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Examining the Physico-Chemical Parameters of Groundwater Quality: The Case of Farrukhabad District, India

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Abstract Water quality is a critical problem for humanity since it is directly related to human health, environmental preservation, and long-term development. The groundwater is water that is held beneath the ground surface in the microscopic pore spaces between rock, sand, soil, and gravel. The present study is being carried out in the district of Farrukhabad to study the quality of groundwater and its appropriateness for drinking. For this purpose, six physical and six chemical characteristics were measured in a total of fourteen groundwater samples (pH, turbidity, total alkalinity, total hardness, electrical conductivity, total dissolved solids (TDS), Ca, Mg, Cl, F, NO_3 and HCO_3). Further to analyze the quality of groundwater and its appropriateness for drinking purposes each computed parameter was compared to the Bureau of Indian Standards' 2012 desired limits. The pH value ranges from 7.10 to 7.79, indicating that the groundwater in the studied region is slightly alkaline. Groundwater can be classified as hard to very hard depending on total hardness, which varies from 188 mg/l to 556 mg/l. All the water samples had Ca, Mg, Cl, and F levels within permissible limits. As per the Water Quality Index (WQI) classification, the majority of the samples are classified in the good water categories, except S12 and S13 samples, which show poor water quality. According to the Pollution Index of Groundwater (PIG) classification, the majority of the samples had negligible to low pollution This paper from the findings of this study, concludes that the groundwater in the Farrukhabad district is of good quality, hence making it suitable for drinking.

Keywords: *Physico-chemical parameters, Water Quality Index (WQI), Pollution Index Groundwater (PIG), Groundwater Quality, Farrukhabad, India*

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1. Introduction

Water is the most valuable gift that nature has given to us. It is highly important for the survival of all living creatures and plays a critical function in human existence. Water that is stored below in the minute pore spaces between rock, sand, soil, and gravel is known as groundwater. Groundwater is the world's biggest unfrozen water supply, with salt concentrations that are almost balanced for human consumption. For many people living in both rural and urban areas, groundwater is an important source of drinking water because it is thought to be much cleaner and pollution-free than surface water. “Groundwater is used for drinking and other uses in numerous Indian states where more than 90% of the population is reliant on it [1,2].

One of the most basic requirements for living beings is clean water. Groundwater extraction has risen significantly, because huge areas of the nation have minimal access to rainfall due to monsoon failures and unpredictable surface flow of water sources like lakes, rivers and artificial basins. Due to an increase in human activity, the availability of pure water is diminishing day by day. “Overcrowding, unplanned urbanization, unrestrained exploration policies, and the discharge of dirty water in inappropriate locations all contribute to the penetration of dangerous substances into ground water [3].

“Rapidly growing populations, intense agricultural operations, exponential industrial expansion, and urbanization have increased water demand to the point that it has harmed both the quality and quantity of groundwater [4]. The reckless discharge of several harmful effluents from diverse enterprises has caused irreversible damage to the chemical and biochemical quality of both surface and groundwater. "The quality of groundwater is determined by the processes and reactions that occur on the water from the time it condenses in the atmosphere until the time it is released by a well or a spring, and it varies by location and water table depth [5].

Long-term discharge of industrial effluents, domestic sewage, and solid waste into landfills causes groundwater pollution and health hazards. "A link between cardiovascular mortality and water intake has been discovered in several studies [6]. Since, the water quality directly affects human health, environmental preservation, and long-term development, water quality is a serious issue for humanity. A rise in the occurrences of outbreaks of infections caused by water has been seen, posing health risks to the residents, whose primary source of water supply is underground water. Many illnesses are caused by the environment's failure to adequately fulfill man's and animals' mineral demands. Dietary problems can take the form of simple deficiencies or excesses. A connection between cardiovascular mortality and water composition has been identified in several researches. The current study was performed to evaluate the water quality of the Farrukhabad district and its appropriateness for drinking, taking into account the aforesaid elements of surface/groundwater pollution.

2. Study Area: The Farrukhabad District

2.1. An Overview

The Farrukhabad district is situated in Uttar Pradesh's western region, between latitudes 26°46'00" and 27°43'00" N and longitudes 79°07'30" and 80°02'00" E. Farrukhabad is the district headquarters, with 3 tehsils: Kaimganj, Farrukhabad and Amritpur. The district is subdivided into to 7 blocks namely Barhpur, Kamalganj, Mohamdabad, Kaimganj, Shamsabad, Nawavganj and Rajepur. According to the 2011 census, Farrukhabad has a population of 18.87 lacs, with 53.36 percent of men and 46.63 percent of women. The population density is 858 people per square kilometer.

