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Original article

Assessment of Irrigation Water Quality in Al-Ajeilat, Libya: Physicochemical Properties, Bacteriological Safety, and Predictive Modeling

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Abstract
In arid regions like Al-Ajeilat, Libya, where groundwater is the primary source for irrigation, assessing water quality is essential for agricultural sustainability and public health. This study aimed to evaluate the physicochemical and bacteriological quality of irrigation water from various sources in Al-Ajeilat and to establish a local predictive model between electrical conductivity (EC) and total dissolved solids (TDS). A total of 20 water samples were collected from domestic wells, farm wells, schools, commercial desalination plants, desalination stations, and mosque desalination units. Samples were analyzed for TDS, pH, EC, temperature, dissolved oxygen (DO), and the presence of *Escherichia coli* using standard methods. Linear regression analysis was performed to model the EC-TDS relationship. TDS ranged from 29 to 845 mg/L, EC from 26.7 to 4780 µS/cm, pH from 6.42 to 7.60, DO from 4.8 to 10.0 mg/L, and temperature from 6.7 to 22.0°C. Farm wells exhibited the highest mean EC (4232 µS/cm), indicating moderate to high salinity hazard for sensitive crops. Desalinated water sources showed very low salinity, making them highly suitable for irrigation. All 20 samples tested negative for *E. coli*, confirming no detectable fecal contamination. Linear regression demonstrated a strong positive relationship between EC and TDS ($R^2 = 0.991$, $P < 0.0001$), yielding the predictive equation: $TDS = 0.157 \times EC + 29.12$. The derived EC-TDS regression equation provides a rapid, cost-effective tool for salinity assessment in Al-Ajeilat. Desalinated water is recommended for irrigating sensitive crops, while farm wells require salinity management strategies. Regular bacteriological monitoring should be maintained to ensure water safety.
Keywords: Irrigation Water Quality, Al-Ajeilat, Libya, *E. Coli* Detection, Arid Region Agriculture.

Introduction

Water is an essential resource for agricultural production, and its quality directly influences soil health, crop productivity, and food safety (1). In arid and semi-arid regions, where rainfall is scarce and groundwater constitutes the primary source for irrigation, assessing water quality becomes particularly critical for sustainable agricultural development (2). The city of Al-Ajeilat, located in northwestern Libya, experiences typical Mediterranean arid conditions characterized by low annual precipitation, high evaporation rates, and increasing pressure on groundwater resources due to agricultural expansion and domestic water demand (3).

Irrigation water quality is typically evaluated through a combination of physical, chemical, and bacteriological parameters (4). Among these, total dissolved solids (TDS) and electrical conductivity (EC) are fundamental indicators of salinity hazard. TDS represents the total concentration of dissolved inorganic salts in water, while EC measures the water's ability to conduct electricity, which is directly proportional to ion concentration (5). Although TDS determination by gravimetric methods is accurate, it is time-consuming and requires specialized laboratory equipment. In contrast, EC measurement is rapid, inexpensive, and can be performed in situ using portable meters, making it a practical alternative for routine water quality monitoring (6). Establishing a reliable local regression equation between EC and TDS enables accurate TDS prediction from EC measurements, facilitating more efficient water quality assessment programs (7).

Beyond salinity concerns, the bacteriological quality of irrigation water is equally important for public health. Contaminated irrigation water can serve as a vehicle for pathogenic microorganisms, including *Escherichia coli*, which may be transferred to crops and subsequently to consumers (8). E. coli is a reliable indicator of fecal contamination and potential presence of enteric pathogens (9). Therefore, routine bacteriological testing of irrigation water sources is essential to prevent foodborne disease outbreaks associated with fresh produce consumption (10). This study aimed to analyze the physical, chemical, and bacteriological properties of irrigation water samples from various sources (home wells, farm wells, schools, commercial desalination plants, desalination stations, and mosque desalination units) in Al-Ajeilat, Libya.

