Status of Geochemical behavior of ground water of Deep Aquifer in Muktainagar Area of Jalgaon District M.S. India

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***Abstract**:- Hydrochemical characteristics of deep ground water samples were estimated for drinking and irrigation purposes collected from Muktainagar area in Jalgaon District, Maharashtra. Water samples were collected from 20 deep aquifer twice a year for the study of pH, EC, TDS, total hardness, total alkalinity, calcium, magnesium, sodium, potassium, chloride, carbonate, bicarbonate, sulphate, phosphate and nitrate. General order of dominance of cations in the study area was found to be* $Na^+ > Mg^{++} > Ca^{++} > K^+$ *and* $HCO_3^- > Cl^- > SO_4^{2-} > NO_3^- > CO_3^{2-} > PO_4^{2-}$ *in pre monsoon whereas in post monsoon it varies as* $Na^+ > Ca^{++} > Mg^{++} > K^+$ *and* $HCO_3^- > Cl^- > SO_4^{2-} > NO_3^- > CO_3^{2-} > PO_4^{2-}$*. The nature of water in the study area is hard having high salinity with low alkalinity. Chloride, sulphate and calcium concentration were within permissible limits whereas magnesium was observed to be more in few aquifers. The RSC, Na%, Mg% and PI for major water samples show higher concentration for irrigation. On the basis of CAI1& II, 60% water samples in the study area shows negative cation anion exchange in post monsoon and 55% positive cation anion exchange is seen in pre monsoon. The present paper incorporates the detail study of ground water behaviour of deep aquifers in the study area.*

***Key words:** -* **Ground water, drinking water, irrigation water, salinity, Muktainagar, Jalgaon area, Maharashtra.**

1. Introduction

As population is growing at tremendous rate, demands related to all sectors of rural and urban is increasing. Major demand is for water. As water a significant role in an individual life, this increases the demand for water. If we study the role of rural life style, water plays a wide role not only in individual life but also in social affairs. In absence of adequate surface water resources, the next dependency source is ground water. The use of ground water is subjected for domestic, agricultural and industrial uses. The increasing demand has over exploited in many areas resulting in permanent depletion of the aquifer and associated environmental consequences such as water quality deterioration and land subsidence. Thus hydro geochemical study of ground water will throw light on the factors behind the matter (Awajiogak2013).

Presently the study area is tracing acute scarcity of ground water. As the demand of water resources is increasing day by day for the domestic and agricultural purposes (Tiwari M. Y. 2015). Therefore qualitative assessment of ground water is essential for every users now a days. Therefore an attempt has been made to assess the geochemical behavior of deep aquifer because water level is depleted day by day in the study area.

2. Description of the study area:-

The present study area is located towards the eastern part of Jalgaon city of Maharashtra State, India. It is located at 21°03’08”North latitude and 76°03’18”East longitude (fig 1). The area of Muktainagar Tehsil is of 63,392 hectares. The average annual rainfall is 750 mm/per annum. Rainfall of the study area is predominant in the monsoon season

from June to September. The study area consists of alluvial plain of Tapti valley associated with Purna River flowing from north to south. The climate of the study area is characterized by hot summer and dry throughout the year. The mean minimum and maximum temperature lies between 10.8°C and 42.2°C.
The area under study is located in Deccan volcanic province. Most of the area lays in the Deccan basaltic flows which are observed in the area under investigation. Tapti-purna alluvial is also observed in northern and south eastern part of the area.

3. Materials and Methods:-

Field sampling was done in the May 2012(pre monsoon) and during Nov 2012(post monsoon). In each season a total 20 samples from deep aquifer was collected throughout the Muktainagar area Jalgaon district (Fig 1). The water samples were collected in precleaned polyethylene one litre bottles. Before the bottles were subjected for sampling, all the water quality measures were used such as it was cleaned with solution of chromic acid and rinsed with distilled water. All the bottles were rinsed thrice before subjected for the collection of water. After collection each bottle was labeled, sealed and transported to the laboratory for further hydro chemical analysis. The analytical procedure and techniques followed by APHA (1995).
Estimation of pH, EC and TDS were measured digitally. The sodium and potassium were determined by using Flame photometer and titration methods was used for calcium, chloride, total alkalinity, carbonate, bicarbonate, total hardness while sulphate, phosphate, nitrate were analysis by Spectrophotometer. Further based on the physicochemical analysis, irrigation quality parameters like sodium absorption ratio (SAR), Kelley's ratio (KR), sodium percentage (Na %), residual sodium carbonate (RSC), Magnesium ratio (Mg %), chloro-alkaline indices (I &II) are formulated as:-

