

GIS Technique for Assessing Quality and Hydrochemistry of Karbala Governorate Groundwater

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Abstract Using GIS methodologies for spatial analysis, this study examined groundwater's hydrogeochemical properties and quality in the Karbala Governorate in western Iraq. The study area is significant due to the presence of groundwater reservoirs within the sand-filled Debdebbba and Dammam limestone formations. The pH, total dissolved solids (TDS), electrical conductivity (EC), and major chemical ion concentrations were measured in several wells using data from the Iraqi General Corporation of Groundwater. The average concentration of the principal ions was distributed in the following order in Karbala's groundwater: $\text{SO}_4^{2-} > \text{Cl}^- > \text{Na}^+ > \text{HCO}_3^- > \text{Mg}^{2+} > \text{K}^+ > \text{NO}_3^-$. According to the results, Karbala's groundwater is unfit for drinking, mostly because of its high total dissolved solids and water quality index readings, and also classified groundwater as having a very high salinity hazard and a medium sodium (alkali) danger. This study highlights the significance of implementing suitable water management and remediation measures by providing insightful information on the hydrochemistry of groundwater in the Karbala Governorate. The findings of this study underscore the importance of assessing groundwater quality before it is used for irrigation to protect public health and the environment.

Keywords: GIS Technique, groundwater, Quality and Hydrochemistry, Karbala, Iraq

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1. Introduction

Water is a vital resource that plays a crucial role in sustaining life and in determining the overall quality of human existence. However, increasing disruptions in precipitation patterns, temperature changes, and soil moisture as a result of climate change have directly impacted on water availability and quality for various purposes such as drinking, agriculture, and livestock use. This global phenomenon has led to the depletion of the water resources and deterioration of water quality in several regions around the world [1]. In addition to the challenges posed by climate change, water resource pollution further exacerbates the problems associated with water scarcity. This pollution is a consequence of human activities, including industrial and agricultural practices, which release contaminants into water bodies, thereby adding pressure to already limited freshwater resources [2]. To mitigate the impact of water scarcity and ensure the availability of clean water, the development and assessment of alternative water sources, including groundwater, has become a crucial goal for governments and researchers worldwide. Groundwater, which is one of the major sources of water, has gained significant attention owing to its wide availability and relatively high

quality. The quality of groundwater is determined by the usual physical and chemical characteristics of the water as well as any alterations caused by human activities and microbial processes in soils [3]. Therefore, studying the hydrochemistry and quality assessment of ground water is essential for understanding its suitability for various purposes such as drinking, industrial, and irrigation use. The Karbala Governorate, located in Iraq, is an important region in terms of its hydrogeological significance. It encompasses groundwater reservoirs within the sandy Debdebbba and Dammam limestone formations. Assessing the hydrochemistry and quality of ground water in this region is crucial for effective water resource management and planning. In this research, we investigated the hydrochemistry and quality of groundwater in the Karbala Governorate using Geographic Information System (GIS) techniques. By analyzing data obtained from multiple wells, we assessed the concentrations of major chemical ions, such as calcium, sodium, magnesium, potassium, chloride, bicarbonate, sulfate, and nitrate, and the electrical conductivity (EC), pH and total dissolved solids (TDS) of the groundwater. Furthermore, we will use water quality indices and classification systems to evaluate the suitability of the groundwater for various applications. Understanding the hydrochemistry and quality of groundwater in the Karbala Governorate will provide valuable insights into the current state of water resources

in the region. The findings of this study can serve as a basis for developing effective management strategies, ensuring the availability of safe and sustainable water supplies, and addressing water-related challenges faced by the population in the Karbala Governorate.

2. Geology of the Study Area

The studied region was located in the Iraqi province of Karbala, 150 km south of Baghdad. It covers a 5034 square kilometer region of land. The borders of the study area are located between latitudes 32°10' and 32°50' north and 43°20' and 44°54' east (Figure 1). The study area is characterized from a geomorphological standpoint by being part of the Karbala Plateau (which is located to the west of the Euphrates River) [4].

