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SPATIAL DISTRIBUTION MAPPING FOR VARIOUS POLLUTANTS OF AL-KUFA RIVER USING GEOGRAPHICAL INFORMATION SYSTEM (GIS)

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ABSTRACT

Geographical Information System (GIS) was employed to produce layers represent the nature of the spatial distribution of the physical and chemical parameters of Al-Kufa river because of its important in Najaf province.

Water samples from seven different stations along Al-Kufa river for twelve months from July-2013to June-2014 were collected. Thirteen water quality parameters were analyzed including total hardness(TH), turbidity (Turb.), temperature (Temp.), (pH), electrical conductivity (Ec), total dissolved solids (TDS), alklinity (Alk.), chloride (Cl^-), calcium (Ca^{+2}), sodium(Na^+), sodium adsorption ratio (SAR), magnesium (Mg^{+2}) and potassium (K^+).

Data analysis showed that the water quality parameters of Al-Kufa river exceeded the Iraqi standards for drinking water, No.417, 2001 except (pH, Alk, Mg^{+2} and Cl^-) that were compatible with the drinking water standards. For irrigation purposes the results showed that the water of Al-Kufa river was compatible with FAO (1997) standards except (TH) which showed an increase in the levels than the maximum allowable levels for irrigation standards. Based on (SAR) classification, the results indicated that there is no harmful effects from sodium on plants. According to Maas (1972) standards the results showed that the water of the river was unacceptable for food and plastic industries. The results of the tests have been linked with (GIS) software to produce layers of these parameters and to show the pollution in the river.

Key words: Al-Kufa River, Water Quality, Spatial Distribution Mapping, GIS.

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1. INTRODUCTION

Water is one of the most essential natural resources for eco-sustainability and is likely to become critical scarce in the coming decades due to increasing demand, rapid growth of urban populations, development of agriculture and industrial activities especially in semi-arid regions [1]. Variations in availability of water in time, quantity and quality can cause significant fluctuations in the economy of a country. Hence, the conservation, optimum utilization and management of this resource for the betterment of the economic status of the country become paramount [2].

The definition of water quality is very much depending on the desired use of water. Therefore, different uses require different criteria of water quality as well as standard methods for reporting and comparing results of water analysis [3]. On the other hand, GIS is very helpful tool for developing solutions for water resources problems to assess in water quality, determining water availability and understanding the natural environment on a local and / or regional scale. From GIS, spatial distribution mapping for various pollutants can be done. The resulting information is very useful for decision-makers to take remedial measures [4].

Al-Kufa River is, the source of water for Al-Najaf province. Due to the population growth, agriculture and urbanization, municipal wastes and agricultural wastes have been increased considerably into the river. The problems of water quality have become more important than the quantity. Therefore, the present study focuses on the water quality analysis of Al-Kufa River using GIS.

2. MATERIALS AND METHODS

2.1. Description of the Study Area

Kufa is a city in Iraq, about 170 kilometres south of Baghdad (capital of Iraq), and 10 kilometres northeast of Najaf. It is located on the banks of the Euphrates River. Euphrates river branches after Al-Kifil town directly about1km into two branches, first one is Al-Kufa river with a length of 73 km and width about 100 m and another branch named Al-Abbasia river. The main source of water for Al-Kufa river is rain water, stored water as lake and reservoirs. The water level is not stable at the river, according to the season of the year. In summer, decline is attributed to its lowest level so that the bottom of the river can be seen in some areas and even in winter the water levels are not rising as required, and the center of the river is not covered with water even in winter and the rainy season. The nature of the land surrounding the river is agricultural land, with some residential buildings and farming land on the other side [5]. Fig. (1) shows the study area.

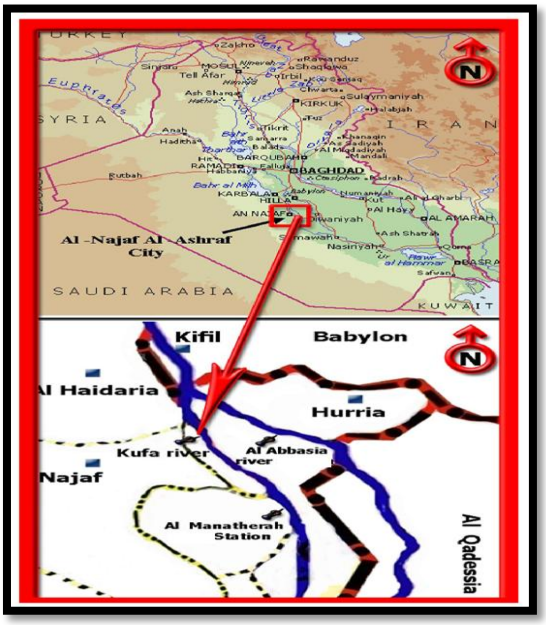

Figure 1 The study area [5].

