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Evaluation of Groundwater Quality in Balatira Watershed, Atpadi Taluka, Sangli District, Maharashtra.

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Abstract: *There are 1531 watersheds in the state of Maharashtra. The Balatira watershed (BM 113) covering an area of 278 Km^2 forms a part of Krishna river watershed falling in drought affected Atpadi taluka in Sangli district of the state. It is bound by North Latitudes 17^o 42' and 75^o 00' and East Longitudes 74^o42' and 75^o 00' forming part of the toposheets 47O/11 and 47O/15. Sampling of groundwater was carried out at 35 observation wells in pre-monsoon and post-monsoon periods of 2014 and 2015. The physico-chemical parameters analysed were Na, K ,Ca, Mg, Cl, HCO_3, CO_3, SO_4 and NO_3*

The concentration of various parameters for potability were compared with those of WHO (2004) standards. The scenarios for the parameters are conflicting but for many parameters the values are within the permissible range. The dominant hydrochemical facies is Ca^{2+}-Mg^{2+}-Cl^--SO_4^{--}; Na^+-K^+-Cl^--SO_4^{--} and Ca^{2+}- Cl^-- SO_4^{--} types. The plot on the Gibbs diagram indicates the samples falling in the rock domain reflecting the role of aquifer chemistry and climatic conditions. The paper bring about various quality aspects in determining the usage of groundwater for various purposes.

Keywords*: Groundwater Quality, Hydrogeochemical Facies, Balatira Watershed*

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I. Introduction

Most human activities involve the use of water in one way or other such as food production, nutrition etc. Which are dependent on water availability in sufficient quantities and good quality (Howari, 2005). It is estimated that approximately one third of the world's population uses groundwater for drinking purposes and today more than half the world's population depends on groundwater for survival (Mohrir, 2002). Groundwater is used for domestic and industrial water supply and also for irrigation purposes in the world. In the last few decades, there has been a tremendous increase in the demand for fresh water due to rapid growth of population and the accelerated pace of industrialisation. Once the groundwater is contaminated, its quality cannot be restored back easily and to device ways and means to protect it. Pure water is the best of life that man has received from nature and everyone of the mankind must do everything possible to maintain its quality for today and for the future. Raju and Reddy (2007) reviewed new trends in hydro-geochemistry and related water quality problems in various geological formations and their health affects.

A graphical interpretation of hydro-geochemistry to quality aspect was proposed by Piper (1994). The same is still in use for deciphering lithogenic and anthropogenic processes.. Safe drinking water quality is a basic human right and an essential component of effective policy for health protection (Altekar, 2004). Water quality and health are emerging area of concern and has been reported by water AID (2005) and World Bank (2005).

Study area: Balatira watershed is located in Atpadi taluka in north eastern part of Sangli district. It forms parts of Survey of India topographic sheets 47O/ 11 and 47O/ 15. It is bound by North latitudes 17^o18' and 17^o28' and East longitudes 74^o42' and 75^o0' covering an area of about 278 Km^2 (see figure 1). The Balatira watershed is designated as BM 113 by GSDA and is a tributary of Man river.

