RESEARCH PAPER

Groundwater in and around Meerut city of Uttar Pradesh: A comprehensive review of quality and management practices

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ABSTRACT
Groundwater is the most important as well as most mismanaged resource on this earth. Its invisibility is the main hindrance in its management. The rapid pace of population growth, urbanization, industrialization, agricultural revolution, and climate change impacting the quality and quantity of groundwater. Meerut is a rapidly growing industrial and educational hub in the National Capital Region (NCR) of Delhi. Along with this, large quantity of wastewater generation and lack of treatment facility is another reason of decline in groundwater quality. The current review paper explores the current status of groundwater quality of Meerut district of Indian state Uttar Pradesh. Along with this, groundwater quality management practices going in the district are also explored. The results of the current review study revealed the declining groundwater level in the district with the highest decline reported as 91cm/year. Continuous decline in the groundwater quality was also found both in urban and rural area of the district. A large variation in the physicochemical parameters of groundwater quality found, such as total hardness ranged from 256 to 836 mg/l, TDS from 510.7 to 850.6 mg/l, and iron values from 6.478 to 12.09 mg/l. Besides this, large quantity of untreated wastewater [190 million litres per day (MLD)] is dumped in surface water bodies due to lack of infrastructure also pressurizing the groundwater resource. The district also lacks a central groundwater treatment facility increasing the possibility of health risks to the residing population. Similarly, the district also lacks groundwater recharge infrastructure except the rainwater harvesting applied by the Meerut Development Authority (MDA) in its own building and at certain other places by the academic institutions. Establishment of the groundwater treatment structures, groundwater recharge ponds, and increase in the wastewater treatment capacity is recommended to save and sustain the groundwater quality and quantity of the Meerut district and its outskirts.
Keywords: Water scarcity, Water quality, Management practices, Challenges, pollutants, groundwater recharge ponds, wastewater treatment.
How To Cite This Article: Tyagi Sk, Sharma D, Kumar V, Saxena N. Groundwater In And Around Meerut City Of Uttar Pradesh: A Comprehensive Review Of Quality And Management Practices. Int J Drug Deliv Technol. 2026;16(26s):803-808. Doi: 10.25258/ijddt.16.26s.85

1. INTRODUCTION

Groundwater is a crucial source of water for drinking, irrigation, and industrial purposes. Both the quality and quantity of the groundwater are equally important for the survival of the human race on this planet. The dependency on the underground water sources is higher in developing nations compared to developed nations (Ruhela et al., 2022). The whole world is concerned to provide a clean water supply to its population to achieve Sustainable Development Goals (SDGs) no. 6; however, a large portion of the world's population still lacks even a basic water quality supply (Bhutiani et al., 2021; Ahamad et al., 2023). The condition is even worse in developing nations like India. As per the report of the World Health Organization (WHO), more than 2 billion people depend on contaminated water for drinking purposes due to the unavailability of a pure water supply. The contaminated water is responsible for various water-borne or water-related diseases in humans (Bojago et al., 2023; Ahamad et al., 2024). WHO reported about 485,000 deaths globally due to diseases related to the consumption of contaminated water.

In India, the quality of groundwater has been a topic of discussion for a very long period of time. The unprecedented industrialization, urbanization, and greed of lavish life intensified the discussion. India is the largest user of groundwater, with almost 70-80% utilization in agricultural activities. Singh (2020) reported that the 21.7 million irrigation structures in India are being used continuously for water abstraction for irrigation purposes. India is the largest groundwater abstraction country in the world, with 231 cubic Km per year. In India, UP is the largest user of ground with 5.28-million-hectare meter (mham) withdrawal per year, out of which 2.15 mham is from western districts of UP (Groundwater Assessment Report, 2013). All these activities lead to the continuous extraction of groundwater from the aquifers, further leading to geogenic contamination in the groundwater (Sajjad et al., 2013; Kumar et al., 2013; Chabukdhara et al., 2017).