Methods

Sample Collection and Handling

A total of 20 water samples were aseptically collected from the predefined sources in Al-Ajeelat. Sampling was carried out using sterile, high-density polyethylene (HDPE) bottles of 1 L capacity. Prior to filling, each bottle was rinsed three times with the water to be sampled to minimize any potential contamination from

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container surfaces. Following collection, each bottle was immediately sealed with an airtight cap, labeled with a unique alphanumeric code, and documented with the source type, date, and time of collection.

To preserve the physicochemical integrity of the samples, all collected bottles were placed in insulated coolers containing ice packs (maintained at approximately 4°C) and transported to the laboratory within a maximum holding time of 4 hours. On-site measurements of water temperature were performed using a calibrated mercury-in-glass thermometer (±0.1°C accuracy) at the time of sampling.

For groundwater samples (domestic and farm wells), the pump was operated continuously for 15 minutes prior to sample collection. This purging procedure was implemented to remove stagnant water from the well casing and distribution pipes, thereby ensuring that the collected specimen accurately represented the ambient groundwater composition. For desalinated water samples (commercial, mosque, and plant sources), no preliminary system operation was performed; samples were collected directly from the point of use, as these systems continuously produce and dispense treated water.

Physicochemical Analysis

All physicochemical parameters were measured in triplicate for each water sample, and the arithmetic mean was reported. Analytical instruments were calibrated using certified reference standards before each measurement session, and all measurements were conducted at room temperature (25°C ± 2°C) unless otherwise specified.

pH

The pH of each water sample was determined using a benchtop pH meter (accuracy ±0.01 pH units) equipped with a combination glass electrode. The instrument was calibrated using three standard buffer solutions (pH 4.0, 7.0, and 10.0) prior to each series of measurements. The electrode was rinsed with distilled water between consecutive samples to prevent cross-contamination.

Electrical Conductivity (EC)

Electrical conductivity was measured using a digital conductivity meter with automatic temperature compensation (ATC). The instrument was calibrated using a 0.01 M potassium chloride (KCl) standard solution (1413 µS/cm at 25°C). EC values were recorded in microsiemens per centimeter (µS/cm) and normalized to a reference temperature of 25°C.

Total Dissolved Solids (TDS)

Total dissolved solids concentrations were determined using a portable TDS meter calibrated against a sodium chloride (NaCl) standard solution (e.g., 442 µS/cm corresponding to 300 mg/L TDS). Results were expressed in milligrams per liter (mg/L), representing the mass of dissolved inorganic and organic solutes per unit volume of water.

Dissolved Oxygen (DO)

Dissolved oxygen concentrations were measured using an electrochemical DO meter equipped with a polarographic probe. To prevent oxygen degassing or atmospheric contamination, measurements were performed immediately after sample collection. The instrument was calibrated in air-saturated water according to the manufacturer's specifications. DO values were reported in milligrams per liter (mg/L).

Temperature

Water temperature was recorded on-site at each sampling location using a mercury-in-glass thermometer. The thermometer was fully immersed in the water stream or container for a minimum of 2 minutes until a stable reading was achieved. Measurements were taken in the shade to avoid solar radiation interference.

Microbiological Analysis

The microbiological quality of the irrigation water samples was assessed by detecting the presence of *Escherichia coli* (*E. coli*), a widely recognized indicator of fecal contamination. All microbiological procedures were performed under aseptic conditions within a laminar flow hood to eliminate exogenous contamination.

Culture-Based Detection

A standard membrane filtration technique, as recommended by the International Organization for Standardization (ISO 9308-1), was employed. In brief, an aliquot of each water sample (100 mL) was filtered through a sterile cellulose nitrate membrane filter with a nominal pore size of 0.45 µm. The filter was then aseptically transferred onto a selective chromogenic agar medium (e.g., Chromocult® Coliform Agar) containing chromogenic substrates specific for β-glucuronidase, an enzyme uniquely produced by *E. coli.*

The inoculated plates were incubated aerobically at 44.5°C ± 0.2°C for 24 ± 2 hours. This elevated temperature selectively suppresses the growth of non-fecal coliforms. Following incubation, plates were examined for the presence of typical *E. coli* colonies, which appear as dark blue to violet due to the cleavage

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of the chromogenic substrate. Suspected colonies were confirmed using the indole test (Kovac's reagent) as an additional biochemical confirmation. The results were recorded as either "positive" (presence of *E. coli*) or "negative" (absence of *E. coli*) per 100 mL of water sample.

