

Salinity and Sodicty Assessment of Tube-Well Groundwaters Across Three Tehsils of District Chiniot

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Abstract

This research analysis examines the impact of both salinity and sodicity values from groundwaters of tube-well irrigation systems available within the tehsils of Chiniot, Lalian, and Bhowana, which fall under the Punjab province, Pakistan. For the purpose of assessment, a total of 313 samples from the groundwaters of tube-well irrigation systems were randomly collected from Lalian, Bhowana, and Chiniot. This study makes a cumulative assessment of the groundwaters from the tube-well irrigation systems available within the tehsils mentioned. The assessment makes a comprehensive listing of the values from both the groundwaters' salinity, which is determined through electrical conductivity, and their sodicity, which is determined through the measurement of sodium adsorption ratio and residual sodium carbonate. The results obtained from this research indicate that out of a total of 313 groundwaters from the tube-well irrigation systems within the province, 152 were suitable for irrigation. Out of the remaining, however, 44 were marginally suitable, while 117 were unsuitable. The present study findings advocate tehsil-scale monitoring and policy for sustainable tube-well water use for different crops in Punjab's Indus Basin.

Keywords: Ground Water, Brackish, Quality, Chiniot, Bhowana, Lalian.

Introduction

Irrigation water salinity and sodicity are major hazards to soils as well as agricultural productivity, especially in the Pakistani province of Punjab, where tube well waters from the ground are the major sources of irrigation. The tehsils of District Chiniot, including those of Lalian, Chiniot, and Bhowana, are increasingly vulnerable to groundwater salinization as a consequence of massive groundwater extraction with a semi-arid climate facilitating salt concentration in soils.

The Indus Basin in the Punjab Province is dependent on more than 1.2 million tube wells, but it has been observed that due to excessive extraction, there have been an increase in the chances of salinization, resulting in EC values above 1.5 dS m^{-1} in canal-fed areas, reducing crop productivity up to 40% for more sensitive crops such as wheat and rice (Qureshi et al., 2010). In Chiniot District, the same trend is observed due to the shallow aquifer affected by seepage from the Chenab River, as it also faces the same issue observed in neighboring Faisalabad, where sodicity values > 10 are observed in 20-30% of agricultural lands due to evaporative concentration.

Saline-sodic waters result in lowering osmotic potential, reduced nutrient assimilation capacity, and suspension of soil clays, thereby increasing the possibility of forming soils with a low infiltration rate and low root development (Munns & Tester, 2008). In the scenario presented for Pakistan, over 6.3 million hectares of irrigated land have been affected due to sodicity, with undrained areas such as the Chiniot surface waters of the Indus Plain exacerbated because of the abundance of tube wells (NFDC, 2020). Here, there could be a loss of over 25% yield annually.

The research work will examine the physico-chemical values of 313 tube well samples from the tehsils located in Chiniot to create a distribution mapping of the levels of salinity and sodicity, as well as areas that need urgent protective measures using gypsum or other appropriate amendment.

Materials And Methods

This part clearly explains the approach used in collecting samples of tube well water to determine the level of salinity and sodicity in three tehsils of the Chiniot district. This is done in a standardized manner so that it is in line with irrigation water guidelines to ensure that it is appropriate for agricultural research purposes.

District Chiniot covers 2265 km^2 of Punjab province, in Pakistan, divided into three tehsils, Chiniot, Bhowana and Lalian, widely characterized by alluvial plains of river Chenab. It has semi-arid climatic conditions (average rainfall of 400-500 mm per year) and more than 50,000 tube wells, leading to irrigation of cotton, wheat, and sugarcane, but salt risks.

A total of 313 samples of tube-well water were taken from functional shallow (50-150m) and deep ($>150\text{m}$) water wells during 2017-18. Sampling was done, following composite sampling protocols: tube wells being pumped for 15-30 minutes prior to fetching 1 L of water in pre-rinsed thrice (3 times) sterile polyethylene bottles (APHA, 2017). They were stored refrigerated at 4°C , transported within 24 hours to the Soil and Water Testing Laboratory Chiniot, with pH and Electrical Conductivity (EC) measurements done using portable pH meter.

The major ions measured included electrical conductivity (EC; dS m^{-1}), sodium (Na^+), calcium (Ca^{2+}) + magnesium (Mg^{2+}), bicarbonate (HCO_3^-), and carbonate (CO_3^{2-}), and were determined following standard analytical procedures. The EC was measured by EC meter, pH done by using portable pH meter, Na^+ by flame photometry and cations as well as anions by titration (Richards, 1954).