Groundwater is the only source of drinking water in Meerut city and its outskirts. Due to its proximity to the Delhi-NCR area, the population and industrial area of the city are growing at a high rate, pressuring the water resources of the city. Agriculture is the main profession of the people living on the outskirts of the city, and therefore, groundwater abstraction through the tubewells is high in the area. All these factors contribute to the declining water quality and level of the city. Keeping the above discussion in mind, the current review study was carried out to analyse the quality of groundwater in Meerut city using available literature. The study also documents the groundwater quality management practices and their utilization status in the city.

2. MATERIALS AND METHODS

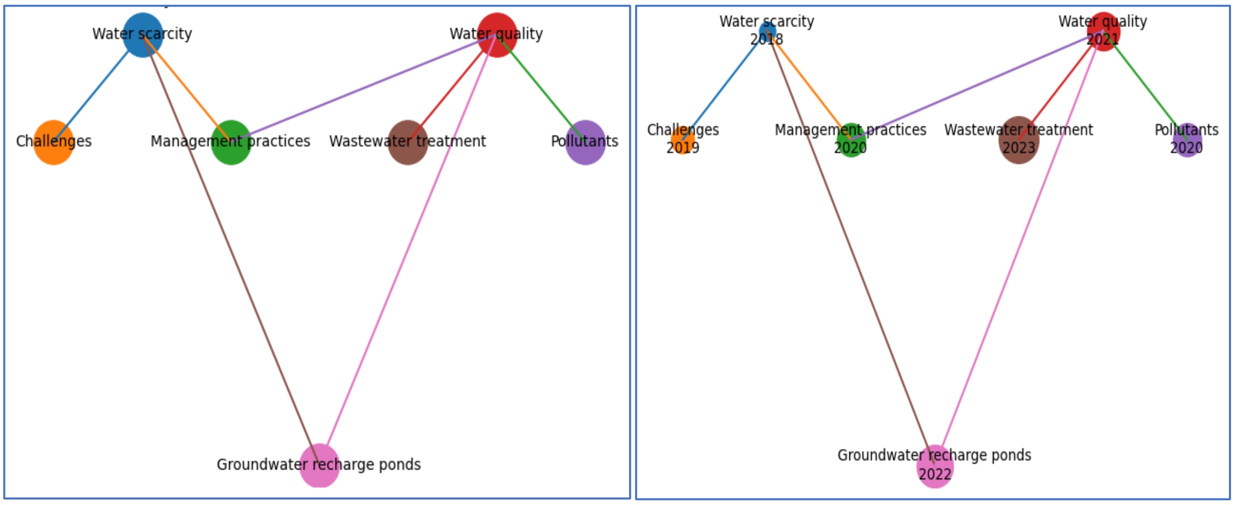
2.1 Study area

The current review study specifically focuses on the water quality of Meerut city and its outskirts. The city is located at 28°57′N latitude and 77°42′E longitude in western Uttar Pradesh on the alluvial plain of the Ganga and the Yamuna. The region is highly populated, and currently, industrialization is at a high pace. The area falls in a sub-tropical climate with annual rainfall of 800-900mm. Shallow to deep confined aquifers were found in the area, with the depth ranging from 0 to more than 150 meters.

2.2 Methodology

The search for the related literature to fulfil the objective of the current study was performed on the different research platforms using the keywords, i.e., groundwater quality, water scarcity, water quality management, challenges in the management of groundwater quality, water conservation practices, etc., and then the collected research papers were segregated using the following criteria as depicted in Figure 1:

1. Groundwater quality articles focusing on the selected study area, i.e., Meerut.
2. Groundwater quality articles of the selected study area for the selected duration, i.e., 2010 onwards.
3. Groundwater quality articles focusing on the management and conservation practices.
4. Groundwater quality articles focusing on the challenges faced during the application of management practices.



(A) **(B)**

Figure 1. Showing the bibliometric analysis of the keywords selected (A) Keyword Co-occurrence Network Visualization (B) Overlay Visualization1

3. GROUNDWATER QUALITY OF THE CITY

A lack of research on the groundwater quality was observed during the literature survey, specifically focusing on the water quality of Meerut and its outskirts. The city is surrounded by small-scale and large-scale industries. Besides this, 5 to 6 large drains also flow through the city, carrying the domestic effluent of the city.

