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Addressing salinity challenges: A comprehensive analysis of saline water and salt-tolerant soil for sustainable crop production in UC Tando Qaiser, Sindh, Pakistan

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Abstract

This study focuses on the physico-chemical characteristics of soils in UC Tando Qaiser, District Hyderabad, Sindh, Pakistan, irrigated by tube well water. The soil samples were collected at depths of 0-20, 20-40, and 40-60 cm, and their particle size distribution, organic matter content, pH, and salinity were analyzed. Results indicate that the soils are heavy in texture, likely influenced by the parent material deposited by the Indus River. Organic matter content was found to be low, possibly due to the absence of farmyard manure and limited cultivation of green manure crops. The majority of soils exhibit a slightly to medium alkaline reaction, characteristic of calcareous soils with high Ca^{2+}, Mg^{2+}, and K^+ content. Slightly-saline soils were observed, emphasizing the need for soil salinity management. Tube well water analysis revealed variations in electrical conductivity, with some samples exceeding permissible limits. Recommendations include strategies to enhance organic matter, mitigate soil salinity, and implement regular monitoring of tube well water quality for sustainable agriculture in the region.

Keywords: Soil analysis; Groundwater quality; Salinity; Soil fertility

1. Introduction

The foundation of Pakistan's economy lies in agriculture, contributing significantly to the GDP and accounting for 80% of the country's total export earnings. With over 48% of the labor force engaged in this sector, the importance of agriculture cannot be overstated [1]. However, the increasing population and evolving lifestyle have escalated the demand for water, putting a strain on agricultural, domestic, and industrial water usage [2].

The success of agricultural production is intricately tied to the availability and efficient utilization of water, a critical input in the process. Pakistan boasts the world's largest irrigation system, the Indus Basin Irrigation system, covering 14.3 million hectares and encompassing major water sources like the Indus River and its tributaries. This extensive system, with its reservoirs, barrages, and canals, caters to over 140,000 farmer-operated watercourses [1].

Despite the colossal irrigation infrastructure, challenges arise due to the increasing demand for water and limited opportunities for further resource development. Groundwater, derived from the infiltration of surface water and local rainfall, has become crucial in meeting the nation's food and fiber requirements. Groundwater now contributes over 40% to crop water needs, with around one million private sector tube wells and approximately 50% operational public sector tube wells [1].

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Water scarcity, particularly in arid and semi-arid regions like Pakistan, is a pressing issue exacerbated by climate change and prolonged droughts. In 2003, surface water resources were drastically reduced by about 70%, emphasizing the need for alternative water sources [3]. While canal water alone is insufficient, the reliance on groundwater for irrigation becomes imperative. Tube wells offer controlled and timely irrigation, addressing the challenges posed by erratic rainfall.

The quality of irrigation water is pivotal in influencing soil physical and chemical characteristics and, consequently, fertility. Poor-quality water can introduce objectionable elements, impacting soil health and crop yield [4]. Notably, a significant percentage of tubewells in the Indus Basin pump sodic water, affecting soil health and agricultural productivity [5].

As the focus shifts towards sustainable crop production without degrading soils, the quality of groundwater takes center stage. Key parameters such as electrical conductivity (EC), sodium adsorption ratio (SAR), and residual sodium carbonate (RSC) become crucial considerations [6]. Understanding the impact of water quality on soil conservation and environmental quality is vital to mitigate the decline in soil quality witnessed globally.

Researchers have explored various aspects of groundwater quality, including the presence of specific ions, heavy metals, and potential contaminants. Studies highlight the significance of monitoring water quality for safe domestic, agricultural, and industrial use. From boron concentration assessments to the evaluation of groundwater suitability for irrigation, these investigations contribute valuable insights into the complex dynamics of water resources and their impact on soil and crop health.

2. Material and methods

Study Area: The study was conducted at UC Tando Qaiser, located in Taluka Hyderabad (Rural), District Hyderabad, Sindh province, Pakistan. The geographical coordinates of the study area are Latitude 25°23'0"N and Longitude 68°31'0"E.

Laboratory Analysis: All soil and groundwater tests were conducted at the Laboratory of Soil Fertility (S.F) at the Agriculture Research Institute, Tandojam.