2.2. Samples collection

In order to give a comprehensive idea of the overall water quality of the river, water samples are collected from seven stations along Al-Kufa River nearby Al-Najaf station to the QadesyiaBridge.

These stations were selected to carry out the present study a long 58.859 km stretch of Al-Kufa River situated in AI-Najaf city. According to the readings of GPS instrument (Garmin modal GPS 72H) the coordinates (x, y, z) for the locations of water samples along Al-Kufa River are described in table (1) and in fig. (2).

Table 1 Description of the monitoring stations along Al-Kufa River within Al-Najaf province

Stations	Location	Coordinates			Distance between stations (km)	Accumulated distance (km)
		X	Y	Z		
K1	Near the water project of Najaf	441263	3550167	14m	-	0
K2	Near the water project of Al-Kufa	443406	3545394	13m	6.916	6.916
K3	Near the water project of Issa	448076	3538949	12m	11.115	18.031
K4	Near the water project of Manathira	452230	3529787	11m	13.316	31.347
K5	Near the Mashkhab bridge	452283	3518815	11m	11	42.347
K6	Near the Shaalan market	453979	3514772	11m	5.739	48.086
K7	Near the Qadisiyah bridge	450873	3507105	11m	10.773	58.859

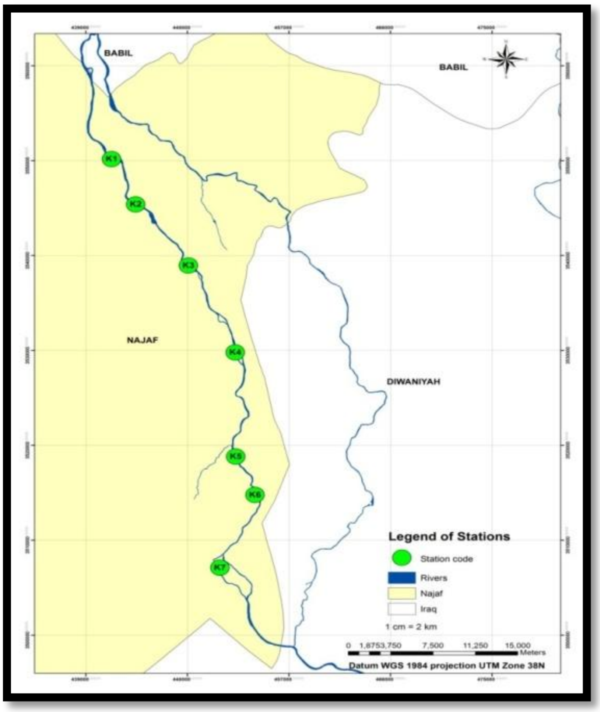

Figure 2 Stations location for water quality monitoring along Kufa River within Al-Najaf province

2.3. GIS for Water Resources

GIS is a powerful tool for developing solutions for water resources such as assessing water quality and managing water resources on a local or regional scale. Use GIS technology to integrate various data and applications into one, manageable system. The suite of tools contained in Arc Hydro facilitate the creation, manipulation, and display of hydro features and objects within the Arc GIS environment [6].So Arc GIS(10.2.2) provides tools to produce mapping of Kufa river.

2.4. The Standards

Table 2 Iraqi Standards for Drinking Water [7]

Parameter	Unit	Iraqi standard
pH	-	6.5-8.5
Alkalinity as $CaCO_3$	mg/l	200-125
Total Hardness as $CaCO_3$	mg/l	500
Magnesium (Mg)	mg/l	100
Calcium (Ca)	mg/l	150
Sodium (Na)	mg/l	200
Chloride (Cl)	mg/l	350
Turbidity	NTU	5
Conductivity	s/cmµ	2000
TDS	mg/l	1000
Potassium(K)	mg/l	10

Table 3 FAO standards for irrigation water [8].

