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RESEARCH

Assessment of Drinking Water Quality at Selected Public Places of Meerut City, Uttar Pradesh, India

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Abstract

Water is essential to all life on Earth, serving as a critical resource for both industrial and agricultural activities. However, the quality of groundwater, particularly in urban areas, is a growing concern due to its direct impact on human health. This study aims to evaluate the groundwater quality in selected public places within Meerut City, Uttar Pradesh, India, to assess its suitability for drinking purposes. A total of 48 groundwater samples were collected from four locations across the city. Various physicochemical parameters, including pH, electrical conductivity (EC), total dissolved solids (TDS), and ion concentrations, were measured and compared against the national standards set by the Bureau of Indian Standards (BIS). The analysis revealed that while certain parameters such as pH, chloride, nitrate, and sulfate levels were within acceptable BIS limits, others, including TDS, total hardness, magnesium, and calcium, exceeded the permissible thresholds. The Water Quality Index (WQI) assessment further categorized the water quality at all studied locations as 'bad,' indicating significant contamination. The findings suggest that the groundwater in these areas is unsuitable for human consumption without prior treatment. The presence of elevated levels of dissolved solids and hardness, along with other contaminants, highlights the need for immediate intervention to mitigate potential health risks. This study underscores the urgent necessity for effective water management and treatment strategies in Meerut City to ensure safe and sustainable access to potable water.

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Statement of Sustainability: Meerut City is a part of the National Capital Region (NCR) of Delhi, India. The city is also an education and industrial hub. It is one of the popular cities of Uttar Pradesh India. Although in the literature, we found few studies on groundwater quality "but" none of the studies explore the quality of drinking water systems placed at public places (bus stations, railway stations, marketplaces, and casting yards). The maximum number of people consumes the drinking water from these public places. A small quantity of contamination in the drinking water of these places can affect a large number of people. Therefore, utmost care of drinking water quality at these places is necessary to protect the huge number of people from various drinking water hazards.

1. Introduction

Water is an indispensable and beneficial resource for all living and non-living factors due to its distinctive physicochemical and biological properties. Water is one of the most crucial elements for the long-term sustainable growth of life on Earth (Tyagi et al., 2024). A significant number of countries worldwide are experiencing water scarcity, with even clean drinking water unavailable to a considerable proportion of the population (Gleick, 2000; Bhutiani et al., 2021). The majority of people in numerous developing countries, including India, rely on surface and groundwater sources, a trend that is becoming increasingly prevalent (Srivastava et al., 2012). Groundwater is often preferred for drinking purposes over surface water due to its abundance and relatively low microbial contamination (Singh et al., 2015; Ruhela et al., 2022). India has an estimated 4,000 billion cubic meters (BCM) of usable water resources available annually due to precipitation. However, only 1,123 billion BCM (of which 690 billion are surface waters and 433 billion are groundwater) are deemed usable each year (Central Water Commission, 2020). Groundwater provides approximately 60% of the nation's agricultural water demands, 50% of the nation's urban water needs, and over 85% of the nation's rural water needs (AQUASTAT, 2010; Sishodia et al., 2016; Sajil Kumar 2017; Agarwal et al., 2019; Shukla and Saxena 2020). The extraction and contamination of groundwater resources have been accelerated by the rapid industrialization, urbanization, and agricultural growth that have occurred across the nation (Adimalla and Venkatayogi, 2018; Ahamad et al., 2018; Subba Rao et al., 2017; Ruhela et al., 2021). The annual extraction of groundwater in India exceeds the combined total of China and the United States. Furthermore, a report published in 2014 by the Central Ground Water Board of India indicates that the country's annual groundwater withdrawal is approximately 245×10^9 m^3. According to the Sustainable Development Goal Report (2023), there is a necessity to accelerate the rate by a factor of six from the current rate to meet the drinking water needs by 2030 (https://sdgs.un.org/goals/goal6).