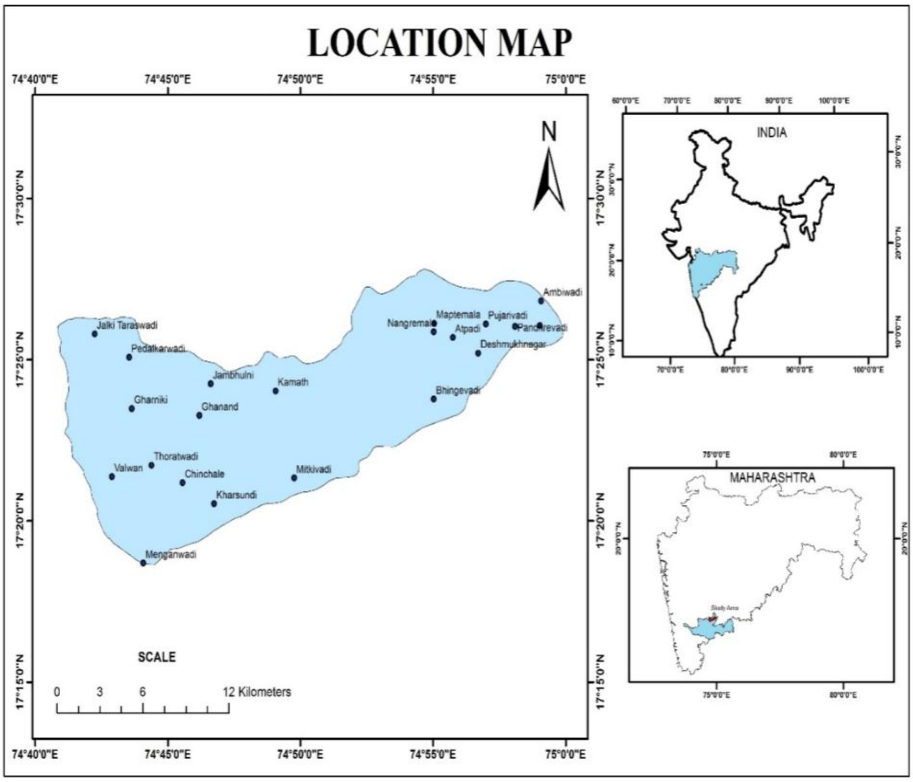


Figure 1: Location map of Balatira watershed, Sangli district, Maharashtra

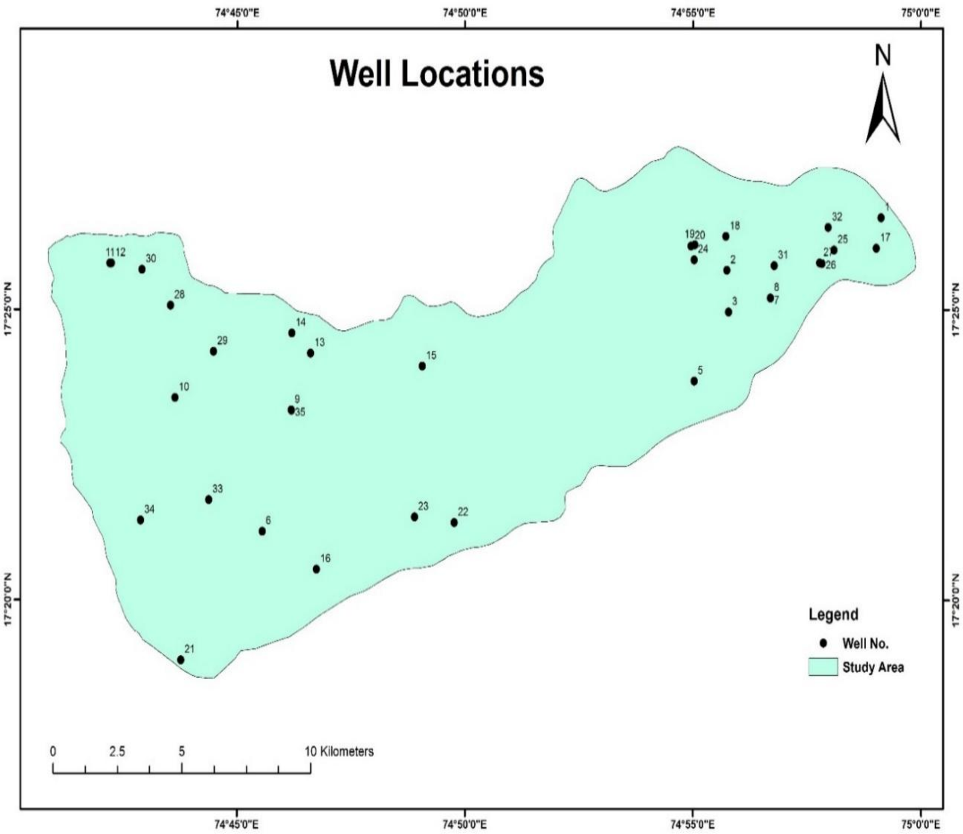


Figure 2: Illustrates locations of identified observation wells sampled in Balatira watershed.

