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RESEARCH ARTICLE

WATER SALINIZATION IN IRAQ AND SOME SUGGESTED SOLUTIONS

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ABSTRACT

The salinity status in the Iraq needs a continuous assessment because it is continuously changing due to many factors. This article highlights the problem in the country and aims to assess the increasing salinization of some water resources. It suggests some recommendations for optimizing the beneficial utilization of this phenomenon. Experimentally, water samples were collected from 1242 site in the Iraq country and chemically analyzed to estimate the salinity parameters and indices for the agricultural suitability including the sodium percentage (Na%), sodium adsorption ratio (SAR), and the permeability index (PI). The analysis results have indicated wide variations in the pH, EC, TDS and types of soluble ions for the estimated resources. The general trend of TDS and EC as parameters of water salinization for some governorates may indicate the presence of some organic contaminants. The TDS approximately equalled the EC in Karbala, Ninewa and Thi-Qar. The sequence of the predominating ions was Ca^{2+} > Mg^{2+} > Na^{+} > K^{+} and NO_3^{-a}> SO_4^{2-} > Cl^{-} > HCO_3^{-}, respectively for the governorates Anbar, Babylon, Baghdad, and Basrah. The predominance of some types of cations and/or anions may be related to environmental, geological, and human practices factors. Many samples can be suitable for irrigation and agricultural use with good Na% (20-40%), acceptable Mg% (<50%), excellent SAR (<10), and PI class 2 and 3. Despite the severity of the problem, suitable management can use the saline water resources for sustainable development to turn the disadvantages into advantages. Suggested Solutions are presented for the agricultural sustainability including the irrigation and fertilization management, planting trees in the right location, biotechnology, and genetic engineering. Examples for the desalination technologies are discussed such as the Bio-Electro-remediation and Reverse electro-dialysis (RED) as an energy-efficient water desalination using Capacitive Deionization (CDI) technique and freeze desalination.

KEYWORDS

Arid regions; Desalination Technologies; Salinity Management; Salinity Tolerance; Water Salinization

1. INTRODUCTION

The problem of water salinization is of a global importance. Salinity categories can include water resources, irrigation, dry and urban lands, and industrial salinity. Normal salinity levels in streams and rivers may originate geologically from the surrounding clay soils because minerals in the clay may ionize and dissolve, while the granite bedrocks remain inert. Ground water is all the subsurface water and the geological environment can affect the contribution of the ground water in salinity since it flows carrying the solubilized ions released by the parent material in contact.

Salinity of water is the dissolved salt content or saltiness of a water resource. Saline water cannot be used for the domestic purposes or irrigating plants due to the presence of soluble salts; sometimes measured as milligrams per litre or part per million (mg/L or ppm). The accurate definition and measurement of salinity of a river, a lake, or the ocean is not easy. A salt is a compound such as sodium chloride (NaCl), magnesium sulfate ($MgSO_4$), potassium nitrate (KNO_3), and sodium bicarbonate ($NaHCO_3$) that produce their ionic forms by dissolution in water. The environmental water resources have a complicated mix of chemical moieties with diverse molecular formula of miscellaneous origins in addition to the salt ions. Their chemical characteristics depend on the temperature and pressure. Salinity measurements are often not including the concentration of the soluble gas such as the oxygen (O_2) or nitrogen (N_2) except the dissolved carbon dioxide (CO_2) since it has partial transformation to carbonate and bicarbonate forms.

Silicon may be measured for some purposes. A commonly used unit for salinity is the total dissolved solids (TDS) and/or electrical conductivity (EC). Though there is a close relationship between TDS and EC, they are not the same but two separate parameters. The first is a gravimetric analysis of the total mass weight of solids dissolved in water measured by weighing. The EC of water is a measurement of all charges in the solution able to conduct electricity. Sometimes, the TDS and EC are measures of the impurities level in the domestic and industrial water supplies. General salinity and EC ranges are presented in Tables 1 and 2. Hardness of water is the existence of ionic forms of calcium and/or magnesium carbonate ($CaCO_3$) that form insoluble residues when the water is used with soap (http://www.unesco.org; GAMA Program 2010).

In agriculture, the presence of the saline irrigation or groundwater in the plant root zone damages the flora of weak salt-tolerance. Saline media damage buildings and shorten the infrastructure lifetime (for example roads, bridges, pipe systems), and require costly specified construction materials for a high protection. The water is often out of the World Health Organisation (WHO) standards to drink. Hardness of water requires extensive and expensive treatment before human use. Hard water damages the water boilers as well as domestic instruments, and increases

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the consumed soap and detergents. Some regions may utilize the ground water for domestic, industry, and agriculture purpose after being processed (http://www.unesco.org; GAMA Program 2010; Ohio 2012; Shilu et al., 2011). Therefore, we need to optimize the method of handling the available natural resources.

Table 1: A General Salinity Scale

Type Of Water	Concentration of Dissolved Solids, (ppm)
Slightly Saline	1,000 - 3,000
Moderately Saline	3,000 - 10,000
Very Saline	10,000 - 35,000
Brine	> 35,000
Fresh Water	< 100
Typical Limit Agriculture Irrigation	2000
Brackish Water, Mildly	1000 - 5,000
Brackish Water, Moderately	5000 - 15,000
Brackish Water, Heavily	15,000 - 35,000
Sea Water	30,000 - 50,000
Dead Sea	330.000

Table 2: General EC range

Solution	Conductivity
Absolute pure water	0.055 µS/cm
Good city water	50 µS/cm
Ocean water	53 mS/cm
Distilled water	0.5 µS/cm
Deionised water	0.1 - 10 µS/cm
Demineralised water	0 - 80 µS/cm
Drinking water	0.5 - 1 mS/cm
Wastewater	0.9 - 9 mS/cm
Seawater	53 mS/cm
10 % NaOH	355 mS/cm
10 % H_2SO_4	432 mS/cm
31 % HNO_3	865 mS/cm

High salinity levels in the aquatic life over a normal range decrease the soluble content of the O_2 gas that can kill some fish by the osmosis regulation and TDS toxicity. Most of the marine beings are able to mitigate or adapt to limited ranges of salinity. They either reside in freshwater or move to saltwater. Kinds like sea star and sea cucumber are not resistant to decreased salinity. Some kinds are affected by the types of soluble ions in water. Changing or modifying the concentrations or types of ions (replacing K by Na as an example) result in harmful effects on the metabolism of the organisms, as they cannot cope with the changed ions biologically. The Iraqi ecosystem has suffered from a remarkable alteration across the recent thirty years and the surface water resources are critically decreased. The crucial water resources Tigris and the Euphrates Rivers have decreased below their third capacity. The hydro-climatic and socio-demographic factors have stressed the communal water stores and networks (Mason, 2022). Agriculturally, poor and traditional practices of irrigation as well as drainage have wasted huge quantities of water as more than ninety percent of the water in the Iraq may be consumed agriculturally although the country's foodstuff requirements are not satisfied. Iraq depends on the imported wheat after it was exporting wheat.

