Bulletin of Pure and Applied Sciences
Geology (Geological Science), Vol.42F, No.2,
July-December 2023: P.266-280
Original Research Article

Print version ISSN 0970 4639
Online version ISSN 2320 3234
DOI: 10.48165/bpas.2023.42F.2.8
Available online at www.bpasjournals.com

Groundwater Contamination through Major Ions and Their Probable Effects on Human Health in Aligarh, Uttar Pradesh, India

[1]Mohd Areeb Khan, [2]Nepal Singh, [3]Ayan Ahmad, [4]Zaid Hasan Khan, [5]Shahnoor Alam and [6]Ajhar Hussain*

Author's Affiliations:
[1-6]Department of Geology, Aligarh Muslim University, Aligarh, Uttar Pradesh 202002, India

***Corresponding Author: Ajhar Hussain**, Department of Geology, Aligarh Muslim University, Aligarh, Uttar Pradesh 202002, India
E-mail: glyazhar@gmail.com

(Received on 17.07.2023, Revised on 13.09.2023, Approved on 03.11.2023, Accepted on 30.11.2023, Published on 15.12.2023)

How to cite this article: Khan M.A., Singh N., Ahmad A., Khan Z.H., Alam S. and Hussain A. (2023). Groundwater Contamination through Major Ions and Their Probable Effects on Human Health in Aligarh, Uttar Pradesh, India. *Bulletin of Pure and Applied Sciences- Geology*,42F(2), 266-280.

Abstract:
All living things require water to maintain their life and carry out their metabolic functions. The quality of groundwater degrades as a result of unethical human involvement in natural systems and excessive groundwater resource use. Since groundwater is routinely used both directly for drinking and for other purposes, it is necessary to examine its quality. The hydrochemistry of the groundwater in Aligarh, Uttar Pradesh, India, was examined to assess its appropriateness for irrigation and drinking, as well as any potential effects on locals' health. Twenty-three groundwater samples were taken from submersible and hand pumps, and their physical and chemical characteristics, including electrical conductivity, pH, total dissolved solids (TDS), Na^+, K^+, Ca^{+2}, Mg^{+2}, Cl^{+2}, HCO_3^-, CO_3^{2-},and SO_4^{2-}, were measured. The groundwater's ionic concentrations fluctuate geographically and momentarily, and the water is alkaline. Higher values of particular characteristics at specified places signify groundwater pollution, rendering it unfit for use in various applications.

Keywords: *Groundwater, Irrigation, Electrical Conductivity, Ionic Concentration*

INTRODUCTION

The discrepant relationship between the availability and demand for water is widening due to the growing world population and has reached such alarming levels that it is endangering human existence in several regions of the world. Around the world, scientists are creating new strategies for conserving water. It is time to return to one type of water recycling: utilizing sewage from cities for agriculture and other purposes.

Because it is an integral component of all living systems, the medium from which life arose, and the environment in which life survives, water is referred to as the matrix of life. It is widely accepted that using clean, untainted water for drinking and other uses is essential for human health and survival (Franks, 2000). Due to its huge storage capacity and relatively low sensitivity to contamination compared to surface water, groundwater is one of the best sources of fresh water on earth. In present time, more than half of the world's population relies on groundwater for survival, with an estimated one-third of the population using it for drinking reasons. The degradation of groundwater quality is brought on by human disturbances. When some compounds are added to or removed from groundwater, their quality criteria are altered beyond their normal changes.

The composition of the recharge components, as well as geological and hydrological fluctuations within the aquifer, determine the chemistry of the groundwater. Because of its unsteady circulation and prolonged interaction with sedimentary materials, groundwater frequently has higher mineral levels than surface water (Mohrir et al, 2009). The research regions, which are highly inhabited, heavily industrialised, and have shallow groundwater tables, have far more severe concerns with groundwater quality.

STUDY AREA

The study was carried out in the Indian state of Uttar Pradesh's western city of Aligarh. Between the Ganga and Yamuna rivers, in the doab area, is where Aligarh is situated. The study area lies between latitude27°55 to 27°56 North and longitude78°02 to 78°04 East. The region is a part of the middle Ganga basin and is located between the Sengerriver in the east and the Karwan River in the west. The city of Aligarh is situated in the region's central depression and is bordered by the eastern and western uplands, two of the region's most notable physiographic units. The city of Aligarh occupies a space of around 36.7 km^2.

The city of Aligarh is a significant hub for the production of brassware and locks. In Aligarh City, there are 5506 industrial units in total, of which 3500 are small businesses, 2000 are medium-sized businesses, and 6 are major businesses. The area's declining environmental quality is mostly due to an increase in industrial activity. It is crucial to identify the different sources of pollution in order to determine the current level of pollution in the region because of the rising trend in industrial activity. Pollution affects every area of the ecosystem in a different way (Kožíšek and František, 2003). The study of water contamination is chosen, however, since it is not just any liquid; it is the elixir of life.

During the study, some stations were selected for detailed study namely Jafari drain, Loco Pond, near Brass and Bone factory around the Industrial area and Nai Basti area .Twenty three groundwater samples have been collected from these locations followed by the drainage pattern for the geochemical analysis.