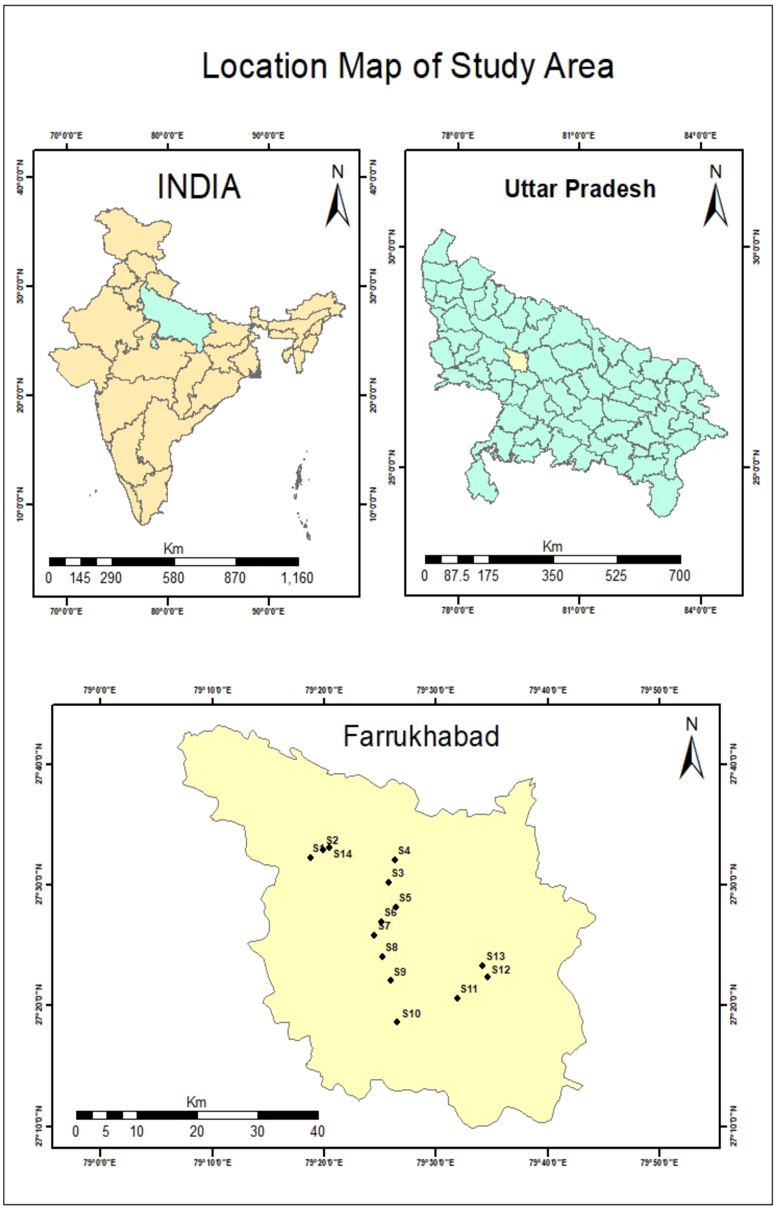

Figure 1. Location map of the study area along with sampling locations

2.2. Physiography of the Region

Physiographically, the district is located in the heart of Indo Gangetic alluvial plain. Between the Ganga and the Ramganga rivers lies Rajepur block. Groundwater and canals are the district's primary sources of irrigation. The canal has a total length of 144 kilometers and irrigates a total area of 2862 hectares. There are 285 government tube wells that irrigate a total of 4874 hectares. A total of 129691 hectares are irrigated by private tube wells. As a result, ground water irrigates 97.92 percent of the land. There are 148630 hectares of net planted land and 137800 hectares of net irrigated land. The ratio of net irrigated to net planted area is 92.71 percent. There are 883 India Mark II hand pumps serving 1228860 people with clean drinking water. Also 5 deep and 2 shallow tube wells were built as part of CGWB's ground water research effort to identify the system of aquifers and its hydrogeological features.

2.3. Climate and Rainfall

The area receives an average of 810 mm of rain each year. Hot and dry summers and a nice cold winter season characterize the climate, which is subtropical humid. From June through September, around 88 percent of the rain falls. During the monsoon, there is a surplus of water available for deep percolation into the earth. The average daily lowest temperature is around 8° Celsius, while the average daily maximum temperature is around 23° degrees Celsius. With a mean maximum temperature of 41°C and a mean minimum daily temperature of 26°C, may is the warmest month. The arrival of the monsoon brings a significant decrease in daytime temperatures. The average monthly maximum temperature is 32.2° Celsius, while the average monthly lowest temperature is 19.5° Celsius. The humidity is high throughout the South-West monsoon season, and it gradually decreases once the monsoon has passed. The monthly mean relative humidity in the morning is 65 percent, while the monthly mean relative humidity in the evening is 47 percent. The winds are usually light. The wind is blowing at 9.6 km/h. The evapotranspiration potential is 1464.5 mm.

