Natural and Applied Sciences International Journal (NASIJ)
eISSN: 2788-4619 (online)
https://ideapublishers.org/index.php/nasij
Vol. 6, No. 1 (January-December), 2025, pp. 59-74
https://doi.org/10.47264/idea.nasij/6.1.3
Original Research Article

Assessment of ground water quality using geo-spatial techniques in Punjab, Pakistan

Muhammad Fahad Bilal[1] | Bilal Ahmad[1] | Shahid Ghazi[1] | Ihtsham Khan[2] | Abdul Majid[1, 2]

1. Centre For GIS, University of the Punjab, Lahore, Pakistan.
2. School of Geosciences and Info Physics, Central South University, Changsha, China.

* Corresponding Author Email: muhammadfahadbilal786@gmail.com

Abstract:

The need for Fresh groundwater has been continually rising because the accessible superficial water resources are unable to satisfy all our needs. The focus of the research paper was to identify the groundwater Quality in Tehsil Liaqatpur, District Rahim Yar Khan, Punjab province of Pakistan, using Geospatial Approaches. Water samples were collected with the help of GPS and sent to a laboratory for testing. The lowest and the highest values of 8 water quality parameters including the pH, electrical conductivity, alkalinity, total dissolved solids, chloride, hardness, sulphate and potassium for each parameter, a unique groundwater quality map is prepared using ArcGIS 10.4 that represents the spatial distribution of groundwater quality in the study area. The spatial distribution is subdivided into three major categories i.e., poor, good, and very good. The results showed that the study area has approximately good quality of water while some Northern, Central, and South-Western portions of Liaqatpur represent the poor quality of water that need attention of the authorities. Analysis also showed that the groundwater of the region needs field treatment before being put into use.

Article History

Received:
13-Aug-2024

Revised:
15-Jan-2025

Re-revised:
10-Jun-2025

Accepted:
13-Jun-2025

Published:
30-Jun-2025

Keywords: GIS, GPS, Water quality, Spatial distribution, Water resources, Groundwater quality, Electrical conductivity.

How to Cite:
Bilal, M. F., Ahmad, B., Ghazi, S., Khan, I., & Majid, A. (2025). Assessment of ground water quality using geo-spatial techniques in Punjab, Pakistan. *Natural and Applied Sciences International Journal (NASIJ), 6*(1), 59-74. https://doi.org/10.47264/idea.nasij/6.1.3

1. Introduction

Water is essential for human survival on earth and has a substantial influence on all ecological features (Bano & Arshad, 2018) Since Pakistan is primarily an agricultural economy, underground freshwater serves as one of the country's key irrigation supplies. Due to the lack of readily available surface water for irrigation, only groundwater has been used as the foundation for agricultural production.(Lytton et al., 2021) These underground water resources are becoming incredibly valuable and contributes significantly to Pakistan's financial stability, also emphasizing the need for protective measures(Ishaque et al., 2023)Due to Pakistan's reliance on agriculture primarily, the importance of water exceeds that of other countries. However, due to its low quality, the water supply also puts customers' health at risk(Fida et al., 2023). But sadly, drinking-water quality concerns receive little attention, and water delivery authorities continue to prioritize quantity over quality. Surface water sources are only used in a small number of Pakistan's main cities. While in the rural regions, the treated irrigation canal water is made available for household (Akhtar et al., 2018).

The broad recommendations for the quality of drinking and household water were provided by WHO and the European Commission after running some quality tests on groundwater on 10 member countries. Standards for drinking water quality have been created with an emphasis on the requirement for hygienic water for a healthy and the minimization of waste(Organization, 2002) (European Community, 1998; WHO, 1995). In Pakistan, groundwater provides roughly 97% of the nation's total rural supply and 53% of the country's overall potable water supply in the state. Due to its comparatively low susceptibility to contamination groundwater is regarded as a significant supply source for portable water(Raza et al., 2017). In contrast to surface water, which needs a variety of pretreatment techniques for residential use, depending on the extent of contamination, groundwater often needed minimal to no treatment due to the thickness of natural infiltration zone (Muhammad et al., 2015)). However, when contamination does occur, it is severe, hard to spot, expensive to fix, making improvement of the quality of groundwater almost practically impossible (Singh et al., 2023)

According to a thorough investigation of the country's water quality by the Pakistan Water Research Council (PCRWR), 84–89% of country's total water sources are polluted(Cantonati et al., 2020). Both the amount and the quality of groundwater are declining. The increase in population concerns the dropping quality of water resources. Furthermore, untreated sewage water is released straight into rivers and canals in around 92% of cases, which deteriorate the quality of limited resources. More than 50 million population is at potential risk of arsenic poisoning due to bacterial and heavy metal pollution (Tariq et al., 2019). The freshwater is served as a groundwater reservoir and is also a major source of water for many streams and rivers, having a significant impact on wildlife rivers and wetland habitats(McAllister et al., 1997).

This study is conducted in Liaqatpur, a tehsil of Rahim Yar Khan. In this area, water quality is dropping with every passing day. Water quality is poorer than canal water making it not near suitable for irrigation purposes. In Liaqatpur drinking water is exposed to high sulphates and chlorides. Laxative effect in water is also reported in the rural areas which proves the water contains less than 500 milligrams sulphate per liter The groundwater of the overall area is hard and contains higher amounts of carbonates which have made it unavailable for human consumption.

2. Methodology

In Pakistan's Punjab province, the city of Liaqatpur serves as the capital of Liaqatpur Tehsil. It is organized into 25 union councils on an administrative level. In 1954, Liaquatpur was promoted to the rank of Town / Municipal Committee as Shown in Figure1. It received the designation of Tehsil Municipal Administration Liaquatpur following the passage of the Punjab Local Government Ordinance 2001.Liaqatpur Tehsil is located in Rahim Yar Khan District with an absolute location of 28.2940° N, latitudes and 70.7168° E longitudes. It is situated 95 meters above sea level at 28°55'60N 70°57'0E. (314 feet). According to the 2017 census, the tehsil has a total area of 4,644 km2 and a population of 1,035,509 people.

