ASSESSMENT OF GROUNDWATER QUALITY IN UNION COUNCIL THUL, JACOBABAD DISTRICT, SINDH, PAKISTAN

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ABSTRACT: In response to growing concerns about groundwater contamination in Union Council (UC) Thul, Jacobabad District, Sindh, Pakistan, this study evaluates the drinkability of groundwater using the Synthetic Pollution Index (SPI) model. A total of 20 groundwater samples were collected from various locations within the study area and analyzed for critical physicochemical parameters, including pH, chloride, nitrate, nitrite, calcium, magnesium, sulfate, electrical conductivity (EC), total dissolved solids (TDS), and total hardness. The pH levels ranged from 7.5 to 7.8, indicating neutral to slightly alkaline conditions. Chloride concentrations varied significantly, ranging from 80 to 1892 mg/L, with some samples exceeding safe limits. Calcium concentrations ranged between 16 and 256 mg/L (mean 81.2 ± 79.48), while magnesium levels ranged from 84 to 1148 mg/L (mean 400.8 ± 363.88), reflecting substantial geochemical variability. EC values spanned 0.4 to 5.1 dS/m, and TDS levels ranged from 280 to 3240 mg/L, suggesting issues with mineral dissolution and salinity. Total hardness varied widely from 100 to 1440 mg/L (mean 482 ± 443.21), identifying areas with hard and very hard water. The SPI model categorized water quality as follows: 30% of the samples were suitable for drinking, 60% were moderately contaminated, and 10% were unsuitable for drinking purposes. Notably, groundwater in Qadri Muhalla and Haji Muhammad Ramzan Noonari was classified as unsuitable for drinking due to elevated contaminant levels. These findings highlight the critical need for water management interventions, including the installation of reverse osmosis (RO) plants, promotion of rainwater harvesting, and public awareness campaigns to ensure safe and sustainable groundwater use in the study area.

Index Terms: Groundwater, physicochemical parameters, TDS, SPI model.

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INTRODUCTION

All living entities require water as their fundamental resource because it supports life and ecosystems and enables human activities [1]. Fast-growing threats to accessible clean water arise through environmental changes and expanding populations together with municipal development and careless water resource governance practices. Drinking water used by numerous people worldwide mostly derives from groundwater yet remains susceptible to natural and human-caused pollution sources [2].

Water from the groundwater reserves is an essential life source that supports residents throughout both rural areas and cities of Pakistan. The water quality in groundwater is declining because of industrial pollution alongside agricultural runoff and seawater intrusion that affects coastal areas particularly in Sindh province [3-7]. Research shows that rural inhabitants use groundwater that fails to satisfy quality benchmarks causing several health issues throughout their communities including diarrhea and typhoid alongside other waterborne diseases [8].

Water pollution in UC Thul's groundwater presents a serious problem to the residents of Jacobabad District within Sindh. Agriculture dominates the region because population figures reveal that farming consumes 85% of available workers. Water from groundwater serves as both the major supply for drinking needs and irrigation demands yet its quality deteriorates because of both human-caused and natural factors in the area. The fundamental role that groundwater plays in UC Thul suffers from a deficiency of thorough research on both water quality and contamination spread [6,10].

The assessed quality of UC Thul groundwater through the Synthetic Pollution Index (SPI) model constitutes the main purpose of this research. The Synthetic Pollution Index combines various physical and chemical parameters in one model that gives an all-encompassing view of water quality while helping to

discover pollution sources and design successful management plans [10]. This research investigation supports groundwater quality revelation in UC Thul through Synthetic Pollution Index measurements thereby delivering essential information to policymakers and other stakeholders to protect this vital water resource sustainably.

Experimental Work

Study Area: The administrative territory of Union Council Thul stands as a tehsil in Jacobabad District located within Sindh Province of Pakistan while also occupying 317,520 acres of land. The area ranks among the most populated union councils inside Jacobabad District as it contains 356,705 inhabitants. The territory consists mostly of agricultural land because more than 85% of residents practice farming. Among the primary crops cultivated in this area are paddy, rice, wheat and barley. All necessary water supply and irrigation needs of the local residents come from groundwater sources.

