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Assessment of Groundwater Quality in Jaipur District, Rajasthan, India, Using Water Quality Index

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Abstract

There are both open and closed bore wells. This research focuses on evaluating the groundwater quality in Jaipur by utilizing the Water Quality Index. For this comprehensive study, 22 water samples were meticulously collected from open and closed bore wells distributed across 22 different blocks within the district. The analysis involved measuring key physicochemical parameters, including pH, electrical conductivity, temperature, total dissolved solids, and salinity. These parameters were chosen due to their significant impact on water quality and their relevance to public health. The average water quality characteristics over the entire study period were used to calculate the Water Quality Index. The results of the study reveal that none of the sampled locations exhibit groundwater quality that is considered excellent for consumption purposes. This study's findings are crucial as they highlight the pressing need for improved water quality management in the Jaipur district. The data and insights derived from this research will assist planners and policymakers in identifying specific areas where intervention is needed. Furthermore, the study emphasizes the importance of implementing strategic measures to enhance water quality and ensure the sustainable extraction of groundwater resources in Jaipur. Such actions are essential for safeguarding public health and ensuring the long-term availability of clean drinking water in the region.

Keywords: Jaipur City, Ground water quality, Water Quality Index, pH, EC, TDS

INTRODUCTION

Groundwater is a vital component of the Earth's water cycle, representing the water that infiltrates through the layers of rocks and soil, eventually accumulating below the surface. This subterranean water resides in geological formations known as aquifers, which are typically composed of materials such as gravel, sand, sandstone, or limestone. These rocks are characterized by their large, interconnected pores, making them porous and allowing water to flow through them efficiently [1–3].

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Within an aquifer, the saturated zone is the specific area where water fills the spaces between the particles of rock and soil, effectively storing significant quantities of water. The upper boundary of this saturated zone is known as the water table, which indicates the depth below the ground surface at which groundwater is located. The position of the water table can vary dramatically, ranging from just a foot below the surface to several hundred meters deep, depending on factors such as topography, geology, and climatic conditions. The dynamics of the water table are influenced by various environmental and human activities. Heavy rainfall can lead to a rise in the water table as the increased volume of water infiltrates the ground and recharges the aquifer. Conversely, extensive and persistent extraction of groundwater for agricultural, industrial, or domestic use can result in a significant lowering of the water table. This fluctuation in the water table level is a critical aspect of groundwater management, as it impacts the availability of water resources for ecosystems and human consumption. Understanding the characteristics and behavior of aquifers and the water table is essential for effective water resource management. It helps in planning sustainable extraction practices, ensuring the long-term availability of groundwater, and protecting the health of both natural ecosystems and human communities that depend on this crucial resource [4–8].

Ground Water Availability

The country's water resource potential, or annual water availability, in terms of natural river runoff (flow), is around 1,869 billion cubic meters (BCM) per year. However, the country's usable water resources have been estimated at 1,123 BCM per year. This is owing to topographic restrictions and uneven resource distribution throughout river basins, making it impossible to harvest the total available 1,869 BCM/year. After allocating 35 BCM for natural discharge, the net annual groundwater availability for the country stands at 398 BCM. Rainfall contributes 68% to the country's annual groundwater resources, while other sources like canal seepage, return flow from irrigation, and recharge from tanks, ponds, and water conservation structures make up the remaining 32%. The growing population has led to a decline in the national per capita annual water availability, dropping from 1,816 cubic meters in 2001 to 1,544 cubic meters in 2011, marking a 15% reduction. Approximately 70% of our planet's surface is covered with water, while the remaining 30% consists of dry land. Aside from such a large volume of water, there are also several underground water reservoirs; however, the main challenge in using this water is the difficulty in accessing it. Due to tremendous advancements in science and technology, the need for water has climbed to a much higher level than it was previously, resulting in a demand for underground water usage. Groundwater reservoirs are significantly purer and safer compared to typical surface water resources. Groundwater plays a crucial role in human life, and with increasing water demands, it is imperative to utilize this resource effectively. Below are details regarding various groundwater reservoirs [9–15].