SAR: - [Na / {√ (Ca + Mg)/2}] (1)
RSC= [(CO_3+HCO_3) - (Ca+ Mg)] (2)
KR: - [Na / (Ca + Mg)] (3)
Na% = [(Na x 100) / (Ca +Mg)] (4)
MR = [(Mg x 100)/ (Ca + Mg)] (5)
PI = [(Na + √ HCO_3)/ (Ca + Mg + Na)] X100 (6)
CAI –I = [{Cl- (Na + K)}/ Cl] (7)
CAI-II=[Cl–(Na+K)]/[SO_4^{2-}+HCO_3^-+CO_3^{2-}+NO_3^-] (8) *Where all the ionic concentrations are expressed in meq/l).*

4. Results and Discussions:-

4.1 Drinking water quality parameters:-
Different chemical and biological parameters specify the quality status of water. In present study area the different parameters were studied, analyzed (in table 1) and compared with guidelines suggested by Bureau of Indian standard (BIS, 2012) and World Health Organization (WHO 1993) in table 2 showing the percentage of water samples exceeding the permissible limit. Ground water is slightly alkaline in nature ranging 7 to 8.1 and 7 to 8.2 in pre monsoon and post monsoon respectively. All the samples are within the permissible limits in both the season.

Electrical conductivity value indicates the presence of dissolved salts in water. In the present study area, EC ranges from 500-3120 µs/cm and 480 -2440 µs/cm during pre monsoon and post monsoon respectively. 18% in pre monsoon and 14% in post monsoon were above the permissible limits. Total dissolved salts ranges from 325 – 2244 ppm and 240 – 1424 ppm in pre monsoon and post monsoon respectively. For total hardness ranges from 81-2211ppm and 21% samples are found above the permissible limit in pre monsoon And in post monsoon it ranges from152 -972 ppm with 8% across the permissible limit. The elevated values of EC, TDS, TH and TA during pre monsoon may be due to evaporation process occurring in summer season.

Calcium found within the permissible limit ranges from 10.4- 84.8 ppm in pre monsoon and only 2% above the limit ranging as20.8 -273.3 ppm. Magnesium found 1.2 – 194.6ppm with 2% above the limit range in pre monsoon and in post monsoon it is 3.9 -117.6 ppm with 2% above permissible limit. Sodium concentration shows 6% and 4% above the permissible limit in pre monsoon and post monsoon respectively. Nitrate is found 70% above the permissible limit in both the season.

The abundance of cations and anions ions are presented as (fig 1) $Na^+ > Mg^{++} > Ca^{++} > K^+$ and $HCO_3^- > Cl^- > SO_4^{2-} > NO_3^- > CO_3^{2-} > PO_4^{2-}$ in pre monsoon whereas in post monsoon it varies as $Na^+ > Ca^{++} > Mg^{++} > K^+$ and $HCO_3^- > Cl^- > SO_4^{2-} > NO_3^- > CO_3^{2-} > PO_4^{2-}$.
Among cation concentration, sodium is more in both the season. Sodium contribution may be due to weathering of alkali feldspars in rocks or dissolution of clay or by agricultural sources (K. Srinivasamoorthy et.al 2014). Then magnesium is next in pre monsoon and in post monsoon calcium is next and the least is potassium in both the season. During infiltration or along the flow, the

tendency to dissolve $CaCO_3$ and CaMg $(CO_3)_2$ ions present in rocks increases the concentration of calcium and magnesium in the ground water. The prolonged agricultural activities may also directly or indirectly influence mineral dissolution in ground water (Bohike, 2002 and K. Srinivasamoorthy et.al 2014).

Among anion the bicarbonate concentration is abundance followed by chloride, sulphate, nitrate, carbonate and phosphate in both the season. Higher value of bicarbonate may be due to oxidation of carbon and other organic waste in the water surface and would have percolated from the surface to the plant root by biological activities (S.Chitradevi et.al. 2011 and S. Venkateswaran 2013). Chloride content is found higher than other anions may be due to erosion and weathering of crystalline rocks (R. Rajesh et.al 2015).