The available groundwater in Iraq may be not enough assigned requiring further update (http://www.unesco.org; Water Issues between Turkey, Syria and Iraq; Water in Iraq Factsheet 2013). The Iraqi semiarid regions include forests, graze, and farmlands. Eroded resources of water have become a problematic issue in the forests and graze areas caused by a non-optimized management. For the croplands, the usual cultivation methods along with the exhaustive cropping had eroded the water resources at the marginal areas. Some parts of the Iraq semiarid regions exhibited highly eroded soil due to water salinity cannot be restored. The water quality may violate the Iraq National Standards as well as those of the WHO. The organic pollutants indicated by the Biochemical Oxygen Demand (BOD) was 36.2 ppm during the year 2010, triple the 10 ppm as a national limit compared to a BOD range 1.04-12.12 ppm during 2005 being an alarm of the increasing water pollutants. The TDS of Euphrates water have raised (457-1200 ppm) during the years 1980 and 2009 (Water Issues between Turkey, Syria and Iraq; Water in Iraq Factsheet 2013; Kundell 2008; Mahmood et al., 2014; Hussein, 1998).

Some Iraqi north regions have a direct dependence on the untreated groundwater supplies only for their agricultural and social purposes that results in many water-borne diseases. Iraq suffers from an extreme water stress (Raheem and Hatem, 2019). Some estimates referred to that the saline hazard affects about 74% of the irrigated area with a 4% severe, 50% medium, and 20% slight salinity. Saline water has been used for the irrigation of the date palm trees and tomato since 1977 (Kundell 2008). Salinity has been documented on the Indian River citrus since 1900 and more recently, in citrus groves of some Florida areas. The osmosis pressure created by the soluble salt ions decreases the available water at the plant root zone necessary for the chemical and physical reactions. A tree cannot absorb and/or transport the enough water under stress.

Although the sandy soil is less affected by salinity, the soil solution salinity at the root zone has a direct effect on the plant growth as it is assumed to be triple the irrigation water salinity. The critical level of salinity that severely affects the plants is dependent on the soil properties and buffering capacity along with the climate. High leaf Na and/or Cl can disturb the nutrients balance at a small concentration below the level of an observable symptom. It was found that the leaves of the citrus could have accumulated Cl or Na from aqueous drops directly contact with it. The lower leaves contained the Cl and Na at concentrations higher than those at the plant top by about four times like in grapefruits and Valencia (Boman and Stover, 2012).

2. Collection of Samples and Lab Tests

About 1242 water sample represent different resources has been collected to estimate the following parameters: pH, EC, TDS and soluble anions and cations; bicarbonates: HCO_3^-, Chlorides: Cl^-, Sulphates: SO_4^{-2}, Nitrates: NO_3^-, and Calcium: Ca^{+2}, Magnesium: Mg^{+2}, Sodium: Na^+ and Potassium: K^+. Salinity indices include the sodium percentage: Na% (Eq. 1), sodium adsorption ratio: SAR (Eq. 3), permeability index: PI (Eq. 4), in addition to the residual sodium carbonate: RSC (Eq. 7) are used to assess the suitability of water to be used agriculturally and in irrigation (Nagarajan, et al., 2010; Prasanth et al., 2012). This is because the Na content inhibits the permeability and structure of soil and the SAR indicates the hazardous alkali Na to a crop. Calcium and magnesium are often in an equilibrium state. An Mg-hazard index has been suggested where a value of 50 % negatively affects the crops productivity due to increased alkalinity of soil (Eq. 2).

A Na-rich groundwater type may be produced due to precipitating calcite and/or cationic exchanging, while Ca—Cl^- rich groundwater may be resulted from a reversible ionic exchanging mechanism (Na + Ca-Clay ⇆ Na-Clay + Ca). Such reactions result in the Na^+ or Ca^{2+} adsorption/release from the aquifers material such as the montmorillonites in the groundwater. The reaction involving the water and environment in contact can be indicated by calculating the chloro-alkaline index CAI 1 or CAI 2 (Eqs. 5, 6). Negative index values indicate a cation exchange of Na^+ and/or K^+ cations from the environment for Mg^{2+} and/or Ca^{2+} cations in water but an opposite reaction pathway gives positive values (Cl > Na + K).

$$\text{Na (\%)} = Na^+ \times \frac{100}{[Ca^{2+} + Mg^{2+} + Na^+ + K^+]} \quad (1)$$

$$\text{Mg (\%)} = Mg^{2+} \times \frac{100}{(Ca^{2+} + Mg^{2+})} \quad (2)$$

$$SAR = \frac{Na^+}{\sqrt{\frac{Ca^{2+} + Mg^{2+}}{2}}} \quad (3)$$

$$PI = [Na^+ + \sqrt{HCO_3^-}] \times \frac{100}{[Na^+ + Ca^{2+} + Mg^{2+}]} \quad (4)$$

$$CAI\ 1 = Cl^- - \left(\frac{Na^+ + K^+}{Cl^-}\right) \quad (5)$$

$$CAI\ 2 = Cl^- - \left(\frac{Na^+ + K^+}{SO_4^{2-} + HCO_3^- + CO_3^{2-} + NO_3^-}\right) \quad (6)$$

$$RSC = (CO_3^{2-} + HCO_3^-) - (Ca^{2+} + Mg^{2+}) \quad (7)$$

Ion concentration (meq L^{-1})

3. Water Analysis Results and Discussion

Figure 1 and data in **Tables 3 and 4** show variations over a wide range of pH, EC and TDS and other salinity parameters for the studied resources.

