with the water quality standards of BIS for drinking purpose. The important constituents that influence the water quality for irrigation such as Electrical Conductivity (EC), Total Dissolved Solids (TDS), Sodium Adsorption Ratio (SAR), Magnesium Adsorption Ratio (MAR), Permeability Index (PI), and Kellys Ratio (KR) were assessed and were compared with standard limits.

INTRODUCTION

Jammu district constitutes 1.9 percent of the total area of the J&K State and is the southern most district of the state. It lies between 32°50'00" and 33°30'00" North latitudes and 74°24'00" and 75°18'00" East longitudes covering the Survey of India toposheet no. 43 L/14 and parts of 43 L/5, L/9, L/10, L/13, P/1 and P/2. It is approximately 600 kms away from National Capital, New Delhi and is linked with a National Highway, Railway and Air routes.

Physiographically, the district is occupied by two major units extending throughout the district. The unit that extends in northern part is the hilly tract of Siwalik formations and the unit extending in the southern part is a plain tract, the Outer Plain. This Outer Plain can be further divided into Kandi and Sirowal formations which are equivalent to Bhabar and Terai formations of Indo-Gangetic Plains. These sediments are of Recent to Sub-Recent age, sediments deposited by the present day streams. The lithology of Jammu district is hetrogeneous and varies significantly from hilly areas to plain areas. The analysis of ground water flow system indicated that the regional flow direction follows the direction of the topographic slope viz. southwest.

STUDY AREA

The Outer Plains extends throughout the southern boundary of Jammu district from east to west has an area of 2000 sq. km. It comprises northern Kandi and southern Sirowal Belt. The Kandi Belt is steeply sloping and has width less than 10-30 km, extending discontinuously from Jammu and Kashmir to Assam (Goyal & Rai, 2000). It has an altitudinal variation between 280 and 490 m above mean sea level. The general lithological sequence in Kandi belt varies from conglomerates to clay with boulders, pebbles and gravels. The grain size in sediments reduces towards Sirowal Belt.

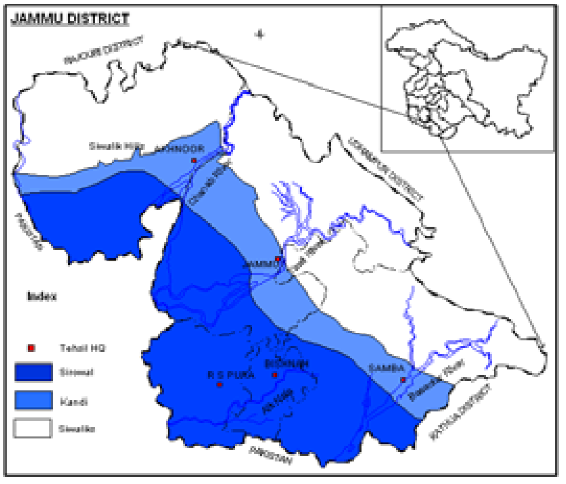

Fig 1: Location Map of the study Area

The Kandi formation merges with Sirowal imperceptibly down gradient where the topographic gradient is reduced to about 1:250 to 1:300. This part of Outer Plains is locally called as Sirowal Belt. Sirowals in Jammu district are at an altitude of less than 320 m amsl. Lithologically, it comprise of finer sediments especially pebbles and gravels with sand and clay. The contact of Kandi with Sirowal is characterized by spring line with oozing water table (Fig 1).

Two major perennial rivers coming from the hills viz. Chenab & Tawi drains the area and enters Pakistan territory in the southwest. Basantar River and Aik Nala also follows the same trend of major rivers. (Fig 1) Apart from these, several seasonal nalas traverse the area, which are boulder laden and have broad shallow channels, having water only for short time after the rains. The total average rainfall of Jammu is 1276 mm, the bulk of the rainfall occurs from June to September. Variation of long term rainfall as per IMD data is shown in Fig. 2.