4.2 Irrigation water quality:-

Salinity hazard: -

Salinity is referred as the total amount of dissolved inorganic solid material, whereas salinization is due to increased TDS values along with chemical contents present in the water. Presence of excessive chemical ions such as sodium, bicarbonate present in water used for irrigation may affect the soil fertility and crop productivity (R. Rajesh et al.2015). Electrical Conductivity plays an important role for water quality used for irrigation. Based on classification done by Wilcox 1955, 90% in pre monsoon and 80% in post monsoon were found safe for irrigation purpose while the remaining 10% and 20% were not considered safe only with permeable soil having moderate leaching (Tables 4).

Sodium Hazard:- SAR values play an important role in irrigation. There is a close relationship between SAR and irrigation water, the extent of Na^+ ions present in water. If water contains high Na^+ and low in Ca^{2+} the ion-exchange complex may become saturated with Na^+ which destroys the soil structure, due to the dispersion of the clay particles (Todd, 1980) and reduces the plant growth (Subra Rao, 2006,Tiwari M.Y.2015). Excess salinity also reduces the osmotic activity of plants (Subramani et al., 2005). Higher cumulative concentration of HCO_3^- and CO_3^{2-} than Ca^{2+} and Mg^{2+} concentration is an indication that residual carbonate will react with sodium, thereby resulting into sodium hazard (Wadie and Abduljalil, 2010). SAR values were found excellent to good condition but 5% was found condition need to be treated in post monsoon. The Na% present in irrigated water is found unsuitable 45% and 35% and 5% and 15% counted as doubtful in pre monsoon and post monsoon respectively. So treated water of such stations should be used for irrigation.

Bicarbonate Hazard: -

Bicarbonate Hazard is expressed in terms of Residual Sodium Carbonate (RSC). RSC values more than 2.5 meq/l are not suitable for irrigation, while those are in between of 1.25 to 2.50meq/l are doubtful and less than 1.25 are good for irrigation. Based on such classification 20 % samples are in good condition in both season. There is a tendency among calcium and magnesium to precipitate out from water leaving higher concentration of bicarbonate and thus the relative concentration of sodium bicarbonate increases (Sadashivaiah et.al 2008). Infertile land can also contribute in high deposition of sodium in water resulted from high concentration of bicarbonates (Eaton, 1950). 65% and 60% are unsuitable for irrigation as they have values more than 2.5meq/l in pre monsoon and post monsoon. Continuous usage of waters with greater RSC value than 1may leads to salt build up in the soil which may hinder the air and water movement by clogging the soil pores and lead to degradation of the physical condition of soil.

Negative RSC values as shown in some samples (Table 3) indicate that sodium build up are less since excess amount of calcium and magnesium are precipitated out leaving free carbonates in the locations of those samples. (Yinusa A. et.al 2013).

Magnesium Hazard:-

Magnesium hazard is counted as magnesium percentage or magnesium adsorption ratio. Magnesium percentage present in water is one of the most important qualitative criteria used for determining the quality of water for irrigation. Generally calcium and magnesium maintain an equilibrium state in most waters but higher magnesium content adversely affect crop yield as the soil becomes saline. (Joshi et.al 2009). 25% and 40% samples were found under safe zone as their MR values were less than 50 in pre monsoon and post monsoon respectively. But 75% and 60% were not safe to be used for irrigation as the values were more than 50 in pre monsoon and post monsoon season respectively.

Kelley's Ratio:-

Kelley 's ratio is counted as the level of Na^+ measured against Ca^{2+} and Mg^{2+}, and it is used to rate irrigation waters (Kelley, 1940; Paliwal, 1967). 60% and 70%

samples of pre monsoon and post monsoon were found suitable for irrigation but 40% and 30% were found unsuitable for irrigation as they have values more than 1.

Permeability Hazard:-

Permeability index (PI) is used to assess probable influence of water quality affecting the physical properties of soils (Doneen, 1966). The soil permeability is affected by long-term use of irrigation water containing higher sodium, calcium, and magnesium and bicarbonate contents in the soil (Vasanthavigar et al., 2010). According to Nagaraju et al (2006), waters can be classified into I, II and III categories based on their PI values. Class I waters are categorized as excellent for irrigation with 75% or more maximum permeability. Class II waters are categorized as good and Class III waters are unsuitable with less than 25% permeability. All the results of PI indicate that groundwater in the study area fall within class I and class II (Doneen, 1966) which make the water suitable for irrigation purposes. Only one sample of post monsoon season fall under class III, unfit for irrigation.