Global Water Distribution and Groundwater Availability in India

The Earth's total water volume is approximately 1.36×10^9 km^3. Of this, only about 8.336×10^6 km^3 is stored as groundwater, which is roughly 0.62% of the Earth's total water. Of the 8.336×10^6 km^3 of groundwater, around 4.168×10^6 km^3 is found within the upper 0.8 km of the Earth's crust, with the remaining 4.168×10^6 km^3 located in deeper strata beyond 0.8 km. Globally, 97.5% of water is contained in the oceans, leaving only 2.5% as freshwater. Of this freshwater, 68.7% is locked in glaciers, 30.1% is groundwater, 0.8% is in permafrost, and 0.4% is found in surface and atmospheric water [16, 17].

Out of the 0.4% of surface and atmospheric water, 67.4% is in freshwater lakes, 12.2% is in soil moisture, 9.5% is atmospheric water, 8.5% is in wetlands, 1.6% is in rivers, and the rest 0.8%, is biological water. According to the Ministry of Water Resources, Government of India, the country's total annual replenishable groundwater resource is estimated to be 433 billion cubic meters (BCM). Of this, approximately 34 BCM accounts for natural outflow. As a result, the country's net annual groundwater resource is approximately 399 billion cubic meters. The total yearly removal of groundwater is calculated at 231 BCM. Out of the 231 BCM withdrawn annually, 213 BCM is used for irrigation, while the remaining 18 BCM is removed for domestic usage. Infiltration enables a substantial amount of precipitation that lands on the earth's surface to seep into the ground. The infiltrated water is retained within the pores of subsurface soil layers. Groundwater refers to the water stored in these soil pores below the earth's surface. Groundwater hydrology examines the presence, distribution, and movement of this water, focusing on how it is stored in the soil voids beneath the Earth's surface and its interaction with surface water. Soil is considered saturated when all its pores are completely filled with water. Porosity refers to the ratio of the volume of voids to the total volume of the soil matrix, indicating the amount of empty space within the soil [18–23].

Hydrogeological Formations and Groundwater

The behavior of groundwater in the Indian subcontinent is intricate due to the varied geological formations, substantial lithological and chronological differences, a complex tectonic structure, climatic variations, and diverse hydrochemical conditions. Research indicates that aquifer groups in soft or alluvial rocks can extend beyond the borders of surface basins. Based on the distinct hydraulics of groundwater, rock formations can be classified into two main categories: porous formations and fissured formations [24].

Sources of Water

Water sources are classified into surface water and subsurface water. *Surface water* includes any water present on the land's surface, whether moving (such as streams and rivers) or stationary (such as lakes, reservoirs, and ponds). This water originates from precipitation runoff and natural groundwater seepage, encompassing all water that is exposed to the atmosphere and subject to surface runoff. That definition distinguishes surface water from both groundwater and ocean water. Patterns of surface runoff are described in terms of land areas that drain rainfall and melting snow to a certain point in a river or stream. These land areas can be referred to as drainage areas, drainage basins, catchments, or watersheds. Each watershed is bound by relatively high ground called a divide, which separates it from other watersheds. Groundwater from springs and seeps also contributes flow to most streams. This is often referred to as base flow. If the adjacent water table is at a level higher than the water surface of the stream, water from the water table flows to the stream. When the water table is lower than the surface level of a stream, the stream will replenish the groundwater. The pattern of flowing to or from the stream can vary according to the seasonal fluctuation of the water table. Many streams would dry up shortly after a rain if it were not for groundwater flow. *Subsurface water*: Groundwater is a crucial water resource globally, with its usage expanding in irrigation, industries, municipal services, and rural water supply schemes. This water is stored in geological formations called aquifers, which are layers of rock or sediment that hold enough permeable material to produce substantial amounts of water. The groundwater system is comprised of wells, springs, and infiltration galleries, all of which are integral to accessing this vital resource [25, 26].

The quality of groundwater is uniform and is free from turbidity and color. Generally, groundwater contains cations such as calcium, magnesium, iron, and manganese, as well as anions like bicarbonate, carbonate, and chloride.

Source Selection

Selecting sources for water supply involves evaluating factors such as hydrology, water quality, reliability, cost, and environmental and social impacts. Specifically, the following considerations should be included when studying water supply sources [27].