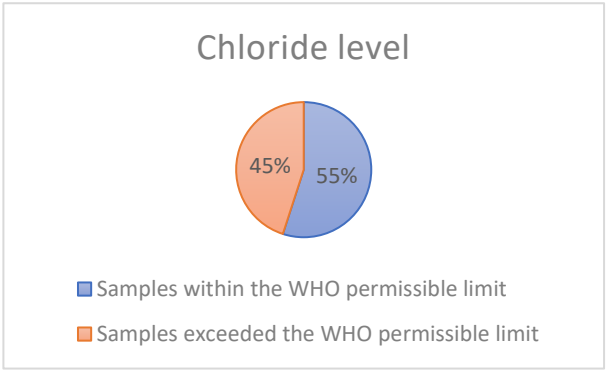
The south pakistan community of UC Thul spreads across 96 dehs (villages) through geographical coordinates 28° 13' N and 68° 46' E and reaches 196 feet (59 meters) above sea level. The community depends heavily on groundwater because the semi-arid climate brings high temperatures along with minimal rainfall to this area. The groundwater quality in UC Thul suffers from declining standards because of both natural factors such as salinity and human-derived influences from overused fertilizers and pesticides in agricultural practices.

Water Sampling and Analysis: Two and twenty groundwater samples were obtained from hand pumps and boreholes positioned within UC Thul's different regions. The selected sampling spots covered every part of the study area to achieve proper representation during this research. Sterile plastic bottles served as sample containers for prevention of any contamination during collection. The laboratory received these tested, labeled and then sealed samples for their subsequent analysis.

The laboratory analyzed 20 groundwater samples at multiple sites in UC Thul by measuring physicochemical parameters which included pH value together with chloride content and nitrate/nitrite levels and calcium and magnesium composition and sulfate presence and electrical conductivity (EC) strength and total dissolved solids (TDS) values and total hardness measurement. The World Health Organization (WHO) prescribed drinking water quality guidelines served as the benchmark for comparing the results measured by standard laboratory methods.

Water Quality Parameters: The analysis of groundwater in UC Thul included these testing areas to measure its quality:

1. pH: Measures the acidity or alkalinity of water. The pH scale has values extending from 0 to 14 at its ends with 7 matching neutral measures. Drinking water according to the WHO requirements should maintain between 6.5 to 8.5 pH levels.
2. High chloride content creates contamination signals that originate from industrial operations or agricultural activities. The WHO has established 250 mg/L as the maximum acceptable amount of chloride in drinking water.
3. The water contaminant nitrate (NO_3^-) exists widely in agriculture fertilizers that leak into groundwater through agricultural runoff. A maximum of 50 mg/L nitrate concentration is permitted by the WHO for drinking water standards.
4. The toxic substance nitrite (NO_2^-) develops when bacteria reduce nitrates regardless of the amount present. Drinking water must contain less than 3 mg/L of nitrite according to WHO recommendations.
5. Human health depends on calcium (Ca^{2+}) along with its role in forming water hardness. Pipeline systems and household appliances develop-scale because of hyper-calcium conditions.
6. Hardened water contains magnesium (Mg^{2+}) as one of its main contributing elements. Water containing high magnesium amounts leads to taste alteration and potential health problems.
7. The natural water compound sulfate (SO_4^{2-}) creates taste changes in drinking water while high amounts can lead to digestive problems. Drinking water containing sulfur up to 500 mg/L meets the standards established by the WHO.
8. Total Dissolved Solids (TDS) establishes the complete count of substances dissolved inside water while consisting of both minerals along with salts and organic materials. TDS concentration in drinking water should not exceed 500 mg/L according to the WHO standards.



9. The Total Hardness measurement determines how much calcium and magnesium ions exist in water supplies. International standards define the WHO permissible limit for drinking water total hardness as 500 mg/L.

10. The amount of electrical charge water can transmit through electrical currents depends on dissolved ion concentrations and this factor is measured through Electrical Conductivity (EC). High EC values reveal that the water has a high salt content. The WHO permits drinking water electrical conductivity to stay below 1500 µS/cm.

An assessment of groundwater quality in UC Thul was performed using the results from physicochemical testing and the Synthetic Pollution Index calculation provided complete framework evaluation.

RESULTS AND DISCUSSION

Physicochemical Analysis of Groundwater Samples: The physicochemical analysis of the 20 groundwater samples collected from UC Thul revealed significant variations in water quality parameters. The results are summarized below:

pH: The pH values of the groundwater samples ranged from 7.5 to 7.8, indicating neutral to slightly alkaline conditions. All samples fell within the WHO-recommended pH range of 6.5 to 8.5 for drinking water. This suggests that the groundwater in UC Thul is not acidic or excessively alkaline, making it suitable for consumption in terms of pH.

