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Ecological Risk Assessment of Drinking Water Quality: Salinity and Heavy Metal Contamination and Their Implications for Kidney Health in Basrah, Iraq

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ABSTRACT

Aims: The purpose of the present study was to investigate the possible association between drinking water salinity, heavy metal contamination, and kidney-related health disorders among residents of Basrah Governorate, southern Iraq.
Materials & Methods: Electrical conductivity (EC), salinity, lead (Pb), and cadmium (Cd) were determined in 24 water samples collected from four sites in Basrah Governorate during the summer and winter seasons. In addition, 10 blood samples were analyzed from patients with renal failure to evaluate renal function biomarkers and electrolyte balance. Also, 58 respondents filled out a structured questionnaire on sources of drinking water as well as kidney-related health conditions.
Findings: Electrical conductivity ranged from 40 to 76,500 $\mu S.cm^{-1}$, salinity from 0.044 to 53,550, lead concentrations from 0.071 to 1.153 $mg.L^{-1}$, and Cadmium concentrations from not detected (ND) to 0.437 $mg.L^{-1}$, with some measurements above international guideline values. The serum creatinine values of the patients studied ranged from 2.6 to 19.0 $mg.dL^{-1}$ and the blood urea values from 30 to 150 $mg.dL^{-1}$. Results of the questionnaire showed that tanker water was the major source of drinking water (63.8%), and most of the respondents reported kidney-related health problems for which they sought medical treatment.
Conclusion: The results suggest a possible correlation between deteriorating drinking water quality, especially salinity and heavy metal contamination, and renal health problems in Basrah Governorate. However, due to the small blood sample size and the cross-sectional nature of this study, larger epidemiological studies with appropriate control groups are needed to confirm these findings. Better water management strategies should be implemented, and drinking water quality should be continuously monitored to reduce possible risk for public health.

Keywords: Basrah; Cadmium; Drinking Water; Lead Pollution; Renal Dysfunction; Salinity.

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Introduction

The world's freshwater resources have been under increasing pressure and have now become one of the most serious environmental problems of the last few decades. Rapid population growth, climate variability, urbanization, and industrial development are driving up global water demand. Consequently, in many regions the utilization of fresh water now exceeds the rates of natural recharge, with serious implications for water security and long-term sustainability [1].

The Shatt al-Arab River is the main surface water source for the Basrah Governorate in the southern part of the country. The river system supports important activities such as drinking water supply, agriculture, fisheries, and domestic use. However, in recent decades the Shatt Al-Arab has suffered progressive deterioration in water quantity and quality due to reduced upstream discharge, wastewater discharge, agricultural runoff, and industrial pollution [2].

Heavy metal contamination is considered one of the most serious threats to aquatic ecosystems because of its persistence, toxicity, and bioaccumulation in living organisms. However, heavy metals are non-biodegradable and may persist in the environment for extended periods, unlike organic pollutants. Research in southern Iraq has found toxic metals such as cadmium and lead in the Shatt Al-Arab River, indicating continued threats of environmental exposure [3].

The kidney is one of the most sensitive organs for chronic heavy metal exposure. Cadmium exposure is known to be associated with tubular dysfunction and progressive renal damage, and lead exposure has been associated with hypertension, nephropathy, and decline in renal function. Thus, prolonged exposure to contaminated water sources may play a major role in the burden of chronic kidney disease in exposed populations [4]. In addition to chemical contamination, increasing salinity is another major issue concerning water quality in Basrah. The salinity of the Shatt Al-Arab River has increased considerably as a result of the intrusion of seawater from the Arabian Gulf and the reduction of river discharge and the saline return flows from the drainage system. In the present study, the electrical conductivity (EC) ranged from 40 to 76,500 $\mu S.cm^{-1}$. On the contrary, salinity varied from 0.044 to 53,550 $mg.L^{-1}$ at sampling sites, showing a significant deterioration of water quality and stressing the environmental relevance of salinity in the studied area. [5]. High salinity and high Sodium intake have been associated with hypertension and adverse renal outcomes in susceptible individuals [6].

