Ground Water Pollution: A Comparative Study of Pre and Post Monsoon Season of Aligarh City, U.P. India

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Abstract: ***Groundwater is known as an important source of water supply due to its relatively low susceptibility to pollution in comparison to surface water. Unethical human intervention in natural system and over exploitation of groundwater resources induces degradation of its quality. In many instances groundwater is used directly for drinking as well as for other household, agricultural and industrial purposes, hence the study of groundwater pollution is extremely important. Twenty groundwater samples were collected during pre and post-monsoon period of the year 2024 and analyzed for twenty physico-chemical parameters. The results were compared with the specifications prescribed by the Bureau of Indian standards. It revealed that concentration of some parameters were higher than the permissible limit prescribed by the Bureau of Indian standards. It indicates signs of water quality deterioration.***

Keywords: water quality, physico-chemical parameters, ground water, rain water harvesting

1. Introduction

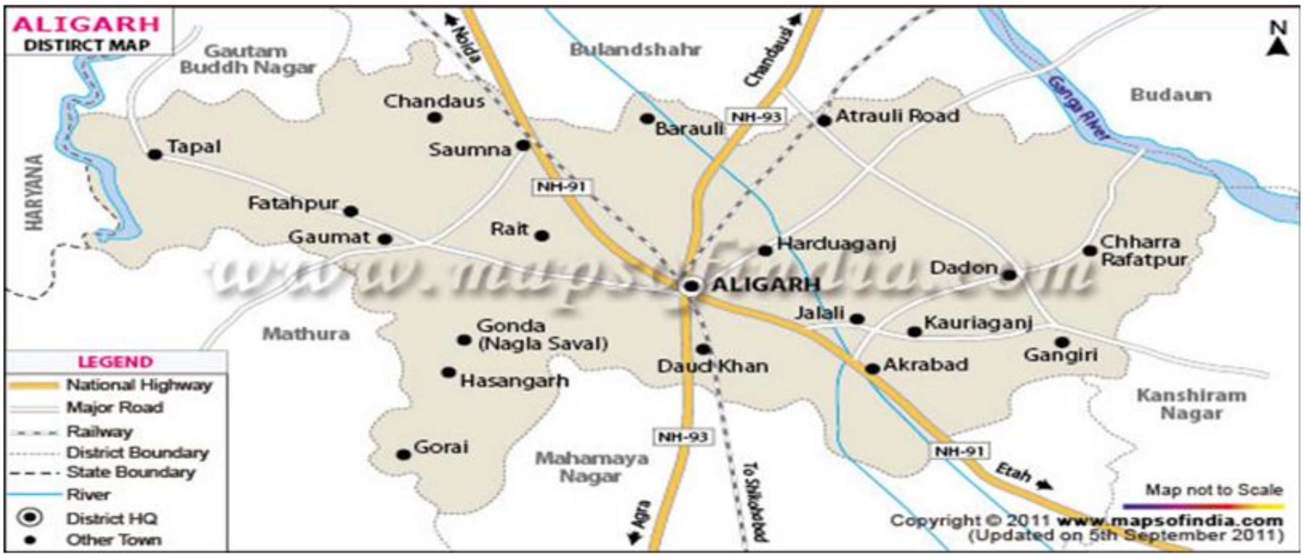
Water, a precious natural resource and national asset, is primary source of drinking water. Groundwater provides drinking water to at least 50% of the global population, and worldwide, approximately 2.5 billion people depend solely on groundwater resources to satisfy their basic daily water needs[1].The anthropogenic disturbances through industrial and agricultural pollution, increasing consumption and urbanization degrade the groundwater quality and impair their use for drinking, agriculture, industrial and domestic uses[2]. Water quality is considered the main factor controlling health and the state of disease in both men and animals[3]. Groundwater quality degradation (pollution) occurs when its quality parameters are changed beyond their natural variations by the introduction or removal of certain substances[4]. Most of the water sources have been either polluted or contaminated by sewage, industrial and agricultural wastes. The problems of groundwater quality are much more acute in the areas which are densely populated, thickly industrialized and have shallow groundwater tables[5].

In the recent past, Aligarh city has witnessed phenomenal growth, which has taken heavy toll of the groundwater resources in the city. The water requirement 205 MLD of the city is fully met by the supplies from groundwater resources. So, it is essential to assess the status of groundwater pollution in Aligarh city.

