# Assessment of Groundwater Quality Index for Agriculture and Domestic Purpose of Taluka Sehwan, District Jamshoro

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**Abstract:**
**Introduction/Importance of Study:** Groundwater has become a crucial source of freshwater globally, serving various purposes including domestic use, agricultural irrigation, and industrial applications. In regions like Taluka Sehwan, Sindh, Pakistan, where surface water sources are often compromised, groundwater plays a particularly vital role in sustaining local populations and economies. However, the quality of groundwater is increasingly threatened by contamination, necessitating comprehensive assessments to ensure its safety and sustainability.
**Novelty Statement:** This study introduces a novel approach by combining the Water Quality Index (WQI) with GIS-based Kriging analysis to provide a thorough assessment and spatial visualization of groundwater quality in Taluka Sehwan. This method directly addresses the critical issue of contamination stemming from Manchar Lake, offering new insights and potential solutions for managing groundwater resources in the region.
**Materials and Methods:** Thirty groundwater samples were collected from various locations within Taluka Sehwan. Sixteen key parameters, including pH, electrical conductivity (EC), and total dissolved salts (TDS), were analyzed in the laboratory. The Water Quality Index (WQI) and irrigation indices—Sodium Adsorption Ratio (SAR), Soluble Sodium Percentage (SSP), Magnesium Hazard (MH), and Permeability Index (PI)—were calculated to evaluate the suitability of the water for drinking and irrigation purposes. The results were then spatially analyzed using GIS-based Kriging, a geostatistical method that enables the visualization of the spatial distribution of groundwater quality across the study area.
**Results and Discussion:** The WQI values in the study area ranged from 34.53 to 213.36. Only 13% of the groundwater was classified as "good," while 23% was deemed "poor," 7% "very poor," 30% "unsuitable," and 27% "unfit" for consumption. The overall WQI suggests that the groundwater in Taluka Sehwan is largely unsafe and non-potable, with only a few localized pockets in the northern region showing acceptable water quality. The Soluble Sodium Percentage (SSP) indicated that 83.33% of the water was categorized as "unsure" and 13.33% as "poor" for irrigation purposes. The Sodium Adsorption Ratio (SAR) results showed that 10% of the water was "excellent," 46.67% "good," 33% "allowable," and 10% "unsuitable" for agricultural use. The Magnesium Hazard (MH) and Permeability Index (PI) analyses revealed that 70% of the groundwater was "excellent" and 30% "safe" for irrigation. Despite the poor water quality for drinking, the irrigation indices suggested that 70-75% of the area could still be suitable for agricultural use. Spatial analyses highlighted significant heterogeneity across the study area, with lower concentrations of contaminants in the north and higher concentrations in the south.
**Concluding Remarks:** The findings of this study underscore the urgent need for policies that prioritize the monitoring of groundwater pollution, research into the sources of contamination, and the development of mitigation strategies. Without proactive measures, the local ecosystem and communities face the risk of irreversible damage due to the deteriorating quality of groundwater resources.
**Keywords:** Groundwater; Sehwan, Manchar Lake; Water Quality Index (WQI); Irrigation Indices; Spatial Analysis.

**Introduction:**

Water stands as an indispensable element for the sustenance of all living beings. The vitality of water quality directly impacts the well-being of humans, flora, and fauna [1]. Groundwater quality, influenced by a myriad of factors such as chemical composition, hydrology, geology, physical attributes, and biology, is under escalating threat due to anthropogenic activities, which detrimentally affect both its quality and quantity [2]. Projections suggest that by 2030, half of the global population could encounter significant water scarcity [3]. Concurrently, accelerated industrialization exacerbates environmental deterioration, as untreated toxic wastewater discharged from industries further compromises groundwater quality, posing risks to human health, soil fertility, and agricultural productivity. According to the World Health Organization, 80.0% of the populace suffers from health ailments due to inadequate access to safe drinking water [4].

Water scarcity and environmental degradation pose formidable challenges, particularly in developing nations like Pakistan [5]. The examination of groundwater quality is critical due to its numerous applications in the home, irrigation, and industrial sectors. Currently, pollution levels are growing, compounded by the effects of climate change, precipitating the collapse of freshwater reserves [6]. This deterioration significantly impairs water resource utilization, especially for potable water supply and agricultural irrigation. Water quality concerns are intricately linked with public health risks, particularly the proliferation of waterborne diseases. Groundwater quality fluctuations across seasons and locations are influenced by various factors such as pumping rates, precipitation patterns, and evapotranspiration rates [7].

Groundwater is a critical resource for both agricultural irrigation and domestic water supply, helping to sustain food production and fulfill the requirements of rising populations [8]. In agriculture, groundwater is often used to offset rainfall deficiencies and support crop development, especially in areas where surface water sources are limited or unreliable [9]. In Pakistan, agriculture is heavily dependent on groundwater, with over 90% of irrigation water sourced from groundwater [10]. Water is a fundamental resource crucial for sustaining life, supporting ecosystems, and facilitating socio-economic development [11]. In Pakistan, where water scarcity is a pressing issue, groundwater serves as a vital source for domestic, agricultural, and industrial purposes, supplementing surface water resources [10]. However, the quality of groundwater is increasingly becoming a matter of concern due to various anthropogenic and natural factors [12], posing significant challenges to public health and environmental sustainability.

In addition to traditional water quality assessment methods, this study will utilize water quality indices such as the Water Quality Index (WQI) to provide a comprehensive assessment of groundwater quality. The WQI aggregates multiple water quality parameters into a single value, facilitating the interpretation of overall water quality and comparison between different sampling sites [13]. The study will evaluate groundwater suitability for irrigation purposes using irrigation indices such as the Sodium Adsorption Ratio (SAR) and the Residual Sodium Carbonate (RSC) index. These indices assess the suitability of water for irrigation based on its salinity and sodicity levels, providing valuable information for agricultural water management [14].

Comprehensive assessments of groundwater quality, such as the proposed research project in Sehwan Sharif, are essential for identifying risks, implementing mitigation measures, and ensuring the long-term viability of groundwater resources for irrigation and residential use. Incorporating irrigation indices such as Sodium Adsorption Ratio (SAR), Residual Sodium

Carbonate (RSC), and Kelly's Ratio becomes essential for evaluating groundwater suitability for irrigation, ensuring optimal crop growth and soil sustainability [15]. Spatial analyses facilitated by GIS mapping provide invaluable insights into the spatial distribution and variability of groundwater quality parameters across diverse geographical regions [16]. Utilizing GIS software such as ArcMap enables the visualization, analysis, and interpretation of complex spatial datasets, allowing stakeholders to identify hotspots of groundwater contamination and prioritize remediation efforts effectively [17]. Moreover, spatial interpolation techniques like kriging and Inverse Distance Weighting (IDW) are commonly employed for predicting groundwater quality at unmonitored locations based on observed data points [18].

In the context of Pakistan, particularly in Sindh province, where agriculture heavily relies on groundwater irrigation, the sustainable management of groundwater resources is paramount for ensuring food security and socioeconomic development [19]. However, rapid urbanization, industrialization, and agricultural intensification have exerted immense pressure on groundwater quality, leading to concerns regarding its long-term sustainability [20]. A variety of hydrogeochemical approaches have been used in various places across the world to assess the suitability of groundwater for drinking and agricultural use. These techniques have recommended a variety of strategies for improving water quality [21]. Several studies have also been conducted to analyze the water quality in the contaminated environs of Manchar Lake. Due to the unsuitability of groundwater and limited government-supplied drinking water, many towns rely on water from the MNVD and Manchar Lake for both drinking and agriculture [22].

The Taluka Sehwan region, home to the historically significant Manchar Lake, is currently grappling with a pressing environmental and public health issue. The deterioration in the quality of water from Manchar Lake has raised alarms about its impact on the surrounding groundwater sources. This degradation is believed to be contaminating the groundwater that is utilized by local populations for agricultural irrigation and even for drinking in certain areas. Despite the groundwater's seemingly acceptable taste, there are concerns that it is polluted with contaminants that may not be immediately detectable through sensory perception. This inconsistency in water quality poses a double-edged threat: it jeopardizes human health due to potential consumption of polluted water and creates an unpredictable agricultural environment where crop yields unpredictably fluctuate, leading to economic instability for local farmers. The study is necessitated by the need to investigate the sources and extent of the pollution, to understand its impact on agriculture and human health, and to develop strategies to mitigate these risks. Ultimately, the research seeks to provide evidence-based recommendations to restore the quality of Manchar Lake and the groundwater to ensure safe agricultural practices and protect the well-being of the local community.