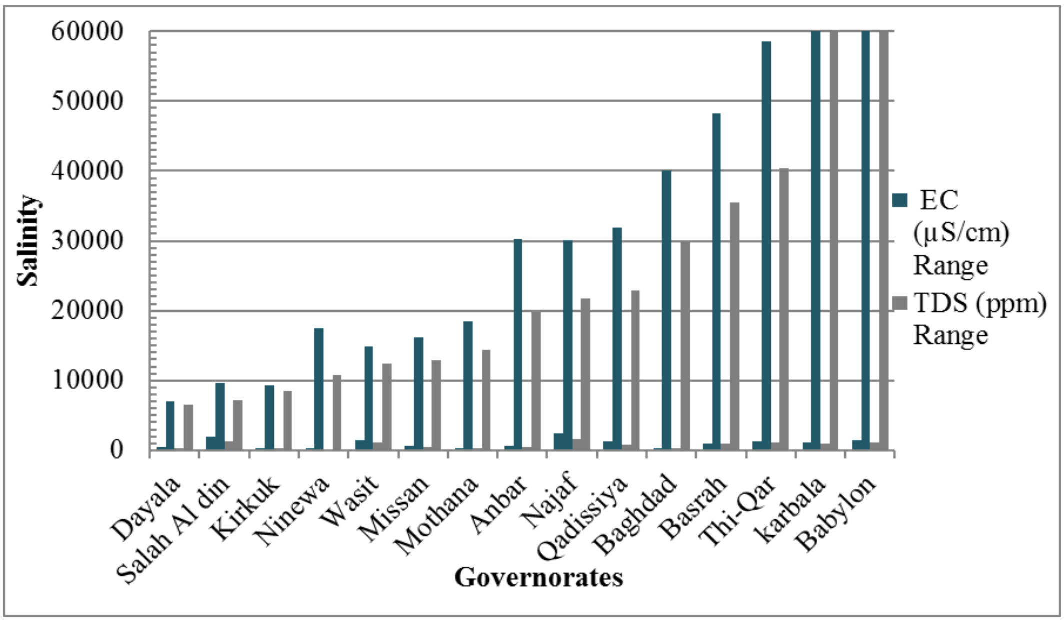


Figure 1: EC (µs/cm) and TDS (ppm) ranges of analyzed resources in Iraq

Table 3: Salinity Ranges of Some Water Resources in Iraq

No.	Governorate	No. of sites	pH Range	EC (µS/cm) Range	TDS (ppm) Range
1	Anbar	86	7.08 - 7.91	668 - 30200	**473 - 19828**
2	Babylon	36	7.11 - 7.77	1379 – 110200	**1082 - 80528**
3	Baghdad	110	7.01 – 7.99	302 - 40100	**260 - 30000**
4	Basrah	100	7.06 – 7.81	1015 - 48300	**965 - 35412**
5	Dayala	100	7.08 – 7.91	496 - 6940	**339 - 6551**
6	Karbala	98	7.08 – 7.91	1125 - 90160	**910 – 70702**
7	Kirkuk	100	7.06 – 8.75	306 - 9380	**280 - 8503**
8	Missan	50	7.11 - 7.91	648 - 16230	**464 – 12887**
9	Mothana	86	7.01 - 8.88	388 - 18480	**250 – 14327**
10	Najaf	98	7.03 - 7.91	2430 - 30100	1680 – **21764**
11	Ninewa	100	6.00 – 8.50	331 - 17449	**196 – 10732**
12	Qadissiya	40	7.08 - 7.91	1234 - 31900	**865 – 22916**
13	Salah Al din	90	7.10 – 8.18	1916 - 9660	**1250 – 7171**
14	Thi-Qar	50	7.09 – 7.71	1370 - 58500	**1130 – 40400**
15	Wasit	98	7.03 – 7.91	1380 - 14830	**1133 – 12460**

Table 4: Salinity Parameters for The Agricultural Use Suitability

No.	Governorate	Na%	Mg%	SAR	PI	CLA1	CLA2	RSC
1	Anbar	20.6 - 74.8	26.9 - 56.9	0.9 - 10.3	26.6 - 89.0	0.8 - 89.2	1.4 - 89.2	(-106.6) - (-0.1)
2	Babylon	29.2 - 75.5	28.7 - 54.4	3.1 - 23.1	35.1 - 89.1	2.0 - 144.9	3.3 -144.9	(-94.8) - 3.3
3	Baghdad	22.8 - 74.5	30.1 - 66.4	1.5 - 15.2	29.9 - 87.2	1.0 - 107.8	1.3 - 107.8	(-64.2) - (-0.3)
4	Basrah	9.7 - 49.0	38.7 - 51.9	1.2 - 10.1	16.5 - 55.7	3.2 - 63.7	4.0 - 63.9	(-81.7) - (-7.3)
5	Dayala	23.4 - 72.9	28.6 - 65.1	1.0 - 10.3	31.3 - 82.4	1.5 - 31.6	1.3 - 32.2	(-37.9) - (-1.8)
6	Karbala	13.8 - 73.9	17.2 - 60.2	1.9 - 20.6	19.9 - 86.6	3.0 - 177.7	4.0 - 178.1	(-111.9) - (-0.5)
7	Kirkuk	19.6 - 76.9	28.5 - 57.4	0.6 - 10.3	25.2 - 86.1	(-3.3) - 46.1	(-3.2) - 46.3	(-52.2) - (-0.6)
8	Missan	27.3 - 72.3	36.2 - 59.3	1.9 - 11.3	32.9 - 81.7	1.3 - 81.8	1.3 - 81.3	(-83.6) - (-1.8)
9	Mothana	20.8 - 82.3	17.3 - 57.1	1.3 - 13.0	27.2 - 86.4	0.2 - 61.5	0.6 - 60.2	(-52.8) - (-1.3)
10	Najaf	24.1 - 73.8	33.5 - 60.5	2.3 - 13.9	3.6 - 15.5	7.2 - 69.0	7.8 - 69.9	(-101.5) - (-1.9)
11	Ninewa	1.9 - 82.2	16.7 - 68.6	0.1 - 18.4	8.1 - 93.7	(-8.0) - 79.6	(-0.1) - 79.7	(-69.1) - (1.8)
12	Qadissiya	23.5 - 75.5	35.1 - 65.9	1.5 - 10.4	30.4 - 89.5	3.1 - 67.1	4.2 - 67.3	(-80.6) - (-0.03)
13	Salah Al din	19.6 - 74.4	33.7 - 54.5	1.3 - 10.6	29.6 - 83.7	3.0 - 41.2	4.1 - 41.5	(-52.8) - (-1.9)
14	Thi-Qar	23.4 - 75.4	36.3 - 54.7	1.5 - 21.5	29.2 - 88.1	2.0 - 206.7	3.4 - 207.2	(-150.6) - (-0.3)
15	Wasit	27.9 - 74.3	37.2 - 56.7	2.1 - 10.4	33.3 - 82.7	5.2 - 63.4	5.3 - 63.5	(-77.4) - (-2.0)