Parameter	Unit	Limits FAO (1997)
pH	-	6-8.5
Calcium (Ca)	mg/l	400
Magnesium (Mg)	mg/l	150
Potassium(K)	mg/l	78
Total Hardness as $CaCO_3$	mg/l	500
Sodium (Na)	mg/l	920
Chloride (Cl)	mg/l	1065
Conductivity	s/cmμ	3000
TDS	mg/l	2000

Table 4 The standard values of industries [9].

Industries	Parameters	Standard value (Si)
Food industry	Turb.	10
Plastic industry	Turb.	2

3. RESULTS AND DISCUSSION

3.1. Water Quality

This study involves determining the physical and chemical parameters of surface water at different stations along Kufa River. In order to reach a better view on the causes of deterioration in water quality. The results were compared with the standards of drinking water, industries and irrigation.

3.1.1. Temperature (Temp)

Temperature values throughout the period of the study at all stations were between (12.5- 40) C^{o} for surface water. The highest value recorded was (40) C^{o}at station (K6) in June 2014 and the lowest value was (12.5) C^{o}at station (K3) in January 2014. The temperature distribution in this way is considered normal suited with the nature of the climate of the region. Iraqi standards did not specify certain limits for temperature, but the importance of the temperature influences the properties of water affects the chemical reactions in addition to its effect on taste and color[10].**Turbidity (Turb):**

3.1.2. Turbidity(Turb)

The turbidity values at all stations were between (1.29-34.6) (NTU) for surface water. The highest value recorded was (34.6) (NTU) at station (K3) in September 2013, while the lowest value was (1.29)(NTU) at station (K3) in April 2014. The highest concentration of turbidity attributed to the existence of Albrakiyah treatment plant. The maximum concentrations of turbidity exceeded Iraqi standards for drinking water, No.417, 2001.According to the standards of (Maas, 1972), the results of turbidity were unacceptable to be used in industries.

3.1.3. Hydrogen Ion Concentration (pH)

The pH values at all stations were between (6.7-8.3) for surface water. The highest value recorded was (8.3) at station (K4) in August 2013, while the lowest value was (6.7) at stations (K6 and K7) in January 2014. The pH value of water decreased as the content of CO_2 increased, while it increased as the content of bicarbonate alkalinity increased in river water [11]. In general, the maximum and minimum concentrations of pH were within Iraqi standards for drinking water. According to the standards of (FAO, 1997), the results of pH were acceptable to be used in irrigation.

3.1.4. Electrical Conductivity (Ec)

Conductivity values throughout the period of the study at all stations were between (1007-3014) (µs/cm). The highest value recorded was (3014) (µs/cm) at station (K7) in December 2013, while the lowest value was (1007) (µs/cm) at station (K1) in September 2013. The results showed that high values of Ec because of heavy rainfall in this month on agricultural land surrounding the river, which led to the increased concentrations of dissolved ions that seeping into the river. The maximum concentrations of conductivity exceeded Iraqi standards for drinking water. According to the standards of (FAO, 1997), the results of Ec were acceptable to be used in irrigation for all stations except at station (K7).

3.1.5. Alkalinity (Alk)

The values of alkalinity at all stations were between (100-156) mg/l as $CaCO_3$ for surface water. The highest value obtained was (156) mg/l as $CaCO_3$ at station (K6) in February 2014, while the lowest value obtained was (100) mg/l as $CaCO_3$at station (K7) in July 2013. In general, the concentrations of alkalinity were within Iraqi standards for drinking water.

3.1.6. Total Hardness (TH)

The values of total hardness at all stations were between (353-710) mg/l as $CaCO_3$ for surface water. The highest value obtained was (710) mg/l as $CaCO_3$ at station (K2) in December 2013, while the lowest value obtained was (353) mg/l as $CaCO_3$ at station (K7) in September 2013. The highest concentration of total hardness attributed to the existence of northern drainage of Al-Kufa and due to the weathering processes during the rainy season especially in December 2013, and the disposal of municipal and agricultural wastes into the river. The maximum of total hardness concentrations exceeded Iraqi standards for drinking water. According to the standards of (FAO, 1997), the results of total hardness were unacceptable to be used in irrigation.