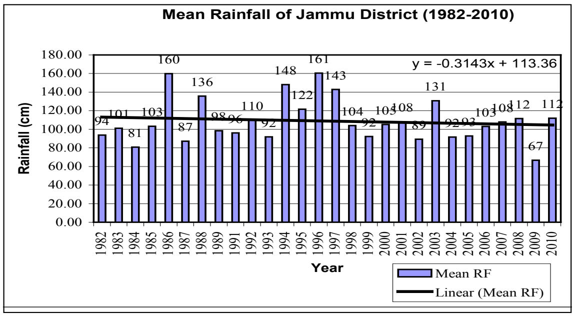

Fig 2: Mean Annual Rainfall of Jammu District

METHODOLOGY AND DATA USED

In the present study the base map was prepared using SoI Toposheets. The data of depth to water levels of 41 National Hydrograph Network Stations (NHNS) were analyzed using the dedicated software 'GEMS' (Groundwater Estimation & Management System). The depth to water level and water quality maps were prepared by using Surfer and Map Info Softwares.

The water samples were also collected from these NHNS and 13 Handpumps during pre monsoon season of 2012 and analysed by adopting standard methods of analysis of water and waste water analysis (APHA, 1998). Various water quality parameters such as pH, Electrical conductivity (EC), Carbonate (CO_3^{2-}), Bicarbonate (HCO_3^-), Chloride (Cl^-), Sulphate (SO_4^{-2}), Nitrate (NO_3^-), Fluoride (F^-), Calcium (Ca^{2+}), Magnesium (Mg^{2+}), Sodium (Na^+), Potassium (K^+), Iron (Fe), Total hardness (TH) were analysed and compared with standards of BIS for drinking water. The suitability of ground water for irrigation is determined by calculating SAR, SSP, PI, MAR and KR.

GROUNDWATER FLOW

Groundwater occurs both under unconfined and confined conditions in the Sirowal and under unconfined to semi-confined conditions in Kandi belt. The flow direction of groundwater is form north-east to south-west viz. Kandi to Sirowal formations and corresponds roughly with the topographic slope (Fig 2). Like lateral flow of water the vertical infiltration in Kandi formation is also high owing to the coarser grain size of sediments. Rainfall is the main source of ground water replenishment in Kandi area whereas seepage from canal system, return flows from surface and ground water irrigation also contributes to a large quantity recharge to ground water in Sirowal belt.

The water level of Kandi belt is deeper than in Sirowal. Depth to water level is deeper towards Siwalik formation and shallower towards Sirowal formation. It is as shallow as 1.0 m below ground level (m bgl) in Sirowal and as deep as 35.0 m bgl in Kandi belt. The hydraulic gradient in Kandi belt is between 1:90 and 1:120 and between 1:200 and 1:250 in Sirowal belt.

BEHAVIOR OF GROUND WATER REGIME

In order to study the water level behavior in Outer Plains, 41 NHNS were monitored during pre-monsoon and post monsoon seasons and their fluctuations were analyzed. Out of 41 wells, 12 wells lie in Kandi Belt and 29 wells in Sirowal Belt. During pre monsoon season viz., May 2012, the depth to water level in Kandi belt varies between 2.34 m bgl at Pallanwala and 37.42 m bgl at Taryai and in Sirowal belt the depth to water levels varies between 2.20 m bgl at Lam and 7.53 m bgl at Bengular.

During post monsoon season viz., November 2012, the depth to water level in Kandi Belt varies between 1.17 m bgl at Pallanwala and 32.52 m bgl and at Taryai. In Sirowal belt it varies between 1.72 m bgl at Didyal and 7.28 m bgl in Bengular. Water level contour map indicates the formation of cone of depression on the extreme ends of Kandi Belt at its contact with Siwalik formation (Fig 3).

There is a significant effect of rainfall in these two belts which is interpreted by comparing May 2012 with November 2012. In the study area, fluctuation varies from 0.19 m (rise) at Samba to 5.78 m (rise) at Hazuribagh in Kandi belt and from -1.07 m (rise) at Bhagwanchak to 5.04 (decline) m at Channi in Sirowal Belt. The effect of rainfall is more prominent in wells lying in Kandi belt that has coarser grain size which contributes to instant rise in water levels in this belt.

