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RESEARCH PAPER

Analyzing the Groundwater Contamination - Central Basin - Erbil City Kurdistan Region -Iraq

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ABSTRACT:

Groundwater is one of the most crucial drinking water sources in Kurdistan. Development, urbanization, and human activities in Erbil have led to a decline in the amount and quality of groundwater. This research aims to investigate and examine the groundwater quality in Kaniqrzhala (Erbil dumpsite) in a central basin in Erbil, as well as the impact of a landfill in this region. The investigation encompasses around 27 wells. The static water level is assessed to examine groundwater movement and the route of contaminant transfer. All the wells are sampled for groundwater quality criteria such as turbidity (pH value, TDS, chloride, calcium, magnesium, hardness, nitrate, sodium, iron, and copper). Surfer software version (16) was used to study the direction of groundwater flow; groundwater contamination was investigated using the GIS program version (10.6.1). The result showed the groundwater flow toward the Greater Zab River; many wells suffer from high contamination. The effect of landfill appears in this area. Groundwater contamination transport in the Kaniqurzala should be studied to predict the future impact using modeling software.

KEY WORDS: Groundwater; Contamination; Analysing; Leachate Effect
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1. INTRODUCTION:

Groundwater is an essential source of water for agricultural, industrial, and domestic. Groundwater use has increased sharply due to rapid population growth, development in all life fields, urbanization, and industrialization. As a result of a shortage of surface water, the demand for groundwater has risen dramatically (Gebrehiwot et al., 2011, Rajappa et al., 2011, Rao et al., 2012, Lanjwani et al., 2019). About thirty percent of the world's population uses groundwater for drinking (Nickson et al., 2005, Rao et al., 2012).

Furthermore, because of the rapid population increase in Erbil, water demand has risen, and the groundwater well makes up about 40% of Erbil city's water supply system. The groundwater in Erbil city is suffering from contamination due to the disposal of domestic and industrial pollutants and agricultural pesticides. In urbanized areas of Erbil, the discharge of untreated wastewater, including human wastes, in septic tanks is widely used. The concentration of nitrate and alkalis in some portions of the city is more than Iraqi and WHO guidelines (Wali et al., 2016, Mawlood, 2019). Salts, metals, pesticides, herbicides, industrial toxins, petroleum usage, and radioactive pollutants can contaminate groundwater. The groundwater quality can decline because of contamination. The quality needs to be improved

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by stopping the source of contamination. Therefore, it is essential to constantly assess groundwater quality and develop sustainable methods(Chauhan et al., 2010). The primary techniques for disposing of and treating municipal solid waste include sanitary landfills, open dumping, and thermal treatment such as anaerobic, gasification, pyrolysis, incineration, and plasma arc gasification. Composting is one method of treating municipal solid waste (MSW). Sanitary landfills are considered one source of groundwater contamination (Davis and Cornwell, 2008). The main disadvantage of landfills is the amount of leachate they produce. Heavy metals, organic materials, inorganic salts, nitrogen compounds, and phenols can be found in leachate (Renou et al., 2008). If the leachate is not disposed of and treated, it might be a source of groundwater contamination. The leachate can percolate through the soil layer and reach groundwater (Bini Samal et al., 2022). Many studies were done to analyse the quality of groundwater in Erbil city; some of these studies illustrate: (Toma, 2006) evaluating groundwater quality in Ankawa district in Erbil city showed that it is suitable for human use (Wali et al., 201) assessed the groundwater vulnerability contamination by utilizing the DRASTIC method with GIS. The result revealed that the south-eastern Erbil city part has a high vulnerability to contaminants due to the aquifer media. (Abubakr, 2019) mapped and assessed the groundwater quality in Erbil city. WQI (water quality index) was created using the method of Horton (1965), and WQI (water quality index) was created using GIS. The result revealed that the groundwater quality was reduced in 2018 compared to previous years. (Othman et al., 2021) analyzed the quality of groundwater in Erbil city by taking 16 groundwater samples; WQI (water quality index) was measured depending on 22 groundwater parameters. The results revealed that the WQI (water quality index) is about 38.87, the quality was poor, and it is not suitable for drinking. It requires treatment. (Bndyan, 2022) assessed the chemical parameters of groundwater in the Erbil basin. The data was collected in wet and dry seasons, and the results showed that the concentrations of bicarbonate, magnesium, nitrate, lead, and boron exceeds the permissible limit, which might be due to urbanization, a flawed wastewater treatment system, and excessive use of filtration. This paper aims to evaluate the effect of the Erbil landfill site on groundwater quality in the area close to the landfill site.