The area is located within the stable platform of Iraq, which, with the exception of the Euphrates Fault, is characterized by a lack of major folding and faulting. The eastern edge of the formation is marked by this fault, which serves as the natural boundary. The research area is part of Iraq's stable platform, which exhibits little surface and subsurface structures [5]. Iraq's Karbala Governorate is distinguished by a varied geological environment that greatly influences the area's hydrogeological features and groundwater supplies. Governorate's Quaternary deposits are made up of alluvial deposits with varying textures, compositions, and water chemistry, such as sand, gravel, and boulders [6]. Quaternary deposits cover more than 60% of the studied region, while Tertiary deposits are

represented by rocks of the Dammam, Euphrates, Al-Nafail, Injana, Zahra, and Al-Dabdaba formations (Figure 2) [7]. Dammam formation is a confined aquifer in the studied region [8].

3. Climate of the Study Area

A desert environment with hot, dry summers and comparatively mild winters prevails in the study area (Table 1). It can become very hot throughout the summer because temperatures can rise dramatically, frequently reaching approximately 45°C at noon. However, winter nights can be rather chilly, with temperatures occasionally falling to or very close to freezing (zero degrees Celsius). Rainfall in the area is influenced by a dry climate; hence, it is typically insufficient. This region is subject to desert conditions, which are usually dry and receive little precipitation. The sedimentary plain from the east is another factor that affects the city and may affect regional weather patterns and moisture availability.

Generally, the climate of Karbala is akin to that of a desert location, with hot summers, chilly winters, and little annual precipitation. The annual average of precipitation is decreasing for the period (1990-2016) which indicate that the region is driven to dryness [10]. Because of the difficulties this sort of environment presents for its citizens and crops, it necessitates rigorous water management and adaptation techniques to deal with dry circumstances [11].

