Geochemical Modeling to evaluate the Groundwater Quality of Chaka, Karchana and Kaundhiyara Blocks of Allahabad District

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***Abstract*: Water is the vital commodity for all living creatures and required for well-being of the human society. The Experiment is based on the Physico-chemical parameters and Geo-chemical analyses of minerals in the groundwater of Chaka, Karchana and Kaundhiyara blocks of Allahabad in order to understand the sources and evolution of the water quality in the region. The aim of the research was to determine the genetic origin of groundwater.**

Geochemical modeling especially computation of saturation index was undertaken using the WATEQ4F model. The dominant minerals which include Aragonite, Calcite, Dolomite (d), Dolomite (c), Magnesite are fall in the category of supersaturation state indicated that groundwater doesn't have more potential to dissolve these minerals . Rest of the minerals like Anhydrite, Brucite, Epsomite and Gypsum fall in the category of undersaturation, which further indicated that groundwater still has potential to dissolve more minerals.

***Keywords*: Groundwater, WATEQ4F model, Saturation Index, Physico-chemical parameters.**

INTRODUCTION

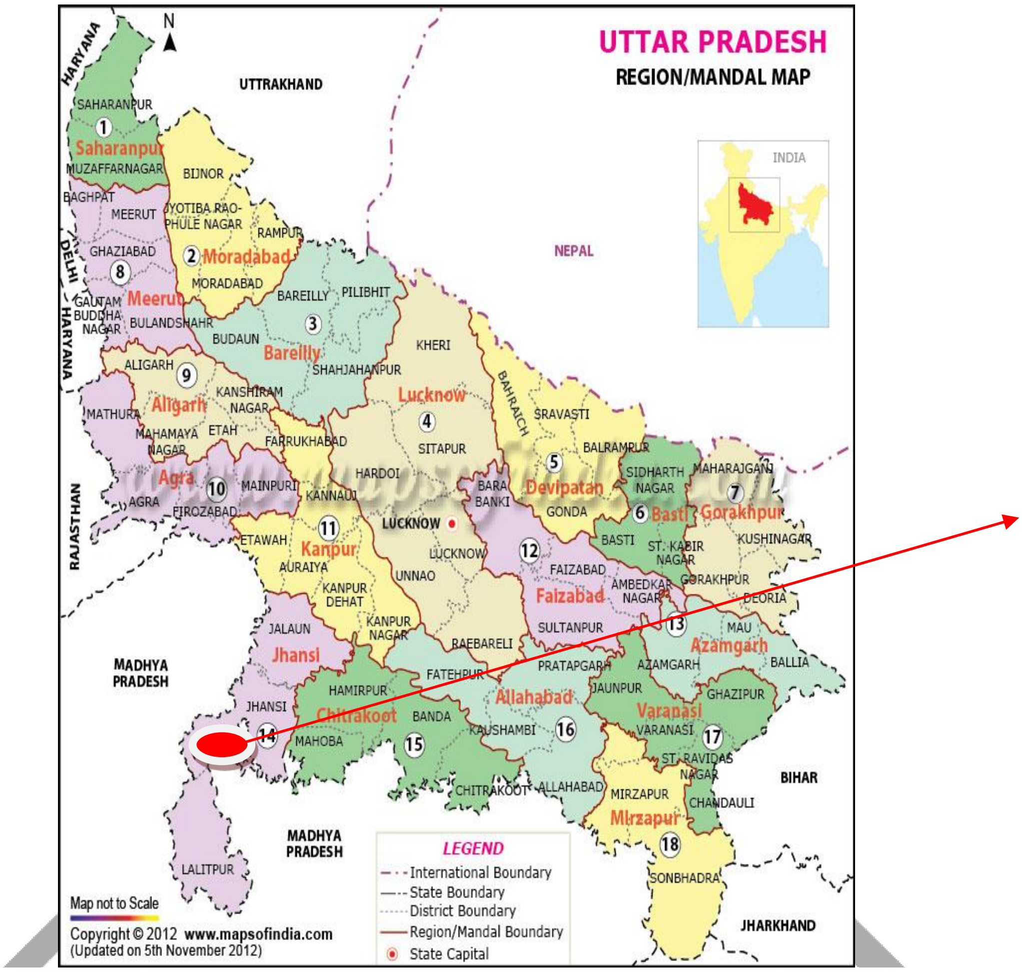
Water is the nature's most essential, abundant and useful compound to the existence of all living beings **(Ganeshbabu *et al.* 2016).** It is essential for the growth and maintenance of our bodies, as it is involved in a number of biological processes. Water constitutes about 70% of the body weight of almost all living organism **(Goel, 2000).** Life is not possible on this planet without water. It acts as a media for both chemical and biochemical reactions and also as internal and external medium for several organisms.