Groundwater

- Aquifer characteristics
- Safe aquifer yield
- Permissible drawdown
- Water quality
- Sources of contamination
- Saltwater intrusion
- Type and extent of recharge area
- Rate of recharge
- Water rights

STUDY AREA

Jaipur, the capital of Rajasthan, India, is the country's tenth most populous city. Situated at 26°54'N latitude and 75°49'E longitude, Jaipur experiences a continental climate with extreme temperatures in both summer and winter, and low to moderate relative humidity. The city records its highest mean monthly maximum temperature of 40.6°C in May and its lowest mean monthly temperature of 8.3°C in January. Jaipur receives the majority of its rainfall, 90%, during the monsoon season from June to September, with an average annual rainfall of 567.70 mm. Studies indicate that the probability of exceeding the average annual rainfall in Jaipur is about 25%, with a normal drought probability of 19.4%, and the likelihood of severe droughts being almost negligible [28].

Given the scarcity of perennial surface water sources, groundwater resources are especially vital for Jaipur. A 2011 study by the State Ground State Board revealed that Jaipur relies on groundwater for 86% of its potable water supply. Over the past thirty years, the water table in Jaipur has significantly declined and continues to do so at an alarming rate, with increasing nitrate concentrations in the groundwater. If current rates of groundwater extraction and pollution continue, the groundwater resources in many parts of Jaipur are at risk of being substantially depleted in the near future.

The physiography and landforms of Rajasthan, including Jaipur, are heavily influenced by the Aravalli hill range, which is the oldest mountain chain in India, trending NE-SW. The heights of the Aravalli ranges vary between 600 meters and over 900 meters above mean sea level. The quartzite formations create prominent scarps, and near Ajmer, these hills branch into several parallel ridges. At Mount Abu, the granite peaks reach their highest elevation at 1,722 meters (mean sea level) at Guru Shikhar [29].

MATERIALS AND METHODS

Experimental Details

Groundwater quality parameter experiment was conducted in the field condition as well as laboratory condition. Experiment on groundwater quality parameter in field test under field condition: In ground water studies, one of the most important issues is the quality of the groundwater. The quality of the groundwater in Jaipur city declined as a result of the city's fast industrialization and urbanization. Twenty-two groundwater samples were taken from different hand pumps across various blocks in Jaipur City.

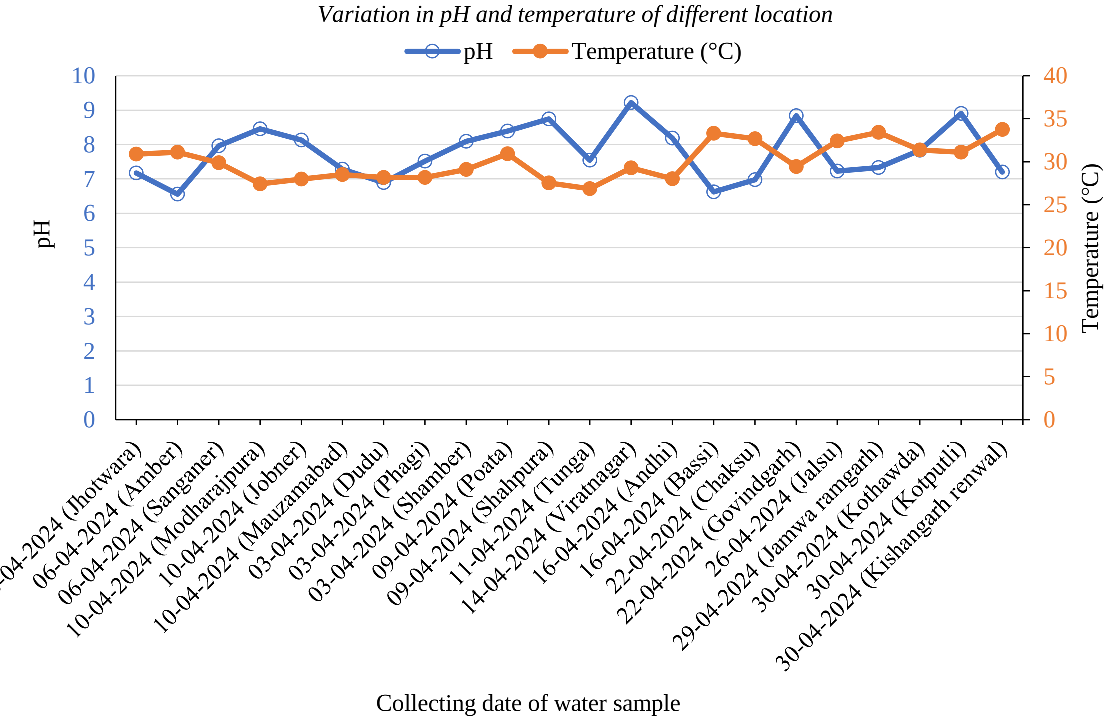
Sampling using the grab sampling method was carried out manually for collecting groundwater samples. Samples were collected in glass bottles of 500 ml capacity with stoppers. Before collection of samples, bottles were washed with 2% nitric acid and thoroughly rinsed with distilled water two times, dried, and then preserved in a clean place. At the time of sample collection, the bottles were filled, leaving no air space, and were then sealed to prevent any leakage. Each sample bottle was distinctly labeled with self-adhesive tags containing the sample number, type, collection date and time, location, and source type. All samples underwent laboratory testing [30].