International evidence suggests that the composition of drinking water has an important role to play in kidney health. High Sodium and fluoride concentrations in drinking water have been significantly associated with increased prevalence of chronic kidney disease in several regional studies [7,8]. These results point to the potential interplay of multiple water contaminants in impacting kidney function. Unsafe drinking water continues to be a significant global public health burden. The World Health Organization estimates that unsafe water, sanitation and hygiene are responsible for hundreds of thousands of deaths every year, mainly from diarrhoeal diseases in children [9]. In addition to infectious diseases, chronic conditions including hypertension, skin conditions,

Table 1) Physicochemical factors and concentrations of lead (Pb) and cadmium (Cd) in water samples collected from the study areas during summer and winter seasons.

Site	Season	Sample Type	Electrical Conductivity ($\mu S.cm^{-1}$)	Salinity ($g.L^{-1}$)	Cadmium Cd ($mg.L^{-1}$)	(Lead) Pb ($mg.L^{-1}$)
Al-Zubair	Summer	Drinking Water	98.4	0.062	0.003	0.105
		Tap Water	1493.0	0.700	0.001	0.111
		River Water	72300.0	56.700	0.251	0.223
	Winter	Drinking Water	401.0	280.000	0.003	0.112
		Tap Water	1328.0	929.000	ND	0.153
		River Water	76500.0	53550.000	0.437	1.153
Al- Faw	Summer	Drinking Water	68.9	0.0440	0.006	0.166
		Tap Water	5230.0	3.200	0.009	0.160
		River Water	60000.0	45.600	0.191	0.789
	Winter	Drinking Water	40.0	28.000	0.003	0.071
		Tap Water	9110.0	6377.000	0.009	0.076
		River Water	39200.0	27440.000	0.142	0.538
l- Ashar	Summer	Drinking Water	210.0	0.130	0.005	0.151
		Tap Water	6270.0	3.900	0.010	0.157
		River Water	36600.0	25.900	0.081	0.378
	Winter	Drinking Water	47.2	33.000	0.001	0.130
		Tap Water	5180.0	3626.000	0.006	0.299
		River Water	28800.0	20160.000	0.120	0.461
Al-Qurna	Summer	Drinking Water	83.9	0.053	0.007	0.160
		Tap Water	2010.0	1.000	0.011	0.149
		River Water	2520.0	1.300	0.003	0.151
	Winter	Drinking Water	97.9	68.000	0.005	0.201
		Tap Water	3410.0	2387.000	0.001	0.143
		River Water	2570.0	1799.000	0.002	0.137

Note: ND (not detected)

and kidney disease have also been linked to long-term exposure to contaminated water [10]. Despite the severe deterioration of water quality in Basrah, previous studies have mainly focused on environmental monitoring of salinity and heavy metal contamination, with little attention to their combined impact on human renal health. In addition, most published studies have investigated water quality or clinical outcomes separately, without combining environmental data, blood biochemical analysis, and questionnaire-based health assessments. Therefore, the present study was designed to combine these complementary approaches to provide a more comprehensive evaluation of the potential association between drinking water quality and kidney-related health problems among residents of Basrah Governorate, southern Iraq.

Materials & Methods

Study Design

This cross-sectional study was conducted in Basrah Governorate, southern Iraq, to investigate the possible association between drinking water quality and renal health disorders. The study encompassed environmental monitoring of drinking water, laboratory analysis of blood samples, and a structured questionnaire survey. Water quality parameters were assessed in samples collected during the summer and winter seasons. Clinical laboratory investigations were performed on blood samples from patients with renal failure. At the same time, residents were surveyed to collect data on drinking water sources, water consumption patterns, and kidney-related health conditions.

Study Area

Four study sites were chosen in Basrah Governorate to represent diverse environmental settings and potential sources of drinking water contamination. The sites selected were Al-Zubair (industrial desert area), Al-Faw (coastal area affected by seawater intrusion), Al-Ashar (urban area), and Al-Qurna (agricultural-marshland area). These sites represent the main environmental conditions throughout Basrah and were selected due to the variation in industrial activities, urbanization, agricultural impact, and salinity levels. The locations of the sampling sites are shown in Figure 1.