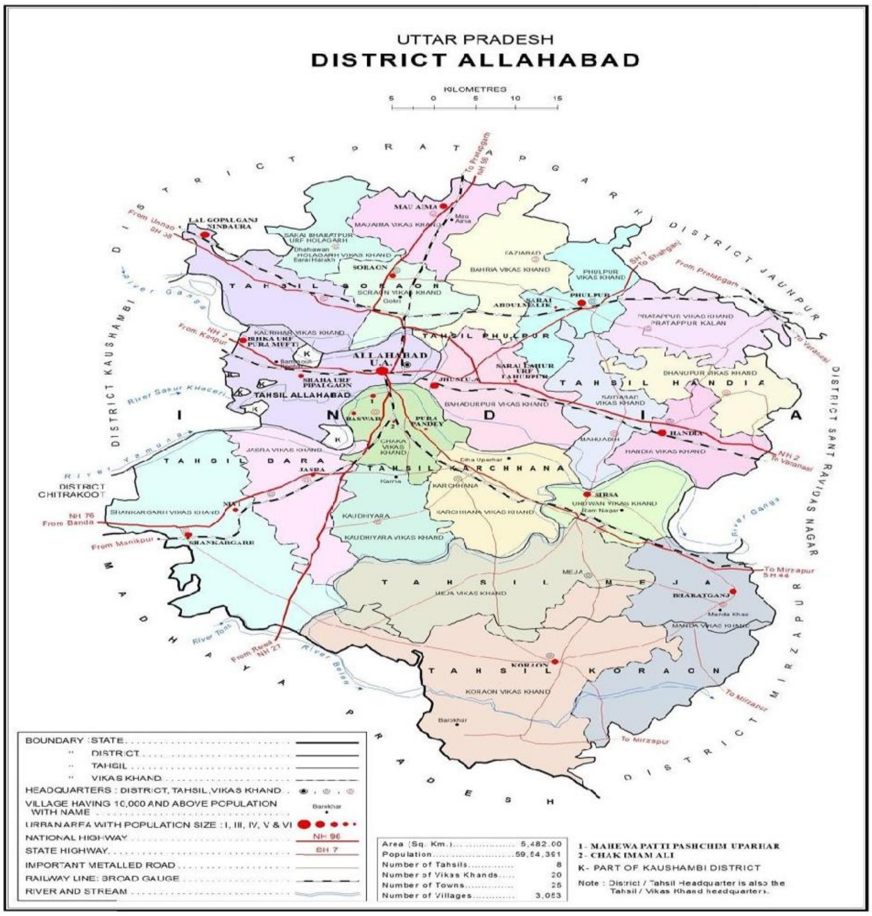
In the present scenarios, many countries are facing the problem of water scarcity; even the good quality of drinking water is not available for the human society. This situation is wide spreading day by day specially in most of the developing countries such as a country like India where majority of population depends on the availability of ground Water **(Srivastava *et al.* 2012b).** Water pollution in developing countries increases after industrialization, unprecedented population growth, and urbanization after the globalization era, i.e., 1990 onwards **(Singh *et al.*2013a).** Hence, monitoring and groundwater resources are very much required for sustainable environment and to fulfill the freshwater demand.

Over the past few decades many hydro-geochemical models have been developed to investigate the surface/ groundwater chemistry **(Srivastava *et al.* 2012a).** The presence of different types of elements in groundwater can be attributed to the interaction between the rock types and flowing water **(Sharif *et al.* 2008; Srivastava *et al.* 2012d).** Many hydro-geochemical processes, including dissolution, precipitation, ion exchange, sorption, desorption and advection are responsible for regulating the chemical composition of the groundwater which can be modelled, to some extent, by hydro-geochemical models such as WATEQ4F **(Singh *et al.*2012).** Therefore, in this study the WATEQ4F model, developed by Ball & Nordstrom (1991), is used to predict the saturation indices of the minerals. Hence, to prevent the contamination from reaching an unacceptable limit, preventive measures are necessary. This research aims to determine the origin of the chemical elements whose concentration in the groundwater is responsible for groundwater chemistry.