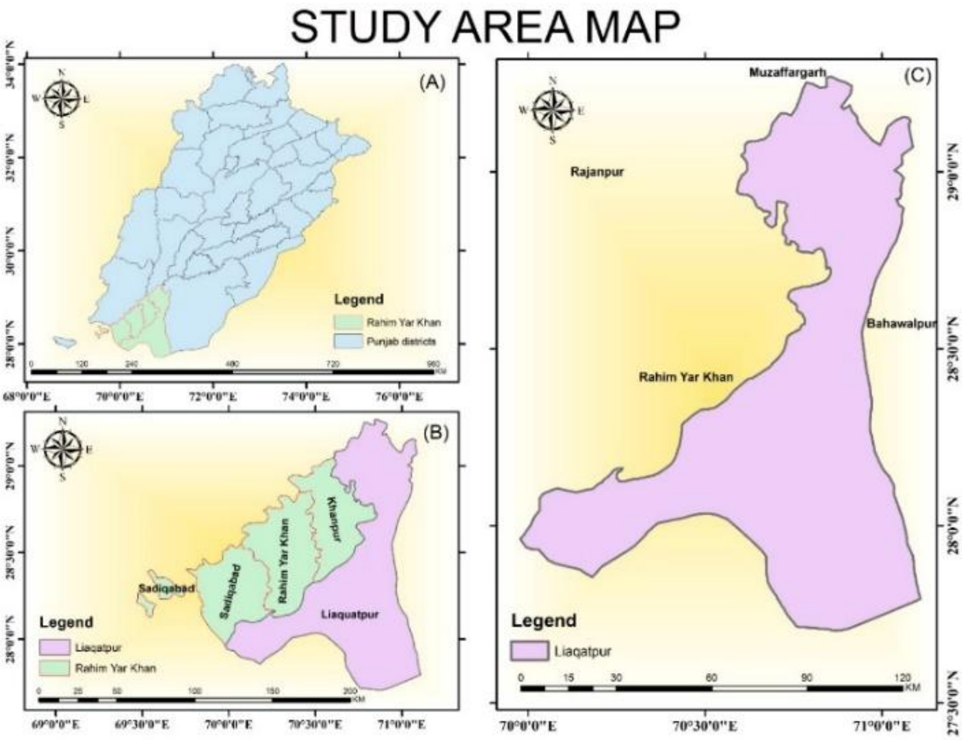


Figure 1: Study Area Map of Liaqatpur

The initial step involved a field analysis with the goal of collecting water samples in order to gain a comprehensive understanding of the area with the use of GPS. Afterward, maps depicting the dispersion of water quality indicators were drawn up to show the results of the analysis. The process requires the gathering and analysis of data from numerous departments and sources. A procedure was devised to take samples and then analyze the data from the samples to perform an accurate study of the water's quality. That approach first and foremost required the establishment of a sampling guide before work could start in the field. The instructions contain information about the date, time, place, and number of sampling sites.

It was found that having a table to record the most fundamental physical attributes was helpful. After that, the proper sampling got started in line with the processes that had been clearly stated. A total of 40 water samples were collected from various sites across the area. Aside from springs, pipe wells, hand drains, and dig wells, there were numerous more places where people could get their water supply. Pipe wells were some of the additional water sources. A trustworthy and representative sampling method is essential for exact and accurate chemical analysis. Therefore, the sampling procedure was conducted with the utmost prudence. Each polyethylene bottle used for sampling is thoroughly cleaned, followed by an extended period of time spent drying entirely on its side.

The most crucial aspects to consider while choosing drinking water are taste and odor. Although they have merely a passing relationship, flavor and odor perception are commonly confounded. Almost always, things that interact with water will cause the water to smell foul as well. The existence of natural resources that have a bad taste but no bad smell makes the opposite not always true. pH is the degree of acidity in a solution is determined by its PH value. It ranges from 0 to 14, with 7 serving as a middle-of-the-road neutral solution (Butler, 1998).Pure water has an acidic pH because it includes an equal quantity of H+ and OHions. Alkaline or neutral solutions have a pH value greater than 7, while acidic solutions have a pH value lower than 7 (Reynolds, 1963) **.** Another important factor that effectively reflects the water quality in a particular place is alkalinity(Van Wyk & Scarpa, 1999). It displays the volume of dissolved alkali metals in carbonates or bicarbonates. It demonstrates water's fundamental nature.

An indicator of a solution's capacity to transport an electrical current is its conductivity. The presence of ions in aqueous solutions is crucially determined by this capacity(Wright, 2007). Conductivity can be measured in milli Siemens per centimeter (mS / cm) or micro siemens per centimeter (us / cm) (Benjankar & Kafle, 2021)**.** Total dissolved solids, or TDS, is the abbreviation for the total concentration of dissolved solids in water. Inorganic salts and a small quantity of organic stuff make up TDS. It might be dissolved or suspended(Corwin & Yemoto, 2017). Chloride is also a key indicator of the water quality(Hong et al., 2023). The taste of water can be impacted by chloride levels in drinking water. the contamination could be done either by detergents used in households or by fertilizers for agriculture.

The derivatives of calcium and magnesium decide the hardness level in water. It is measured by adding equal amounts of carbonates of Ca and Mg(Welsh et al., 2000). The definition of soft is 60 mg/L or less. The range of 60 to 120 mg/L is regarded as medium hard. Hard is classified as 120 to 180 mg/L or higher. More than 180 mg/L is regarded as very hard. Some of the sulphate dissolves into the groundwater as it passes through sulphate-containing soil and rock formations(Bottrell, 2007). Sulfate-containing minerals include calcium sulphate, magnesium sulphate, and sodium sulphate. When calcium and magnesium, the two most prevalent components of hardness, are coupled with high concentrations of sulphate in the water we drink, a laxative effect may result. Bacteria that consume and break down sulphates produce hydrogen sulphide gas (H2S)(Sengupta, 2013).

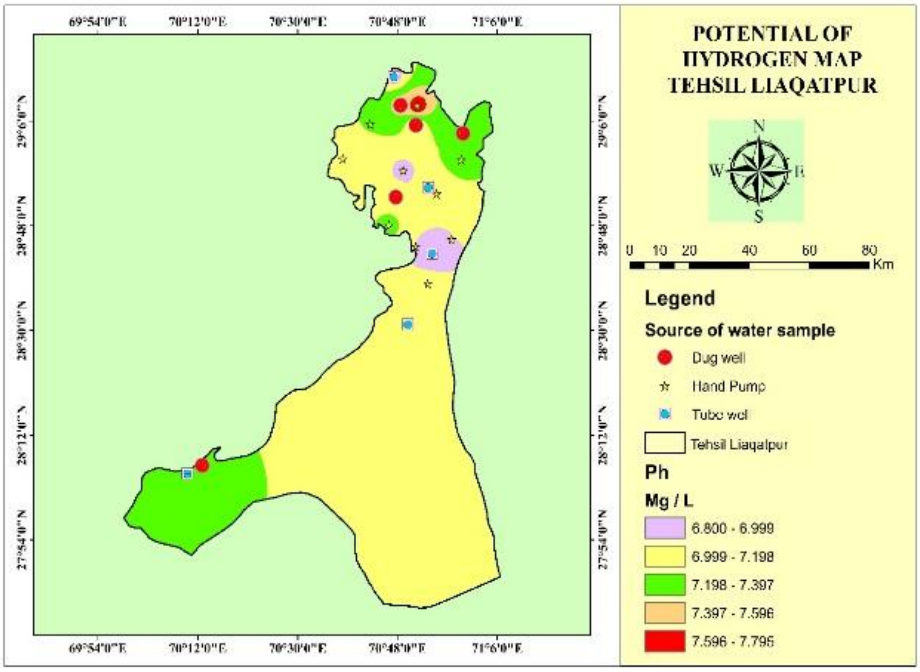
Potassium is an important mineral useful for human consumption in a specific limit. Plants and crops also need it in order to grow and produce. The maximum permissible limit of potassium in the drinking water is 12 mg/l as per WHO. When the limit exceeds or depletes, the natural balance is disturbed which is not suitable for both human and plant usage(Chhabra & Chhabra, 2021).

3. Results and discussions

Several physiochemical tests were run in the lab to pinpoint the precise water quality levels. The samples were collected from a variety of water sources, including hand pumps, tube wells, and dug wells. Eight distinct water quality parameters were chosen and put to the test. All these factors could exhibit spatial variance since the water sources differ.

3.1. pH

We can state that the pH level can inform us about the water's condition and whether it is fit for human consumption or not. When pH is high, it results in a bitter taste, deposits build up on water pipes and water-using appliances, and chlorine disinfection is less effective, necessitating the use of additional chlorine. Metals and other materials will corrode or dissolve in low pH water. We can state that the pH level can inform us about the water's condition and whether it is fit for human consumption or not. pH range recommended by the WHO is between 6.5 to 8 and is 6.53. According to tests done in the tehsil Liaqatpur, the lowest and highest values recorded are 6.8 and 7.8, respectively. Additional spatial distribution of Liaqatpur water's pH value can be seen in the Figure. 2 and Graph.1 shows comparison of Ph with WHO Guidelines.