**Objectives:**

The primary objectives of this study are to assess groundwater quality in Sehwan Sharif using water quality indices such as the Water Quality Index (WQI), evaluate its suitability for irrigation with indices like the Sodium Adsorption Ratio (SAR) and Residual Sodium Carbonate (RSC) index, identify the sources and extent of groundwater pollution and its impact on agriculture and human health, employ GIS mapping and spatial interpolation techniques to analyze the spatial distribution and variability of groundwater quality parameters, and develop evidence-based recommendations to restore and maintain the quality of groundwater and Manchar Lake for safe agricultural practices and public health protection.

**Novelty:**

The novelty of this research lies in its comprehensive approach, integrating multiple water quality indices for a thorough evaluation, advanced spatial analysis using GIS and techniques like kriging, specific focus on the Taluka Sehwan region and Manchar Lake, and the combination of hydrogeochemical methods with spatial analyses and traditional water quality assessments. This integrated approach is among the first to address the groundwater quality issues in this specific region, providing actionable insights and strategies for sustainable groundwater management and policy-making.

**Methods and Materials:**


**Figure 1:** Flow Diagram of Methodology.

**Study Area:**

Jamshoro District, covering 11,260 km² and comprising four talukas, plays a crucial role in meeting Sindh's agricultural needs. Among these, Taluka Sehwan is of particular significance for my research on groundwater quality assessment, lying between Latitude 26.32° to 26.64° N and Longitude 67.86° to 67.72° E. Sehwan is characterized by a warm, arid climate and is situated on the eastern bank of the Indus River. This region also houses Pakistan's largest freshwater lake, whose size fluctuates seasonally between 350 km² and 520 km². Additionally, the Kirthar Mountain Range lies to the southeast, adding to the area's unique geographical features. The variations in groundwater quality parameters in this region are particularly notable and warrant in-depth study for effective water resources management. The study area, with its strategic location on the eastern bank of the Indus River and proximity to this significant freshwater lake, provides a unique environment for investigating groundwater quality parameters. The region experiences a warm, arid climate with temperatures ranging from 25°C to 45°C and an annual precipitation of approximately 16.25mm. These climatic and geographical factors contribute to the distinct characteristics of the groundwater in Taluka Sehwan, making it an essential area for research focused on effective water resource management.

**Data Collection and Analysis:**

In November 2023, 30 groundwater samples were systematically collected from tube wells and hand pumps across various locations within Taluka Sehwan, located in the Jamshoro district of Sindh, Pakistan. These samples were carefully stored in narrow-mouthed polythene bottles, pre-washed three times with the same water to be sampled, ensuring the integrity of the samples. A comprehensive analysis of various physicochemical parameters was conducted, including Total Alkalinity (Ta), Chloride (Cl), Electrical Conductivity (Ec), Turbidity (Tn), Hardness (H), Magnesium (Mg), Potassium (K), Nickel (Ni), Manganese (Mn), Calcium (Ca), pH, Sodium (Na), Fluoride (F), Arsenic (As), and Iron (Fe). The measurements for EC, TDS, and pH were carried out using a multimeter (Lovibond) and a pH meter (HANNA), following standard methods as prescribed by APHA 2520-B, APHA 2540-D, and APHA 4500-H+-B, respectively. Suspended particles were filtered out using a 0.45-millipore membrane filter paper. Total alkalinity, hardness, and chloride levels were determined through titration, adhering to standard methods (APHA 2320-B, APHA 4500-Cl B, and APHA 2340-C). The concentrations of calcium, magnesium, sodium, potassium, nickel, manganese, arsenic, and iron were analyzed via Inductively Coupled Plasma Mass Spectrometry (ICP-MS) at the USPCAS-Muet laboratory, following APHA guidelines and association standards (1995). The geographic coordinates of each sampling point were precisely determined using GPS technology, ensuring accurate spatial analysis of the groundwater quality data.