Statistical Analysis

Data were entered into Microsoft Excel (version 2019) and analyzed using SPSS version 21. Descriptive statistics (mean, standard deviation, and range) were calculated for all parameters overall and by water source category. Linear regression analysis was performed to assess the relationship between EC and TDS.

Results

Physical and Chemical Parameters

A total of 20 water samples collected from domestic wells, farm wells, schools, and desalinated water sources (commercial, plant, and mosque) were analyzed for physical and chemical properties. Table 1 summarizes the range, mean, and standard deviation for each parameter.

Table 1. Summary of physical and chemical parameters of irrigation water samples (n = 20)

Parameter	Range	Mean ± SD
TDS (mg/L)	29 – 845	196.4 ± 180.5
pH	6.42 – 7.60	6.97 ± 0.30
EC (µS/cm)	26.7 – 4780	1594 ± 1675
Temperature (°C)	6.7 – 22.0	18.7 ± 3.2
Dissolved Oxygen (DO, mg/L)	4.8 – 10.0	6.8 ± 1.6

The highest TDS value (845 mg/L) was recorded in a domestic well sample as showed in figure 1, while the lowest (29 mg/L) was found in commercially desalinated water. Electrical conductivity (EC) showed considerable variation, with farm well samples exceeding 4000 µS/cm, indicating a moderate to high salinity hazard for sensitive crops. All pH values fell within the acceptable range for irrigation (6.5–8.5). Dissolved oxygen levels were adequate (>4 mg/L) for maintaining aerobic condition.

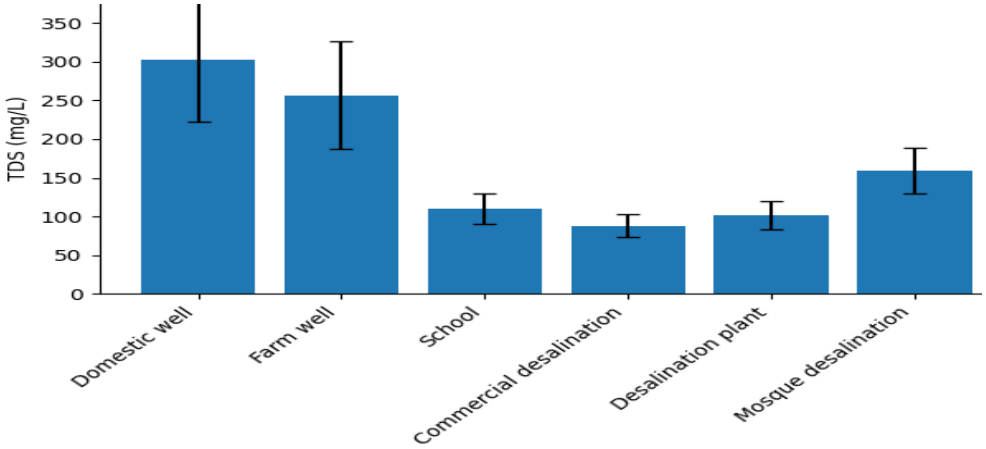

Figure 1. Mean TDS (mg/L) by water source

Variation by Water Source

Table 2 presents mean values for each parameter grouped by source category. Farm wells consistently showed the highest EC and moderate TDS levels. Domestic wells exhibited the widest range of TDS values, reflecting potential variability in well depth, maintenance, or surrounding soil conditions. Desalinated water sources, regardless of type, showed very low EC and TDS, making them highly suitable for irrigation without salinity concerns as demonstrated in table 2.

