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Water Quality and Radionuclides Content Assessment of the Al-Najaf Sea: Case Study

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ABSTRACT

The Al-Najaf state is witnessing an increased economic development and attracting more investments that require the development of new areas and exploring new water resources. This study evaluates the quality of 12 surface water samples and groundwater from 12 wells for irrigation according to the salinity and sodicity hazards based on electrical conductivity (EC) and sodium adsorption ratio (SAR). In addition, the concentrations of radionuclides, which include Thorium (^{232}Th), Uranium (^{238}U), Potassium (^{40}K) and Cesium (^{137}Cs) were tested in four soil samples in the study area. It was found that the average values of pH, total hardness, Na, Ca, Mg, K, Cl, SO_4, NO_3 for groundwater and surface water were 8 and 6, 2287 and 4006 mg/L, 1140 and 1232 mg/L, 378 and 637 mg/L, 327 and 587 mg/L, 2 and 2 mg/L, 989 and 2007 mg/L, 1149 and 1325 mg/L, as well as 2 and 2 mg/L, respectively. From salinity and sodicity hazards analysis, the groundwater had EC of 5242 µS/cm and SAR of 61, whereas surface water had EC of 6253 µS/cm and SAR of 50. Furthermore, the concentrations of radionuclides, i.e. ^{232}Th, ^{238}U, ^{40}K and ^{137}Cs in the soil samples were found to be 11.02, 34.12, 544.45, and 1.6 Bq/kg, respectively. The concentrations of radionuclides were within the worldwide baseline, expect for ^{40}K. The study concluded that both water sources are classified as very high salinity and sodium water (class C4-S4), and it cannot be used for irrigation, only suitable for the salt tolerant crops.

Keywords: irrigation water; water quality assessment; salinity; sodicity; radionuclides; Al-Najaf Sea.

INTRODUCTION

Water is an essential resource for humans' consumption and irrigation. Due to increased urbanization and human population, agricultural and industrial expansions demand more water. Furthermore, the water supply is affected by the water characteristic, which is caused by anthropogenic activities including city expansion, industrial and agricultural growth, and natural processes like precipitation quantity, weather condition, and residue transport (Bouaroudj et al., 2019). Poor quality of irrigation water has adverse effects on crop production and its quality, as well as the public health of farmers and consumers who are directly involved with irrigation water. The water quality impact assessment is measured by the irrigation water effect on soil and crops. Monitoring the irrigation water quality is therefore essential to improve crop yield and soil condition under good management practices. Thus, special management practices are needed to overcome poor water and soil quality in order to increase crop production and yield (Etteieb *et al.*, 2017).

It was found that the primary drawbacks in irrigation water and soil are salinity, ion toxicity, and sodicity. The amount of soluble salts concentration in irrigation water that may affect crops is referred to as salinity. Toxicity indicates the crucial levels of chloride (Cl^-), boron (B^{3+}), sodium (Na^+) and certain trace elements, which have a negative effect on plant growth. Sodicity refers to the deterioration of soil structure due the presence of sodium in excess, which can reduce water diffusion to the soil (Zaman *et al.*, 2018b). In this regard, the United Nations Food and Agriculture Organization (FAO) has set the permissible limits of several quality indicators for water to be suitable for irrigation (Ayers & Westcot, 1985).

On the basis of the US Salinity Laboratory Staff (USSLS) (US Salinity Laboratory Staff, 1954) report, the data on electrical conductivity (EC) and sodium adsorption ratio (SAR) can be linked to a classification diagram of sixteen classes (C1-C4 and S1-S4) for the purpose of examining the suitability of water for irrigation. However, this classification diagram is only valid for EC below 2250 μS/cm. Since higher values of salinity is generally observed in the irrigation waters, Shahid SA and Mahmoudi H (2014) has modified the USSLS classification diagram to provide the water salinity at higher values equal to 30 000 μS/cm.

In Iraq, high demand for food security requires the development of new agricultural areas and new irrigation water resources. Unfortunately, most of the lands surrounding fresh surface water (the Tigris and Euphrates rivers) are used; thus, there is a need to develop new agricultural lands nearby to utilize alternative water resources such as lakes and marshes. Recently, the Al-Najaf state has been witnessing an increased economic development and attracting more investments. In this regard, several projects have been initiated in the Al-Najaf Sea area due to its strategic location and available resources. The Al-Najaf Sea is noted as one the essential wetlands which is located in the southwestern part of Iraq. Concurrently, the interest to the Al-Najaf Sea has increased in order to benefit from its surface water and groundwater sources. Consequently, it is important to identify the quality and suitability of the surface water and groundwater for irrigation and other consumption demands in this area. However, there are very limited reliable studies comprising the full assessment of the Al-Najaf Sea water resources quality, as well as radioactive elements in soil.