Some water sources in Kirkuk (pH 8.75), Mothana (pH 8.88), and Ninewa (pH 8.50) have exceeded the WHO permitted pH range of drinking water (pH 8.5). The salts leached from soil along with the domestic sewage elevate the TDS content in the groundwater. The EC may not correlate directly to the ion concentration as shown in Figures 2. For example, the correlation is linear for the NaCl solution, but not for a highly concentrated H_2SO_4. In some highly concentrated solutions, the ionic interactions can shift the conductivity / concentration linear relationship. It is not easy to accurately verify how ions individually contribute in the EC. This is related to the difference in the ionic charge, size, weight, mobility, and interaction with other moieties. Solutions of equal EC, while differ in their constituting ions (KCl or NaCl) also differ in their TDS due to the difference in molecular weight. Types of ions in water resources are related to the neighbouring environment and leakage from septic tanks (Yehia, et al., 2021).

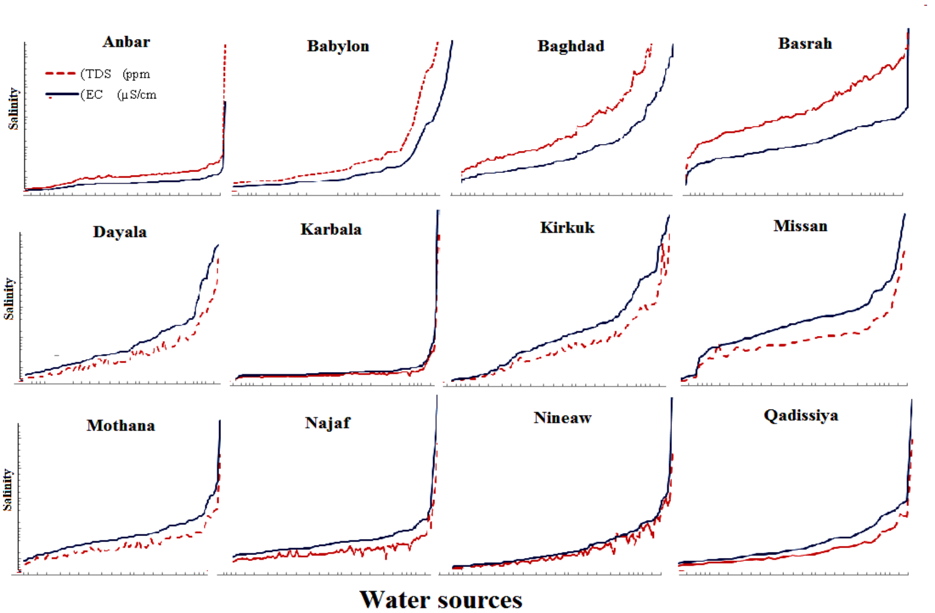


Figure 2: General behaviour of the EC (µs/cm) and TDS (ppm) for the studied water sources in some Iraq Governorates

The TDS parameter includes the summation of tiny particulates (< 2 µm/0.0002 cm) in addition to some soluble organic moieties. The TDS of the fresh water almost equals the EC such as the general behaviour in Figure 2 (Karbala, Ninewa, and Thi-Qar). The TDS of the contaminated water or regions may include organo-contaminants like urea, hydrocarbons …etc. Petroleum hydrocarbons remain one of the most prevalent groups of water and soil contaminants. A rapid increase/decrease of the EC may point to a contamination. An agricultural overflow or a sewage escape can raise the EC because of the added Cl^-, PO_4^{-2}, NO_3^- ions. An oil leak and organio-hydrocarbon moieties do not dissociate into ions that decrease the EC. Conductivity is a suitable indicator to compare measures (Mahmood, 2013; Atekwana et al., 2004; Sulaymon et al., 2009).

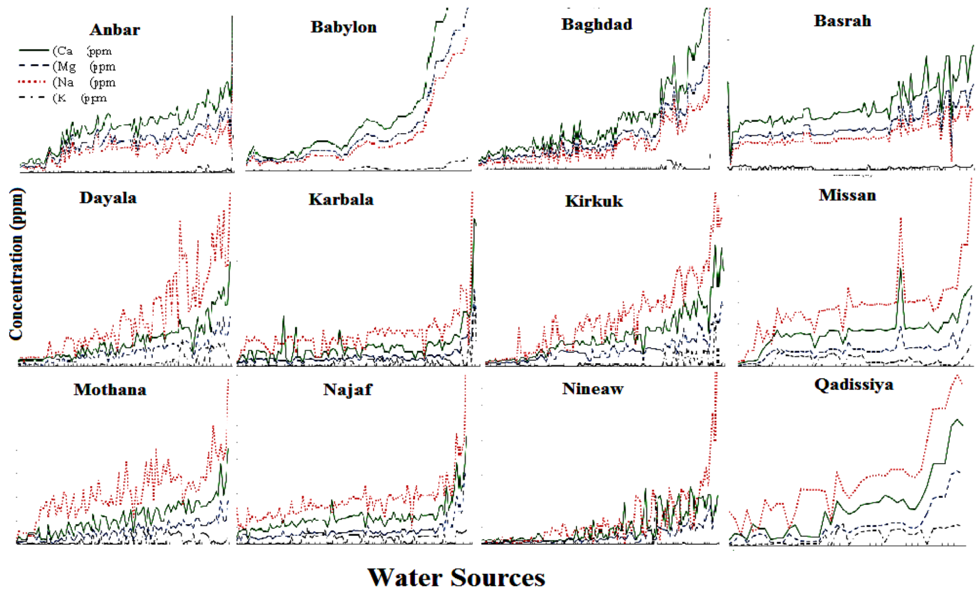


Figure 3: General behaviour of the soluble cations in the studied water resources in some Iraq Governorates