Table 1: Illustrates the quality of groundwater samples with reference to WHO (2004)) for pre-monsoon 2014, post-monsoon 2014, Pre-monsoon 2015 and Post-monsoon 2015.

Sr. No.	Parameters	WHO Limits (ppm)	Pre-monsoon 2014		Post-monsoon 2014		Pre-monsoon 2015		Post-monsoon 2015	
			Avg	Sample %	Avg	Sample %	Avg	Sample %	Avg	Sample %
1	pH	8.5	7.5	0	8.23	0	7.3	0	7.6	0
2	Ec	1500 (mhos/cm)	3061.4	88.6	1450.6	28.6	2809.2	25.7	2154.3	65.7
3	TDS	500	2243	100	1074.5	71.4	1231.9	85.7	1004.7	80
4	Alk	200	242.8	57.1	768.8	94.3	509.1	100	580.1	97.1
5	TH	300	848.2	94.3	349.5	100	342.6	82.8	314.5	88.6
6	Ca	75	169.1	77.1	152.8	71.4	69.4	20	120.9	60
7	Mg	30	103.4	91.4	94	85.7	81.6	94.3	67.6	68.6
8	Na	200	303.9	71.4	335.7	28.6	473.8	60	509.6	60
9	K	150	11.3	0	1.92	0	2.2	0	2.33	0
10	Cl	250	325.3	45.7	302.3	65.7	407.1	45.7	713.2	68.6
11	CO_3	300	26.8	0	30.9	0	30	0	30	0
12	HCO_3	400	241.5	17.1	363.4	45.7	356.7	28.6	322.4	11.4
13	SO_4	200	601.7	100	462.3	48.6	474.8	65.7	314.7	48.6
14	NO_3	50	253.9	100	376.4	97.1	226.6	62.8	125.6	51.4

II. Material And Methodology

Thirty five water samples are collected in pre monsoon during May 2014 and May 2015 and similar number in the post monsoon were collected during November 2014 and November 2015 (figure 2). The samples are collected in pre-cleaned polyethylene bottles. The groundwater samples are analysed as described by American Public Health Association (APHA, 1995) procedure, and suggested precautions are taken to avoid contamination. The groundwater quality parameters pH, EC, TDS, TH, Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, CO_3^{2-}, HCO_3^{-}, Cl^{-}, $SO_4^{2-}$and NO_3^{-} were estimated.

Piper diagram: The Piper Tri-linear diagram is one of the most useful graphical representation in groundwater quality studies to understand the hydrogeochemical facies in terms of analogies, dissimilarities and water types in the study area (Piper, 1944 and1953). The diamond shaped field between the two triangles is used to represent the composition of water with respect to both cations and anions. In the two tri-angular fields, percentage epm values of major cations and anions are plotted separately and then projected on to the central field for the representation of overall characteristic of water. The classification for cation and anion facies, in terms of major ion percentages and water type, is according to the domain in which they occur on the diagram segments.

