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Assessment

Physiochemical Properties of Ground Water from Rohtak

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ABSTRACT: Water is essential for the survival, growth, and productivity of plants and animals. Agriculture in Rohtak, a key city in Haryana, features a mix of traditional crops like wheat, rice, and sugarcane. There is also a growing use of polyhouses for high-value vegetables and fruits. The district has Indo-Gangetic alluvium, and the soils range from fine to medium-textured. Groundwater in the area is mostly alkaline, hard, and saline, with high levels of chlorides and fluorides. This study aimed to examine the groundwater in the city. Three hand pumps were selected for testing: Sector 3, Sector 27, and near Tilyar Lake, Rohtak. The groundwater from these pumps was sampled and compared to tap water provided by the Municipal Council. The physicochemical analysis showed that the groundwater samples had an alkaline pH. In contrast, tap water had a near-neutral pH and lower ionic content, highlighting the effectiveness of municipal treatment. Some groundwater samples had reduced dissolved oxygen levels, indicating oxygen-depleted conditions below the surface. This could lead to the movement of metals and worsen water quality. The heavy metal analysis raises significant concerns. The levels of arsenic, lead, cadmium, and mercury in groundwater samples—especially from Sector 27 and Tilyar Lake—were found to exceed the permissible limits set by WHO and BIS for drinking water. These elevated levels could pose long-term health risks, including neurological damage, kidney problems, and cancer. Although zinc levels were within acceptable limits, higher concentrations in groundwater might still affect its taste and quality. Overall, the findings suggest that untreated groundwater from various locations is not safe for direct human consumption.

INTRODUCTION

Water is the foundation of life on Earth and the most important natural resource for the survival, growth, and productivity of plants (Brendel, 2021). Every plant, from tiny mosses to large forest trees, relies on water as a physical medium and as a key element for growth and development. Water is not just a resource; it is a life-sustaining force that connects soil, atmosphere, plants, animals, and humans in an interdependent ecosystem.

In plants, water is crucial for photosynthesis. It is a raw material for producing carbohydrates and oxygen. It also acts as a solvent and transport medium, allowing essential nutrients and minerals to move from the soil to different parts of the plant. Proper water availability helps maintain cell turgidity, which is vital for cell expansion, structural support, and overall plant health (Akinci et al., 2010). Through transpiration, water regulates plant temperature and helps with nutrient uptake from the root zone.

The quality and availability of water significantly affect plant growth and agricultural productivity. When water is insufficient, plants experience water stress. This leads to reduced photosynthetic efficiency, stunted growth, and lower yields. Conversely, too much water can cause root hypoxia, nutrient leaching, and higher vulnerability to disease. Additionally, water quality factors like salinity, pH, and dissolved pollutants directly impact soil health and plant metabolism. This highlights the

important connection between water conservation and sustainable plant growth.

Given the increasing variability in climate, shrinking freshwater resources, and widespread environmental damage, protecting water systems is crucial for maintaining plant diversity and food security. Sustainable water management is not just an environmental concern; it is necessary for healthy plant growth, resilient ecosystems, and the long-term survival of life on our planet.

Groundwater is a key freshwater resource, supporting drinking water supplies, agriculture, and natural ecosystems, especially in areas where surface water is limited or seasonal. Unlike surface water, groundwater stays in contact with geological formations for extended periods (CGWB, 2013). This contact strongly influences its physical and chemical properties. These properties determine how suitable groundwater is for drinking, irrigation, industrial use, and ecological support.

The physical and chemical properties of groundwater include measurable characteristics such as temperature, pH, electrical conductivity, total dissolved solids, dissolved oxygen, hardness, alkalinity, and the concentration of major ions and trace elements (CGWB, 2018; Kothari et al., 2021). These parameters reflect complex interactions between water, soil, rock minerals, and human influences as groundwater flows through aquifers. Natural processes like mineral dissolution, ion exchange, and redox reactions, along with human activities such as agriculture, industrial discharge, and urbanization, shape groundwater chemistry ((Sengupta, 2013).