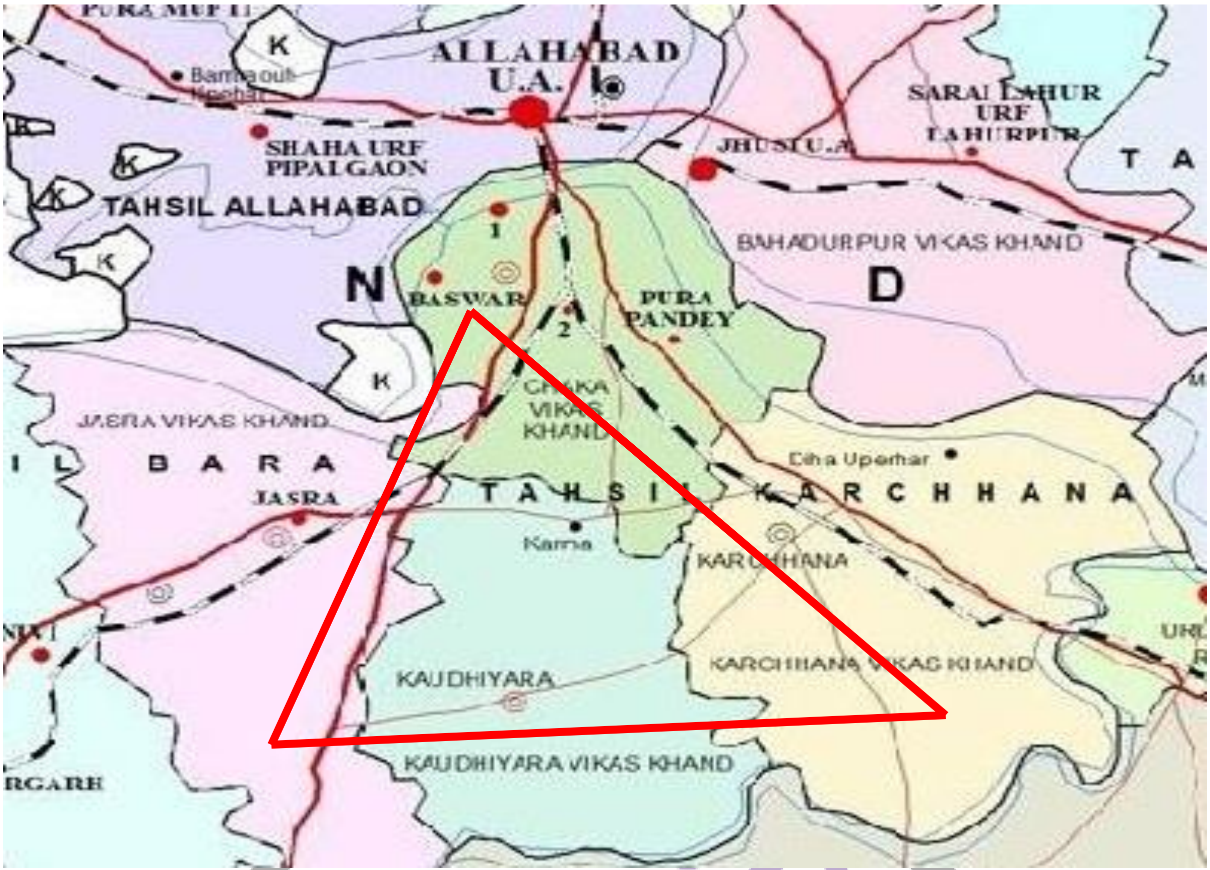
MATERIALS AND METHODS

The experiment was conducted at the Department of Environmental Sciences and Natural Resource management, College of Forestry, Sam Higginbottom University of Agriculture, Technology and Sciences, Allahabad to ascertain the ground water quality of three block of Allahabad District. The samples were collected from Chaka 25°21'56"-25°24'12"N Latitude and 81°51'10"-81°53'90"E Longitude, Karchhana 25°11'24"-25°17'34"N Latitude to 81'48'31" - 81°59'00"E Longitude and Kaundhiyara Block 25°10'22"-25°28'04"N Latitude, 81°48'31"- 81°83'55"E Longitude.