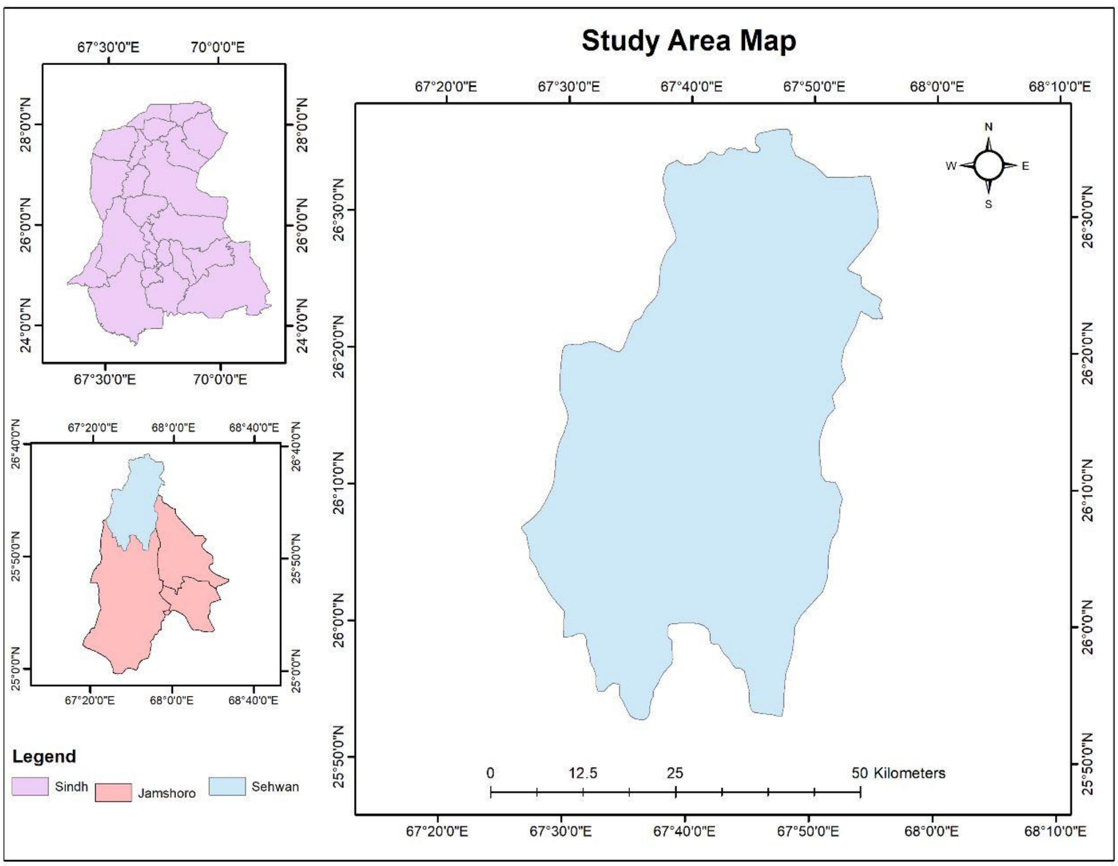



**Figure 2:** Study area map.

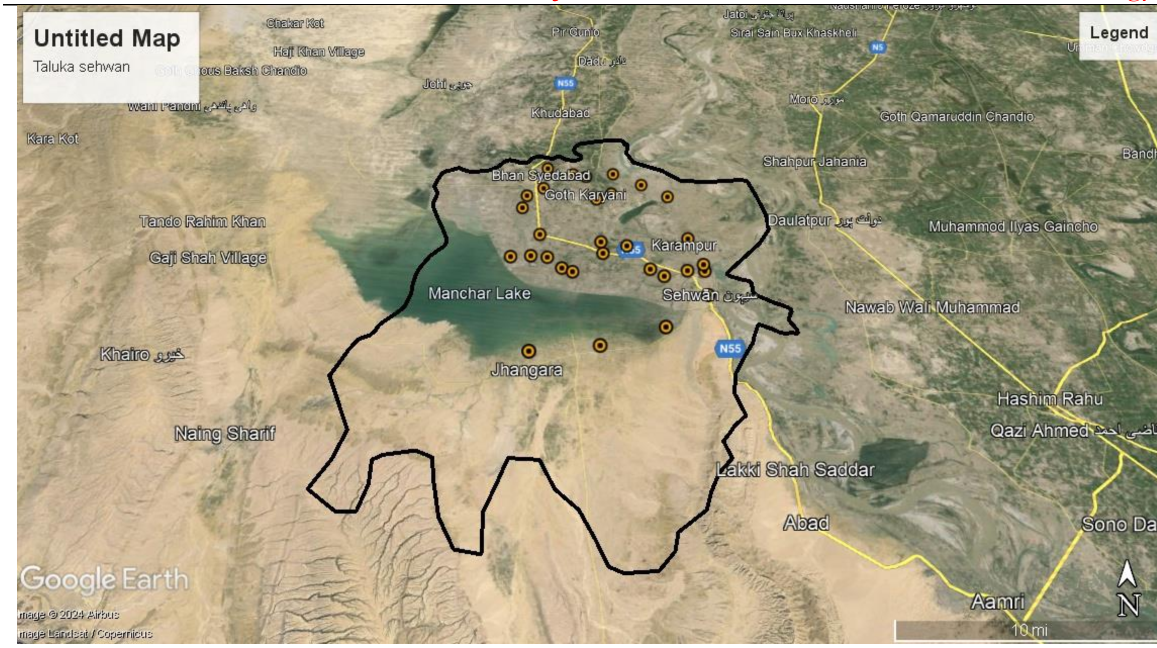



**Figure 3:** Study area map.

**Water Quality Index (WQI):**

The Water Quality Index (WQI) is an essential tool for evaluating groundwater quality within a specific area, as evidenced by numerous studies. Researchers such as Khan and Qureshi (2018) [23], Solangi et al. (2019) [24], and Javeda et al. (2021) [25] have effectively utilized WQI to determine the suitability of water for human consumption, underscoring its importance in identifying health risks linked to contaminated groundwater. Moreover, studies conducted by Changsheng et al. (2022) [26], Bhatti et al. (2020) [27], and Ram et al. (2021) [28] highlight the significance of WQI in informing water management strategies aimed at protecting public health. By applying the prescribed formula, WQI allows for the classification of groundwater samples into various quality categories, facilitating the identification of areas that require remediation. This categorization is vital for prioritizing efforts to address water quality issues and ensuring the safety and sustainability of water resources.

**Table 1:** Ranges of water quality index for possible use.

| Based on the calculated WQI | | Possible usages |
|---|---|---|
| 0–25 | Excellent | Drinking, Irrigation, and Industrial |
| 25–50 | Good | Domestic, Irrigation, and Industrial |
| 51–75 | Poor | Irrigation and Industrial |
| 76–100 | Very Poor | Irrigation |
| 101–150 | Unsuitable | Restricted uses for Irrigation |
| >150 | Unfit for Drinking | Proper treatment is required before use (Gabr et al., 2021) |

The water quality index approach for assessing drinking appropriateness was performed in the following steps:

- We allocated weights (wi) to factors depending on their relevance for assessing drinking quality.
- Relative weight (Wi) was computed using Equation (1) from Talalaj (2014) [29].

$$W_i = \frac{w_i}{\sum_{i=1}^{n} w_i} \tag{1}$$

Where, $w_i$ = weight of each parameter; $W_i$ = relative weight; and n = number of parameters

- Quality scaling ($q_i$) was determined using Equation (2) [30].

$$q_i = \frac{C_i}{S_i} \times 100 \quad (2)$$

Where, $C_i$ = concentration of each parameter [mg/l]; $S_i$ = WHO standard limit of each parameter [mg/l]

- A sub-index (SI) (Equation (3)) for each sampling point was calculated and all parameters will be summed to obtain the water quality index WQI (Equation (4)) [31].

$$SI_i = W_i \times q_i \quad (3)$$

$$WQI = \sum_{i=1}^{n} SI_i \quad (4)$$

Where, $SI_i$ = sub-index

**Irrigation Indices:**

With the help of the concentration of different parameters like magnesium, calcium, sodium, potassium, etc., the irrigation indices have been computed such as Soluble Sodium percentage, Sodium adsorption ratio, Residual sodium carbonate, Magnesium hazard, and Permeability index. SSP had been computed by applying the given equation below and the concentration of this index is shown in meq/l: [32]

$$SSP = \frac{(\text{Sodium} + \text{Potassium})}{(\text{Calcium} + \text{Magnesium} + \text{Sodium} + \text{Potassium})} \times 100 \quad (5)$$

SAR was computed by using the equation given below, the concentration of these indices is shown in meq/l: [33]

$$SAR = \frac{\text{Sodium}}{\sqrt{(\text{Calcium} + \text{Magnisium})/2}} \quad (6)$$

RSC had been computed by the below-given equation, the concentration of these indices is also shown in meq/l: [32]

$$RSC = \text{Bicarbonate} + \text{Carbonate} - (\text{Calcium} + \text{Magnesium}) \quad (7)$$

MH was calculated by the equation given below; concentration is also shown in meq/l of each parameter used in the equation: [32]

$$MH = \frac{\text{Magnesium}}{\text{Calcium} + \text{Magnesium}} \times 100 \quad (8)$$

PI had been computed by the -equation, The PI method is used to assess the quality of groundwater for agricultural use, all parameters concentration is in meq/l that present in the below equation (Hasan, et al., 2017) [34].

$$PI = \frac{\text{Sodium} + \sqrt{\text{Bicarbonate}}}{\text{Calcium} + \text{Magnesium}} \times 100 \quad (9)$$

**Table 2:** Ranges of Irrigation Indices for possible use.

| Irrigation Indices | Extent | Grading |
|---|---|---|
| **Sodium Adsorption Ratio** | <10 | Excellent |
| | 18-26 | Good |
| | 10-18 | Allowable |
| | >26 | Unsuitable |
| **Residual Sodium Carbonate** | <1.25 | Good |
| | >1.25 | Poor |
| **Soluble Sodium percentage** | <20 | Excellent |

| | | |
|---|---|---|
| | 20-40 | Good |
| | 40-60 | Allowable |
| | 60-80 | Unsure |
| | >80 | Poor |
| **Magnesium Hazard** | <50 | Secure |
| | >50 | Unsuitable |
| **Permeability Index** | >75 | Excellent |
| | 25-75 | Safe |
| | <25 | Poor |

## Results:

### Evaluation of WQI of Samples and Spatial Distribution:

The analysis of groundwater samples collected from various tube wells used for domestic purposes in the study area reveals significant variability in water quality, underscoring the need for targeted water management strategies. Out of the 30 water samples analyzed, only 4 (13.33%) met the standards for drinking, irrigation, and industrial use without requiring treatment. In contrast, 7 samples (23.33%) were deemed suitable for irrigation and industrial purposes with caution, while 2 samples (6.67%) required significant caution even for these uses. Furthermore, 9 samples (30%) were found to be fit only for irrigation, and 8 samples (26.67%) were unfit for drinking, necessitating thorough treatment before any use.

The spatial analysis of the Water Quality Index (WQI), illustrated in Figure 4, reveals distinct patterns across the geographical area studied. A small pocket in the northern region shows good water quality, indicating a favorable zone for various uses. However, as one moves southwards from this area, the water quality deteriorates, with several locations classified as poor, very poor, or even unfit for use. Interestingly, a concentrated portion in the central area maintains good water quality amidst the surrounding degradation, highlighting the heterogeneous nature of water quality within the study area.

### Evaluation of Irrigation Indices of Samples and Spatial Distribution:

The Sodium Soluble Percentage (SSP) in the study area ranges from 55% to 86.7%. Notably, none of the samples fall into the "excellent" category, with 1 sample (3.33%) classified as "allowable," 25 samples (83.33%) as "unsure," and 4 samples (13.33%) as "poor" in terms of water quality for irrigation. These findings suggest potential sodium hazards in some areas.

The Sodium Absorption Ratio (SAR) values of the groundwater range from 3.48 to 32.68, indicating that 3 samples (10%) fall into the "excellent" category, 14 samples (46.67%) are classified as "good," 10 samples (33%) as "allowable," and 3 samples (10%) as "unsuitable" for agricultural use. These results emphasize the necessity of careful water management practices to ensure sustainable agriculture and mitigate potential adverse effects on soil and crop health.

Residual Sodium Carbonate (RSC) values range from -25.5 to 3.64, indicating that all collected samples are suitable for agriculture. The calculated Magnesium Hazard (MH) values of the groundwater samples range from 0.755 to 4.187, with all samples considered suitable for agricultural use.

Permeability Index (PI) values range from 60.3 to 122, with 21 samples classified as "excellent" and 9 samples as "safe" for agricultural use. These findings underscore the importance of assessing groundwater quality to ensure sustainable agricultural practices. In areas with elevated PI values, proper management strategies may be required to mitigate potential risks associated with sodium and bicarbonate concentrations in the water.