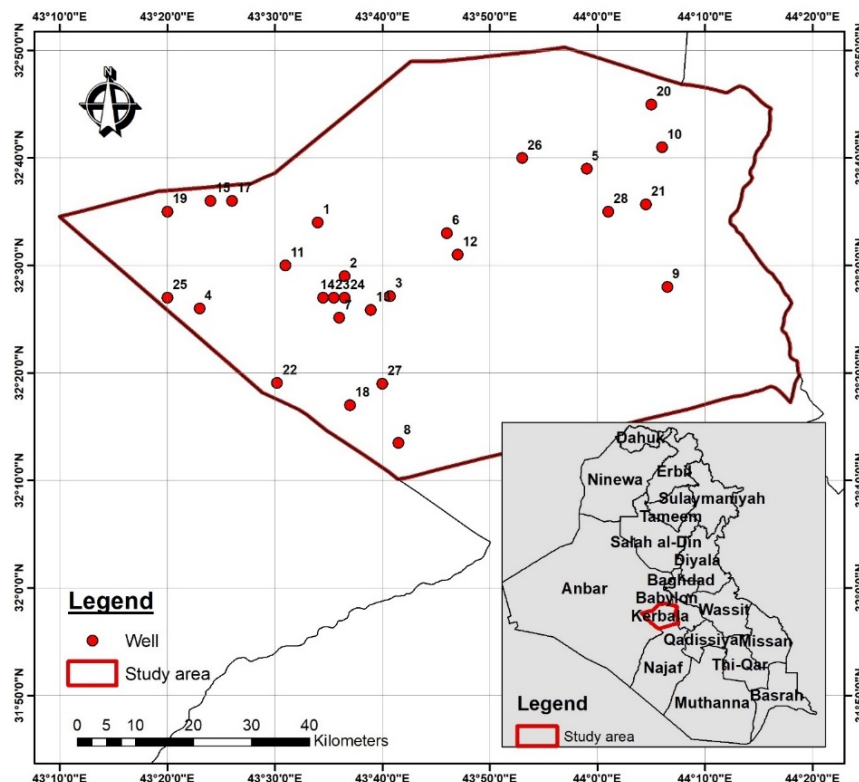


Figure 1. Study area and Location of Well Sampling Points

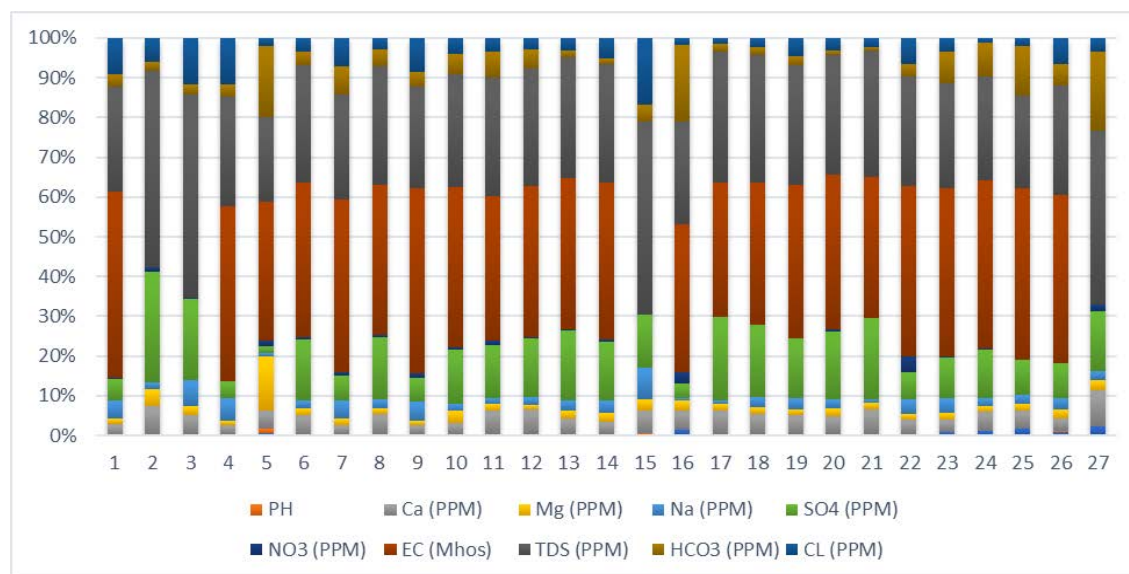


Figure 3. Percentage of major ions in all the water wells of the studied area

5. Results and Discussion

Depending on the nation and its regulatory structure, different authorities are responsible for guaranteeing the security and suitability of drinking water for human consumption. Government departments or agencies in charge of the environment, health, and water resources are often responsible for regulating and overseeing drinking water quality in Iraq. According to the information given, the requirements for safe drinking water include chemical safety, lack of unwanted physical qualities (such as color, turbidity, odor, and taste), and freedom from hazardous bacteria [13]. Researchers matched the water composition to drinking water standards established by Iraqi standard specifications (2009) and World Health Organization (WHO) guidelines from 2007 to assess the groundwater in the study locations. Researchers matched the water's composition to drinking water standards established by [14] and [15] guidelines from 2007 to assess the groundwater in the studied locations. The majority of the wells in both regions had pH readings within the permitted ranges for drinkable water. This shows that the acidity or alkalinity of water is typically within the range that is safe for human consumption. According to both the Iraqi standard and the WHO recommendations, both study regions' TDS readings were higher than the recommended 1000 mg/L limit for drinking water (Table 2). Increased TDS levels may affect the flavor and overall palatability of water, and may necessitate additional treatment to satisfy drinking water requirements. To identify potential problems and confirm that water is suitable for human consumption, it is essential to compare groundwater quality to drinking standards. Further treatment procedures are required to improve the quality of water and make it suitable for drinking if it does not meet the required standards. To protect public health and guarantee that the water supplied to communities is secure, chemically sound, and free of hazardous contaminants,

relevant authorities must monitor and control the quality of drinking water.