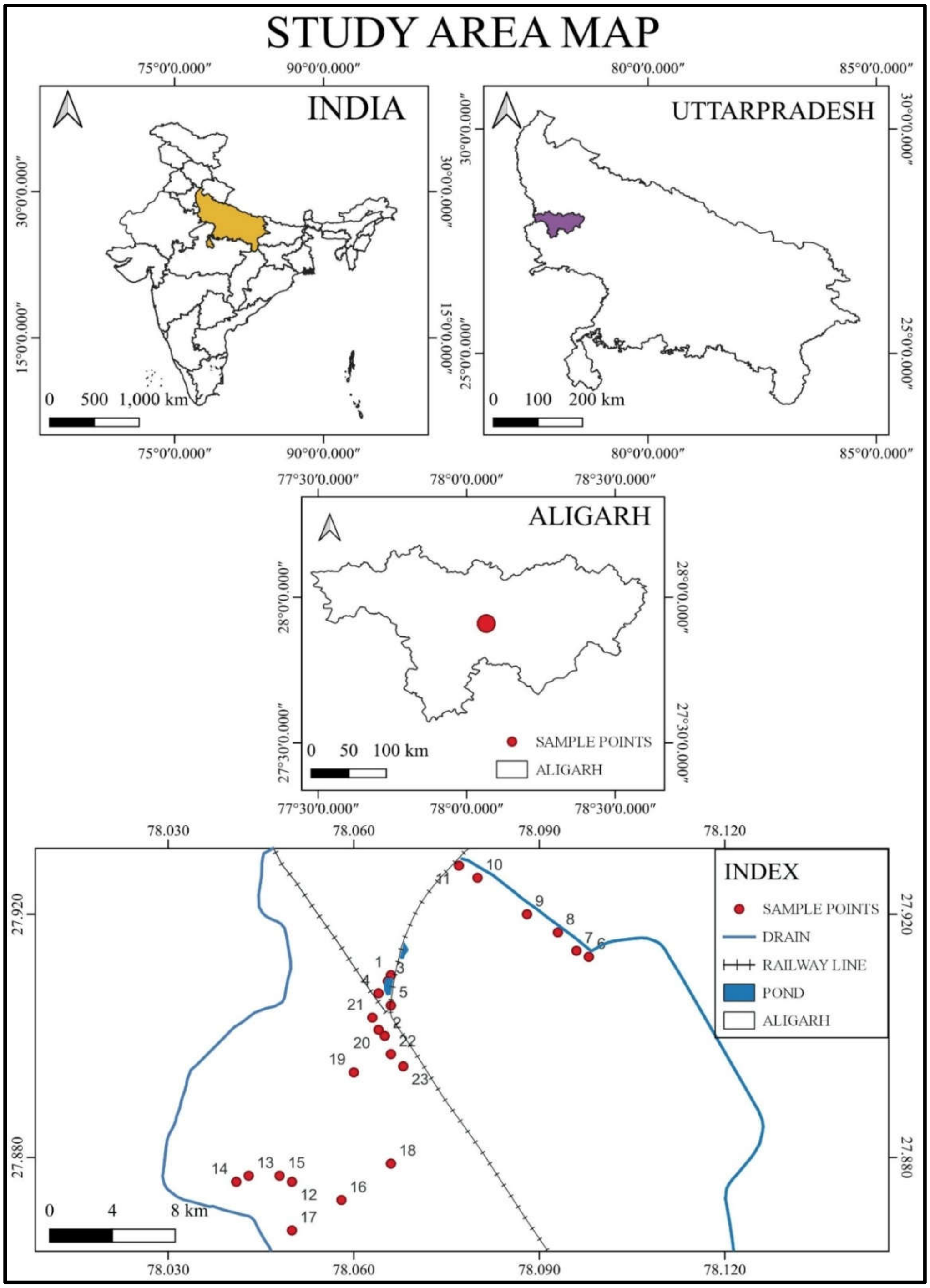


Figure 1: Study area

Table 1: Location of the samples

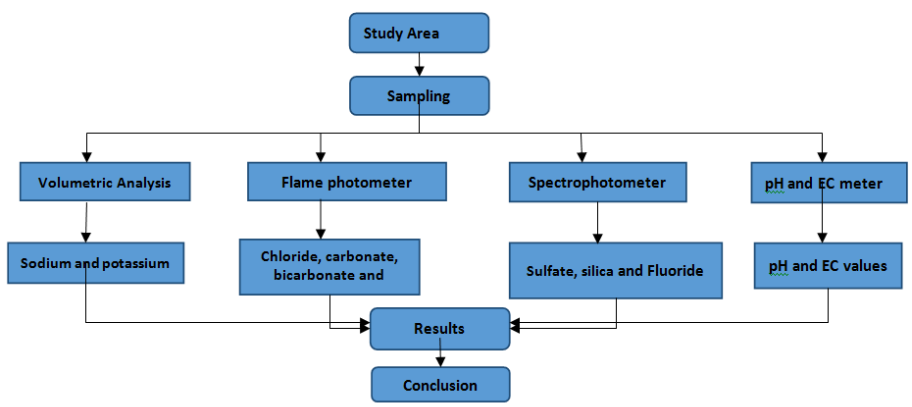
ID	DATE	LATITUD	LONGITUDE	ALTITUDE	SPECIMEN	Water Level	BORING	ADDRESS
		E (N)	(E)	(FT)	(HANDPUMP/ SUBMERSIBLE)	(FT)	(FT)	
S1	45016	27°54'38''	78°03'58''	433.4	Handpump (35/01)	120	200	Near Railway crossing bhamola, Aligarh
S2	45016	27°57'34''	78°03'56''	432.7	Handpump (35/02)	120	200	Near zuberi lodge Bhamola, Aligarh
S3	45016	27°54'34''	78°03'55''	436.4	Handpump (36/68)	120	200	Near Modern ideal public school street no 7 Bhamola, Aligarh
S4	45016	27°54'28''	78°03'52''	429.5	Handpump (36/72)	120	200	Near street No7 Loco colony Bhamola, Aligarh
S5	45016	27°54'19''	78°04'1''	439.3	Handpump (36/61)	130	200	Opposite to Mortuary Near Bareilly Railway track Police line, Aligarh
S6	45016	27°54'50''	78°05'53''	433.1	SUBMERSIBLE	110	200	Eid-Gaahwalipuliya, Raza Nagar Aligarh bye-pass road
S7	45016	27°54'53''	78°05'46''	426.2	SUBMERSIBLE	110	210	Jeevangarh Razanagar along the Jafari drainage, Aligarh
S8	45016	27°55'02''	78°05'36''	428.8	Handpump	110	200	Iqra-SS Nagar puliya, Aligarh
S9	45016	27°55'15	78°05'20''	429.5	SUBMERSIBLE	100	80	Near SIG hospital Badam Nagar Dhorramaafi, Aligarh
S10	45016	27°55'37''	78°04'50''	432.7	Handpump	100	200	Hamdard Nagar 'A' Jamalpur, Aligarh
S11	45016	27°55'41''	78°04'38''	433.7	Handpump	100	200	Near Blind centre sabzimandi Shahanshahbadjamalpur, Aligarh
S12	45017	27°52'35''	78°03'2''	508.8	SUBMERSIBLE	150	200	In Front of Karbala Gaffari Masjid Shahjamal, Aligarh
S13	45017	27°52'41''	78°02'36''	439.6	SUBMERSIBLE	150	150	Near Neewri mod Gonda Road, Aligarh
S14	45017	27°52'37''	78°02'31''	430.1	Handpump	150	200	Rorawar Shahjamal, Aligarh
S15	45017	27°52'38''	78°02'56''	430.1	Handpump	150	200	Near Iqra lodge Maboodnagar Shahjamal, Aligarh
S16	45017	27°52'24''	78°03'29	428.5	SUBMERSIBLE	140	200	Pile Shah gali Haddi