2. MATERIAL AND TOOLS

2.1 Study Area

Kani-Qirzhala area was selected within the central basin in Erbil city, which includes the source of groundwater contamination, such as a landfill. The study area covers about 60 km^2. The Erbil landfill is placed on a hill connected by two drainage valleys in the Erbil plain, about 10 kilometres west of Erbil City in the Central Basin. It covers around 0.35 km^2 and is located at 36° 11' 40.60" N and 43° 53' 05.10" E, as shown in figure(1a) and figure (1b) shows the location of wells under study. This location is roughly 435 meters above sea level. Erbil dumpsite has been operational since 2001. It receives a different type of domestic waste, between (1900- 2000) tons of solid waste per day as average disposal at the Erbil dumpsite (Municipal ministry).

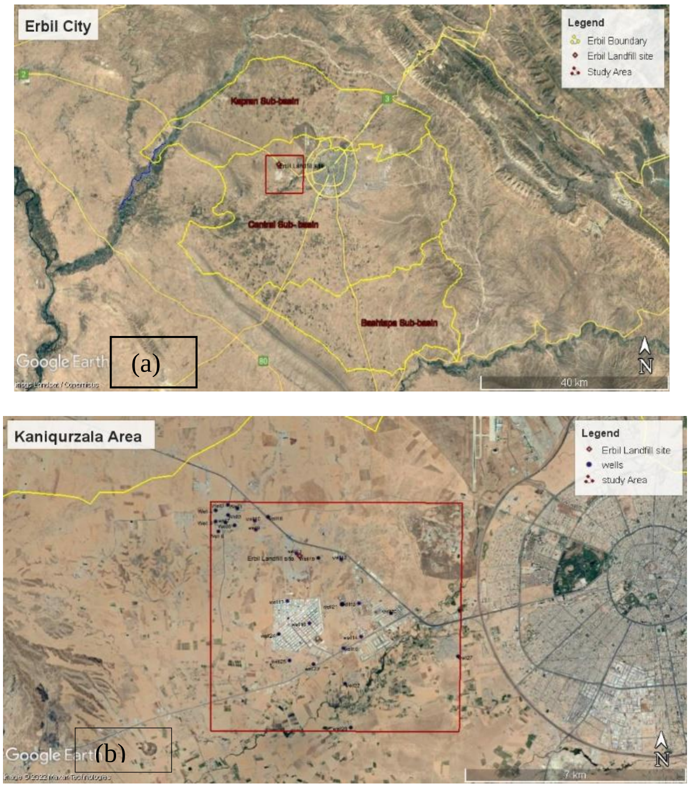


Fig. (1): a) the location of the Erbil dumpsite and study area, **b)** location of wells under study.

2.2 Data collection

The data was collected from 27 wells in the study area. Groundwater samples were taken from the well to study the quality. The groundwater samples were tested in (Erbil Environmental Office), and the static water level for the same wells was measured to check the direction of groundwater flow in the study area. Also, data about the groundwater static water table was obtained from the Groundwater Directorate/ Hawler, which covers most of Erbil city except the Kani-Qirzhala area. A sample from Erbil landfill leachate was taken to check the properties of leachate, which was tested in (the Erbil Environmental Office).

2.3 Spatial Interpolation

The spatial interpolation method uses the points with known values to extrapolate the values of other points. Based on measurements taken at known sites (Zimmerman et al., 1999). Physical or chemical parameter values are routinely estimated using spatial interpolation methods in areas that are not measured(Murphy et al., 2010). The different approaches for point interpolation may be further divided into accurate and approximate. Ordinary Kriging and inverse distance weighting methods are used for spatial interpolation (Lam, 1983). The direction or distance between sample sites is assumed to show a spatial correlation that may be utilized to explain surface variation in the Kriging method. The formula applied in Ordinary Kriging is:

$$Z(X_o) = \sum_{i=1}^{N} \lambda_i Z(X_i) \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Z(X_0): interpolated point, N: scattered observation points number in the set, Z (Xi): scattered observation points values, λi : are the weights with the exception that the consequences utilize in Kriging are depend on a model variogram.