The generated piper tri-linear diagrams for pre-monsoon and post-monsoon of representative samples during 2014 and 2015 from the study area are shown in figure 3. The groundwater samples of pre-monsoon and post-monsoon 2014 and 2015 belongs to three subzones : Ca^{2+}-Mg^{2+}-Cl^{-}-SO_4^{2-} type, Na^{+}- K^{+}-Cl^{--}-SO_4^{2-} type and Ca^{2+}-Cl^{-} -SO_4^{-} types. It is evident from the piper plot that out of 35 groundwater samples, The groundwater samples of Ca^{2+}- Mg^{2+}- Cl^{-}- SO_4^{2-}type consists of 26%, 17%, 31% and 37% of permanent hardness; Na^{+}- K^{+}- Cl^{--}- SO_4^{2-}saline type are 14%, 23%, 60% and 57%; Ca^{2+}- Cl^{-} - SO_4^{-} type are 60%, 60%, 9% and 6% and 26%, 17%, 31% and 37% are in the mixed zone for the four seasons representing pre-monsoon 2014, post-monsoon 2014, pre-monsoon 2015 and post-monsoon 2015 illustrating the presence of permanent hardness and saline type in the groundwater.While those falling under zone 6 (9%) belongs to the permanent hardness category and exhibited CaCl type wherein noncarbonated hardness exceeds 50% indicating of groundwater from formation that are composed of limestone and dolomite or from recharge zones with short residence time (Hounslow 1995). 13 % samples in zone 5 belongs to the temporary hardness class and exhibited Mg bicarbonate type having carbonate hardness over 50%, illustrating reverse/inverse ion exchange (Davis and Dewiest 1966) responsible for the groundwater chemistry. The samples falls under zone 7 and 8 are saline and alkali carbonate type. Hence water type originating from halite dissolution (saline) or alkali carbonate enrichment.

Evaluation of the water types using piper plot suggest that there is a clear indication of the contribution from the weathering of pyroxene, amphibole and plagioclase in the hard rocks such as basalt in the Balatira basin. The study conducted during post monsoon season and in this period dissolution of the minerals are the major processes occurring in the groundwater environment. Since the water flow is high there will not be much time for infiltration. Dominance of calcium and magnesium in the groundwater samples collected from high topography suggested an inverse ion exchange process. During this process calcium from the aquifer will be exchanged by sodium from the groundwater. However, in the lower topographic region water is dominated by the sodium and chloride ions which is represented by the discharge zone. Sluggish flow in these relatively flat regions of pediment in the Balatira watershed enables sufficient rock-water interaction. The eastern part of the study area covered by thick alluvium and the groundwater samples of those wells are rich in sodium chloride type of water.

According to table 2 illustrates further, that in four seasons, alkaline earth type of water (Ca^{2+} + Mg^{2+}) exceed the alkalis (Na^{+} + K^{+}) in 83 %, 77%, 50% and 50% samples. Where as in anion strong acids (Cl- + SO_4^{2-}) exceed the weak acids (HCO_3^{-} + CO_3^{2-}) in 100% samples during pre-monsoon and post-monsoon seasons of 2014 and 2015. 60%, 60%, 9% and 6% samples shows secondary salinity (non-carbonate hardness) where dominating ions are alkaline earth and strong acids. 14%, 23%, 21% and 57% samples shows primary salinity (dominant ions are alkali and weak acids) during the pre-monsoon 2014, post-monsoon 2014 , pre-monsoon 2015 and post-monsoon 2015 season .Reverse ion exchange waters (Ca-Mg-Cl type) are less easily defined and less common, but represent groundwater where Ca+Mg is in excess to Na+K either due to the preferential release of Ca and Mg from mineral weathering of exposed bedrock or possibly reverse base cation exchange reactions of Ca + Mg into solution and subsequent adsorption of Na onto mineral surfaces.

Figure 3 : Groundwater samples plotted in Piper – Trilinear diagram during 2014 -15