Chloride (Cl^-): Chloride concentrations varied widely, ranging from 80 to 1892 mg/L, with an average value of 556.5 mg/L. Approximately 55% of the samples had chloride levels within the WHO permissible limit of 250 mg/L, while 45% exceeded this limit. High chloride levels in some samples may be attributed to agricultural runoff or natural salinity.

Calcium (Ca^{2+}): Calcium concentrations ranged from 16 to 256 mg/L, with a mean value of 81.2 mg/L. About 60% of the samples had calcium levels within acceptable limits, while 40% exceeded the recommended levels. Excessive calcium can contribute to water hardness and scaling in pipes and appliances.

Magnesium (Mg^{2+}): Magnesium levels ranged from 84 to 1148 mg/L, with an average value of 400.8 mg/L. All samples exceeded the WHO permissible limit for magnesium, indicating high levels of hardness and potential health risks associated with excessive magnesium intake.

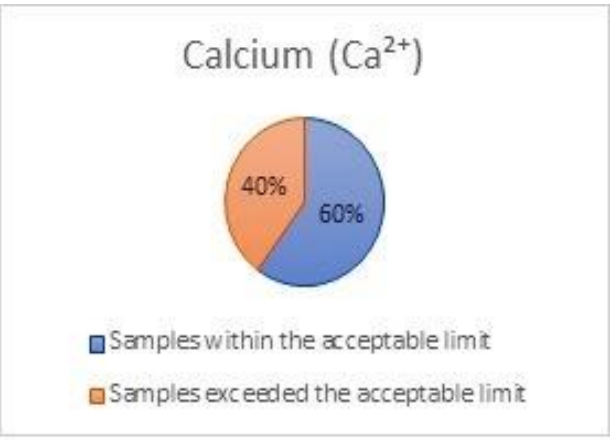
Electrical Conductivity (EC): EC values ranged from 0.4 to 5.1 dS/m, with an average of 2.08 dS/m. Only 10% of the samples had EC values within the WHO permissible limit of 1500 µS/cm (1.5 dS/m), while 90% exceeded this limit. High EC values indicate elevated salinity, which can affect the taste of water and pose health risks.

Total Dissolved Solids (TDS): TDS levels ranged from 280 to 3240 mg/L, with an average of 1333.25 mg/L. Only 10% of the samples had TDS levels within the WHO permissible limit of 500 mg/L, while 90% exceeded this limit. High TDS levels suggest significant mineral dissolution and salinity issues in the groundwater.

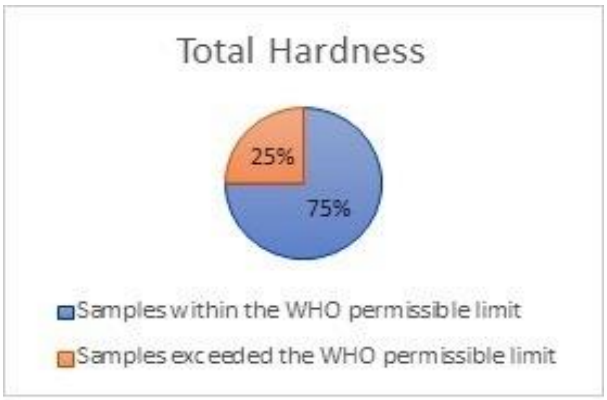
Total Hardness: Total hardness values ranged from 100 to 1440 mg/L, with a mean value of 482 mg/L. Approximately 75% of the samples had total hardness levels within the WHO permissible limit of 500 mg/L, while 25% exceeded this limit. High hardness levels can affect the suitability of water for domestic use.