3.1.7. Calcium (Ca^{++})

The values of calcium concentration for surface water were (72.38-215) (mg/l). The highest value obtained was (215) (mg/l) at station (K6) in November 2013. The lowest value was (72.38) (mg/l) at station (K5) during June 2014.Soil erosion and mining of dolomite can be attributed to high values of calcium and magnesium concentration in river water [12]. The maximum of calcium concentrations exceeded Iraqi standards for drinking water. According to the standards of (FAO, 1997), the results of calcium ion were acceptable to be used in irrigation.

3.1.8. Magnesium (Mg^{++})

Magnesium concentrations for surface water were ranging (15.1- 92.6) (mg/l). The highest value obtained was (92.6) (mg/l) at station (K3) in January 2014. The lowest value was (15.1) (mg/l) at station (K6) in November 2013.All values of magnesium concentrations were within Iraqi standards for drinking water. According to the standards of (FAO, 1997), the results of magnesium ion were acceptable to be used in irrigation.

3.1.9. Chloride (Cl^{-})

The values of chloride concentrations for surface water were between (107-344) (mg/l). The highest value obtained was (344) (mg/l) at station (K7) in December 2013. The lowest value was (107) (mg/l) at station (K2) in October 2013.All values of chloride concentrations were within Iraqi standards for drinking water. According to the standards of (FAO, 1997), the results of chloride ion were acceptable to be used in irrigation.

3.1.10. Total Dissolved Solids (TDS)

Total dissolved solids values at all stations were between (706-1922) (mg/l) for surface water. The highest value obtained was 1922 (mg/l) at station (K7) in December 2013, while the lowest value obtained was (706) (mg/l) at station (K6) in July 2013. The results showed that high value of TDS because of heavy rainfall in this month on agricultural land surrounding the river, which led to the increased concentrations of dissolved ions that seeping into the river. The maximum concentrations of the total dissolved solids exceeded Iraqi standards for drinking water. According to the standards of (FAO, 1997), the results of total dissolved solids were acceptable to be used in irrigation.

3.1.11. Sodium (Na^{+})

Sodium values throughout the period of the study at all stations were between (74-290) (mg/l) for surface water. The highest value recorded was (290) (mg/l) at station (K7) in December 2013 and the lowest value was (74) (mg/l) at station (K2) in October 2013. The maximum concentrations of sodium exceeded Iraqi standards for drinking water. According to the standards of (FAO, 1997), the results of sodium ion were acceptable to be used in irrigation.

3.1.12. Potassium (K^{+})

Potassium values at all stations were between (3.5-13) (mg/l) for surface water. The highest value recorded was (13) (mg/l) at stations (K2, K6) in December 2013 and the lowest value was (3.5) (mg/l) at stations (K1, K3, K4) in January 2014. The maximum concentrations of potassium exceeded Iraqi standards for drinking water. According to the standards of (FAO, 1997), the results of potassium ion were acceptable to be used in irrigation.

3.1.13. Sodium Adsorption Ratio (SAR)

The test results showed that the SAR values at all stations in surface water varied from (2.344–2.699) (meq/l). Based on the classification of the salinity laboratory of the U.S. Department of Agriculture for (SAR) values, the test results showed that there is no harmful effects from sodium on plants because the values of SAR were less than ten[13].

3.2. Using the (GIS) software

In this study thirteen physico–chemical parameters were considered in the analysis. GIS is used to represent the spatial distribution of the parameters. Producing new maps of GIS represented the maximum and minimum values of the parameters at all stations in the study area to show the impact of pollution on the surface water quality. The following Figures from **(3)** to **(27)** show the distribution of most parameters.