2.1. Tube Well Water Sampling and Procedure

- Site Selection: Tube wells existing in the study area were identified for water sampling.
- Sample Collection: Water samples were collected from each tube well site. Representative samples were obtained by allowing the tube wells to flow for a minimum of ten minutes.
- Sample Containers: Collected tube well water samples were stored in properly washed 1.5-liter polyethylene containers.
- Laboratory Analysis: Samples were sent to the Laboratory of Soil Fertility (S.F) at Agriculture Research Institute, Tandojam, for analysis. The following parameters were determined: Electrical Conductivity (EC, dS m^{-1}), pH, cations (Na^+, Ca2+, Mg^{2+}), anions (CO_3^{2-}, HCO_3^-, SO_4^{2-}, Cl^-), Sodium Adsorption Ratio (SAR), and Residual Sodium Carbonate (RSC).

2.2. Soil Sampling and Procedure

- Sampling Sites: Soil samples were collected from areas irrigated by tube well water in UC Tando Qaiser, district Hyderabad.
- Sampling Depths: Soil samples were collected in triplicate at depths of 0-20, 20-40, and 40-60 cm using an auger.
- Sample Collection: Collected soil samples were carefully labeled and placed in polythene bags.
- Transport: Soil samples were transported to the Laboratory of Soil Fertility (S.F) at Agriculture Research Institute, Tandojam.
- Preparation: Air-dried soil samples were crushed and passed through a 2mm sieve.

Laboratory Analysis: The soil samples were analyzed for physico-chemical properties, including soil texture, Electrical Conductivity (EC, dS m^{-1}), pH, cations (Na^+, Ca^{2+}, Mg^{2+}), anions (CO_3^{2-}, HCO_3^-, Cl^-, SO_4^{2-}), Sodium Adsorption Ratio (SAR), and Exchangeable Sodium Percentage (ESP).

3. Results

3.1. Soil analysis

3.1.1. Physio-chemical soil properties

The physio-chemical analysis of soil samples collected from various villages is summarized in Table 1. Samples were systematically obtained at depths of 0-20 cm, 20-40 cm, and 40-60 cm, providing a comprehensive overview of soil composition. Maximum sand content was recorded at 0-20 cm (25.50%), 20-40 cm (22.40%), and 40-60 cm (28.80%), while minimum sand content was noted at 0-20 cm (12.20%), 20-40 cm (10.50%), and 40-60 cm (8.80%). Similarly, maximum silt content was observed at 0-20 cm (42.5%), 20-40 cm (48.6%), and 40-60 cm (41.5%), with minimum silt content noted at 0-20 cm (10.3%), 20-40 cm (7.5%), and 40-60 cm (13.3%). In terms of clay content, the highest values were at 0-20 cm (77.50%), 20-40 cm (78.50%), and 40-60 cm (73.90%), while the lowest values were at 0-20 cm (30.9%), 20-40 cm (40.9%), and 40-60 cm (38.9%). Averaging percentages from the same soil depths revealed trends of 17.3%, 15.11%, and 16.4% for sand, 33.5%, 25.87%, and 29.1% for silt, and 49.2%, 59.02%, and 54.5% for clay. These findings underscore a prevalent clay soil profile across the surveyed areas, with subtle variations in soil texture at different depths.

Table 1 Physio-chemical soil properties sites.

Name of Villages	Sand %	Silt %	Clay %
Tando Qaiser	14.93	33.00	52.07
Rawal Pahor	21.60	35.97	42.43
Hussain Khan Thoro	16.90	24.37	58.73
Nangar Wassan	15.07	25.40	59.53
Murad Shah	12.43	26.07	61.50
Hayat Dhamach	21.97	17.57	60.47
Shahnawaz Junejo	15.67	33.13	51.20
Misre Khan Solangi	10.93	21.23	67.83
Bhendo Sharif	18.53	18.67	62.80
Jhando Khoso	17.93	37.60	44.60
Mori Mangar	12.80	26.50	60.70

3.1.2. Soil organic matters (SOM)

The soil organic matter (SOM) percentages are detailed in Table 2, presenting an insightful overview of the villages' organic content. The analysis considered samples obtained at varying depths of 0-20 cm, 20-40 cm, and 40-60 cm. Examining the SOM values, the maximum, minimum, and average SOM percentages at 0-20 cm were determined as 0.98%, 0.65%, and 0.82%, respectively. Similarly, at the depth of 20-40 cm, the maximum SOM was 0.85%, the minimum was 0.41%, and the average was 0.67%. Delving into the deepest layer of 40-60 cm, the maximum, minimum, and average SOM percentages were recorded as 0.80%, 0.45%, and 0.60%, respectively. Notably, village-wise variations were observed, with Shahnawaz Junejo showcasing the highest SOM percentage at 0-20 cm (0.98%), whereas Jhando Khoso exhibited the lowest SOM percentage at 20-40 cm (0.41%). These findings underscore the spatial heterogeneity of organic matter distribution across different depths and villages.