Table 3 (Iraqi Ministry of Water Resources, 2017) displays the measured variables from twenty-seven wells in the study area. These variables were used to evaluate the quality of groundwater and determine the spatial distribution of variable concentrations. Table 2 shows the various uses for each variable.

When it comes to evaluating water quality, figuring out water availability, controlling flooding, comprehending the natural world, and managing water resources locally or regionally, GIS may be a very useful tool [16].

The prediction maps for eight physicochemical variables that were measured from the studied area's wells were used in this study. Prediction maps were created using the ArcGIS (10.8) software's interpolation approach on twenty-seven wells.

The interpolation inverse distance weighted method (IDWT) was used in the GIS to create an interpolating map of the quality of groundwater index for drinking applications for each variable. Using the values of specified points close to the unidentified points, the IDWT method is used for estimating the unidentified point at a given position. Rather of using alternative methods, the spatial interpolation methodology is used to create prediction maps of groundwater quality.

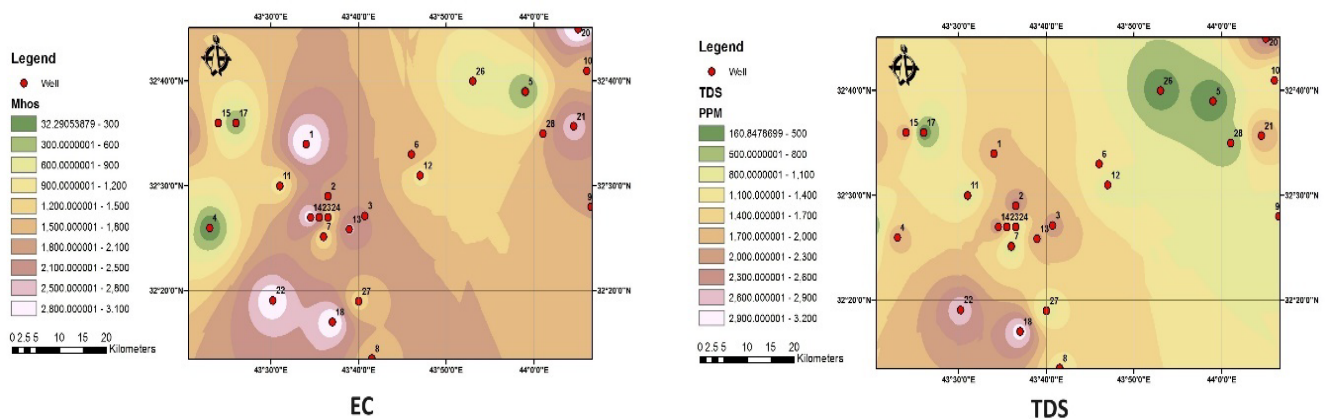
The groundwater distribution maps that have been created will assist scientists and researchers in assessing the quality of groundwater as well as its ranges and distribution within the study region. Using the eight variables measured in 27 wells within the study region, the IDW technique and the GIS were coupled to create prediction maps for groundwater quality for various purposes. Figure 4 Figure 5) shows the prediction maps for the selected groundwater variables in the research region, including (Na, TDS, EC, Cl, HCO₃, SO₄, Mg, NO₃, and pH).

Table 2. The maximum, minimum, and average values of pH, TDS, EC, TH, cations, and anions in ppm, in comparison with Iraq standard (IQS, 2009) and WHO standard 2007

Chemical Constituent (mg/l)	Min	Max	average	Iraq standard (IQS, 2009)	WHO Standard (2007)	Exceeding limits
pH (no unit)	5	8	7.2	6.5-8.5	6.5-8.5	Not exceed
EC(μS/cm)	259	3300	1873	1500	1500	Exceed
TDS	160	3072	1461	1000	1000	Exceed
Mg ²⁺	23	221	92	100	125	Not exceed
Na ⁺	7	388	140	200	200	Not exceed
HCO ₃ ⁻	64	220	159	200	200	Not exceed
Cl ⁻	14	799	252	350	250	Exceed
SO ₄ ⁻	12	1950	677	400	250	Exceed
NO ₃ ⁻	5	244	42	50	50	Not exceed