Thus, the intentions of this investigation were to examine the groundwater and surface water of the Al-Najaf Sea for its quality, and to evaluate their utilization for irrigation based on sodium adsorption ratio (SAR) and electrical conductivity (EC). Concurrently, the study aimed to determine the concentrations of radionuclides including Thorium (^{232}Th), Uranium (^{238}U), Potassium (^{40}K) and Cesium (^{137}Cs) in the soil samples.

MATERIALS AND METHODS

Study Area

The study area is the Al-Najaf Sea (Bahr Al-Najaf), located west of the Al-Najaf Governorate between longitudes 32°00'39.6"N & 44°13'53.2"E, as shown in Figure 1. The Al-Najaf Sea is considered one of the key depression wetlands in Iraq that is located in the lower parts of Iraq, in a region called the Middle Euphrates to the west of the Euphrates River, and 2 km west of the Al-Najaf city. Geologically, the Al-Najaf sea area is located within the boundaries of the Al-Salman subzone including the stable shelf. The exposed rocks are sedimentary rocks of the upper Quaternary and Cretaceous period. The area increases steadily from northeast to southwest 50 m every 10–15 km, whereas, it declines gradually from the southwest and west to the north east and north.

Currently, its lowland is filled with water due to the surface runoff during winter via wadies, effluents from industries, agriculture lands and fish farms via marshes, and flow of groundwater to the surface via wells. The area of study is characterized by some wades that discharge stormwater from the west and south-west to the east and northeast directions which is associated with the declined route of the regional topography. Additionally, the groundwater in the area is recharged from other depressions nearby and also from declined underground channels from Euphrates. The climate in the area is commonly sub-arid to arid with an average of humidity of 41%, wind speed of 10 km/hr, evaporation of 3483 mm/year, precipitation of 1.3 mm/year and temperature of 24°C.