Table 2 Soil organic matter (SOM) % at different depths irrigated by tube well water of UC Tando Qaiser

Location of tubewell/villages	**Soil Organic Matters (SOM) %**		
	Soil Sampling Depths		
	0-20 cm	**20-40 cm**	**40-60 cm**
Tando Qaiser	0.92	0.85	0.72
Rawal Pahor	0.85	0.73	0.60
Hussain Khan Thoro	0.91	0.80	0.8
Nangar Wassan	0.80	0.45	0.45
Murad Shah	0.90	0.75	0.50
Hayat Dhamach	0.72	0.60	0.50
Shahnawaz Junejo	0.98	0.72	0.72
Misre Khan Solangi	0.71	0.70	0.62
Bhendo Sharif	0.65	0.60	0.55
Jhando Khoso	0.72	0.41	0.45
Mori Mangar	0.89	0.79	0.69
Maximum	0.98	0.85	0.80
Minimum	0.65	0.41	0.45
Average	0.82	0.67	0.60

3.1.3. Soil pH

Table 3 Soil pH at different depths irrigated by tube well water of UC Tando Qaiser

Location of tubewell/village	**pH**		
	Soil Sampling Depths		
	0-20 cm	**20-40 cm**	**40-60 cm**
Tando Qaiser	7.9	8	8.2
Rawal Pahor	7.8	7.9	8.1
Hussain Khan Thoro	7.9	7.9	8
Nangar Wassan	7.9	7.9	8
Murad Shah	7.8	7.7	8
Hayat Dhamach	7.8	8	8.2
Shahnawaz Junejo	7.9	8	8.2
Misre Khan Solangi	7.7	7.7	8
Bhendo Sharif	7.9	7.9	8
Jhando Khoso	8	8.1	8.2
Mori Mangar	7.4	7.7	7.8
Maximum	8	8.1	8.2
Minimum	7.4	7.7	7.8
Average	7.81	7.89	8.06

The pH values of the soil in the studied villages are detailed in Table 3, offering a comprehensive insight into the acidity or alkalinity levels. The analysis incorporated samples obtained at varying depths of 0-20 cm, 20-40 cm, and 40-60 cm. Evaluating the pH values, the maximum, minimum, and average pH at 0-20 cm were determined as 8.00, 7.4, and 7.8, respectively. Similarly, at the depth of 20-40 cm, the maximum pH was 8.1, the minimum was 7.7, and the average was 7.89. Exploring the deepest layer of 40-60 cm, the maximum, minimum, and average pH were recorded as 8.2, 7.8, and 8.06, respectively. Noteworthy variations were observed among villages, with Shahnawaz Junejo exhibiting the highest pH value at 8.20. In contrast, Mori Mangar presented the lowest pH among the sampled villages. These findings underscore the diversity in soil acidity levels across different depths and villages within the study area.

3.1.4. Soil EC dS m⁻¹

Table 4 presents the electrical conductivity (EC) values determined from soil samples in the selected villages. Samples were meticulously collected at depths of 0-20 cm, 20-40 cm, and 40-60 cm, reflecting variations in EC across different layers. Analyzing the data, the maximum, minimum, and average EC values at 0-20 cm were identified as 7.1, 4.6, and 5.58, respectively. Moving to the depth of 20-40 cm, the corresponding values were 6, 4.28, and 4.70. Delving into the deepest layer of 40-60 cm, the EC values ranged from a maximum of 4.97 to a minimum of 3.3, with an average of 4.13. Notably, the village of Tando Qasir exhibited the highest EC value at 7.1, recorded at the 0-20 cm depth. Conversely, Bhendo Sharif displayed the lowest EC value among the sampled villages, specifically at the 40-60 cm depth. These findings emphasize the variability in soil electrical conductivity across depths and villages within the study area.