2.4. Hydrogeology

In the Ganga-Yamuna Doab, the Farrukhabad covers a small portion of the Indo-Gangetic alluvial plain. The region is underlain by quaternary sediments that mostly consist of clay, fine to coarse sand, and gravels in different quantities and different grades. The CGWB has dug five boreholes in the district as part of its exploratory drilling project. The examination of subsurface lithological logs indicates 4 different granular zones, separated by poorly permeable / impermeable horizons, down to a depth of 450 mbgl. Each granular zone represents a different sedimentological cycle or habitat. Farrukhabad district has four types of aquifer systems based on drilling data. At a depth of 27 mbgl-100 mbgl, the first aquifer system comprises of fine to medium sand, kankar, and occasionally coarse sand and gravels. The second aquifer system is made of fine to medium sand and is located at a depth of 140 mbgl-200 mbgl. The third aquifer system, which consists of fine-grained sand and clay, is located at a depth of 240 mbgl-310 mbgl. The fourth and final aquifer system comprises of fine-grained sand and is found at depths of 405 mbgl-440 mbgl.

3. Research Methodology

3.1. Collection of Samples

Total of 14 samples were obtained from the designated locations in the Farrukhabad area namely (Rutaul village (S1), Kaimganj Bus Stand (S2), Faizbagh (S3), Kotwali Shamsabad (S4), Railway Crossing Shamsabad (S5), Nawabganj (S6), Nawabganj (S7), Karanpur (S8), Sirauli Mohamadabad (S9), Rohilla Mohamadabad (S10), Kamalganj (S11), Dilawal Farrukhabad (S12), Farrukhabad railway station (S13), Kaimganj Bajaar (S14)), as indicated in Table 1. The groundwater sample site points were coordinated using the GPS. Water samples from the hand pumps were collected in plastic bottles of 1L each. These bottles were marked once the samples were collected, and every effort was made to get them to the laboratory as soon as possible for Physico-Chemical examination.

3.2. Physico-Chemical Analysis

Analysis of collected water samples was carried out for six major physical and chemical parameters which includes pH, Turbidity, Total alkalinity, Total hardness, Electrical Conductivity, Total dissolved solids, Calcium, Magnesium, Chloride, Fluoride, Nitrates and Bicarbonates. Turbidity was measured using the Nephlometer, pH using pH meter, Total alkalinity using indicator technique, Total dissolved solids using TDS meter. The filtration method was used to assess total hardness, calcium and magnesium hardness, and the silver nitrate method was used to determine chloride.

Table1. Groundwater sampling locations of Farrukhabad district

Sample No.	Latitude	Longitude	Location Name
S1	25.537	79.312	Rutaul Village
S2	27.548	79.331	Kaimganj Bus Stand
S3	27.503	79.429	Faiz Bagh
S4	27.533	79.438	Kotwali Shamsabad
S5	27.468	79.439	Railway crossing Shamsabad
S6	27.448	79.418	Nawabganj
S7	27.429	79.408	Nawabganj
S8	27.401	79.419	Karanpur
S9	27.367	79.432	Sirauli Mohamadabad
S10	27.309	79.442	Rohilla Mohamadabad
S11	27.343	79.533	Kamalganj
S12	27.972	79.576	Dilawal Farrukhabad
S13	27.383	79.569	Farrukhabad Railway Station
S14	27.551	79.341	Kaimganj Bazar

4. Results and Discussion

Fourteen distinct locations in Farrukhabad district were selected to study the physio-chemical analysis of groundwater.

These samples were inspected for six physical (pH, Turbidity, Total hardness, Electrical conductivity, Total dissolved Solids) parameters and six chemical (Calcium, Magnesium, Chloride, Fluoride, Nitrate, Bicarbonate) parameter. The results thus obtained were compared to the one given out by Bureau of Indian Standard under Indian standard drinking water specification IS: 10500:2012.

4.1. Physical Parameters

The findings of the analysis of six physical characteristics are reported in Table 2.