In contrast, Inverse Distance Weighting method, the observation points are weighted throughout interpolation in this approach. Compared to another, the importance of one point decreases as the distance from the new location increases; the standard IDW (Inverse Distance Weighting) formula is (Ibrahim and Nasser, 2017):

$$z(X_o) = \sum_{i=1}^{N} \lambda_i Z(X_i) \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

N: scattered observation points number in the set, Z : scattered observation points value; i=1, 2…N ,λi : are the observation points' weights allocated. The typical weighting function is provided by:

$$\lambda_{i=} \frac{d_{ij}^{-p}}{\sum_{i=1}^{n} d_{ij}^{-p}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

P: weight power, d: distance between the neighboring point j and grid node i.

In some studies (Laslett, 1994, Phillips et al., 1997, Weber and Englund, 1994), a Kriging method gave the best result, while in others (Gallichand and Marcotte, 1993, Bruvold and Ongerth, 1969), inverse distance weighting presented the best result. After, (Ibrahim and Nasser, 2017) concluded that the Kriging method is most accurate than the IDW(inverse distance weighting) method. Therefore, the Kriging method is used to investigate and interpolate groundwater parameters in the study area.

3. RESULT AND DISCUSSION

3.1 Direction of Groundwater Flow

The direction of groundwater flow in Erbil city is presented in figure2. The result shows the groundwater flow from the East side to the West side or from an area of high elevation to the region of low elevation toward Great Zab River, Surfer software version 16 is used for this purpose. The direction of groundwater flow in the study area only can be present in figure 3. The result shows groundwater flows toward the East and the South East side to the West and North West sides of the study area or from the high groundwater head to the low groundwater head.

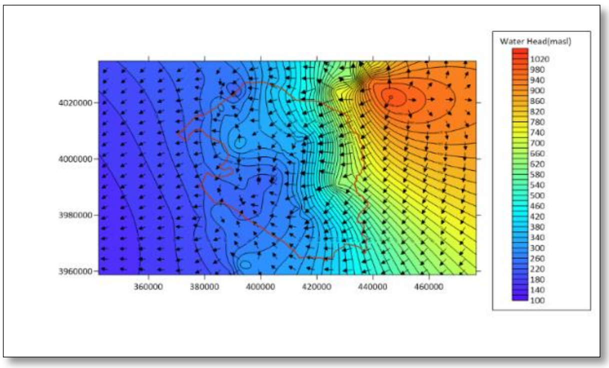


Fig. (2): Direction of groundwater flow in Erbil city.

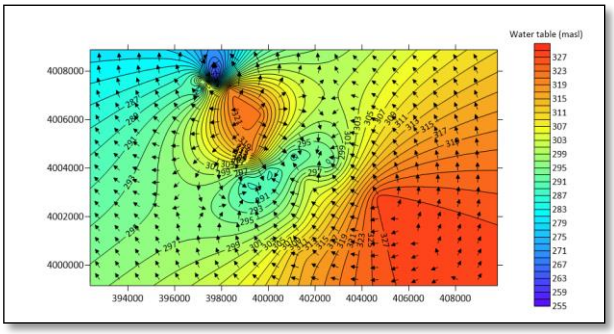


Fig. (3): Direction of groundwater flow in study area.

3.2 Properties of Landfill Leachate

The properties of Erbil landfill leachate are presented in table 1. All the leachate properties are more than the acceptable standard, and the landfill leachate discharge to the surrounding area leads to contamination of the soil layers and can penetrate groundwater.

Table1: Properties of Erbil dumpsite leachate.

Physical and Chemical Parameters	**Results**	**Permissible level for wastewater (Erbil Environmental Office)**
Total Suspended Solids (TSS) mg/L	12000	40
Turbidity(NTU)	3300	5-25
pH	6.1	6.4-8.5
Temperature (C^{o})	18.9	12-25
Electrical Conductivity µs/cm	46100	3000
Dissolved Oxygen(DO)mg/L	2.01	More Than 5
Biochemical Oxygen Demand (BOD5)mg/L	14789	40
Chemical Oxygen Demand(COD)mg/L	21128	100
Oil and Grease mg/L	8.633	5
Chloride mg/L	6666	450
Calcium mg/L	3168	400
Total Dissolved Solid mg/L	27660	2500
Alkalinity mg/L	17820	250
Hardness mg/L	11880	500
Sodium mg/L	8733	230
Potassium mg/L	16632	20
Nitrate(NO$_3^-$) mg/L	5264	50
Sulphate (SO$_4^{2-}$) mg/L	5999	400
Phosphate (PO$_4^{3}$-) mg/L	1110	12
Magnesium(Mg^{2+}) mg/L	963.5	150