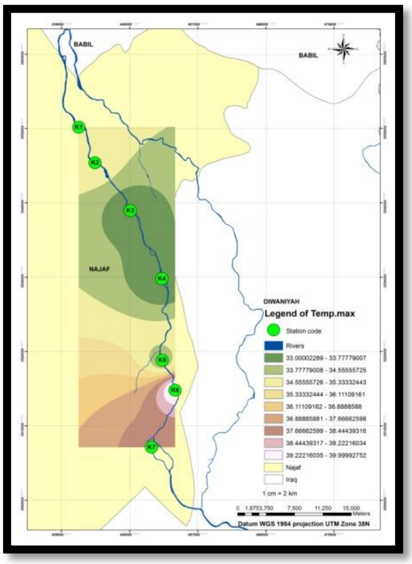

Figure 3 Temp. Maximum

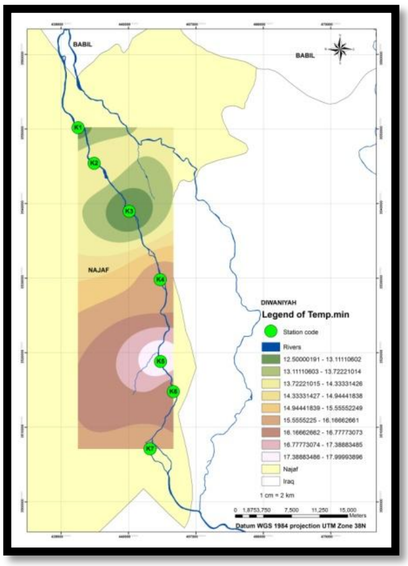

Figure 4 Temp. Minimum

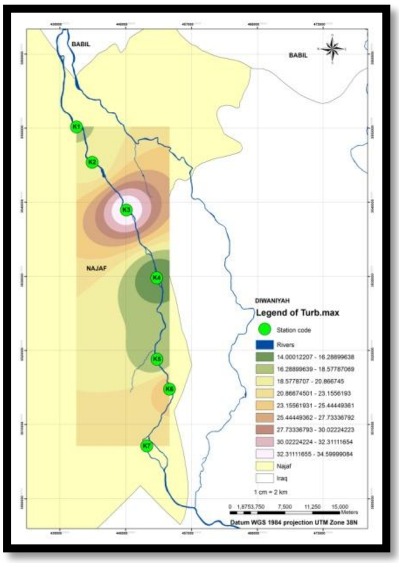

Figure 5 Turb. maximum

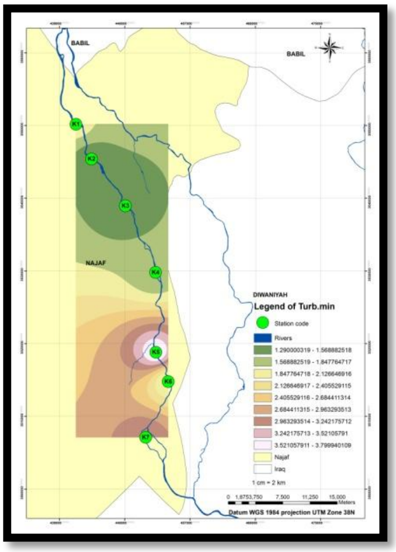

Figure. 6 Turb. minimum

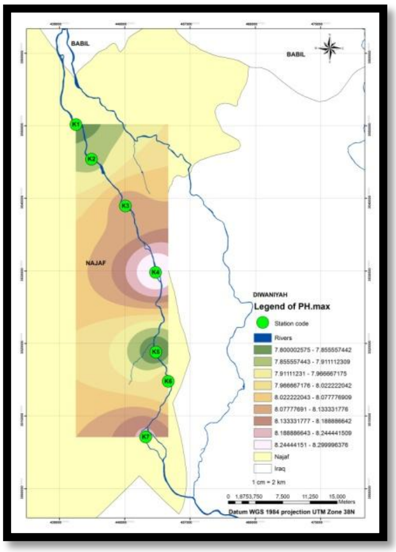

Figure 7 pH maximum

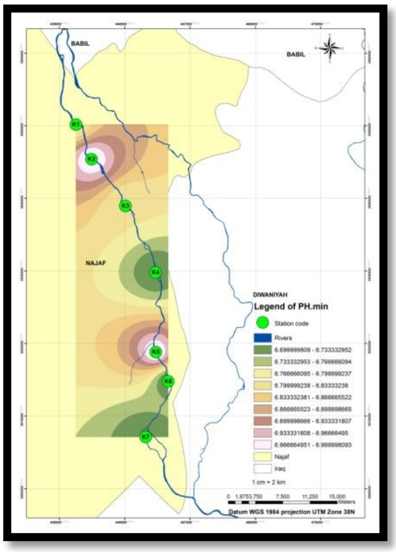

Figure 8 pH minimum