Map of the selected area of experiment



Map of Selected area of Experiment.

Collection of Sample and Analysis

Water samples were drawn from hand pump of mentioned blocks during January to March 2018 in clean bottles without air bubbles. The sample bottles were rinsed thoroughly with sample water, sealed tightly and labeled in the field after collection. The hand pumps were continuously pumped prior to avoid contamination from the surface. The depth of hand pump was 140-150 feet deep in these blocks. The samples were collected as per the standard methods of water examination, **APHA (1998).** The 90 samples were collected from 10 sites of each block in triplicates systematically and analyzed for ten parameters pH, EC, Total dissolved solid, Calcium Hardness, Magnesium Hardness, Total Hardness, Alkalinity, Chloride, Sulphate and Nitrate as per standards laid by APH/AWWA **(Keith, 1996).**

WATEQ4F Model Description

WATEQ4F is a geochemical model, which computes the major and trace elements speciation and mineral saturation for natural water. It models the thermodynamic speciation of major and important minor inorganic ions and complex species in given water samples and in situ measurements of temperature, pH, and redox potential. From this model, the states of reaction of the water with solid and gaseous phases are calculated. The saturation index (SI) of a mineral is obtained from Equation (1) (**Appelo & Postma 2005).**

$$SI = \log (IAP/Kt) \ldots\ldots\ldots\ldots\ldots (1)$$

Where, IAP and Kt is the ion activity product and the solubility product (tabulated in the WATEQ4F database for a wide variety of mineral phases; **Ball et al. 1991).**

When SI is below zero, the water is undersaturated with respect to the mineral in question. When SI is zero means water is in equilibrium with the mineral, where as when SI greater than zero means a supersaturated solution with respect to the mineral in question.

RESULTS AND DISCUSSION

The results on Physico-chemical parameters pH, EC, Total Dissolved Solid, Calcium Hardness, Magnesium Hardness, Total Hardness, Alkalinity, Chloride, Sulphate and Nitrate are present in table 4.10. The genetic origin of ground water sample was analyzed by computing the readings of Physico- chemical parameters in WATEQ4F model. The main objective to use WATEQ4F model is to calculate saturation indices.

The saturation state of minerals in the groundwater can be expressed by the saturation index (SI). The saturation index (SI) is vital to envisage the subsurface mineralogy from groundwater data without collecting the samples of the solid phase and analyzing the mineralogy (Deutsch 1997).

The results of the experiment on Saturation Indices of different minerals found in Chaka, Karchana and Kaundhiyara block during experiment are presented in table 4.11 and figure 4.11, 4.12 and 4.13.

Anhydrite ($CaSO_4$), Aragonite ($CaCO_3$), Brucite (Mg $(OH)_2$), Calcite ($CaCO_3$), Dolomite(d) ($MgCa(CO_3)_2$), Dolomite(c) ($MgCa(CO_3)_2$), Epsomite ($MgSO_4 \cdot 7H2O$), Gypsum ($CaSO_4 \cdot 2H2O$) and Magnesite ($MgCO_3$) all these minerals were present in each selected site of the blocks.

The minerals such as Anhydrite($CaSO_4$), Brucite (Mg $(OH)_2$), Epsomite ($MgSO_4 \cdot 7H2O$)and Gypsum ($CaSO_4 \cdot 2H2O$) shows the value of Saturation Index less than zero in all locations of Chaka, Karchana and Kaundhiyara block during Experiment. The result showed that water is under saturated with respect to the mineral, and the mineral would tend to be dissolved by the water.

The mineral Aragonite ($CaCO_3$), Calcite ($CaCO_3$), Dolomite (d) ($MgCa(CO_3)_2$), Dolomite(c) ($MgCa(CO_3)_2$) and Magnesite ($MgCO_3$) shows the value of saturation Index greater than Zero in all locations of Chaka, Karchana and Kaundhiyara block during Experiment. The result showed that water is supersaturated with these minerals, and the minerals would tend to precipitate.

Conclusion

The chemical composition of groundwater sources of Chaka, Karchana and Kaundhiyara block are strongly influenced by minerals like Anhydrite, Aragonite, Brucite, Calcite, Dolomite(d), Dolomite(c), Epsomite, Gypsum and Magnesite.

The minerals like Anhydrite, Brucite, Epsomite and Gypsum are in found in understaturated state and the minerals like Aragonite, Calcite, Dolomite (d), Dolomite (c) and Magnesite are in superstaturated state.