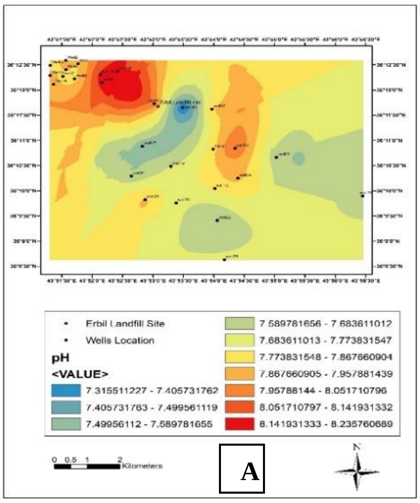
3.3 Quality of Groundwater in Study Area

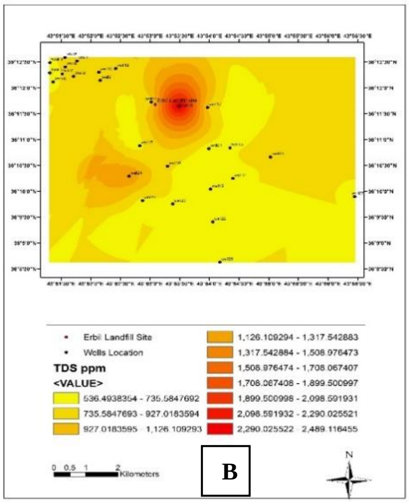
Groundwater quality parameters are present in table 2, which also compares with the World Health Organization standard (WHO) and is classified as a physical and chemical parameter.