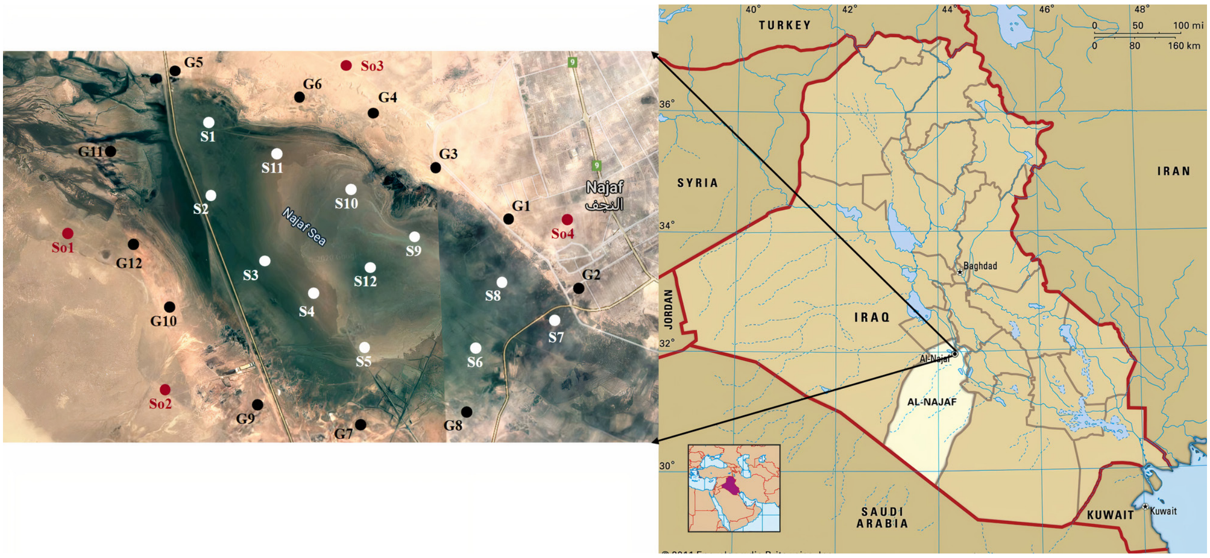

Figure 1. Al-Najaf Sea location

Sampling and experimental work

Twelve groundwater samples were frequently taken from twelve wells at 20 m depth, twelve surface water samples were frequently taken from the Al-Najaf Sea, and three soil samples were taken from the surrounding area. The water samples were collected monthly for examination from March 2019 to February 2020 to cover all four seasons, and only average values of 12 months were reported. In order to assess the quality of the ground and surface waters in the Al-Najaf Sea, the chemical characteristics were tested, including pH, EC, TH, Na^+, Ca^{+2}, Mg^{+2}, K^+, Cl^-, SO_4^{-2} and NO_3. The soil samples were also tested to determine the concentrations of radionuclides like ^{232}Th, ^{238}U, ^{40}K and ^{137}Cs.

Water quality evaluation

Many techniques have been applied for the quality criteria examination of irrigation water. In this study, the quality of irrigation water in the study area was examined by using the US Salinity Laboratory Staff (USSLS) classification (US Salinity Laboratory Staff, 1954). In this classification diagram, salinity and sodicity hazards are considered by incorporating the data on electrical conductivity (EC) and sodium adsorption ratio (SAR). The SAR is defined by the following equation (1) to measure the relative concentration of sodium ions (Na) to calcium ions (Ca) and magnesium ions (Mg).

$$SAR = \frac{Na}{\sqrt{\frac{Ca+Mg}{2}}} \quad (1)$$

According to the USSLS classification (US Salinity Laboratory Staff, 1954), the irrigation water sodicity can be categorized based on SAR, i.e. low hazard (SAR<10), medium hazard (10–18), high hazard (18–26) and very high hazard (>26). On the basis of the diagram of the USSLS classification, irrigation water is classified into four types C1, C2, C3 and C4 based on salinity hazard and S1, S2, S3, and S4 based on sodium hazard. However, the USSLS classification [5] diagram is only valid for EC below 2250 µS/cm. Since the value of water salinity is generally observed in the irrigation waters is higher than 2250 µS/cm, thus, Shahid SA and Mahmoudi H (2014) modified the USSLS classification diagram to accommodate higher water salinity values up to 30000 µS/cm. In addition, the total hardness (TH) of water (expressed as $CaCO_3$) can be computed by Eq. (2).

$$CaCO_3 = 2.5\,(Ca^{2+}) + 4.1\,(Mg^{2+}) \quad (2)$$

RESULTS AND DISCUSSION

Characteristic of surface water and groundwater

The water samples from 12 wells and 12 locations around the Al-Najaf Sea were tested for chemical characteristics, and the results are listed in Table 1, and compared with the permissible limits for surface irrigation water released by the Food and Agriculture Organization of the United Nations (FAO) (Ayers & Westcot, 1985).

pH. For groundwater, the water pH was varied from 6.8 to 8.3 (moderately alkaline) within the permissible limits. The alkaline level of groundwater reflects relatively higher concentrations of bicarbonates, indicating a limestone and gypsum aquifers in the area of the Al-Najaf Sea. In contrast, the surface water pH ranged from 5.1 to 6.8 (moderately acidic) with 75% of the samples slightly below the permissible limits. This might be due to anthropogenic activities like fish farming and use of nutrients, breakdown of organic substances, and high surface water temperature. The irrigation water with poor pH values can cause the potting material to become too acidic which then can restrict the plant root growth, leading to rapid breakdown of fertilizers, and nutrients deficiency caused by excessive rinsing of phosphorus, potassium, magnesium, aluminum and iron (Zhao *et al.*, 2013). On the other hand, a pH value of less than 6 occurs so often in nature that is considered as neutral. However, since the soil can alter the water pH and majority of crops have pH tolerance at a wide range of water pH [3], thus the pH of irrigation water is not a reliable parameter for water quality.