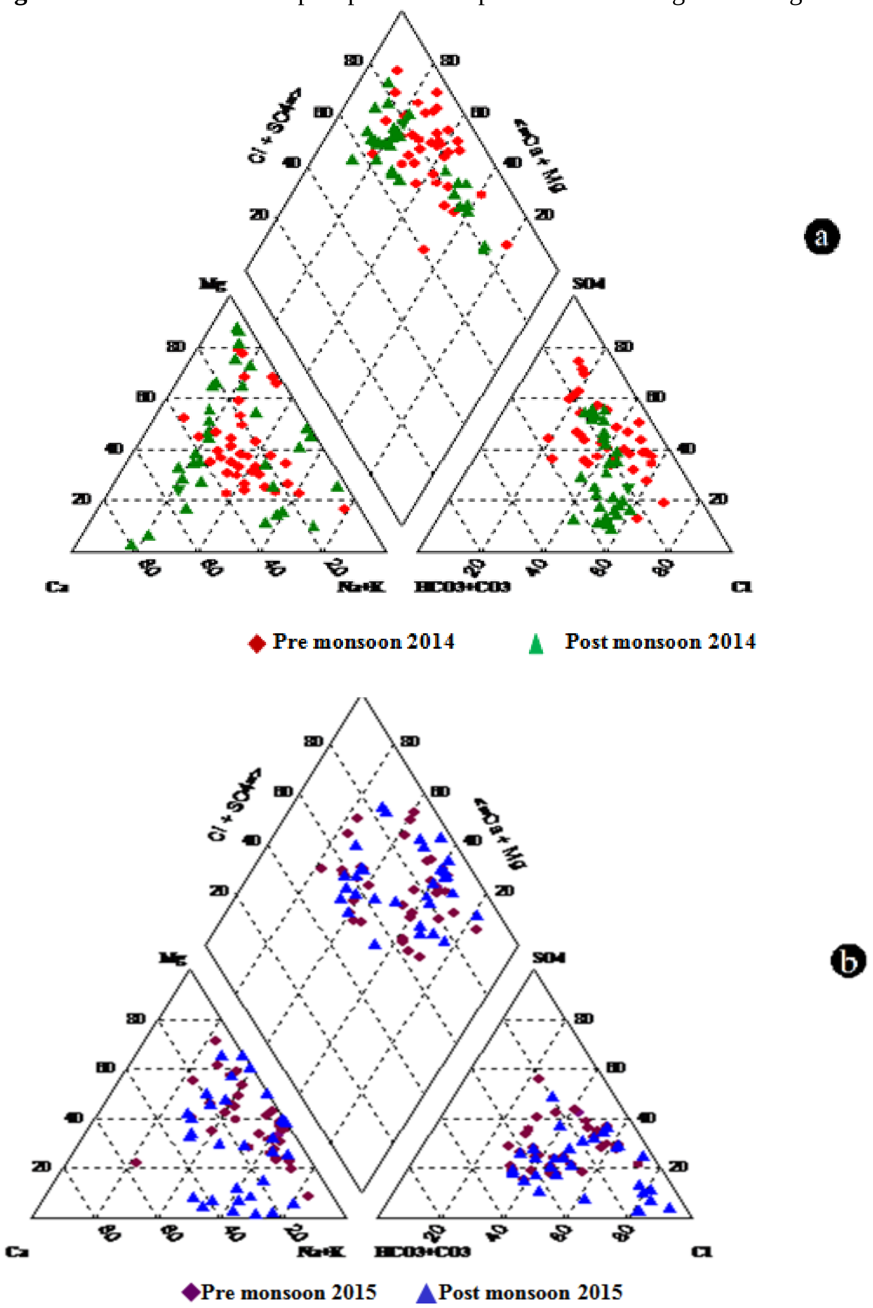


Table 2: Characterization of groundwater of Balatira watershed on the basis of Piper Tri-linear diagram