2. Study Area

The study concentrates on Aligarh city, Uttar Pradesh, India. The Aligarh city lies between the Karwan river in the West and the Senger river in the East, Aligarh lies between latitude 27º 54' and 28º North and longitude is 78º and 78º 5' East. The Aligarh city is spread over an area of about 100.8 km^2. Aligarh has grown as prominent education and commercial centre in Northern India. Aligarh serves as a nucleus for hundreds of ancillary and small-scale industrial units. There are a total of 5506 industrial units in Aligarh city. The indiscriminant growth which is hallmark of Aligarh has left its impressions on the environment. Environmental quality of the area is deteriorated mainly as a result of the increasing industrial activities.

The area falls under sub-tropical climatic zone and is characterized by hot summer and chilly winter. Aligarh experiences the tropical monsoon type of climate with marked North-East and South-West monsoons. Average temperature in summer remains around 28 to 33ºC. Rainy season commences in the middle of June and continues till September. July is the wettest month. The normal annual rainfall is 760 mm. The average relative humidity in the morning is 62.25% and in the evening it is 44.2%.



Hydrogeology of Study Area

Aligarh district falling in central Ganga Plain, lies in inter fluvial tract of Ganga and Yamuna. Geological data indicates that the area is underlain by moderately thick pile of quaternary sediments, which comprises of sand of various grades of clays and kankar. The thickness of deposits varies from 287 to 380 Meter older alluvium occupies the upland while the newer alluvium occupies low land area along the course of Ganga, Yamuna and their tributaries and Kali rivers. Groundwater occurs in the pore spaces of unconsolidated alluvial material in the zone of saturation[6].

In Aligarh district groundwater occurs under water table conditions in the upper zones of first aquifer group while in deeper aquifers it is under semi confined conditions. Depth of water level in the area generally varies from 24.43 to 31.6 M below ground level during pre-monsoon period and during post-monsoon period it ranges between 24.6 and 34.5 M below ground level.

Hydrogeologically, there is a three to four tier aquifer system. Aquifers seem to merge with each other, thus, developing a single bodied aquifer. This makes the aquifer vulnerable to contamination. Due to excessive withdrawal of water from these aquifers, they are highly strained. The discharge of these wells varies from 30 to 50 M^3/hour at a nominal draw down of 3 to 4.5 M[6].

In the area of study main source of groundwater recharge is rain water during the rainy season. Water table fluctuates corresponding to recharge or withdrawal from it. Mainly the recharge takes place during rainy season i.e. June to September and withdrawal during rest of the year. The following three tier aquifer systems have been demarcated in the area.

First Aquifer Group generally occurs between the depth ranges of 00.00-122.00 M below ground level and constitutes the most potential aquifer group, covering almost entire area below soil capping. The aquifer material is sand which is fine to medium grained. This aquifer group forms the main source of water supply to open wells, hand pumps and shallow tubewells. About 90% of state government tubewells have been constructed in this aquifer group. Being the only fresh water aquifer in the area, it holds almost the entire groundwater development activities and thus is overstressed.

Second Aquifer Group is separated with the overlying shallow aquifer group by thick clay and occurs between the depth ranges of 100 to 150 M below ground level. The aquifer material is generally medium sand but at places, it is a mixture of fine to coarse grained sand. The disposition of third aquifer group ranges between 130 and 300 M below ground level. This aquifer group is regionally extensive and in confined state. It has the great quantitative potential but the quality of formation water is brackish to saline. Cumulative thickness of granular zone in this aquifer group varies from 50 to100 M.[7]

The three tier aquifer system seems to merge with each other, thus developing a single body aquifer. This makes the aquifer vulnerable to contamination[8]. In the light of the above criteria; groundwater in the study area is vulnerable to pollution.

3. Material and Methods

In order to achieve the objectives of the present study twenty water samples were collected each during pre-monsoon in the month of May 2024 and post-monsoon seasons in the month of October during the year 2024. The site of sampling is selected randomly by considering the population, location and source. All the sampling, their preservation and procedures carried out for the examination of water samples were performed according the Standard Methods for the Examination of Water and Wastewater recommended by APHA, AWWA, WPCF (2005)[9].