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Table.4.10: Physico-Chemical Parameters of Water Samples of Chaka, Karchana and Kaundhiyara Blocks.

PARAMETERS										
Sites	**pH**	**EC**	**TDS**	**Ca Hardness**	**Mg Hardness**	**Total Hardness**	**Alkalinity**	**Chloride**	**Sulphate**	**Nitrate**
C 1	8.13	0.7	370	254	354	608	380	110	501	8.2
C 2	8.05	0.6	324	182	416	599	355	75	469	9.63
C 3	8.01	0.4	301	171	377	548	375	104	945	9.17
C 4	7.95	0.9	440	220	415	635	435	105	703	8.92
C 5	7.92	0.7	416	198	365	563	503	105	817	6.09
C 6	8.11	0.4	235	171	362	534	373	65	753	9.41
C 7	7.89	0.5	292	151	505	657	361	89	612	8.78
C 8	8.33	0.6	311	102	544	646	498	160	764	8.12
C 9	8.06	0.8	436	172	632	804	511	105	456	8.83
C 10	8.02	0.6	351	114	496	611	530	95	755	6.74
K 1	8.52	0.4	235	156	392	548	355	45	383	9.9
K 2	7.96	0.4	246	129	400	529	356	35	421	8.45
K 3	8.05	0.6	372	205	398	603	455	110	315	7.43
K 4	8.03	0.5	307	210	383	593	445	60	419	8.52
K 5	7.85	0.7	371	210	346	556	481	114	664	6.66
K 6	8.25	0.5	284	192	339	532	408	140	765	8.95
K 7	7.96	0.8	431	232	357	589	448	115	687	8.15
K 8	8.02	0.6	319	194	369	563	380	100	708	8.82
K 9	7.82	0.7	365	198	376	575	413	104	648	9.38
K 10	7.85	0.6	332	203	352	556	420	80	601	6.49
KO 1	8.41	0.5	310	85	586	671	446	59	556	8.5
KO 2	8.37	0.7	397	96	542	638	461	110	713	10.67
KO 3	8.16	0.9	602	95	551	647	450	285	942	8.04
KO 4	7.98	0.8	752	72	506	579	643	210	783	8.63
KO 5	8.43	0.6	376	81	428	510	408	110	495	9.49
KO 6	8.14	0.7	430	83	548	634	491	94	643	8.05
KO 7	8.21	0.9	494	116	584	701	473	165	731	9.13
KO 8	8.29	0.6	380	74	547	621	395	109	114	7.09
KO 9	8.43	0.5	313	90	446	536	373	39	696	9.29
KO 10	8.36	0.5	308	70	456	527	376	70	473	8.12

All values are in mg/l, except pH, EC. Unit of EC are dSm^{-1}

Table 4.11 Saturation Index of Minerals present in water samples of Chaka, Karchana and Kaundhiyara Blocks during Experiment