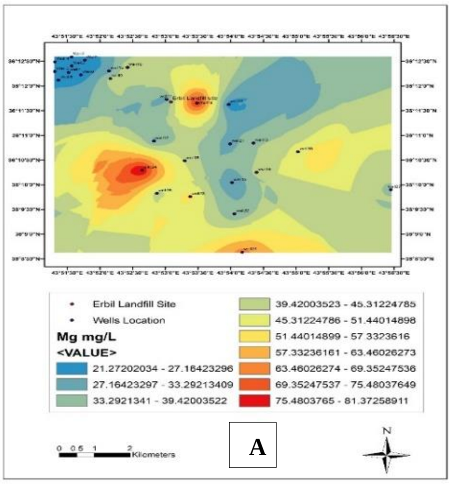
The pH value in groundwater samples is ranged between 7.2-8.2 as presented in table2. This value is within the acceptable limit of WHO standard. The allowable limit of pH value should be between 6.5-8.5, Figure (4A) shows the spatial distribution of pH values in the Kani-Qirhzala area. Total dissolved solids contain a small quantity of organic and inorganic salt, which dissolve in water. The source total dissolved solids in drinking water are sewage, natural origin, industrial wastewater, and urban runoff (WHO, 2004). The total dissolved solid concentration ranges between 539-2514 ppm, as shown in table2. The maximum permissible limit for TDS according to WHO, should be less than 500 ppm, and all TDS concentrations in wells exceed the WHO standard. The high TDS concentration can be due to the effect of landfill leachate. The highest concentration is recorded in well 19 and well 24 figure (4B) shows the spatial distribution of TDS in the study area. Chloride is one of the primary anions in water, and a salty taste can be due to high chloride concentration. The chloride concentration in the study area varies between 46.02-570 mg/Las illustrated in table 2. The maximum acceptable limit of chloride, according to WHO, is 250mg/L(WHO, 2004). The chloride concentrations in wells within permissible limits except in well 19 and 24 are about 570 mg/L and 386 mg/L, respectively. Groundwater naturally contains chlorides, but water softeners, road salt, natural salt deposits, fertilizers, sewage, and landfill leachate can raise chloride concentration in groundwater. Figure (4C) shows the spatial distribution of chloride in the study area. The solubility of calcium carbonate, sulphate, and, in rare cases, chloride determines the range of calcium in groundwater (Toma, 2006). According to(WHO, 2004) , the acceptable standard of calcium is 75 mg/L; according to the Iraqi standard 2001, the concentration of calcium should be less than 50 mg/L; the highest concentration of calcium was recorded in wells 5, 7, 9, 80, 19, 23, 24 and 27 if these wells compared with WHO standard, due to human activity and the effect of landfill leachate in the study area. Figure (4 E) shows the spatial distribution of calcium in the study area. The magnesium concentration in the study area varied from 21 mg/L to 84.48 mg/L as shown in table2; the desirable limit of magnesium in groundwater should be less than 30mg/L(WHO, 2004). The highest concentration is recorded in well 24, and some other wells exceed the permissible limit. The source of magnesium in groundwater is dolomite formation (Toma, 2006) due to landfill leachate's effect. The high concentration of magnesium causes water hardness. Figure (5A) shows the spatial distribution of magnesium in the study area. Magnesium and calcium ions, found in sedimentary rocks such as limestone and chalk, are groundwater's main sources of hardness(WHO, 1996).The total hardness concentration in the study area varies from 220 mg/L to 1268mg/L as presented in table2. According to WHO, the maximum permissible limit of hardness should be less than 300mg/L(WHO, 2004). The highest hardness concentration was noticed in wells 9, 13, 14, 16, 19, 20, 22, 23, 24, 25, 26, and 27. This may be due to landfills leachate these wells located in the direction of groundwater flow in the study area. If the total hardness is less than 75 mg/L, classified as soft; if hardness is ranged between 75 and 150 mg/L, it is classified as moderately hard; if hardness is ranged between 150 and 300 mg/L, it is classified as hard; and if it is more than 300 mg/L, it is extremely hard (Davis, 1966, Rao et al., 2012). Figure (5B) shows the spatial distribution of hardness in the study area. The sodium concentration in the study area varies between 67.2 mg/L to 792 mg/L, as shown in table 2; according to (WHO, 2004) standards, the maximum sodium concentration for drinking water should not exceed 200 mg/L; the highest sodium concentration was recorded downstream area of the landfill (18 to 27). Sodium happens naturally in groundwater, but sodium concentration can increase for many reasons, such as road salt, sewage, fertilizer, and water softeners. It may be because of landfill leachate. Figure (5C) shows the spatial distribution of sodium in the study area. The nitrate concentration varies between 22mg/L – 70.88, as presented in table2 mg/L, and the maximum permissible limit according to WHO, the nitrate in the drinking water sample should be less than 50 mg/L. Nitrate levels in groundwater are typically low, but they can rise due to leaching or runoff from agricultural land and pollution from animal and human waste(WHO, 2004). The source of NO_3 is not lithological. In natural cases, the concentration of NO_3 in the water should not exceed ten mg/L (Cushing et al., 1973). As a result, a greater concentration of NO_3, more than ten mg/L, indicates anthropogenic contamination. The research region is due to poor sanitary conditions and the uncontrolled use of fertilizers for higher agricultural yields. It cannot neglect the effect of landfill leachate. Figure (5D) shows the spatial distribution of nitrate in the study area. The iron concentration, according to WHO standards, the maximum permissible limit is 0.3 mg/L, and the highest concentration of iron was recorded in wells 19, 24, and 25. Figure (5E) presents iron's spatial distribution in the study area. The maximum permissible limit of copper concentration in drinking water should be less than 2 mg/L. the highest copper concentration was recorded in well 24. Figure (5F) presents copper's spatial distribution in the study area.

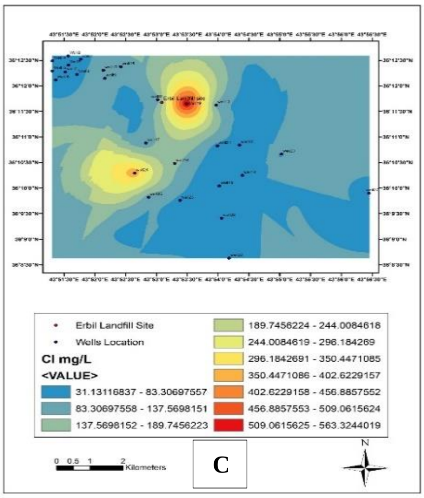
Table2: Physical and Chemical groundwater Parameters