4. Results and Discussion

The results obtained were evaluated in accordance with the standards prescribed under Indian Standard Drinking water specification IS: 10500:1991 of Bureau of Indian Standards[10]. The physical and chemical characteristics of groundwater are tabulated in table 1 & 2.

Table 1: Results of the Physico-Chemical Analysis

Parameters	Pre-monsoon 2024			Post-monsoon 2024		
	Minimum	Maximum	Mean	Minimum	Maximum	Mean
Temperature in ˚C	26.00	33.00	28.95	17.00	24.00	19.88
pH	7.26	8.55	8.25	7.01	8.52	8.28
TDS in mg/L	241.00	581.00	447.43	224.00	563.00	435.88
EC in µ mohs/cm	332.00	1510.00	834.16	344.00	1482.00	826.65
Turbidity in NTU	0.06	0.21	0.17	0.05	0.15	0.13
Iron in mg/L	0.08	0.24	0.19	0.06	0.21	0.15
Nitrate in mg/L	0.21	26.31	6.89	0.19	25.23	6.50
Sulfate in mg/L	15.40	213.30	146.92	13.20	179.20	138.53
Fluorides in mg/L	0.03	0.76	0.26	0.01	0.71	0.26
Chloride in mg/L	78.00	283.00	223.88	52.00	273.00	252.93
Alkalinity in mg/L	161.00	260.00	188.10	156.00	242.00	179.38
Hardness in mg/L	197.00	268.00	257.13	187.00	268.00	260.95
Calcium in mg/L	52.00	76.00	72.43	47.00	87.00	78.95
Magnesium in mg/L	22.56	35.90	30.74	21.02	28.67	25.35
Copper in mg/L	0.007	0.062	0.046	0.004	0.086	0.041
Zinc in mg/L	0.014	1.841	0.398	0.009	1.836	0.391
Manganese in mg/L	0.006	0.109	0.043	0.003	0.142	0.036
Lead in mg/L	0.001	0.019	0.011	0.001	0.013	0.008
Chromium in mg/L	0.000	0.060	0.024	0.001	0.090	0.022
Cadmium in mg/L	0.001	0.0032	0.003	0.001	0.005	0.002

The maximum value of the parameters pH, EC, TDS, hardness, calcium, magnesium, copper, manganese, lead, chromium and cadmium are found more than the limits prescribed by IS: 10500.

Table 2: Comparisons of parameters during pre and post monsoon

Sr. No.	Parameter	Permissible limit as per BIS IS:10500: 2012	No, of sample exceeding permissible limit				Combined % of samples above permissible limit
			Pre-monsoon 2024	%	Post- monsoon 2024	%	
1	Temperature in ˚C	30-40*	0	0	0	0	0
2	pH	6.50-8.50	04	20	01	5	12.5
3	TDS in mg/l	500.00	7	35	5	25	30
4	EC in µ mohs/cm	1500.00	4	20	0	0	10.0
5	Turbidity in NTU	1.00	0	0	0	0	0
6	Iron in mg/l	0.30	0	0	0	0	0
7	Nitrate in mg/l	45.00	0	0	0	0	0
8	Sulfate in mg/l	200.0	2	10	0	0	5
9	Fluorides in mg/l	1.00	0	0	0	0	0
10	Chloride in mg/l	250.00	8	40	6	30	35.0
11	Alkalinity in mg/l	200.00	7	35	2	10	22.5
12	T. Hardness in mg/l	200.00	5	25	3	15	20.0
13	Calcium in mg/l	75.00	2	10	4	20	12.0
14	Magnesium in mg/l	30.00	4	20	0	0	10.0
15	Copper in mg/l	0.05	6	30	4	20	35.0
16	Zinc in mg/l	5.00	0	0	0	0	0
17	Manganese in mg/l	0.10	3	15	3	15	15.0
18	Lead in mg/l	0.01	2	10	3	15	12.5
19	Chromium in mg/l	0.05	3	15	2	10	12.5
20	Cadmium in mg/l	0.003	4	20	2	10	15.0

***Source:** WHO (2006) Drinking water guideline

Physico-Chemical Analysis of Water Quality Parameters

Temperature

Temperature in water quality test is used as a good measure of contamination as it has marked effect on chemical reaction rates in water[11,12,13]. The water temperature controls the rate of all chemical reactions, behavioral characteristics of solubility of gases and salts in water. The results of analysis show temperature of all water samples were within the WHO prescribed limit for drinking water. The maximum water temperature 33^{0}C and minimum 17^{0}C was observed during study period. The variation in temperature may be due to different timing of collection and influence of season[14].