RESULTS AND DISCUSSION

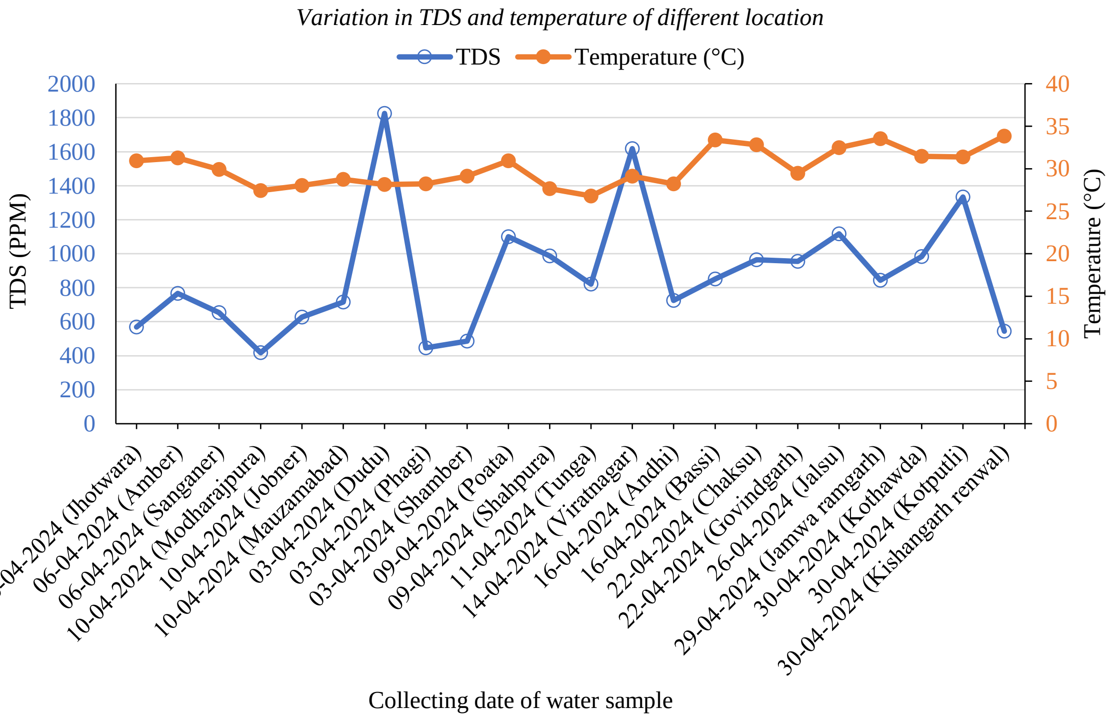
Both field and laboratory experiments under field conditions and controlled results are presented and will be followed by a discussion on the results of an experimental part. It was observed that the temperature value of groundwater was variable in the range 26.8°C to 33.7°C. The temperature was almost with an average value of 30.09°C. Statistical summary of all physical water quality parameters: it was observed that the PH value of groundwater was variable in the range of 6.19 to 8.42. The average value of pH is 7.8. It was observed that the TDS value of groundwater was variable in the range of 490 ppm to 1632 ppm. The average value of TDS is 883.45 ppm (Figure 1).