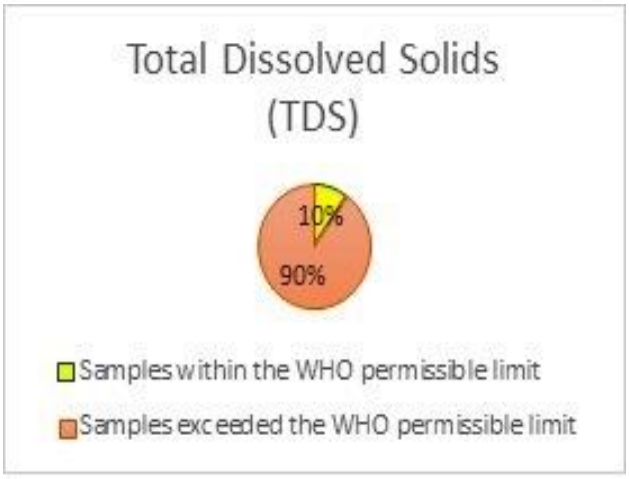
Sulfate (SO_4^{2-}):

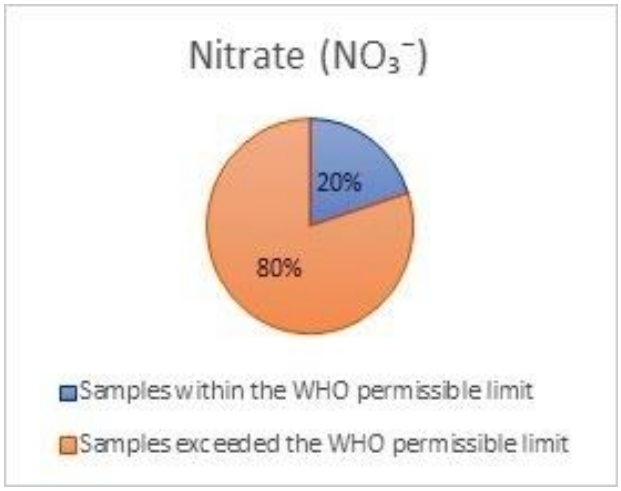
Sulfate concentrations ranged from 100 to 1500 mg/L, with an average of 415 mg/L. About 75% of the samples had sulfate levels within the WHO permissible limit of 500 mg/L, while 25% exceeded this limit. High sulfate levels can cause digestive issues and affect the taste of water.



Nitrate (NO_3^-): Nitrate levels ranged from 0 to 18 mg/L, with an average of 9.6 mg/L. Approximately 20% of the samples had nitrate levels within the WHO permissible limit of 50 mg/L, while 80% exceeded this limit. High nitrate levels are often associated with agricultural runoff and can pose health risks, particularly for infants.



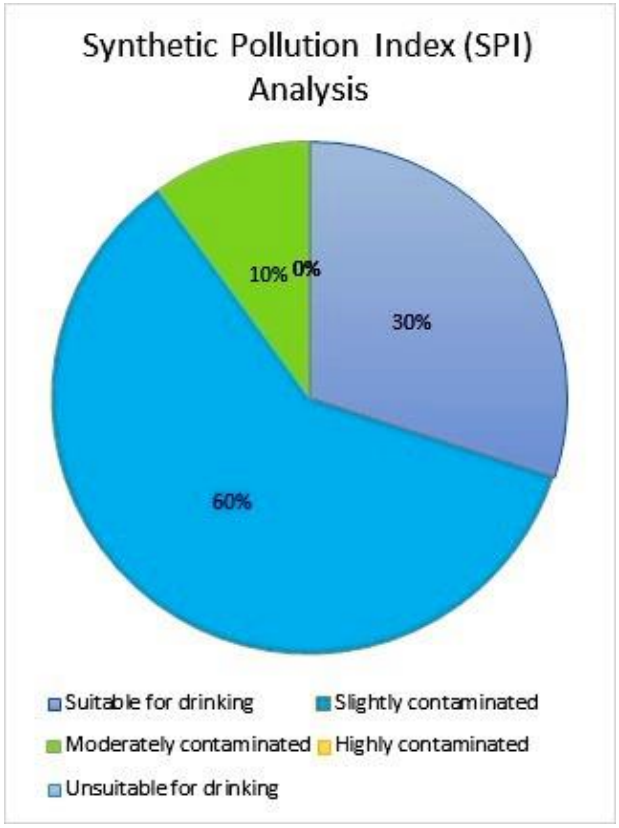




Nitrite (NO_2^-): Nitrite concentrations ranged from 0 to 1 mg/L, with an average of 0.11 mg/L. All samples had nitrite levels within the WHO permissible limit of 3 mg/L, indicating minimal risk from nitrite contamination.