Table 3. Concentrations of the groundwater of 27 wells in the studied region (Iraqi Ministry of Water Resources, 2017)

No of well	Latitude	longitude	PH	Mg (ppm)	Na (ppm)	SO ₄ (ppm)	NO ₃ (ppm)	Cl (ppm)	HCO ₃ (ppm)	EC (Mhos)	TDS (ppm)
	32.566	43.566	8	92	322	394	10	639	220	3300	1869
	32.45	43.591	-	221	97	1440	60	310	115	-	2561
	32.45	43.60	8	106	276	864	9	500	100	-	2176
	32.433	43.383	7	66	388	283	-	799	207	2993	1878
	32.65	43.983	8	101	7	12	12	14	134	259	160
	32.55	43.766	-	82	92	710	30	160	150	1800	1372
	32.418	43.60	-	42	107	140	20	165	166	1000	607
	32.133	43.566	-	62	90	660	25	120	180	1600	1270
	32.466	44.108	-	47	188	230	40	330	140	1800	994
	32.683	44.10	-	115	74	520	20	150	205	1550	1092
	32.50	43.516	-	48	46	390	30	100	185	1050	873
	32.516	43.783	-	38	53	430	10	80	145	1100	858
	32.45	43.605	-	134	179	1200	10	210	130	2600	2077
	32.45	43.575	-	173	237	1170	40	400	110	3100	2338
	32.60	43.40	5	111	308	508	-	639	170	-	1863
	32.60	43.433	-	28	8	40	35	20	220	425	295
	32.283	43.616	7	151	85	1950	-	135	183	3150	3072
	32.583	43.333	7	110	148	1120	-	148	123	2204	1967
	32.75	44.083	-	112	230	1220	15	373	192	3120	2446
	32.595	44.075	-	137	161	1155	31	213	79	2675	2048
	32.25	43.416	8	156	82	1770	-	210	64	3100	2786
	32.45	43.591	-	92	230	412	244	408	180	2645	1693
	32.45	43.608	-	44	81	240	9	80	186	975	613
	32.45	43.333	-	34	40	249	5	25	171	872	537
	32.666	43.883	-	23	33	124	-	27	180	614	328
	32.316	43.666	8	72	88	290	-	209	177	1350	884
	32.583	44.016	-	28	25	170	20	40	220	-	491