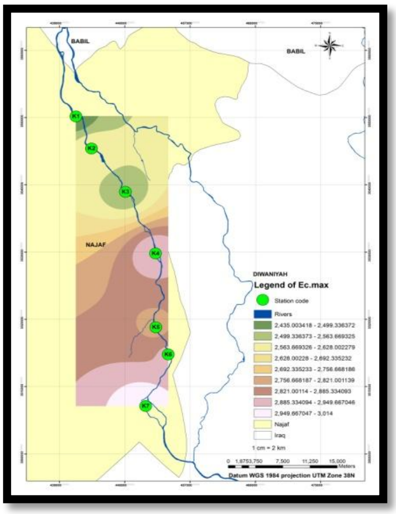

Figure 9 Ec maximum

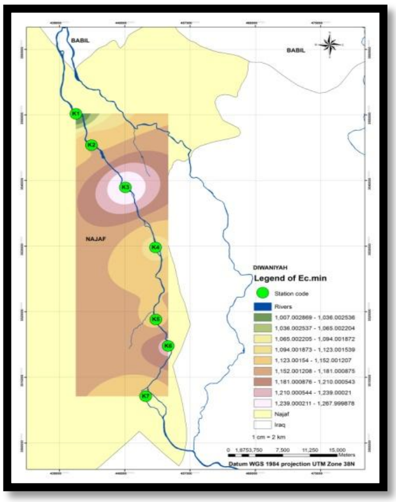

Figure 10 Ec minimum

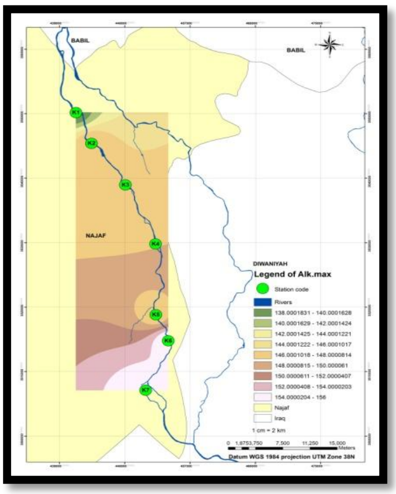

Figure 11 Alk. Maximum

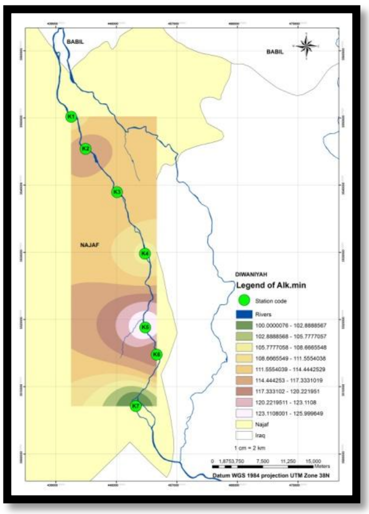

Figure 12 Alk. Minimum

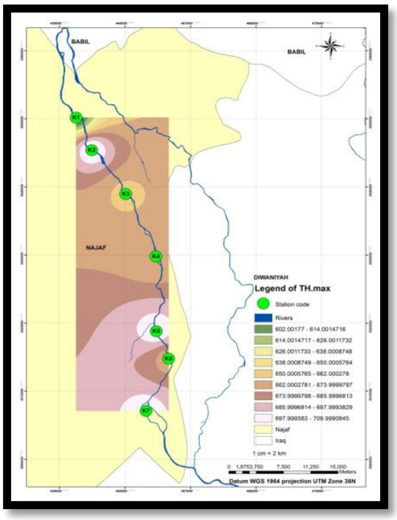

Figure 13 TH maximum

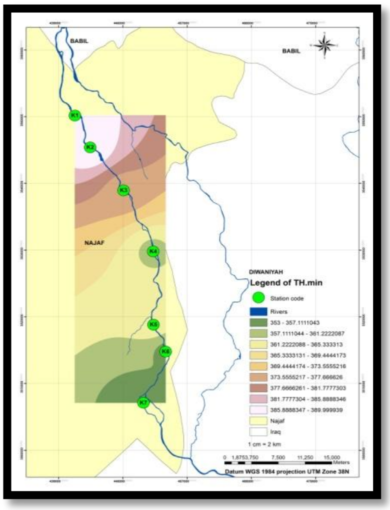

Figure 14 TH minimum