**Table 3:** Results of Physiochemical Parameters.

| S. No | Sample ID | TDS | pH | Fl mg/l | Cl mg/l | Ca mg/l | Mg mg/l | Na mg/l | TA mg/l | K Mg/l | Fe mg/l | EC µs/cm | Hard mg/l | AS ppm | Ni (ppm) | Turb (NTU) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | A | 3440 | 6.78 | 0.02 | 420 | 108.86 | 345.74 | 1725 | 256 | 42 | 447 | 6800 | 1800 | 0.033 | 2.7 | 1.32 |
| 2 | B | 3010 | 6.88 | 0.03 | 420 | 102.32 | 272.90 | 1465 | 250 | 36 | 386 | 6010 | 1900 | 0.042 | 7.4 | 1.46 |
| 3 | C | 2510 | 7.13 | 0.022 | 360 | 95.31 | 216.28 | 1275 | 230 | 20 | 294 | 5000 | 1800 | 0.048 | 2.1 | 73.7 |
| 4 | D | 2230 | 7.12 | 0.005 | 432 | 83.89 | 225.75 | 1374 | 286 | 28 | 329 | 4520 | 2200 | 0.036 | 0.86 | 54.7 |
| 5 | E | 2660 | 6.93 | 0.06 | 480 | 75.00 | 192.96 | 1652 | 334 | 22 | 232 | 5260 | 2400 | 0.033 | 0.4 | 55.1 |
| 6 | F | 3380 | 7.03 | 0.026 | 420 | 99.00 | 284.12 | 1511 | 204 | 35 | 321 | 6690 | 2000 | 0.039 | 2.5 | 3.10 |
| 7 | G | 550 | 7.35 | 0.07 | 120 | 50.95 | 79.30 | 570.9 | 280 | 13 | 223 | 1104 | 260 | 0.057 | 0.55 | 1.40 |
| 8 | k | 3310 | 7.14 | 0.055 | 432 | 85.40 | 279.62 | 2652 | 318 | 38 | 270 | 6740 | 1700 | 0.042 | 0.16 | 1.56 |
| 9 | I | 3410 | 7.04 | 0.07 | 408 | 120.97 | 554.26 | 2659 | 196 | 94 | 379 | 7020 | 1900 | 0.057 | 11 | 4.99 |
| 10 | J | 2480 | 7.01 | 0.001 | 360 | 76.13 | 229.98 | 1793 | 228 | 43 | 317 | 4960 | 1600 | 0.069 | 18 | 30.0 |
| 11 | H | 2260 | 7.08 | 0.045 | 348 | 94.49 | 239.31 | 1873 | 284 | 32 | 362 | 4540 | 1840 | 0.213 | 104 | 119 |
| 12 | L | 1735 | 7.05 | 0.078 | 300 | 84.98 | 226.52 | 1793 | 314 | 93 | 251 | 3470 | 900 | 0.072 | 31 | 1.46 |
| 13 | M | 731 | 7.15 | 0.009 | 120 | 57.03 | 59.15 | 540 | 274 | 7.1 | 210 | 1405 | 400 | 0.129 | 65 | 1.48 |
| 14 | N | 610 | 7.26 | 0.004 | 108 | 26.68 | 49.22 | 493 | 132 | 8.2 | 104 | 1220 | 300 | 0.102 | 64 | 1.42 |
| 15 | O | 670 | 7.40 | 0.007 | 120 | 29.48 | 81.99 | 561 | 300 | 15.2 | 123 | 1237 | 290 | 0.054 | 21 | 1.28 |
| 16 | P | 616 | 7.32 | 0.081 | 120 | 26.99 | 43.17 | 377 | 90 | 9.3 | 118 | 1236 | 276 | 0.057 | 10 | 1.67 |
| 17 | Q | 402 | 7.37 | 0.012 | 60 | 18.53 | 49.68 | 303 | 74 | 7.6 | 112 | 822 | 200 | 0.042 | 35 | 31.5 |
| 18 | S | 817 | 7.20 | 0.056 | 132 | 41.60 | 75.53 | 637 | 380 | 17.6 | 177 | 1630 | 300 | 0.045 | 11 | 238 |
| 19 | T | 827 | 7.15 | 0.032 | 120 | 38.21 | 133.40 | 825 | 340 | 20.6 | 186 | 1641 | 320 | 0.039 | 3.6 | 256 |
| 20 | U | 1044 | 7.24 | 0.04 | 144 | 62.60 | 114.18 | 780 | 388 | 11.5 | 196 | 2050 | 400 | 0.048 | 3.8 | 75.4 |
| 21 | V | 1630 | 7.02 | 0.072 | 240 | 106.89 | 137.91 | 876 | 296 | 34.1 | 282 | 3270 | 700 | 0.051 | 2.2 | 37.2 |
| 22 | W | 474 | 7.39 | 0.022 | 60 | 38.80 | 40.93 | 424 | 180 | 7.43 | 148 | 950 | 220 | 0.036 | 0.36 | 1.78 |
| 23 | X | 4090 | 6.83 | 0.028 | 1044 | 103.80 | 275.14 | 2818 | 490 | 28.7 | 319 | 8490 | 2800 | 0.033 | 0.31 | 4.65 |
| 24 | Y | 6070 | 6.8 | 0.076 | 1320 | 7.713 | 18.016 | 77.76 | 560 | 9 | 22 | 12610 | 3600 | 0.051 | 0.71 | 124 |
| 25 | Z | 941 | 7.35 | 0.002 | 132 | 44.08 | 65.77 | 830 | 372 | 9.4 | 134 | 1878 | 360 | 0.054 | 1.4 | 1.60 |
| 26 | AB | 1305 | 8.11 | 0.0087 | 204 | 33.01 | 63.33 | 1045 | 304 | 37.5 | 110 | 2590 | 480 | 0.042 | 1.8 | 1.70 |
| 27 | AD | 4050 | 6.96 | 0.028 | 1080 | 111.18 | 384.51 | 2196 | 408 | 21.5 | 331 | 8220 | 2800 | 0.048 | 0.58 | 1.60 |
| 28 | AE | 3430 | 6.98 | 0.065 | 720 | 73.26 | 178.42 | 2080 | 364 | 17.8 | 231 | 6870 | 1800 | 0.042 | 0.40 | 40 |
| 29 | OP | 2490 | 6.88 | 0.014 | 384 | 101.47 | 247.75 | 1655 | 442 | 33.5 | 300 | 5000 | 1400 | 0.045 | 5.9 | 15 |
| 30 | TP | 1881 | 6.85 | 0.012 | 408 | 115.94 | 180.12 | 584 | 366 | 28.2 | 401 | 3760 | 880 | 401 | 1.2 | 225 |

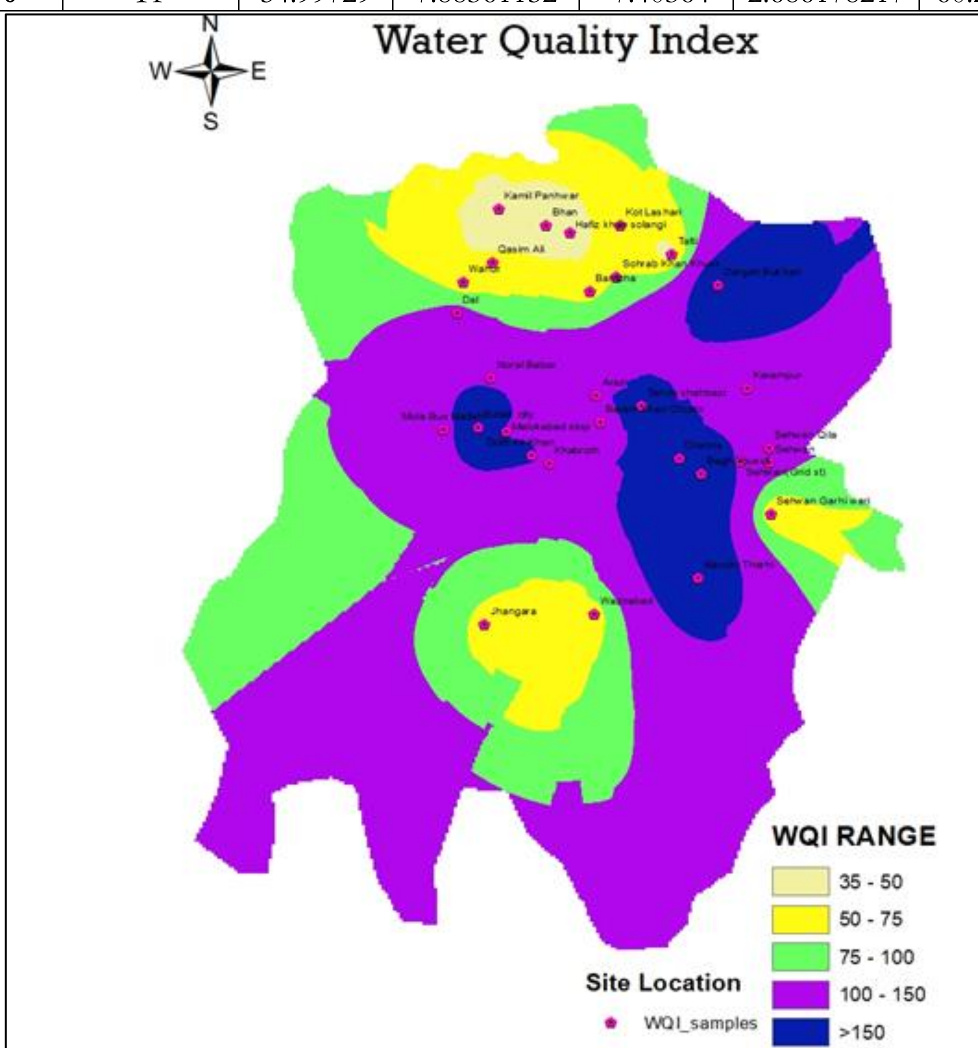
**Table 4:** Results of Water Quality Index.