pH

The pH is one of the most frequently used tests in water chemistry[15]. In the present study pH values varied from 7.01 to 8.85 throughout the observation period for all sampling stations. pH values were found higher than the permissible limit prescribed by BIS in 12.5% of the samples. These variations in pH values may be due to the condition of earth and minerals present. Carbon dioxide in groundwater normally occurs at a much higher partial pressure than in the earth's atmosphere. When groundwater was exposed to the

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atmosphere, CO_2 will escape and the pH will rise. A direct relationship between human health and pH of drinking water is impossible to ascertain, because the pH is closely associated with other aspects of water quality[16]. It was also unable to establish any significant correlation between the incidence of diseases and pH[17]. The low pH does not cause any harmful effect[18]. However, a low value, below 4.0 will produce sour taste and higher value above 8.5 shows alkaline taste.

Total Dissolved Solids (TDS)

The TDS values in the study area varied from 224 to 581 mg/L during the study period. 30% of the samples were found more than maximum permissible limit (500 mg/l) prescribed by BIS which is clear indicating that the groundwater in some of the locations is very hard and unsuitable for drinking purposes. Primary sources for TDS in groundwater are agricultural and residential runoff, leaching of soil contamination. Naturally occurring total dissolved solids arise from the weathering and dissolution of rocks and soils. Water with high TDS is of inferior palatability and may induce an unfavorable physiological reaction in the transient consumers and gastrointestinal irritation.

Electrical Conductivity (EC)

Electrical conductivity is viewed as a valuable indicator of the amount of dissolved materials in water[19]. Electrical conductivity is the manifestation of the dissolved salts and is an indicator of water pollution. In the study area, EC values in groundwater vary from 332 µmohs/cm to 1510 µmohs/cm. In the study, 10% of the samples were found exceeding maximum permissible limit (1500 mg/L) prescribed by BIS. The EC values are divided in to three groups, the division suggest that 90% of the wells were below the permissible limit while 10% of samples were higher than permissible limit <1500 µS/cm for domestic use[20].

Table 3: Classification of groundwater on the basis of conductivity values

Conductivity range in µS/cm	Classification	Percentage of samples
<1500	Permissible	90
1500-3000	Not permissible	10
>3000	Hazardous	0

Turbidity

The presence of suspended matters such as clay, organic, inorganic and microorganisms make water turbid[16]. Turbidity is the cloudiness or haziness of a fluid caused by individual particles (suspended solids) that are generally invisible to the naked eyes[22]. The turbidity for all the samples was found below the maximum specified value (5.0 NTU) as per BIS Standards. In this study it varied from 0.05 to 0.21 NTU. The cause of turbidity in boreholes may be traced to dissolved clay and mud materials into the groundwater. Frequency of drawdown from borehole can also contribute to turbidity in water. Viruses, Cysts and Micro organisms associate with suspended particulate material of water create water borne diseases. It is therefore more important to have a very low turbidity to qualify as safe drinking water[23].

Iron

Iron concentrations in this study varied from 0.06 to 0.24 mg/L. All samples were found within permissible limit (0.30 mg/L) prescribed by BIS. Water percolating through soil and rock can dissolve mineral containing iron and hold them in solution. Iron can affect the flavor and color of food and water. Iron deficits lead to anemia, causing tiredness, headaches and loss of concentration. Acute exposure to iron is characterized by vomiting, gastrointestinal bleeding, coma and jaundice[24]. Iron will cause reddish-brown staining of laundry, porcelain, dishes, utensils and even glassware.

Nitrate

Nitrogen is a very minor constituent of the rocks. Part of the nitrate may be taken inside the ground by plants before the rain water infiltrates below the root zone. But the greatest contribution of nitrate to groundwater is from decaying organic matter, sewage waste and nitrate fertilizers. In this study, values of nitrate concentration in varied from 0.19 to 26.31mg/L. At all sampling stations nitrate concentration values were found within specified limit 45 mg/L as prescribed by BIS. The primary health hazard from drinking water with nitrate-nitrogen occurs when nitrate is transformed to nitrite in the digestive system. The nitrite oxidizes iron in the hemoglobin of the red blood cells to form methemoglobin, which lacks the oxygen-carrying ability of hemoglobin. This creates the condition known as methemoglobinemia (sometimes referred to as "blue baby syndrome"), in which blood lacks the ability to carry sufficient oxygen to the individual body cells causing the veins and skin to appear blue. Groundwater when not polluted contains less than 5 ppm of nitrates. Excessive content of nitrate in groundwater may cause infant methemoglobinemia[25].