Assessing the physical and chemical properties of groundwater is essential for understanding water quality, identifying sources of contamination, and evaluating health and environmental risks. Changes in these parameters can affect nutrient availability, metal mobility, microbial activity, and soil structure when groundwater is used for irrigation. Long-term shifts in groundwater chemistry can also indicate environmental degradation and unsustainable water use. In the face of increasing groundwater exploitation, climate change, and pollution pressures, systematic monitoring and interpretation of physicochemical properties are crucial for ensuring sustainable groundwater management. Protecting groundwater quality not only safeguards human health but also supports agricultural productivity, ecosystem stability, and overall environmental resilience.

MATERIALS AND METHODS

Sample collection

Water samples were taken from three sites: Sector 3 (Lat. 28.896921, Long. 76.625218), Sector 27 (Lat. 28.862423, Long. 76.649782), and Tilyar Lake (Lat. 28.880222, Long. 76.634892) in Rohtak city, Haryana (Figures 1 and 2).

We collected hand pump water from these three sites, along with municipal tap water as a positive control. The samples were stored in light and dark bottles and taken to the laboratory in Asthal Bohar, Rohtak, Haryana.

pH

We measured the pH of the water, on-site during collection the pH paper was used. After bringing the water samples to the laboratory at Baba Mastnath University, we tested the pH using a pH meter (Eutech, Thermo Fisher Scientific, Singapore).

Hardness of groundwater

We determined the hardness of the water using the EDTA titration method described by Reda (2016). We diluted 25 mL of the water sample (noted as 'V') to about 50 mL with distilled water in an Erlenmeyer flask. The control flask had only distilled water. We then added 1 mL of ammonia buffer solution to the water samples. After that, we added two drops of Eriochrome Black T indicator solution to turn the contents wine red. The burette stand was set up, and we slowly added 10 mM standard EDTA titrant with continuous stirring until the reddish color disappeared and the solution turned blue. We recorded the volume of EDTA used as V1, and calculated the hardness using the following formula:

Calculation

$$\text{Hardness as CaCO}_3 = \frac{1000 V1}{V}$$



Figure 1. Map showing sample collection sites (Sector 27, Sector 3, and Tiliyar Lake, Rohtak) and laboratory at Baba Mastnath University, Asthal Bohar, Rohtak.



Figure 2. Ground Water collection from the three sites i.e., (a) Sector 3, Rohtak, (b) Sector 27 Rohtak, and (c) Tiliyar Lake, Rohtak.

Dissolved Oxygen (DO) of the groundwater samples

For this, we used a 300 mL glass-stoppered DO bottle, filling it gently from the bottom while allowing overflow for at least 2–3 volumes. We carefully avoided air bubble formation. We placed the stopper on the bottle, ensuring no air space was trapped. Then, we added 2 mL of MnSO_4 solution just below the surface using a pipette. Next, we added 2 mL of alkaline iodide-azide reagent as described for the MnSO_4 addition. We used the stopper to cover the bottle, and gently inverted it several times to mix, forming a brown, orange, or white precipitate. We allowed the precipitate to settle in the lower third of the bottle (typically 10–15 minutes). After that, we added 2 mL of concentrated H_2SO_4 . We again applied the stopper and gently inverted the bottle to dissolve all precipitates, resulting in a uniform yellow-brown solution (iodine).

To titrate, we took 100 mL of the fixed sample in an Erlenmeyer flask and titrated it with 0.025 N sodium thiosulfate solution until the yellow color faded. We added 1–2 mL of starch solution indicator to turn the solution blue. We measured the volume of thiosulfate used (mL).

Calculation

$$\text{Dissolved Oxygen} = \frac{V_{\text{thio}} \times N \times 8000}{\text{Sample Volume (mL)}}$$

Heavy metal detection

We estimated heavy metals like arsenic, cadmium, lead, and mercury in water and soil samples using standard procedures (Srikanth et al., 2013).

RESULTS

Physicochemical properties of water samples

Transparency of water.

We placed the water in transparent containers to examine transparency. We rinsed the bottles to stir the water. The water from Sector 3 and Tilyar was clear, while the water from Sector 27 was murky (Figure 3).