The soluble ions' concentration of the analyzed groundwater sources are illustrated by Figures 3 and 4. Analysis results reveal partially unsuitable sources for domestic use or irrigation regarding the EC, Ca^{2+}, Mg^{2+}, Na^+, NO_3^-, SO_4^{2-} and Cl^-. A number of samples exceed the permissible concentration limits of the WHO standards. The predominant cationic and anionic sequence is $Ca^{2+} > Mg^{2+} > Na^+ > K^+$ and $NO_3^- > SO_4^{2-} > Cl^- > HCO_3^-$, respectively for the governorates Anbar, Babylon, Baghdad, and Basrah. Another sequence of cations indicates that $Na^+ > Ca^{2+} > Mg^{2+} > K^+$ for Dayala, Karbala, Kirkuk, Missan, Mothana, Najaf, Nineaw, Qadissiya, Salah Al din, Thi-Qar, and Wasit. Same governorates exhibited the anion sequence $SO_4^{2-} > Cl^- > HCO_3^- > NO_3^-$ (Fig. 4). The residual Na_2CO_3 values that are greater than zero may increase the Na hazard. Anionic bicarbonate (−) mainly interacts with Na or Ca to form $NaHCO_3$ or $CaHCO_3$ in the ground water and high aqueous HCO_3^- concentrations may lower other anions such as Cl^- or SO_4^{-2} and increases the water pH (Nagaz et al., 2012).

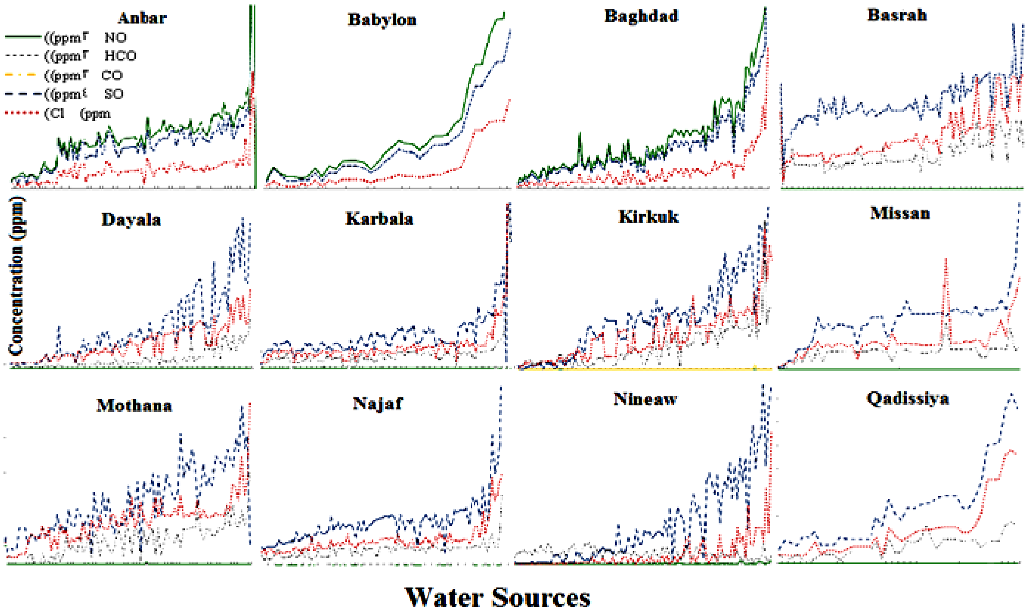


Figure 4: General behaviour of the soluble anions in the studied water resources in some Iraq Governorates

3.1 Agricultural Use Suitability

Many water samples can be suitable for irrigation and agricultural use as presented in Table 4 that showed a good Na% (20-40%), acceptable Mg% (<50%), excellent SAR (<10), and PI class 2 and 3 (Prasanth et al., 2012; Pamei et al., 2022). Most of the RSC values were suitable (<1.25) except of some Babylon samples that were not suitable (>2.5). Only Kirkuk and Nineaw showed some samples with negative CAI 1 and CAI2 referring to that the Na^+ and/or K^+ cations within the aquifer matter are replaced by aqueous Mg^{2+} and/or Ca^{2+} cations as indicated by Figure 8b and Figure 12b (Nagarajan, et al., 2010; Yehia, et al., 2021).

3.2 Suggested Solutions

The global climate change and regional environmental conditions necessitate miscellaneous optimization plans to adapt and mitigate their impacts since the removal of salts from the affected areas is costly. Some possible options include the utilization of salt-resistant plants, planting trees for wood production and carbon-credit, in addition to the investments in the hydroponic systems and aquaculture in salinised water. There is necessity to concentrate efforts using informative maps for managing salinity on the ground with time-adaptive management programs (Hill 2004; Salinity and Water Quality 2012; Kularatne 2001). Australia and Italy had presented funds for projects to prepare science-based plans for expanded investment regarding managing the water salinization in Iraq. The project partners included five Iraqi ministries, national research organizations and universities, and an international team of researchers, led by ICARDA. The Australia practice in managing the salinity with some agro-ecological similarity presents tools verified in Australia to be modified for the Iraq environment (Heaney et al., 2001; ICARDA, 2013; ICARDA, 2014).

Satellite imagery is an innovative approach to build up the remote-sensing salinity predictive modelling. Some of which are accurate by more than eighty percent being applicable to assess salinization of alike dry land conditions for an upcoming sustainable development (Wu et al., 2014; Raheem and Hatem, 2019). Sometimes, the significant salinity changes in Iraq are independent of the environmental conditions as accumulated salts in water or arid climate but dependent on the utilization and managing practices of the cultivated area by farmers. Therefore, quantification the salt-stressed allocations and their variations with time and place are of pressing importance. A diachronic salinity maps and analysis using multi-temporal remote sensing have been carried out for the Dujaila region in Iraq. Nevertheless, it is not easily to detect the salt concentrated in the subsoil by the optical remote sensing. Even for less saline topsoil (surface) <10–15% salts, it interferes with the soil constituents. Reflection is increased as the salt content increases at the topography surface with possible interference caused by ferric oxides that can lead to misinterpretation of salinity. Further site studies with better-qualified satellite images are still required to validate and improve the mapping and modelling (Wu et al., 2014; CharacMis et al., 2005).