								Godownchauraha Aksha colony, Aligarh
S17	45017	27°52'08''	78°03'01''	428.5	SUBMERSIBLE	140	250	Maddum Nagar Kamela road near Haddigodown, Aligarh
S18	45017	27°52'46''	78°04'00''	494.1	SUBMERSIBLE	170	350	Jama Masjid Upper Fort, Aligarh
S19	45017	27°53'41''	78°03'38''	429.1	Handpump (47/20)	140	200	345,Shakti nagar Nagla Masami, Aligarh
S20	45017	27°54'05''	78°03'51''	434.4	SUBMERSIBLE	130	200	Industrial Estate, Aligarh
S21	45017	27°54'13''	78°03'47''	433.7	SUBMERSIBLE	130	200	A-8 industrial Estate, Aligarh
S22	45017	27°53'50''	78°03'59''	428.8	Handpump	140	200	Avasvikas colony Naibasti, Aligarh
S23	45017	27°53'45''	78°04'06''	432.1	Handpump (19/15)	140	200	Near Shiv Mandir Shikari Nagar Nai

METHODOLOGY

Sample Collection and Preparation

In order to study geochemical analysis of Groundwater various stations were selected namely Near Loco Pond, Around Jafari Drain, Around Brass & Bone Factories, and Around Industrial Area & Nai Basti, Aligarh. Twenty-three groundwater samples have been collected from these locations for major ion studies.



The water samples for partial chemical analysis were taken from the Handpump and Submersible and placed in clean, double-stoppered plastic bottles with a one-litre capacity (which were previously thoroughly cleansed and rinsed with distilled water to prevent contamination). After the samples were collected, the vial was immediately sealed by capping it with inner and outer lids.

Analytical Techniques

According to the established procedures suggested by APHA (1998), the samples for a thorough chemical analysis were examined in the Geochemical Laboratory of the Geology Department at Aligarh Muslim University, Aligarh. Major components including Na^+, K^+, Ca^{+2}, Mg^{+2}, Cl^-, CO_3^{-2}, HCO^{3-}, SO_4^{-2}, and F^- were detected in the samples. Volumetric analysis was used to identify the concentration of the key elements sodium and potassium while Flame

Photometer was used to determine the concentration of the other important elements chloride, carbonate, bicarbonate, and calcium. Spectrophotometer is used to measure the content of sulphate, silica, and fluoride. A series of blank samples were prepared for the spectrophotometric analysis of each element in order to account for any analytical and instrumental error. Using a pH meter, the hydrogen ion concentration (pH) of water samples was calculated. The electrical conductivity meter is used to calculate the Electrical Conductivity (EC) of water samples.

RESULTS AND DISCUSSION

The primary source of drinking water and other domestic needs in the research region is the groundwater. The graphs below list the different chemical tests that were carried out in March and April 2022 to evaluate the water quality in the city of Aligarh.

pH

The pH values of the water samples, which varied from 7.58 to 9.09 with an average value of 8.49 and were 47.82% higher than the BIS-recommended standard level (6.5 to 8.5), demonstrate the alkaline nature of the water samples.

If our water is overly "acidic" or "basic," indicating that caustic cleaners have tainted it (Morin-Crini, Nadia, et al. 2022).

Drinking acidic water can cause a number of health issues that can be fatal or extremely incapacitating. When consuming acidic water, the most frequent health issues include nausea, vomiting, diarrhoea, renal disease, liver disease, stomach pains, and liver disease (Bunnell, et al. 2007).

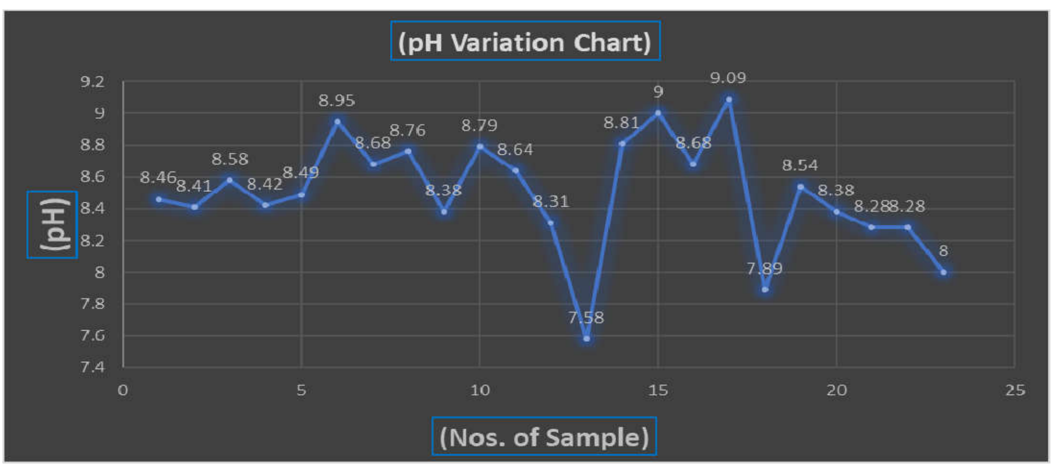


Figure 2: pH variation chart

Electrical Conductivity

A helpful indicator of water quality for salinity risks is electrical conductivity. The EC value shouldn't be more than 400 S/cm, as per WHO guidelines.