In the first phase, an experiment was carried out on groundwater quality parameters under the field conditions. The salient findings of the experiment were as below:

- The average value of pH is 7.8.
- The average value of TDS is 883.45 ppm.
- The average temperature is 29.90°C



(a)

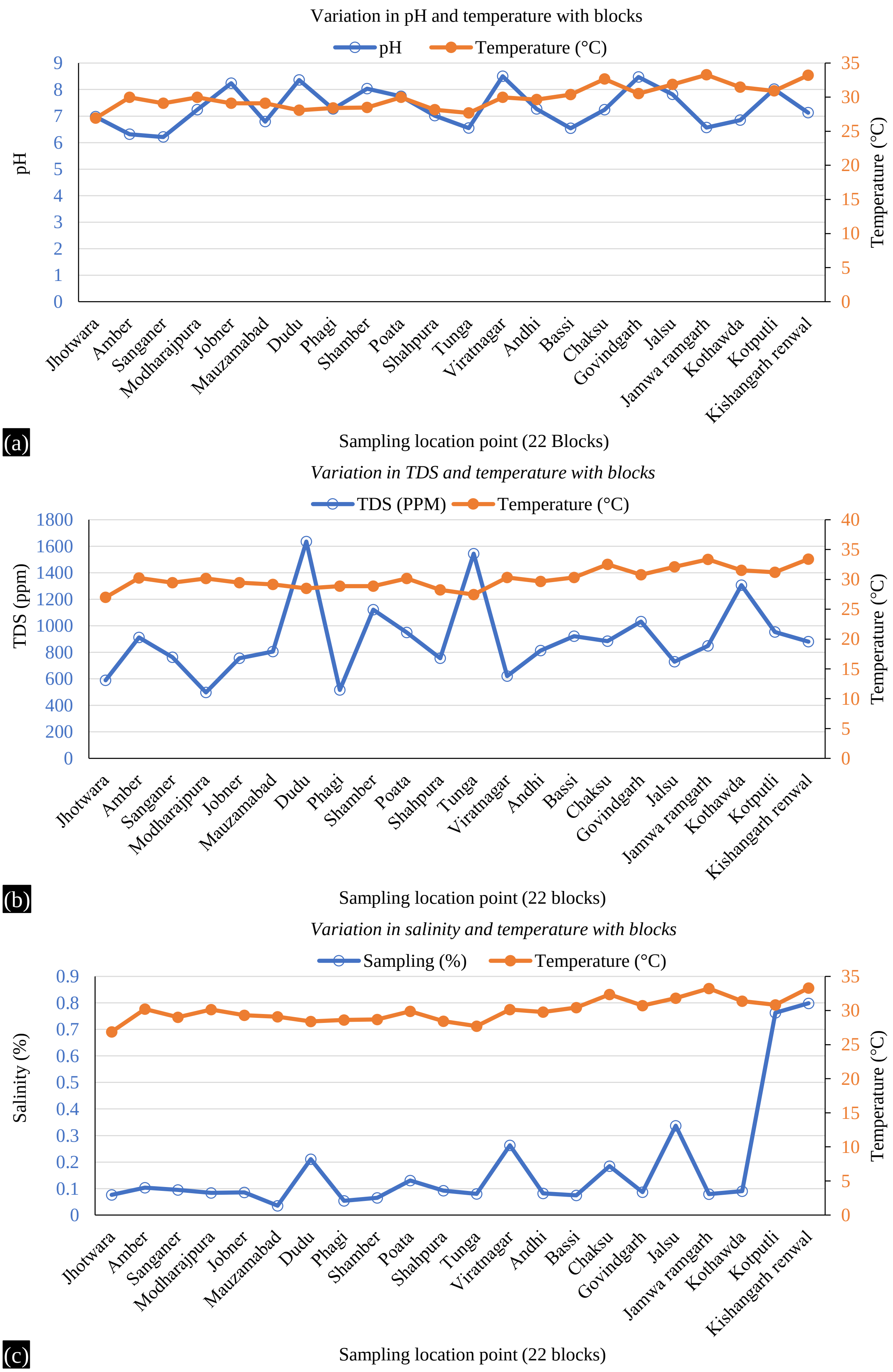


(b)

Figure 1. Variation in pH, TDS, and temperature of different location points.