Sulfate

The sulfate content in water is important in determining the suitability of water for public and industrial supplies. Sulphates are naturally occurring anion present in all kinds of natural waters and primarily compounded to all types of minerals found in watershed and acid rain. The concentration of sulfate in the study area varied from 13.20 to 213.3 mg/L. 5% of samples were found above the standard limit (200 mg/l) prescribed by BIS. Higher concentration of sulfate in water can cause malfunctioning of alimentary canal and shows cathartic effect on human beings[26].

Fluoride

The fluoride concentration values in the study area varied from 0.01 to 0.76 mg/L. The concentration of fluoride in all the samples was found below the maximum specified value (1.0 mg/L) as per BIS Standards. Fluoride is beneficial for human beings as a trace element, this protects tooth decay and enhances bone development, but excessive exposure to fluoride in drinking-water, or in combination with exposure to fluoride from other sources, can give rise to a number of adverse effects[27].

Chlorides

The salty taste produced by chloride concentrations is variable and dependent on the chemical composition of water[28]. Chlorides concentrations varied from 52.0 to 283.0

mg/L. In 35% of total samples, the chloride values were found more than the maximum limit (250 mg/L) prescribed by BIS Munawar (1970) is of the opinion that higher concentrations of chlorides indicate higher degree of organic pollution[29]. The occurrence of chloride in ground water is attributed to dissolution of chlorite rocks and sewage discharges[30]. It also reaches the ground water through the leaches from the percolated surface water over the land when cow dung heaps and such other organic waste abound in near vicinity[31]. Chlorides are not usually harmful to people; however, the sodium part of table salt has been linked to heart and kidney disease. Sodium chloride may impart a salty taste at 250 mg/L. However no adverse health effects on humans have been reported from intake of water containing highest content of chloride[32].

Alkalinity

The presence of carbonates, bicarbonates, and hydroxides is the main cause of alkalinity in natural waters[33].The alkalinity in this study varied from 156.0 to 260.0 mg/L during study period. 22.5% samples were found above the standard limit (200 mg/L) prescribed by BIS indicating presence of bicarbonate, carbonate and hydroxide salts. It also indicates that approximate one fourth of the water samples in the study area were hard. Large amount of alkalinity imparts a bitter taste to water. Excess alkalinity in water is harmful for irrigation, which leads to soil damage and reduce crop yields.

Total Hardness

Hardness is the important parameter for determining the usability of groundwater[34]. In the present study, the total hardness of the water samples ranged from 187.0 to 268.0 mg/L. 20% of samples were found above the standard limit (200 mg/L) prescribed by BIS. Hard water is useful for the growth of children, if within permissible limit. Hardness of water causes disadvantages in domestic uses by producing poor lathering with soap, deterioration of cloths, scale forming and skin irritation.

Calcium

Calcium is naturally present in water. It may dissolve from rocks such as limestone, marble, calcite, dolomite, gypsum, fluorite and apatite. Calcium is a determinant of water hardness. The presence of calcium in drinking water is natural geological source, industrial waste, mining by products and agricultural wastes. The concentration of calcium in the study area ranged from 47 to 87 mg/L. 12% of samples were found above the standard limit (75 mg/L) prescribed by BIS. In the present investigation the higher values of calcium were observed in samples from the sites situated in industrial areas which are due to high pollution of water.

Magnesium

A large number of minerals contain magnesium; Magnesium is washed from rocks and subsequently ends up in water. Magnesium is often associated with calcium in all kinds of waters, but its concentration remains generally lower than the calcium[35]. In the study area, values of magnesium concentration in groundwater samples varied from 21.02 to 35.90 mg/L. At 15% sampling stations magnesium concentration values were found above specified limit (30 mg/L) as prescribed by BIS.

Manganese

Manganese was one of the most abundant metals in the earth’s crust and usually occurs together with iron[36]. The values of manganese concentration in water samples varied from 0.003 to 0.142 mg/L. In 15% of the samples, Manganese concentration were found above the standard limit (0.10 mg/l) prescribed by BIS.