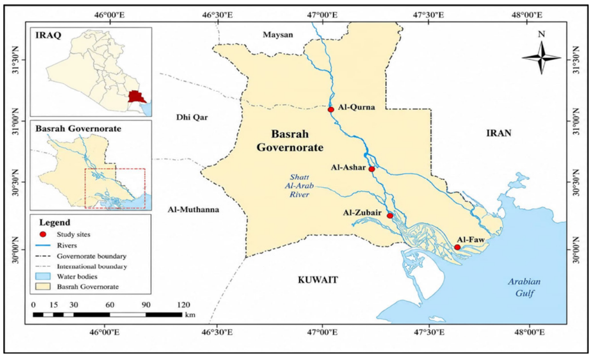

Figure 1) Map of the study sites in Basrah Governorate, southern Iraq, including Al-Zubair, Al-Faw, Al-Ashar, and Al-Qurna.

Water Sampling

In the summer and winter seasons, a total of 24 drinking water samples were collected from four study sites in Basrah Governorate. Samples of river water, tap water, and reverse osmosis (RO) water were collected at each site in sterile 100 mL polyethylene bottles. The bottles were rinsed with the respective water before sample collection and properly labeled and transported to the laboratory under appropriate conditions. Water samples were then analyzed for electrical conductivity (EC), salinity, and selected heavy metals including lead (Pb) and cadmium (Cd) according to standard analytical procedures.

Water Analysis

Electrical conductivity (EC), salinity, and total dissolved solids (TDS) were measured using a WTW Cond 315i multiparameter meter (Germany). The concentrations of Lead (Pb) and Cadmium (Cd) were determined by an Atomic Absorption Spectrophotometer (PG-990, United Kingdom). Before analysis, the instrument was calibrated with certified standard solutions, and all measurements were done according to the manufacturer's instructions and standard laboratory procedures.

Blood Sampling and Laboratory Analysis

A total of ten venous blood samples (5 mL each) were collected from patients with renal failure after obtaining their informed consent. Participants were recruited by convenience sampling from a healthcare institution in Basrah Governorate. Qualified medical personnel collected blood samples using sterile serum separator tubes (SST) under standard aseptic conditions. The samples were sent to the laboratory, where they were centrifuged to obtain serum and analyzed under standardized laboratory conditions.

Serum creatinine, blood urea, Sodium, potassium, chloride, calcium, and magnesium concentrations were determined by a Mindray BS-230 automated clinical chemistry analyzer (Mindray, South Korea). Samples were analyzed after standard internal quality-control procedures were performed according to the manufacturer's instructions.

Inclusion and Exclusion Criteria

Inclusion criteria were: confirmed clinical diagnosis of renal failure, age of an adult (≥18 years), voluntary agreement to participate in the study, and signing the informed consent. Patients who did not have complete clinical or laboratory records and those who refused to participate were excluded from the study.

Questionnaire Survey

A structured questionnaire was given to 58 adult residents of Basrah Governorate who volunteered to participate in the study. The questionnaire included demographic characteristics, main drinking water source, water consumption patterns, duration of residence, previous history of kidney disease, chronic diseases, and kidney-related health complaints. Before implementation, the questionnaire was reviewed by specialists for content validity.

Statistical Analysis

Descriptive statistics were analyzed using MS Excel. Quantitative data are presented as minimum and maximum values, and questionnaire data are presented as frequencies and percentages.

Findings

Water Sample Analysis

The study took place in four localities. Table 1 presents the results of water sample analysis from three study sources.

To assess the quality of water in the studied areas, a set of physical and chemical tests was done on some water samples collected from different parts of Basra Governorate, including Al-Zubair, Al-Faw, Al-Ashar, and Al-Qurna. Sampling was performed in both summer and winter seasons. The analyses focused on key indicators that reflect the characteristics of water and its suitability for human consumption.

The results included measurements of electrical conductivity (EC) and salinity, which are indicators of the concentration of dissolved salts in water. Furthermore, the levels of heavy metals, namely Pb and Cd, were also measured owing to their importance in environmental and public health. Data are presented in tables and figures to show differences between studied locations and seasons (Table 1).