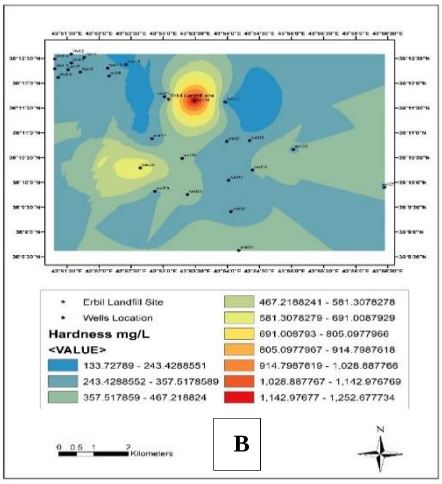
NO.	Date	Location	pH	TDS	Cl^-	Ca^{++}	Hardness	NO_3^-	Mg^{++}	Na^+	Iron	Copper
Physical or chemical parameters			chemical	physical	chemical	Chemical	chemical	chemical	chemical	Chemical	chemical	Chemical
Unit				mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
World Health Organization standard(WHO)			6.5-8.5	500	250	75	300	50	30	200	0.3	2
1	10/4/2022	Well1	7.8	765	75.55	70.4	268	35.44	22.38	83.1	0.06	0
2	10/4/2022	Well2	8	818	75.52	68.89	270	22.98	23.78	73	0.05	0
3	10/4/2022	Well3	7.9	750	85.9	75.8	279	38.5	21.77	85.5	0.02	0.001
4	10/4/2022	Well4	7.7	667	75.82	75.2	282	47.1	22.87	75	0.011	0.002
5	10/4/2022	Well5	8	745	81.3	76.8	281	45.8	21.65	86	0.03	0
6	10/4/2022	Well6	7.9	700	77.36	68.7	280	42	26.33	83	0.04	0
7	10/4/2022	Well7	7.8	734	75.51	78.4	283	39.87	21.16	78.4	0.01	0.004
8	10/4/2022	Well8	7.8	804	78.89	73.6	280	41.5	23.35	85.6	0.09	0.005
9	18/4/2022	Well9	8.2	864	101.31	84.8	348	26.58	42.03	119	0.06	0.001
10	18/4/2022	Well10	8.2	789	99.41	62.4	276	32.78	29.19	113.6	0.04	0
11	18/4/2022	Well11	8.1	868.8	110.46	64	288	40.31	31.14	138.7	0.09	0.003
12	18/4/2022	well12	7.9	871.8	121.5	57.6	240	22.15	23.35	174.9	0.002	0.001
13	18/4/2022	well 13	8.1	738.6	77.32	59.2	305	70.88	38.19	107.7	0.001	0.002
14	18/4/2022	well 14	7.9	603.6	58.91	75.2	360	48.41	41.84	69.3	0.008	0
15	18/4/2022	Well 15	7.8	539.4	46.02	67.2	280	33.67	27.25	67.2	0.05	0.001
16	18/4/2022	well16	7.7	770.4	154.6	80	384	33.66	44.76	118	0.009	0
17	18/4/2022	Well 17	7.5	667.2	99.41	51.2	260	21.26	32.11	104.2	0.07	0
18	19/5/2022	Well18	8.2	813	110	16	220	33.22	43.7	280.8	0.04	0
19	19/5/2022	Well19	7.2	2514	570	376	1268	58.6	79.8	366.3	2.8	0.5
20	19/5/2022	Well20	7.6	732	82.8	73.6	348	43.41	48.66	370.2	0.1	0
21	19/5/2022	Well21	7.8	609.6	66.3	51.2	256	51.2	31.14	439	0.008	0
22	19/5/2022	Well22	7.6	580.8	57	65.6	304	22	34.06	469	0.001	0.002
23	19/5/2022	Well23	7.7	693.6	71	78.4	420	36.4	54.5	623	0.008	0
24	19/5/2022	Well24	7.6	1308	386	145.6	704	58.47	82.48	698	2.3	2.1
25	19/5/2022	Well25	7.9	662.4	110.5	65.6	336	44	41.84	728.1	1.1	0.001
26	19/5/2022	Well 26	7.7	726	62.6	73.6	456	70.8	66.18	728.9	0.07	0
27	19/5/2022	Well27	7.6	648	60.8	78.4	352	23.1	37.95	792	0.01	0.001

