DOI 10.7343/as-2025-832

ACQUE SOTTERRANEE
Italian Journal of Groundwater
journal homepage: https://www.acquesotterranee.net/

2025-AS53-832

Management and monitoring of mixed groundwater and surface water quality in Bechar, southwestern Algeria

Gestione e monitoraggio della qualità delle acque sotterranee e superficiali nella città di Bechar, Algeria sud-occidentale

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Supplementary file - *File supplementare*

Annex - *Appendice*

Drinking Water Quality Index (DWQI)

In this study, we used DWQI according to the classical method based on the approach provided by Horton (1965) and developed by Brown et al. (1972) to estimate the influence of natural and anthropogenic factors on water quality, based on pH, EC, TDS, Ca^{2+}, Mg^{2+}, Na^+, K^+, HCO_3^-, Cl^-, SO_4^{2-} and NO_3^- presented in Table 1 (Yidana et al., 2010).

Tab. 1 - Relative weights assigned to physico-chemical parameters of DWQI.

Tab. 1 - Pesi relativi assegnati ai parametri fisico-chimici del DWQI.

Physico-chemical parameters	Unit	WHO (2017) S_i	Unit Weight W_i
Ph	-	8.5	0.423
EC	uS/cm	1500	0.002
TDS	mg/L	500	0.007
Ca^{2+}	mg/L	75	0.048
Mg^{2+}	mg/L	50	0.072
Na^+	mg/L	200	0.018
K^+	mg/L	12	0.299
HCO_3^-	mg/L	120	0.030
Cl^-	mg/L	250	0.014
SO_4^{2-}	mg/L	250	0.014
NO_3^-	mg/L	50	0.072
		$\sum S_i$	$\sum W_i=1$

Eleven drinking water quality metrics are included in the generated dataset that is examined in this study in order to evaluate the suggested model. Using the following formula (1), the DWQI was calculated:

$$DWQI = \sum_{i=1}^{n} W_i \cdot \left(\frac{c_i}{S_i} \cdot 100 \right) \quad (1)$$

c_i represents each chemical parameter's concentration, W_i stands for each parameter's weight unit, which is calculated using Equation (2), and Si stands for the drinking water standards.

$$W_i = \frac{w_i}{\sum w_i} \quad (2)$$

Equation (3) is used to calculate w_i for each parameter using the suggested standards (WHO, 2017):

$$w_i = \frac{K}{S_i} \quad (3)$$

Where K is the constant of proportionality, and Equation (4) is used to compute it:

$$K = \frac{1}{\sum S_i} \quad (4)$$

Tab. 2 - Classification of water quality (Sahu & Sikdar, 2008).

Tab. 2 - Classificazione della qualità delle acque (Sahu & Sikdar, 2008).

Ranking	DWQI Value	Explanation
<50	Excellent water	Good for human health
50-100	Good water	Suitable for human consumption
100-200	Poor water	Water in poor condition
200-300	Very poor water	Needs special attention before use
>300	Unsuitable for drinking	Requires too much attention

Assessment of Irrigation Water Quality Indices (IWQIs)

The presence of dissolved salts or other undesirable elements determines the suitability of irrigation water. A comprehensive evaluation of this suitability relies on analyzing the physical and chemical properties of water parameters, including temperature, pH, EC, TDS, Na^+, K^+, Ca^{2+}, Mg^{2+}, Cl^-, SO_4^{2-}, NO_3^-, and HCO_3^- (Mukherjee et al., 2022).

Furthermore, the subsequent table outlines a range of computations that can aid in the assessment of irrigation water suitability through various indicators such as the Sodium Adsorption Ratio (SAR), percentage of sodium (Na%), and Soluble Sodium Percentage (SSP). Additionally, the Permeability Index (PI) and Kelly index (KI) are utilized to assess the influence of calcium, magnesium, and sodium concentrations on water quality. The potential salinity (PS) indicates the degree of salt accumulation in the soil, presenting a substantial challenge for downstream water users. An accurate understanding of these factors can enhance water resource management to support sustainable agriculture, as given in Table 3.