| S. No. | Sample ID | Location Names | WQI | Category of Groundwater |
|---|---|---|---|---|
| 1 | A | Tando shahbazi | 166.807 | Unfit for Drinking |
| 2 | B | Arazi | 150.3855 | Unfit for Drinking |
| 3 | C | Baram Khan Chutto | 131.278 | Unsuitable |
| 4 | D | Khabroth | 136.7727 | Unsuitable |
| 5 | E | Sehwan Qila | 141.2171 | Unsuitable |
| 6 | F | Goth Ali Khan | 155.7935 | Unfit for Drinking |
| 7 | G | Sehwan Garhi wari | 55.67355 | Poor |
| 8 | k | Malokabad stop | 145.7714 | Unsuitable |
| 9 | I | Bubak city | 201.7711 | Unfit for Drinking |
| 10 | J | Mola Bux Mallah | 127.8395 | Unsuitable |
| 11 | H | Noral Babar | 142.7472 | Unsuitable |
| 12 | L | Dal | 113.6838 | Unsuitable |
| 13 | M | Wahur | 55.28714 | Poor |
| 14 | N | Kamil Panhwar | 42.49191 | Good |
| 15 | O | Qasim Ali | 54.9943 | Poor |
| 16 | P | Bhan | 41.76499 | Good |
| 17 | Q | Hafiz khan solangi | 34.53824 | Good |
| 18 | S | Bambha | 64.69239 | Poor |
| 19 | T | Kot Lashari | 71.93792 | Poor |
| 20 | U | Sohrab Khan Khusk | 75.20288 | Very poor |
| 21 | V | Karampur | 95.78458 | Very poor |
| 22 | W | Talti | 39.59964 | Good |
| 23 | X | Dargah Bukhari | 213.362 | Unfit for Drinking |
| 24 | Y | Nandhi Therhi | 207.9891 | Unfit for Drinking |
| 25 | Z | Wazirabad | 60.79841 | Poor |
| 26 | AB | Jhangara | 67.1513 | Poor |
| 27 | AD | Bagh Yousuf | 231.309 | Unfit for Drinking |
| 28 | AE | Channa | 156.7389 | Unfit for Drinking |
| 29 | OP | Sehwan(Grid st) | 140.0473 | Unsuitable |
| 30 | TP | Sehwan | 122.2174 | Unsuitable |

**Table 5:** Computed irrigation indices of collected samples.

| S. No. | Sample ID | SSP | SAR | RSC | MH | PI |
|---|---|---|---|---|---|---|
| 1 | A | 68.64991 | 18.125079 | -15.0293 | 3.212147392 | 70.52475 |
| 2 | B | 69.57338 | 17.06803717 | -11.8801 | 2.741471162 | 71.78444 |
| 3 | C | 70.88085 | 16.43361732 | -9.50953 | 2.322218852 | 73.36194 |
| 4 | D | 72.20466 | 17.62169237 | -9.15973 | 2.352302388 | 74.82051 |
| 5 | E | 78.3695 | 22.81728434 | -7.17762 | 1.849418678 | 80.92184 |
| 6 | F | 69.65355 | 17.36781034 | -12.6418 | 2.816754399 | 71.59206 |
| 7 | G | 73.05349 | 11.60197247 | -2.28345 | 1.263224336 | 79.35813 |
| 8 | K | 80.70333 | 31.05724932 | -11.1798 | 2.130881874 | 82.30124 |
| 9 | I | 68.8842 | 22.62799236 | -24.5123 | 4.18701781 | 69.95193 |
| 10 | J | 77.24122 | 23.00487841 | -9.61743 | 2.119424123 | 79.15654 |

| | | | | | | |
|---|---|---|---|---|---|---|
| **11** | H | 76.75683 | 23.19518309 | -10.0058 | 2.148154705 | 78.78998 |
| **12** | L | 77.12603 | 22.93126126 | -8.9894 | 2.081731564 | 79.37009 |
| **13** | M | 75.12389 | 11.91353101 | -1.64482 | 0.960318327 | 81.89927 |
| **14** | N | 79.77079 | 13.00327014 | -1.63645 | 0.859638799 | 85.24417 |
| **15** | O | 74.60026 | 11.97149343 | -1.69448 | 1.343309236 | 81.38106 |
| **16** | P | 76.82133 | 10.42587534 | -1.73617 | 0.854027328 | 82.51165 |
| **17** | Q | 72.27296 | 8.297803598 | -1.92695 | 1.101288916 | 78.29998 |
| **18** | S | 76.80276 | 13.54983405 | -1.07248 | 1.152899311 | 83.7164 |
| **19** | T | 73.3719 | 14.0651448 | -3.72714 | 1.808033515 | 78.19732 |
| **20** | U | 72.84171 | 13.48862215 | -3.14263 | 1.563334576 | 78.25801 |
| **21** | V | 69.3558 | 13.13387426 | -5.9927 | 1.743493623 | 73.36486 |
| **22** | W | 77.51815 | 11.28042961 | -1.20036 | 0.755432969 | 84.73463 |
| **23** | X | 81.33514 | 32.67905601 | -10.0432 | 2.028816038 | 83.21643 |
| **24** | Y | 64.17952 | 3.480755468 | 3.646631 | 0.773598359 | 121.6935 |
| **25** | Z | 82.45488 | 18.42528772 | -0.79363 | 0.885463065 | 88.09235 |
| **26** | AB | 86.77034 | 24.41597245 | -0.97272 | 0.76909811 | 91.03267 |
| **27** | AD | 71.75178 | 22.02741781 | -15.4569 | 3.187261812 | 73.69465 |
| **28** | AE | 82.9984 | 29.7204397 | -6.28236 | 1.532534516 | 85.23947 |
| **29** | OP | 73.66823 | 20.06561513 | -9.23715 | 2.352397609 | 76.42406 |
| **30** | TP | 54.99729 | 7.88361152 | -7.40364 | 2.686178217 | 60.29513 |