EC values in the research region ranged from 318 to 2080 S/cm, with an average of 726.43 S/cm.

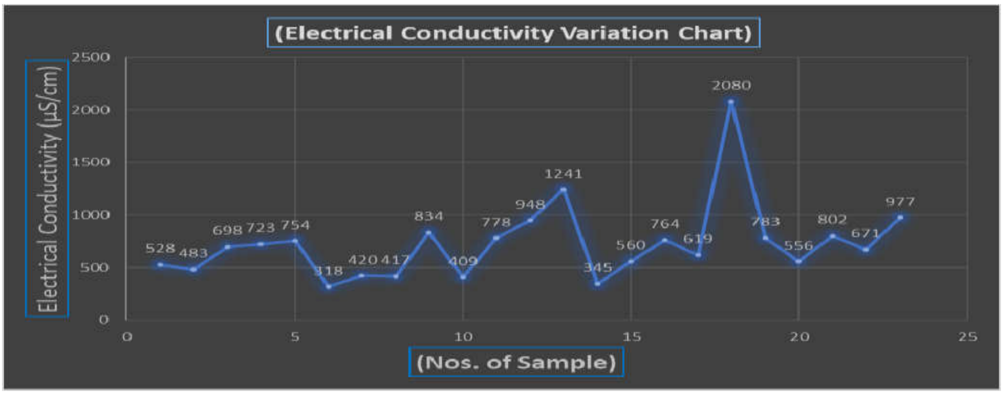


Figure 3: Electrical conductivity variation chart

Total Dissolved Solid (TDS)
The recommended TDS level for drinking purposes is 500 mg/l, while the maximum limit is 1000 mg/l, according to BIS. In the current investigation, TDS concentrations varied from 190.7 mg/l to 1257 mg/l. The average total dissolved solids concentration in the research region was 448.98 mg/l, which is less than the BIS limit. Utilising water with a high TDS level over an extended period exposes the body to numerous contaminants and chemicals, raising the risk of chronic illnesses including cancer, liver failure, and kidney failure (McMahon FG et al., 1982).

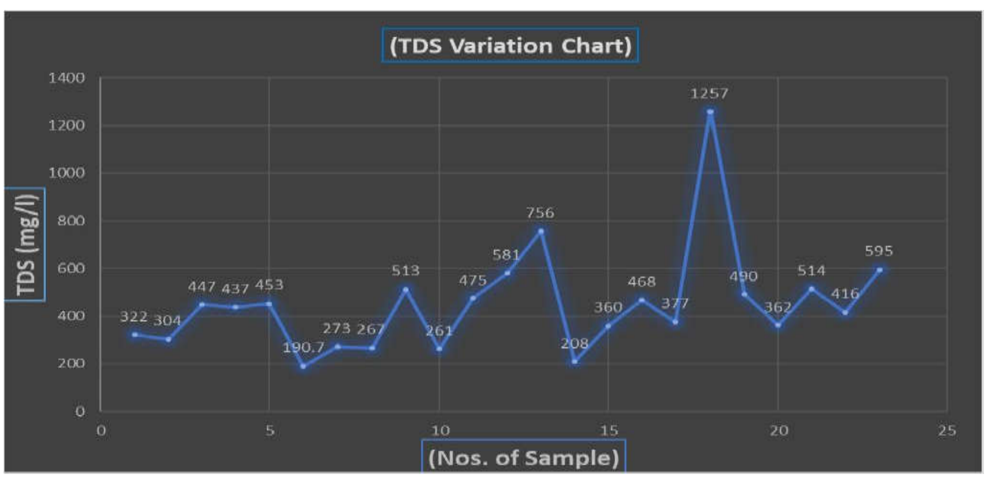


Figure 4: TDS variation chart

Hardness
Total hardness, which can be expressed as the CaCO3 equivalent concentration, is a gauge of how effectively water can handle calcium and magnesium concentrations. The investigation's water samples range in total hardness from 104 mg/l to 1000 mg/l. It was discovered that 86.9% of the samples were over the BIS-recommended standard limit (200 mg/l). The high degree of hardness in the research region is due to the improper disposal of industrial wastes and untreated or inadequately treated sewage. Numerous illnesses, including cardiovascular issues, diabetes, infertility, neurological disorders, renal dysfunction, etc. are brought on by the increasing hardness of the water (McMahon FG et al., 1984).

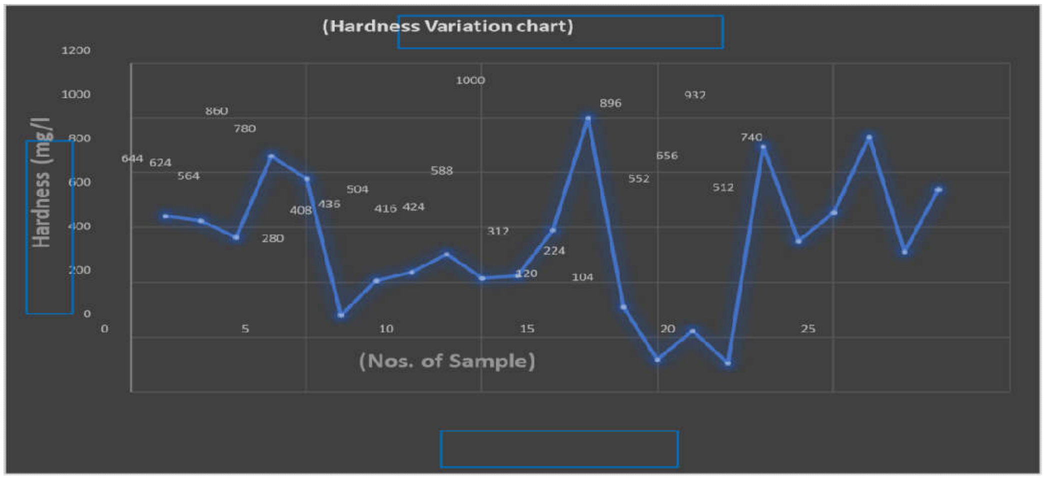


Figure 5: Hardness variation chart

Calcium and Magnesium

The water samples used in the investigation of total calcium and magnesium vary from 0 mg/l to 89.7792 mg/l and 16 mg/l to 218.53 mg/l, respectively. The majority of samples—86.95%—were found to be over the BIS-recommended standard limits of 75 mg/l and 30 mg/l, respectively.