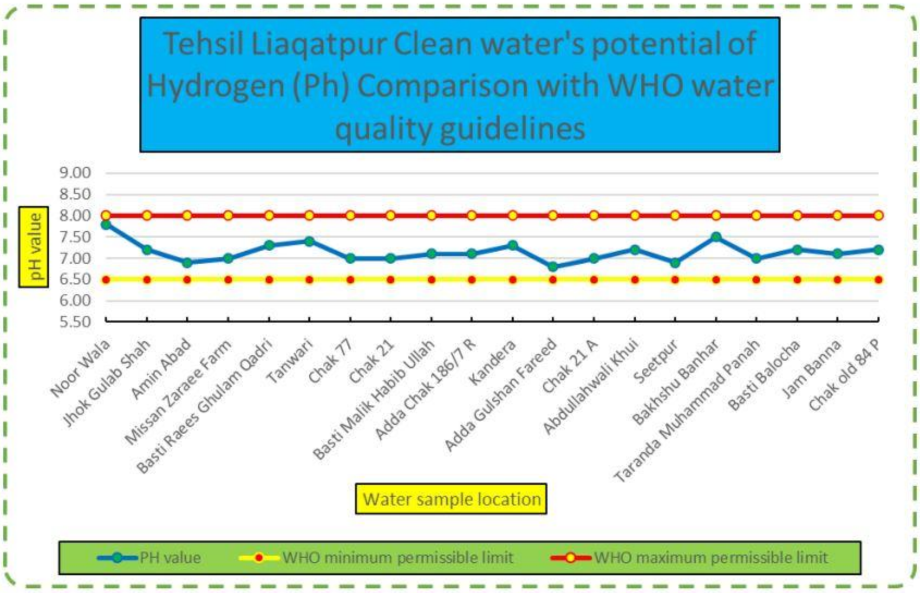
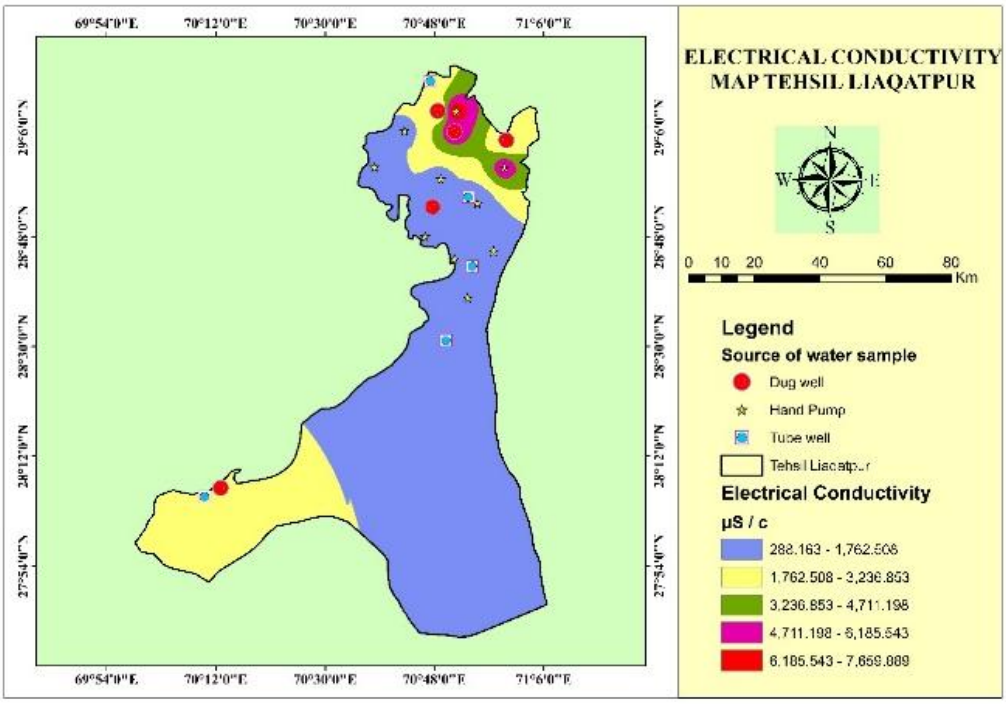


Figure 2. Spatial distribution of ph. Graph 1. pH comparison with WHO guidelines

3.2. Electrical Conductivity (EC)

The electrical conduction increases with the amount of dissolved charged compounds (often referred to as salts) in the water. The conductivity of water is significant because it can provide information on the concentrations of dissolved compounds, chemicals, and minerals in the solution. A higher conductivity will result from higher concentrations of certain contaminants. The WHO's maximum allowable limit for electrical conductivity is 500 S/c. According to Liaqatpur water quality testing, the lowest and highest EC values were 500 S / c (Basti Malik Habibullah) and 7698 S / c (Noor Wala), respectively. Graph 2 and figure3 are used to convey spatial interpretation