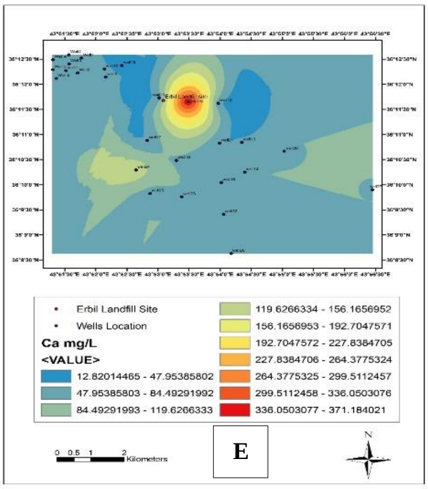












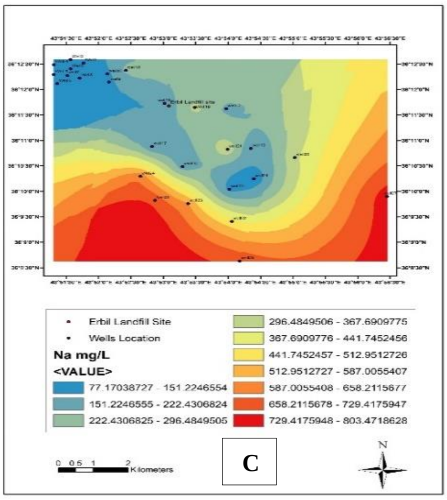


Fig. (4): Spatial distribution of groundwater quality A) pH value, B) TDS, C) chloride, D) calcium

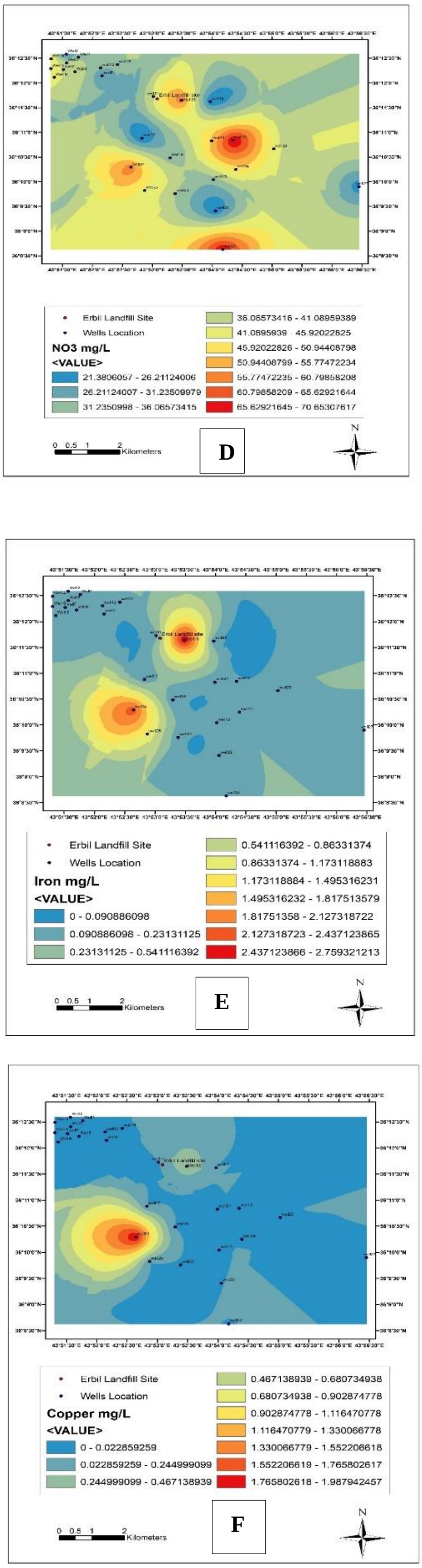


Fig. (5): Spatial distribution of groundwater quality parameters A) Magnesium, B) Hardness, C) sodium, D) nitrate, E) iron, F) copper.

4. CONCLUSION

The groundwater is an essential source of drinking water in Erbil. Rapid development and urbanization cause depletion in groundwater quality and quantity, and most landfill leachate properties are above the permissible limit. The results show there is high contamination in many tested wells. The TDS concentration of all wells is above WHO standarstandards19 in shallow water, and most water quality parameters are above WHO standards. Well, 24 suffers from high contamination in all water quality parameters. High nitrate concentration was recorded in wells (13, 19, 21 and 24), and all the wells above 10 mg/L may be due to the Erbil dumpsite leachate effect and human activities. The results show that contaminants might transport from landfill leachate to surrounding wells. The use of engineering modelling software is essential to predict the future effect.

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