In the second phase, an experiment was carried out on groundwater quality parameters under laboratory-controlled conditions. The salient findings of the experiment (Figure 2) were as below:

- The average value of pH is 7.86.
- The average value of TDS is 880.04 ppm.
- The average value of salinity is 0.17%.
- The average value of EC is 1583.09 µs/cm.
- The average temperature is 30.90°C


Variation in pH and temperature with blocks
pH
Temperature (°C)
Jhotwara
Amber
Sanganer
Modharajpura
Jobner
Mauzamabad
Dudu
Phagi
Shamber
Poata
Shahpura
Tunga
Viratnagar
Andhi
Bassi
Chaksu
Govindgarh
Jalsu
Jamwa ramgarh
Kothawda
Kotputli
Kishangarh renwal
(a)
Sampling location point (22 Blocks)
Variation in TDS and temperature with blocks
TDS (PPM)
TDS (ppm)
Temperature (°C)
(b)
Sampling location point (22 blocks)
Variation in salinity and temperature with blocks
Sampling (%)
Salinity (%)
Temperature (°C)
(c)
Sampling location point (22 blocks)

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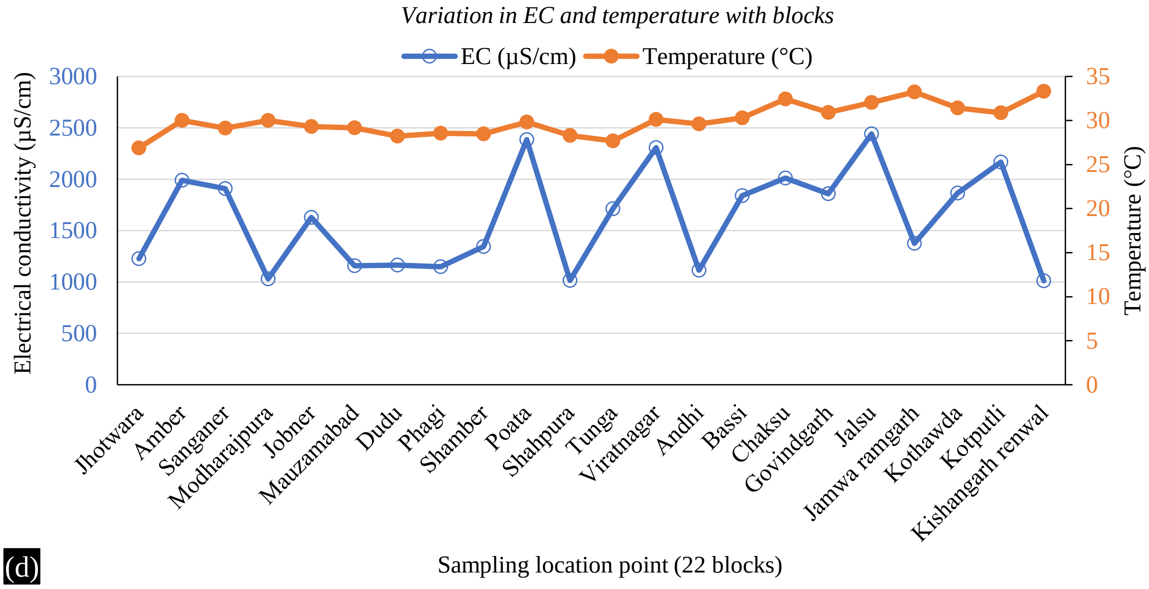

Figure 2. Variation in pH, TDS, salinity, EC, and temperature with different blocks.

CONCLUSIONS

Based on the present investigation in the Jaipur district, and according to the available data, it has been concluded that the excessive concentrations of electrical conductivity (EC) and total dissolved solids (TDS) render the groundwater unsuitable for drinking purposes in certain blocks. These elevated levels of EC and TDS can have detrimental effects on human health if consumed without proper treatment. Therefore, it is imperative to implement effective treatment methods to reduce these concentrations to acceptable levels before the groundwater can be deemed safe for consumption. This might involve the use of advanced filtration systems, reverse osmosis, or other purification technologies designed to remove or significantly reduce the presence of dissolved solids and salts. Moreover, regular monitoring and assessment of groundwater quality should be conducted to ensure the effectiveness of the treatment processes and to prevent future contamination. Public awareness campaigns are also essential to inform local communities about the potential risks of consuming untreated groundwater and the importance of adhering to safe water practices. Additionally, sustainable groundwater management practices should be adopted to prevent over-extraction, which can exacerbate the concentration of contaminants. This includes the promotion of water conservation techniques, efficient irrigation practices, and the development of policies to regulate groundwater use.