Tab. 3 - The formula and references of the IWQIs.

Tab. 3 - Formule e riferimenti per IWQIs.

Index	Formula	Reference
Na%	$\frac{(Na^+ + K^+)}{(Ca^{2+} + Mg^{2+} + Na^+ + K^+)} \cdot 100$	**(Wilcox, 1955)**
SAR	$\left(\frac{Na^+}{\sqrt{(Ca^{2+} + Mg^{2+})/2}}\right) \cdot 100$	**(Richards, 1954)**
SSP	$\frac{Na^+}{(Ca^{2+} + Mg^{2+} + Na^{2+})} \cdot 100$	**(Todd, 1980)**
KI	$\frac{Na^+}{(Ca^{2+} + Mg^{2+})}$	**(Kelly, 1940)**
PS	$Cl^- + (SO_4^{2-}/2)$	**(Doneen, 1964)**
PI	$\frac{Na^+ + \sqrt{HCO_3^-}}{(Ca^{2+} + Mg^{2+} + Na^+)} \cdot 100$	**(Doneen, 1964)**

Irrigation Water Quality Index (IWQI)

The assessment of the Irrigation Water Quality Index (IWQI) involved the evaluation of five critical water quality parameters: Electrical Conductivity (EC), Sodium ion concentration (Na^+), Chloride ion concentration (Cl^-), Bicarbonate ion concentration (HCO_3^-), and Sodium Adsorption Ratio (SAR) (Abbasnia et al., 2018b). Before data analysis, concentration units underwent conversion from mg/L to meq/L utilizing conversion factors derived from Lesch & Suarez, (2009). This section of the study focused on the IWQI evaluation, encompassing the calculation of water quality parameter values (Q_i) using the formula below and accumulated witness (W_i). A summarized presentation of irrigation water quality parameters and their recommended threshold values are presented in Table 4 (Ayers & Westcot, 1999).

$$Q_i = Q_{\max} - \left(\frac{\left[\left(X_{ij} - X_{\inf} \right) \cdot Q_{imap} \right]}{X_{amap}} \right) \quad (5)$$

Where Q_{max} is the upper value of the corresponding class of Q_i, X_{ij} is each parameter's observed value, X_{inf} is the value that corresponds to the lower limit of the class, Q_{imap} is the class amplitude, and X_{amap} is the class amplitude to which the parameter belongs.

Tab. 4 - Limits on the variables that are used to calculate the quality measurement (Q_i)(Ayers & Westcot, 1999).

Tab. 4 - Limiti sulle variabili utilizzate per calcolare l'indice di qualità (Q_i)(Ayers & Westcot, 1999).

Q_i	EC (µs/cm)	SAR	Na^+ (meq/L)	Cl^- (meq/L)	HCO_3^- (meq/L)
85–100	200 ≤ EC < 750	2 ≤ SAR < 3	2 ≤ Na < 3	1 ≤ Cl < 4	1 ≤ HCO_3 < 1.5
60–85	750 ≤ EC < 1500	3 ≤ SAR < 6	3 ≤ Na < 6	4 ≤ Cl < 7	1.5 ≤ HCO_3 < 4.5
35–60	1500 ≤ EC < 3000	6 ≤ SAR < 12	6 ≤ Na < 9	7 ≤ Cl < 10	4.5 ≤ HCO_3 < 8.5
0–35	EC < 200 or EC ≥ 3000	SAR < 2 or SAR ≥ 12	Na < 2 or Na ≥ 9	Cl < 1 or Cl ≥ 10	HCO_3 < 1 or HCO_3 ≥ 8.5

Finally, using Equation (6), the IWQI was calculated. Table 5 presents the relative weight of every parameter according to Meireles et al. (2010).

$$IWQI = \sum_{i=1}^{n} Q_i W_i \quad (6)$$

Tab. 5 - The IWQI parameters' weights (Meireles et al., 2010).

Tab. 5 - Pesi dei parametri IWQI (Meireles et al., 2010).

Parameters	Wi
EC	0.211
Na^+	0.204
Cl^-	0.194
HCO_3^-	0.202
SAR	0.189
TOTAL	1

Tab. 6 - IWQI classification (Meireles et al., 2010).