Electrical Conductivity Analysis

Laboratory analyses indicated clear differences in electrical conductivity (EC) values between study sites (Figure 2), as well as between different water types sampled in both summer and winter. The electrical conductivity values varied from 40 to 76,500 $\mu S.cm^{-1}$, which showed considerable differences in the dissolved salt concentrations of the water samples collected.

The highest value of electrical conductivity was found in the water of Al-Zubair River in the winter season, which was 76500 $\mu S.cm^{-1}$, which is very high compared with other samples. By contrast, Al-Faw had the lowest value of drinking water in the winter season, 40 $\mu S.cm^{-1}$, which reflects a very low content of dissolved salts.

The electrical conductivity of river water was higher than that of drinking and tap water at most of the locations of the study. Seasonal variation was also observed at some sites, with several samples exhibiting higher values in winter than summer.

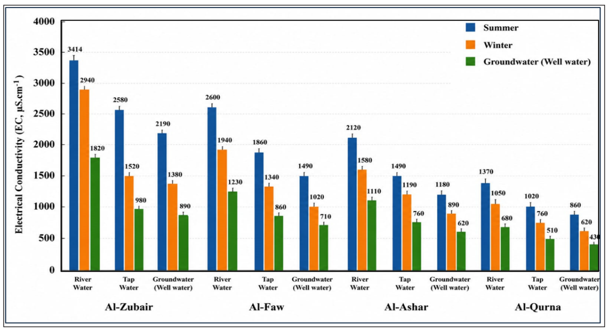

Figure 2) Electrical conductivity (EC) values of water samples collected from the study areas during summer and winter seasons.

Salinity Analysis

The results of the salinity analysis of water samples collected from the different study sites (Al-Zubair, Al-Faw, Al-Ashar and Al-Qurna) in both summer and winter seasons showed clear variation in salinity among locations and water types (Figure 3). The salinity values ranged from 0.044 to 53,550, indicating substantial differences in dissolved salt concentrations across the study areas. The highest salinity value in Al-Zubair River water was observed during the winter season, with a concentration of 53,550, which was significantly higher than the other samples. On the other hand, the lowest value was observed in drinking water in Al-Faw during summer, at 0.044.

In most of the study sites, the river water had higher salinity than drinking and tap water. Spatial variation was also observed where Al-Zubair had higher values than Al-Faw, Al-Ashar and Al-Qurna. The World Health Organization (WHO) does not establish a health-based guideline value for salinity. However, high salinity is considered an important parameter affecting acceptability as it has negative impacts on taste and palatability of drinking water. The high salinity values in some sampling sites, especially in the winter season, were associated with very high electrical conductivity values, indicative of high mineralization of the water. The results indicate a degradation of the quality of drinking water and possibly a decrease in its suitability for human consumption.

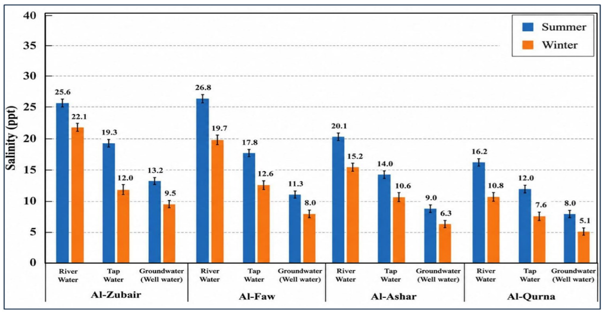

Figure 3) Salinity values of water samples collected from the study areas during summer and winter seasons. Values are expressed in parts per thousand (ppt). Error bars represent ± standard deviation.