In conclusion, addressing the issues of high EC and TDS levels in the groundwater of Jaipur district requires a multi-faceted approach involving immediate treatment, continuous monitoring, public education, and sustainable management practices. These measures are crucial to ensure the provision of safe and clean drinking water for the residents of the affected areas, thereby safeguarding public health and promoting overall well-being.

REFERENCES

1. Chopra RPS, Krishan G. Analysis of aquifer characteristics and quality in southwest Punjab, India. J Earth Sci Eng. 2014; 4: 597–604.
2. Chopra RPS, Krishan G. Assessment of groundwater quality in Punjab. J Earth Sci Clim Change. 2014; 5: 243. Doi: 10.4172/2157-7617.1000243.
3. Krishan G, Rao MS, Loyal RS, Lohani AK, Tuli NK, et al. Groundwater level analyses of Punjab, India: A quantitative approach. Octa J Environ Res. 2014; 2 (3): 221–226.
4. Krishan G, Lapworth DJ, Rao MS, Kumar CP, Smilovic M, et al. Natural (baseline) groundwater quality in the Bist-Doab catchment, Punjab, India: A pilot study comparing shallow and deep aquifers. Int J Earth Sci Eng. 2014; 7 (1): 16–26.

5. Krishan G, Rao MS, Purushothaman P, Rawat YS, Kumar CP, et al. Groundwater resources in Bist-Doab region, Punjab, India: An overview. NDC-WWC J. 2014; 3 (2): 5–13.
6. Krishan G, Lohani AK, Rao MS, Kumar CP. Prioritization of groundwater monitoring sites using cross-correlation analysis. NDC-WWC J. 2014; 3 (2): 28–31.
7. Krishan G, Singh RP, Takshi KS. Water level fluctuation as the sum of environmental and anthropogenic activities in Southeast, Punjab (India). J Environ Anal Toxicol. 2015; 5: 298.
8. Krishan G, Singh RP, Khanna A, Singh S, Ghosh NC. Recent groundwater status of groundwater in Haridwar district, Uttarakhand. In: Proceedings of National Seminar on R & D Perspective for Rejuvenation of River Ganga; 2015 Dec 16-17; Roorkee, Uttarakhand, India. NIH; 2015. 12–13 p.
9. Krishan G, Singh S, Sharma A, Sandhu C, Grischek T, et al. Assessment of river quality for river bank filtration along Yamuna River in Agra-Mathura districts of Uttar Pradesh. In: Proceedings of National Conference on Monitoring and Management of Drinking Water Quality (MMDWQ) & XXVIII annual conference of National Environment Science Academy; 2015 Dec 21-23; Dehradun, Uttarakhand, India. UCOST; 2015.
10. Lapworth DJ, Krishan G, Macdonald AM, Rao MS, Gooddy DC, et al. Using environmental tracers to understand the response of groundwater resources in new India to sustained abstraction. In: Proceedings of the 41st International Conference of International Association of Hydro-geologists (IAH-2014) on Groundwater: Challenges and Strategies; 2014 Sep 18–19; Marrakech, Morocco: NERC.
11. Lapworth DJ, Krishan G, Rao MS, MacDonald AM. (2014). Intensive groundwater exploitation in the Punjab: an evaluation of resource and quality trends. NERC Open Res Arch BGS-UK, OR-14-068. [Online] Available at https://nora.nerc.ac.uk/id/eprint/509752/
12. Lapworth DJ, MacDonald AM, Krishan G, Rao MS, Gooddy DC, et al. Groundwater recharge and age-depth profiles of intensively exploited groundwater resources in northwest India. Geophys Res Lett. 2015; 42 (10): 10664–10671. Doi: 10.1002/2015GL066416.
13. Rodell M, Velicogna I, Famiglietti JS. Satellite-based estimates of groundwater depletion in India. Nature. 2009; 460 (7258): 999–1002. Doi: 10.1038/nature08238.
14. Macdonald AM, Bonsor HC, Rao MS, Krishan G, Steenburgen FV, et al. Groundwater topologies in the Indo-Gangetic Basin. In: Proceedings of International Conference on Advances in Water Resources Development & Management; 2013 Oct 23–27; Chandigarh, India. PU; 2013.
15. Macdonald AM, Bonsor HC, Krishan G, Rao MS, Ahmed KM, et al. Groundwater in the Indo-Gangetic Basin: evolution of groundwater typologies. In: Proceedings of the 41st International Conference of International Association of Hydro-geologists (IAH-2014) on Groundwater: Challenges and Strategies; 2014 Sep 18–19; Marrakech, Morocco: NERC.
16. MacDonald AM, Bonsor HC, Taylor R, Shamsudduha M, Burgess WG, et al. Groundwater resources in the Indo-Gangetic Basin: resilience to climate change and abstraction. British Geological Survey Open Report, OR/15/047. 2015. p. 63.
17. Gautam SK, Maharana C, Sharma D, Singh AK, Tripathi JK, et al. Evaluation of groundwater quality in the Chotanagpur plateau region of the Subarnarekha River basin, Jharkhand State, India. Sustain Water Qual Ecol. 2015; 6: 57–74. Doi: 10.1016/j.swaqe.2015.02.002.
18. Krishan G, Rao MS, Kumar CP. Estimation of radon concentration in groundwater of coastal area in Baleshwar district of Odisha, India. Indoor Built Environ. 2014; 23 (3): 396–404. Doi: 10.1177/1420326X13480254.
19. Krishan G, Rao MS, Kumar CP. Radon concentration in groundwater of East Coast of West Bengal, India. J Radioanal Nucl Chem. 2015; 303 (3): 2221–2225. Doi: 10.1007/s10967-014-3655-0.
20. Singh S, Singh C, Kumar K, Gupta R, Mukherjee S. Spatial-temporal monitoring of groundwater using multivariate statistical techniques in Bareilly district of Uttar Pradesh, India. J Hydrol Hydromech. 2009; 57 (1): 45–54. Doi: 10.2478/v10098-009-0005-1.
21. Singh SK, Srivastava PK, Gupta M, Mukherjee S. Modeling mineral phase change chemistry of groundwater in a rural-urban fringe. Water Sci Technol. 2012; 66 (7): 1502–1510. Doi: 10.2166/wst.2012.352.