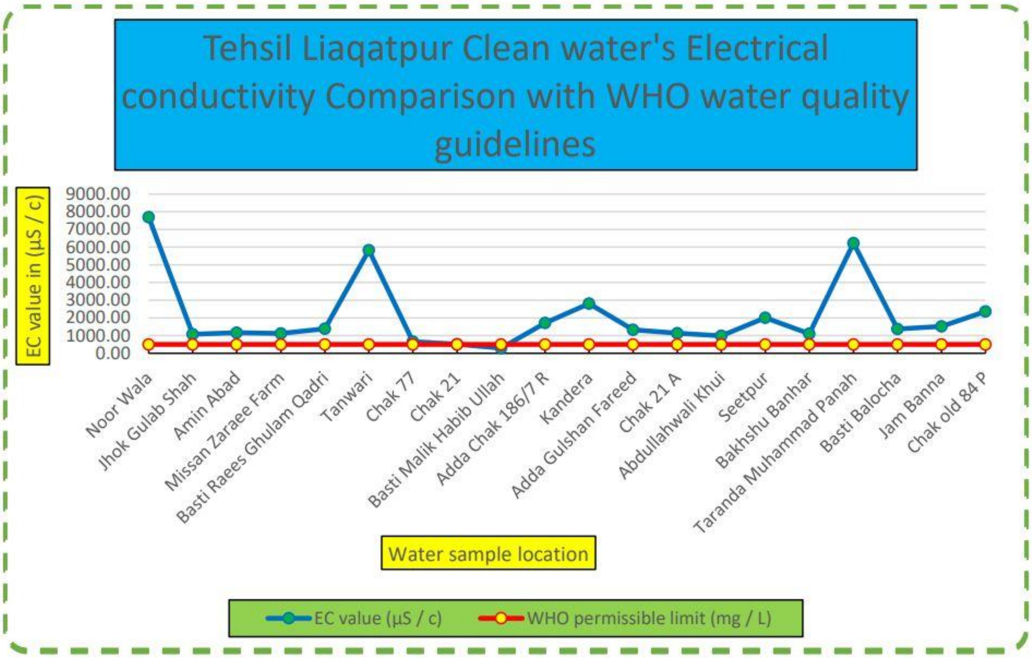
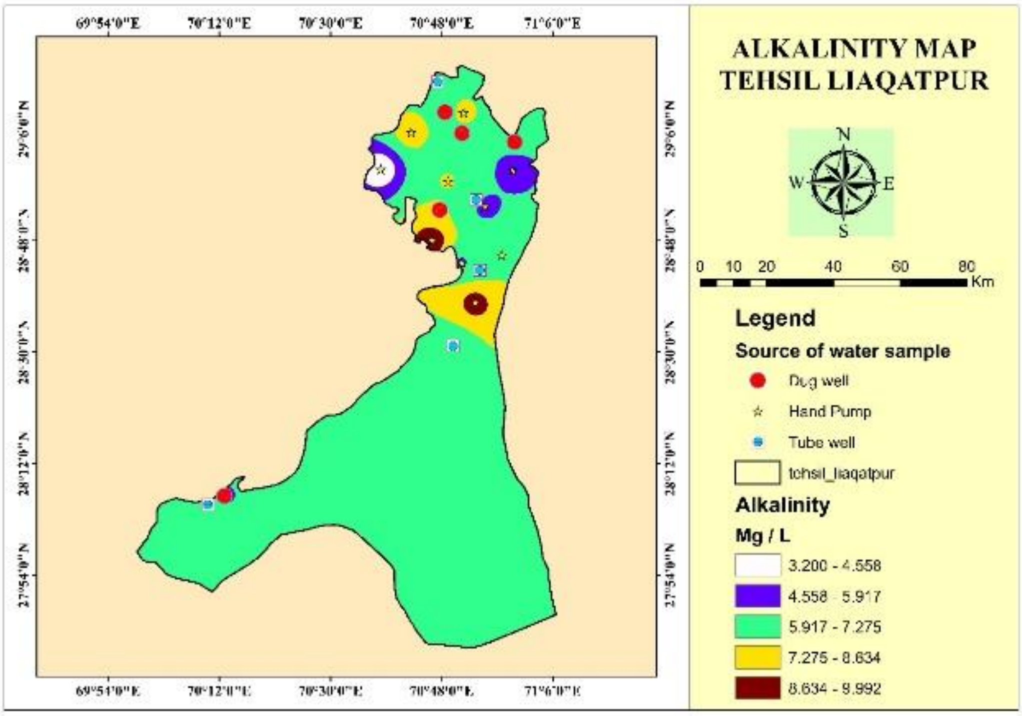


Figure 3. Spatial Distribution of EC Graph 2. EC comparison with WHO guidelines

3.3. Alkalinity

According to the WHO, groundwater has an alkalinity ranging from 20 to 200. The acceptable level for human intake is 600 mg/L, while 200 mg/L is the normal value for alkalinity. Additionally, Liaqatpur Tehsil's physiochemical test findings reveal that the region's total alkalinity is much lower than 20 mg/L. Figure 4 and Graph 3 show spatial interpretation.



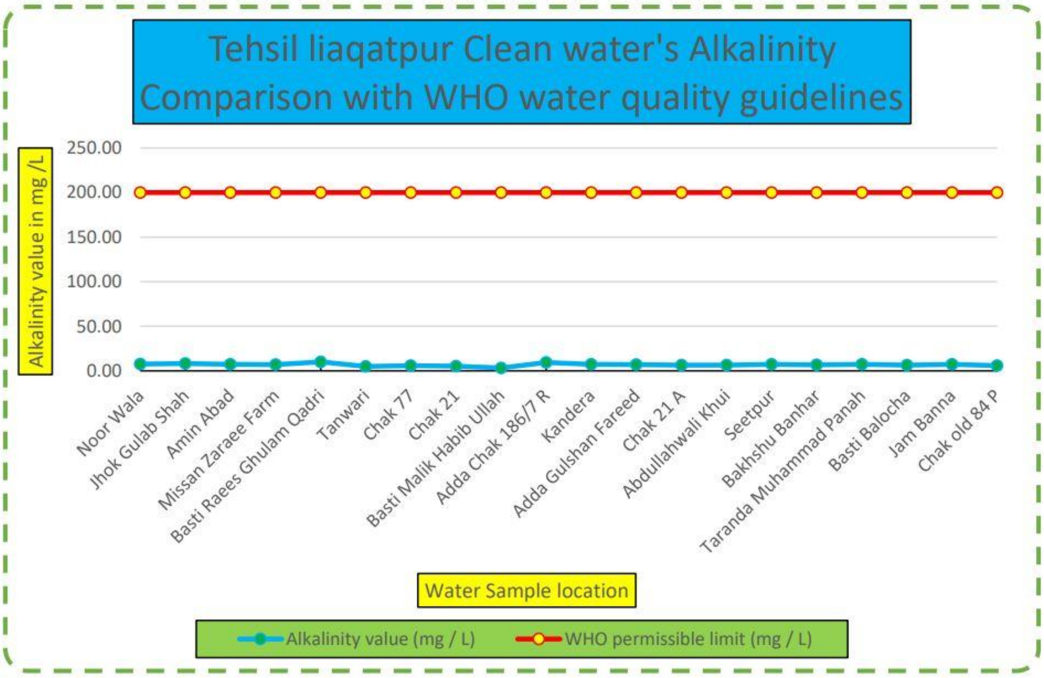
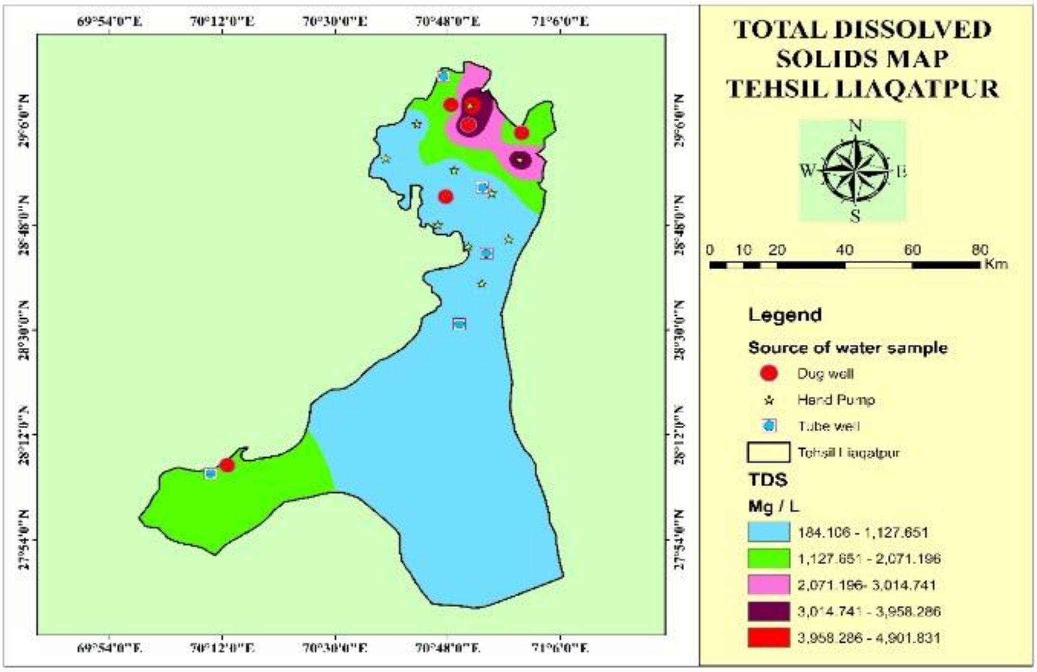


Figure 4. Spatial Distribution of Alkalinity   Graph 3. Alkalinity comparison with WHO guidelines

3.4. Total Dissolved Solids (TDS)

Inorganic salts and a small quantity of organic stuff make up TDS. It might be dissolved or suspended. The WHO recommends a TDS range of 500 mg/l. Water ceases to be fit for residential use and irrigation when the value exceeds or falls below this particular range. In the study area, the value of TDS ranges from minimum to maximum as 184 mg / L at Basti Malik Habibullah to 4926 mg / L at Noor Wala respectively. Graph 4 and figure 5 are used to convey spatial interpretation.