Sub-division of the diamond	Characteristics of corresponding subdivisions of diamond shaped fields	Percentage of samples in this category in seasons			
		2014		2015	
		Pre-monsoon	Post-monsoon	Pre-monsoon	Post-monsoon
1.	Alkaline Earths (Ca+Mg) exceeds alkalies (Na+K)	83	77	50	50
2.	Alkalies exceeds alkaline earths	17	23	50	50
3.	Weak acids (CO3+HCO3) exceed strong acids (SO4+Cl)	-	-	-	-
4.	Strong acids exceed weak acids	100	100	100	100
5.	Carbonate hardness (secondary alkalinity) exceeds 50% i.e. chemical properties are dominated by alkaline earths and weak acids.	-	-	-	-
6.	Non-carbonate hardness (secondary salinity) exceeds 50% i.e. chemical properties are dominated by alkaline earths and strong acids.	60	60	9	6
7.	Non-carbonate alkali (primary salinity) exceeds 50% i.e. chemical properties are dominated by alkalies and strong acids.	14	23	21	57
8.	Carbonate alkali (primary alkalinity) exceeds 50% i.e. chemical properties are dominated by alkalies and weak acids.	-	-	-	-
9.	Mixed type (No cation-anion exceed 50%)	26	17	31	37
10.	Calcium Magnesium chloride type	60	60	9	6
11.	Sodium chloride type	14	23	60	57

Chadha's diagram: The lithology, environment and movement of water control the type and concentration of salts in natural waters (Gopinath and Seralthan 2006). Hence, a hydrochemical diagram proposed by Chadha (1999) was also applied to identify different hydrochemical processes. In this diagram, the difference in milliequivalent percentages between alkaline earths (Ca + Mg) and alkali metals(Na + K) expressed as percentage reacting values, is plotted on the X axis and the difference in milliequivalent percentage between weak acidic anions (HCO_3) and strong acidic anions ($Cl + SO_4$) is plotted on the Y axis. Chadha (1999) suggested the hydrochemical processes in each of the four quadrants of the graph by differences between alkaline earth and alkali metals and between weak and strong acidic anions. These are broadly brief as reverse ion exchange water (Ca–Mg–Cl type), recharging water (Ca–Mg–HCO_3-type), seawater/end-member waters (NaCl type), and base ion exchange water (Na–HCO_3 type). Recharging waters are formed when water enters into the ground from the surface, it carries dissolved carbonate in the form of HCO_3 and the geochemically mobile Ca. Reverse ion exchange waters are less easily defined and less common, but represent groundwater where Ca + Mg is in excess to Na + K either due to the preferential release of Ca and Mg from mineral weathering of exposed bedrock or possibly reverse base cation exchange reactions of Ca +Mg into solution and subsequent adsorption of Na on to mineral surfaces. Seawater types are mostly confined to the coastal areas as they show typical seawater mixing.

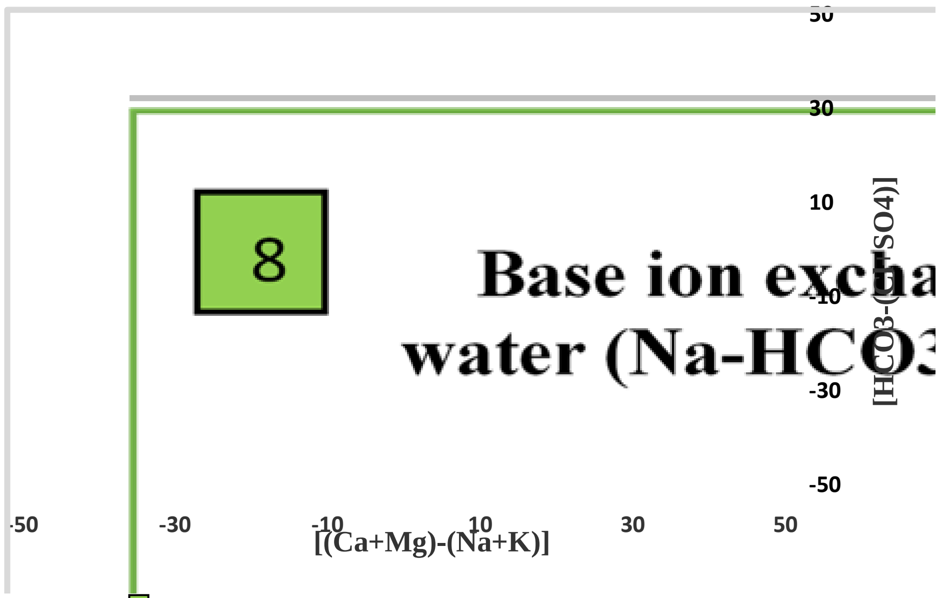
The positions of data points at field 6 (Ca–Mg–Cl type, Ca–Mg dominant Cl type or Cl dominant Ca–Mg type waters) exhibited in Fig.4 signifies the predominance of reverse ion exchange in majority of the samples of season 2014; such water will have a permanent hardness and does not deposit residual sodium carbonate in irrigation use and hence, foaming problem will not arise. In contrast, recharge characteristics were observed in samples falling in field 7 (seawater: Na–Cl type, Na dominant Cl type or Cl dominant Na type waters) indicating the typical salinity. While no representation of samples either in field 5 (recharging waters: Ca–Mg–HCO_3 type, Ca–Mg dominant HCO_3 type or HCO_3 dominant Ca–Mg type waters), having temporary hardness. or 8 (base ion exchange waters: Na–HCO_3 type, Na dominant HCO_3 type or HCO_3 dominant Na type waters), or base ion exchange processes (i.e., residual sodium carbonate disposition) in the study area.