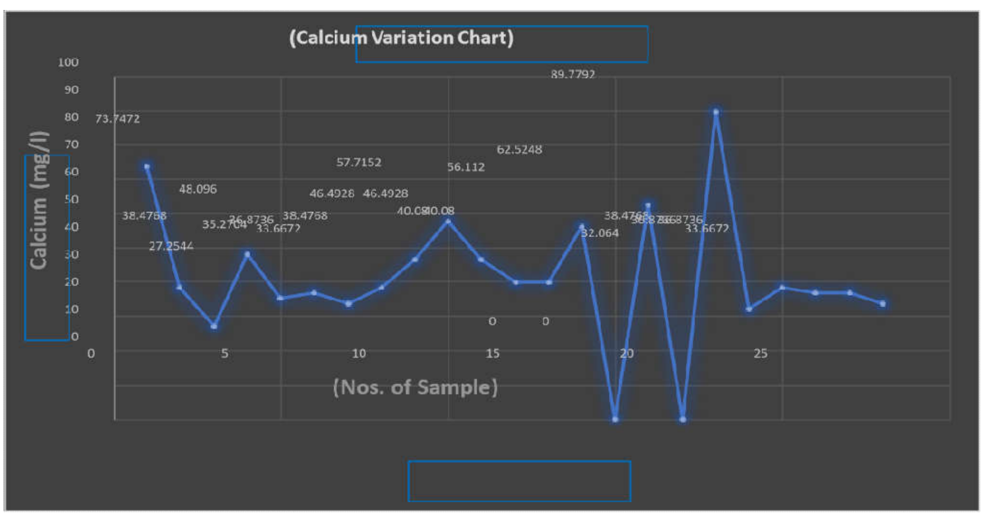


Figure 6: Calcium variation chart

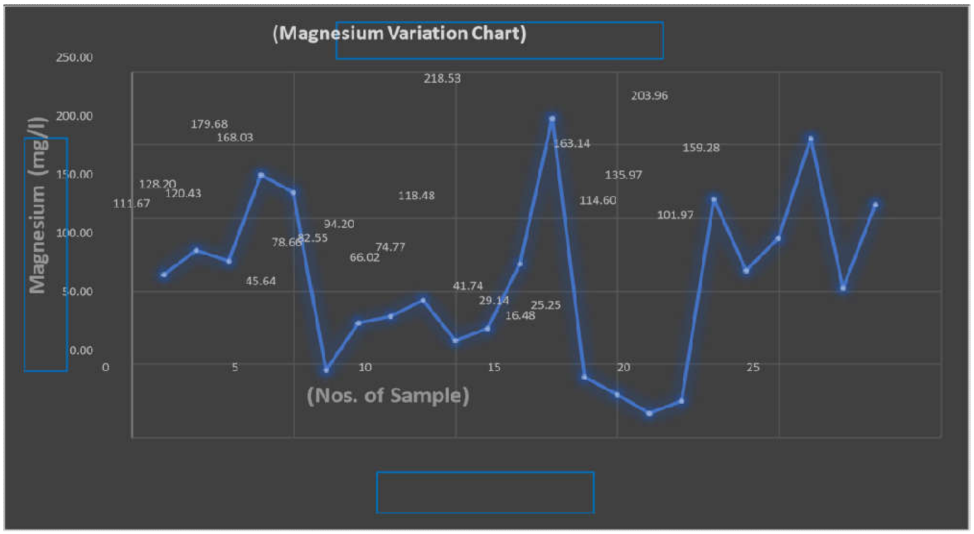


Figure 7: Magnesium variation chart

Chlorides

The average chloride content in the studied sites was 103.96 mg/l, with a range of 19.88 to 343.64 mg/l. The chloride readings in 4.3% of the sample were higher than the BIS-recommended upper limit (250 mg/l). When concentrations rise beyond 250 mg/l, the water starts to taste strongly of salt. Although chloride is often not thought to pose a health danger, it can change the taste of water at very low amounts and can cause hyperchloremia, which is a condition when there are excessive levels of chloride in the blood (Ramesh, et al, 2001). When the concentration is between 200 and 300 mg/L, the majority of people will notice that the water has an odd taste, but at 400 mg/L, the salty flavor is particularly noticeable.

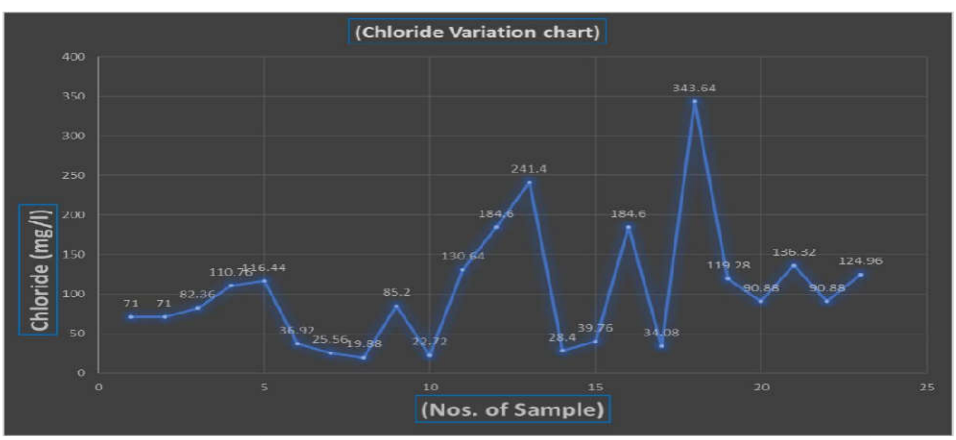


Figure 8: Chloride variation chart

Total Alkalinity

The average alkalinity in the water samples was 854.60 mg/l, with values ranging from 624 mg/l to 1248 mg/l. The bicarbonate concentrations in the sample surpassed the BIS-recommended upper limit (600 mg/l) in 100% of the cases. Blood bicarbonate levels can be elevated due to metabolic alkalosis, a disease that raises tissue pH. The loss of acid from your body, such as via vomiting and dehydration, can result in metabolic alkalosis.