Lead and Cadmium Analyses

Laboratory analysis of the water samples showed that the concentrations of lead (Pb) and cadmium (Cd) varied significantly by season at the study sites (Figure 4). The concentration of lead ranged from 0.071 to 1.153 mg.L^{-1} with the highest recorded in the water of the Al-Zubair River in winter and the lowest in the drinking water samples in Al-Faw in winter. Concentrations of lead were lower in summer than in winter at most locations. All lead values recorded were above the international permissible limit for drinking water (0.01 mg.L^{-1}) [9, 13]. For cadmium (Cd), concentrations ranged between non-detectable levels (ND) to 0.437 mg.L^{-1}. The highest concentration was found in water from the Al-Zubair River during winter, while cadmium was not detected in some samples, such as Al-Zubair tap water. Some of the recorded values were higher than the permissible limit of

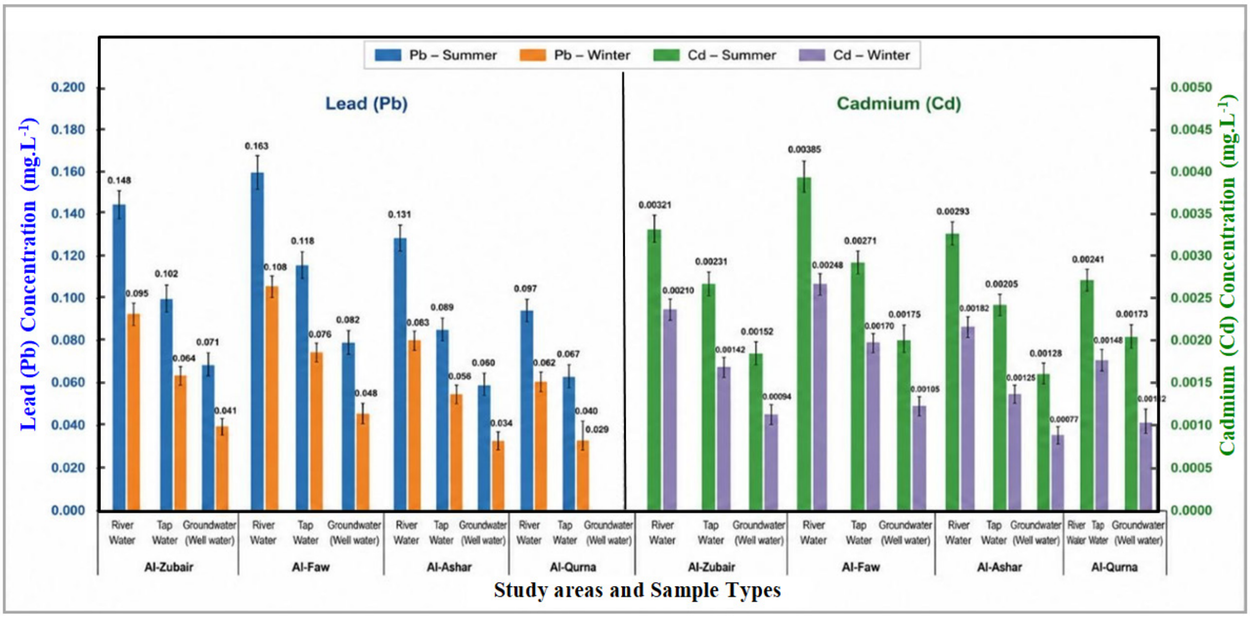

Figure 4) Seasonal variation of Lead (Pb) and cadmium (Cd) concentrations in different water sources across the study areas.

0.003 $mg.L^{-1}$ [9, 22], which suggests possible contamination at some study sites.

Blood Analysis

Ten patients with clinically diagnosed renal failure were included in the blood analysis. Due to limitations in sample volume and laboratory resources, the blood samples were divided into two analytical groups (n = 5 each). The first group was analyzed for hematological factors (RBCs, WBCs, and platelets) together with serum creatinine and urea. In contrast, the second group was analyzed for serum creatinine, urea, and electrolyte factors (Na, K, Cl, Ca, and Mg). The grouping was based solely on the laboratory analyses performed and did not reflect any differences in the clinical characteristics of the patients.

First Group (Hematological and Renal Function Factors)

The kidney function and hematological changes were assessed in five patients with renal failure in terms of creatinine, urea, red blood cells (RBCs), white blood cells (WBCs), and platelets. In most samples, creatinine and urea levels were elevated, indicating impaired kidney function. Some patients had decreased RBC counts, but WBC counts were generally within normal ranges with minor variation in one sample. Platelet counts were normal to mildly low. (Table 2).

Statistical analysis of mean ± standard deviation confirmed that creatinine and urea levels were above normal reference ranges. Male patients had relatively higher creatinine values than female patients, while lower RBC values were more common among female patients (Table 3).