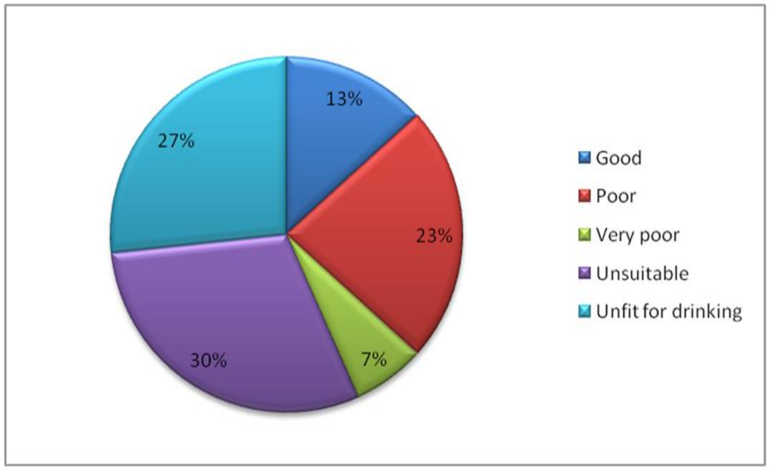



**Figure 4**: Graphical and spatial map of WQI.

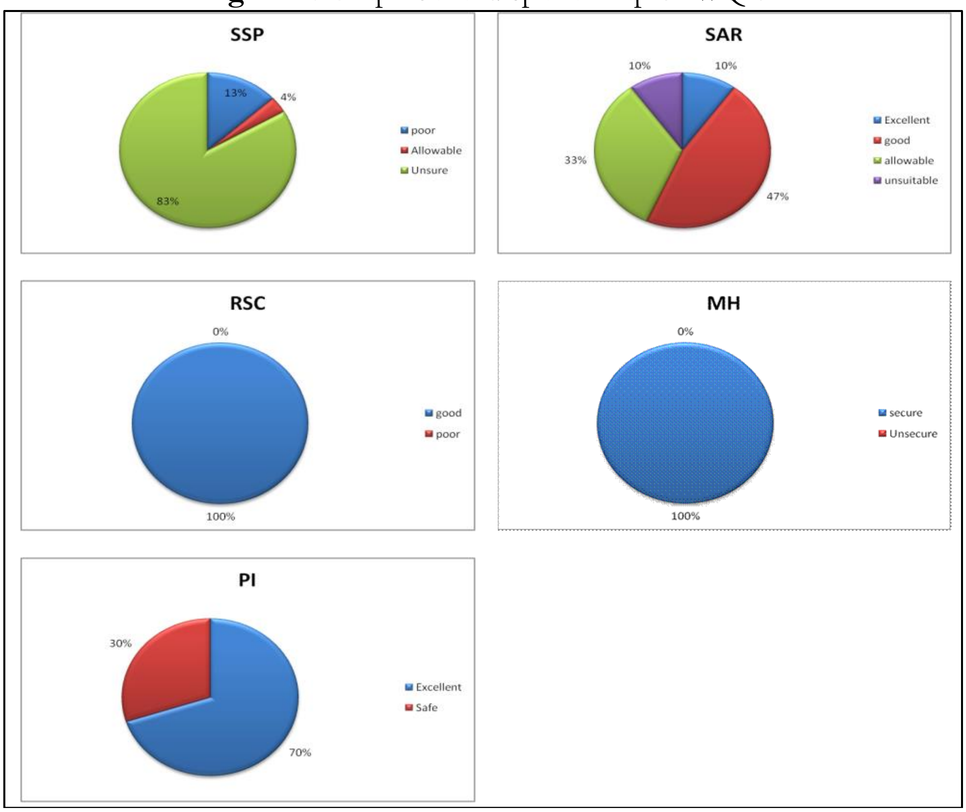



**Figure 5:** Graphical Representation of Irrigation Indices.

The groundwater quality for agricultural purposes in the study area was assessed and visualized using spatial distribution maps of various irrigation indices, including Sodium Soluble Percentage (SSP), Sodium Absorption Ratio (SAR), Permeability Index (PI), and Kelley's Ratio (KR). The SSP map revealed zones ranging from "unsure" to "poor," indicating areas with elevated soluble sodium percentages, which could pose challenges for agricultural use due to potential sodium hazards. In contrast, the SAR distribution map showed zones categorized as "good," with SAR values ranging from 10.3 to 23.5. This range suggests that the water quality is generally suitable and allowable for agricultural use in most parts of the study area. The northern region exhibits higher PI values compared to the southern part, with most areas falling within a PI range of 30 to 70, indicating a general suitability for agricultural use. Although Magnesium Hazard (MH) values below 50 are typically considered safe for irrigation, both the northern and southern parts of the study area exhibit slightly elevated MH values.

This suggests that the middle part of the region may be marginally less suitable for irrigation, as depicted in Figure 3.3. Despite this, the overall groundwater quality for agricultural use is deemed good based on most indices. However, the SSP and SAR indices highlight low to medium sodium hazards in certain areas of Taluka Sehwan, which could adversely affect soil permeability and structure over time. These findings underscore the need for ongoing monitoring and tailored management practices to address specific localized risks.

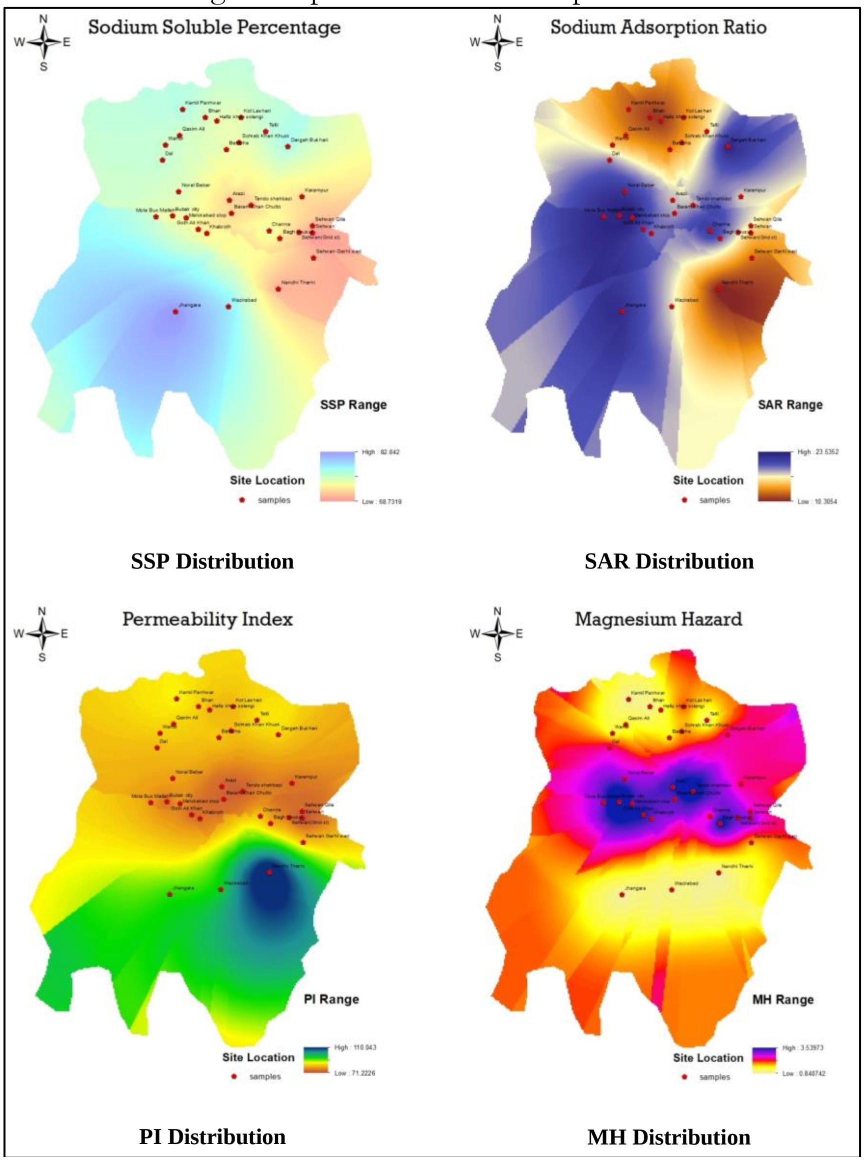



**Figure 6:** Spatial Distribution of Irrigation Indices

**Evaluation of Physiochemical Parameters of Samples and Spatial Distribution:**

The analysis of groundwater samples collected from the study area presents a mixed picture of water quality. While the pH levels are within the suitable range, other parameters raise significant concerns. Total dissolved solids (TDS) are within acceptable drinking water standards for only 66.67% of the samples, and 70% of the samples exhibit total alkalinity levels that align with WHO guidelines. However, only 40% of the samples fall within the permissible limits for hardness, indicating that the majority of the water has moderate to high hardness levels, which could affect its suitability for domestic use. Turbidity levels are particularly concerning, with 46.67% of the samples displaying high turbidity, which not only impacts the aesthetic quality of the water but also potentially affects its portability. Additionally, a substantial portion of the samples (63.33%) shows very high electrical conductivity (EC) values, indicating elevated mineral content, which could pose long-term challenges for both drinking water quality and agricultural use. Overall, the groundwater quality in the study area presents a mixed scenario. While certain parameters like pH and total alkalinity meet drinking water standards, others, such as TDS, hardness, turbidity, and EC, reveal potential issues that warrant attention. These findings highlight the need for targeted water management strategies to address specific water quality concerns in the region.

