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Study of groundwater quality by the assessment of physico-chemical parameters and water quality index in Aligarh, Uttar Pradesh

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ABSTRACT

The present work is aimed to calculate the water quality index (WQI) for irrigation suitability and livestock drinking purposes of the groundwater of Aligarh. WQI is calculated on the basis of Weighted Arithmetic Index by analysing 13 physico-chemical parameters. The parameters namely pH, total alkalinity, total hardness, Ca & Mg hardness, turbidity, conductivity, total dissolved solids (TDS), total solid (TS), total suspended solid (TSS), dissolved oxygen (DO), chemical oxygen demand (COD) and chloride. The WQI for these samples range from 37.10-93.93. The analysis reveals that the groundwater of the area needs some treatment before consumption, and it is need to be protected from the perils of contamination.

Key words: Groundwater, WQI, physico-chemical analysis, Aligarh (Uttar Pradesh).

INTRODUCTION

Water is the most important, abundant and useful natural resources on the earth because no life is possible without water. It is essential for the survival of all living beings and plays an
important role in our life [1].

But unfortunately the water quality is influenced by the natural and anthropogenic activities including environmental stress particularly pollution such as domestic, agriculture, industrial, hydropower etc. Therefore scientific study needs to review strategies for conservation and better utilization of groundwater. Water quality index is one of the most effective tools to monitor the groundwater as well as surface water pollution and can be used efficient in the implementation of water quality upgrading programmes [2-4]. WQI provides the single number that expresses overall quality based on the different physico-chemical parameters like pH, total alkalinity, total hardness, Ca & Mg hardness, turbidity, conductivity, total dissolved solids (TDS), total solid (TS), total suspended solid (TSS), dissolved oxygen (DO), chemical oxygen demand (COD) and chloride, etc.

The groundwater quality of Sialkot, an industrial city of Pakistan was studied in relation to heavy metal pollution and its implication on human health during October-November 2005 and found that the groundwater of the study area cannot be considered of good quality [5]. The study of physico-chemical characteristics of Bore well water quality in Vidharbh Region, Nagpur city-south zone was carried out and concluded that some parts of bore well water needed treatment for drinking purpose due to hardness, pH, DO, alkalinity and chlorides are present in desirable limits and some sort little variation [6]. Assessed the WQI for the ground water of Koilwar block of Bhojpur, Bihar and analyzed that the ground water of the Koilwar block needs some treatment before consumption and it also needs to be protected from contamination [7]. The fifteen physico-chemical and microbiological water quality parameters recorded at the eight sampling stations during 2013 by using statistical techniques such as Correlation, Hierarchical clustering analysis (CA), principle component analysis (PCA) and factor analysis (FA), and WQI tool was also applied to turn complex water quality data into information that is understandable and used

by the public and the analysis revealed that the water quality of Keenjhar is not suitable for drinking purpose before proper treatment [8]. The impact of the groundwater quality of Vuyyuru, part of East Coast of India was investigated by physical and chemical parameters [9]. The WQI analyzed for the ground water samples of Sugar town, Mandya city and revealed that the groundwater is crystal clear, odourless and palatable and WQI falls in the Excellent Range but needs certain degree of treatment before consumption (at least disinfection) [10]. Various physico-chemical parameters evaluated to study the suitability of groundwater mainly for drinking purpose in Taj-city Agra and found that all the water quality of all samples is not suitable for drinking without prior treatment [11]. Evaluation of physico-chemical parameters was carried out to assess the quality of groundwater in Kurnool environs, A.P., India and concluded that the groundwater of Kurnool, though fit for domestic and drinking purpose, need treatments to minimize the contamination especially the alkalinity [12]. The present work is an attempt to measure the water quality of various water sources of 16 locations of Aligarh, U.P, India.

Study Area

Fig 1: Location of Aligarh to Mangalayatan University

Aligarh is a city located in Uttar Pradesh state of Northern India. The city is about 90 miles east to New Delhi, situated on a plain between the Ganges and Yamuna. The city is the administrative district of Aligarh District. Aligarh is located at the co-ordinates 27.88°N 78.08°E. It has an elevation of approximately 178 metres (587 feet). The Mangalayatan University is strategically located on the Aligarh-Mathura Highway having close proximities to the Yamuna Expressway in Uttar Pradesh.

EXPERIMENTAL SECTION

The water sample from the hand pumps were collected in polythene bottles. After the collection of samples, these bottles were labelled and possible efforts made to transport them to the laboratory as earlier as possible. The samples were chemically analysed for various water quality parameters such pH, total alkalinity, total hardness, Ca & Mg hardness, turbidity, electrical conductivity, total dissolved solids (TDS), total solid (TS), total suspended solid (TSS), dissolved oxygen (DO), chemical oxygen demand (COD) and chloride using standard procedures described in NEERI Manual [13]. The methods used for estimation of various physico-chemical parameters are tabulated in Table1.

Table1: Methods used for estimation of physico-chemical parameters

S. No.	Parameter	Methods
1	pH	pH meter
2	Electrical Conductivity	Conductivity meter
3	Turbidity	Nephlometer
4	Alkalinity	Indicator method
5	TDS	Filtration method
6	TSS	Evaporation method
7	Dissolved Oxygen	Wrinkler's method
8	COD	Open reflux method
9	Chloride	Silver nitrate method

Calculation of WQI

In this study, 13 parameters were chosen for the calculation of WQI. It has been calculated by using the standards of drinking water quality recommended by WHO [14], BIS [15] and ICMR [16]. The weighted arithmetic index method has been used for the calculation of WQI of the groundwater [17]. Further quality rating or sub index (Q_n) was calculated using the following formula.

$$Q_n = 100 * [(V_n - V_{i0})/(S_n - V_{i0})] \quad (1)$$

where,
Q_n = quality rating for the n^{th} water quality parameter.
V_n = estimated value of the n^{th} parameter at a given sampling station.
S_n = standard permissible value of n^{th} parameter
V_{io} = ideal value of n^{th} parameter in pure water.
V_{io} = ideal value of n^{th} parameter in pure water. (i.e. 0 for all other parameters except the parameter pH and DO (7.0 mg/l and 14.6 mg/l respectively)

The unit weight (W_n) was calculated by a value inversely proportional to the recommended standard value (S_n) of the corresponding parameters.

$$W_n = K/S_n \quad (2)$$

where,
W_n = unit weight for n^{th} parameter
S_n = standard value for n^{th} parameters
K = proportionality constant.