Figure 3. The transparency of the water samples collected from Sector 3, Sector 27 and Tilyar lake Rohtak

Taste characteristics of groundwater samples

We evaluated the taste of groundwater samples from different locations using a scale from 1 to 10, where lower values indicate better taste and higher values indicate poorer taste quality. The results showed noticeable differences in taste among the sampled waters (Figure 4).

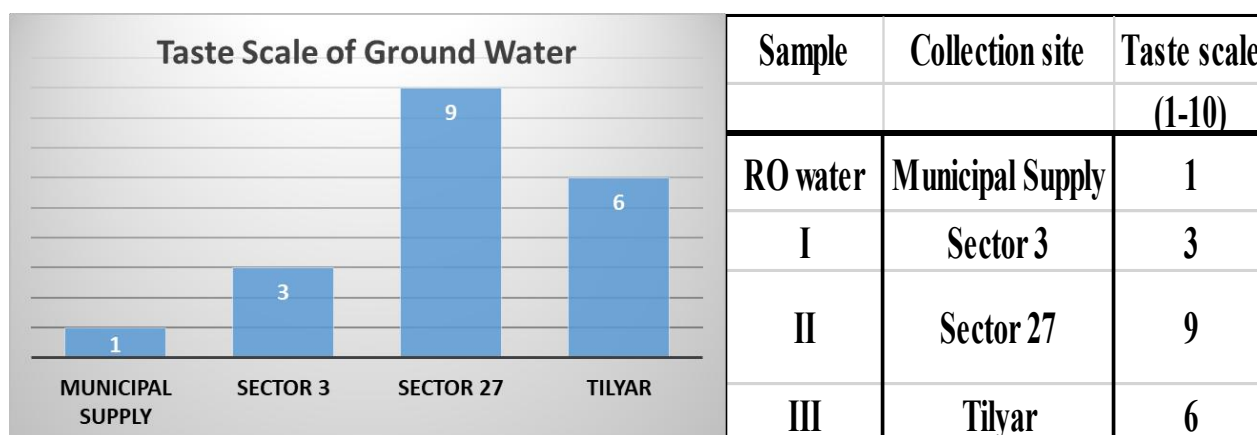


Figure 4. The taste of the three water samples namely, Sector 3, Sector 27 Rohtak and Tilyar Lake was scored on a scale of 1-10 taking RO water as 1 and most salty water tasted as 10 and the observation was recorded.

pH of different groundwater samples in comparison with WHO/BIS guidelines

We analyzed the pH of groundwater samples from various locations and compared them with tap water (municipal supply) as the control (Figure 5 and 6). The observed pH values were assessed against the World Health Organization (WHO) and Bureau of Indian Standards (BIS: IS 10500:2012) guidelines, which recommend a pH range of 6.5–8.5 for drinking water. The control sample (tap water) showed a near-neutral pH of 7.28, which is within the acceptable limits from both WHO and BIS, indicating good quality for human consumption. Groundwater sample I (Sector 3) had an alkaline pH of 8.62, just above the upper permissible limit (8.5). Sample II (Sector 27) had the highest pH of 9.0, clearly exceeding recommended standards, which suggests poor compliance with drinking water guidelines. Groundwater sample III (Tilyar) had a pH of 7.5, remaining within the acceptable range and similar to the control value. Overall, while one groundwater sample and the control met WHO/BIS standards, two groundwater samples had alkaline pH levels above the recommended limits, raising potential concerns for long-term domestic use without proper treatment.

