Case Report

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Evaluation of Groundwater Quality in Larkana Pakistan Based on the Use of Synthetic Pollution Index

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Evaluation of Groundwater Quality in Larkana Pakistan Based on the use of Synthetic Pollution Index

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Abstract: In light of growing concerns over water contamination, particularly in regions like Sindh, Pakistan, this research aimed to evaluate and map the groundwater quality in Taluka Larkana for both drinking and irrigation applications, addressing the expressed worries of the local community. A total of forty groundwater samples were collected from various sources such as hand pumps, taps, and tube wells. These samples underwent comprehensive analysis encompassing parameters including color, odor, taste, turbidity, pH, total hardness (TH), electrical conductivity (EC), and total dissolved solids (TDS), with comparisons drawn against WHO guidelines. Results indicated that taste, color, odor, and turbidity of the groundwater samples generally fell within acceptable ranges. However, EC levels varied from moderately elevated to excessively high. Notably, a significant proportion of samples (84% EC, 21% Cl, 30% Ca, 37% Mg, 22% TH, and 84% TDS) exceeded WHO-recommended thresholds. Assessment via the SPI model classified approximately 16% of samples as moderately contaminated, while 65% were deemed highly contaminated, and 19% were found unsuitable for drinking purposes. These findings underscore the pressing need for concerted efforts to address water quality issues in the region.

Keywords: groundwater quality; SPI; Larkana

1. Introduction

Water exists in various forms, including vapor in the air, as well as in rivers, lakes, streams, and canals. Approximately 71% of the Earth's surface is covered by water, with the ocean containing about 96.5% of this water. Water plays a vital role in sustaining ecosystems and supporting life, particularly human life, as it is essential for drinking, agriculture, recreation, industry, transportation, and other fundamental activities [1–3].

Despite its crucial importance, the availability and suitability of water have diminished over time, posing challenges to sustain the growing global population. Historically, water scarcity has driven human migrations in search of sustenance, leading to the decline of civilizations such as Mohenjo-Daro and Harappa [4–6]. Factors contributing to water scarcity include not only population growth but also excessive utilization, as highlighted in reports by the Food and Agriculture Organization (FAO) and the Organization for Economic Co-operation and Development (OECD) [7,8].

Water scarcity often manifests in drought conditions, affecting millions of people worldwide and causing significant economic losses, particularly in agriculture. Droughts lead to crop failures and land degradation, exacerbating food insecurity and economic instability [9].

Furthermore, water quality is compromised by chemical pollutants and improper waste disposal practices, resulting in widespread contamination. Waterborne diseases claim millions of lives annually, surpassing the toll of war casualties. Contaminants such as microbial pathogens, heavy metals, pesticides, arsenic, and chromium pose significant health risks, particularly in Asian countries like Pakistan and Bangladesh [10–12].

According to the World Health Organization (WHO), billions of people lack access to safe drinking water, leading to dire public health consequences [13,14]. Developing countries strive to mitigate waterborne diseases and improve access to safe water, but challenges persist due to rapid population growth and inadequate resources [15].

This research aimed to raise awareness among policymakers and authorities regarding groundwater quality in Taluka Larkana, emphasizing the need for water treatment before consumption and irrigation. Identifying vulnerable areas within Taluka Larkana is crucial for implementing targeted interventions to safeguard public health and ensure sustainable water management.

2. Methodology

2.1. To Determine the Physical and Chemical Characteristics of Groundwater Samples

Groundwater samples were obtained from various sources within the study area, including hand pumps, tube wells, and electric motors. Samples from tube wells were specifically collected for irrigation purposes. Prior to sample collection, water was purged from the tube wells to ensure representative sampling, with a purging duration of one minute per foot of depth. Similarly, water from taps or motors was allowed to discharge for at least one minute before sampling. Samples were collected in clean plastic bags or bottles, each labeled with a unique code corresponding to its location (e.g., Loc-1 for the first location), and the coordinates of each sampling site were recorded using GPS technology. Throughout the sampling process, adherence to relevant standards and guidelines was maintained. The collected groundwater samples underwent analysis for various physical and chemical parameters using established standard methods.

2.2. Determination of Quality of Water Based on the SPI (Synthetic Pollution Index) Model Value

Various models for assessing water quality are utilized worldwide for different purposes. Among these, the Synthetic Pollution Index (SPI) model has garnered significant attention from researchers globally, as evidenced by studies conducted by many previous research work done by scholars, who have applied it extensively to evaluate both surface water and groundwater quality.

In this study, the overall quality of groundwater in the research area was assessed using the SPI model, which considers observed concentrations of key water quality indicators such as turbidity, pH, chloride (Cl), calcium (Ca), magnesium (Mg), total hardness (TH), electrical conductivity (EC), total dissolved solids (TDS), among others.