The overall water quality index was calculated by aggregating the quality rating with the unit weight linearly by using equation (1) and (2) we have

$$WQI = \sum_{i=1}^{n} Q_n W_n / W_n \quad (3)$$

Table 2: **WQI and status of water quality** (Chatterjee and Raziuddin, 2002 [18]).

Water quality index	Water quality status
0-25	Excellent water quality
26-50	Good water quality
51-75	Poor water quality
76-100	Very poor water quality
>100	Unfit for drinking

Table 3: **Parameter wise ICMR/BIS standards and their assigned unit weight**

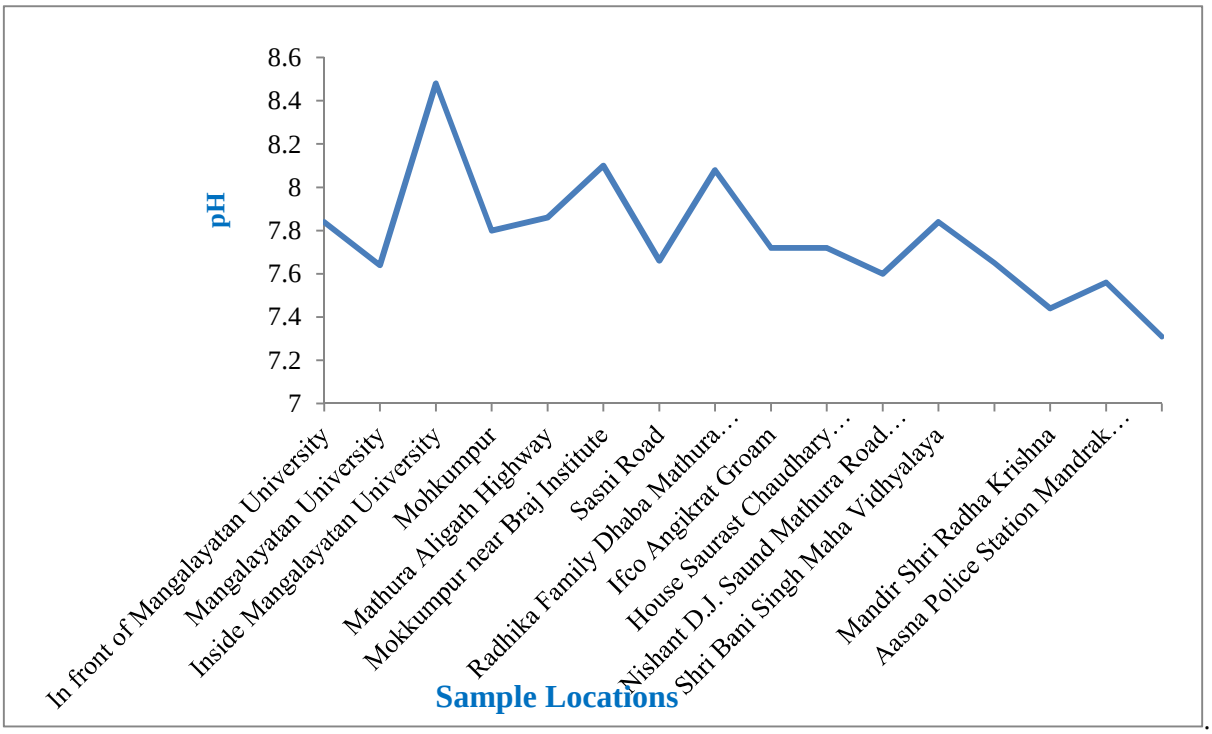
S. No.	Parameter	ICMR/BIS Standards	Assigned Unit Weight (W_n)
1	pH value	6.5- 8.5	0.117647058
2	Total alkalinity (mg/l)	200- 600	0.005000000
3	Total hardness (mg/l)	300- 600	0.003333300
4	Calcium hardness (mg/l)	75- 200	0.013333300
5	Magnesium hardness (mg/l)	30- 150	0.033333300
6	DO (mg/l)	0- 5	0.200000000
7	COD (mg/l)	0- 10	0.100000000
8	Turbidity (NTU)	0- 5	0.200000000
9	Conductivity (µS/cm)	300- 2250	0.003333300
10	TS (mg/l)	1000- 2000	0.001000000
11	TDS (mg/l)	500- 2700	0.002000000
12	TSS (mg/l)	500-1000	0.002000000
13	Chloride	200- 1000	0.005000000