Indices of Base Exchange:-

The Chloro-alkaline indices (CAI) indicate the ion-exchange between the groundwater and its host environment along with the flow path. Schoeller (1965, 1977) suggested two Chloro-Alkaline Indices CAI 1, 2 for the interpretation of ion exchange between groundwater and host environment (formula7 &8). Ion-exchange is said to be direct when the indices of exchange between Na/K in groundwater and Mg/Ca in host rock are positive. The exchange is considered as indirect when indices are negative. 55% in pre monsoon and 40% in post monsoon of the samples gave positive Chloro-Alkaline index ratios, reflecting dominance of direct ion-exchange of Na/K in the water with Mg/Ca in the host rock (Tiwari M.Y.2015). The remaining 45% in pre monsoon and 60% in post monsoon of the samples gave negative ratios. Thus direct ion exchange is seen in pre monsoon and indirect exchange is seen in post monsoon at maximum sample stations.

5. Conclusion: -

From the foregoing discussion, the area is facing scarcity of ground water resources. Ground water is being utilized for domestic and agricultural purposes. The comparative status of BIS and WHO is clearly reflects the salts concentrations are dominantly in deep aquifers due to the existing basaltic nature and tapti-purna alluvial in the area. The concentration of magnesium and bicarbonate were found above the permissible limit in 10% deep aquifers. Whereas 70% deep aquifers showed more nitrate content than permissible limit. Major samples showed high RSC, KR, Mg% and Na% which is very harmful for agriculture. CAI-I &II showed negative ion exchange process in post monsoon and positive exchange was seen in pre monsoon.

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Table 1: Statistical summary of physicochemical parameters of deep aquifer samples from Muktainagar area.

	Pre monsoon 2012					Post monsoon 2012				
N=20	Max.	Min.	Avg.	Std. Dev.	Median	Max.	Min.	Avg.	Std. Dev.	Median
pH	8.1	7.0	7.4	0.3	7.4	8.2	7.0	7.5	0.4	7.4
EC	3120.0	500.0	1409.6	717.7	1300.0	2440.0	480.0	1315.9	596.3	1260.5
TDS	2244.0	325.0	974.2	513.0	907.0	1424.0	240.0	808.1	336.0	798.0
Turbidity	4.1	0.1	0.8	1.0	0.3	3.7	0.2	1.1	1.1	0.6
TH	2211.2	81.0	774.8	610.2	683.1	972.2	152.0	386.6	225.7	298.0
TA	1208.0	22.0	364.9	274.1	320.0	1087.8	37.8	375.9	256.4	353.5
Ca^{2+}	84.8	10.4	29.9	17.8	25.2	273.3	20.8	80.5	57.8	70.5
Mg^{2+}	194.6	1.2	40.6	44.9	29.9	117.6	3.9	45.7	29.6	46.6
Na^{+}	378.0	19.6	101.7	91.4	85.0	417.2	31.0	119.1	93.8	92.8
K^{+}	2.7	0.0	1.0	0.7	0.9	3.4	0.0	1.2	0.7	1.2
Cl^{-}	483.6	20.6	157.6	146.1	118.2	349.0	20.0	161.5	105.4	139.0
SO_4^{2-}	88.3	5.0	46.3	27.5	41.6	146.3	4.4	60.6	40.1	50.0
CO_3^{2-}	92.4	0.0	27.0	25.2	16.3	156.2	0.0	39.7	45.1	18.5
HCO_3^{-}	1194.0	56.0	354.3	255.5	370.0	1065.7	42.1	417.5	265.3	452.4
NO_3^{2-}	98.2	17.1	39.5	20.6	32.4	105.5	18.4	42.5	22.1	34.8
PO_4^{2-}	4.8	0.0	1.0	1.4	0.5	5.7	0.0	1.3	1.4	1.1

Note: - All the parameters are expressed in ppm. Except EC in $\mu s/cm$ and pH. Here N= number of ground water samples.

Table 2:- Physicochemical parameters showing the % of samples exceed the permissible limit as per BIS and WHO standards.