Table 2. Values of physical parameters

Sample No.	pH	Turbidity	Total Alkalinity	Total Hardness	Electrical Conductivity	TDS
S1	7.68	0	450	192	624	265
S2	7.79	0	355	188	664	213
S3	7.68	4	416	22	612	371
S4	7.59	2	580	472	600	576
S5	7.53	0	340	250	642	344
S6	7.48	0	380	196	450	237
S7	7.10	1	292	524	461	538
S8	7.10	1	340	496	442	560
S9	7.20	2	345	202	1230	435
S10	7.27	1	252	334	1152	376
S11	7.38	3	638	556	1064	287
S12	7.43	0	262	324	1024	357
S13	7.12	3	476	362	1021	599
S14	7.22	2	410	312	1429	497

4.1.1. pH Scale of Water

An aqueous solution's acidity or basicity is measured using pH scale. The pH of acidic solution (those with a higher concentration of H+ ions) is lower than that of basic or alkaline solution. The pH scale is logarithmic, with inverse order showing the concentration of hydrogen ions. "pH is an essential ecological component that gives a vital piece of information and a role in many types of geochemical equilibrium and solubility calculations [7]. The groundwater in the research region was somewhat alkaline. The pH values of the collected samples fluctuated between 7.10-7.79 and were found within the acceptable limit of 6.5-8.5 [8].

4.1.2. Turbidity

Turbidity can be defined as the amount of cloudiness of water, which is pre-dominantly because of suspended particles such as 'clay', 'silt', 'organic' and 'inorganic matter'. The turbidity of the study region ranges between 0-4 NTU which lie within the acceptable limit of BIS i.e. 5 NTU.

4.1.3. Total Alkalinity

Total alkalinity is known as the ability of water to neutralize acids. Alkalinity is caused mostly by minerals dissolved in water which are obtained from soil's rich in minerals. Ammonia or hydroxide may also be responsible for alkalinity in rare situations. The total alkalinity of research area fluctuated from 262 mg/l to 638 mg/l. All of the samples obtained were under the BIS permissible limit i.e. 600 mg/l except the sample S11 collected from Ratanpur (Kamalganj).

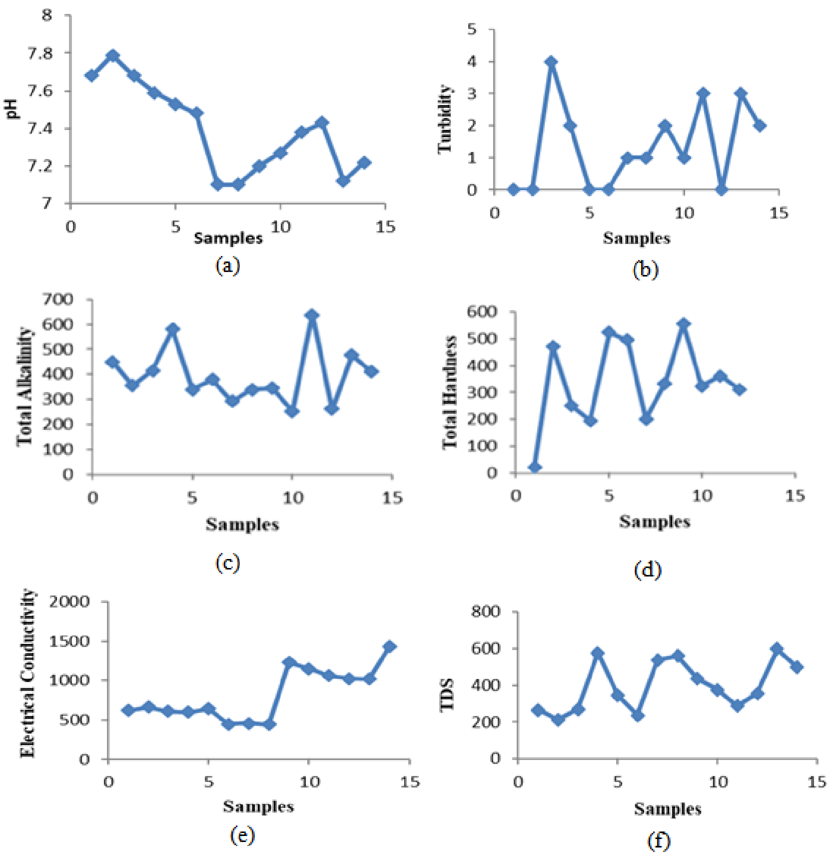

Figure 2. Variation of Physical Parameters (a) pH (b) Turbidity (c) Total Alkalinity (d) Total Hardness (e) Electrical Conductivity (f) TDS

4.1.4. Total Hardness

Water's hardness is a characteristic that hinders soap from forming lather and raises the boiling point of water. The research area's total hardness varies from 188 mg/l – 556 mg/l in which the majority of samples are exceeding the acceptable limit i.e. 200 mg/l but all the collected samples are under the permissible limit i.e. 600 mg/l of BIS.