RESULTS AND DISCUSSION

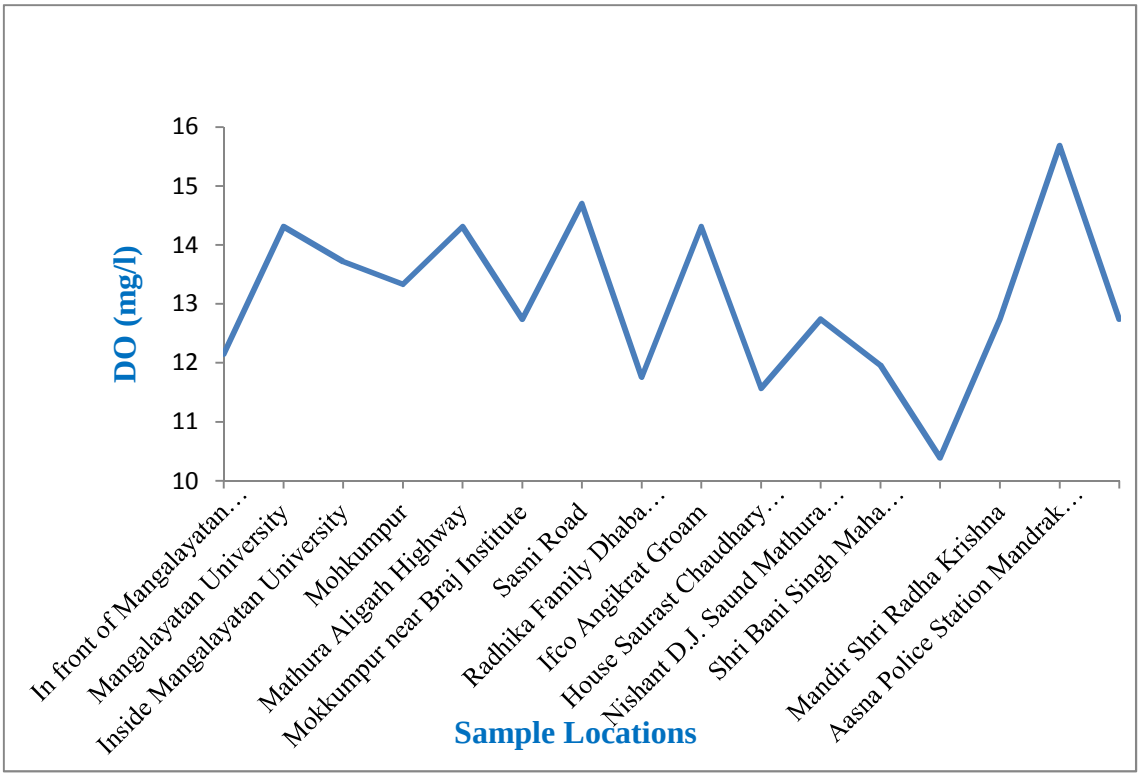
pH

pH is an important parameter which determines the suitability of water for various purposes. The pH level measured the acidity or alkalinity of the water. The results obtained from analysis of 16 ground water samples are given in Table 4. High value of pH may results due to waste discharge, microbial decomposition of organic matter in the

water body [19]. The mild alkalinity indicates the presence of week basic salts in the soil and CO_2 in water as bicarbonate. In the present study all the samples have pH values below the prescribed values. (Graph1)



Graph1: Sample Locations vs pH



Graph 2: Sample Locations vs DO (mg/l)

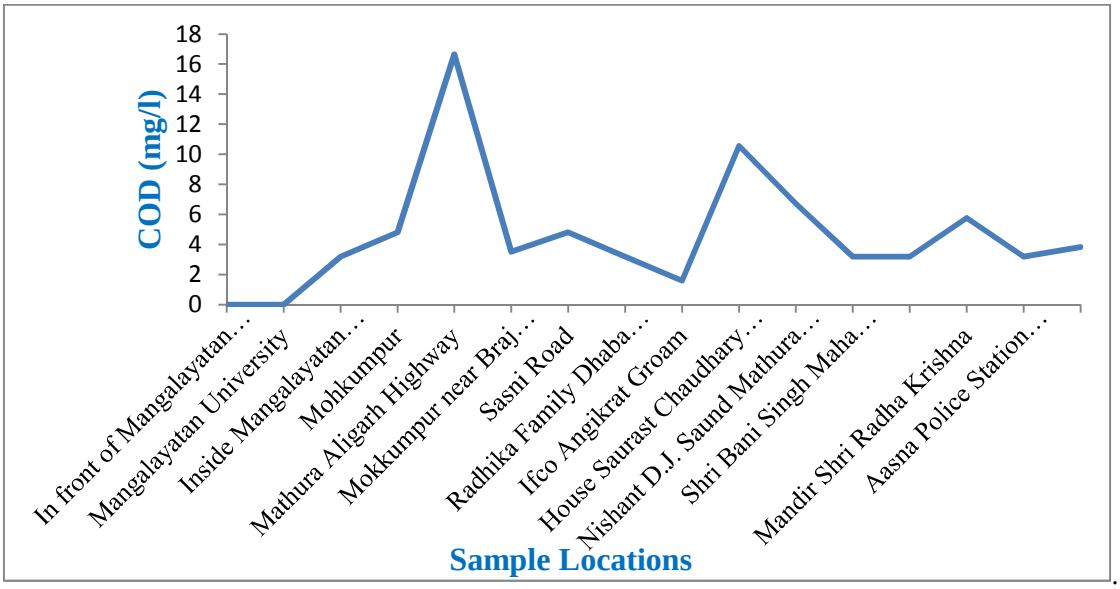
Dissolved Oxygen (DO)

Dissolved oxygen is an important parameter in water quality assessment and biological processes prevailing in the water. The DO values indicate the degree of pollution in the water bodies. The presence of DO enhances the quality

of water and also acceptability. An ideal DO value of 5.0 mg/l is the standard for drinking water [20]. DO of bore well water under the area determined in the present investigation ranged between from 10.39-15.68 mg/l which shows the high degree of pollution due to presence of bacteria and minerals in water. (Graph 2)

Chemical oxygen demand (COD)