Total hardness (TH). Water hardness (expressed as $CaCO_3$) shows the presence of metallic cations (Ca^{2+} and Mg^{2+}), and it can be calculated using Eq. (2). The TH showed that both water sources are very hard according to total hardness classification of water by US Environmental Protection Agency (US EPA) (1986), as listed in Table 2. High levels of TH do not cause health risk; however, it is considered as an undesirable feature in water. The observed high TH in both

Table 1. The Chemical characteristics of ground and surface waters

		PH	Total hardness (mg/L)	Na (mg/L)	Ca (mg/L)	Mg (mg/L)	K (mg/L)	Cl (mg/L)	SO4 (mg/L)	NO_3 (mg/L)
Permissible limit [4]		6.5–8.4	1250	207	400	61	78	106	960	30
Groundwater	G1	6.9	2162	1132	320	331	2.2	721	820	2.1
	G2	6.9	1308	1060	321	123	2.2	715	849	2.3
	G3	6.8	2863	1330	591	337	2.6	1608	1897	1.5
	G4	8	2346	1130	318	377	2.1	715	816	2
	G5	8.1	1675	1050	303	223	2	700	822	2.1
	G6	7.5	2976	1300	590	365	2.4	1595	1784	1.4
	G7	8	2300	1130	293	381	2.1	712	810	1.9
	G8	8.2	1947	1000	300	291	1.9	699	821	2
	G9	7.8	2905	1228	517	392	2.3	1508	1777	1.3
	G10	8.1	2314	1119	267	400	2.1	710	800	1.8
	G11	8.3	1894	1000	267	298	1.9	682	820	1.9
	G12	8.1	2758	1200	445	400	2.3	1508	1770	1.2
	G Avg.	8	2287	1140	378	327	2	989	1149	2
	G (%)*	0	100	100	33	100	0	100	33	0
Surface Water	S1	5.2	3604	1056	665	472	1	2202	1339	2.2
	S2	5.1	3462	1191	643	451	1.6	1786	1186	2.5
	S3	5.1	3714	1200	645	511	3.8	2344	1874	2.3
	S4	5.8	4110	1394	675	589	2.45	2035	1264	2.1
	S5	5.2	4187	1411	727	576	1.3	1756	1184	2.5
	S6	5.4	4598	1505	712	685	3.3	2132	1639	2.2
	S7	5.8	4869	1512	796	700	2.9	2173	1116	2
	S8	6.3	4556	1478	692	687	2.2	1785	1482	2.45
	S9	6.2	4504	1299	658	695	3.2	2026	1629	2.1
	S10	6.8	3712	980	527	582	2.8	2112	1109	1.9
	S11	6.5	3560	908	456	588	2	1708	1079	1.35
	S12	6.4	3190	852	445	505	3.2	2020	1004	2
	S Avg.	6	4006	1232	637	587	2	2007	1325	2
	S (%)*	83	100	100	41	100	0	100	100	0

water sources is related to the main soil types in the area investigated, where limestone and gypsum are the most dominant formations.

Cations content. Sodium (Na^+), calcium (Ca^{2+}), magnesium (Mg^{2+}) and potassium (K^+) are the primary soluble mineral cation salts. Figure 2 shows the total ionic content fraction (%) for both water sources. For groundwater and surface water, the concentrations of Na, Ca, Mg, and K were in the following ranges: 1000–1300 mg/L and 852–1512 mg/L, 303–591 mg/L and 445–796 mg/L, 132–400 mg/L and 451–700 mg/L, and 1.9–2.6 mg/L 1–3.8 mg/L, respectively. For both water sources, Na^+ was the most dominating cation, compared to a moderate content of Ca and Mg and trace level of K. Na was the most dominant soluble cation, followed by a moderate content of Ca and Mg, and trace level of K. The percentage of samples exceeding the permissible limits for groundwater were Na^+ (100%), Ca^{2+} (33%), Mg^{2+} (100%) and K^+ (0%); while for surface water were Na^+ (100%), Ca^{2+} (41%), Mg^{2+} (100%) and K^+ (0%).

When sodium levels become excessive, compared to Ca and Ma proportion, soils are called sodic. High Na content increases soil swelling and aggregate breakdown due to clay soil dispersion, thus causing soil structure degradation and water penetration problems. In contrast, the soil can be easily tilled with easily permeable granular structure when both Ca and Ma are predominantly cations adsorbed onto the soil medium. Additionally, excessive absorption of Na concentration by plants is toxic, which appears in the form of leaf damage (Zaman *et al.*, 2018b).