Second Group (Electrolytes and Minerals)

Five additional patients with renal failure were analyzed for creatinine, urea, Sodium (Na), Potassium (K), chloride (Cl), Calcium (Ca), and Magnesium (Mg). Sodium levels ranged between 134 and 138 mmol. L^{-1} and remained within normal limits. Potassium ranged from 3.6 to 6.4 $mmol.L^{-1}$, with elevated values in some samples. Chloride ranged from 98 to 109 $mmol.L^{-1}$, with a slight elevation in one sample.

Calcium levels ranged from 8.7 to 10 mg. dL^{-1} and

Table 2) Hematological and renal function factors of renal failure patients in the study.

Sample No.	Gender	Creatinine ($mg.dL^{-1}$)	Urea ($mg.dL^{-1}$)	WBC ($\times 10^3.\mu L^{-1}$)	RBC ($\times 10^6.\mu L^{-1}$)	PLT ($\times 10^3.\mu L^{-1}$)
1	Male	4.9	65	5.28	5.03	248
2	Male	5.6	81	5.29	4.28	129
3	Female	4.9	57	5.8	2.78	239
4	Male	5.1	53	8.09	3.97	171
5	Female	2.6	30	3.09	3.23	137

Note: RBC: red blood cells; WBC: white blood cells; PLT: platelets.

Table 3) Mean ± standard deviation of hematological and renal function factors among renal failure patients.

Factor	Gender	Samples	Observed Values	Mean	SD	Normal Range
Creatinine ($mg.dL^{-1}$)	Male	3	5.6, 4.9, 5.1	5.2	0.35	0.7-1.3
	Female	2	4.9, 2.6	3.75	1.66	0.6-1.1
Urea ($mg.dL^{-1}$)	Male	3	53, 81, 65	66.3	14.3	15-45
	Female	2	30, 57	43.5	19.3	15-45
RBC ($\times 10^6.\mu L^{-1}$)	Male	3	3.97, 4.28, 5.03	4.43	0.54	4.7-6.1
	Female	2	3.23, 2.78	3.005	0.32	4.2-5.4
WBC ($\times 10^3.\mu L^{-1}$)	Male	3	8.09, 5.29, 5.28	6.22	1.69	4-10
	Female	2	5.8, 3.09	4.45	1.23	4-10
Platelets ($\times 10^3.\mu L^{-1}$)	Male	3	171, 129, 248	182.7	49.2	150-450
	Female	2	137, 239	188	71.9	150-450

were mostly within normal limits. Magnesium ranged from 2.3 to 3.1 $mg.dL^{-1}$, with mild increases in some patients. Urea levels were markedly elevated (104–150 $mg.dL^{-1}$), while creatinine ranged from 6.8–7.07 $mg.dL^{-1}$, with one severe case reaching 19 $mg.dL^{-1}$ (Table 4) This part of the study aimed to assess changes in electrolytes and minerals associated with water salinity and dissolved constituents in drinking water, and their effects on electrolyte balance and kidney function.

Questionnaire Analyses

A total of 58 participants were enrolled in the survey. Females constituted 72.4% of the sample, while males accounted for 27.6%, with a mean age of 46.6 years. Regarding drinking water sources, tanker water was the most commonly used source (63.8%), followed by bottled water (17.2%), treated water (12.1%), and tap water (3.4%). Daily water intake showed that 62.1% of participants consumed approximately 2

Table 4) Electrolyte and mineral profile of renal failure patients included in the second study group.

Sample No.	Creatinine ($mg.dL^{-1}$)	Urea ($mg.dL^{-1}$)	Magnesium (Mg) ($mg.dL^{-1}$)	Calcium (Ca) ($mg.dL^{-1}$)	Potassium (K) ($mmol.L^{-1}$)	Sodium (Na) ($mmol.L^{-1}$)	Chloride (Cl) ($mmol.L^{-1}$)
1	6.90	150	2.3	8.9	5.4	138	100
2	7.07	104	2.6	9.6	5.0	136	98
3	6.80	137	3.1	9.6	5.0	138	99
4	19.00	123	2.7	10.0	3.6	137	99
5	6.80	132	2.5	8.7	6.4	134	109

$L.d^{-1}$, whereas 22.4% consumed 1 $L.d^{-1}$ and 15.5% reported 3 Ld. Concerning kidney-related symptoms, 13.8% of participants reported facial swelling, and 19.0% reported urine discoloration. Also, 74.1% of the participants were under medical treatment and 20.7% had a history of dialysis.