4.1.5. Electrical Conductivity

Electrical conductivity, also known as specific conductance, is a material's or a solution's ability to conduct electric current. Electrical conductivities of the study area were in the range 442 µmhos/cm to 1429 µmhos/cm. "The presence of high quantities of Na, K, and Cl in groundwater is indicated by high electrical conductivity readings[9].

4.1.6. Total Dissolved Solids

Total Dissolved Solids (TDS) is a metric used to calculate the total quantity of organic and inorganic components in a liquid. Anything in water that isn't pure H_2O molecules are referred to as this. The most prevalent solids are minerals, salts, organic materials and they can serve as a general indication of water quality. All the samples that were collected are in the range of 213 mg/l to 599 mg/l which fall under the BIS limit i.e. 500 mg/l to 2000 mg/l.

4.2. Chemical Parameters

Analysis of six chemical parameters was carried out and the results are reported in Table 3.

Table 3. Values of chemical parameters

Sample No.	Calcium	Magnesium	Chloride	Fluoride	Nitrate	HCO_3
S1	82	64	24	0.66	2.6	276
S2	88	66	26	0.42	2.9	287
S3	96	74	42	0.32	6.2	235
S4	120	84	46	0.36	7.8	246
S5	110	70	41	0.40	15.2	239
S6	72	56	7.4	0.30	5.4	230
S7	165	52	10	0.31	5.9	224
S8	174	61	6	0.34	5.2	278
S9	76	51	92	0.61	18	314
S10	86	62	84	0.69	22	408
S11	108	42	196	0.16	6	326
S12	136	88	210	1.45	9.2	356
S13	142	92	186	2.26	10.4	380
S14	113	90	23	0.62	3.1	283

4.2.1. Calcium

Calcium is found naturally in water. Presence of calcium is mainly due to dissolution from the rocks such as calcite, apatite, marble, limestone, gypsum, dolomite and fluorite in the aquifer. The calcium concentrations were observed and were in the range of 72 mg/l to 142 mg/l which lies within the BIS permissible limits i.e. 200 mg/l. Calcium concentration increases when groundwater comes in contact with porous rocks containing deposit of minerals like limestone or dolomite. Calcium is mainly responsible for water hardness, and it may have an adverse effect on other chemicals' toxicity.

4.2.2. Magnesium

Magnesium is a key component in influencing the quality of groundwater. Magnesium gets washed down from the rocks and ends up in the water. Magnesium serves a variety of functions, and as a result, it may wind up in water in a variety of ways. Magnesium is an essential mineral that is consumed by all organisms except insects. It is a necessity for plant photosynthesis since it is a central atom of the chlorophyll molecule. Magnesium is present not just in saltwater but also in rivers and rainwater, allowing it to diffuse organically throughout the ecosystem. High concentration of magnesium is considered as hard water. The concentrations of magnesium found in all the 14 samples lies within the range of 42 mg/l to 92mg/l. According to BIS, the maximum amount allowed in drinking water is 100 mg/l.

4.2.3. Chloride

Natural water has a wide variety of chloride concentration. Chlorides are a frequent kind of water pollution. The presence of excessive quantities of chloride ions in ocean water is the primary cause of its unsuitability for drinking. Chloride contamination in surface water can occur as a result of adjacent salt storage or salty rocks, freshwater mixing with ocean water, and the breakdown of salty industrial wastes, among other things. The leaching of salts from the soil into the well reservoir of water results in the presence of chloride, which is a typical cause of well water pollution. The acceptable limit of chloride according to BIS is 250 mg/l. The concentrations of chloride in all the samples fluctuated between 6 mg/l to 210 mg/l. Chloride make water corrosive by increasing is electrical conductivity.

4.2.4. Fluoride

"Fluorine is the lightest of the halogens and one of the most reactive elements in the universe [10]. "Fluorine is a negatively charged ion that is found in water in small amounts or in high concentrations as a significant ion [11,12,13]. Exposure of drinking water with more than 1.5 ppm fluoride for a long term can cause health issues as mentioned by the WHO. According to the Bureau of Indian Standards, the maximum amount of fluoride allowed in drinking water is 1.5 mg/l [8]. Fluoride values in all of the samples range from 0.16 mg/l to 2.26 mg/l.

4.2.5. Nitrates

Natural nitrate concentrations in groundwater are typically relatively low (less than 10 mg/l NO3), but human activities such as agriculture, industry, residential effluents, and combustion engine emissions cause nitrate concentrations to grow. The concentration of nitrate found in all the samples are in the range of 2.6 mg/l to 22 mg/l and the acceptable limit of nitrates according to BIS is 45mg/l. Groundwater pollution can directly influence human health because high amounts of nitrate in drinking water have ill-health effects on human well-being.