Table 4 Soil EC dS m^{-1} at different depths irrigated by tube well water of UC Tando Qaiser

Location of tubewell/villages	**EC (dS m^{-1})**		
	Soil Sampling Depths		
	0-20 cm	**20-40 cm**	**40-60 cm**
Tando Qaiser	7.1	5.3	4.9
Rawal Pahor	6.21	6	4.82
Hussain Khan Thoro	5.9	4.5	4.22
Nangar Wassan	5.1	4.3	3.86
Murad Shah	4.6	4.28	3.78
Hayat Dhamach	5.88	5.31	4.97
Shahnawaz Junejo	4.72	4.5	4.16
Misre Khan Solangi	5.28	4.53	4.15
Bhendo Sharif	5.3	4.41	3.3
Jhando Khoso	6.16	4.28	3.78
Mori Mangar	5.15	4.3	3.49
Maximum	7.1	6	4.97
Minimum	4.6	4.28	3.3
Average	5.58	4.70	4.13

3.1.5. Soil Na^+ meq L^{-1}

The results showed that Na^+ meq L^{-1} determined from the selected villages were soil samples in Table 5. Analysed samples taken from at depths are 0-20, 20-40 and 40-60cm, maximum, minimum and average was analysed Na^+ meq L^{-1} affected soil from the depth of 0-20cm is 34.3, 19.96 and 24.75 respectively. Similarly maximum, minimum and average was analysis Na^+ meq L^{-1} affected soil from another depth of 20-40cm is 27.7, 16.65 and 20.32 respectively. Further the last depth 40-60 cm soil Na^+ meq L^{-1} maximum, minimum and average is analysed is 21.56, 12.95 and 17.35. Soil was collected maximum Na^+ meq L^{-1} analysed from village Tando Qasir is 34.3 at depth 0-20 cm was recorded. Similarly at depth 40-60 cm and the minimum Na^+ meq L^{-1} soil samples collected from village Behndo Sharif respectively.

Table 5 Soil Na^+ meq L^{-1} at different depths irrigated by tube well water of U.C Tando Qaiser

Location of tubewell/villages	**Soluble Na^+ (meq L^{-1})**		
	Soil Sampling Depths		
	0-20 cm	**20-40 cm**	**40-60 cm**
Tando Qaiser	34.3	24.96	21.56
Rawal Pahor	27.3	27.7	21.56
Hussain Khan Thoro	26.98	19.8	18.76
Nangar Wassan	22.82	21.45	16.46
Murad Shah	19.96	19.2	16.13
Hayat Dhamach	23.35	22.6	21.55
Shahnawaz Junejo	20.38	17.41	15.8
Misre Khan Solangi	22.56	16.65	16.7
Bhendo Sharif	22.4	16.96	12.95
Jhando Khoso	25.35	16.95	15.18
Mori Mangar	26.9	19.86	14.26
Maximum	34.3	27.7	21.56
Minimum	19.96	16.65	12.95
Average	24.75	20.32	17.35

3.1.6. Soil Ca^{2+} meq L^{-1}

Table 6 Soil Ca^{2+} meq L^{-1} at different depths irrigated by tube well water of UC Tando Qaiser

Location of tubewell/villages	**Ca^{2+} (meq L^{-1})**		
	Soil Sampling Depths		
	0-20 cm	**20-40 cm**	**40-60 cm**
Tando Qaiser	20.24	19	18.5
Rawal Pahor	20.7	20.7	16.43
Hussain Khan Thoro	19.3	14.55	13.4
Nangar Wassan	16.87	17.76	12.34
Murad Shah	15.22	13.65	14.34
Hayat Dhamach	24.4	18.45	17.76
Shahnawaz Junejo	16.87	18.34	17.65
Misre Khan Solangi	17.89	17.68	15.44
Bhendo Sharif	19.56	17.8	12.45
Jhando Khoso	22.55	19.46	12.87
Mori Mangar	18.67	14.34	12.48
Maximum	24.4	20.7	18.5
Minimum	15.22	13.65	12.34
Average	19.29	17.43	14.87

The results showed that Ca^{2+} meq L^{-1} determined from the selected villages were soil samples in Table 6. Analysed samples taken from at depths are 0-20, 20-40 and 40-60cm, maximum, minimum and average was analysed Ca^{2+} meq L^{-1} affected soil from the depth of 0-20cm is 24.4, 15.22 and 19.297 respectively. Similarly maximum, minimum and average was analysis Ca^{2+} meq L^{-1} affected soil from another depth of 20-40cm is 20.07, 13.65 and 17.43 respectively. Further the last depth 40-60 cm soil Ca^{2+} meq L^{-1} maximum, minimum and average is analysed is 10.87, 0.88 and 3.05. Soil was collected maximum Ca^{2+} (20.4 meq $L^{-1)}$ from village Hayat Dahmach at depth 0-20 cm was recorded. Similarly at depth 40-60 cm the minimum Ca^{2+} (12.34 meq L^{-1}) soil samples collected from village Nangar Wassan was recorded.