3.3 In Agriculture

Salinity management (SM) is a significant challenge for rural communities, agricultural industries and the governments and there is an interest to evaluate the benefits and costs of SM programs. The Salinization of soil or water sources directly affects the agricultural productivity along with the regional economies. SM is often costly and time-consuming (Kularatne, 2001). High and sustainable agricultural productivity in a saline environment can be improved through two main approaches: either modulating the settings to fit the accessible plant typs or modify the plant types to fit the situated settings. Approaches may be applied independently or simultaneously to optimize the low-quality water use-efficiency. This could be achieved by suitable and sustainable technical intervention (Tyagi, 2003; Roy et al., 2014).

Improving of the managing strategies needs the study of the factors, which control the salinity/crop yield relationships depending on the growth stages. The plant development is inhibited by the excessive salt ions. They raise the osmosis pressure at the root zoon that decrease the available water and inhibits the germination giving small plant of low leaf-area index. Sodic water with relatively higher Na^+ and carbonate (CO_3^{-2} - HCO^-) affects the soil physical properties such as the infiltration and aeration (Fetouani et al., 2008). The high salinity of some water resources is sometimes considered critical for agricultural use when the salinity exceeds the tolerance plant levels. The impact of artificial pollution; whether it is agricultural, industrial or domestic, is insignificant with the increase in the fertilization and some agro-chemicals for increasing the agricultural yield (CharacMis et al., 2005).

3.3.1 Irrigation

The main purpose of managing the irrigation in many regions is to optimize the SM. Greater amounts of the saline water and more frequent irrigation are required than when good quality water is used. The irrigation regime significantly affected the water productivity of the carrots irrigated with saline water (Nagaz et al., 2012). Some farmers' practices included the saving of the rains in a quite levelled field and mixing the saline and/or alkaline with better quality water to maintain or ameliorate a suitable saline level. When residual Na_2CO_3 cannot be minimized to an accepted level, it is possible to dilute, blend or apply repeatedly, and schedule to irrigate at plant ages of lower sensitivity to salts. At the fields of quite higher water table, supply of the sub-surface drainage enables using highly saline water and reduces the general necessity to irrigate. For advanced irrigation systems, water use efficiency under salt stressed environments could be improved by a number of actions such as utilizing water for the higher-value crops of lower irrigation requirement and transferring the water adopting policies (Tyagi, 2003).

Optimization of the efficiency and sustainability of the irrigation as well as the fertilization programs increase the Water Use Efficiency WUE. For example, potassium deficiency reduces WUE in olive trees, sunflower plants, Faba beans, Sugar cane, and Rice. The productivity had been increased by Potassium Nitrate via the increase in WUE for Mango trees and Tomatoes. Nitrate combats chloride in the irrigation water, while toxic Na compete the K for enzyme binding groups. A suitable K/Na ratio in the plant is more significant than decreasing the Na content. Potassium Nitrate reverses the adverse effects of salinity on Greenhouse tomatoes, Chinese cabbage *(cv. Kazumi)* and lettuce *(cv. Salinas)* under salinity (Achilea, 2014).

3.3.2 Planting Trees

Planting trees in the right location can restrict the spread of salinity as well as provide some other valuable benefits such as shelter for stock, wildlife habitat, amenity and capital value, and firewood and fence posts. Some significant evidence is that trees will reduce the water table of saline seepages (areas that have saline water close to it or at the topsoils). Reducing the water-table height will not spread the salted area. Nevertheless, trees must be used in conjunction with other techniques especially drainage. Economically, the payback and expenses of planting trees sometimes provides indirect management of salinity. Planting trees to control the salinity in presence of a confined groundwater needs the assessment of the expected financial outcomes prior to consider cost-effectively applicable (Hill 2004; Riccobono et al., 2011; Nidzgorski and Hobbie 2016; Ilstedt et al., 2016).

3.3.3 Fertilization Programs

The program, which applies small doses of fertilizers frequently often, causes not as much of salt-stress of a program that applies two or three doses yearly. Controlled-release fertilizers as well as the regular Fertigation are options to limit the salt-stress due to the highly saline irrigating water. Selection of the source of the plant nutrients that exert a quite small osmotic pressure within the soil solution be capable to lessen the salt-stress. The problems of salinity are quickly declined as the accumulated salt leach by rains that minimize the role played by the fertilization technique. A fertilizer salt index quantifies how it is osmotically affecting the soil solution when it is soil-applied compared with the $NaNO_3$ index 100. The phosphorus (P) as well as the organio and slow-release fertilizers have lower salt index in comparison with the more dissolvable fertilizers. Some growers fertilize by pre-mixed materials.

High application doses of nutritive salts may disturb the nutrients equilibrium in soil. Managing the irrigation and fertilization with saline irrigation water necessitates regular evaluations of the water by an EC meter. The low-quality water is recommended to be used away of leaves in the high evaporative circumstances. Irrigation at night minimizes the evaporation to decrease the osmotic action of the concentrated fertilization salt. Doses of fertilizers with small salt-index shall be optimized to eliminate the unnecessary concentrations of nutrients in the soil or plant. Analysis of the leaf tissue can reveal the extreme Na or Cl contents, or nutrients deficiency resulted from the disturbed equilibrium caused by the salt-stress. The Na content > 0.25% or Cl > 0.5% alarms to a coming problem (GAMA Program 2010; Mahmood et al., 2013; Boman and Stover, 2012; Salinity in the Central Valley 2006; Shaw and Skorulski).

3.3.4 Agricultural Biotechnology

The main goal of studies concerning the salinity is to optimize the crops production efficiency under salinity stress comparable to their grow-efficiency under normal conditions. Some bio-technologic approaches may help this by gene engineering to improve the salinity resistance behaviour of plants depending on a number of genes (Biswas et al., 2019). The efficiency of these technologies may be examined by quantifying the plant productivity under salt-stress circumstances. Growing salt sensitive crops needs an EC < 700 μS/cm, while salt tolerant crops are required when the irrigation water is ≈ 5000 μS/cm (Roy et al., 2014; Shaw and Skorulski; Shrivastava and Kumar 2014).