The quantity and quality of groundwater are rapidly declining as a consequence of both natural and anthropogenic processes (Bhakar and Singh, 2019; Ram et al., 2021). The contamination of groundwater is a more complex issue than many others, due to the difficulty and expense of replenishing aquifers (Tiwari et al., 2015; Wang and Lu, 2024). The study of groundwater flow and storage in hard rock locations represents a significant challenge for researchers, the general public, and those engaged in the management of water resources. In their 2019 review of the groundwater literature, Bhakar and Singh concluded that the majority of locations in Rajasthan do not have groundwater suitable for drinking. The authors asserted that rapid economic growth and anthropogenic activities are concurrently responsible for the deterioration in groundwater quality. A similar observation was also reported by Ahamad et al. (2023) and Ahamad et al. (2024) in their study of groundwater quality in all the arid and semi-arid states of India.

In the Meerut region of North India, as per our knowledge, there is a lack of groundwater studies, and especially none of the studies was found depicting the quality of ground or drinking water at public places. As a result, the current study's objective was to evaluate the groundwater quality and its suitability for drinking purposes at the chosen public locations of Meerut City Uttar Pradesh, India.

2. Materials and Methods

2.1. Sampling and Analysis

The main purpose of sampling is to gather a part of the material that properly represents the substance being sampled yet is small enough in volume to be easily handled and transferred to the laboratory. Every month, samples were gathered from the four sites that were chosen (Table 1 and Figure 1) and placed in a two-liter plastic container. All four sites chosen were public places (bus stand, marketplace, construction yard) where the consumption of groundwater is maximum by the public. After sampling, the samples were brought to the lab so that the remaining parameters could be examined. The samples were analyzed according to the standard procedures outlined in the CPCB (2010) and APHA (2012). The parameters analyzed during the study period were total dissolved solids (TDS), electrical conductivity (EC), hydrogen ion concentration (pH), total hardness (TH), calcium (Ca), magnesium (Mg), chloride (Cl), total alkalinity (TA), sulfate (SO_4^{--}), and nitrate (NO_3^-). Parameters like TDS (Model no: 065 G), EC (Model no: ESICO 1601), and pH (Model no: EI 112) were analyzed using the digital meters. TH, Ca, and Mg were examined using the ethylene diamine tetra acetic acid (EDTA) method. Cl was analyzed using the argentometric or silver nitrate method. Sulphate was analyzed using the barium chloride method while nitrate was analyzed using the brucine method.

Table 1. List of sampling sites selected in Meerut city for water quality assessment.

Site Number	Sampling Site Name	Geo-coordinates
Site 1	Casting Yard	28.920891 N, 77.667419 E
Site 2	Meerut Central	29.012663 N, 77.704389 E
Site 3	Bhaishali Station	28.989362 N, 77.700722 E
Site 4	Begumpul Station	28.995398 N, 77.705589 E

2.2. Water Quality Index (WQI)

The process of calculating the WQI involves converting intricate data on water quality into information that the public can use and comprehend (Singh and Hussian, 2016). Because it is based on a few crucial characteristics, the WQI is a very practical and effective tool that can offer a straightforward indicator of water quality (Brown et al., 2017; Cude, 2021). WQI was computed by linearly combining the unit weight and quality rating using the following formula:

$$WQI = \frac{\Sigma QiWi}{\Sigma Wi}$$

Where, Qi = Quality rating and Wi = Relative weight

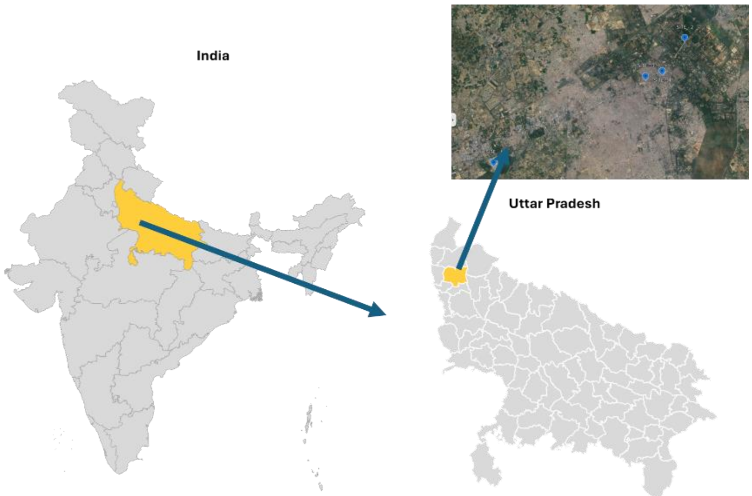

Figure 1. The map of the study area shows the sampling sites.

2.3. Data Analysis

The obtained data was also analyzed using Microsoft Office Excel (Version 2010, Microsoft Corp., USA) to summarize the data into average, and standard deviation, and then for the calculation of WQI values at different sites.

3. Results and Discussion

The average results of the selecetd sites are given in Table 2. Correlation coefficient between the parameters is shown in Table 3.

3.1. Total Dissolved Solids (TDS)

Inorganic salts including calcium, magnesium, potassium, sodium, bicarbonates, chlorides, and sulfates, as well as trace quantities of organic materials dissolved in water, make up total dissolved solids. It stands for the flavor of groundwater. Following WHO (2011) guidelines, drinking water is deemed pleasant if the value of TDS is less than 600 mg/L; if TDS exceeds 1000 mg/L, it is deemed unappealing. Water conductivity rises in response to an increase in dissolved solids. The results obtained revealed that site 2 recorded the lowest TDS (832.0±7.0 mg/L) whereas site 4 recorded the highest TDS (850.6±14.3 mg/L). TDS levels were discovered to be higher above the BIS standard limit (500 mg/L) at every location under investigation. Ram et al. (2021) observed the maximum value (879 mg/L) of TDS in the Mahoba District of Uttar Pradesh. High values of TDS of drinking water quality indicate the poor conditions of drinking water sources at these places. It also shows the neutrality of the government towards the health of people. The higher TDS values in the groundwater may be due to the presence of a high quantity of salts and ions which may be due to geogenic and anthropogenic causes. Although reverse osmosis (RO) plants were observed at all the locations, they were observed in poor condition and therefore they are unable to reduce the dissolved salts from the water that passes from their filters. A strong positive correlation of TDS with most of the parameters (0.89 to 0.97) shows that dissolved ions are contributing most to the quality degradation of groundwater in the studied area. A similar correlation of TDS with other parameters was observed by Maedeh et al. (2013) and Kothari et al. (2021).

3.2. Electrical Conductivity (EC)

Any material or solution's capacity to carry electrical current through water is measured by its electrical conductivity (Bhutiani et al., 2019). The amount of dissolved material in a water sample directly correlates with EC. During the research period, site 2 recorded the lowest EC (1223.5±10.3 μS/cm) while site 4 recorded the highest EC values (1250.9±21.0

μS/cm). Values of EC were found to be over the recommended threshold (750 μS/cm) for drinking purposes at every site under investigation. Due to their proximity to densely populated areas, certain locations with high EC indicate that sewage may be mingling with groundwater. A higher value of EC in the drinking water quality of all the selected sources indicates the presence of a high concentration of ions which again is the lack of maintenance of the water filters installed at these places. The intense anthropogenic interferences are also another reason (Hem, 1991; Ahamad et al., 2024) due to which the values of these ions enhanced in the groundwater of the city. EC also shows a strong positive correlation with TH, Ca, Mg, Cl, sulfate, and nitrate. Maedeh et al. (2013) observed a similar correlation between EC and other parameters while studying the groundwater of the Tehran Plain of Iran. Ahamad et al. (2018) observed the mean value of EC as 759.33 in the Varanasi city of Uttar Pradesh.