Sites	Anhydrite	Aragonite	Brucite	Calcite	Dolomite (d)	Dolomite (c)	Epsomite	Gypsum	Magnesite
C 1	-1.121	1.147	-2.844	1.291	2.528	3.078	-2.978	-0.901	1.206
C 2	-1.303	0.922	-2.889	1.066	2.292	2.842	-2.945	-1.084	1.195
C 3	-1.029	0.847	-3.068	0.991	2.119	2.669	-2.696	-0.810	1.097
C 4	-1.071	0.970	-3.122	1.114	2.303	2.853	-2.799	-0.851	1.157
C 5	-1.027	0.959	-3.253	1.103	2.267	2.817	-2.769	-0.808	1.133
C 6	-1.107	0.959	-2.861	1.103	2.328	2.878	-2.787	-0.887	1.194
C 7	-1.314	0.673	-3.145	0.817	1.959	2.509	-2.792	-1.094	1.110
C 8	-1.411	1.014	-2.260	1.157	2.844	3.394	-2.684	-1.191	1.656
C 9	-1.452	1.007	-2.711	1.151	2.674	3.224	-2.883	-1.233	1.492
C 10	-1.343	0.826	-2.915	0.970	2.377	2.927	-2.708	-1.124	1.377
Ka 1	-1.435	1.274	-1.963	1.417	3.041	3.591	-3.031	-1.215	1.593
Ka 2	-1.469	0.711	-3.074	0.855	2.002	2.552	-2.979	-1.249	1.116
Ka 3	-1.419	1.088	-2.896	1.231	2.557	3.107	-3.129	-1.200	1.294
Ka 4	-1.280	1.058	-2.981	1.202	2.468	3.018	-3.019	-1.061	1.235
Ka 5	-1.075	0.917	-3.395	1.061	2.136	2.686	-2.863	-0.855	1.044
Ka 6	-1.050	1.168	-2.616	1.312	2.668	3.218	-2.808	-0.830	1.325
Ka 7	-1.030	1.026	-3.165	1.170	2.325	2.875	-2.848	-0.811	1.124
Ka 8	-1.088	0.938	-3.029	1.081	2.239	2.789	-2.814	-0.868	1.127
Ka 9	-1.120	0.798	-3.415	0.942	1.960	2.510	-2.846	-0.900	0.987
Ka 10	-1.126	0.854	-3.376	0.997	2.032	2.582	-2.892	-0.907	1.003
Ko 1	-1.632	0.964	-2.044	1.108	2.861	3.411	-2.790	-1.412	1.722
Ko 2	-1.460	0.995	-2.173	1.139	2.833	3.383	-2.708	-1.241	1.663
Ko 3	-1.360	0.778	-2.611	0.922	2.406	2.956	-2.601	-1.141	1.453
Ko 4	-1.530	0.666	-2.996	0.810	2.266	2.816	-2.686	-1.311	1.425
Ko 5	-1.614	0.972	-2.121	1.116	2.758	3.308	-2.889	-1.314	1.612
Ko 6	-1.563	0.785	-2.580	0.929	2.480	3.030	-2.744	-1.344	1.520
Ko 7	-1.393	0.937	-2.466	1.081	2.667	3.217	-2.692	-1.173	1.555
Ko 8	-2.341	0.794	-2.263	0.938	2.556	3.103	-3.464	-2.122	1.567
Ko 9	-1.441	0.958	-2.126	1.102	2.700	3.250	-2.748	-1.221	1.567
Ko 10	-1.706	0.813	-2.229	0.957	2.532	3.082	-2.891	-1.487	1.544