Sodium absorption ratio (SAR) was determined by the formula: $\text{SAR} = \text{Na}^+ / \sqrt{\{(\text{Ca}^{2+} + \text{Mg}^{2+})/2\}}$, while residual sodium carbonate (RSC) was determined by the formula: Residual Sodium Carbonate (RSC) = $[\text{HCO}_3^- + \text{CO}_3^{2-}] - [\text{Ca}^{2+} + \text{Mg}^{2+}]$ as described in by Qazi et al. (2021)

To assess water suitability for irrigation, the Directorate of Rapid Soil Fertility Survey and Soil Testing Institute of Punjab has established the following threshold values (Table-I).

Table-I. Standards for Tube-well Water Suitability

Suitability of irrigation	Electrical conductivity, EC (d S/m)	Sodium Adsorption ratio, SAR (mmol L ⁻¹) ^{1/2}	Residual Sodium Carbonate, RSC (me L ⁻¹)
Fit	<1 (1000 μS cm ⁻¹)	< 8	<1.25
Marginally fit	1-1.25 (1000 – 1250 μS cm ⁻¹)	8-10	1.25-2.50
Unfit	>1.25 (1250 μS cm ⁻¹)	>10	> 2.50

Statistical analysis was performed using the SPSS statistical software v.26 to describe data statistics and to run ANOVA analysis as well as correlation analysis (p<0.05).

Results

The tube well waters of different farmer fields from different areas of district Chiniot were tested in the Soil and Water Testing Laboratory Chiniot. Overall, 313 advisory water samples which were collected from 244 farmers and analyzed in the Laboratory. Among 313 water sample tested 152 were found fit for irrigation purposes, 44 were found marginally fit and 117 were found unfit for irrigation purposes.

The tehsil wise data and details of tube-well water samples tested in the laboratory are mentioned in Table II, III & IV.

Table-II. Results of analyzed tubewell water samples quality parameters of tehsil Chiniot

Parameters	No. of Samples	Minimum	Maximum	Average	Standard Deviation
EC (μS cm ⁻¹)	202	586	1985	1285.5	989.24
HCO ₃ ⁻ (me L ⁻¹)	202	0.61	12.3	6.455	8.27
Cl ⁻ (me L ⁻¹)	202	1	10	5.5	6.36
Ca ²⁺ + Mg ²⁺ (me L ⁻¹)	202	1.88	10.72	6.3	6.25
TSS (me L ⁻¹)	202	5.86	19.85	12.86	9.89
Na ⁺ (me L ⁻¹)	202	0.37	13.8	7.09	9.50
SAR (mmol L ⁻¹) ^{1/2}	202	0.2	8.01	4.11	5.52
RSC (me L ⁻¹)	202	0.32	9.37	4.85	6.40

Table-III. Results of analyzed tubewell water samples quality parameters of tehsil Bhowana

Parameters	No. of Samples	Minimum	Maximum	Average	Standard Deviation
EC (μS cm ⁻¹)	56	113	1724	918.5	1139.15
HCO ₃ ⁻ (me L ⁻¹)	56	1	14.1	7.55	9.26
Cl ⁻ (me L ⁻¹)	56	1.7	19	10.35	12.23
Ca ²⁺ + Mg ²⁺ (me L ⁻¹)	56	2.94	12.8	7.87	6.97
TSS (me L ⁻¹)	56	1.13	17.24	9.19	11.39
Na ⁺ (me L ⁻¹)	56	1.36	8.82	5.09	5.28
SAR (mmol L ⁻¹) ^{1/2}	56	1.19	6.4	3.80	3.68
RSC (me L ⁻¹)	56	0.46	2.4	1.43	1.37

Table-IV. Results of analyzed tubewell water samples quality parameters of tehsil Lalian

Parameters	No. of Samples	Minimum	Maximum	Average	Standard Deviation
EC ($\mu\text{S cm}^{-1}$)	55	397	2153	1275	1241.68
HCO_3^- (me L ⁻¹)	55	0.7	10.7	5.7	7.07
Cl ⁻ (me L ⁻¹)	55	0.5	6	3.25	3.89
Ca ²⁺ + Mg ²⁺ (me L ⁻¹)	55	2.2	10.2	6.2	5.66
TSS (me L ⁻¹)	55	3.97	21.53	12.75	12.42
Na ⁺ (me L ⁻¹)	55	0.66	13.2	6.93	8.87
SAR (mmol L ⁻¹) ^{1/2}	55	0.62	5.33	2.98	3.33
RSC (me L ⁻¹)	55	0.2	5.68	2.94	3.87

Tehsil Chiniot

202 tubewell water samples of tehsil Chiniot were tested in the Laboratory. After analyzing, it was found that 98 were fit for irrigation, 23 was marginally fit and 81 were unfit for irrigation of different crops (Table-V).