3.3. pH

pH is the logarithmic negative of the hydrogen ion concentration. The intensity of the acidic or basic solution is indicated by the pH. It establishes the water's corrosivity and, typically, has no direct effect on human health (WHO, 2011). The geology of the region, the amount of atmospheric precipitation, and the types of human activity all affect the pH of groundwater. The pH levels during the research period were highest (7.3±0.1) at site 3 and lowest (7.1±0.0) at site 1. pH was measured between 6.5 to 8.5, which is within the range of BIS standards. The pH values obtained during the study period indicate the near-neutral nature of drinking water. Agarwal et al. (2019) obtained a similar nature of drinking water in their study. Week negative correlation of pH with nitrate was observed in the study. Similar results were also obtained by Kothari et al. (2021).

3.4. Total Hardness (TH), Calcium (Ca), and Magnesium (Mg)

Carbonates, bicarbonates, chloride, and sulfate of calcium and magnesium are the main sources of hardness, as shown by their strong positive association. Since this kind of rock has a major influence on calcium and magnesium contents (Adimalla and Li, 2019; Ahamad et al. 2023), the schist rocks in the catchment serve as the main source of calcium in the springs. According to Farid et al. (2022), total hardness is a crucial criterion for assessing the suitability of groundwater for industrial, residential, and irrigation uses. The results revealed that the total hardness values were minimum (347.4±3.2 mg/L) at site 3 and site 4 had the highest (378.8±7.5 mg/L). At every site that was examined, the hardness level was higher than the BIS standard limit of 200 mg/L. According to Sawyer and McCarthy (1967), every sample is classified as hard water. Stomach issues are brought on by an increased degree of hardness. Therefore, actions may be taken to prevent the condition from increasing hardness further, as calcium's reaction with iron, zinc, magnesium, and phosphorus reduces the body's absorption of these minerals (Rawat et al. 2018; Rezaei et al. 2020). The findings align with the findings of Agarwal et al. (2019). Janardhana Raju et al. (2011) also observed the values of TH in the range of 169-694 mg/L with a mean value of 341 mg/L. Ahamad et al. (2018) also observed a similar range and mean values (344.93 mg/L) of TH in Varanasi. Urolithiasis, human heart problems, and kidney stones may result from elevated levels of TH in groundwater (Chabukdhara et al., 2017). A vital component of human health is calcium. A lack of calcium in drinking water increases the risk of kidney stones, hypertension, stroke, brittle bones, and colon cancer, among other health problems (WHO, 2011). Here, 75 mg/L is the maximum amount of calcium that is allowed. Throughout the investigation, site 3 recorded the lowest calcium levels (85.5±1.9 mg/L), whereas site 1 recorded the highest levels (90.0±2.3 mg/L). All the sites under investigation had calcium levels above the recommended BIS threshold of 75 mg/L. While magnesium is an essential ion for cell function in enzyme activation, high concentrations of the mineral can have laxative effects (WHO, 2011). Hypertension, coronary heart disease, elevated vascular responses, endothelial dysfunction, and other conditions are caused by the lowest magnesium reading (39.7±3.5 mg/L) was recorded at site 3 during the research period, while the highest magnesium reading (46.1±5.9 mg/L) was recorded at site 4. At every site under investigation, the normal BIS limit of 30 mg/L for magnesium was exceeded. A strong positive correlation of TH with sulfate indicates the presence of calcium and magnesium sulfate are the major ions contributing to the hardness of groundwater in the study area.

3.5. Chloride

Chloride is thought to be a sign of contaminated water. According to Sadat-Noori et al. (2014), its increased content imparts a salty flavor to water and has a laxative effect. Groundwater salinity decreases when chloride ion concentration decreases. The lowest chloride levels (18.9±0.4 mg/L) were recorded at site 2 during the research period, whereas the highest levels (23.3±0.8 mg/L) at site 4. Groundwater is dangerous for human health because of its greater chlorine content (Sadat-Noori et al. 2014; Ahamad et al., 2023). In the current study, the level of chloride was found to be under the BIS limit of 250 mg/L. Chloride shows a strong positive correlation with TDS, EC, TH, nitrate, and sulfate except pH. With pH, the chloride ions show a negative correlation indicating that an increase in chloride ions leads towards the acidic nature of water.