N=20	BIS	Pre monsoon 2012 (% of samples exceeding limit)	Post monsoon 2012 (% of samples exceeding limit)	WHO	Pre monsoon 2012 (% of samples exceeding limit)	Post monsoon 2012 (% of samples exceeding limit)
pH	6.5 – 8.5	WPL	WPL	7 -9.2	WPL	WPL
EC	1400	18	14	1500	18	9
TDS	500-2000	2	WPL	500-1500	6	WPL
TH	300-600	21	8	100-500	23	10
TA	200-600	4	4	--	--	--
Ca^{2+}	75-200	WPL	2	75 -200	WPL	2
Mg^{2+}	30-100	2	2	30-150	2	WPL
Na^{+}	-	--	--	50-200	6	4
K^{+}	10	WPL	WPL	10-12	WPL	WPL
Cl^{-}	250-1000	WPL	WPL	250-600	WPL	WPL
SO_4^{2-}	200-400	WPL	WPL	200 -600	WPL	WPL
HCO_3^{-}	-	--	--	300-600	2	2
NO_3^{2-}	45	14	14	50-100	WPL	2

Note: - WPL stands for within permissible limits.

Table 3:-Statistical summary of agricultural data collected from deep aquifer of Muktainagar area.

	Pre monsoon 2012					Post monsoon 2012				
	Max.	Min.	Avg.	STDEV	Median	Max.	Min.	Avg.	STDEV	Median
SAR	17.7	1.8	5.9	3.9	4.6	21.4	2.9	7.2	4.5	5.8
RSC	21.3	0.1	5.4	5.0	4.2	16.7	-8.9	3.6	5.3	3.0
KR	5.7	0.1	1.6	1.8	0.6	4.3	0.1	1.0	1.1	0.6
Na%	569.0	12.7	163.3	178.7	61.6	432.8	14.2	99.7	114.6	59.9
Mg%	92.4	7.4	57.9	27.0	68.7	74.9	7.4	47.4	21.2	53.3
PI	123.8	35.6	76.4	24.3	82.4	107.1	16.9	61.0	22.3	62.6
CAI I	0.7	-3.1	-0.5	1.3	0.0	0.7	-4.7	-0.8	1.7	0.0
CAI2	2.6	-1.0	0.2	0.7	0.0	1.8	-0.7	0.1	0.5	0.0

Table 4:- Classification of water based on irrigation strategy of deep aquifer of Muktainagar area.

Classification	Category	Ranges	No of samples		% of the sample	
			Pre monsoon 2012	Post monsoon 2012	Pre monsoon 2012	Post monsoon 2012
Electrical conductivity (EC) (Wilcox 1955)	Excellent	<250	00	00	--	--
	Good	250 -750	05	03	25	15
	Permissible	750 -2250	13	13	65	65
	Doubtful	2250 -4000	02	04	10	20
	unsuitable	>4000	00	00	--	--
Sodium absorption Ratio (SAR) (Richard 1954)	Excellent	<10	16	17	80	85
	Good	10 -18	04	02	20	10
	Fair	18 -26	00	01	--	5
	Poor	>26	00	00	--	--
Residual sodium carbonate (Richard 1954)	Suitable	<1.25	04	04	20	20
	marginal	1.25 – 2.50	03	04	15	20
	unsuitable	>2.50	13	12	65	60
Kelley's Ratio (Kelley 1940)	suitable	<1	12	14	60	70
	unsuitable	>1	08	06	40	30
Sodium % (Na%) (Doneen 1962)	Excellent	0 - 20	02	03	10	15
	Good	20 – 40	03	04	15	20
	Permissible	40 – 60	05	03	25	15
	Doubtful	60 – 80	01	03	5	15
	unsuitable	>80	09	07	45	35
Magnesium % (Pandian & Sankar 2007)	suitable	<50	05	08	25	40
	unsuitable	>50	15	12	75	60
Permeability Index (Doneen 1964)	Class I	>75	11	05	55	25
	Class II	25 - 75	09	14	45	70
	Class III	<25	00	01	--	5
Chloro- Alkaline Indices (CAI) (Schoeller 1967)	Base Exchange Reactions	Negative value	09	12	45	60
	Cation –Anion Reactions	Positive value	11	08	55	40