Many strategies that are often utilized to cope with salinity conditions are costly and time-consume, which necessitate the development of instant uncomplicated and economic biologic strategies. Microorganisms possess unique properties like salinity tolerance, gene variety, creation of well-matched solutes, and fabrication of plant growth promoting hormones. *Bacillus, Pseudomonas, Pantoea, Paenibacillus, Burkholderia, Achromobacter, Azospirillum, Microbacterium,* etc. are some examples. Plant growth promoting bacteria have ameliorated the development of salt-stressed tomato, pepper, bean, and lettuce. Their bio-control role in the plant is through some mechanisms such as an agent induces a genetic compatibility to trigger the osmotic response and produce hormones and nutrients (Umesha et al., 2018; Omondi and Otieno, 2017).

A suitable biotechnology is to get better the crop yield and soil nutrients status by means of interactive plant roots/soil organisms' relationships. Microbial polysaccharides are capable to form macro- and micro-aggregates by binding the soil particles. The plant roots and fungal hyphens spread within the pores connecting the micro-aggregates leading to the stabilization of macro-aggregates. Treating plants by bacteria that produce Exo-poly saccharides (EPS) has improved the tolerance towards salinity and water stress by improving the soil structure. Additionally, the EPS could immobilize the Na^+ ions and restrict their absorption by plant from the soil solution. The rhizosphere microorganisms, especially the useful bacteria and fungi, are capable to reduce the plant pathogens thus enhance the plant performance and yield under stress environments.

Many plant growth-promoting rhizobacteria (PGPR) stimulate the plant maturity as they provide a nitrogen-fixation mechanism, soluble phosphate, phytohormones, and iron sequestered by bacterial siderophores. The nutrient uptake by plants may be enhanced through production of phytohormones like auxins, cytokinin's and gibberellins), by enzyme reduction of ethylene contents and/or by creation siderophores. The plant life is partially controlled by the biosynthesised ethylene concentrations. An indirect effect is the plant protection from some soil-borne diseases mostly attributable to the pathogenic fungi. Bacteria isolates obtained from a habitat under stress can be effective in the treatment of seeds by bacteria as they exhibited a stress tolerance capability along with the plant growth-promoting character. Inoculation of plants by such bacteria has improved the roots and shoots length, biomass, as well as the biochemically synthesized chlorophyll, carotenoids, in addition to the proteins.

The strategy of utilizing salt-tolerant crops is strongly recommended since the gene expression along with the protein synthesis patterns change under the saline conditions. The salt-tolerance behaviour of a plant (halophyte) and the difference in such behaviour among genotype species (glycophytes) of plant is based on a genetic salt response. The transgenic studies used to estimate the salinity stress tolerance are usually performed in lab or greenhouse conditions with controlled varieties of seeds or mature plant species. This may be less correlated to the salinity tolerance at the field and the high-salinity soils conditions. Some models of transgenic stress-tolerant plant species were successfully developed like tobacco, Arabidopsis or rice but additional trials are required. However, using the genetic engineering and plant breeding for developing a stress-tolerant-crop variety may be costly and time consuming. The use of a microbial inoculated plant species for stress alleviation may be an economic of a quick availability and an environment friendly option (Shrivastava and Kumar 2014).

3.4 In Industrial Applications

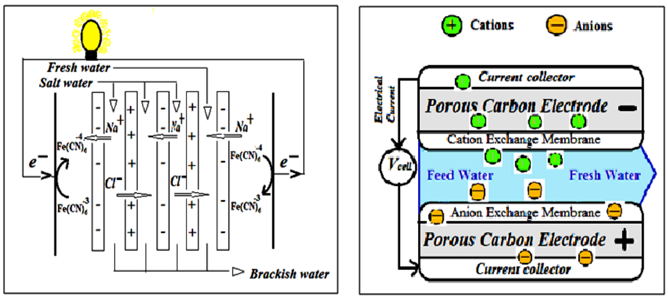
Deep saline formations (DSFs) represent the prime worldwide geologic store of the carbon dioxide (CO_2) (Celia et al., 2015; Mkemai and Bin, 2020). Formation water in the CO_2 reservoir can be extracted with variable low/high saline qualities. The water may be used for recovering the geothermal heat, salts, and/or minerals after removing the miscellaneous unnecessary substances. Some examples are the dissolved inorganic ions, dissolved gases (N_2, O_2, CO_2) methane, hydrogen sulphide, particulates (Sand, silt …etc), hydrocarbons (Crude oil as dispersed, colloidal, emulsified), dissolved organics (humic acids and fulvic acids) as well as the radioactive substance (radium, uranium) of natural occur. The use of tree bark is an effective method to monitor some contaminants (Shilu et al., 2011; Atekwana et al., 2004; Sulaymon et al., 2009; Achilea 2014; Riccobono et al., 2011).

Regulatory limits have been set in some countries such as the United States and Canada to protect the lowest-salinity water sources possibly a future source for the potable or drinking water (salts concentration < 10,000 ppm). The less-saline groundwater related to a gas or oil reservoir, perhaps not considered for potable water due to quality standards otherwise permitted for the CO_2 storages applications. The Energy & Environmental Research Centre have analysed the extraction of the formation water from the CO_2 storage reservoirs through a sponsored project in cooperation of the IEA Greenhouse Gas R&D Programme with the U.S. Department of Energy. The project agenda "Development of Storage Coefficients for CO_2 Storage in Deep Saline Formations" has presented the Average Global Database (AGD) with 20,938 records from 23 countries to estimate the CO_2 reservoir capacity. Treating the high TDS formation water sometimes may be eliminated due to the extreme cost. It possibly will be practical in definite site-specific circumstances for instance a mixture of low/moderate quality extracted water, economic energy is available, and adequate require of local water so that case studies are required (Klapperich et al., 2014).

3.5 Desalination Technologies

A public, economic, and technologic challenge is the sustainability of an available fresh water since the clean water is a basic human right still missed for one per seven persons worldwide. Increased extraction focusing on the groundwater results in cumulative salinity levels in the deep-water resources. Developing an economic desalination technology is significantly important. miscellaneous techniques have been introduced such as the distillation, reverse osmosis, forward osmosis, pressure retarded osmosis, magnetic and filtration treatment processes including nano-filtration, micro-filtration, ultra-filtration, Bio-Electro-remediation and electro-dialysis (Chandnani et al., 2022).