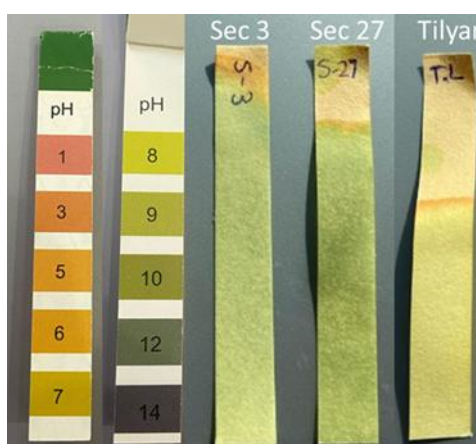


Figure 5. pH of the water samples using pH Paper collected from Sector 3, Sector 27 and Tilyar lake, Rohtak

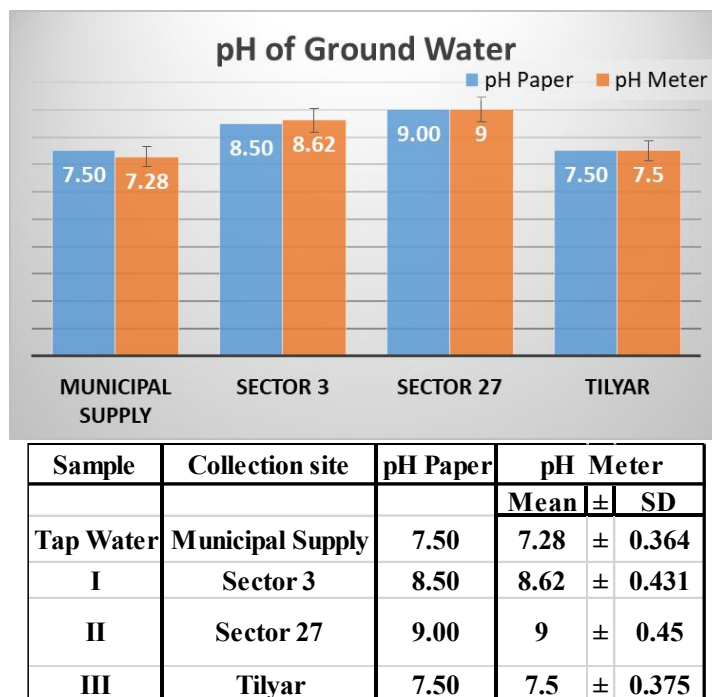


Figure 6. pH of the water samples collected from Sector 3, Sector 27 and Tilyar lake Rohtak

Hardness of the groundwater samples:

Hard water generally requires more soap to produce lather and can leave scale in pipes, heaters, and boilers. Hard water can be suitable for human consumption, similar to soft water, but it can create issues with soap and is not ideal for cleaning. Thus, its removal from water is often needed. Hardness can vary by location, with surface waters typically being softer than groundwater. Water is usually classified by its hardness level.

The average total hardness of groundwater samples was significantly higher than that of the control (120 ± 6.00 mg/L) (Figure 7). Sample II had the highest hardness (336 ± 16.8), classifying it as very hard water. Samples I (288 ± 14.40) and III (280 ± 14.00) were classified as hard water. The relatively high standard deviation values for hardness indicate variability in calcium and magnesium ion concentrations at the sampling sites.

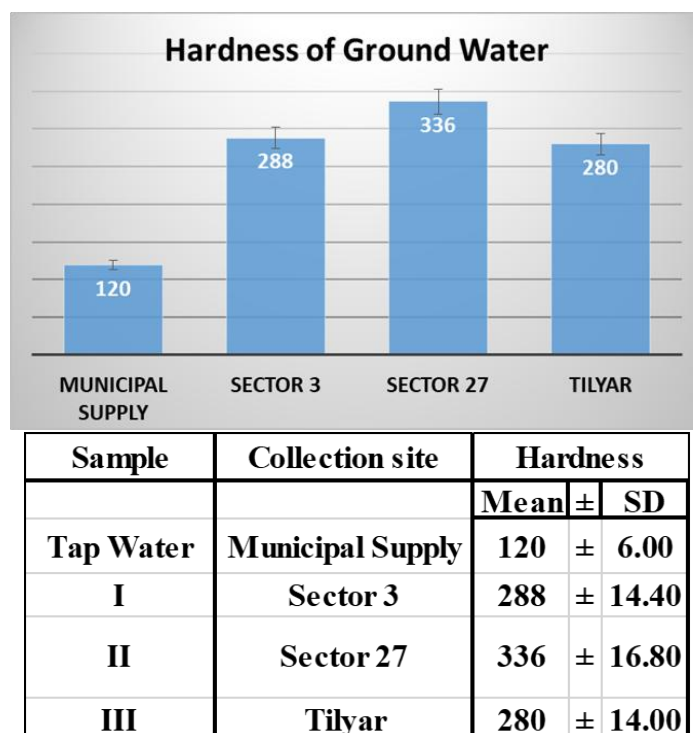


Figure 7. Hardness of water samples collected from Sector 3, Sector 27 and Tilyar Lake of Rohtak