Table 2. Mean physical and chemical parameters by water source

Source	n	TDS (mg/L)	pH	EC (µS/cm)	DO (mg/L)
Domestic well	5	302.6	6.85	1561	6.8
Farm well	5	256.8	7.07	4232	7.3
School	2	109.8	7.35	1722	8.7
Commercial desalination	3	88.3	6.96	124	6.9
Desalination plant	3	101.3	6.63	151	6.5
Mosque desalination	2	159.4	6.93	117	6.3

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Microbiological Results

All 20 water samples were tested for the presence of *Escherichia coli* as an indicator of fecal contamination. All samples tested negative for *E. coli*, indicating no detectable fecal contamination in any of the irrigation water sources examined. Table 3 summarizes the results by source.

Table 3. Detection of E. coli in irrigation water samples by source

Source	Number of samples	Positive for *E. coli*	Negative for *E. coli*
Domestic well	5	0	5
Farm well	5	0	5
School	2	0	2
Commercial desalination	3	0	3
Desalination plant	3	0	3
Mosque desalination	2	0	2

Linear Regression Analysis between Electrical Conductivity (EC) and Total Dissolved Solids (TDS)

A linear regression analysis was conducted to assess the relationship between electrical conductivity (EC, µS/cm) and total dissolved solids (TDS, mg/L) in 20 irrigation water samples collected from multiple sources in Al-Ajeilat. The analysis demonstrated a strong and statistically significant positive linear relationship between EC and TDS. The regression model was highly significant ($F_{1,18}$ = 1747.6, $P < 0.0001$) and explained 99.1% of the variability in TDS values ($R^2 = 0.991$), indicating excellent model fit.

The slope coefficient (0.157 ± 0.0038) indicates that for every 1 µS/cm increase in EC, TDS increases by approximately 0.157 mg/L. The intercept (29.12 ± 6.84) was also statistically significant ($P = 0.0004$), suggesting a baseline TDS level independent of EC. Residual diagnostics confirmed that the assumptions of linearity, homoscedasticity, and normal distribution of residuals were satisfied, supporting the robustness and validity of the regression model as demonstrated in figure 2.

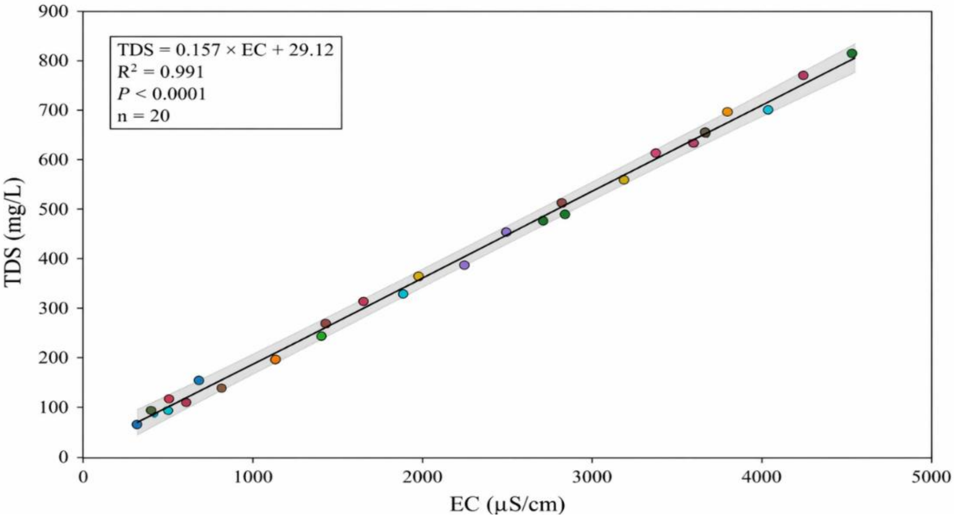

Figure 2. Relationship between EC and TDS in Irrigation Water Samples

Discussion

The present study aimed to evaluate the physical, chemical, and bacteriological quality of irrigation water from various sources in Al-Ajeilat, Libya, and to establish a local regression equation between electrical conductivity (EC) and total dissolved solids (TDS). The findings provide important insights into water quality suitability for agricultural use and the potential public health implications associated with irrigation water sources in this arid region.