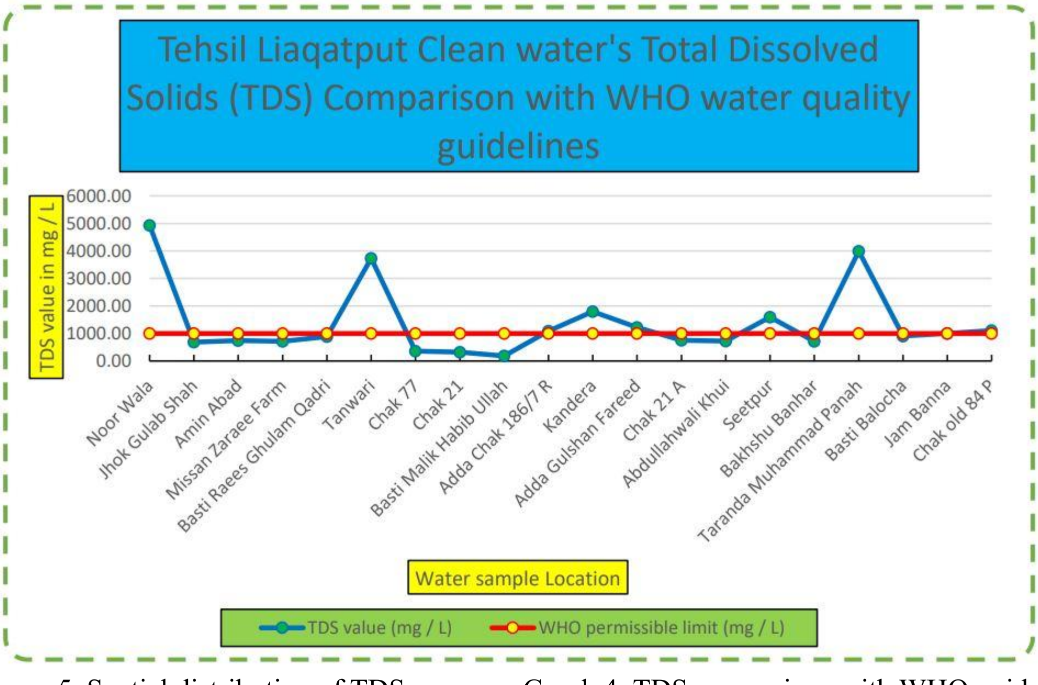
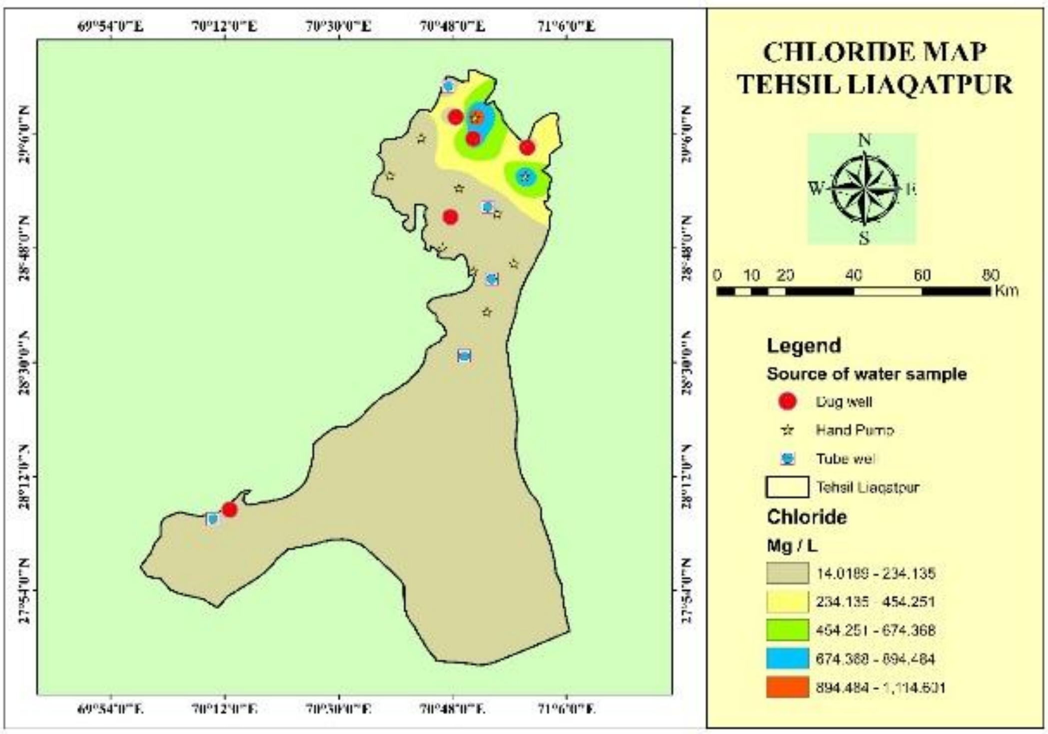


Figure 5. Spatial distribution of TDS Graph 4. TDS comparison with WHO guidelines

3.5. Chloride

Chloride is a key indicator of the water quality. The taste of water can be impacted by chloride levels in drinking water. thTe contamination could be done either by detergents used in households or by fertillizers for agriculture. According to the WHO, the acceptable limit for chloride is 200–250 mg/l. The research area's lowest and highest chloride values were found to be at Basti Malik Habibullah (14.00) and Noor Wala (1121.00) respectively. Further spatial distribution of Liaqatpur water's chloride content is shown in the Graph 5 and Figure 6.