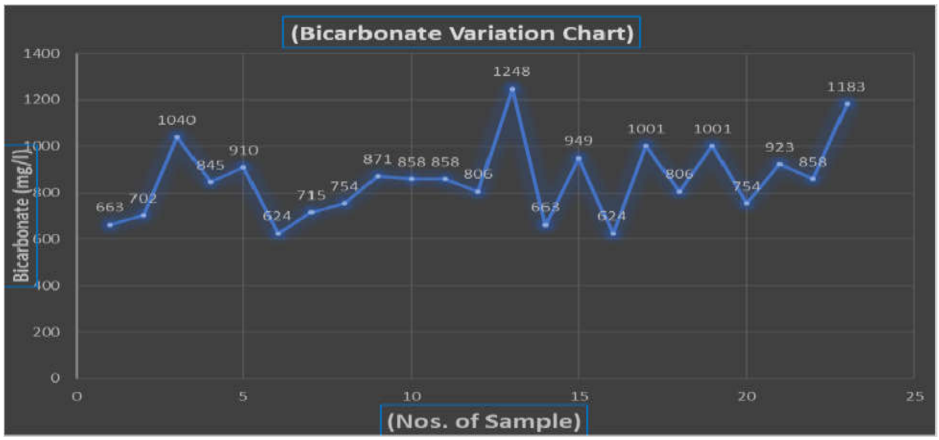


Figure 9: Bicarbonate variation chart

Silica

With an average value of 10.79 mg/l, the silica concentrations in the water samples varied from 6.50 mg/l to 16.60 mg/l. (20 mg/l to 25 mg/l) is the silica concentration range that BIS specifies. Water can become contaminated by silica dust particles, which are extremely minute and nearly 100 times smaller than the sand found on beaches. If we continue to consume this tainted water, several chronic health issues, such as kidney damage and renal failure, may result. Diseases include chronic obstructive pulmonary disease (COPD), silicosis, lung cancer, and TB can occasionally be deadly. In addition, exposure to silica has been related to other conditions like cancer and kidney disease.

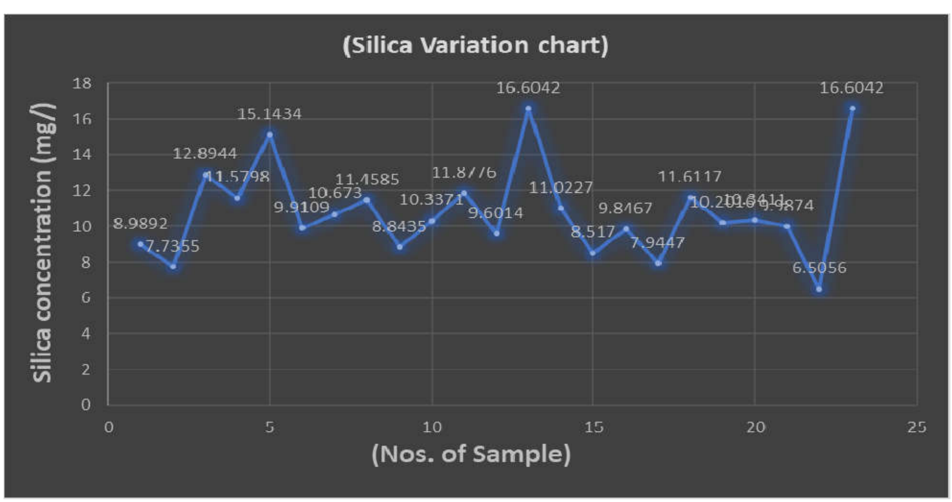


Figure 10: Silica variation chart

Sulfate

With an average value of 149.05 mg/l, sulphates were discovered in the concentration range of 34.95 mg/l to 217.43 mg/l. The results were found to be higher than the BIS-recommended standard limit (200 mg/l) in 4.3% of the samples. The amount of sulfate in water affects its acceptability for use in industrial and public sources. Water with a greater sulfate content might make the alimentary canal malfunction and has a cathartic impact on people. Due to studies linking diarrhea to consuming water with high amounts of sulfate, health concerns surrounding sulfate in drinking water have been raised. Groups within the general population are a cause for worry because they may be more susceptible to the laxative effects of sulfate when they abruptly switch from drinking water with low sulfate concentrations to drinking water with high sulfate concentrations.

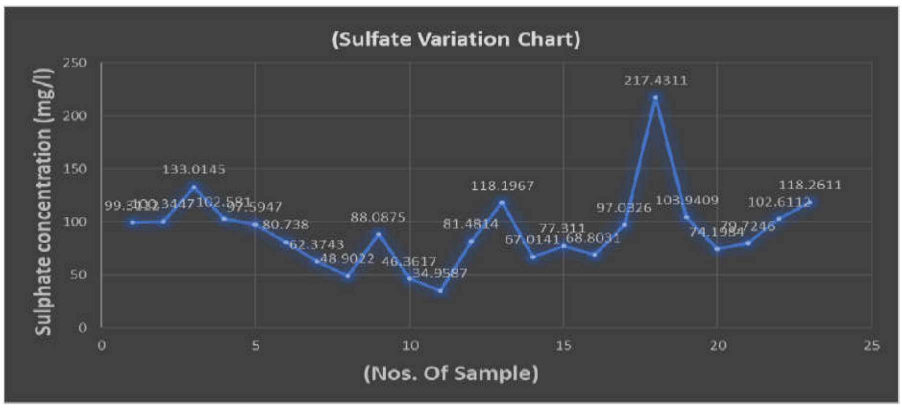


Figure 11: Sulfate variation chart

Fluoride

The investigated area's fluoride concentrations vary from 0.25 mg/l to 1.88 mg/l, with an average of 1.075 mg/l. The results were found to be higher than the standard limit (1.5mg/l) set by BIS in 4.38% of the samples. As a trace element, fluoride is advantageous to humans because it prevents tooth decay and promotes bone growth. However, fluorosis and fluorodemaare also brought on by excessive fluoride levels.