Table 2. Classification of water according total hardness

Term	Degree of Water Hardness
Soft	0 < TH ≤ 75
Moderately hard	75 < TH ≤ 150
Hard	150 < TH ≤ 300
Very hard	300 < TH

Anions content. Chloride (Cl^-), sulfate ($SO4^{2-}$) and nitrate (NO_3^-) are the major soluble mineral anion salts. For groundwater, SO_4 (29%) was the dominant soluble anion followed by Cl (25%); whereas for surface water, opposite trend was observed where Cl (35%) was the most dominant soluble anion followed by SO_4 (23%). The concentration of SO_4 was in between 8000–1897 mg/L and 1004–1874 mg/L, exceeding the threshold by 33% and 100%, for groundwater and surface water, respectively.

For both water sources, all of the Cl content was above the permissible limit, showing high a very high Cl concentration > 106 mg/L, which is classified as a serious problem. High Cl concentration in surface water may be due to the dissolution of gypsum soil and industrial effluent discharge in the area. High Cl content is alarming and considered as a major factor effecting the growth and yield of the crops. At low concentrations, Cl is an important element for plant growth, but at high concentration may be toxic. Even moderately tolerant plants are harmed by the Cl concentrations between 140 and 350 mg/L. These

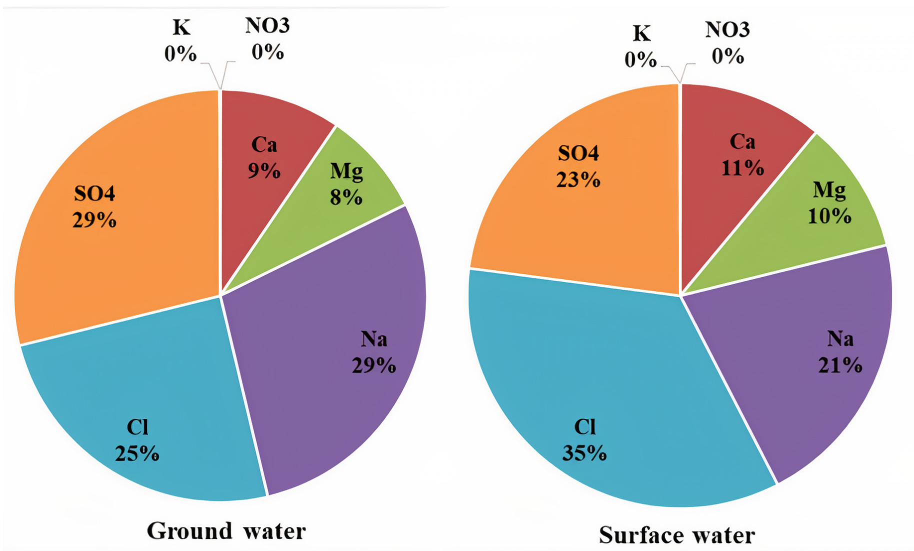

Figure 2. Total ionic content fraction for both water sources

levels can lead to immediate root and leaf intake chloride toxicity (Bouaroudj *et al.*, 2019).

The NO_3 concentrations were low (<30 mg/L) for both water sources, and classified in the class 'no problem' according to FAO (Ayers & Westcot, 1985). NO_3 is generally a product of fertilizer application, if high nitrate and bicarbonate are present, a disruption of the absorption process of iron (Fe) and other nutrients in crops may occur (Shahabi *et al.*, 2005).

Salinity and sodicity hazards of surface and ground waters

Salinity and sodicity are important water quality parameters for the environmental values of water resources (including potential beneficial uses). In order to examine the quality of irrigation water, the USSLS classification (US Salinity Laboratory Staff, 1954) has taken into account the salinity and sodicity hazards coupled with electrical conductivity (EC) and sodium adsorption ratio (SAR) data. The EC and SAR values for both water resources compared with the permissible limits by FAO (Ayers & Westcot, 1985) are shown in Table 3, and water quality evaluation according to the USSLS classification (US Salinity Laboratory Staff, 1954) is shown in Figure 3.

Sodium adsorption ratio (SAR). The calculated values based on equation (1) were in the range (59–71) and (39–57) for groundwater and surface water, respectively. All SAR values exceeded the permissible limits by FAO (Ayers & Westcot, 1985). Relatively high concentration of Na to the concentrations of Ca and Mg results in higher SAR. While Na directly contributes towards the total salinity content and possible toxicity to vulnerable plants, its high concentration effect on the soil physical properties is a major issue. Continuous irrigation with high SAR may impress the soil permeability, leading to an infiltration problem. The excessive amounts of colloidally adsorbed Na break down the soil physical structure, leading to rigid and dense soil when it is dry and gradually becomes impenetrable to water infiltration. It is important to note that when sandy soils are irrigated with high SAR water, it is not easily depraved as compared to other type of soils [3].