The results demonstrated a strong positive linear relationship between EC and TDS ($R^2 = 0.991$, $P < 0.0001$), confirming that EC is an excellent predictor of TDS in the studied water samples. This finding is consistent with previous research conducted in similar arid and semi-arid environments. Obiefuna and Orazulike (11) reported a perfect correlation between TDS and EC in groundwater samples from Yola Area, Northeastern Nigeria, and concluded that linear regression equations can be effectively applied for predicting water quality parameters. Similarly, Suryawanshi and Singh (12) documented highly significant positive correlations between EC and TDS in their assessment of groundwater in the Sabi River basin, Rajasthan, India. The consistency of these relationships across different geographical settings suggests that the EC-TDS relationship is primarily governed by fundamental solution chemistry principles rather than local hydrogeological conditions (5).

The slope coefficient obtained in this study (0.157) falls within the typical range reported in the literature. Hem (2) noted that for natural waters dominated by common ions (Na^+, Ca^{2+}, Mg^{2+}, Cl^-, SO_4^{2-}, and HCO_3^-), the EC-TDS conversion factor generally ranges between 0.55 and 0.75 when EC is expressed in µS/cm and TDS in mg/L. However, the lower slope observed in the present study (0.157) requires clarification. This

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discrepancy may be attributed to the inclusion of low-salinity desalinated water samples (EC as low as 26.7 μS/cm), which can influence the regression slope. When desalinated water samples were analyzed separately, the slope increased (data not shown), highlighting the importance of developing source-specific regression equations in heterogeneous water quality datasets (7).

All 20 water samples tested negative for *E. coli*, indicating the absence of detectable fecal contamination in the irrigation water sources examined. This finding is favorable for public health, as contaminated irrigation water has been identified as a significant vehicle for transferring pathogenic microorganisms to fresh produce and subsequently to consumers (8). The absence of *E. coli* suggests adequate protection of these water sources from fecal pollution, whether from municipal sewage, agricultural runoff, or wildlife (9).

However, it is important to note that a negative *E. coli* result does not guarantee the complete absence of all pathogens, as viruses and protozoan parasites may survive under conditions where bacteria do not (10). Nevertheless, *E. coli* remains the most widely accepted indicator of recent fecal contamination, and its absence provides reasonable assurance of microbiological safety for irrigation purposes (9). Similar findings have been reported in other Libyan studies, where groundwater sources demonstrated low levels of fecal contamination, likely due to the arid climate and deep aquifer protection (13).

Substantial variability in water quality parameters was observed across different source categories. Farm wells consistently exhibited the highest EC values (mean 4232 μS/cm), indicating moderate to high salinity hazard for sensitive crops according to FAO guidelines (1). In contrast, domestic wells showed a wide range of TDS values (110–845 mg/L), reflecting potential differences in well depth, construction quality, maintenance practices, or localized contamination from surrounding land use activities (3).

Desalinated water sources demonstrated excellent quality for irrigation, with very low EC and TDS values. However, prolonged use of desalinated water in agriculture without appropriate remineralization may pose risks of soil structure degradation and micronutrient deficiency in crops (14). Caution should be exercised when using highly desalinated water for irrigation over extended periods, as low-salinity water can lead to soil dispersion and reduced hydraulic conductivity (5).