22. Singh SK, Srivastava PK, Pandey AC, Gautam SK. Integrated assessment of groundwater influenced by a confluence river system: Concurrence with remote sensing and geochemical modelling. Water Resour Manage. 2013; 27: 4291–4313. Doi: 10.1007/s11269-013-0406-7.
23. Singh SK, Srivastava PK, Singh D, Han D, Gautam SK, et al. Modeling groundwater quality over a humid subtropical region using numerical indices, earth observation datasets, and X-ray diffraction technique: A case study of Allahabad district, India. Environ Geochem Health. 2015; 37 (1): 157–180. Doi: 10.1007/s10653-014-9647-x.
24. Kim AG, Cardone CR. Scatterscore: A reconnaissance method to evaluate changes in water quality. Environ Monit Assess. 2005; 111 (1–3): 277–295. Doi: 10.1007/s10661-005-8225-0.
25. Liou SM, Lo SL, Wang SH. A generalized water quality index for Taiwan. Environ Monit Assess. 2004; 96 (1–3): 35–52. Doi: 10.1023/B.0000031715.83752.a1.
26. Sargaonkar A, Deshpande V. Development of an overall index of pollution for surface water based on a general classification scheme in Indian context. Environ Monit Assess. 2003; 89 (1): 43–67. Doi: 10.1023/A:1025886025137.
27. Tsegaye T, Sheppard D, Islam KR, Johnson A, Tadesse W, et al. Development of chemical index as a measure of in-stream water quality in response to land use and land cover changes. Water Air Soil Pollut. 2006; 174 (1–4): 161–179. Doi: 10.1007/s11270-006-9098-6.
28. Tiwari AK, Singh AK. Hydrogeochemical investigation and groundwater quality assessment of Pratapgarh district, Uttar Pradesh. J Geol Soc India. 2014; 83 (3): 329–343. Doi: 10.1007/s12594-014-0080-3.
29. Krishan G, Khanna A, Singh S, Singh RP, Ghosh NC. Water quality index of groundwater in Haridwar district, Uttarakhand. Water Energy Int. 2016; 58 (3): 55–58.
30. World Health Organization. Guidelines for drinking water quality. 2nd ed. Geneva, Switzerland: World Health Organization; 1996.