**Figure 4. Spatial distribution of EC and TDS using (IDW) Method**

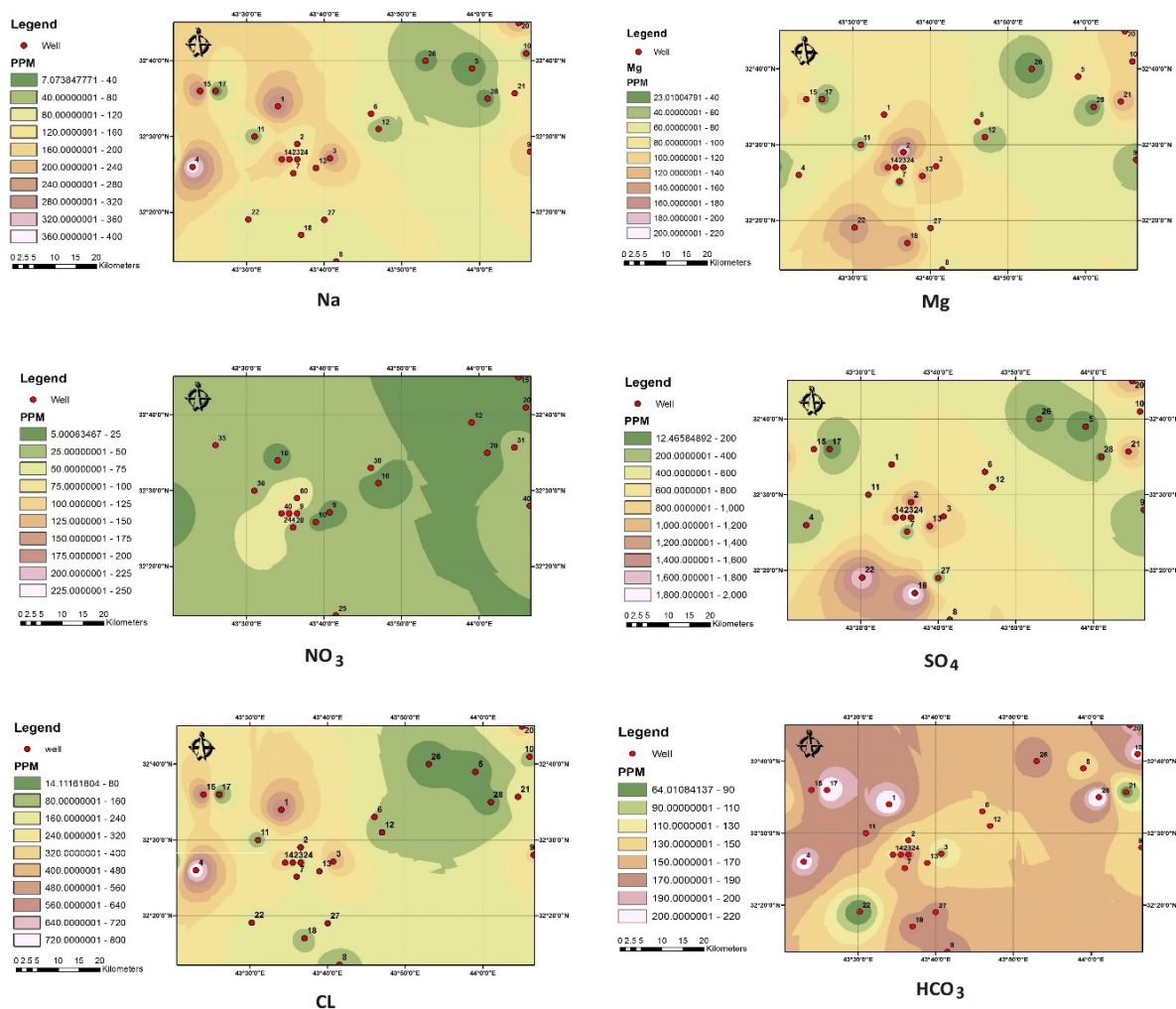


Figure 5. shows the distribution of Na, Mg, NO₃, SO₄, CL and HCO₃ concentrations in all wells using (IDW) Method

6. Conclusion

This study focuses on assessing the hydrochemical characteristics and quality of the groundwater in the Karbala Governorate, Iraq, using GIS techniques for spatial analysis. The studied region is significant because of the presence of groundwater reservoirs within the sandy Debdebbba and Dammam Limestone formations. Data from multiple wells sourced from the Iraqi General Corporation of Groundwater were analyzed to determine the concentrations of major chemical ions, pH, electrical conductivity (EC), and total dissolved solids (TDS). The average concentrations of major ions in the Karbala groundwater followed the order SO₄-2 > Cl- > Na+ > HCO₃- > Mg+2 > K+ > NO₃-.

The research findings indicate that groundwater in Karbala is unsuitable for drinking purposes because of its high total dissolved solids and water quality index values. Additionally, groundwater is classified as having a very high salinity hazard and a medium sodium (alkali) hazard. This highlights the potential risks of using water for irrigation, which could adversely affect the soil structure and plant growth. This study provides valuable insights into the hydrochemistry of groundwater in the Karbala Governorate, emphasizing the need for appropriate water management and remediation strategies. The application

of GIS techniques aids in understanding the spatial distribution of groundwater quality, facilitating informed decision-making for effective water resource management and conservation. Overall, this study underscores the importance of evaluating groundwater quality for irrigation purposes to safeguard the health of both humans and the environment.

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