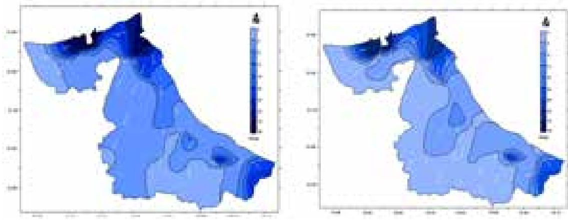

Fig 3: Depth to Water Level Maps Pre-monsoon and Post-monsoon seasons of 2012.

HYDROCHEMICAL CHARACTERIZATION

Water quality analysis is one of the most important aspects in groundwater studies. The hydro-chemical study reveals quality of water that is suitable for drinking, agriculture and industrial purposes. This includes the determination of the general water quality, major ionic constituents, hydro-chemical facies and water types. The quality of the ground water varies from place to place and with the depth to water table. Fresh ground water is normally associated with recharge areas whereas ground water in discharge areas is more mineralized. Ground water can be classified according to the most dominant percentage of cations and anions present based on concentrations in equivalents per million [epm].

The physical and chemical quality of ground water is important in deciding its suitability for drinking purposes. As such the suitability of ground water for potable uses with regard to its chemical quality has to be deciphered and defined on the basis of the some vital characteristics of the water. (CGWB, 2010)

The suitability of ground water for irrigation purpose has been evaluated based on salinity, Sodium Absorption Ration (SAR) and Residual Sodium Carbonate (RSC). An attempt has also been made to classify the ground water on the basis of different classification schemes, viz., Piper trilinear diagram and U.S. Salinity diagram. (CPCB, 2008)

The quality of ground water of the phreatic zone is assessed through the results of water samples collected from the dugwells and handpumps of the study area.

pH:

pH may be defined as negative logarithm of Hydrogen ion concentration. The pH of ground water in the study area ranged from 7.17 to 8.42. The average pH for these 54 samples is 7.73. The pH values for all the samples are well within the limits prescribed by Bureau of Indian Standards (BIS, 2007) for various uses of water including drinking and other domestic supplies.

EC:

The measurement of electrical conductivity is directly related to the concentration of ionized substances in water and may also be related to problems of excessive hardness and/or other mineral contamination. The average EC is 838.89 μS/cm, the minimum EC of ground water was observed 380 μS/cm at Pandhorian and maximum EC is 3300 μS/cm at Suchetgarh. The contour maps for pH and EC values shows their concentrations in the study area (Fig 4).

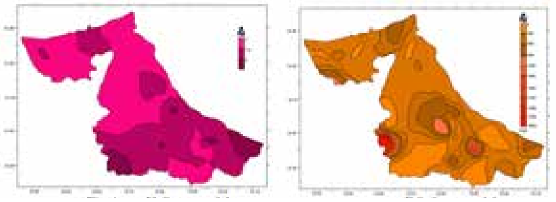

Fig 4: pH Contour Map EC Contour Map

Major Ionic Constituents

In natural water, dissolved solids consist mainly of inorganic salts such as Carbonates, Bicarbonates, Chlorides, Sulphates, Phosphates and Nitrates of Calcium, Magnesium, Sodium, Potassium, Iron etc. and small amounts of organic matter and dissolved gases. The cations Calcium, Magnesium, Sodium, Potassium and Iron and anions Bicarbonate, Chloride, Fluoride, Sulphate and Nitrate were identified in the samples of study area and their distributions are shown in fig 5, 6 and 7.

Cations:

The dominant cation is Calcium, followed by Magnesium and Sodium. Calcium and Magnesium along with their Carbonates, Sulphates and Chlorides make the water hard. The average values for Calcium and Magnesium are 91.15 mg/l and 27.98 mg/l and minimum and maximum values ranged from 26 to 218 mg/l and 6 - 134 mg/l respectively. The concentration of Sodium in the study area varies from 6.70 to 310 mg/l. Potassium is an essential element for all living beings and derived in food chain mainly from vegetation and soil. Its concentration in the ground water of the study area varies from 0.5 to 310 mg/l of minimum and maximum respectively.