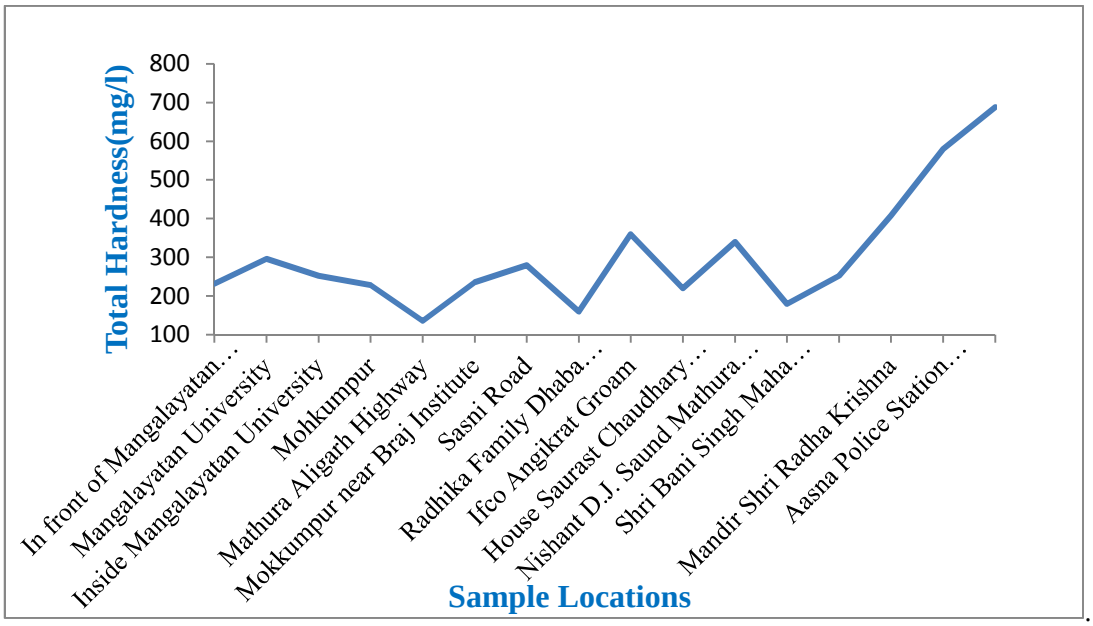
Chemical Oxygen Demand is a measure of pollution in aquatic system. High COD may cause oxygen depletion on account of decomposition by microbes to a level detrimental to aquatic life [21]. In the present study COD values of various ground water samples were found from 0-16.64 mg/l. Highest values of COD found in sample5 (Mathura Aligarh Highway). It may be due to seepage from sewage drainage or industrial discharge in nearby localities. (Graph 3)



Graph 3: Sample Locations vs COD (mg/l)

Total hardness

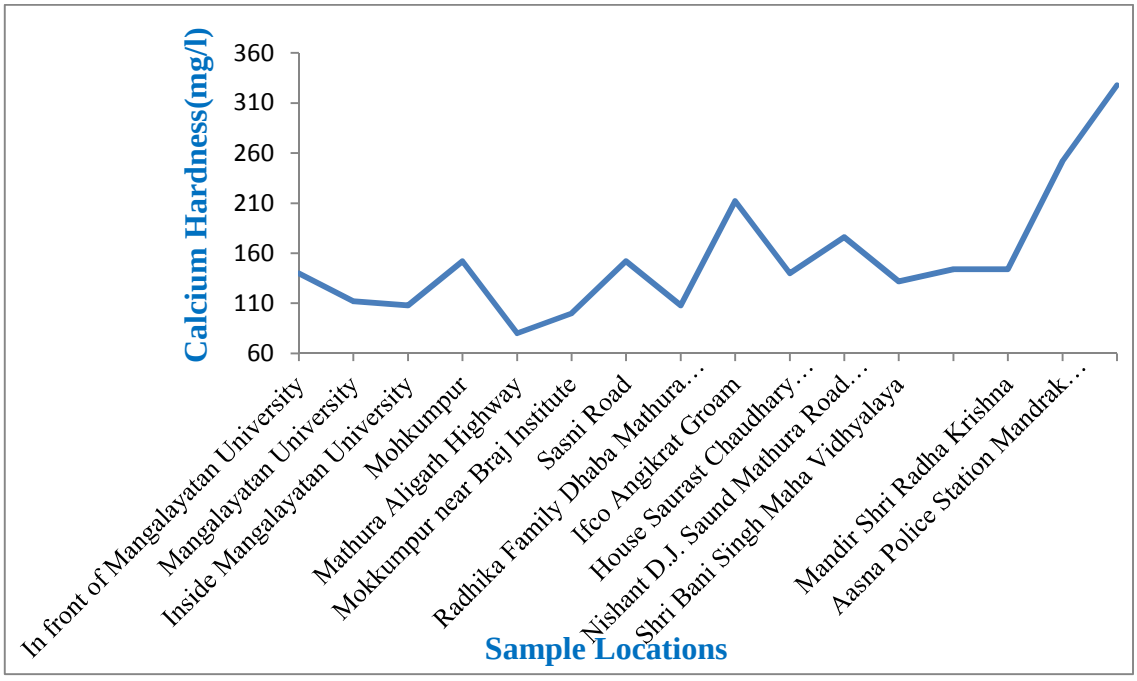
The presence of carbonates and bicarbonates of calcium and magnesium, sulphates, chlorides nitrates, influence the groundwater to become hard. In the present study total hardness varied from 136-688 mg/l. The values for sample16 (Shri Maheshwar Inter Collage Aligarh) was higher than the ISI prescribed limit. (Graph 4)



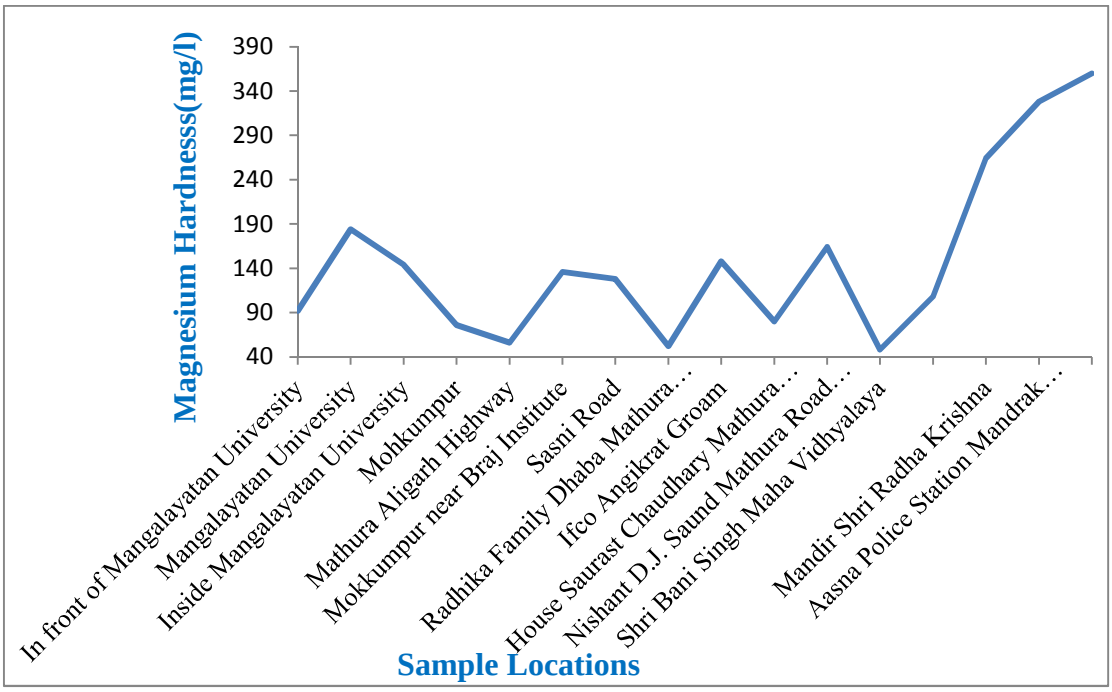
Graph 4: Sample Locations vs Total hardness (mg/l)