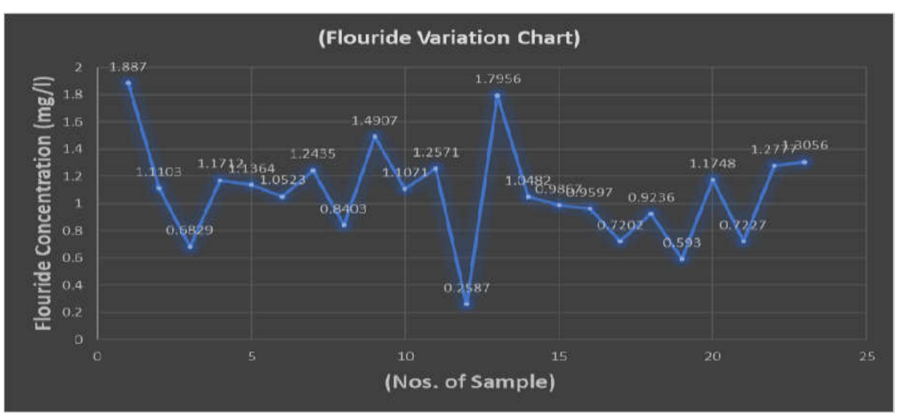


Figure 12: Fluoride variation chart

Sodium

The results indicate that salt concentrations in the studied locations vary from 44.06 to 99.54 mg/l, with an average value of 78.16. The amount of salt in drinking water is 200 mg/l as per WHO guidelines. A very high oral intake of sodium chloride may result in stomach pain, diarrhoea, vomiting, dehydration, convulsions, twitching muscles, and even death. The main adverse health impact for long-term, low-level exposures is hypertension, or elevated blood pressure. A substantial amount of research indicates that consuming too much salt causes age-related rises in blood pressure that result in hypertension.

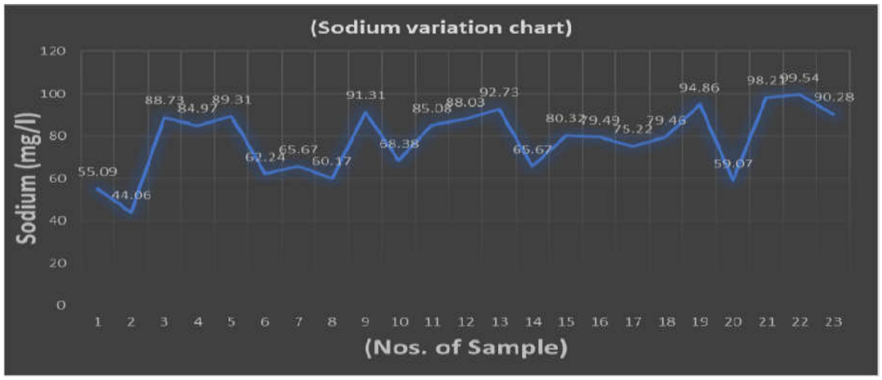


Figure 13: Sodium variation chart

Potassium

The WHO has established a potassium acceptable limit of 12 mg/l. According to the findings, the potassium content in the research sites ranged from 0.1 to 9.99 mg/1. Has a 6.52 mg/l average value. High levels of potassium chloride disrupt nerve impulses, which impairs almost all body processes but primarily the heart's ability to beat. At quantities as low as 2 g, potassium alum can produce stomachaches and nausea, and at greater concentrations, it can be caustic and even fatal. Potassium deficiency is generally uncommon, but it can cause sadness, weakened muscles, irregular heartbeat, and disorientation.

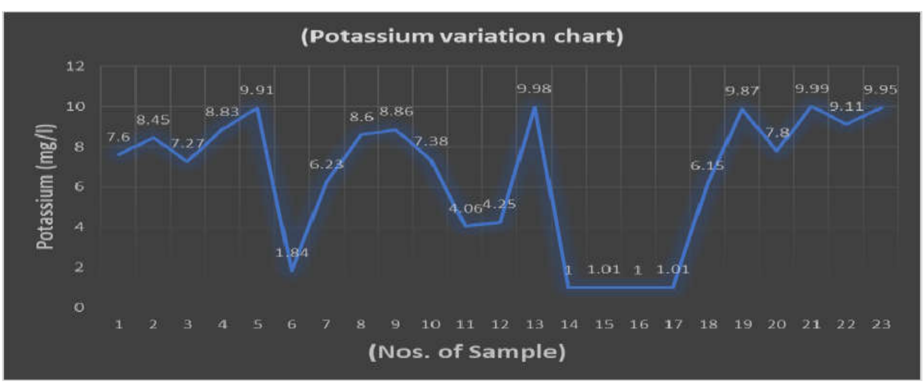


Figure 14: Potassium variation chart

Statistical Analysis

Studies on the quality of groundwater frequently make use of multivariate statistical analysis techniques.

The statistical analysis used in the present work shows how valuable it is for enhancing our understanding of groundwater composition and identifying the natural associations between the variables. The correlation coefficient is used to gauge how strongly two continuous variables are correlated. This indicates if the relationship between the variables is positive or negative, i.e., whether one increases when the other increases or decreases when the other increases.

The correlation matrix is given in the table given below.

In the study region, there is a positive correlation between magnesium and potassium. Magnesium levels in groundwater samples from the region were found to be higher than allowed. It indicates that there is a pollution source that is causing the content of magnesium in water to rise. Magnesium and potassium have a positive link with one another in the research region, so if the process keeps going, they will both rise as well.