3.1.7. Soil Mg^{2+} meq L^{-1}

The results showed that Mg^{2+} meq L^{-1} determined from the selected villages were soil samples in Table 7. Analysed samples taken from at depths are 0-20, 20-40 and 40-60cm, maximum, minimum and average was analysed Mg^{2+} meq L^{-1} affected soil from the depth of 0-20cm is 17, 10.32 and 12.83 respectively. Similarly maximum, minimum and average was analysis Mg^{2+} meq L^{-1} affected soil from another depth of 20-40 cm is 12.78, 8.66 and 10.36 respectively. Further the last depth 40-60cm soil Mg^{2+} meq L^{-1} maximum, minimum and average is analysed is 10.65, 8.45 and 9.769. Soil was collected maximum Mg^{2+} (17 meq L^{-1}) analysed from village Tando Qasir at depth 0-20 cm was recorded. Similarly, minimum Mg^{2+} (8.45 meq L^{-1}) soil samples collected from village Mori Mangar at depth of 20- 40 cm respectively.

Table 7 Soil Mg^{2+} meq L^{-1} at different depths irrigated by tube well water U.C of Tando Qaiser.

Location of tubewell/villages	**Mg^{2+} (meq L^{-1})**		
	Soil Sampling Depths		
	0-20 cm	**20-40 cm**	**40-60 cm**
Tando Qaiser	17	9.34	9.4
Rawal Pahor	14.6	12.26	10.6
Hussain Khan Thoro	13	9.78	10.45
Nangar Wassan	12.56	8.66	10.43
Murad Shah	11.32	9.56	10.12
Hayat Dhamach	11.56	12.78	10.65
Shahnawaz Junejo	10.32	9.65	8.78
Misre Khan Solangi	13.67	10.89	9.68
Bhendo Sharif	11.89	10	8.68
Jhando Khoso	14.78	11.68	10.22
Mori Mangar	10.45	9.34	8.45
Maximum	17	12.78	10.65
Minimum	10.32	8.66	8.45
Average	12.83	10.36	9.77

3.1.8. Soil K^{+} meq L^{-1}

The results showed that K^{+} meq L^{-1} determined from the selected villages were soil samples in Table 8. Analysed samples taken from at depths are 0-20, 20-40 and 40-60cm, maximum, minimum and average was analysed K^{+} meq L^{-1} affected soil from the depth of 0-20cm is 18.65, 12.1 and 14.797 respectively. Similarly maximum, minimum and average was analysis K^{+} meq L^{-1} effected soil from another depth of 20-40cm is 17.45, 11 and 14.701 respectively. Further the last depth 40-60cm soil K^{+} meq L^{-1} maximum, minimum and average is analysed is 15.45, 10.45 and 13.407. Soil was collected maximum K^{+} (18.65 meq L^{-1}) analysed from village Bhendo Sharif at depth 0-20 cm was recorded. Similarly, minimum K^{+} (10.45 meq L^{-1}) soil sample collected from village Mori Mangar at depth 40-60 cm respectively.

Table 8 Soil K^+ meq L^{-1} at different depths irrigated by tube well water UC of Tando Qaiser

Location of tubewell/villages	**K^+ (meq L^{-1})**		
	Soil Sampling Depths		
	0-20 cm	**20-40 cm**	**40-60 cm**
Tando Qaiser	17.2	15.4	13.16
Rawal Pahor	12.1	11	15.3
Hussain Khan Thoro	14.18	16	13.8
Nangar Wassan	13	17.2	15.16
Murad Shah	16	13.8	12.1
Hayat Dhamach	12.8	16.2	13.76
Shahnawaz Junejo	12.6	11.82	12.4
Misre Khan Solangi	14.9	13.76	12.56
Bhendo Sharif	18.65	17.45	13.34
Jhando Khoso	17.78	16.48	15.45
Mori Mangar	13.56	12.6	10.45
Maximum	18.65	17.45	15.45
Minimum	12.1	11	10.45
Average	14.797	14.701	13.407

3.2. Groundwater irrigation water analysis

Table 9 Analysed pH and EC water samples from selected village's tube well water of U.C Tando Qaiser.