Calcium hardness

Calcium is from natural sources like granitic terrain which contain large concentration of this element. The result shows that calcium values for most samples in the range of 80-328 mg/l. High values of calcium hardness may be due to the presence of carbonates and bicarbonates. In the study area of all the samples *Ca* hardness are found within the prescribe limits except sample9 (Ifco Angikrat Groam), sample15 (Aasna Police Station Mandrak Aligarh) and sample16 (Shri Maheshwar Inter Collage Aligarh). (Graph 5)



Graph 5: sample Locations vs Calcium Hardness (mg/l)



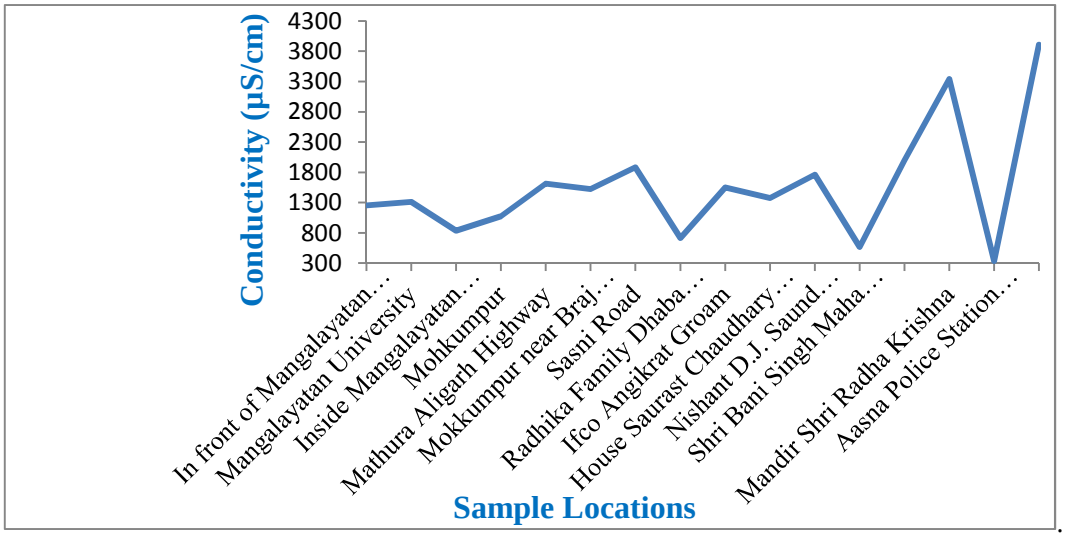
Graph 6: Sample Locations vs Magnesium Hardness (mg/l)

Magnesium Hardness

Magnesium in the groundwater of the study area are found to be 48-360mg/l and all the samples of Mg hardness are found within the prescribed limits except sample2 (Mangalayatan University), sample11 (Nishant D.J. Saund Mathura Road Kandli), sample14 (Mandir Shri Radha Krishna Aligarh), sample15 (Aasna Police Station Mandrak

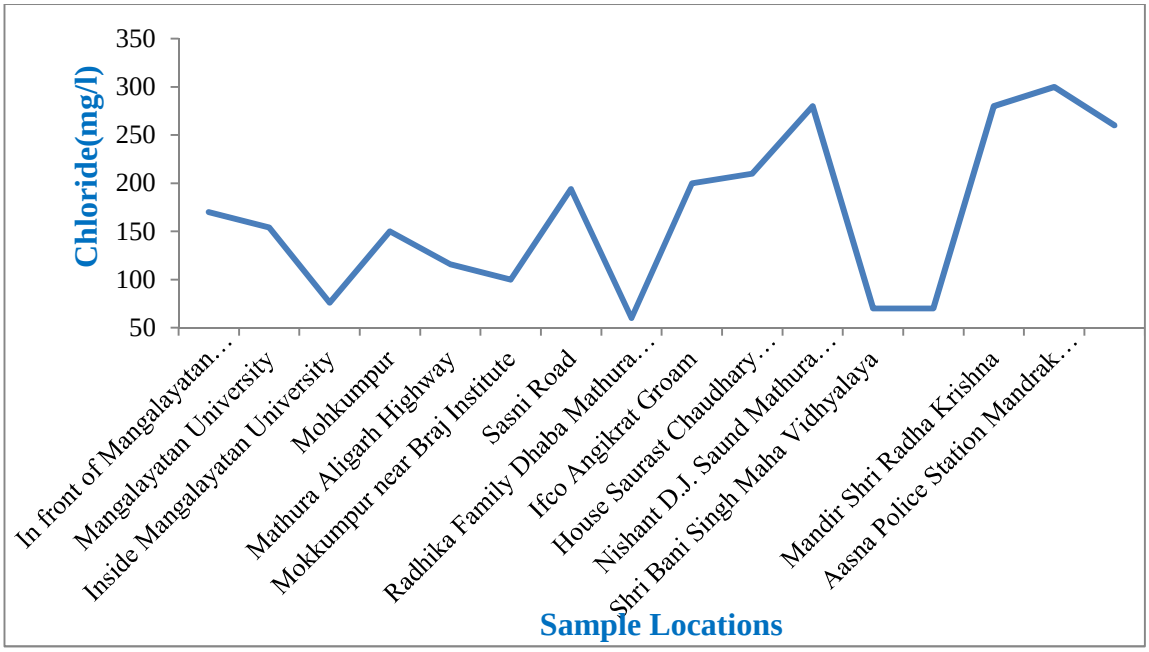
Aligarh) and sample16 (Shri Maheshwar Inter College Aligarh) which is higher than prescribed limits may be due to rock weathering and aquifer materials.
(Graph 6)