According to the USSLS classification (US Salinity Laboratory Staff, 1954) showed in Figure 3, both water sources are classified as very high salinity and sodium water (class C4-S4). C4 indicated that this water is suitable for irrigation of salt tolerant crops. High rates of salinity decrease the growth of plants and makes water adsorption via plant roots difficult. This is due to high osmotic water pressure resulting from high water soluble ions at plant roots. In order to ensure the substantial leaching , it is essential to have penetrable soils and adequate drainage. S4 showed that this water is unacceptable for the irrigation purposes, but acceptable at medium or low salinity. In this study, sodicity class S4 irrigation water is still possible to be used where the soil water solution contains high Ca or it can be applied to irrigate gypsum soil (Bouaroudj *et al.*, 2019).

Electrical conductivity (EC). EC is used to show the overall soluble salts concentration which may indicate salinity hazard in irrigation water. The key element for soluble mineral salts are anions (chloride (Cl^-), sulfate ($SO4^{2-}$), bicarbonate (HCO_3^-), carbonate (CO_3^{2-}), and nitrate (NO_3^-)) and cations (sodium (Na^+), calcium (Ca^{2+}), magnesium (Mg^{2+}), potassium (K^+)) (Zaman *et al.*, 2018a). It was found out from Table 3 that EC recorded a very high value of more than 3000 µS/cm for both types of water, representing a "serious

Table 3. The SAR of ground and surface water sources

		G1	G2	G3	G4	G5	G6	G7	G8	G9	G10	G11	G12	G avg.	Permissible limit [4]
Ground water	EC (µS/cm)	3978	3872	7642	4045	3913	7841	4045	3932	7941	4045	3953	7900	5242	3000
	SAR	63	71	62	61	65	59	62	58	58	61	59	58	61	25
		S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S avg.	Permissible limit [4]
Surface water	EC (µS/cm)	4744	4454	5194	5934	6836	7225	7992	7887	6940	6000	5877	5955	6253	3000
	SAR	44	51	50	55	55	57	55	56	50	42	40	39	50	25

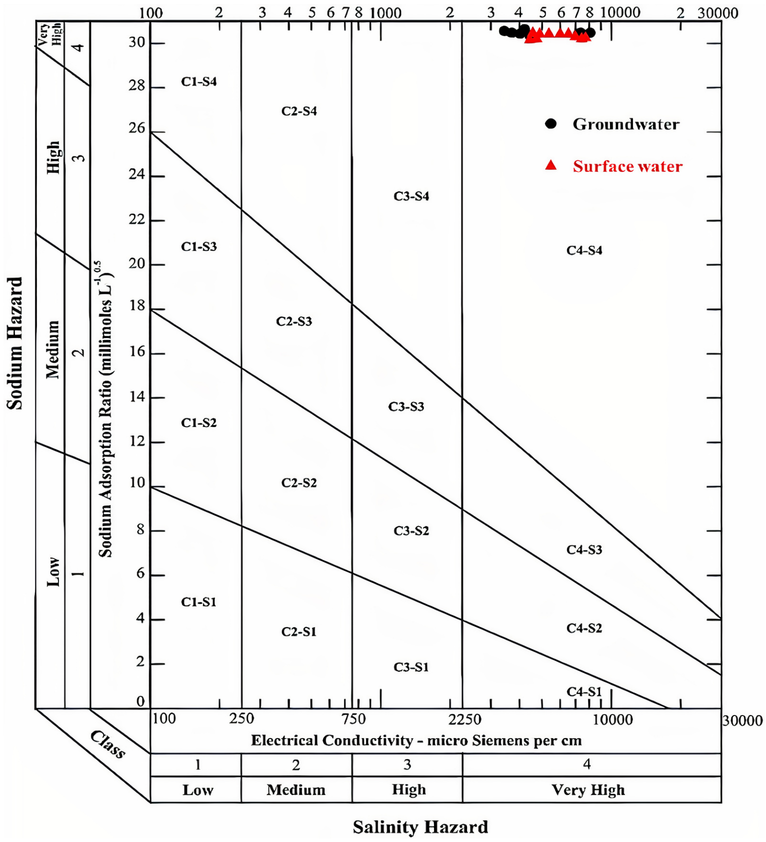

Figure 3. Diagram for the classification of irrigation water according to the USSLS classification