The analysis of water samples collected from the study area was conducted through the following steps.

Step-I: Determination of the constant of proportionality (K):

The constant of proportionality (K) value was determined using the relation as described in Equation 3.4.

$$K = \frac{1}{\sum_{i=1}^{N} \frac{1}{\mathrm{Si}}} \tag{3.4}$$

In the above relation, S_i represents the standard level for the i^{th} water quality parameter, whereas, n shows the number of parameters.

Step-II: Determination of the relative weight (W):

The relative weight (W) was determined using the relation as described in Equation 3.5.

$$\mathrm{W} = \frac{K}{S} \tag{3.5}$$

In equation 3.5 W represents the weight coefficient.

Step-III: Determination of SPI value

Finally, the SPI was calculated using the following relation.

$$\mathrm{SPI} = \sum_{i=0}^{n} \frac{C}{S} W \tag{3.6}$$

Here, C represents the observed value for each analysed physicochemical parameter.

The estimated values of SPI using the above discussed relationships were compared with threshold values used to assess overall quality of drinking water as shown in Table 1

Table 1. Thresholds of SPI for various categories of water.

S.No.	Value	Overall Water Quality
1.	SPI <0.2	Suitable for drinking
2.	SPI between 0.2-0.5	Slightly contaminated
3.	SPI <0.5-1.0	Moderately contaminated
4.	SPI >1.0-3.0	Highly contaminated
5.	SPI > 3.0	Unsuitable for drinking purposes

So all the samples having SPI value less than 0.2 were categorized as suitable, and slightly contaminated when the value of SPI ranged between 0.2 to 0.5, like 0.3, 0.33, 0.45 etc. All the samples SPI value of which was between 0.5 and 1.0 was categorized as moderately slighted and if SPI value of any samples was found >1.0 to 3.0 was categorized as highly contaminated. However, the samples having SPI value greater than 3.0 were categorized unsuitable for drinking purposes.

3. Result and Discussion

3.1. To Determine the Physical and Chemical Characteristics of Groundwater Samples

This study evaluated various physicochemical parameters of water quality, including color, odor, taste, pH, chloride (Cl), electrical conductivity (EC), calcium (Ca), magnesium (Mg), total hardness (TH), and total dissolved solids (TDS). The findings were compared against established permissible limits for each parameter.

Color, Odor, and Taste: Analysis of groundwater samples indicated that the majority were colorless and odorless, with most samples exhibiting a sweet taste. However, samples from specific locations such as Loc-07 (Lashari village), Loc-09 (Zakario Mahesar), Loc-17 (Rasheed Wagon), Loc-20 (Gul Muhammad Chawro), Loc-21 (Hashim Chawro), and Loc-23 (Village Shahbeg Jamal) were found to have a bitter taste, rendering them unsuitable for drinking purposes. Approximately 13.95% of samples exhibited this bitter taste.

Turbidity: Turbidity analysis revealed that most groundwater samples had turbidity levels ranging from 0 to 3 NTU (Nephelometric Turbidity Units), with an average value of 0.9 NTU. The recommended turbidity level for drinking water is 5 NTU (WHO, 2011). High turbidity indicates the presence of suspended particles in water, potentially facilitating the interaction with harmful minerals and pesticides, leading to human health concerns.

pH: The pH values of groundwater in Taluka Larkana ranged from 7 to 7.9, with an average of 7.5. These values fell within the desirable range for drinking water (6.5-8.5, WHO, 2011), indicating suitability for consumption. pH levels outside this range can lead to health issues such as stomach acidity or skin irritation.

Electrical Conductivity (EC): EC is a critical parameter for determining water suitability for consumption and irrigation. The recommended EC value for drinking water is 400 uS/cm (WHO, 2011). Analysis revealed that EC values in the study area ranged from 560 to 722 uS/cm, with an average of 474 uS/cm. Only seven locations had EC values within permissible limits, suggesting widespread contamination likely due to soil salt leaching and inadequate sewage systems.

Total Hardness (TH): TH reflects the concentrations of dissolved calcium and magnesium in drinking water. The WHO guideline recommends TH levels below 100 mg/L, with a maximum

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allowable limit of 500 mg/L. However, TH concentrations in Taluka Larkana ranged from 100 to 1080 mg/L, averaging 514 mg/L. Nine locations exceeded permissible limits, indicating potential health concerns and the need for water treatment.