Conductivity
The conductivity values ranged between 334.283-3910.44 µS/cm wherein few samples showed the values beyond the permissible limits except sample14 (Mandir Shri Radha Krishna Aligarh) and sample16 (Shri Maheshwar Inter Collage Aligarh). Higher values suggest the presence of high amount of dissolved inorganic substance in ionized form. (Graph 7)



Graph 7: Sample Locations vs Conductivity

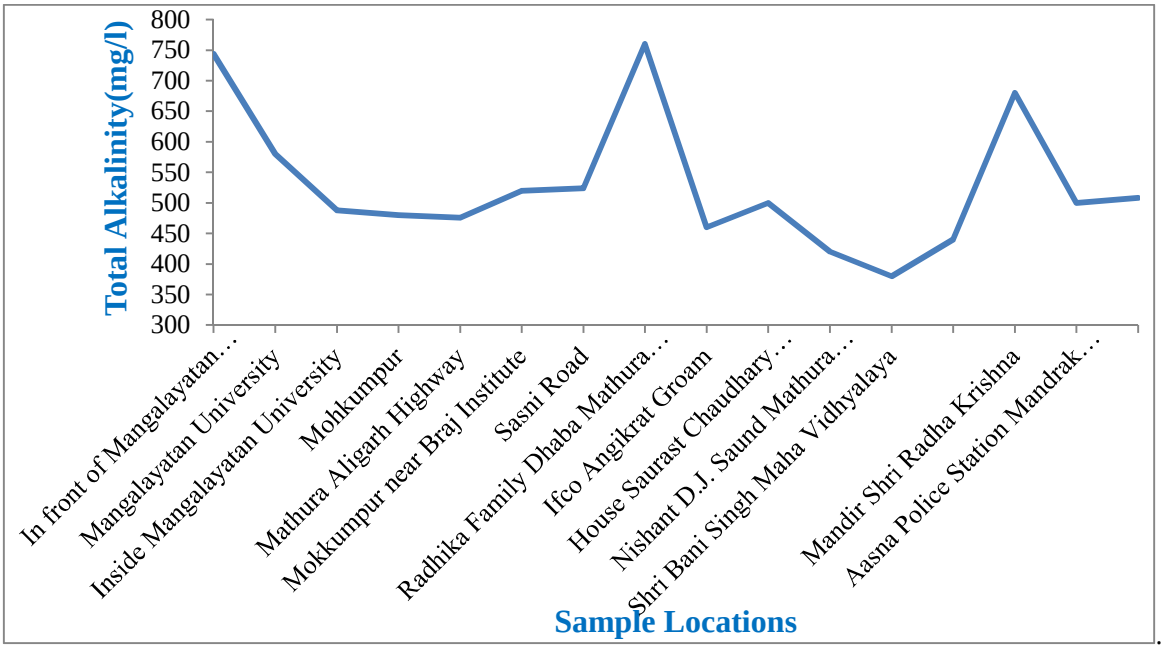
Chlorides
Chloride concentration of all the samples is found to be well within the permissible limits. The high chlorides content may harm metallic pipes and structure. Excess of chloride in groundwater imparts salinity in water and affect the human consumption. (Graph 8)



Graph 8: Sample Locations vs Chloride (mg/l)

Alkalinity

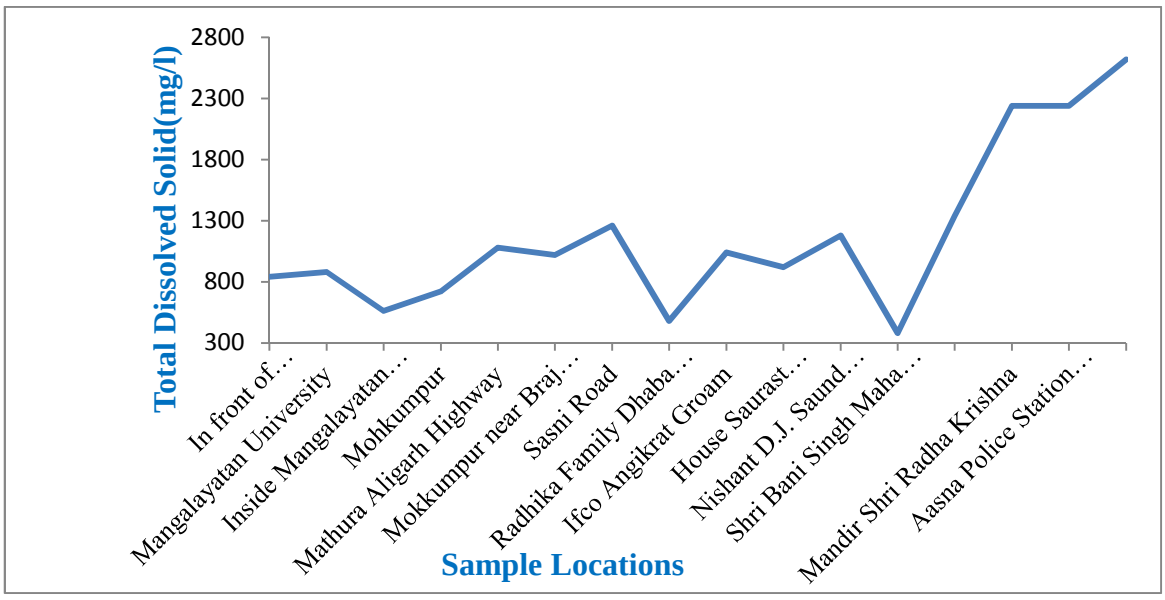
Value in water provides an idea of natural salts presents in water. In the present study the alkalinity are ranged from 380-760 mg/l. The alkalinity values are under the reasonable limit 600 mg/l and are due to the presence of carbonates, bicarbonates and hydroxides. In the study area all the samples showed the values well within the limits except sample1 (In front of Mangalayatan University), sample8 (Radhica Family Dhaba Mathura Road Aligarh) and sample14 (Mandir Shri Radha Krishna Aligarh). (Graph 9)