Dissolved Oxygen (DO) levels in groundwater samples

We analyzed the concentration of dissolved oxygen (DO) in groundwater samples and compared it to tap water used as the control. The results are presented as mean $\pm$ standard deviation (SD) to show the variability among sampling locations (Figure 8).

The control (tap water) had a higher average DO value (4.5 ± 0.225), indicating well-aerated conditions and effective treatment. In contrast, groundwater samples had lower average DO concentrations, with noticeable variation among locations. Among the groundwater samples, Sample III (Tilyar) had a relatively high mean DO (4.53 ± 0.23), and Sample I (Sector 3) showed a moderate mean DO value (4.52 ± 0.23), indicating better oxygenation. Sample II (Sector 27) showed the highest mean DO (5.35 ± 0.27), suggesting lower oxygen availability and greater variability across locations.

The results show that groundwater samples have lower and more variable DO levels compared to tap water, with some sites having significantly depleted oxygen concentrations.

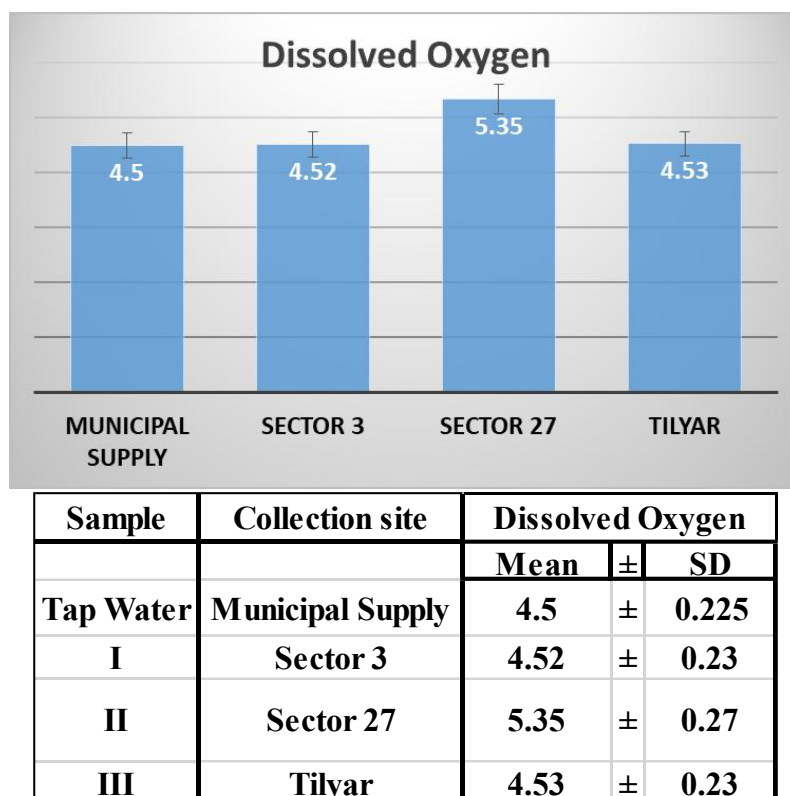


Figure 8. Dissolved Oxygen (DO) of water samples collected from Sector 3, Sector 27 and Tilyar Lake of Rohtak

Heavy metal concentrations in groundwater samples

We analyzed concentrations of arsenic (As), lead (Pb), cadmium (Cd), mercury (Hg), and zinc (Zn) in groundwater samples from various sites and compared them to tap water used as the control (Figure 9). The results are displayed as mean $\pm$ standard deviation (SD), indicating variability among sampling sites.