Mishra et al. (2013) studied the groundwater quality of the areas located near drains in the Meerut city of Uttar Pradesh, with reference to the physicochemical and microbiological parameters. The authors reported the heavy metal contamination (Aluminum, Copper, Zinc, Cadmium, Lead) in more than 50% of the samples. Similarly, microbial contamination also exceeded the standard permissible limit of the Bureau of Indian Standards (BIS, 2012), and a decrease in microbial load was also detected as the distance of the sampling sites from the drains was increased. The results are a direct indicator of the contribution of the sewage drains in increasing the microbial load of the groundwater due to seepage and the effectiveness of the ground strata working as a filtering medium. With reference to the seasonal (winter, summer, rainy seasons) variation, the highest pollution load reported in summer is an indicator of the evapotranspiration effect due to high solar radiation in summer. In the rainy season, the dilution effect reduced the pollution load (Joshi et al., 2016).

Kumar et al. (2018) carried out the groundwater assessment from the Muzaffarnagar to Ghaziabad districts of Uttar Pradesh. The authors reported the increase in the acidic nature of the groundwater as the distance of the sampling sites increased from the Ganga Canal. The shifts in the pH of the groundwater towards an acidic nature may be due to the dominating effects of agricultural runoff, domestic, and industrial effluents (Tyagi and Sarma, 2021). The author also reported that the groundwater at a higher depth (16.5 meters) was alkaline, whereas that at a lower depth (3.4 meters) was acidic. The increase in the value of the salts with increasing distance from the Ganga canal may be due to evapotranspiration and geogenic effects (Subba Rao, 2018). The author reported the suitable quality of the groundwater for irrigation and domestic purposes. A similar pattern in the physicochemical parameters of groundwater was reported by Kumar et al. (2013).

Kumar et al. (2019) studied the groundwater quality along the Ganga canal in Meerut district. The authors analyze the variation in physicochemical parameters of the groundwater with reference to increasing distance from the Ganga canal and report the gradual decrease in the values of all the studied physicochemical parameters. The values of all the studied physicochemical parameters were found below the standard limit of BIS and therefore recommended suitable for drinking and irrigation purposes.

Tyagi and Sarma (2021) explore the groundwater quality of the Ghaziabad district (nearest to Meerut city) and report the rock-water interaction and evapotranspiration as the major groundwater chemistry controlling factors. The authors also reported the elevated levels of total hardness (256-836 mg/l), nitrate (0-34.35 mg/l), fluoride (0.30-2.20 mg/l), and chloride (7.1-475.7 mg/l). The enhanced level of these ions indicates the groundwater interaction with calcareous deposits and intense anthropogenic activities. Ruhela et al. (2022) also reported the higher values of total dissolved solids (510.7 to 567.9 mg/l), total hardness (345.9 to 394.3 mg/l), calcium (113.7 to 129.5 mg/l), magnesium (70.4 to 79.3 mg/l), and nitrate (29.3 to 39.2 mg/l) in the surrounding areas of Meerut city. The water quality index (WQI) values revealed the good to poor water quality in the area. Deswal et al. (2015) also reported the high values of TDS, hardness, and calcium in the groundwater of the cantonment area of Meerut city.

The groundwater of the Daurala block of the district Meerut was found heavily affected with high values of hardness (635 mg/l), potassium (56 mg/l), iron (1.716 mg/l), and manganese (0.366 mg/l). The high iron values of 6.478 mg/l and 12.09 mg/l are in the Machhra and Rohta blocks of the Meerut district, respectively. In the groundwater of the Kharkhoda block, the manganese was reported to be 0.520 mg/l. The high uranium values of 0.032 and 0.053 parts per billion (ppb) were detected in the groundwater of Meerut and Sardhana blocks of the Meerut district, respectively (CGWB report, 2023-24).