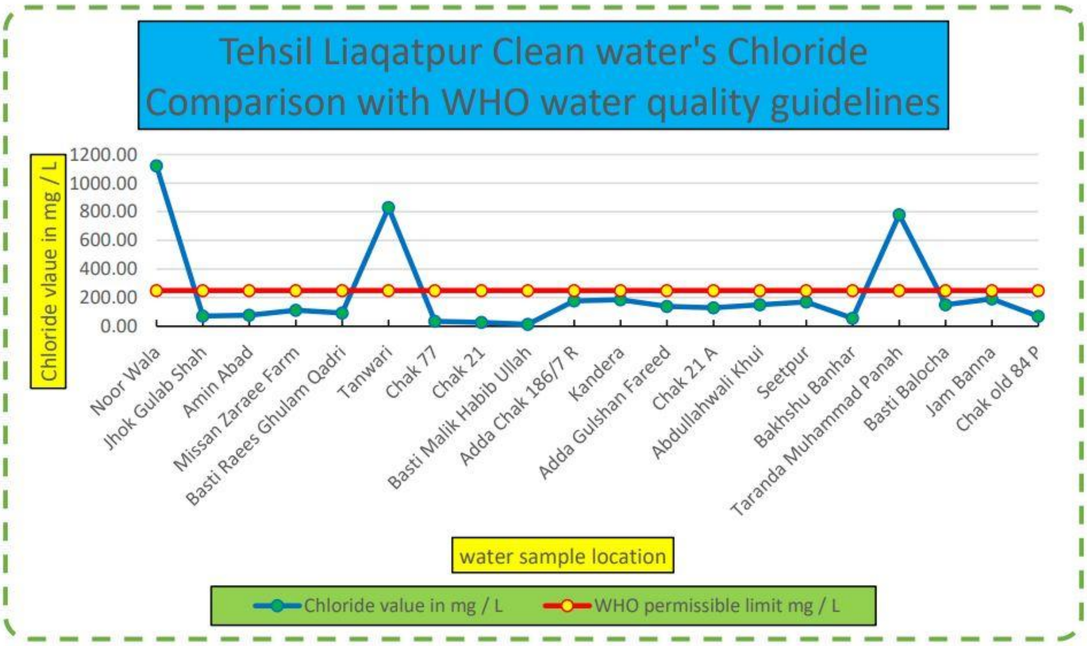
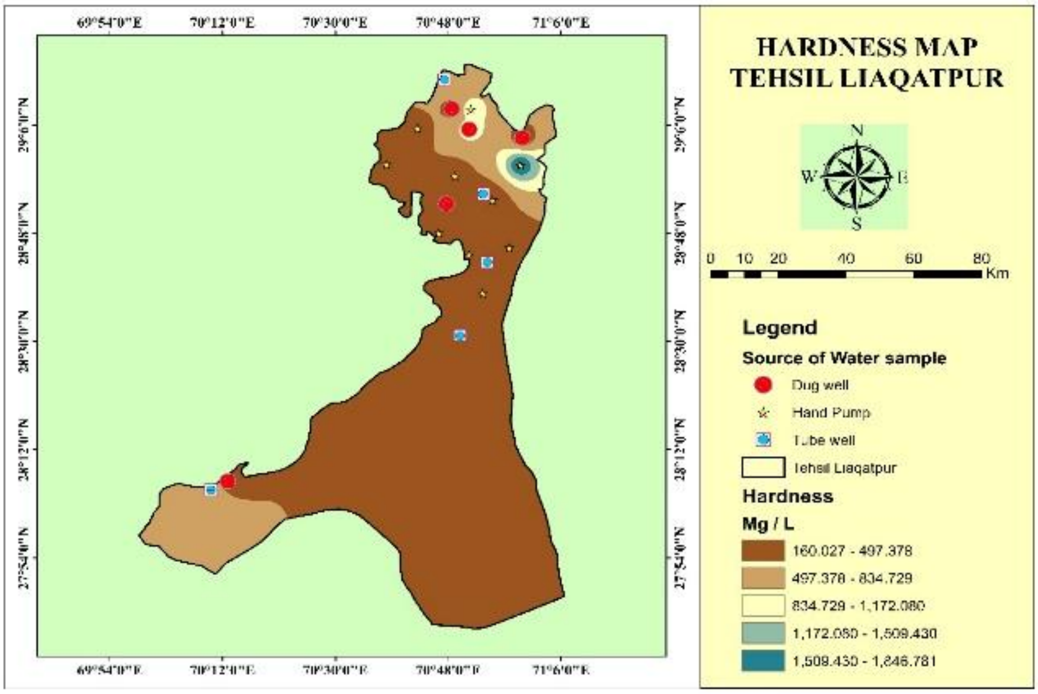


Figure 6. Spatial Distribution of Chloride   Graph 5. TDS comparison with WHO guidelines

3.6. Hardness

The derivatives of calcium and magnesium decide the hardness level in water. It is measured by adding equal amounts of carbonates of Ca and Mg. The definition of soft is 60 mg/L or less. The range of 60 to 120 mg/L is regarded as medium hard. Hard is classified as 120 to 180 mg/L or higher. More than 180 mg/L is regarded as very hard. In the study area the lowest value was recorded at Basti Malik Habibullah (160.00) and highest value was observed at Tanwari (1850). Means the water of the area is overall hard which is also visible in Figure 7 and Graph.6



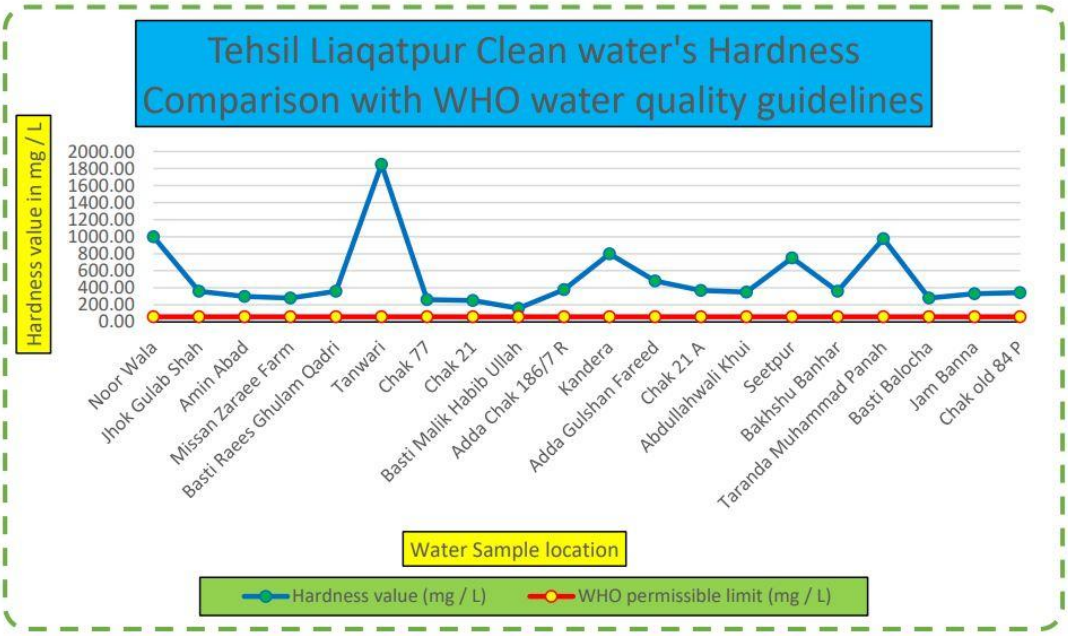
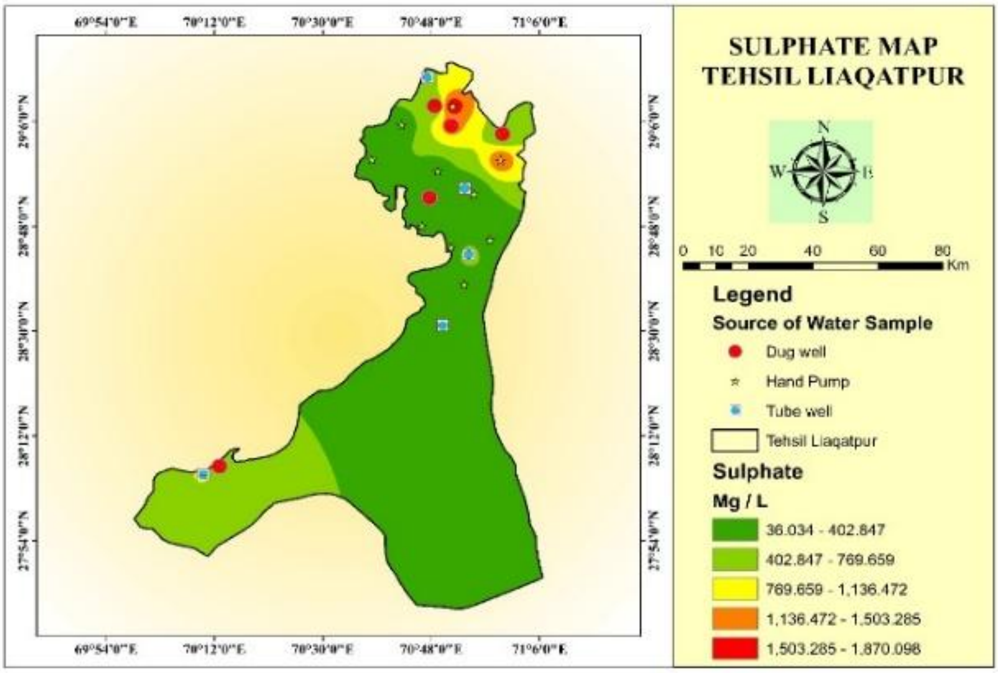