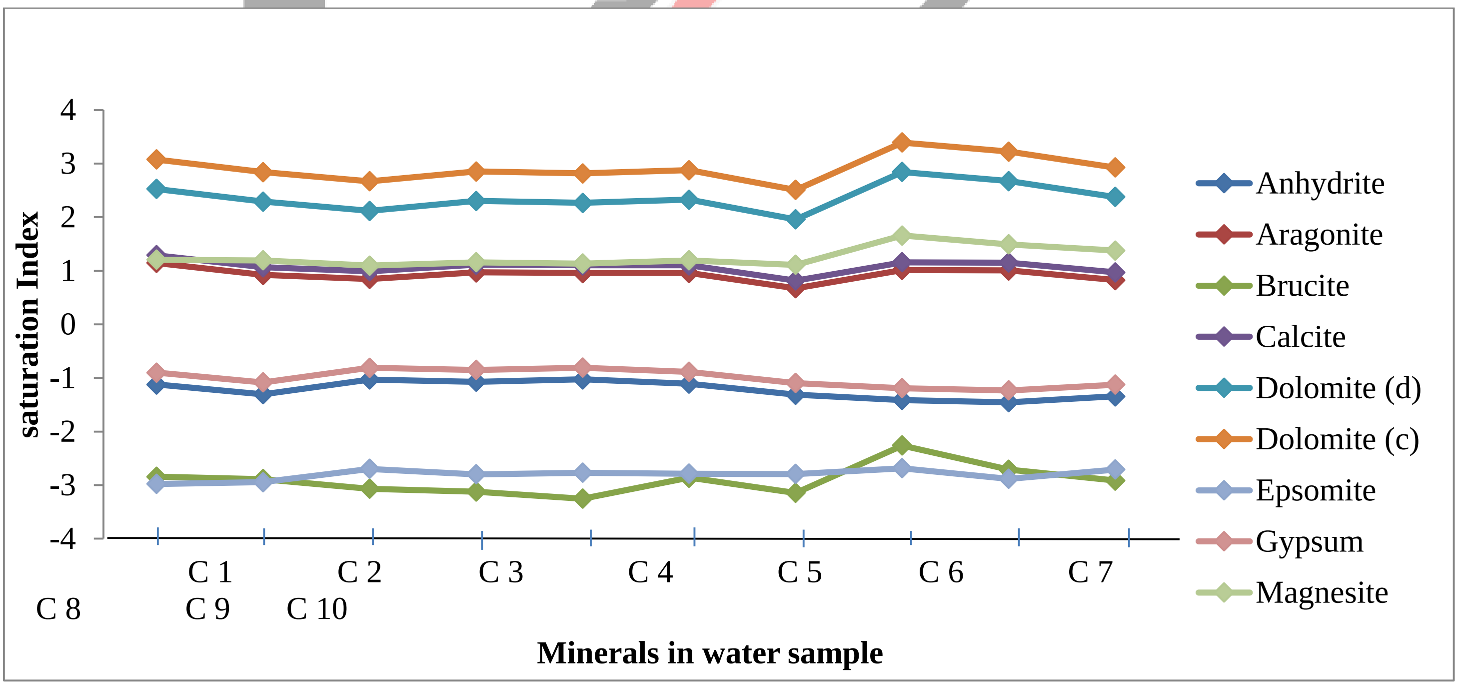

Fig 4.11 Saturation Index of Minerals present in water samples of Chaka Block

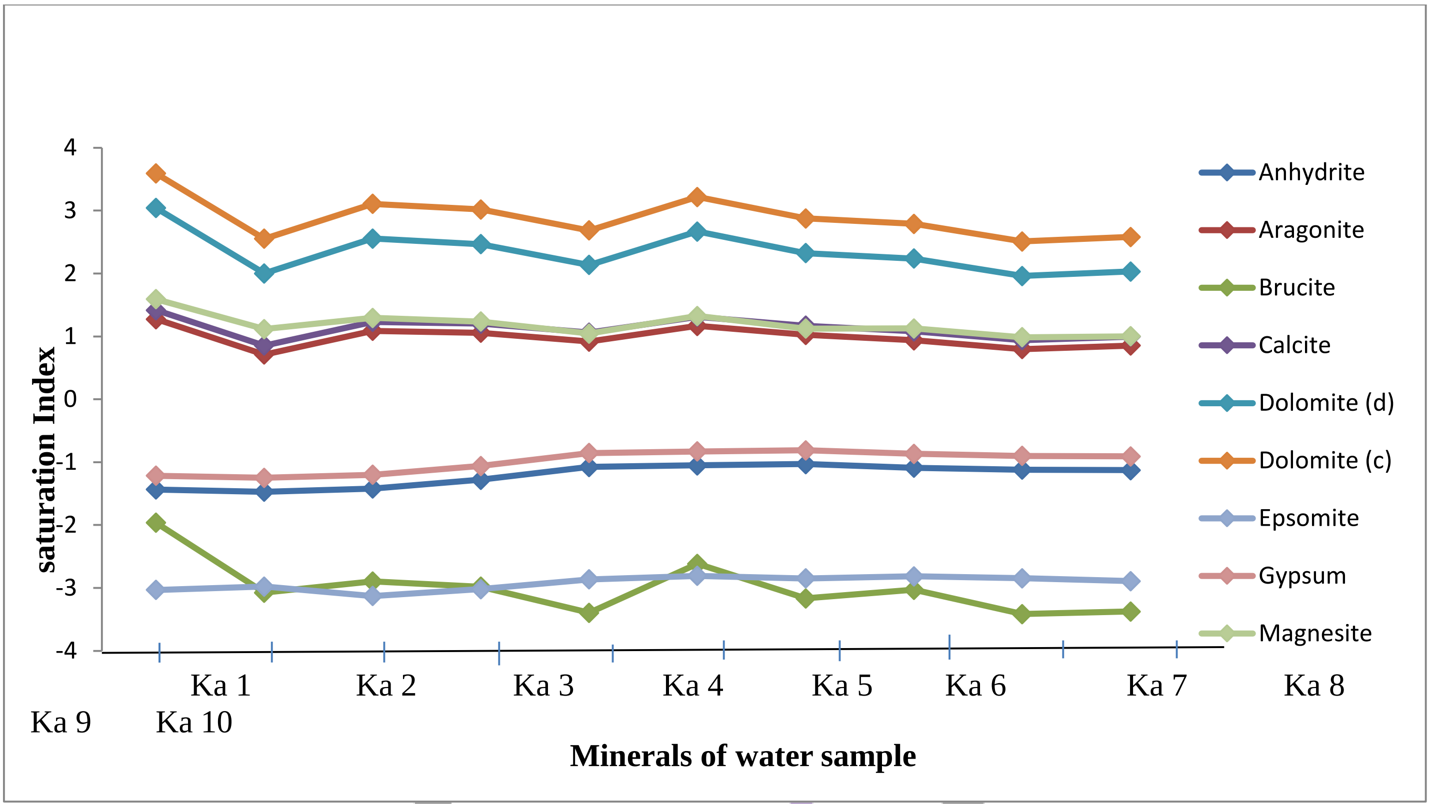