problem" class for the irrigation water. In comparison, the surface water had higher concentration of EC than the groundwater, suggesting that the groundwater in the Al-Najaf Sea area is less harmful to be used for irrigation. High saline contents in surface water might be due to the evaporation of water. Moreover, both water sources are considered moderately saline water according to the saline water classification by FAO (Rhoades, 1992), as tabulated in Table 4.

Although soil may contain water, high EC concentration can make accessible water for plants is less. High concentration of EC makes plants unable to compete for water with other ions in the soil solution. As the EC concentration rises significantly, unusable plant water in the soil solution can be noticed, since plants only absorb pure water from the soil (Bauder *et al.*, 2011). According to the EC results, both water sources are mostly suitable for irrigation of medium and salt tolerance crops. A comparison can be made to the reported data (Ghalib *et al.*, 2019), as shown in Table 5.

Radionuclides content

The sources of radionuclides are natural background radiation and anthropogenic. Due to the ionizing radiations emission from different sources, soils may contain natural radionuclides like Thorium (^{232}Th), Uranium (^{238}U) and Potassium (^{40}K), and substantially man-made radionuclides

Table 4. Classification of saline water sources

Water class	Electrical conductivity (μS/m)	Salt concentration (mg/L)	Type of water
Non-saline	< 700	< 500	Drinking and irrigation water
Slightly saline	700 – 2000	500 – 1500	Irrigation water
Moderately saline	2000 – 10000	1500 – 7000	Primary drainage water and groundwater
Highly saline	10000 – 25000	7000 – 15000	Secondary drainage water and groundwater
Very highly saline	25000 – 45000	15000 – 35000	Very saline groundwater
Brine	> 45000	> 45 000	Seawater

Table 5. Relative tolerances of crops to salt concentrations

Crops Division	Low salt tolerance crops Ec (μs /cm)	Medium salt tolerance crops Ec (μs /cm)	High salt tolerance crops Ec (μs /cm)
Fruit Crops	0 – 3000 Limon, Apricot, Orange, Apple. Pear, Peach	3000 – 4000 Olive, Figs, Cantaloupe, Pomegranate	4000- 10000 Date palm.
Vegetable Crops	3000 – 4000 Green beans, Celery, Radish.	4000 –10000 Cucumber, Onion, Carrot, potatoes, lettuce Tomato, Cauliflower.	10000–12000 Spinach, beets
Field Crops	4000 – 6000 Fields beans	6000- 10000 Sunflower, Flax, Corn, Rice. Sorghum	10000- 16000 Cotton, Sugar beet, Barley (grains)

such as Cesium (^{137}Cs). Table 6 shows that the average concentrations of ^{232}Th, ^{238}U, ^{40}K and ^{137}Cs in the soil samples from four sites around the Al-Najaf Sea area were 11.02, 34.12, 544.45, and 1.6 Bq/kg, respectively. They were compared with baseline estimated worldwide by the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) (UNSCEAR, 2000). According to the external exposure rates of natural radionuclides in soil (UNSCEAR, 2000), the concentrations of Th^{232} and 50% of U^{238} samples were within the limits, whereas 50% of U^{238} samples and all of K^{40} samples exceeded the limits.

In a uranium mine in Abu-Skhair Province in the Najaf State in Iraq, Al-Gazaly *et al.* (2014) reported that the average concentrations of ^{232}Th, ^{238}U and ^{40}K were 9.36, 77.33 and 426.31 Bq/kg, respectively. The content of ^{238}U was higher than the value reported in this study due to the nature of the study area, whereas ^{40}K was lesser and ^{232}Th was similar. This might be due to the type of surrounding mineral, chemical structure of the rock, groundwater flowrate, and ions holding in soil (Jadiyappa, 2018).