Arsenic (As)

Arsenic concentrations ranged from ~ 0.23 mg/L in tap water and ~ 0.25 mg/L in Sector 3 to ~ 0.32 mg/L in Tilyar Lake, with groundwater samples from Sector 27 and Tilyar Lake (~ 0.31 mg/L) showing the highest mean values. All groundwater samples had elevated arsenic levels compared to the control.

Cadmium (Cd)

Cadmium concentrations ranged from ~ 0.02 mg/L (Sector 3) to ~ 0.038 mg/L (Tilyar Lake). Groundwater samples from Sector 27 (~ 0.034 mg/L) and Tilyar Lake (~ 0.038 mg/L) recorded higher mean cadmium values than the control, indicating increased cadmium contamination.

Lead (Pb)

Lead concentrations ranged from approximately 0.005 mg/L in Tilyar Lake to about 0.014 mg/L in Sector 27. The highest average Pb concentration occurred in Sector 27, followed by Sector 3 at around 0.09 mg/L and tap water at about 0.01 mg/L, with Tilyar Lake having the lowest Pb levels.

Mercury (Hg)

Mercury levels were lowest in Tilyar Lake, measuring around 0.008 mg/L, and highest in Sector 27 at about 0.05 mg/L. Both tap water and Sector 3 had similar average Hg values, around 0.01 mg/L, while Sector 27 showed significantly higher concentrations.

Zinc (Zn)

Zinc concentrations varied, with tap water showing around 3.0 mg/L and Tilyar Lake showing about 5.0 mg/L. Groundwater samples revealed higher Zn levels than the control, with Tilyar Lake having the highest average concentration, followed by Sector 3 at roughly 4 mg/L and Sector 27 at about 3.5 mg/L.

Overall, groundwater samples, especially from Sector 27 and Tilyar Lake, showed higher average heavy metal concentrations and more variability than treated tap water.