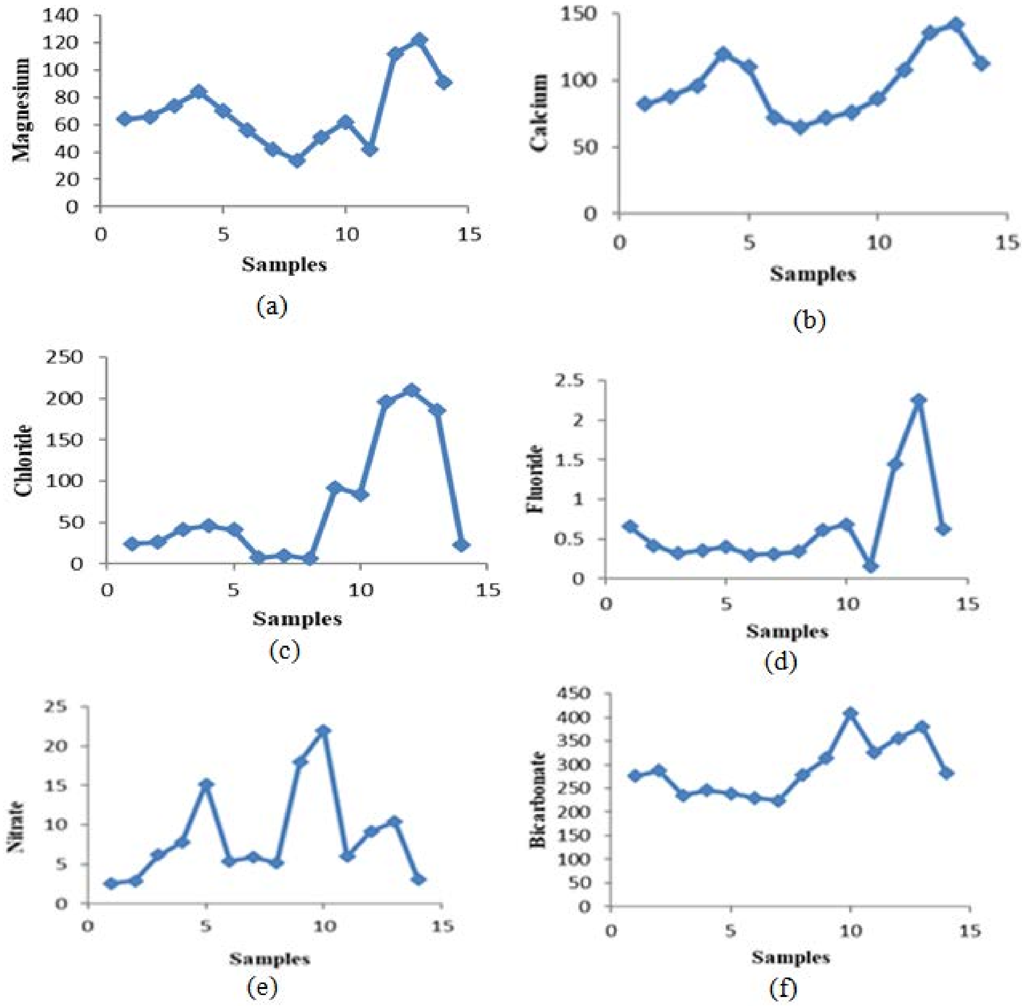

Figure 3. Variation of chemical parameters (a) Calcium (b) Magnesium (c) Chloride (d) Fluoride (e) Nitrate (f) Bicarbonate

4.2.6. Bicarbonates

"The existence of organic materials in the aquifer that is oxidized to create carbon dioxide, which promotes mineral dissolution, is one probable source of bicarbonate) [14]. "Half of the bicarbonate ions would come from the fossil carbon in the calcite and dolomite in the aquifer. This weathering adds calcium, magnesium, and bicarbonate ions to the groundwater. The weathering of silicate minerals can produce bicarbonate ions [15]. The bicarbonate concentration in the groundwater samples fluctuated between 224 to 408 mg/L and the BIS permissible limit of bicarbonate is 600 mg/L

4.3. Water Quality Index (WQI)

In urban, rural, and industrial contexts, the water quality index (WQI) is a valuable tool for assessing the quality of drinking water. WQI is defined as an index that indicates the combined influence of numerous water quality parameters that are examined and factored into the water quality index calculation. The BIS drinking water quality standard from 2012 was used to calculate the WQI. "Three stages were taken to calculate WQI [16-24]. The initial stage was to give a weight (w_i) to each of the nine parameters (pH, turbidity, EC, TDS, Total hardness, Calcium, magnesium, Nitrate, and fluoride) based on their perceived impacts on primary health. "Because of their relevance in determining water quality, metrics including total dissolved solids, chloride, sulphate, and nitrate have been given a maximum weight of 5 [25]. As stated in Table 4, the relative weight in the second stage (Wi) was calculated using the following equation.