3.6. Total Alkalinity

It is a measurement of the amount of hydroxide, bicarbonate, and carbonate ions in water (Chabukdhara et al., 2017). Potable water should have an alkalinity level of no more than 200 mg/L; over that, the flavor becomes unpalatable (Haritash et al., 2017). Site 3 had the lowest alkalinity (317.4±6.9 mg/L) whereas site 2 had the highest concentration (326.0±6.0 mg/L). The alkalinity in the research region is beyond the BIS limit (200 mg/L) at all the selected locations. Total alkalinity shows a positive moderate correlation with TH and Ca while a strong negative correlation with pH.

Table 2. Average values of physicochemical characteristics of all the selected four sites (*n*=24).

Site/Parameters	Site 1	Site 2	Site 3	Site 4	Standard**
TDS (mg/L)	838.8±12.4	832.0±7.0	834.8±12.9	850.6±14.3	500
EC (µS/cm)	1233.5±18.2	1223.5±10.3	1227.6±18.9	1250.9±21.0	-
pH	7.1±0.0	7.2±0.0	7.3±0.1	7.2±0.0	6.5-8.5
Total Hardness (TH)	365.6±9.8	353.6±2.2	347.4±3.2	378.8±7.5	300
Calcium (Ca)	90.0±2.3	86.9±1.7	85.5±1.9	89.8±5.0	75
Magnesium (Mg)	42.2±4.2	39.7±3.5	41.7±4.3	46.1±5.9	30
Chloride (Cl)	21.8±1.5	18.9±0.4	20.5±0.6	23.3±0.8	250
Total Alkalinity (TA)	318.8±3.9	326.0±6.0	317.4±6.9	325.2±2.3	200
Sulphate	185.5±5.7	181.7±1.9	177.3±1.4	192.5±2.1	200
Nitrate	3.9±0.1	3.6±0.1	3.7±0.1	3.9±0.4	45

*: All the values are in mg/L except pH, **: BIS (2012).

3.7. Sulphate

The existence of sulfide-bearing minerals in aquifers, the usage of sulfate-rich fertilizers, and industrial wastes are the causes of sulfate's presence in groundwater (Machiwal and Jha, 2015). Minimum sulfate (177.3±1.4 mg/L) was recorded at site 3 whereas maximum sulfate (192.5±2.1 mg/L) was recorded at site 4. Although at every location under investigation, sulfate was shown to be within the 200 mg/L BIS limit most of the values are near the BIS standards. A high level of industrial activity and anthropogenic causes are indicated by the excess sulfate content in the research area during the study period. If the trend of natural and anthropogenic activities works continuously at the synchronization of the present-day rate, the sulfate level will be beyond the standard limit of BIS which will cause health risks to the consumer. A higher concentration of sulfate may result in respiratory illness (Chabukdhara et al., 2017). Sulfate ions show a strong positive correlation with most of the studied parameters except pH. With pH, the sulfate ions show a negative correlation indicating that if the sulfate ions increase in the water, the nature of water will shift towards acidic due to the formation of acids.

3.8. Nitrate

Fertilizers, atmospheric precipitation, crop residues, decomposing organic waste, and septic tanks, are some sources of nitrate, a biomarker of organic pollution (Nakagawa et al. 2017; Subba Rao et al. 2017). The lowest (3.6±0.1 mg/L) values of nitrate were recorded at site 2 and the highest (3.9±0.4 mg/L) was recorded at site 4. At all the selected locations, values of nitrate were found under the BIS limit of 45 mg/L. Several authors have similarly discovered lower nitrate ion concentrations in the groundwater of their respectable sites (Jamshidzadeh and Barzi, 2018; Hossain et al., 2021). Nitrate ions show a strong positive correlation with most of the studied parameters like sulfate ions except pH. Consumption of drinking water containing a high concentration of nitrate can cause hypertension, goiter, gastric ulcer, etc. (Majumdar and Gupta, 2000; Chabukdhara et al. 2017).