Discussion

Water Quality and Environmental Conditions

The present analysis has shown a significant spatial variability of water quality factors in the studied sites, with uniformly high levels of electrical conductivity and salinity in the river and in selected tap water samples. This trend indicates an ongoing increase in the dissolved ionic constituents, primarily Sodium and chloride, indicating increasing salinization of surface and distributed water resources. This pattern is likely related to a combination of decreased freshwater influx, seawater intrusion, and long-term hydrological imbalance in the region. [11].

Seasonal variation was also observed, with maximum salinity values recorded during the winter season, especially in Al-Zubair river water. This is consistent with the results presented in Table 1. The seasonal gradient suggests a strong hydroclimatic control, with increasing evaporation rates and decreasing river discharge leading to concentration effects in aquatic systems. The observed variability is compatible with a non-static water chemistry dynamic, rather than stable equilibrium conditions. [12].

Lead and cadmium were found in several samples in trace metal profiling, with river water consistently showing higher levels than treated supplies. The spatial gradient shows the incomplete removal during the treatment stage and also suggests upstream contamination sources such as industrial effluents, petroleum-related activities, agricultural runoff, and distribution infrastructure deterioration. From a toxicological point of view, the presence of these metals is of concern because of their cumulative, non-threshold health effects even at low levels of exposure. [13].

Renal and Hematological Outcomes

The biochemical tests indicated that some participants in the study had high levels of serum creatinine and urea. This suggests reduced glomerular filtration efficiency and impaired renal function at an early stage. The pattern and degree of elevation indicate chronic renal stress rather than acute dysfunction, and a gradual process of decline that may have been affected by long-term environmental exposure [14].

In several cases, the decreased red blood cell count was suggestive of anemia secondary to chronic kidney dysfunction. Mechanistically, this is based on reduced erythropoietin synthesis secondary to impaired renal parenchymal function leading to reduced erythropoietic stimulation of the bone marrow [15].

Sodium, potassium, calcium, and magnesium imbalances were also found. These changes suggest a dysfunction of renal homeostatic regulation. Potassium imbalance is of particular clinical interest because of its relationship to cardiac electrical instability and increased susceptibility to arrhythmias. The overall biochemical picture indicates systemic dysregulation rather than a simple laboratory variation [16].

The correlation of deteriorating environmental water quality with parallel renal and biochemical alterations observed in populations chronically exposed to saline and contaminated drinking water indicates a reasonable exposure-response relationship for progressive renal dysfunction [17].

Population Exposure and Behavioral Determinants

The response rate was higher in women, possibly due to a higher level of engagement in health reporting and use of health services [13]. Age was consistently associated with morbidity; older people were more likely to report chronic conditions including hypertension and renal disorders. This is consistent with the well-established notion of cumulative health burden and age-dependent susceptibility to chronic disease [18].

Factors associated with exposure, such as length of residence and source of drinking water, appeared to be important factors influencing the potential risk of exposure among the participants. Cumulative exposure was associated with dependence on untreated or irregularly treated water sources and length of residence in affected areas, suggesting a time-dependent accumulation of risk. [18].

We saw many reports of adaptive coping methods, such as using bottled water and home filtration systems. However, these interventions are likely to only partially mitigate and not fully remove dissolved salts and trace metals and may impose additional socioeconomic burdens, especially in resource-limited households [13].

Integrated Environmental–Health Interpretation

The hydrochemical, biochemical, and epidemiological datasets, when considered together, demonstrate a coherent, biologically plausible exposure–response pattern. The observed changes in water quality, with increased salinity and heavy-metal contamination, correspond with measurable changes in renal biomarkers, electrolyte balance, and hematological factors in exposed individuals.