Figure 7. Spatial distribution of Hardness Graph 6. TDS comparison with WHO guidelines

3.7. Sulphate

Some of the sulphate dissolves into the groundwater as it passes through sulphate-containing soil and rock formations. Sulfate-containing minerals include calcium sulphate, magnesium sulphate, and sodium sulphate. When calcium and magnesium, the two most prevalent components of hardness, are coupled with high concentrations of sulphate in the water we drink, a laxative effect may result. Bacteria that consume and break down sulphates produce hydrogen sulphide gas (H2S). Sulphate has a 200–250 mg/L maximum acceptable limit according to the WHO. The sulphate concentration in groundwater was found to be lowest at Basti Malik Habibullah (36.00) and highest at Noor Wala (1880), respectively. Further spatial distribution of sulphate value of Liaqatpur water is given in Graph7 and Figure 8.



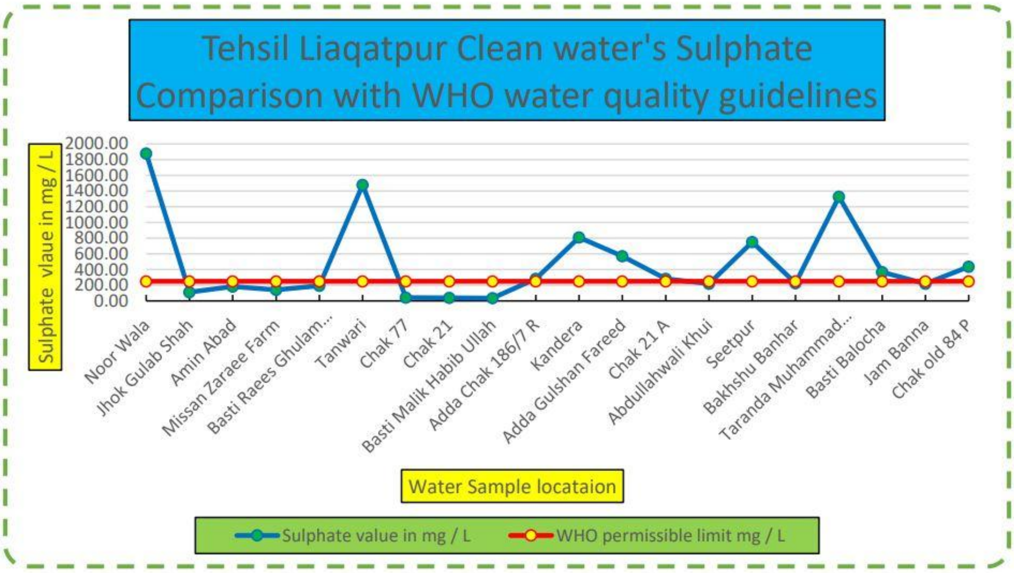
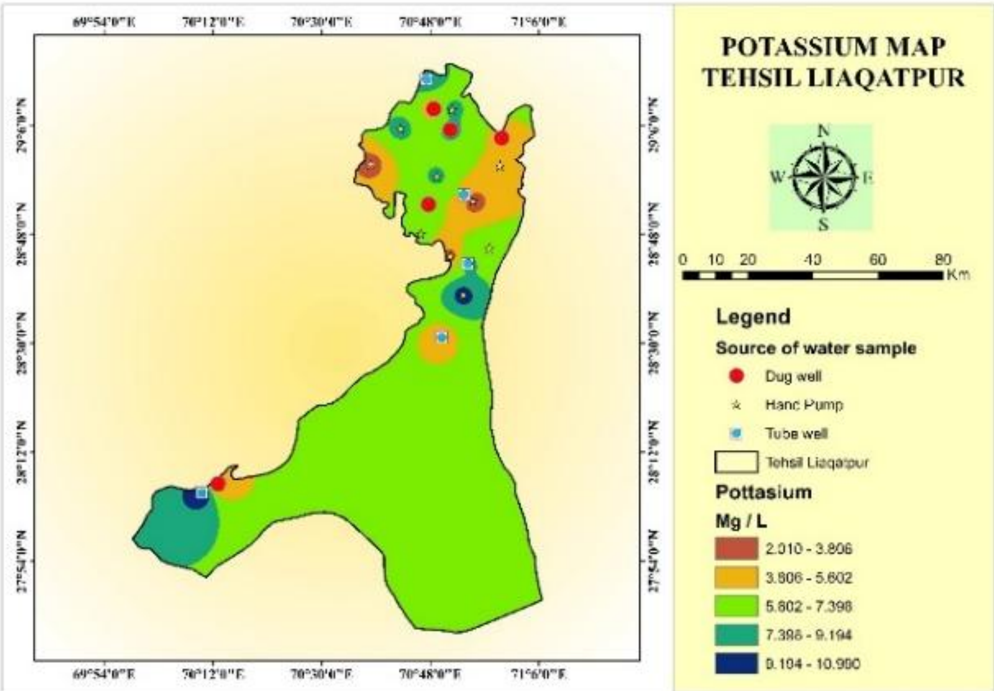


Figure 8. Spatial distribution of Sulphate   Graph 7. Sulphate comparison with WHO guidelines

3.8. Potassium

The maximum permissible limit of potassium in the drinking water is 12 mg/l as per WHO. In the study area, the overall potassium concentration in water is less than 12 mg/l. The lowest reading was observed as 2.00 mg/l and highest 11.00 mg/l. Further spatial distribution of potassium value of Liaqatpur water is given in the Figure 9 and Graph 8.