Tab. 6 - Classificazione IWQI (Meireles et al., 2010).

IWQI Category	Range
No restriction	85–100
Low restriction	70–85
Moderate restriction	55–70
High restriction	40–55
Severe restriction	0–40

Sodium Percentage (Na%)

The Na% ratio can be used to assess the suitability of water for irrigation purposes due to the effect of Na^+ concentrations on soil permeability (Todd & Mays, 2004). High levels of sodium ions (Na^+) in irrigation water can lead to the replacement of calcium ions (Ca^{2+}) and magnesium ions (Mg^{2+}) associated with soil particles, reducing soil permeability and negatively affecting its physical structure. Sodium is exchanged in water for Calcium and Magnesium in the soil, reducing conductivity and thus water ability to infiltrate the soil. There are five categories for irrigation water quality based on the Na% ratio (Wilcox, 1955).

Tab. 7 - Statistical analysis and classes of Na%.

Tab. 7 - Analisi statistica e classi di Na%.

Na% Value	Water Category
<20	Excellent
20–40	Good
40–60	Permissible
60–80	Doubtful

Sodium Adsorption Ratio (SAR)

This index is a useful tool for assessing the suitability of water for irrigation based on Sodium hazards (Subramani et al., 2005) . It is utilized in irrigation to determine the soil capacity to remove Calcium and Magnesium ions and absorb Sodium from groundwater, leading to soil particle dispersion and reduced infiltration capacity (Wang et al., 2012; Hanson et al., 1999).

Tab. 8 - Statistical analysis and classes of SAR.

Tab. 8 - Analisi statistica e classi di SAR.

SAR Value	Water Suitability
<10	Excellent
10–18	Good
18–26	Doubtful or fairly poor
>26	Unsuitable

Soluble Sodium Percentage (SSP)

The elevated Na^+ concentration compared to Ca^{2+} and Mg^{2+} in water can lead to toxicity issues, resulting in leaf damage and plant tissue corrosion (Diwakar et al., 2015). Therefore, the Soluble Sodium Percentage (SSP) index was utilized to assess salinity levels by comparing Na^+ concentrations to Ca^{2+} and Mg^{2+} concentrations.

Tab. 9 - Statistical analysis and classes of SSP.

Tab. 9 - Analisi statistica e classi di SSP.

SSP Value	Water Suitability
<60	Safe
≥60	Unsafe

Kelly Index (KI)

Levels of Sodium, Calcium, and Magnesium in water are used to calculate the KI value. The Kelly Index (KI) was also utilized in this study to assess irrigation water quality (Kelly, 1940). According to the KI index, if the value is greater than 1, this indicates an excess amount of Sodium. In contrast, a value less than 1 indicates that the water is suitable for irrigation (Kelly, 1940; Sundaray et al., 2009).

Tab. 10 - Statistical analysis and classes of KI.

Tab. 10 - Analisi statistica e classi di KI.

KI Value	Water Suitability
≥1	Unsuitable
<1	Good

Potential Salinity (PS)

To assess the suitability of water for use in irrigation, we utilize the PS index, which is based on the concentrations of Chloride and Sulfate ions (Doneen, 1964).

Tab. 11 - Statistical analysis and classes of PS.

Tab. 11 - Analisi statistica e classi di PS.

PS Value	Water Category
<3	Excellent to good
3–5	Good to injurious
>5	Injurious to unsatisfactory

Permeability Index (PI)

Over time, the soil is affected by water with high Sodium, Magnesium, Calcium, and Bicarbonate levels (El-Amier et al., 2021). Therefore, the PI index is considered useful for evaluating irrigation water quality in this case. According to the PI index, decisions can be made regarding its suitability for irrigation, as it is classified into 3 categories (Doneen, 1964).

Tab. 12 - Statistical analysis and classes of PI.

Tab. 12 - Analisi statistica e classi di PI.

PI Value	Water Category
<25%	Unsuitable-Class III
25–75%	Good-Class II
>75%	Suitable-Class I