The output of Chadha's plot (Fig. 4a & b) is in confirmation with that of Piper trilinear diagram (Fig. 3) in chemical analysis data of all the samples collected from the study area have been plotted on Chada's diagram (fig 4a & b). It is evident from the results, that during 2014 season 74% samples fall in group 6 (Ca-Mg – Cl type) and 25% samples fall in group 7 (Na- K- Cl type) in pre-monsoon and 77% samples fall in group 6 and 23% fall in group 7 in post-monsoon. In 2015, pre-monsoon 71% samples fall in group 7 (Na-Cl type) 23%

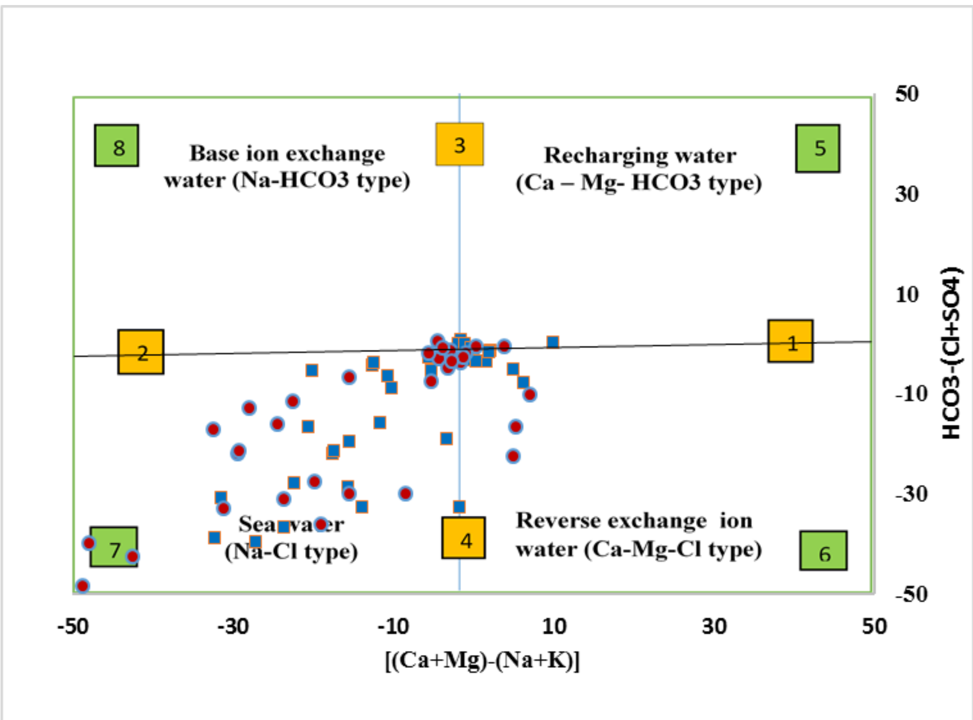
samples fall in group 6 (Ca – Mg – Cl type) and 6% in group 5 (Ca – Mg – HCO^3 type) and 68% samples fall in group 7, 17% fall in group 6, 6 % in group 5 and 9% in group 8 (Na – K - HCO^3 type) during post-monsoon.