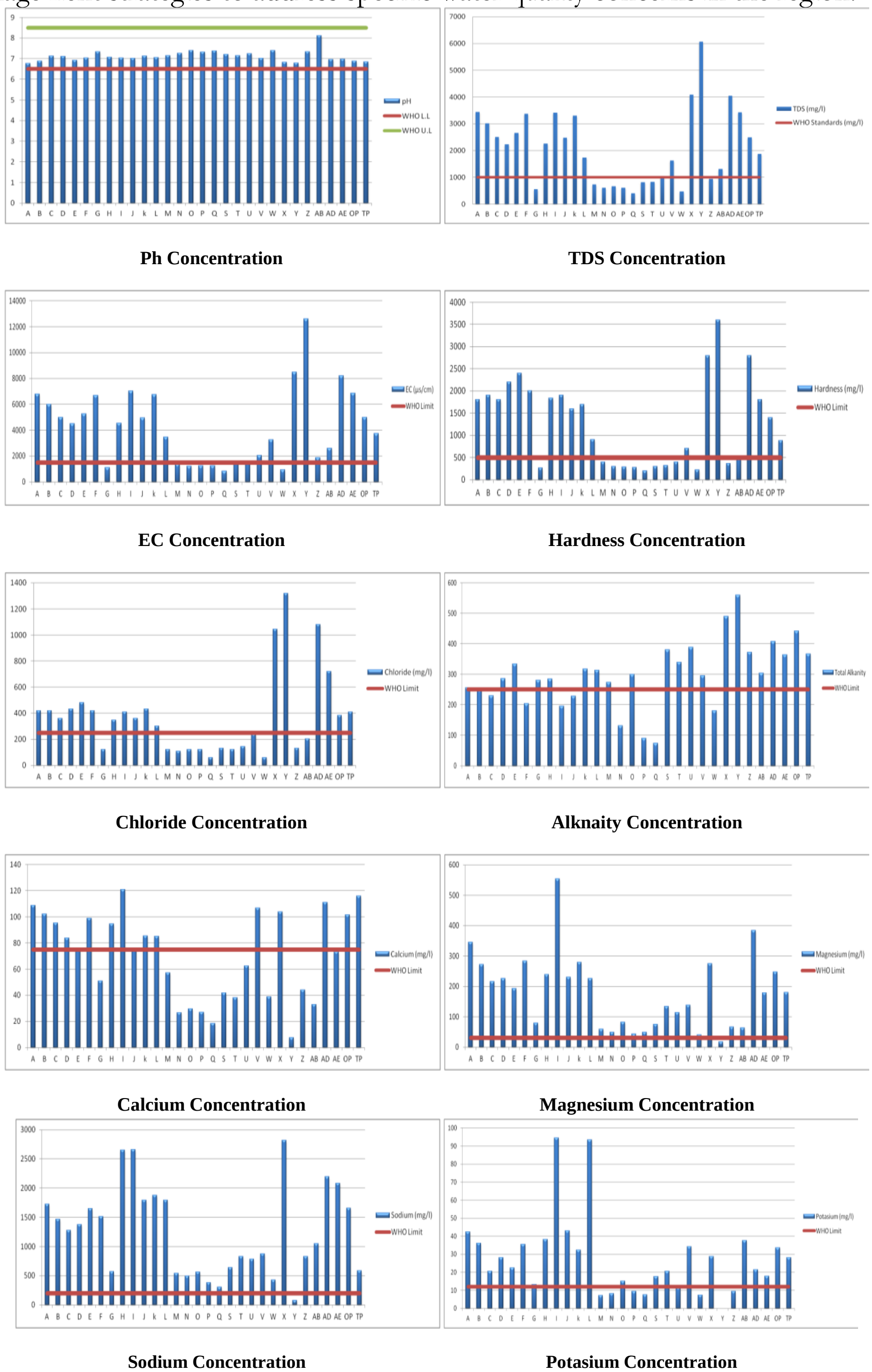
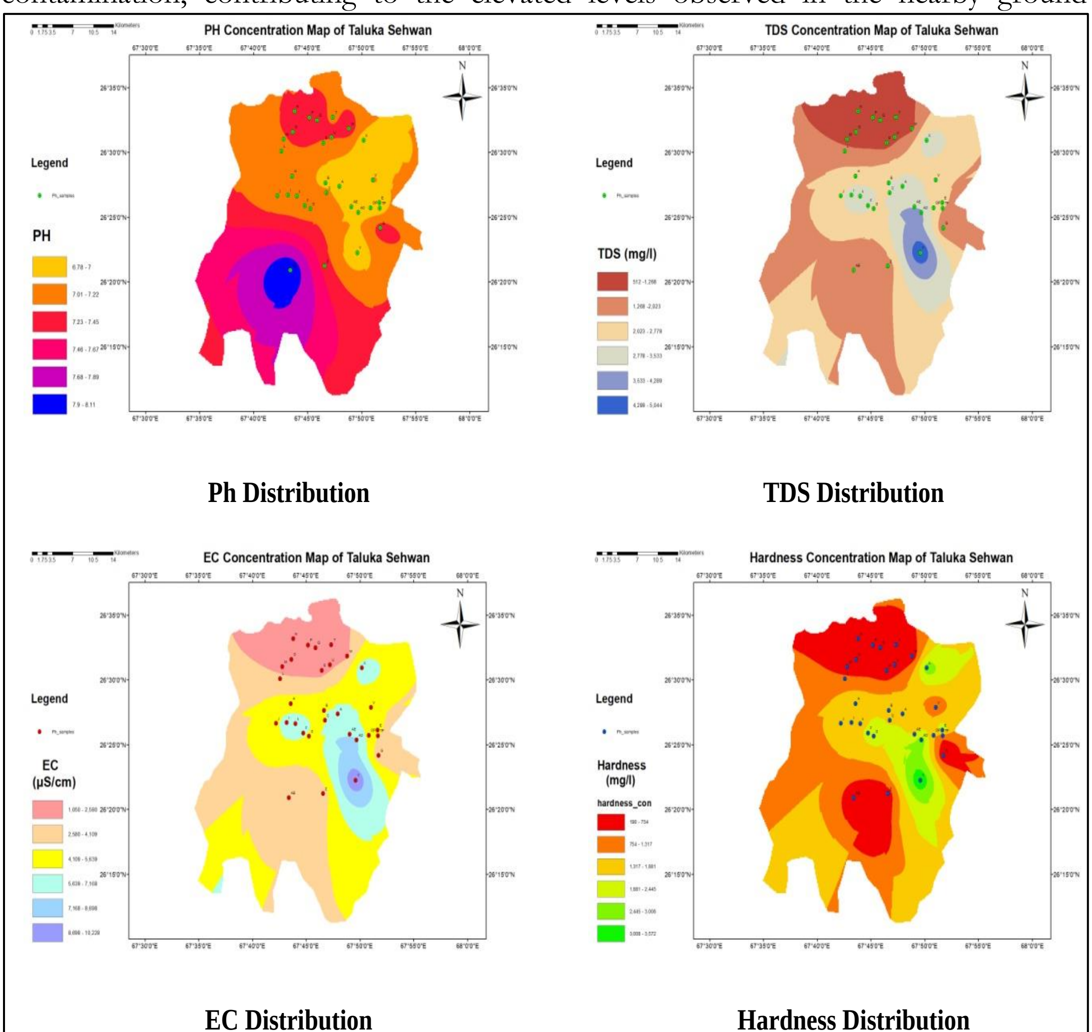



**Figure 7:** Graphical representation of physiochemical parameters range

The groundwater analysis reveals that while calcium levels are within acceptable limits in 14 samples (46.67%), there are significant concerns regarding magnesium, sodium, and potassium concentrations. A staggering 29 samples (96.67%) exhibit magnesium and sodium levels that exceed safe thresholds, and 23 samples (76.67%) have potassium levels above WHO standards. These elevated concentrations highlight the urgent need for targeted water treatment to address these specific contaminants. Given the high levels of magnesium, sodium, and potassium, continuous monitoring of these cations is strongly recommended to track any changes over time. Additionally, educating the local community on water conservation practices and proper usage could help alleviate some of the pressure on groundwater resources, potentially mitigating further degradation of water quality. The data indicates that the groundwater in the study area is not safe for consumption due to its elevated magnesium, sodium, and potassium levels. To ensure water quality and safety, several actions are recommended: continuous monitoring, implementation of water treatment measures, protection of water sources, and public awareness campaigns. These recommendations are based on WHO and EPA standards, underscoring the importance of maintaining water safety. Spatial mapping of the physiochemical parameters across the study area reveals a consistent pattern: lower concentrations in the northern regions and higher concentrations in the southern and southeastern areas. This suggests that the central part of the study area is particularly contaminated. Additionally, the concentration of contaminants decreases as the distance from Manchar Lake increases. Samples collected near Manchar Lake show high concentrations of various parameters, indicating that the lake may be a source of contamination, contributing to the elevated levels observed in the nearby groundwater.