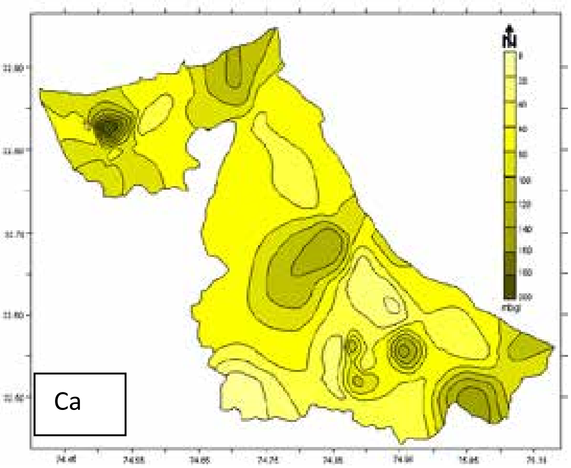

Fig 5: Ca concentration in the study area

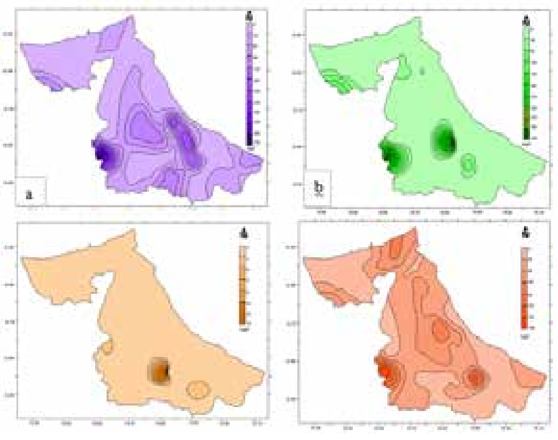

Fig 6: Concentrations of Anions in the study area a) Na, b) K, c) Fe, d) Mg

Anions:

The presence of Carbonates, Bicarbonates and Hydroxides are the main cause of alkalinity in natural waters. Bicarbonates represent the major form since they are formed in considerable amount from the action of Carbonates upon the basic materials in the soil. It is the dominant anion and its value in the ground water samples of the study area varies from 140 to 1171 mg/l. The concentration of Chloride varies from 7.10 to 312 mg/l. The average minimum and maximum values for Sulphate concentration in the ground water samples of the study area are 5 and 370 mg/l respectively. Nitrate content in drinking water is considered important for its adverse health effects. The nitrate content in the study area varies from minimum of 0.17 to maximum 350 mg/l. Eleven samples have NO_3 concentrations higher than the prescribed limits of 45 mg/l because of anthropogenic causes viz. use of nitrogenous fertilizers, irrigation practices and dense cattle population in the area. The Fluoride values ranged from 0.09 to 1.60 mg/l. Three samples have the fluoride levels above the permissible limit of 1 mg/l. The presence of Iron in ground water is due to the processes involved during rock formation. The concentration limits of Iron in water samples ranges between 0.08 mg/l and 14.50 mg/l. Sixteen samples has Iron values above 0.3 mg/l. The highest value of Iron is found in a sample from handpump of Pandhorian (14.50 mg/l).