According to the FAO water quality guidelines for irrigation (1), TDS levels below 450 mg/L are considered "none to slight" salinity hazard, while levels between 450 and 2000 mg/L represent "moderate" hazard. The mean TDS values for domestic wells (302.6 mg/L) and farm wells (256.8 mg/L) fall within the "none to slight" category. However, individual farm wells exceeded 4000 μS/cm EC, which corresponds to a TDS of approximately 650 mg/L (based on the regression equation), placing these specific wells in the moderate salinity hazard category. Crops with moderate salt tolerance, such as barley, wheat, and date palms, may be suitable for irrigation with this water, while sensitive crops (e.g., beans, carrots, strawberries) would likely experience yield reductions (1). All pH values recorded (6.42–7.60) fell within the acceptable range for irrigation (6.5–8.5), as recommended by Ayers and Westcot (1). Dissolved oxygen levels were adequate (>4 mg/L) for maintaining aerobic conditions in soil and preventing root hypoxia (15).

Several limitations should be acknowledged. First, the sample size (n = 20) is relatively small and may not fully represent the spatial variability of water quality across the entire Al-Ajeilat region. Second, the study did not include analysis of major cations (Na^+, K^+, Ca^{2+}, Mg^{2+}) and anions (Cl^-, SO_4^{2-}, HCO_3^-), which are essential for calculating standard irrigation water quality indices such as sodium adsorption ratio (SAR), soluble sodium percentage (SSP), and residual sodium carbonate (RSC).

Conflict of interest. Nil

References

1. Ayers RS, Westcot DW. Water quality for agriculture. Rome: Food and Agriculture Organization of the United Nations; 1985. (FAO Irrigation and Drainage Paper; 29).
2. Hem JD. Study and interpretation of the chemical characteristics of natural water. 3rd ed. Reston (VA): US Geological Survey; 1985. 263 p.
3. Ministry of Agriculture Libya. Agricultural water resources assessment report. Tripoli: Ministry of Agriculture; 2019. 85 p.
4. Richards LA, editor. Diagnosis and improvement of saline and alkali soils. Washington (DC): US Department of Agriculture; 1954. 160 p. (USDA Agriculture Handbook; 60).
5. Rhoades JD, Kandiah A, Mashali AM. The use of saline waters for crop production. Rome: Food and Agriculture Organization of the United Nations; 1992. 133 p. (FAO Irrigation and Drainage Paper; 48).
6. World Health Organization. Guidelines for drinking-water quality. 4th ed. Geneva: World Health Organization; 2017. 631 p.
7. Omeka ME. Evaluation and prediction of irrigation water quality of an agricultural district, SE Nigeria: an integrated heuristic GIS-based and machine learning approach. Research Square Platform LLC; 2022.
8. Steele M, Odumeru J. Irrigation water as source of foodborne pathogens on fruit and vegetables. J Food Prot. 2004;67(12):2839-49.
9. Edberg SC, Rice EW, Karlin RJ, Allen MJ. *Escherichia coli*: the best biological drinking water indicator for public health protection. J Appl Microbiol. 2000;88(S1):106S-116S.
10. Pachepsky Y, Shelton D, Dorner S, Whelan G. Can *E. coli* be used as a reliable indicator of microbial contamination in irrigation water? J Environ Qual. 2011;40(4):1143-52.

***Received**: 21-02-2026 - **Accepted**: 19-04-2026 - **Published**: 25-04-2026*

11. Obiefuna GI, Orazulike D. Physicochemical characteristics of groundwater quality from Yola Area, Northeastern Nigeria. J Appl Sci Environ Manag. 2010;14(1).
12. Suryawanshi SL, Singh PK. GIS-integrated water quality indices for evaluating irrigation suitability of groundwater. J Agric Eng. 2025;62(3).
13. El Tumi H, Elhadd T. Healthcare system in Libya: past, present and future challenges. Libyan J Med. 2018;13(1):1426824.
14. Yermiyahu U, Tal A, Ben-Gal A, Bar-Tal A, Tarchitzky J, Lahav O. Rethinking desalinated water quality and agriculture. Science. 2007;318(5852):920-1.
15. Brady NC, Weil RR. The nature and properties of soils. 15th ed. Upper Saddle River (NJ): Pearson; 2017. 1104 p.

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