$$W_i = \frac{wi}{\sum_{i=1}^{n} wi}$$

Where, $w_i \rightarrow$ Weight of each parameter
$n \rightarrow$ Number of parameters
$W_i \rightarrow$ Relative weight

Table 4. Relative weight of parameters

Chemical parameter	Indian standard (BIS) 10500 2012	Weight (w_i)	Relative weight $W_i = w_i/\sum_{i=1}^{n} wi$
Ph	8.5	4	0.148148
TDS	500	4	0.148148
Total Hardness	200	2	0.074074
Calcium	75	2	0.074074
Magnesium	30	2	0.074074
Nitrate	45	5	0.185185
Fluoride	1	4	0.148148
Chloride	250	3	0.111111
Bicarbonate	200	1	0.037037
		Σw_i=27	ΣW_i=1

In the third step, the following equation was used to rate the quality (qi) of each parameter.

$$q_i = \frac{(Ci - CiO)}{(Si - SiO)} * 100$$

Where, $C_i \rightarrow$ Estimated value of each parameter
$S_i \rightarrow$ Standard desirable limit
$C_iO \rightarrow$ Ideal value of each parameter

To calculate the WQI, the sub index (SIi) of each individual parameter was first calculated using the equation below.

$$SI_i = W_i x q_i$$

The total WQI is calculated by adding the SIi of all groundwater samples together.

$$WQI = \Sigma SI_i$$

The calculated WQI for all the samples of the study area ranges from 51.21 to 129.55 as shown in Table 5. Overall the groundwater of the study area is good for drinking. Processes such as septic tank leakage, waste water infiltration, agricultural fertilizers, and effluent discharged from various businesses can all be implicated for the samples showing poor quality. This research shows that using WQI techniques to analyze water quality can give helpful information.

Table 5. Values of WQI and type of water in the study area

Samples	WQI	Status	Water Quality Index (mg/l)	
S1	62.605	Good		
S2	59.950	Good		
S3	56.824	Good		
S4	88.111	Good		
S5	71.263	Good	<50	Excellent
S6	51.215	Good	50-100	Good
S7	64.739	Good	100-200	Poor
S8	64.048	Good	200-300	Very Poor
S9	68.792	Good	>300	Unfit for use
S10	80.544	Good		
S11	73.474	Good		
S12	109.104	Poor		
S13	129.553	Poor		
S14	78.807	Good		

4.4. Pollution Index of Groundwater (PIG)

PIG is an important technique for assessing groundwater quality variations caused by geological and anthropogenic factors, as proposed by [26]. It's a numerical scale that determines the severity of several water quality metrics. PIG is calculated in five step process. In step 1 the factors (pH, TDS, Cl, HCO_3, NO_3, F, Ca and Mg) based on the impact they have on human health, they were given a relative weight (Rw) ranging between 1 to 5. The weight parameter was determined in the second stage using the following equation (Wp).

$$W_p = \frac{R_w}{\Sigma R_w}$$

In third Step, each parameter's concentration status (S_c) was calculated by dividing the water quality standard limit, as specified by BIS, 2012 using the given equation.

$$S_c = \frac{C_i}{D_s}$$

Where Ci is the concentration of each chemical parameter, and Ds denotes the standard of drinking water quality for each chemical parameter. Finally, the overall chemical quality parameter (Ow) was collected in the fourth and fifth steps, and PIG was calculated using the calculations below.

$$O_w = W_p * S_c$$

$$PIG = \Sigma O_w$$

If the concentration of water quality indicators in a specific water samples are the same as in drinkable water, the health consequences of the water quality may be insignificant. As per the pollution index of groundwater categorization, majority of the samples of research area lie within the range of insignificant pollution to low pollution as shown in Table 6.

Table 6. Values of Pollution Index of Groundwater (PIG)

Samples	PIG	Status	Pollution Index of Groundwater (mg/l)	
S1	0.701	Insignificant Pollution		
S2	0.664	Insignificant Pollution		
S3	0.684	Insignificant Pollution		
S4	0.842	Insignificant Pollution		
S5	0.754	Insignificant Pollution	< 1	Insignificant Pollution
S6	0.583	Insignificant Pollution	1 – 1.5	Low Pollution
S7	0.639	Insignificant Pollution	1.5 – 2	Moderate Pollution
S8	0.661	Insignificant Pollution	2 – 2.5	High Pollution
S9	0.814	Insignificant Pollution	> 2.5	Very High Pollution
S10	0.897	Insignificant Pollution		
S11	0.722	Insignificant Pollution		
S12	1.161	Low Pollution		
S13	1.394	Low Pollution		
S14	0.850	Insignificant Pollution		

4.5. Correlation between WQI and PIG

The WQI and PIG were compared to see whether there was a possible link between them. The connection between WQI and PIG is quite excellent with $R^2 = 0.9503$. The result shows that WQI and PIG have a positive linear connection. For the evaluation of one of the variable (WQI or PIG) by using the formula as mentioned,

WQI = 93.828*PIG – 0.5653, the other variable should be known. From this aforementioned calculation, it can be deduced that WQI is roughly 100 times beyond the PIG values.