Ruhela et al. (2024) studied the groundwater quality of the water sources used by the general public, i.e., railway stations, bus stands, and other public places. The authors reported TDS (832.0 to 850.6 mg/l), total hardness (347.4 to 378.8 mg/l), calcium (85.5 to 90.0 mg/l), and magnesium (39.7 to 46.1 mg/l) values above the BIS standards. They observed the ‘bad’ water quality at all public places and recommended the primary treatment before its utilization for drinking purposes. Gautam and Rai (2023) also reported the higher value of nitrate (0.0 to 104.0 mg/l), total hardness (110.0 to 655.0 mg/l), calcium (8.0 to 116.0 mg/l), and magnesium (10.0 to 102.0 mg/l) in the upper doab region.

Industrial activities and effluent discharge are major contributors to groundwater degradation across the region. Industrial units, particularly sugar mills, use large quantities of fresh water and discharge untreated effluent into adjacent water bodies (Malik et al., 2025). These discharges leach into aquifers, leading to elevated levels of chemical contaminants in groundwater (Patel et al., 2026). Urban sewage, largely untreated in many parts of the city due to insufficient sewer networks, contributes to the percolation of pollutants into recharge zones. Agricultural runoff containing fertilizers and pesticides also contributes to nitrate and chemical loading, although specific quantitative values for Meerut require further in-depth analysis consistent across seasons and hydrogeological profiles.

4. WATER QUALITY MANAGEMENT PRACTICES

Despite the immense importance of groundwater for sustaining life on this earth, it is the most mismanaged resource on this earth. Along with increasing urbanization, the area of concrete surfaces is also increasing, resulting in increased surface runoff and decreased water infiltration through soil strata, i.e., groundwater recharge (Sinha et al., 2016). The decreasing groundwater recharge led to the exploitation of the groundwater resource. Sinha et al. (2016) reported an increase in the overexploited blocks in UP from 2 blocks in the year 2000 to 111 in the year 2011, and at the same time, the highest decline (91cm/year) in water table was reported in Meerut district.

India received about 4000 billion cubic meters (BCM) of rainfall water, out of which only 18-20% is actually utilized due to a lack of water storage infrastructure (Duggal, 2019; Singh, 2020). Ansari et al. (2021) studied the groundwater stress in different parts of Meerut city and reported a rise in water level (0.11-0.47 meters/year) in rural areas of the city, which may be due to groundwater recharge; however, decline in water level (0.12-0.33 meters/year) was reported in the urban areas of the city, which may be due to heavy abstraction for agricultural and industrial purposes and absence of groundwater recharge practices. Shahnum and Shah (2024) also reported the decline in groundwater level in almost all the blocks of Meerut District. Groundwater lowering as well as overexploitation were found in the Meerut district of Uttar Pradesh. The net groundwater availability has been continuously decreasing in Uttar Pradesh since 1975 due to an increase in the abstraction and a decrease in groundwater recharge (Sinha, 2021).

Although various laws, acts, and policies were available for groundwater management at the national and international levels, at the state level (Uttar Pradesh), the first comprehensive policy for groundwater management came into force in 2013. After this, the “Bhujal Sanrakshan Mission” was launched in 2016, and the Uttar Pradesh Ground Water (Management and Regulation) Act was enacted in 2019. Even after the enforcement of the Rain Water Harvesting and Recharging Policy (2001) and the Policy for Sustainable Ground Water Management in Uttar Pradesh (2013), no effective results were seen due to the penalty provision for the non-implementation of rainwater harvesting structures in the buildings (Singh, 2020). Later, the penalty provision was added in the Uttar Pradesh Ground Water (Management and Regulation) Act, 2019. The act makes registration mandatory and also regularizes the abstraction quantity for industrial, commercial, and bulk users.

The act provides a clause for a fee for groundwater abstraction and also provides a clause for a penalty for abstracting groundwater in an unauthorized manner. However, the act does not apply to domestic and agricultural users.