In the soil samples from the Salah Aldeen State (north-west of Baghdad) in Iraq, a study by Shaker M. Al-Jobori *et al.* (2013) reported that the concentration of Th^{232}, U^{238}, K^{40} and Cs^{137} were 15.83, 56.28, 323.61 and 4.43 Bq/kg. The concentrations of Th^{232}, U^{238} and Cs^{137} were slightly higher that these reported in this study, while the concentrations K^{40} were lower. The main variation in the Cs^{137} concentration is due to the changes in the soil structure by the human activity. ^{137}Cs is bound in the soil surface layers, washed away and redeployed into ecosystem. ^{137}Cs was found in the environment mostly as a result of the nuclear weapons activities and the Chernobyl nuclear plant accident in 1986. (Jadiyappa, 2018). The concentration of Cs^{137} is expected to be less towards the southern hemisphere, which was also proven by this study as the Al-Najaf Sea area (South-west of Baghdad) is south of Salah Aldeen State.

From 1990 to 2000, Iraq has recorded increased birth defects from 3.2 cases per 1,000 births to 22 cases per 1,000 births. For instance, Basrah (south of Iraq) recorded the birth of 300 deformed children within 2005, this is as a result of the US attach with nuclear weapons during the gulf war in 1990. In 2018, Ahmed *et al.* (2018) reported that Abu Al Khasib and Ad Dayr in Basra had average activity concentration of ^{238}U of 43.56 and 35.53 Bq/kg, ^{232}Th of 19.39 and 20.33 Bq/kg, 321.76 and 337.02 Bq/kg, respectively. In comparison, the levels of ^{238}U and ^{232}Th were much higher than these reported in our study. Such health defects might be associated with people's exposure to uranium. Uranium is found at changing low concentration in soil, food, water, and air. The people who consume the yields farmed in contaminated soil and live nearby hazardous locations may suffer a stronger exposure

Table 6. Radionuclides concentration in four sites around AL-Najaf Sea area

	^{232}Th**		^{238}U**		^{40}K**		^{137}Cs*
	Bq/kg	mg/L (ppm)	Bq/kg	mg/L (ppm)	Bq/kg	mg/L (%)	Bq/kg
Radionuclide content [14]	30		35		400		51
So1	12.2	3.00	28.9	2.34	577.1	1.84	1.8
So2	10.1	2.48	29.3	2.37	533.6	1.70	1.3
So3	8.3	2.04	38.2	3.09	517.1	1.65	1.7
So4	13.5	3.31	40.1	3.24	550	1.75	1.6
Average	11.02	2.71	34.12	2.76	544.45	1.73	1.6

than other people. Accordingly, constant exposure to radioactive decay of uranium causes higher health hazards than enriched uranium, as this form of uranium emits harmful radiation (Abojassim & Mohammed, 2017; Abojassim *et al.*, 2019).

According to the "soil–plant–animal-human" chain, plants are the main recipients of radioactive contamination to the food chain, where plant root systems absorb the radionuclides from the soil, resulting in ingestion exposure. The absorption of radionuclides from the soil by plant roots depends not only on the physiology of plant roots but also on processes in the soil (UNSCEAR, 2000). High concentrations of radionuclides may gradually accumulate in the food chain, causing health hazards and may lead to serious diseases like cancer in human being. However, the values of radionuclides in this study are still within the acceptable limit and no contamination may occur.

CONCLUSION

The quality of groundwater and surface water of the Al-Najaf Sea has been successfully evaluated. The available water resources can support the development of the area to some extent, and supply water of low quality. Total hardness showed that both water sources are very hard due to the main soil types of limestone and gypsum in the area. High content of anions (Cl and SO_4) compared to cations (Na, Ca, and Mg) characterized both water sources, whereas the magnitude of ions in groundwater were in the order of SO_4 > Na > Cl > Ca > Mg, and in surface water they were in the order of Cl > SO_4 > Na > Ca > Mg. According to the USSLS classification, the evaluation of salinity and sodicity hazards based on EC and SAR indicated that both water sources are classified as very high salinity and sodium water (class C4-S4). The groundwater had lower salinity and higher sodicity compared to surface water. However, both water sources are considered highly saline and mostly suitable for the irrigation of salt tolerant crops. Regarding the radionuclide content in the soils of the Al-Najaf Sea, the average concentrations of ^{232}Th, ^{238}U, ^{40}K and ^{137}Cs area were 11.02, 34.12, 544.45, and 1.6 Bq/kg, respectively. The measured values were within the worldwide average baseline, except for ^{40}K. However, the radionuclide content does not present any health hazards at this level.

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