Fig 4.12 Saturation Index of Minerals present in water samples of Karchana Block

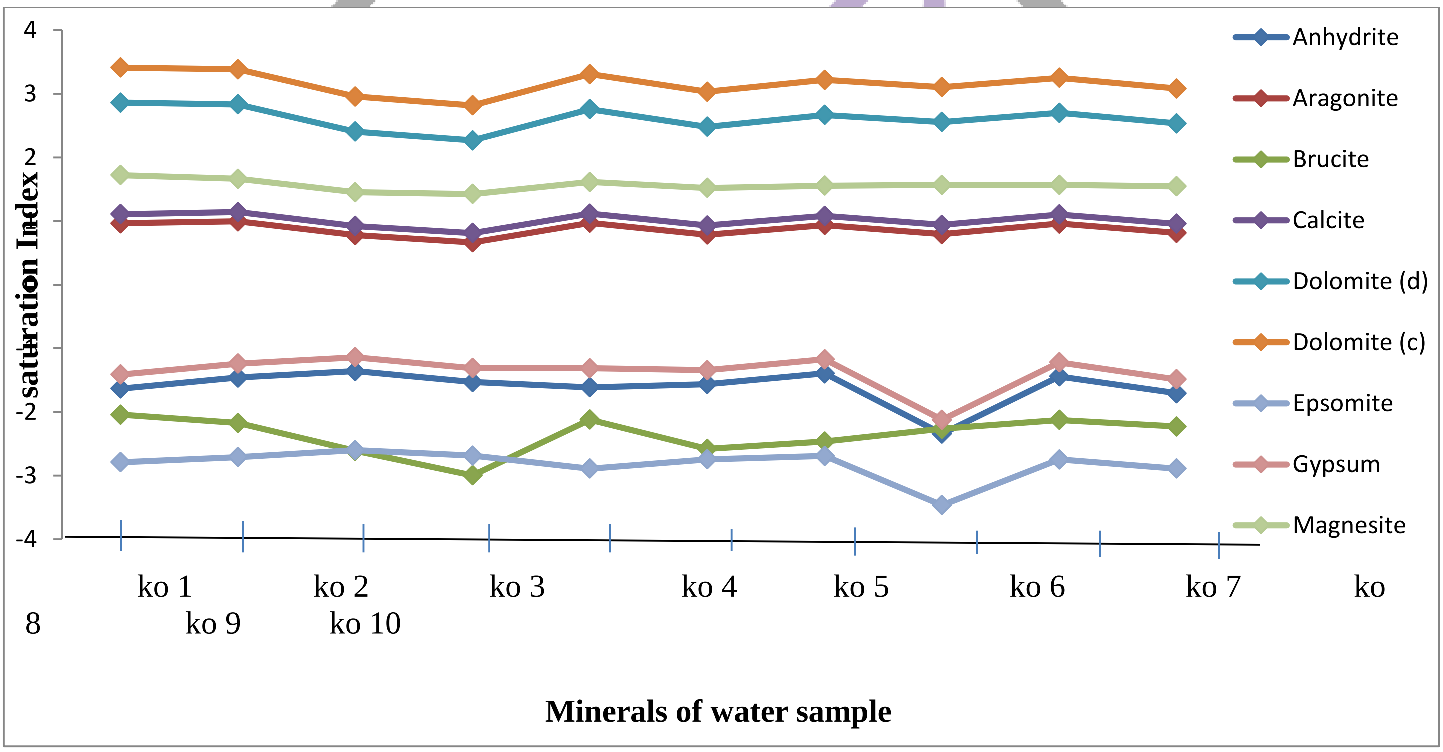

Fig 4.13 Saturation Index of Minerals present in water samples of Kaundhiyara Block