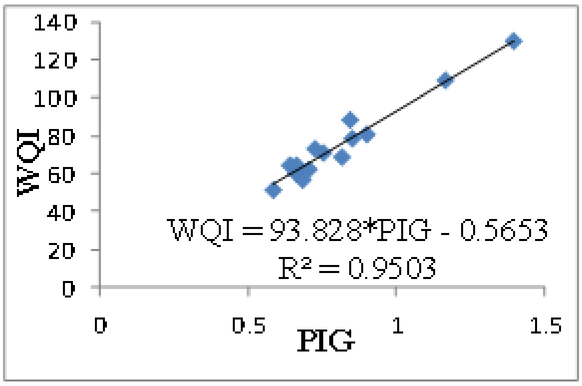

Figure 4. Correlation between WQI and PIG

4.6. Suitability for Drinking

The Physico-Chemical parameters were compared for the groundwater quality with the Bureau of Indian Standards, 2012 guidelines for drinking and human consumption. Six physical and chemical parameters were examined in all of the samples collected. All groundwater samples were below permissible limits for HCO3, Ca, and Mg among the major ions, but had high EC values (all the samples exceeded permissible limits except three samples). All groundwater samples, on the other hand, were found to be within the allowable pH ranges and the groundwater in the study region was slightly alkaline. The weathering and dissolution of aquifers are accountable for high concentration of F in groundwater. F is necessary for the development of bones and teeth in small amounts, but high levels of F in groundwater can induce bone deformation and dental issues. Except for 7% of the samples that exceeded the permissible limit of 15 mg/l, all of the collected samples were found to be under the permissible limit of BIS, 2012. Before consumption, samples that exceed permissible limit should be treated.

WQI and PIG were employed to assess the quality of the groundwater. The WQI values for the samples collected varied from 51.21 to 129.55, with an average of 75.64. According to the Water Quality Index, 12 of the 14 samples (85.71%) have good water quality, whereas 2 samples (14.28 %) have poor water quality. PIG is a pollution index for groundwater that works similarly to WQI. According to PIG's conclusion, 85.71 percent of 14 samples fall into the insignificant pollution category, while 14.28 percent fall into the low pollution category.

5. Conclusions

The area's fast population expansion increases resident's reliance on groundwater, yet the quality of the groundwater isn't up to the mark. People need to be more conscious about illustrations of groundwater and how different activities might contribute to groundwater contamination. The current research evaluates the appropriateness of groundwater for drinking in the Farrukhabad district using selected groundwater samples. Total fourteen groundwater samples from distinct locations were collected and examined for six physical and chemical parameters in the laboratory. To assess appropriateness of drinking water, the computed data of the collected samples were compared to the BIS, 2012 drinking water standard. IS: 10500:2012. Overall, groundwater of the study region illustrates alkaline nature and is classified as hard to very hard water type. The pH of the samples collected ranges from 7.10 to 7.79. All of the collected samples' turbidity, total hardness, and total dissolved solids values are within the BIS, 2012 permitted limits. Except for one sample taken from Ratanpur (Kamalganj), total alkalinity values are within permissible limits. Calcium, Magnesium, Chloride, Fluoride, Nitrate, and Bicarbonates were also examined, and the results showed an overall increased concentration, although all of the values were within permitted limits.

Water quality index (WQI) and pollution index of groundwater (PIG) were also calculated to further analyze the groundwater quality of the obtained groundwater samples. The WQI values for the selected samples varied from 51.21 to 129.55, with the majority of samples falling into the category of good water quality. The values of Pollution Index of Groundwater (PIG) varied from 0.58 to 1.39. The majority of the samples, according to the PIG categorization, are classified as insignificant pollution. Although this study used a restricted number of samples and parameters to evaluate groundwater quality and assess its general appropriateness for drinking purposes, it can be stated that the overall groundwater quality of Farrukhabad district is good and the groundwater is safe for drinking. Furthermore, larger investigations of groundwater over a wider range of geographical and temporal dimensions are recommended.

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