Name of water samples villages locate tubewell	**pH**	**EC (dS m^{-1})**
Tando Qaiser	8.1	4.62
Rawal Pahor	8	3.6
Hussain Khan Thoro	8	3.8
Nangar Wassan	8.1	1.02
Murad Shah	8.1	1.12
Hayat Dhamach	7.9	1.62
Shahnawaz Junejo	8	2.48
Misre Khan Solangi	7.8	1.62
Bhendo Sharif	7.7	1.6
Jhando Khoso	7.8	1.66
Mori Mangar	7.6	0.7
Maximum	8.1	4.6
Minimum	7.6	0.7
Mean	7.92	2.17

The results showed that pH and EC determined from the selected villages were water samples in Table 9. Analysed samples taken from the selected villages located tube wells, maximum, was analysed pH and EC (dSm^{-1}) water effected on soil recorded the range of pH is 8.1 and EC is 4.62, respectively. Similarly the minimum was analysed pH and EC water effected on soil recorded the range of pH is 7.6 and EC is 0.7 respectively. Further the average was analysed pH and EC (dSm^{-1}) water effected on soil recorded the range of pH is 7.92 and EC is 38.8 respectively. Water samples were collected maximum pH from the village Tando Qaisar, Nagar Wasan, Murad Shah is 8.1 and EC from village Tando Qaisar is 4.62 was recorded. Similarly the minimum pH and EC of water samples collected from village Mori Magar respectively.

The results showed that cations (Ca^{2+}, Mg^{2+}, Na^{+} and K^{+}) determined from the selected villages were water samples in Table 10. Analysed samples taken from the selected villages located tube wells, maximum, was analysed Ca^{2+}, Mg^{2+}, Na^{+} and K^{+} meq L^{-1} water effected on soil recorded the range of is 25.3, 6.5, 43.6 and 4.20 respectively. Similarly the minimum was analysed Ca^{2+}, Mg^{2+}, Na^{+} and K^{+} meq L^{-1} water effected on soil recorded the range is 38, 3.8, 38.8 and 1.1 respectively. Further the average was analysed Ca^{2+}, Mg^{2+}, Na^{+} and K^{+} meq L^{-1} water effected on soil recorded range are 21, 5.15, 41.2 and 2.65 respectively. The maximum Ca^{2+} meq L^{-1} of collected water Sample analysed 25.3 from village Tando Qaiser. The maximum Mg^{2+} (6.5 meq L^{-1}) and Na^{+} (43.6 meq L^{-1}) was found in village Tando Qaiser. The maximum K^{+} meq $L^{-1}$was analysed 4.2 from village Mori Mangar. Similarly the minimum Ca^{2+} (16.7 meq L^{-1}) and Na^{+} (38.8 meq L^{-1}) was analysed in the village Murad Shah. The minimum Mg^{2+} was found 3.8 meq L^{-1} in the village Nagar Wassan and the minimum K^{+} was analysed 1.1 meq L^{-1} in the village Tando Qaiser respectively.

Table 10 Analysed cations water samples from selected village's tube well water of U.C Tando Qaiser

Name of water samples villages locate tubewell	**Ca^{2+}**	**Mg^{2+}**	**Na^{+}**	**K^{+}**
	Meq L^{-1}			
Tando Qaiser	25.3	6.5	43.6	1.1
Rawal Pahor	23.2	4.4	40.5	1.3
Hussain Khan Thoro	21.1	4.1	42.1	2.1
Nangar Wassan	19.3	3.8	39.7	1.9
Murad Shah	16.7	5.1	38.8	2.5
Hayat Dhamach	22.5	5.3	42.3	2.7
Shahnawaz Junejo	19.6	5.2	40.25	2.9
Misre Khan Solangi	18.3	5.8	42.5	3.2
Bhendo Sharif	17.1	5.2	43.2	3.8
Jhando Khoso	23.7	6.1	42.2	2.7
Mori Mangar	18.1	5.7	41.2	4.2
Maximum	25.3	6.5	43.6	4.2
Minimum	16.7	3.8	38.8	1.1
Mean	21	5.15	41.2	2.65