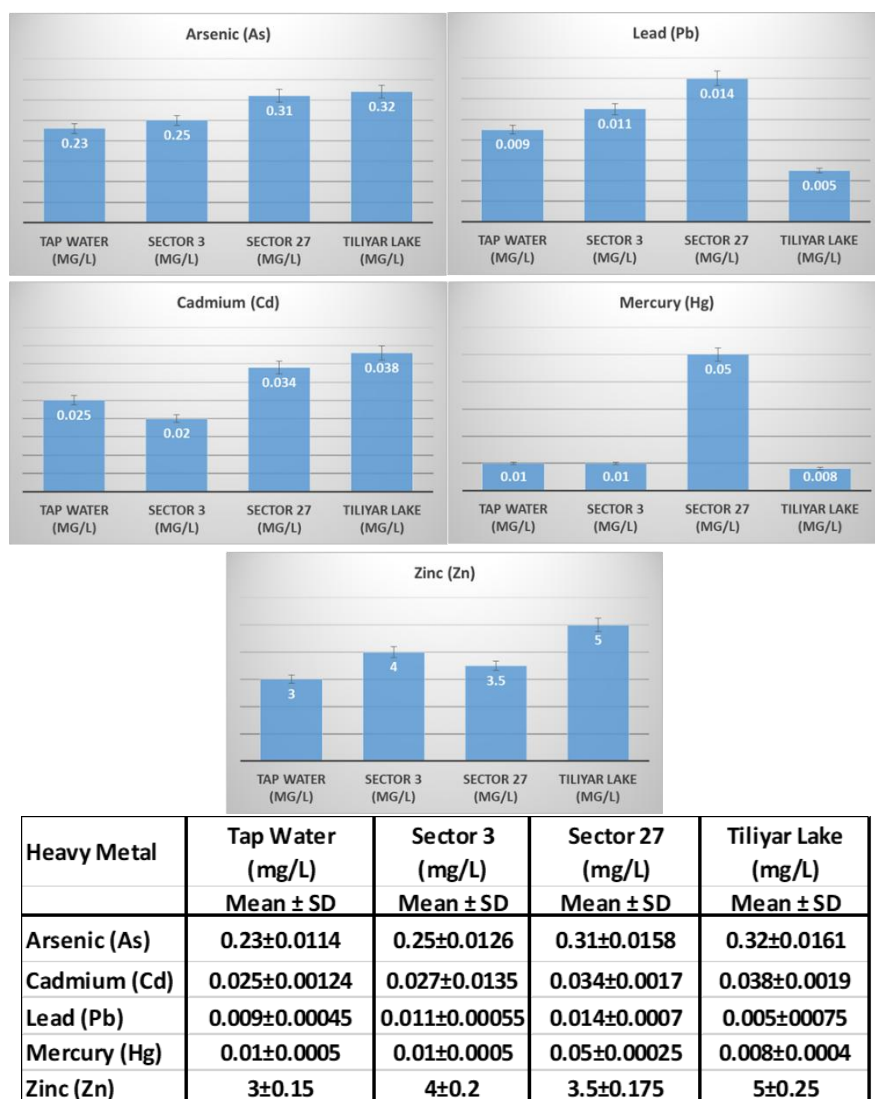


Figure 9. Heavy Metals (HM) of water samples collected from Sector 3, Sector 27 and Tilyar Lake of Rohtak

DISCUSSION:

The reverse osmosis (RO) water sample from the municipal supply had the best taste, scoring the lowest at 1.0, which indicates high acceptability for drinking. Groundwater sample I from Sector 3 had a mildly to moderately acceptable taste, with a taste scale value of 3. Sample III from Tilyar Lake received a moderate score of 6.0, suggesting dissolved salts or minerals affect its taste. In contrast, groundwater sample II from Sector 27 had the highest taste scale value of 9.0, indicating poor taste quality and low consumer acceptability. The unpleasant taste may result from high levels of dissolved solids or ions that cause hardness, as noted by Bruvold and Ongerth in 1969 and WHO in 1996, which are typically found in urban and peri-urban groundwater.

Groundwater hardness is largely determined by the levels of calcium and magnesium ions and has a strong link with both pH and total dissolved solids (Kothari et al., 2021). Hard water samples usually had alkaline pH levels due to the presence of bicarbonate alkalinity from dissolved carbonate minerals. This is common in groundwater systems of semi-arid and alluvial regions in northern India, where calcareous soils and sedimentary formations are abundant (CGWB, 2018; Kothari et al., 2021).

Total hardness values support the prevalence of calcium and magnesium ions in groundwater (Czekala et al., 2011). Increased hardness, along with notable variability, reflects the dissolution of limestone and dolomite, which is typical of alluvial aquifers. While hardness itself does not generally pose severe health risks, high average values can affect water usability in homes and infrastructure, especially when accompanied by high TDS and alkalinity (Sengupta, 2013). The results show that treated water (RO) was very acceptable, while many groundwater samples had lower taste quality. This highlights how local hydro-geochemical conditions impact taste and the importance of proper treatment before consumption.

The pH is a key physicochemical factor that influences groundwater chemistry, taste, corrosion potential, and overall suitability for drinking (García-Ávila et al., 2025). Variation in pH among groundwater samples reflects differences in geological formations, mineral dissolution, and interactions between water and rocks (Benmerabet et al., 2025). The near-neutral pH of tap water likely results from municipal treatment methods, including controlled chlorination and buffering, which help maintain pH within acceptable levels. Similar results have been noted in treated municipal water supplies in urban areas of India (BIS, 2012).

Higher pH values recorded in groundwater samples from Sector 3 and Sector 27 indicate alkaline conditions, usually linked to carbonate, bicarbonate, and hydroxide ions from calcareous soils and sedimentary rocks. Extended groundwater residence time and limited recharge can further increase alkalinity (Hem, 1985; Todd & Mays, 2005). Although pH values slightly above 8.5 are not an immediate health risk, very alkaline water ($\text{pH} \geq 9$) can taste bitter, hinder disinfection, and cause scaling in pipes, affecting both taste and infrastructure (WHO, 2017; Khandelwal et al., 2019). The poor taste found in groundwater sample II may be related to its high pH and dissolved solids. Groundwater sample III had a pH within acceptable levels, indicating more balanced geochemical conditions and better buffering. Similar findings have been observed in areas with active recharge and less human impact (Freeze & Cherry, 1979).