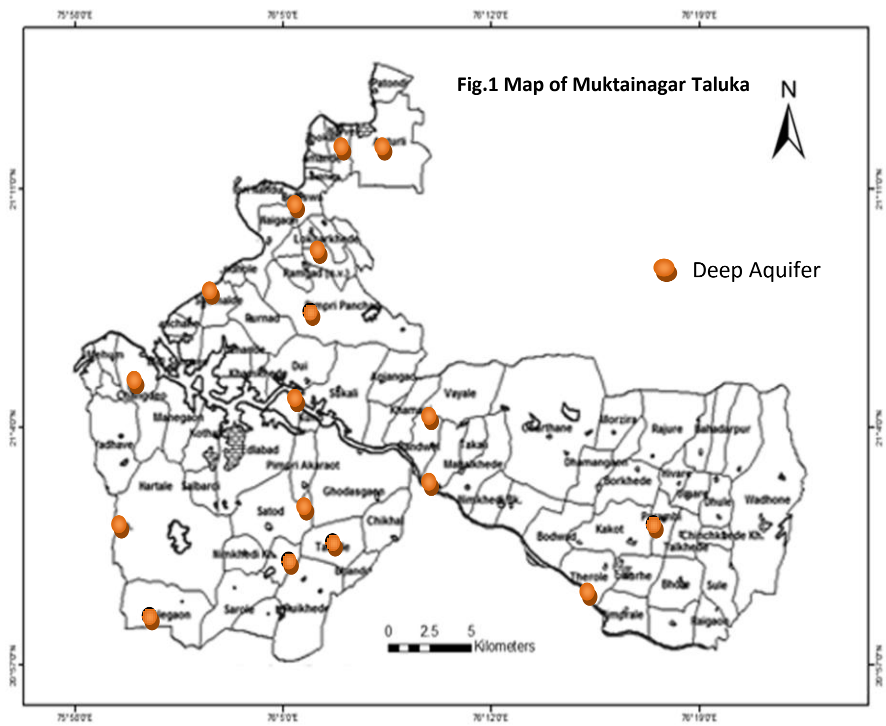
Fig.1 Map of Muktainagar Taluka
N
Deep Aquifer
0 2.5 5
Kilometers

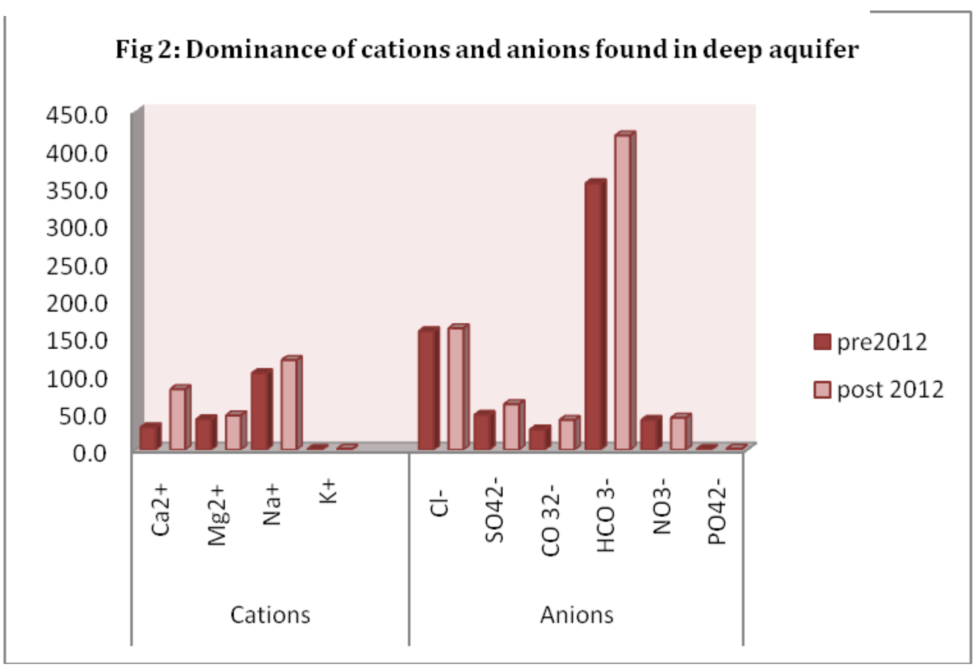
Fig 2: Dominance of cations and anions found in deep aquifer
450.0
400.0
350.0
300.0
250.0
200.0
150.0
100.0
50.0
0.0
pre2012
post 2012
Ca2+
Mg2+
Na+
K+
Cl-
SO42-
CO 32-
HCO 3-
NO3-
PO42-
Cations
Anions