6 Alkaline earths exceed alkali metals and strong acidic anions exceed weak acidic anions. Such water has permanent hardness and does not deposit RSC in irrigation use. The position of data points in the diagram represents Ca^{2+} -Mg^{2+}-Cl -type, Ca^{2+} -Mg^{2+}-dominant Cl^- -type or Cl^- -dominant Ca^{2+} -Mg^{2+}-type waters. 7 Alkali metals exceed alkaline earths and strong acidic anions exceed weak acidic anions. Such water generally creates salinity problems both in irrigation and drinking uses. The position of data points in the diagram represent Na^+ - Cl^- type and Na_2SO_4 - type, Na^+ -dominant Cl^- -type and Cl^- - dominant Na^+-type waters. The observation is that the most samples before the rainfall were in domain 7 and after the rainfall, switched towards domain 5 which suggests that there is a significant effect of monsoon on the hardness and salinity.

Figure 4: Chadha's diagram of groundwater samples of Balatira watershed during 2014 and 2015.



Pre-monsoon and Post-monsoon 2014



Pre-monsoon and Post-monsoon 2015

III. Conclusions

Groundwater is an important source of drinking water for many people around the world. Contamination of groundwater generally results in poor drinking water quality, loss of water supply, high cleanup costs, high-cost alternative water supplies and potential health problem. In the present study, interpretation of hydrochemical analysis reveals that the groundwater in area is hard to very hard. In the study area groundwater samples from 35 dug wells of 4 seasons (pre-monsoon 2014, post-monsoon 2014, pre-monsoon 2015 and post-monsoon 2015) were collected and analysed by using standard methods. The analytical results of physico-chemical parameters of groundwater were compared with the standard guideline values recommended by World Health Organization (W.H.O), 2004) for drinking purpose. Hydrochemically, the groundwater contains higher concentration of TDS, Alk, TH, Mg and Cl moderate concentration of Ca, SO4 and NO3 and lower concentration of Na, K and HCO3.

Hydrochemical facies of the groundwater consists of 3 hydrochemical facies, Ca^{2+}-Mg^{2+}-Cl^{-}-SO_4^{2-} type, Na^{+}- K^{+}-Cl^{--}-SO_4^{2-} type and Ca^{2+}-Cl^{-} -SO_4^{-} types. Assessment of groundwater quality from 35 well samples indicate that the groundwater belong to hard to very hard category and TDS of groundwater indicate that only 16% are permissible and majority of groundwater samples are unfit for drinking purposes. Chadha's diagram plot demonstrate the hydrochemical processes like recharging, reverse ion exchange, sea water mixing and base ion exchange chiefly acting in an aquifer. In the present study , piper diagram classified 60 % of the samples indicating the permanent hardness and remaining 40 % samples demonstrate temporary hardness. Chadha plot also demonstrated the dominance of reverse ion exchange water having permanent hardness (Ca-Mg- Cl type) in majority of the samples over recharging water with temporary hardness i.e Na-Cl type. It is therefore evident that primary salinity and secondary alkalinity.

The groundwater is laden with objectionable concentration of cations and anions which may possibly have been derived through combined sources viz., mineralization, chemical weathering of rock, and intense agricultural activities. This preliminary study needs continuous monitoring of the quality of the groundwater in the region as further exploitation of groundwater may increase the values of the some of the parameters viz., EC, TDS, Mg^{2+}, $NO^{3\ -}$ and Cl and deteriorate the water quality in near future which ultimately will prove to be disastrous for the entire living beings in the region.

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