Ph Distribution

TDS Distribution

EC Distribution

Hardness Distribution

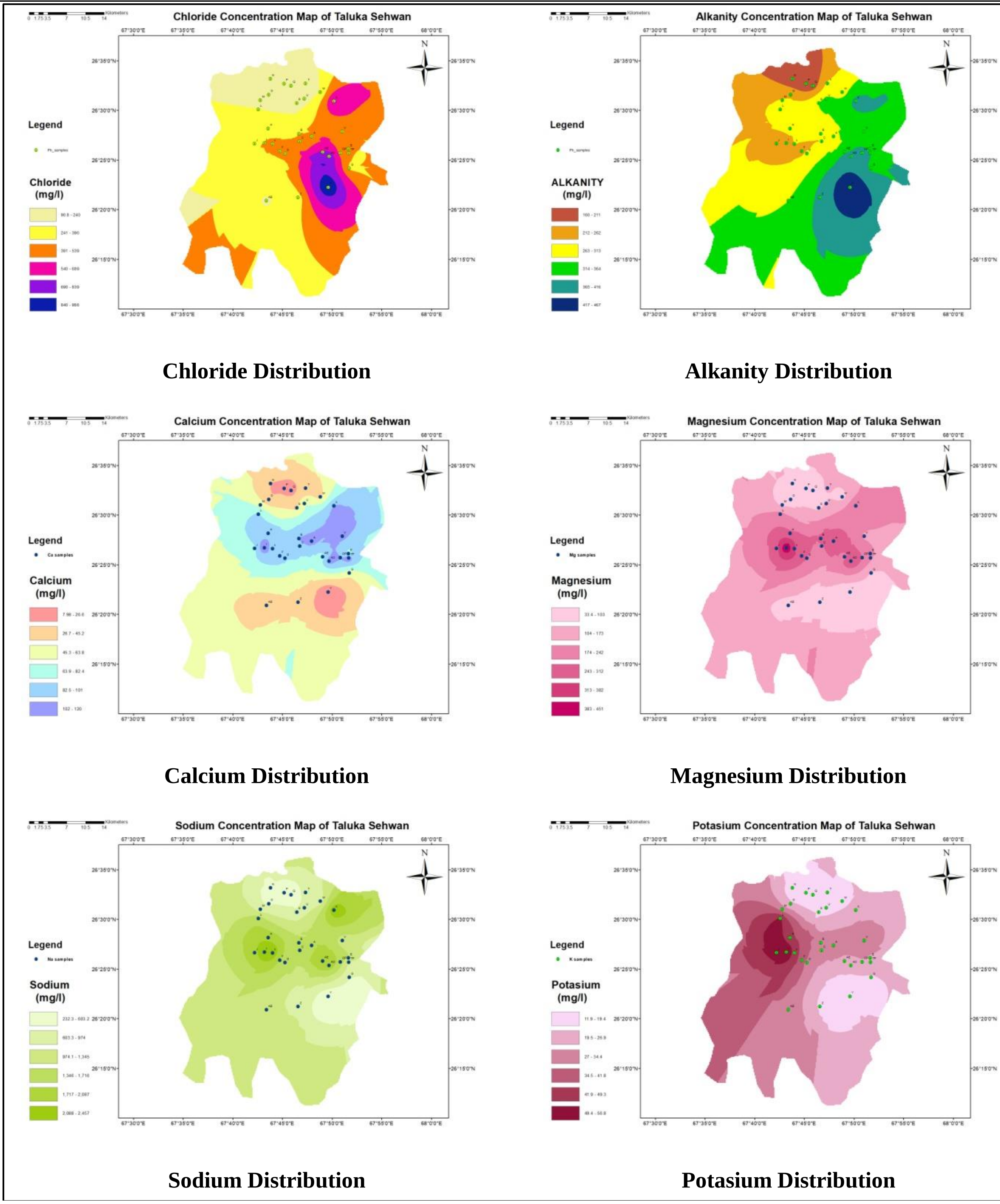



**Figure 8:** Spatial Distribution of Physiochemical Parameters

## Discussion:

This study investigates groundwater quality in the Taluka Sehwan region, revealing significant variability among the samples. Only a small percentage met the standards for drinking, irrigation, and industrial use without treatment. Irrigation indices, including Sodium Soluble Percentage (SSP) and Magnesium Hazard (MH), highlight the critical need for careful water management practices to support sustainable agriculture. These findings are consistent with previous research by Singh K.K. et al. (2020) [32], Awedat, A. M. (2014) [35], and Rengasamy P. (2010) [36], which also emphasized the challenges of maintaining water quality for agricultural use due to sodium hazards. Analysis of physiochemical parameters such as pH, Total Dissolved Solids (TDS), alkalinity, hardness, turbidity, and electrical conductivity (EC) produced mixed results, echoing similar recommendations by WHO and EPA standards to ensure water quality and safety in the region. The study found higher contaminant concentrations in the southern and southeastern areas, potentially linked to the proximity to Manchar Lake. These results underscore the urgent need for comprehensive water management strategies to address these challenges and ensure water sustainability for agricultural, domestic, and industrial purposes.

**Conclusion:**

Based on the comprehensive analysis conducted in this study, several key conclusions about groundwater quality and its suitability for various uses in the Taluka Sehwan region can be drawn. According to WHO criteria, the Water Quality Index (WQI) analysis reveals that groundwater from tube wells and hand pumps in this area is generally unsuitable for drinking. Only four out of the 30 samples (13.33%) meet the standards for drinking, irrigation, and industrial use without treatment. The spatial distribution map of WQI indicates that most regions do not provide suitable water for drinking purposes. The Soluble Sodium Percentage (SSP) evaluation shows that only one sample (3.33%) falls within allowable limits, while 25 samples (83.33%) are categorized as uncertain, and four samples (13.33%) are classified as poor for irrigation quality. This suggests that most locations are prone to sodium hazards. Approximately 53% of the study area has groundwater that is deemed safe for agriculture based on Sodium Absorption Ratio (SAR) values, whereas 47% of the area is vulnerable to sodium hazards. Indices such as Magnesium Hazard (MH) and Residual Sodium Carbonate (RSC) indicate that the water is generally suitable for agricultural use. Distribution maps for SSP and Permeability Index (PI) show that most upper and lower areas are suitable for agriculture, though certain central parts are affected by sodium hazards, which could impact crop yields. The analysis of cation concentrations reveals mixed results: calcium levels are acceptable in 14 samples (46.67%), but high magnesium and sodium levels were detected in 29 samples (96.67%), exceeding safe limits. Additionally, potassium levels surpassed WHO standards in 23 samples (76.67%), which poses health risks and necessitates targeted treatment to address the impacts on both human health and agricultural productivity.

**Recommendations:**

- Establish regular monitoring programs to track groundwater quality changes.
- Develop local capacity for water quality testing and treatment.
- Promote sustainable agricultural practices to minimize groundwater contamination.
- Prioritize vulnerable communities in access to clean water resources.
- Explore nature-based solutions for groundwater remediation.

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**Conflict of Interest:**

The authors declare no conflict of interest.

**Data Availability Statement:**

The Data was collected by taking Samples throughout the Taluka Sehwan.

**Authors Contribution:**

All authors contributed to the study's conception and design. A.A did Conceptualization; Data curation; Formal analysis; Funding acquisition; Validation; Visualization; Roles/Writing – original draft; Writing – review & editing, M.Z did Roles/Writing – original draft; Writing – review & editing, A.L.Q did Supervision; Roles/Writing – original draft; Writing – review & editing, S.H did Conceptualization;

Formal analysis; Funding acquisition; Project administration; Supervision; Validation; Roles/Writing – original draft; Writing – review & editing

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