Copper

The Copper concentrations were varied from 0.004 to 0.086 mg/L. 35% of samples were found above the standard limit (0.05 mg/l) prescribed by BIS. At a normal concentration copper is a biologically important trace element; at elevated concentration it is toxic for living organisms. It is an important and indispensable element for the vital functions of humans, animals and plants. The deficiency of Cu in the human body could indirectly increase the risk of skin cancer[37].

Zinc

The importance of zinc human nutrition has been recognized since 1962 when zinc deficiency was observed among rural habitants of the Middle East[38]. The zinc concentrations varied from 0.009 to 1.841 mg/L. The values of zinc concentration for all the samples were found below the maximum specified value (5.0 mg/L) as per BIS Standards.

Lead

The lead concentrations were varied from 0.001 to 0.019 mg/L. 12.5% of samples were found above the standard limit (0.01 mg/L) prescribed by BIS. Lead (Pb) concentration in natural waters increases mainly through anthropogenic activities[39]. The beneficial effects of lead are not known. Lead taken into the body can be injurious to health. The bulk of lead contamination in the human body is of nutritional origin. High exposure to lead may cause decreased fertility. It may also cause renal and gastrointestinal disturbances. Children exposed to lead pollution are under high risk of mental retardation, impaired learning ability, disturbances of peripheral nervous system, and renal atrophy. Hanif S. A., et al., (2007) studied lead toxicity in lock factory workers in the study area. The study shows that level of lead was high in blood of workers. The cause may be exposure to lead in the lock factories supplemented by the lead from drinking water[40].

Chromium

The chromium concentrations varied from not detected level to 0.090 mg/L. 12.5% of samples were found above the standard limit (0.05 mg/L) prescribed by BIS. Pollution caused by chromium is of great concern as it is toxic even at very low concentrations. Chromium has also been reported as carcinogen[41]. Normally, higher chromium values may be expected in terrains characterized by the presence of basic rocks. The study area, confined to gangetic plains, the only suggestion that may be offered was that chromium in groundwater of the study area is of anthropogenic origin. High concentration of Chromium in groundwater may cause ulceration of nasal septum and dermatitis[42].

Cadmium

The Cadmium concentration of water samples of the study area was varied from 0.001 to 0.005 mg/L. In 15% samples Cadmium concentration found above the BIS permissible limit (0.003 mg/l). Cadmium does not exist in nature as native metal but principally as sulfide ore namely greenokite, which is strongly associated with the zinc sulfide as salphalerite and is recovered from some copper ores during smelting and refining. It is rarely found in natural water. Cadmium is frequently used in electroplating and in pigment manufacturing industries. This makes the study area a potential cadmium hazard zone owing to the vast metal and electroplating industries working in the city. Of all the toxic metals, cadmium has drawn a great amount of attention in Aligarh City. In high amount, Cadmium is a deadly poison, but even small amount taken over a long period of time accumulates in the biological system and causes serious illness. Cadmium is considered to be toxic if its concentrations exceed 0.01 mg/L[43].

5. Conclusion

From the detailed, physico-chemical study of the groundwater samples it was observed that the nature of water remained alkaline in the study area. The results shows higher concentration of magnesium (10%), total hardness (20%), alkalinity (22.5%), cadmium (15%), pH (12.5%), lead (12.50), TDS (30%), calcium (12%), copper (35%), sulfate (5%), chloride (35%), manganese (15.0%), chromium (12.5%), which indicates signs of water quality deterioration as per BIS standards. Higher concentrations of parameters in the area were attributed to anthropogenic influence such as small and medium scale industries and automobile workshops. Hence, Groundwater quality analysis should be carried out from time to time to monitor the rate and kind of contamination. This would help to prevent damage to the overall groundwater system.

Comparing the mean values of groundwater quality parameters of Aligarh it can be concluded that values of parameters found lower during post-monsoon period showing an improvement in quality due to fresh recharge without pollution from external sources and clearly indicated seasonal variation. Augmenting the ground water resources by recharging the ground water aquifers through rain water harvesting and thus reducing the high concentration of the chemical parameters is a very important measure. Public awareness programmes should be initiated to create a sense of awareness in them to save water around their habitants.

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