The groundwater recharge practice has been enhanced due to the effectiveness of the "Varsha Jal Sanchayan evam Bhujal Recharge Yojana" policy on the ground level. Although efforts for groundwater recharge have been witnessed at the government level, with negligible public participation. Therefore, there is a need to sensitize the general public to change their attitudes towards these crucial problems of groundwater shortage. In Uttar Pradesh, maximum groundwater recharge (about 50%) was reported in the monsoon season with rainfall water, followed by 28% with other sources in the non-monsoon season, and 18% with other sources in the monsoon season (GoI, 2020; Pandey et al., 2022).

Six major drains (Abu nala 1 &2, Surajkund nala, Odean road nala, Clock tower nala. Baccha park nala, and Kishanpur nala) carries the 310 MLD of wastewater generated in the urban area of Meerut district. Out of this huge quantity of wastewater generated, the district possesses the treatment capacity of only 50-60MLD, leaving the large quantity untreated. This large gap in the wastewater treatment is due the absence of the required infrastructure. Although, a 220 MLD wastewater treatment plant in under construction and two wastewater treatment plant of 65 and 48 MLD capacity are under proposal stage.

5. CHALLENGES IN GROUNDWATER MANAGEMENT

Even after the enforcement of various policies, acts, and laws, and miscellaneous management efforts, significant challenges remain:

- **Budgetary Constraint:** Even after the detection of arsenic in the ground in the Indo-Gangetic plain (Uttar Pradesh) in 2003, more specifically in Ballia and thereafter in 20 more districts along the Ganga River, no specific budget is allocated for contamination mapping and finding appropriate remedial measures.
- **Lack of awareness:** The existing acts, laws, and policies failed to provide satisfactory results, which may be due to a lack of awareness among the public, government officials, and public representatives.
- **Variation in land aquifer system characteristics:** The groundwater management practices largely depend on land and aquifer characteristics (Joshi et al., 2018). The geography, geology, and type of aquifer affect the storage quantity and physicochemical characteristics of the groundwater.
- **Faulty Policies:** Despite the groundwater scarcity, the subsidy on tubewells installation and electricity consumption is one of the major challenges for sustainable groundwater management (Ahamad et al., 2023 & 2025). Besides this, the minimum support prices (MSPs) of water-intensive crops are another big challenge (Pandey et al., 2022).
- **Legal framework:** Despite the groundwater scarcity, the subsidy on tubewells installation and electricity consumption is one of the major challenges for sustainable groundwater management (Ahamad et al., 2023 & 2025). Besides this, the minimum support prices (MSPs) of water-intensive crops are another big challenge (Pandey et al., 2022). A dedicated legal framework regarding the ownership of the groundwater is the need of the hour to avert the groundwater decline.
- **Unchanged Environmental Standards:** The effluent standard in India was designed in the early 1990s (Chakraborti et al., 2011), and since then, science and technology have shown exceptional growth, and now we can treat wastewater at a microscale level and can identify the health hazards of individual pollutants. However, no change in the effluent standards was done causing environmental nuisance.

6. CONCLUSION

The current review study was carried out to explore the current groundwater quality and management practices in the Meerut district and its outskirts. A systematic review of literature approach was followed to fulfill the objectives of the study. The review results revealed the alarming condition of the groundwater quality and quantity of the rural and urban area of the district with the increasing sloid concentration, detection of heavy metals, and decreasing groundwater level (91cm/year). Besides this, lack of any groundwater treatment facility and groundwater recharge practice is a matter of concern for the district as well as state authority. Lack of sufficient wastewater treatment facility is also a major concern for the groundwater management of the district. Strict applications of the groundwater regulatory policies, compulsory rainwater harvesting in large residential, academic, and industrial units, groundwater treatment plants, and infrastructure development for groundwater recharge and wastewater treatment is recommended for the sustainable groundwater quality and quantity management. Awareness campaigning with the help of national service schemes (NSS) and national cadet corps (NCC) unit of the academic institutions may also be helpful in increasing the sensitivity among the mass towards groundwater consumption and management practices.

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