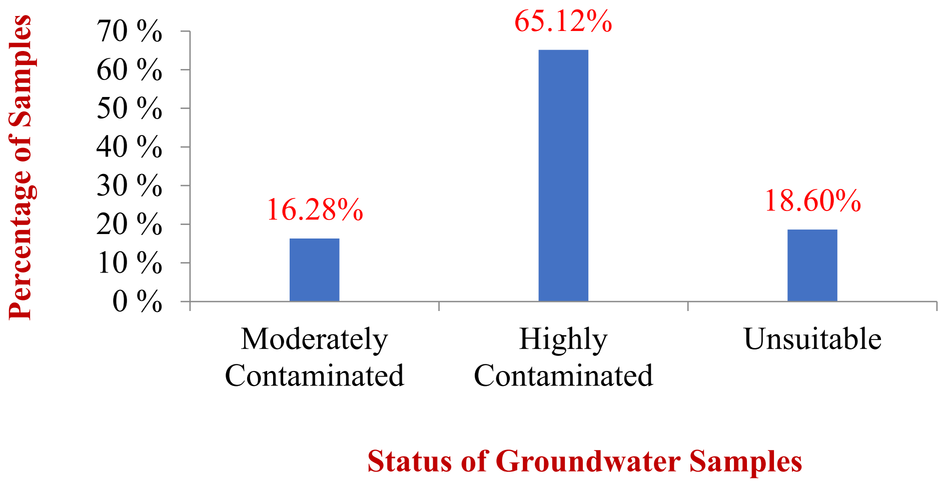
Total Dissolved Solids (TDS): TDS comprises inorganic salts and organic matter dissolved in water, with higher concentrations potentially affecting individuals with heart or kidney diseases. WHO recommends TDS levels below 500 mg/L for drinking water. However, TDS values in the study area ranged from 300 to 4450 mg/L, with an average of 1252 mg/L. Only seven locations met permissible limits, highlighting widespread contamination and health risks associated with elevated TDS levels.

3.2. To Assess the Quality of Groundwater for Domestic Use Based on the Spi Model

The Synthetic Pollution Index (SPI) model is widely utilized for evaluating the overall quality of water intended for drinking purposes. This model offers a predictive assessment of water quality, categorizing it into five distinct classifications: Suitable, Slightly Contaminated, Moderately Contaminated, Highly Contaminated, and Unsuitable.

Analysis of the overall groundwater quality using the Synthetic Pollution Index (SPI) revealed SPI values ranging from 0.72 to 5.64, with an average value of 2.096. Water is deemed suitable for drinking when its SPI value is below 0.5 meq/L; however, no samples in the study area met this threshold. Notably, seven samples collected from locations Loc-14, 22, 28, 29, 30, 32, and Loc-34 were classified as moderately contaminated water. Furthermore, twenty-eight samples fell into the category of highly contaminated water, while eight samples from locations Loc-5, 6, 9, 17, 20, 21, 23, and Loc-27 were deemed unsuitable for drinking. Additionally, the results identified union councils such as Rasheed Wagan, Ratokot, Talbani UC, and Zakrio Mahesar as highly vulnerable areas categorized as unsuitable for drinking water.

In summary, 16.3% of samples were classified as moderately contaminated, 65.12% as highly contaminated, and 18.6% as unsuitable for drinking purposes based on the SPI assessment.



4. Conclusion

Pakistan is grappling with issues of drinking water quality and scarcity, leading millions of people to consume contaminated and unsafe water. Consequently, the contamination of groundwater has resulted in the spread of waterborne diseases such as cholera, dengue, malaria, gastroenteritis, among others. Furthermore, the availability of safe water for consumption in Pakistan is limited, with only 36% to 39% of the population having access to suitable drinking water, albeit this varies across different regions.

In light of these challenges, this study aimed to assess the groundwater quality of Taluka Larkana, located in the Sindh province of Pakistan, specifically for drinking purposes. A total of 40 samples were collected from hand pumps, taps, and tube wells to evaluate the groundwater quality in Taluka Larkana for both drinking and irrigation purposes. The results of the study are summarized below.

The collected samples underwent analysis to determine various physical and chemical parameters, including color, odor, taste, turbidity, pH, chloride, calcium, magnesium, hardness, electrical conductivity, and total dissolved solids, which were then compared with the permissible limits set by the World Health Organization (WHO). Additionally, the Synthetic Pollution Index (SPI) model was employed to assess the overall quality of water in Taluka Larkana for drinking purposes.

Overall, none of the samples were found to be vulnerable in terms of pH levels. However, a significant proportion of samples exceeded the permissible limits for certain parameters, with 83.72% exceeding the limits for electrical conductivity, 20.93% for chloride, 30.23% for calcium, 37.2% for magnesium, 20.93% for total hardness, and 83.72% for total dissolved solids.

Subsequently, the suitability of groundwater samples was evaluated using the Synthetic Pollution Index (SPI) model. The results indicated that 16.27% of samples were moderately contaminated, 65.12% were highly contaminated, and 18.6% were deemed unsuitable for drinking purposes. Notably, none of the samples fell within the suitable category for consumption, highlighting the pressing need for interventions to improve water quality in the region.

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