These results emphasize the need for ongoing monitoring of groundwater pH, particularly in urban and peri-urban zones, and underline the necessity of effective treatment methods like neutralization or blending before use.

Dissolved oxygen is an important indicator of groundwater quality and redox conditions. It affects biological activity, organic matter breakdown, and the solubility of metals and nutrients (Zheng et al., 2023). Compared to surface water, groundwater typically has lower DO levels due to less contact with the atmosphere and slow replenishment rates. The higher average DO value with minimal standard deviation in tap water reflects controlled aeration during treatment and constant exposure to atmospheric oxygen. These conditions are typical of municipal water supplies and show stable oxygen levels (WHO, 2017). While there are no specific BIS or WHO limits for DO in drinking water, low DO values often indicate poor taste and potential development of anaerobic conditions. Such environments can mobilize iron, manganese, and other reduced compounds, which could negatively impact water usability (Todd & Mays, 2005). Continuous DO monitoring, alongside BOD and redox-sensitive ions, is vital for thorough groundwater quality assessments. Heavy metals in groundwater pose serious concerns due to their toxicity, persistence, and ability to accumulate in living organisms. The variations in metal concentrations reflect the combined effects of natural processes and human activities.

The high arsenic levels in all groundwater samples significantly exceed the WHO and BIS limit of 0.01 mg/L, indicating serious contamination. Such high levels of arsenic are often connected to natural release from sedimentary deposits, especially under alkaline and reducing conditions characterized by high pH and low dissolved oxygen in some samples. Similar arsenic contamination has been reported in the alluvial plains of northern India (Khan and Rai, 2023).

Lead concentrations, particularly in Sector 27, went beyond the WHO/BIS guideline value of 0.01 mg/L, suggesting contamination from urban runoff, plumbing, battery waste, and vehicle emissions (Liven et al., 2021). The comparatively lower Pb levels in Tilyar Lake may result from dilution and mixing effects of surface water.

Cadmium present above the acceptable limit (0.003 mg/L) in all groundwater samples shows significant human impact

(Benmerabet et al., 2025). Cadmium contamination often comes from industrial waste, phosphate fertilizers, and improper waste handling. High Cd levels can lead to long-term health issues, including kidney damage and bone harm.

Mercury levels, particularly in Sector 27, were well above the WHO guideline limit of 0.006 mg/L, indicating possible contamination from industrial discharge, airborne deposition, or improper mercury product disposal. High mercury levels are concerning due to their toxic effects and tendency to accumulate in organisms (Agustiani et al., 205).

In contrast, zinc concentrations, though elevated in groundwater samples, remained within the acceptable BIS limit of 5 mg/L. Zinc is a necessary trace element, often linked to natural mineral dissolution and the corrosion of galvanized pipes. However, higher levels of Zn may still affect water taste and overall quality (Akoteyon et al., 2011).

The consistently high heavy metal concentrations in Sector 27 indicate significant urban and human impacts, while elevated levels in Tilyar Lake show surface-groundwater interactions and sediment contamination. The relatively lower metal levels in tap water highlight the effectiveness of municipal treatment processes.

CONCLUSION

This study provides a detailed assessment of the physicochemical properties and heavy metal contamination of groundwater from selected locations, using tap water as a control. The findings clearly show that groundwater quality varies greatly across the study area and is heavily influenced by local hydro-geochemical conditions and human activities. The study emphasizes the immediate need for regular groundwater quality monitoring, source-specific treatment, and public awareness regarding groundwater contamination. Implementing proper remediation measures, careful waste disposal, and sustainable groundwater management practices is essential to ensure safe drinking water and protect public health in the area. Overall, the results stress the importance of ongoing monitoring, identifying sources, and applying appropriate remediation strategies to minimize heavy metal exposure from groundwater consumption.

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