Graph 9: Sample Locations vs Total Alkalinity

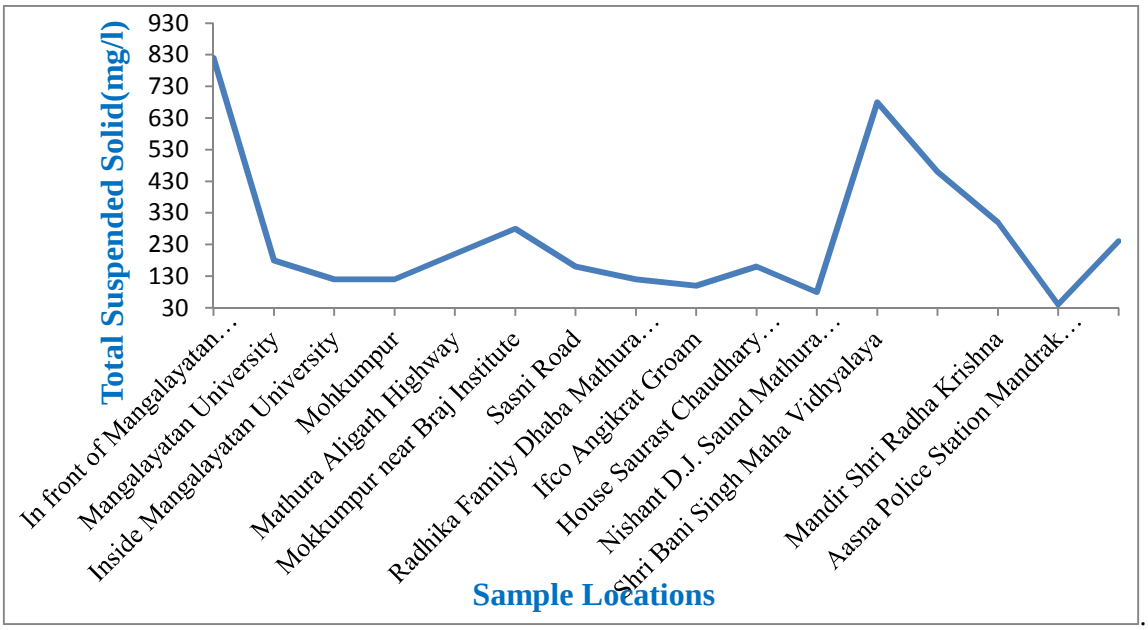
Total Dissolved Solid (TDS):

Total dissolved solid are present due to the concentrations of all minerals in water indicate the general nature of salinity of water. In the present study TDS value ranged from 380-2620 mg/l and all sample shows within the desirable limits of 2700 mg/l. TDS in groundwater originate from natural sources, sewage, urban run-off and industrial wastes. (Graph 10)



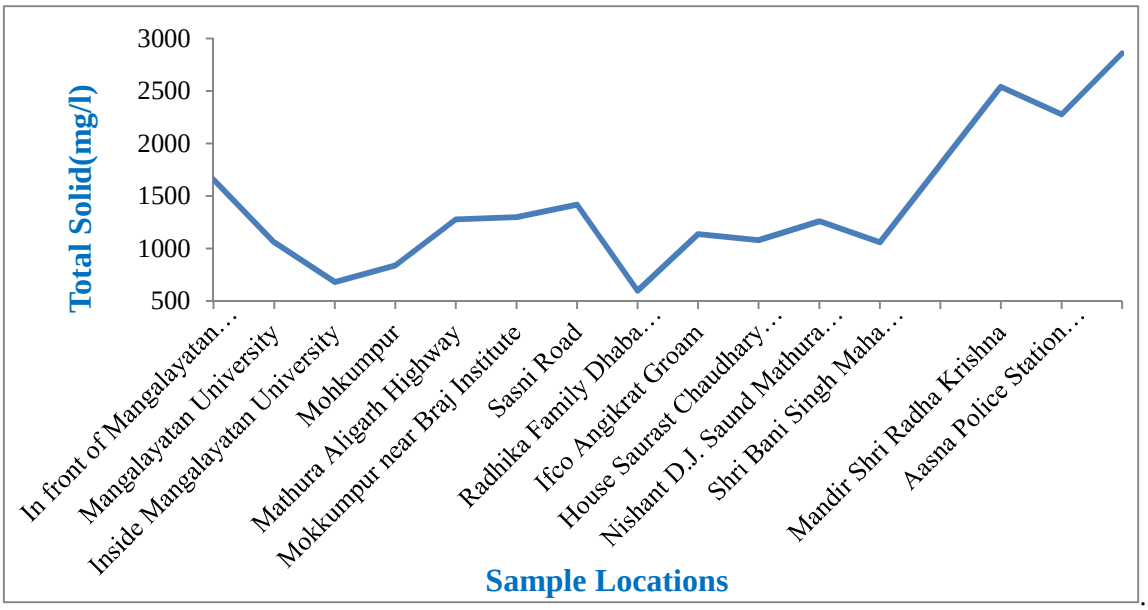
Graph 10: Sample Locations vs Total Dissolved Solid (mg/l)

Total Suspended Solid (TSS):
The entire sample for TSS is within permissible limits (500 mg/l) except sample1 (In front of Mangalayatan University) and sample12 (Shri Bani Singh Maha Vidhyalaya). (Graph 11)



Graph 11: Sample Locations vs Total Suspended Solid (mg/l)

Total solid (TS)
Mostly all the samples of TS are within the permissible limits except sample14 (Mandir Shri Radha Krishna Aligarh), sample15 (Aasna Police Station Mandrak Aligarh) and sample16 (Shri Maheshwar Inter Collage Aligarh). (Graph 12)