The consistency of the direction of the associations across independent datasets is suggestive of a cumulative exposure effect rather than an acute, toxicological response. The cross-sectional design limits causal inference, but the convergence of environmental and biological indicators strengthens the plausibility of a long-term environmental health impact.

From an inferential perspective, identified patterns suggest a possible association between water quality deterioration and renal health indicators, especially among populations dependent on untreated or unstable water sources. Nevertheless, caution is needed in interpretation of these findings, given the cross-sectional design and small sample size. This finding is in line with the extensive literature showing associations between long-term exposure to saline and metal-contaminated drinking water and increased risk of renal dysfunction, hypertension, and metabolic disturbances, especially in areas with poor water infrastructure and persistent environmental stressors [11–13,18].

Conclusion

The present comprehensive study correctly and thoroughly reveals a significant and growing environmental health risk concerning renal health within the geographical boundaries of the Basrah Governorate, Iraq. This alarming situation has been established and directly correlated to the continuous and progressive deterioration in the quality of drinking water of the region and the alarming increase in salinity. Many drinking water samples have been analyzed and found to contain higher-than-normal levels of important constituents, including electrical conductivity, various dissolved salts, and, notably, several heavy metal contaminants. Overall, the results suggest that the water resource in the region is under significant environmental stress. The observed degradation can be attributed to a combination of anthropogenic activities, reduced freshwater inflow, and tidal intrusion from the Arabian Gulf, which have been reported in previous studies as potential contributors to salinization. The Shatt Al-Arab River, a main source of water for the governorate, is increasingly suffering from salinization. Upstream dams decreased freshwater flows, and the salinization may be partly attributed to tidal intrusion from the Arabian Gulf.

Besides the environmental assessment, the clinical findings were generally in line with impaired renal function in the examined patients, as indicated by elevated renal biomarkers and electrolyte abnormalities. The findings may support a possible association between declining water quality and kidney health. However, a causal relationship cannot be determined due to the cross-sectional study design and limited sample size. Moreover, systematic data collection and analysis of questionnaire data from residents within the studied regions have provided further corroboration. These findings suggest a possible association between poor drinking water quality and observed kidney health indicators, but further studies with larger sample sizes, appropriate statistical analyses and a control group are required to confirm these associations. Together, the results of the environmental water analysis, clinical biomarker assessment and epidemiological survey point to the need for a multifactorial approach to public health. It is recommended that continuous environmental monitoring, improved water quality management and implementation of effective water treatment strategies should be undertaken to minimize the potential health risks. Further well-designed epidemiological studies with larger sample sizes, appropriate statistical analysis, and suitable control groups are required to better clarify the relationship between drinking water quality and renal health outcomes.

Future Research

The present study provides useful information regarding the association between deterioration of water quality and renal health, but several questions remain and should be investigated in the future. First, large-scale longitudinal cohort studies are needed to determine the temporal and causal relationships between specific water contaminants (e.g., cadmium, lead, salinity) and the incidence of chronic kidney disease, taking into account confounders such as age, comorbidities, and socioeconomic status. Second, future studies should include full biomonitoring of exposure, i.e., blood, urine, and hair levels of all relevant heavy metals in the general population, to better assess individual exposures and internal dose. Third, more sophisticated analytical techniques such as isotope fingerprinting and multivariate source apportionment modeling may be used to help determine the specific sources of salinity and metal contamination, which may help to develop a specific mitigation strategy. Finally, intervention programs that test the effectiveness of different water treatment technologies (such as reverse osmosis, solar distillation, and activated carbon filters) in reducing renal markers in affected communities would provide practical evidence to guide public health policy.

Fifth, because of the synergistic effects of multiple contaminants, toxicological studies using in vivo and in vitro models are suggested to help understand the combined nephrotoxic mechanisms of salinity, cadmium, lead, and other trace elements. Encouragingly, extending the geographic coverage to other water-stressed areas in southern Iraq and the Gulf region would help identify if the observed trends are part of a larger environmental health crisis. It will be crucial to have collaborative research that incorporates the work of environmental scientists, epidemiologists, nephrologists, and local health authorities if actionable prevention and remediation programs are to be developed from results.

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