Table 2: Pearson's correlations

	Calcium	*Magnesium*	*Chloride*	*Bicarbonate*	*Silica*	*Sulfate*	*Flouride*	*sodium*	*Potassium*
Calcium	1								
Magnesium	0.203979466	1							
Chloride	0.485097693	0.543269495	1						
Bicarbonate	0.430193225	0.469826429	0.256369141	1					
Silica	0.094453118	0.530430438	0.358222084	0.553021793	1				
Sulfate	0.276896313	0.483641275	0.66015409	0.309762068	0.21761113	1			
Flouride	0.29627356	0.188614722	0.021219135	0.041563401	0.217432501	0.00838716	1		

sodium	0.171764394	0.358285797	0.436465607	0.6519542	0.283624741	0.239433822	0.166270722	1	
Potassium	0.136037462	0.798394424	0.179232639	0.410296994	0.351827431	0.2394692	0.278395064	0.275204434	1

Hill-Piper diagram

It was developed by Hill (1940) and Piper (1944). This diagram consists of two triangles and diamond shaped structure in between these two triangles. The triangles contain Cations and Anions in left and right triangles respectively. The central diamond shaped structure consist of plots which is extended from these two triangles. We can analyse the water quality by looking the facies of Cations or Anions which they fall in. Each triangle consists of four facies, in Cation triangle, Ca type, Mg type, Na+K type and no dominant type in centre of the triangle and in Anion triangle, sulphate type, chloride type, bi-carbonate type and no dominant type.

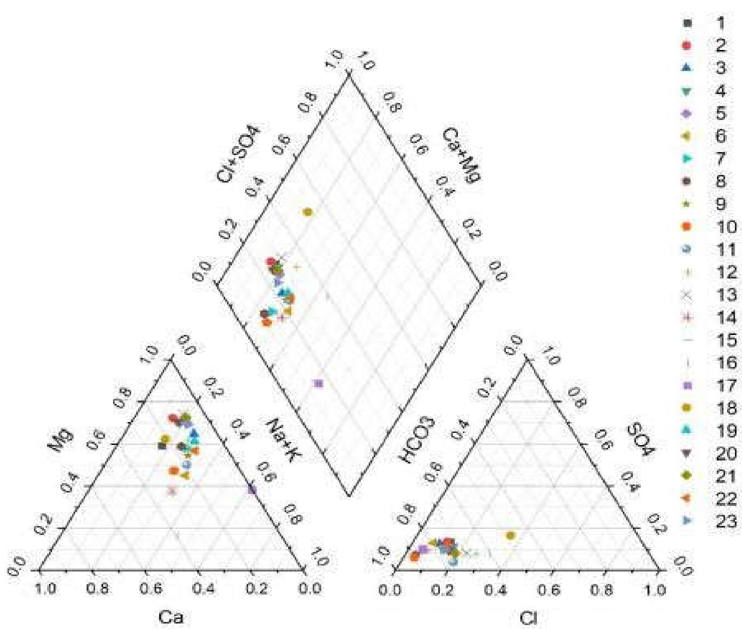


Figure 15: Hill-Piper diagram

CONCLUSION

Studies on the incidence of diseases and metal toxicity in Aligarh demonstrate that this industrial city has a poor history for health. The quality of the groundwater is also substandard. The results of the current study show that the World Health Organization's (2006) permitted values for the elements calcium, magnesium, bicarbonate, and sulphate are exceeded in the drinking water of the study location. The poor health of the locals indicates that this high concentration may be having an adverse impact on them. A positive association between some of the components that are affecting the environment may be seen, according to the statistical analysis of the elements. Therefore, given the present situation, an upsurge in one element may result in an increase in the concentration of other elements. The current study included certain restrictions. Therefore, it is advised that water quality evaluations be conducted periodically with a focus on constituents to produce more accurate findings. It is necessary to analyse the soil and the crops grown in the town's surroundings that are consumed by the residents in order to determine the concentration of elements in them.

In the absence of any relevant databases in the public health authorities, a questionnaire must be developed to regularly assess the local health situation. The responses from J N Medical college and nearby private clinical practitioners should also be included on this questionnaire. To conclude that the town's bad health is being caused by the polluted drinking water, a more thorough link between the components present in the water and the prevalence of diseases must be made. The health of the population must be protected; hence, safety precautions must be taken. 47.82% of the samples tested for pH were found to be over the BIS-recommended minimum range (6.5 to 8.5). In the case of hardness, 86.9% of samples were found to be beyond the BIS-recommended standard level (200 mg/l). The standard limits of 75 mg/l and 30 mg/l specified by BIS for calcium and magnesium, respectively, were found to be exceeded in 4.34% and 86.95% of samples. In the instance of bicarbonate, 100% of the sample had bicarbonate readings that were higher than the BIS-recommended upper limit (600 mg/l).

REFERENCES

1. Franks F, (2000). Water: A Matrix of Life, 2nd Edition, RSC Paperback, UK, pp 225.
2. Mohrir A. Ramteke D.S., Moghe C.A., Wate S.R. and Sarin R. (2009). Surface and Groundwater Quality Assessment in Binaregion, IJEP, 9, 22.
3. Kožíšek, František (2003). Health significance of drinking water calcium and magnesium. National Institute of Public Health 29, 9285-9286.
4. APHA (1998) Standard methods for the examination of water and wastewater, 20th edn. American Public Health Association, Washington DC, 220 p
5. Morin-Crini, Nadia, et al. (2022). Worldwide cases of water pollution by emerging contaminants: a review. Environmental Chemistry Letters. 1-28.
6. Bunnell J. E., Finkelman R. B., Centeno J. A. and Selinu O. (2007). Medical Geology: A globally Emerging Discipline. Geologica Acta, 5(3), 273-281.
7. McMahon FG et al. (1982). Upper gastrointestinal lesions after potassium chloride supplements: a controlled clinical trial. Lancet, 2, 1059–1061.
8. McMahon FG et al. (1984). Effect of potassium chloride supplements on upper gastrointestinal mucosa. Clinical Pharmacology and Therapeutics, 35, 852–855.
9. Ramesh, R., Subramanian, V. and Ramanathan, A.L. (2001). Point and Non-point sources of Groundwater Pollution: Case Studies along the East Coast of India. Proceedings of the International Workshop on Ecohydrology, Capital Publishing Company, New Delhi, India, pp107.
10. Hill (1940). Geochemical patterns in the Coachella valley, california, Transand Laboratory Staff, USDA Handbook. 60 : 160.
11. Piper (1994). Graphical procedure in the geochemical interpretation of water analysis.
12. WHO (World Health Organization) (2004). Guidelines for drinking water quality, vol 1, 3rd edn. WHO, Geneva, p 515.

****