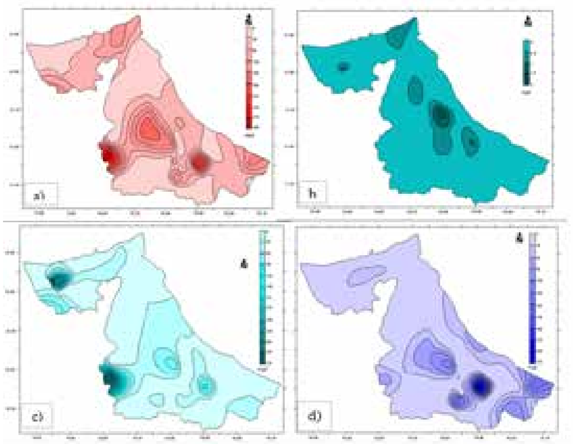

Fig 7: Concentrations of Anions in the study area a) Cl, b) F, c) SO_4, d) NO_3

The major ions are in the preferential order of Ca^{2+} >Mg^{2+} >Na^{+} >K^{+} and HCO^{3-} > Cl^{-} > $SO_4^{-}4$>NO_3^{-} >. Calcium and Magnesium are the dominant cations and bicarbonate is the dominant anion in this region.

Hardness

Water hardness is caused primarily by the presence of cations such as Calcium and Magnesium and anions such as Carbonate, Bicarbonate, Chloride and Sulfate in water. In Outer Plains, the total hardness varies between 180 to 850 ppm. According to Sawyer and McCarty's (2003) classification for hardness, none of the samples fall under soft and moderately hard class whereas 29 samples fall under hard and 25 samples under very hard class for water samples. The hardness classification is given in Table 1 and shown in fig 8.

Table 1: Classification of water based on hardness by Sawyer and McCarty

Hardness as $CaCO_3$ (ppm)	Water class	Water samples
0-75	Soft	0
75-150	Moderate Hard	0
150-300	Hard	29(152.3-299.5)
>300	Very hard	25(329.7-840)

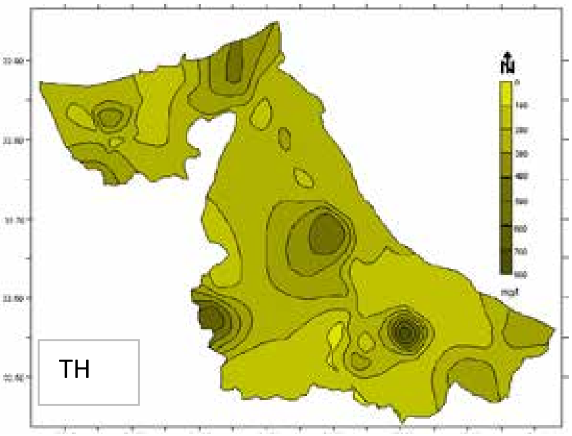

Fig 8: TH concentration in the study area.

Suitability for Irrigation

The suitability of the shallow groundwater for irrigation has been qualified according to irrigation indices (SAR, SSP, Salinity Hazard, PI, MAR and KR). The minimum, maximum and average values of these indices are given in table 2.

Table 2: Quality Parameters for Irrigation Water.

	SAR	SSP	PI	MAR	KR
Min	0.27	6.56	43.05	6.10	0.06
Max	10.64	74.36	126.79	72.44	4.20
Average	1.94	26.58	90.14	31.65	0.61

SAR

A better measure of the Sodium hazard for irrigation is the Sodium Absorption Ratio (SAR) which is used to express reactions with the soil. The SAR was calculated by following equation given by Richards (1954) as

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

During pre –monsoon 2012, the SAR values of 53 samples were found to be less than 10 and are classified as excellent for irrigation and one sample is classified as good, has SAR value of 10.64. The statistics of water samples for SAR values is given in Table 3.

Table 3: Suitability for Irrigation

Sodium Hazard class	SAR in EPM	Remark on quality	No. of samples
S1	10	Excellent	53
S2	10 – 18	Good	01
S3	18 - 26	Doubtful	00
S4 and S5	>26	Unsuitable	00

Irrigation water having high SAR levels can lead to the build-up of high soil sodium levels over time, which in turn can adversely affect soil infiltration and percolation rates due to soil dispersion. Additionally, excessive SAR levels can lead to soil crusting, poor seedling emergence and poor aeration.