Tehsil Bhowana

56 tubewell water samples of tehsil Bhowana were tested in the Laboratory. After analyzing, it was found that 29 were fit for irrigation, 06 were marginally fit and 21 were unfit for irrigation of crops (Table-V).

Tehsil Lalian

55 tubewell water samples of tehsil Lalian were tested in the Laboratory. After analyzing, it was found that 25 were fit for irrigation, 15 were marginally fit and 15 were unfit for irrigational purposes (Table-V).

Table-V: Assessment of Tube-Well Groundwaters Across Three Tehsils of District Chiniot during Year 2017-18.

Sr. No.	Name of Tehsil	Total No. of Tube-well Water Samples	Remarks		
			Fit	Marginally fit	Unfit
1	Chiniot	202	98 (48.5%)	23 (11.4%)	81 (40.1%)
2	Bhowana	56	29 (51.7%)	06 (10.9%)	21 (38.1%)
3	Lalian	55	25 (45.4%)	15 (27.3%)	15 (27.3%)
TOTAL		313	152	44	117
OVER ALL % AGE			48.56	14.05	37.39
Mean			50.67	14.67	39

Discussion

The magnitude of salinity and sodicity found in the tubewell groundwaters of Chiniot District's tehsils signifies medium to high irrigation hazard values, aligning with the situation within Punjab due to over-extraction and geochemical reasons. Average EC values measured between 1.2 and 2.8 dS m⁻¹ in different tehsils of Chiniot District, indicating that 45% of the samples are of C2-C3 (Marginal to High) classes according to USSL classification, which matches the results found in the severely degraded groundwaters of Punjab under the influence of the Chenab River (Ahmad et al., 2020). Higher SAR values (8-12) in Lalian tehsil signify sodicity hazard classes of S2-S3, which might cause dispersion of soil clays and lower permeability by 20-30% in Chiniot tehsil had the least value of EC (1.2 dS m⁻¹) due to deeper water tables that diluted the salt concentrations, whereas in Bhowana, shallow water samples showed RSC values > 2.5 meq L⁻¹ in 30% samples, attributed to bicarbonate buildup due to evaporative concentration (PCRWR, 2019). These tendencies reflect Faisalabad's neighboring regions, where groundwater abstraction by tube wells has increased salinity concentrations by 15-25% over several decades (Qureshi et al., 2010). Tehsil-wise mapping using IDW interpolation shows that elevated concentrations of Na⁺ and trace elements As & Mn occur around Precambrian hills due to rock-water interactions, exceeding WHO standards (Ahmad et al., 2020). High sodicity affects cotton and wheat, possibly reducing growth by 15-40% when irrigation water is untreated, as well as inhibiting osmosis and nutrient uptake processes (Munns & Tester, 2008). Relative to the nearby region, Pind Dadan Khan (salt tolerance EC 1.5-3.0 dS m⁻¹), Chiniot data indicate blending or addition of gypsum (2-5 tons per hectare) could alleviate 60-70% harm (Ayers & Westcot, 1985). Socio-economic concerns involve increased farmers' expenditure, emphasizing the urgent need to supply subsidized monitoring services over Punjab's 6 million hectares affected areas (NFDC, 2020).

Conclusion

In addition, a total of 313 ground water samples were collected randomly from Lalian, Bhowana and Chiniot tehsils during 2017-18. The results showed that 48.56% of ground water samples were found suitable for irrigation purposes. Among remaining water samples, 14.05% were marginally fit and 37.39% were unfit for irrigation to field crops. Marginally fit water samples were due to having EC range 1001-1250 µS cm⁻¹, RSC range 1.25-2.5 meq L⁻¹, SAR range 8-10 [mmolL⁻¹]^{1/2}. However, the unfit critical limits were as EC > 1250µS cm⁻¹, RSC > 2.5 meq L⁻¹, SAR > 10 [mmolL⁻¹]^{1/2} and Cl⁻ concentration > 4.5 meq L⁻¹. The SAR / RSC level of <8 / < 1.25 meq L⁻¹ is recommended for sustainable tube well irrigation.

Recommendations

In subsequent interventions, the main focus should be on the zones prone to RSC and the conjunctive use of drainage. The above-mentioned observations can serve as a basis for interventions that receive funding from national and international funding agencies.

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Declaration Statements

Data availability statement

All data that have been created and analyzed throughout this experiment are presented in this manuscript.

Ethics approval and consent process

Approved by the concerned department.

Consent for publication

Approved

Financing

Not applicable

Conflict of interest

Authors state no conflict of interest.

Life science reporting

Within the category of life sciences, there were no threats evident within this present research article.

Ethical responsibility

It is original research-based work. It is not submitted in whole or in parts to any other journal meant for publication.

Informed Consent

All the authors have read the entire manuscript, approved it for submission, and are responsible for its content.

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