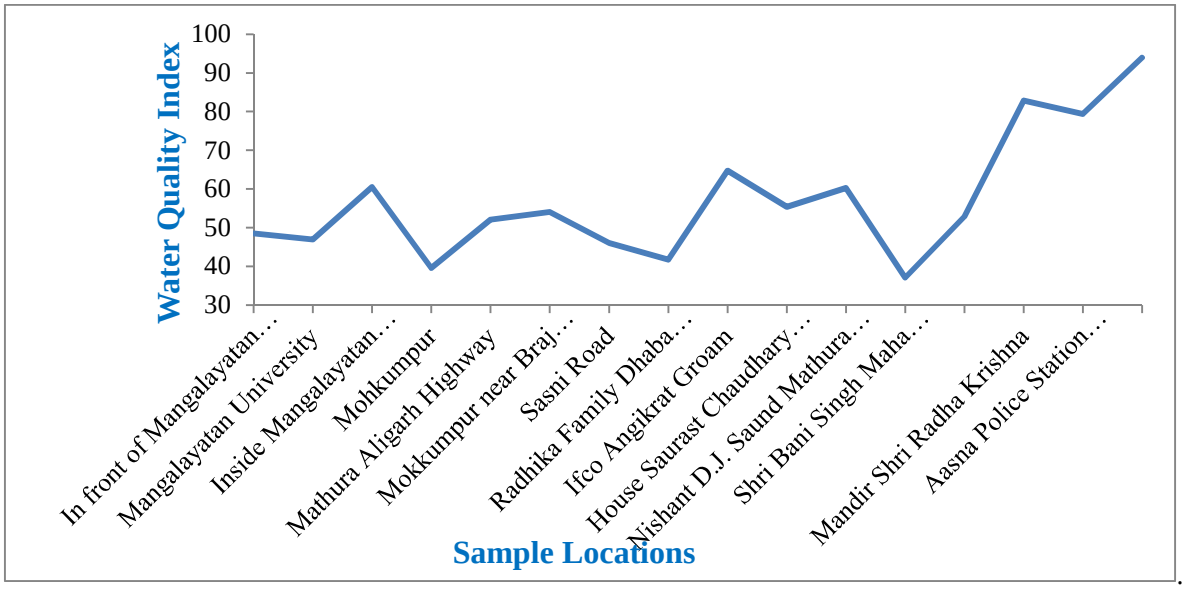
Graph 12: Sample Locations vs Total Solid (mg/l)

Table 4: WQI of water samples of Aligarh

S. No	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
pH	7.84	7.64	8.48	7.8	7.86	8.1	7.66	8.08	7.72	7.72	7.6	7.84	7.65	7.44	7.56	7.31
Total Alkanity	744	580	488	480	476	520	524	760	460	500	420	380	440	680	500	508
TH	232	296	252	228	136	236	280	160	360	220	340	180	252	408	580	688
Ca	140	112	108	152	80	100	152	108	212	140	176	132	144	144	252	328
Mg	92	184	144	76	56	136	128	52	148	80	164	48	108	264	328	360
DO	12.15	14.31	13.72	13.3	14.3	12.7	14.7	11.8	14.3	11.57	12.7	11.96	10.4	12.74	15.68	12.7
COD	0	0	3.2	4.8	16.6	3.52	4.8	3.2	1.6	10.56	6.72	3.2	3.2	5.76	3.2	3.84
Turbidity	1	0	1	1	0	0	0	0	3	0	0	0	0	1	1	0
Conductivity	1253.7	1313	835.8	1075	1612	1522	1881	716	1552	1373	1761	567.2	2000	3343	334.3	3910
TS	1660	1060	680	840	1280	1300	1420	600	1140	1080	1260	1060	1800	2540	2280	2860
TDS	840	880	560	720	1080	1020	1260	480	1040	920	1180	380	1340	2240	2240	2620
TSS	820	180	120	120	200	280	160	120	100	160	80	680	460	300	40	240
Chloride	169.95	154	75.98	150	116	100	193.9	60	200	209.9	280	69.98	70	279.9	299.9	260
WQI	48.533	46.96	60.53	39.6	52	54	46.06	41.7	64.7	55.38	60.3	37.11	52.9	82.83	79.33	93.9

WATER QUALITY INDEX

WQI is established through the measurement of various important physico-chemical parameters of the groundwater. The calculation of WQI for various physico-chemical parameters are presented in Table 4. The values of WQI showed the higher percentage of poor category of groundwater was found in the sample location. It may be due to the effective ionic leaching, over exploitation and anthropogenic activities such as discharge of effluents from industrial, agricultural and domestic uses. It is found that the 18.75% of groundwater on the sample location are very poor quality. This clearly indicates that water samples for this region are highly polluted. They are not suitable for drinking purpose and other useful human activities. The WQI indicates that sample location 14, 15, 16 are highly polluted. The orders of WQI for different samples location are: 12 < 4 < 8< 7< 2 < 1< 5< 13 < 6 < 10< 11 < 3< 9< 15< 14< 16. The groundwater collected from sample location 3, 5, 6, 9, 10, 11, and 13 has poor water quality and 1, 2, 4, 8, and 12 have good water quality. The location are may be polluted due to waste dumping and industrial effluents wastes and sewage water. We observed that, the water quality from various stations is not used for human consumption by local people. (Graph 13)



Graph 13: Sample Locations vs Water Quality Index

CONCLUSION

The WQI for 16 groundwater samples ranges from 37.10509-93.93368 The high value of WQI at these locations has been found to be mainly from the higher values of total dissolved solids, hardness, chloride, carbonates and bicarbonates in the groundwater. About 43.75% of water samples are poor in quality and 18.75% of water samples are of very poor quality and should not use directly for drinking purpose and the groundwater source are not suitable for drinking purpose with other proper treatment and analysis also reveals that the groundwater of the area needs some degree of treatment before consumption, and it also needs to be protected from the industrial waste and sewage contamination.

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