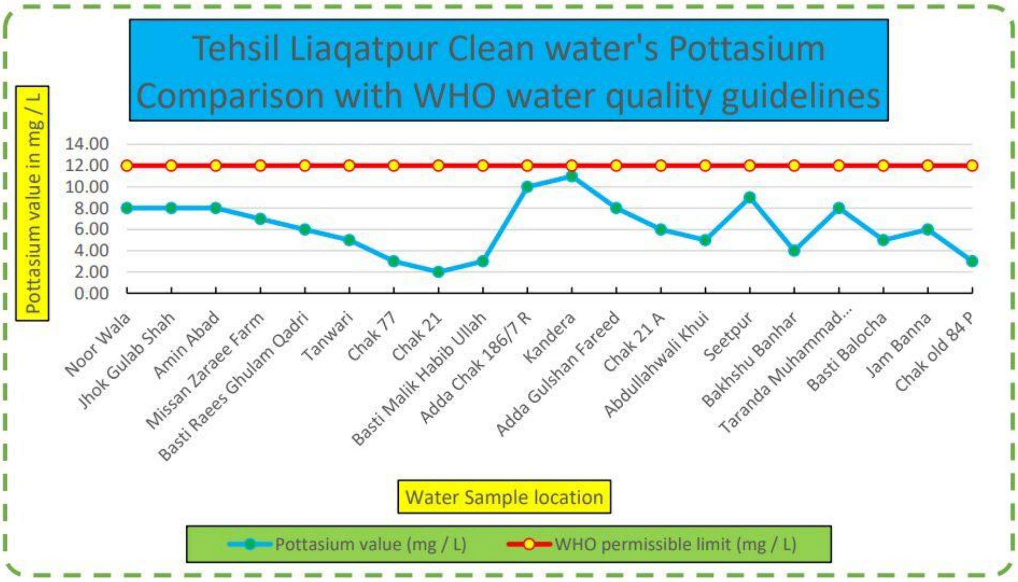


Figure 9. Spatial distribution of Sulphate Graph 8. Sulphate comparison with WHO guidelines

4. Conclusions

The main objective of the research was to identify the groundwater quality as well as potential zones of Liaqatpur Tehsil, District Rahim Yar Khan. For groundwater quality, firstly 20 samples were taken from 3 different sources i.e., dug well, tube well, and hand pump. The exact location of the sources of water was obtained using GPS. Then these samples were taken to the laboratory for different tests. Eight different tests were performed at Soil and Water Testing Laboratory Rahim Yar Khan naming hardness, pH, sulphate, alkalinity, chloride, potassium, total dissolved solvent (TDS), and electrical conductivity (EC). The results obtained from these tests were imported to ArcGIS for further analysis. The same coordinate system was assigned to all the layers i.e., WGS_1984_UTM_Zone 42. After that interpolation was done to gather the spatial information of these parameters. The lowest and highest values of above mentioned 8 parameters were obtained and then the weighted overlay technique was applied to the data. Then for each parameter, groundwater quality maps were prepared, and a final potential quality map was obtained which represents the spatial distribution of groundwater quality in the study area. The spatial distribution was subdivided into three major categories: poor, good, and very good. As per the obtained map, it is evident that most of the study area has approximately good quality of water while some northern, central, and south-western portions of Liaqatpur represent the poor quality of water.

Declaration of conflict of interest:

The author(s) declared no potential conflicts of interest(s) with respect to the research, authorship, and/or publication of this article.

Funding:

The author(s) received no financial support for the research, authorship and/or publication of this article.

Publisher's Note:

IDEA Publishers Group (NASIJ IDEA-PG) stands neutral with regard to jurisdictional claims in the published maps and institutional affiliations.

References

Akhtar, S., Ahmad, S., Huifang, W., Shahbaz, A., Ghafoor, A., Imran, S., & Zafar, A. (2018). An analysis of wastewater irrigation practices and its impacts on the livelihood generation and food chain contamination in Faisalabad District, Pakistan. ISABB Journal of Health and Environmental Sciences, 5(4), 33–42.

Bano, I., & Arshad, M. (2018). Climatic changes impact on water availability. Perspectives on Water Usage for Biofuels Production: Aquatic Contamination and Climate Change, 39–54.

Benjankar, R., & Kafle, R. (2021). Salt concentration measurement using re-usable electric conductivity–based sensors. Water, Air, & Soil Pollution, 232, 1–16.

Bottrell, S. H. (2007). Stable isotopes in aqueous sulphate as tracers of natural and contaminant sulphate sources: a reconnaissance study of the Xingwen karst aquifer, Sichuan, China. Geological Society, London, Special Publications, 279(1), 123–135.

Butler, J. N. (1998). Ionic equilibrium: solubility and pH calculations. John Wiley & Sons.

Cantonati, M., Poikane, S., Pringle, C. M., Stevens, L. E., Turak, E., Heino, J., Richardson, J. S., Bolpagni, R., Borrini, A., & Cid, N. (2020). Characteristics, main impacts, and stewardship of natural and artificial freshwater environments: consequences for biodiversity conservation. Water, 12(1), 260.

Chhabra, R., & Chhabra, R. (2021). Irrigation water: Quality criteria. Salt-Affected Soils and Marginal Waters: Global Perspectives and Sustainable Management, 431–486.

Corwin, D. L., & Yemoto, K. (2017). Salinity: Electrical conductivity and total dissolved solids. Methods of Soil Analysis, 2(1), 0.

Fida, M., Li, P., Wang, Y., Alam, S. M. K., & Nsabimana, A. (2023). Water contamination and human health risks in Pakistan: a review. Exposure and Health, 15(3), 619–639.

Hong, Y., Zhu, Z., Liao, W., Yan, Z., Feng, C., & Xu, D. (2023). Freshwater water-quality criteria for chloride and guidance for the revision of the water-quality standard in China. International Journal of Environmental Research and Public Health, 20(4), 2875.

Ishaque, W., Mukhtar, M., & Tanvir, R. (2023). Pakistan's water resource management: Ensuring water security for sustainable development. Frontiers in Environmental Science, 11, 1096747.

Lytton, L., Ali, A., Garthwaite, B., Punthakey, J. F., & Saeed, B. (2021). Groundwater in Pakistan's Indus Basin. World Bank. Accessed at File: Groundwater-in-Pakistan-s-Indus-Basin-Present-and-Future-Prospects, 20(1).

McAllister, D. E., Hamilton, A. L., & Harvey, B. (1997). Global freshwater biodiversity: striving for the integrity of freshwater ecosystems. Sea Wind: Bulletin of Ocean Voice International; 11 (3).

Muhammad, A. M., Zhonghua, T., Dawood, A. S., & Earl, B. (2015). Evaluation of local groundwater vulnerability based on DRASTIC index method in Lahore, Pakistan. Geofísica Internacional, 54(1), 67–81.

Organization, W. H. (2002). Guidelines for drinking-water quality. World Health Organization.

Raza, M., Hussain, F., Lee, J.-Y., Shakoor, M. B., & Kwon, K. D. (2017). Groundwater status in Pakistan: A review of contamination, health risks, and potential needs. Critical Reviews in Environmental Science and Technology, 47(18), 1713–1762.

Reynolds, E. S. (1963). The use of lead citrate at high pH as an electron-opaque stain in electron microscopy. The Journal of Cell Biology, 17(1), 208.

Sengupta, P. (2013). Potential health impacts of hard water. International Journal of Preventive Medicine, 4(8), 866.

Singh, K., Kumar, R., & Pandit, B. A. (2023). Conservation and Management by Artificial Recharge of Aquifer. Advances in Water Management Under Climate Change, 319.

Tariq, A., Ullah, U., Asif, M., & Sadiq, I. (2019). Biosorption of arsenic through bacteria isolated from Pakistan. International Microbiology, 22, 59–68.

Van Wyk, P., & Scarpa, J. (1999). Water quality requirements and management. Farming Marine Shrimp in Recirculating Freshwater Systems, 4520, 141–161.

Welsh, P. G., Lipton, J., Chapman, G. A., & Podrabsky, T. L. (2000). Relative importance of calcium and magnesium in hardness-based modification of copper toxicity. Environmental Toxicology and Chemistry: An International Journal, 19(6), 1624–1631.

Wright, M. R. (2007). An introduction to aqueous electrolyte solutions. John Wiley & Sons.