Soluble Sodium Percentage (SSP)

Soluble Sodium Percent is an important factor for studying Sodium hazard. High percentage Sodium water for irrigation purpose may stunt the plant growth and reduces soil permeability (Joshi et al., 2009). The Soluble Sodium Percentage (SSP) was calculated by following equation (Todd, 1984)

$$SSP = \frac{(Na+K) \times 100}{(Ca+Mg+Na+K)}$$

where all ions are expressed in meq/l.

In the study area SSP ranges between 6.56 and 64.36. Forty eight samples (89%) have SSP values less than 50 which indicates good quality water and 6 samples (11%) have more than 50 indicates the unsuitable water quality for irrigation.

Salinity Hazard

Salinity and Toxicity problems of irrigation water are attributed to Sodium Absorption Ratio (Raihan and Alan, 2008). The SAR is defined by US Salinity Laboratory Staff (1954), as Sodium rich water which may cause deterioration of the physical structure of the soil (pore clogging). In the study area, nearly majority of the samples fall within the medium salinity to low Sodium hazard (C2S1) representing 77.7% while 14.8% fall within high salinity and low Sodium hazard (C3S1) and 3.7% falls within the medium salinity and medium hazard (C2S2) and one each in high salinity and medium Sodium C3S2 and high salinity and high Sodium hazard (C3S3) respectively (Figure 9).

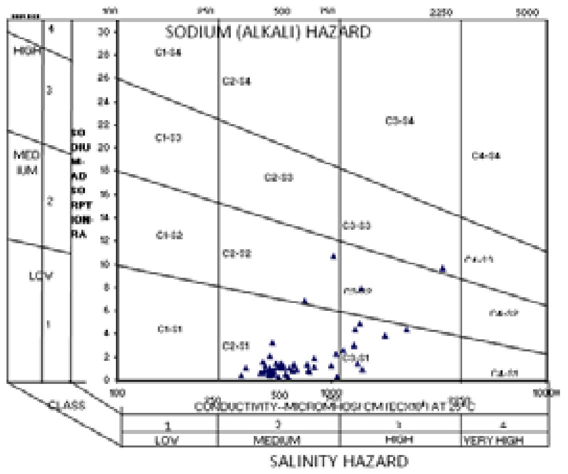

Fig 9 US Salinity Diagram of water samples for irrigation suitability

Permeability Index (PI):

The soil permeability is affected by the long-term use of irrigated water and the influencing constituents are the total dissolved solids, Sodium Bicarbonate and the soil type. In the present study, the permeability index values range between 43.05 and 126.79 meq/l. The above result therefore suggests that water samples fall within Class I and Class II and can be categorized as good irrigation water. The permeability Index (PI) was calculated by the following equation

$$PI = \frac{Na+\sqrt{HCO_3}}{Ca+Mg+Na} \times 100$$

where all ions are expressed in meq/l.

Magnesium Adsorption Ratio (MAR)

Generally, Calcium and Magnesium maintain a state of equilibrium in water. More Magnesium in water will adversely affect crop yields as the soils become more saline (Joshi et al., 2009). The values of the Magnesium Adsorption Ratio of shallow groundwater in present study vary from 6.10 to 72.44%. A total of 8 samples have MAR above 50% making water unsuitable for irrigation. When Magnesium adsorption ratio exceeds 50% it causes a harmful effect to the soil.

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Kelly's Ratio (KR)

Water having KR more than one indicates an excess level of Sodium (Kelley, 1946). As discussed, excess sodium levels make water unsuitable for irrigation. The KR values of water samples of the study area ranged between 0.06 and 4.20% thus 46 samples fall within the permissible limit of 1.0 indicating water suitable for irrigation purpose, and eight samples have KR >1 indicating the unsuitable water quality for irrigation. 86% samples indicates good quality water while remaining 14% shows KR more than 1 indicating the unsuitable water quality for irrigation.

Piper's Trilinear Diagram

The Piper's diagram consists of two lower triangular fields and a central diamond shaped field where all the three fields have scales reading in 100 parts (Piper, 1944). The percentage reacting values of the cations and the anions of the syudy area are plotted as a single point at the lower left and right triangles, respectively. These are projected upwards parallel to the sides of the triangles to give a point in the rhombus. The point is represented by a circle whose area is proportional to the absolute concentration (actual mg/L) of the water. The water quality plotted by the location of points in the different zones of the diamond-shaped field as shown in Fig.10 reveals that the quality is fresh and water is Bicarbonate rich.