3.9. Water Quality Index (WQI)

Values of WQI are given in Figure 2. WQI is a commonly used technique to assess whether groundwater is suitable for human use. The BIS recommended drinking water quality standards were used to determine the WQI. Because magnesium has the highest quality rating (Qi), it was regarded as a criterion pollutant at all the study locations.

According to Chaterjee and Raziuddin (2002), the groundwater quality is characterized as (I) excellent, when WQI is 0–25; (II) good, when WQI is 26–50); (III) poor water, when WQI is 51–75); (IV) extremely bad water, when WQI is 76–100); and (V) unfit for drinking, when WQI is > 100. WQI values varied from 55.8 to 69.8 at all sites under investigation. As a result, groundwater quality is poor at all the selected locations of the city. Similar results i.e. poor water quality of drinking water was observed by several researchers (Singh and Hussain, 2016; Krishan et al., 2016; Singh et al., 2019; Kothari et al., 2021).

Table 3. Correlation Coefficient between different parameters.

Parameters	TDS	EC	pH	TH	Ca	Mg	Cl	TA	Sulphate	Nitrate
TDS	1.00									
EC	1.00	1.00								
pH	-0.49	-0.49	1.00							
TH	0.95	0.95	-0.74	1.00						
Ca	0.89	0.89	-0.83	0.99	1.00					
Mg	0.99	0.99	-0.34	0.88	0.81	1.00				
Cl	0.98	0.98	-0.29	0.85	0.77	1.00	1.00			
TA	0.29	0.29	-0.98	0.59	0.69	0.14	0.08	1.00		
Sulphate	0.91	0.91	-0.80	1.00	1.00	0.83	0.80	0.66	1.00	
Nitrate	0.97	0.97	-0.26	0.84	0.75	1.00	1.00	0.05	0.78	1.00

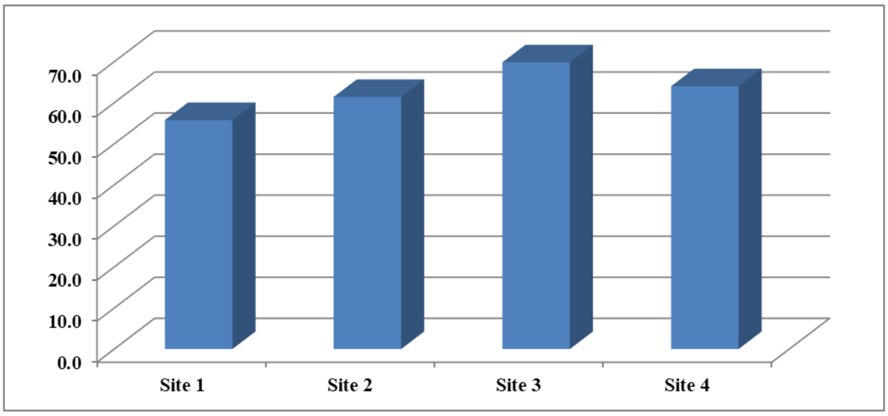

Figure 2. WQI values of all the sites.

4. Conclusion

The current study aimed to ascertain if groundwater at the chosen locations of Meerut City is suitable for drinking purposes. Some physicochemical parameters like pH, TDS, total hardness, magnesium, and calcium, were found to be over the BIS limit, while others, like chloride, nitrate, sulfate, and pH, were found to be within the limit. The water quality at all the selected locations fell into the poor category according to the WQI classification. The regular consumption of this water by people can cause different health implications. The results of this study can help stakeholders and policymakers in Meerut City and other comparable urban areas in the development of sustainable water management and public health protection strategies. We may infer from the current study that the groundwater in the study region must be treated since it is not fit for human consumption in its raw state

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