The results showed that anions (Cl^{-}, CO_3^{2-}, HCO_3^{-} and SO_4^{2-} meq L^{-1}) determined from the selected villages were water samples in Table 18. Analysed samples taken from the selected villages located tube wells, maximum, was analysed Cl^{-}, CO_3^{2-}, HCO_3^{-} and SO_4^{2-} meq L^{-1} water effected on soil recorded the range of is 32.5, 0, 12.4 and 19.16 respectively. Similarly the minimum was analysed Cl^{-}, CO_3^{2-}, HCO_3^{-} and SO_4^{2-} meq L^{-1} water effected on soil recorded the range of is 20, 0, 9.6 and 14.7 respectively. Further the average was analysed Cl^{-}, CO_3^{2-}, HCO_3^{-} and SO_4^{2-} meq L^{-1} water effected on soil recorded the range of is 31.05, 0, 11 and 16.93 respectively. The maximum Cl^{-} (32.5 meq L^{-1}) was analysed in the village Mori Magar. The maximum HCO_3^{-} meq $L^{-1}$and SO_4^{2-} meq L^{-1} of water samples were analysed 12.4 and 19.16 from village Tando Qaisar respectively. Similarly the minimum Cl^{-} meq L^{-1} was analysed 20 from village Misre Khan Solangi. The minimum similarly HCO_3^{-} meq $L^{-1}$and SO_4^{2-} meq L^{-1} of water samples was analysed 9.6 and 14.7in the village Jhando Khoso and Murad Shah respectively.

4. Discussion

The particle size distribution results revealed a predominant heavy texture in the soils of the study area, consistent with findings by Dahri [7] on Dharejo Farm soils. This heavy texture is likely influenced by the characteristics of the parent material transported and deposited by the Indus River. The significance of texture in shaping the physico-chemical behavior of soils underscores its crucial role in soil productivity.

Analysis of organic matter content in soils irrigated by tube well water in UC Tando Qaiser indicated low organic matter levels, possibly due to the absence of farmyard manures or limited cultivation of green manure crops. Similar observations of low organic matter content in Sindh soils have been reported by researchers such as Junejo [8], Korai [9], and Keerio [10].

Soil pH analysis demonstrated that the majority of soils in the study area exhibited a medium to slightly alkaline reaction. Elevated pH levels are indicative of the calcareous nature of Sindh soils, characterized by high concentrations of Ca^{2+}, Mg^{2+}, and K^+. This finding aligns with previous research by Soomro [11] and Dahri [7], which reported slightly to moderately alkaline reactions in Sindh soils.

The soils in the studied area were identified as slightly-saline due to irrigation with tube well water. This observation is consistent with Chachar's [12] findings regarding the saline nature of Taluka Pano Akil soils. Soil salinity is a critical factor influencing crop growth and productivity.

Analytical results of tube well water samples provided insights into the presence of anions and cations responsible for salinity, hardness, and high conductivity. pH values within the range of 7.5-8.5 indicate suitability for various uses. However, variations in electrical conductivity (EC) suggest that water samples from village Tando Qaisar may be hazardous, while others exhibit marginal quality for irrigation, according to WAPDA [13] standards. Elevated levels of Ca^{2+} and Mg^{2+} in most villages indicate potential hazards, and soluble Na^{2+} and K^+ exceed permissible limits in several locations.

5. Conclusion

In conclusion, the study provides valuable insights into the physico-chemical characteristics of soils in UC Tando Qaiser, District Hyderabad, Sindh, Pakistan. The heavy texture of the soils, attributed to the nature of parent material deposited by the Indus River, plays a crucial role in influencing soil behavior. Low organic matter content in the soils highlights the need for measures to enhance soil fertility, such as incorporating farmyard manure or cultivating green manure crops. The slightly alkaline nature of the soils, characteristic of calcareous soils in the region, underscores the importance of understanding local soil reactions. The identification of slightly-saline soils emphasizes the challenges associated with irrigation using tube well water, necessitating careful soil salinity management for sustainable agriculture. Analysis of tube well water quality indicates variations in electrical conductivity and highlights potential hazards, particularly in the water samples from village Tando Qaisar.

Recommendations

Recommendations include implementing strategies for organic matter enhancement, adopting soil salinity mitigation measures, and maintaining regular monitoring of tube well water quality to ensure safe and sustainable agricultural practices in the region.

Compliance with ethical standards

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Disclosure of conflict of interest

No conflict of interest to be disclosed.

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