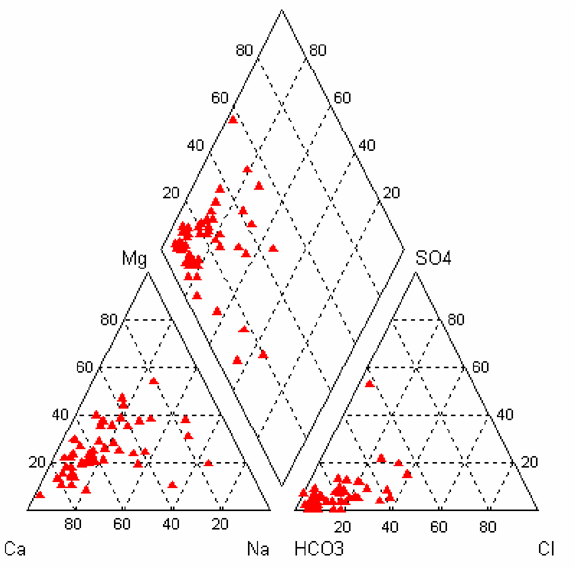

Fig 10: Piper Diagram

CONCLUSIONS

For developing and managing the ground water resources scientifically, it is necessary to obtain complete and accurate information and data of ground water regime of the area including quantitative as well as qualitative approaches. To know the behavior of ground water regime in the Outer Plains of Jammu district consisting of Kandi and Sirowal deposits of Quaternary age, 41 dug wells were monitored during pre-monsoon and post monsoon seasons of 2012. The water levels have indicated that the water level in the Kandi belt is quite deeper owing to its coarser sediments as compared to Sirowal belt which has finer sediments. The fluctuation of water levels during pre-monsoon and post- monsoon season directly reflects the effect of rainfall due to which rise in water levels is observed except for few patches where fall was observed. The highest fluctuation observed is rise of 5.78 m at Hazuribagh.

To know the water quality of study area the ground water samples were collected during May 2012, from 54 locations tapping phreatic zone were analysed and compared with the quality standards of Bureau of Indian Standards for drinking. The results for drinking water reveals that all the constituents viz., pH, EC, CO_3, HCO_3, Ca, Mg, Na, K, Cl, SO_4, NO_3, F, TH and Fe, are well within the permissisible limits of BIS except for the few locations where NO_3 (11 locations >45 mg/l), F (3 locations > 1 mg/l) and Fe (16 locations > 0.3 mg/l) were found to be above permissible limits. 25 water samples fall in hard category and 29 fall in very hard category. The major ions are in the preferential order Ca^{2+} >Mg^{2+} >Na^{+} >K^{+} and HCO_3^- > Cl^- > SO_4^{-2} > NO_3^-. Calcium and Magnesium and Bicarbonate are the dominant cations and anion in this region.

For irrigation water, SAR, SSP, Salinity Hazard, PI, MAR and KR were calculated. The SAR values for 53 samples was found to be less than 10 and are classified as excellent for irrigation except for a single sample which is classified as good and has SAR value of 10.64. The SSP values in 89% of samples are less than 50, indicates good quality water and 11% have values more than 50 indicates the unsuitable water quality for irrigation. The type of water that predominates in the study area is Ca-Mg-HCO_3 type in i.e, 38.88% of water samples. 25.92% have Ca-HCO_3 and 27.77% has mixed type of water based on hydro-chemical facies. In the study area, 77.7% samples fall in C2S1 class indicating medium salinity to low Sodium hazard while 14.8% fall in C3S1 class having high salinity and low Sodium hazard and 3.7% falls (C2S2) class possessing medium salinity and medium hazard and one each in C3S2 high salinity and medium Sodium and high salinity and C3S3 class viz, high Sodium hazard respectively.

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