Reverse electro-dialysis (RED) is a technology for power generation via blending differed saline-water, **Figure 5**. Electricity could be generated by means of the salinity differences between two solutions for example seawater and river-water.). A RED cell consists of ordered number of alternated ion exchange membranes (having cation/anion selectivity) and partitions for seawater and river water. The salinity difference across the membrane types creates a potential difference. Connecting an external circuit to the system creates an electrical current resulted from a produced voltage (Kulkarni, 2017; Ramasamy et al., 2021). The voltage is increased by stacking multiple cells each one includes a cation exchange membrane (CEM), seawater partition, an anion exchange membrane (AEM) and a river water partition.



Reverse electro-dialysis (RED) mechanism **Capacitive Deionization (CDI) mechanism**

Figure 5: Principal mechanisms of the reverse electro-dialysis (RED) and the Capacitive Deionization (CDI) technologies

Electrodes at the two ends of the stack create redox-reactions result in the electric current generation capable of powering an external device. Additionally, it is possible to control the amount of power produced from the RED through the adjustment of the water-flow, particularly with the availability of a suitable reservoir for storing the freshwater. It is possible to store the energy produced via a salinity-gradient to use at a low level of the power production. The worldwide runoff of rivers' water into the seas can support some of the large-scale electricity require (Vermaasa et al., 2012). Regional water distribution systems (WDSs) are those that "utilize a single system for mixing and conveying multi-quality waters from different sources". They are frequently large-scale networks across a region possibly will convey raw water for non-drinking purposes including agriculture, domestic, industry, and the non-uniform needs for water quality (WQ). Studies have provided optimized designs and operations in these systems (Mala-Jetmarova et al., 2014).

The promise of the Capacitive Deionization (CDI) as a water desalination technique depends on the electrodes synthesized from the optimized porous carbon with a capacity to store salt' ions as well as save energy efficiently, Figure 5. The desalinated water is produced by means of an electric voltage difference between two porous electrodes to temporary immobilizes and/or remove cations and anions of salts in brackish water. This ‘‘electrochemical demineralization’’ also known as ‘‘electro-sorb process for desalting water’’ provides ion and electrons transportation with energy recovery. The main target is making such technologies cost-energy effective for the seawater deionization and for the brackish water of low or moderate salt content (10,000 ppm). Some techniques take out the water as a bulk phase the, from the saline constituents (Cuong et al., 2022; Chen et al., 2020).

The mentioned CDI technique utilizes multiple paired opposite-positioned electrodes in stacked assembly for storing ionic species upon application of an electric voltage difference. An electric double layer (EDL) is being formed in the interior of the intraparticle pores along with the immobilization of the selectively extracted salt ions from saline water. After some time, the electro-sorbed ions saturates pores' volume so that the device reaches its' capacity to store ions. The electrode(s) can be regenerated by releasing the ions from it's' exchange sites through the reduced or reversed voltage of the cell. The ions are then streamed as well as the electrode(s) recover its original capacity to adsorb ions. The procedure is physical free of any chemical reaction, so a CDI device serves a longer time and less maintained. Novel designs and materials are continuing to introduce an electrode optimized for the target regarding the performance (desalting capacities, final salt concentrations), and/or system requirements (flow rates, stacks construction), and/or costs considerations (efficiency, materials costs, duration) (Porada et al., 2013).

The nano-structured materials could be considered in water purification devices. Such materials exhibit larger relative surface areas and several advantages for water purification over the conventional micro-structured materials. They are interesting chlorine-free approaches safe from the carcinogenic by products possibly produced due to the interaction between the chloramines or chlorine and water (Narayan, 2010). A decreased temperature leads to an increased water density (freezing). As water freezes, salts and impurities separate from the molecular structure, so that iced water is a pure H_2O regardless the original solution is composed. The seawater salinity is possibly investigated using the electromagnetic wave measures of ice fraction (Hales et al., 2015). The sea-iced formulations nearby the Polar Regions are free of salt ions. Freezing the water molecules directs the salts into pockets of brine water isolates from the ice, leaves behind air pockets, and increases the salinity of the water adjacent the ice. Such saline water has higher density so that it sinks with the creation of a convection pattern capable to affect the ocean circulation hundreds of kilometres (Kalista et al., 2018).

The freeze desalination idea had been recognized since the 1950s based on the rule that the ice crystal structure cannot hold salt ions. The freezing water precipitates and departure behind a highly saline solution. The iced crystals can be recovered from a polluted solution continuously using filtration processes with no need to add "fresh water", for washing the crystals, or any chemicals then produce fresh water by melting the ice. Some advantages are that freezing is a thermodynamically efficient procedure; not sensitive to the constituting salts in the feed water; can be recovered as clean water but may be of high capital costs. Suitably, it may be cost effective for mining water (Circulating in mines). The freeze desalination is applicable for treating the industrial wastewater and can be aligned with other desalination methods for reducing the discarded briny water and producing a variety of salt types from seawater (El Kadi and Janajreh 2017; Shone and At, 1987; Michel et al., 2005; Freeze Desalination; Lu and Xu).

4. Conclusion

About 1242 site of water resource in Iraq from 15 governorates have been analyzed and the water Salinization is found to be a general phenomenon. Variations covered a broad range of pH, EC, TDS as well as types of the dissolved ions for the estimated resources that may indicate the presence of some organic contaminants. Some types of cations and/or anions are predominant and permit some applications. Many solutions may help in the management of the water Salinization in order to turn the disadvantages into advantages. Suitable management can use saline water resources for sustainable development taking into account the social health aspects. Agriculturally, planting trees, irrigation regimes, fertilization programs, and agricultural biotechnology are applicable technologies under salt stress conditions. Extracting the formation water from CO_2 storages, Reverse electro-dialysis (RED), multi-quality water distribution systems (WDSs), Capacitive Deionization (CDI), Nano-structured materials and freeze desalination are available industrial technologies. Matching a suitable application for a specific saline site may need case studies for the true assessment of the salinity management approach to be utilized economically, environmentally, socially and scientifically.

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