Synthetic Pollution Index (SPI) Analysis: The Synthetic Pollution Index (SPI) model was used to evaluate the overall quality of groundwater in UC Thul. The SPI integrates multiple physicochemical parameters into a single numerical index, providing a comprehensive assessment of water quality. The SPI values were categorized as follows:

- Suitable for drinking (SPI < 0.2): 30% of the samples
- Slightly contaminated (SPI = 0.2–0.5): 60% of the samples
- Moderately contaminated (SPI = 0.5–1.0): 10% of the samples
- Highly contaminated (SPI = 1.0–3.0): 0% of the samples
- Unsuitable for drinking (SPI > 3.0): 0% of the samples



The SPI analysis revealed that 30% of the groundwater samples in UC Thul are suitable for drinking, while 60% are moderately contaminated and 10% are unsuitable for consumption. The most contaminated areas include Qadri Muhalla and Haji Muhammad Ramzan Noonari, where groundwater quality is severely compromised due to high levels of chloride, TDS, and hardness.

Conclusions and Recommendations

Conclusions: The study assessed the quality of groundwater in Union Council (UC) Thul, Jacobabad

District, Sindh, Pakistan, using the Synthetic Pollution Index (SPI) model. A total of 20 groundwater samples were collected from various locations and analyzed for key physicochemical parameters, including pH, chloride, nitrate, nitrite, calcium, magnesium, sulfate, electrical conductivity (EC), total dissolved solids (TDS), and total hardness.

The results revealed significant variations in groundwater quality across the study area. The pH levels ranged from 7.5 to 7.8, indicating neutral to slightly alkaline conditions, which are within the WHO-recommended range for drinking water. However, other parameters showed concerning trends:

- Chloride concentrations ranged from 80 to 1892 mg/L, with 45% of the samples exceeding the WHO permissible limit of 250 mg/L.
- Calcium levels ranged from 16 to 256 mg/L, with 40% of the samples exceeding acceptable limits.
- Magnesium concentrations ranged from 84 to 1148 mg/L, with all samples exceeding the WHO permissible limit.
- Electrical Conductivity (EC) values ranged from 0.4 to 5.1 dS/m, with 90% of the samples exceeding the WHO permissible limit of 1.5 dS/m.
- Total Dissolved Solids (TDS) levels ranged from 280 to 3240 mg/L, with 90% of the samples exceeding the WHO permissible limit of 500 mg/L.
- Total Hardness values ranged from 100 to 1440 mg/L, with 25% of the samples exceeding the WHO permissible limit of 500 mg/L.
- Sulfate concentrations ranged from 100 to 1500 mg/L, with 25% of the samples exceeding the WHO permissible limit of 500 mg/L.
- Nitrate levels ranged from 0 to 18 mg/L, with 80% of the samples exceeding the WHO permissible limit of 50 mg/L.

The SPI model categorized the groundwater quality as follows:

- 30% of the samples were suitable for drinking.
- 60% of the samples were moderately contaminated.
- 10% of the samples were unsuitable for consumption.

The most contaminated areas included Qadri Muhalla and Haji Muhammad Ramzan Noonari, where groundwater quality was severely compromised due to high levels of chloride, TDS, and hardness. These findings highlight the urgent need for water management interventions to ensure the availability of safe and clean drinking water for the local population.

Recommendations: Based on the findings of this study, the following recommendations are proposed to address groundwater contamination in UC Thul:

Installation of Reverse Osmosis (RO) Plants: The government should install RO plants in areas with high levels of contamination, such as Qadri Muhalla and Haji Muhammad Ramzan Noonari, to provide clean and safe drinking water to the local population.

Promotion of Rainwater Harvesting: Rainwater harvesting systems should be promoted to reduce dependence on groundwater and provide an alternative source of clean water.

Public Awareness Campaigns: The government and local organizations should conduct public awareness campaigns to educate communities about the risks of drinking contaminated water and the importance of water conservation.

Boiling of Water: Communities should be encouraged to boil water for 3 to 5 minutes before consumption to disinfect harmful bacteria and reduce health risks.

Improved Agricultural Practices: Farmers should be trained to adopt sustainable agricultural practices, such as the judicious use of fertilizers and pesticides, to minimize groundwater contamination.

Regular Monitoring of Groundwater Quality: Regular monitoring of groundwater quality should be conducted to identify contamination sources and implement timely interventions.

Development of Water Treatment Facilities: The government should invest in the development of water treatment facilities to ensure the availability of safe drinking water for all residents of UC Thul.

By implementing these recommendations, the quality of groundwater in UC Thul can be improved, ensuring the health and well-being of the local population and promoting sustainable water resource management.

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