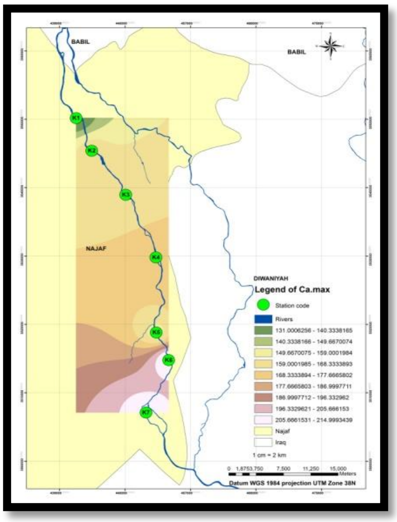

Figure 15 Ca^{+2} maximum

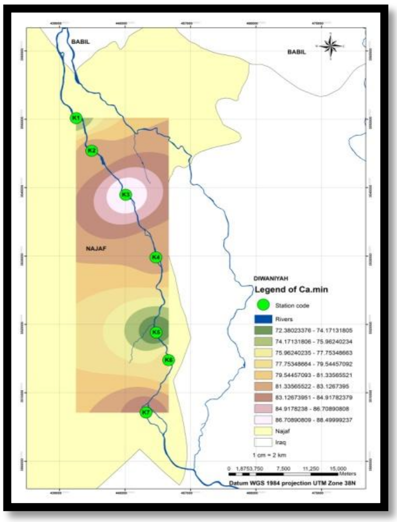

Figure 16 Ca^{+2} minimum

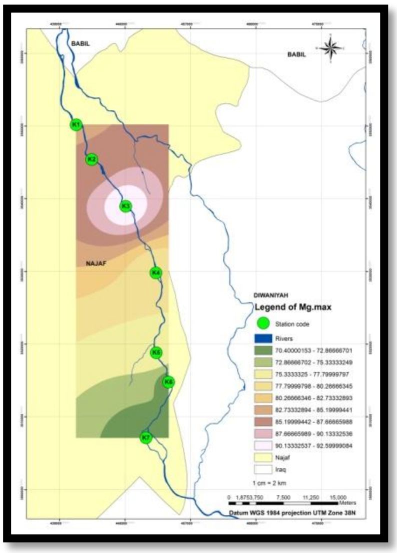

Figure 17 Mg+2 maximum

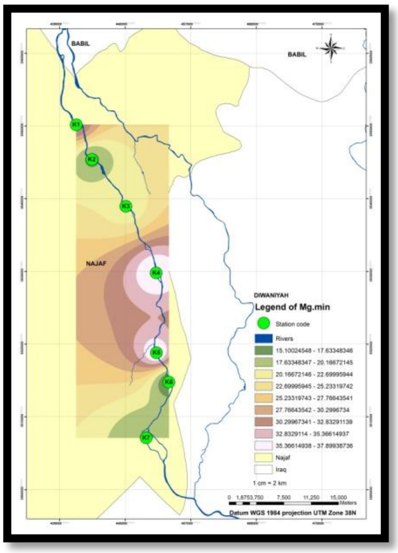

Figure 18 Mg+2 minimum

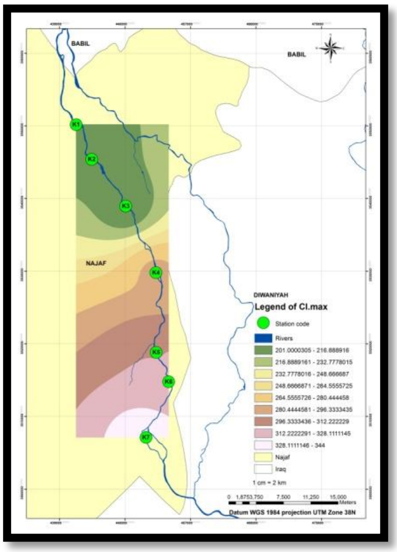

Figure 19 Cl^- maximum

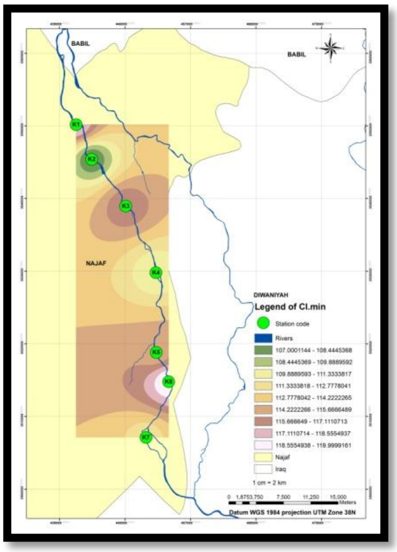

Figure 20 Cl^- minimum

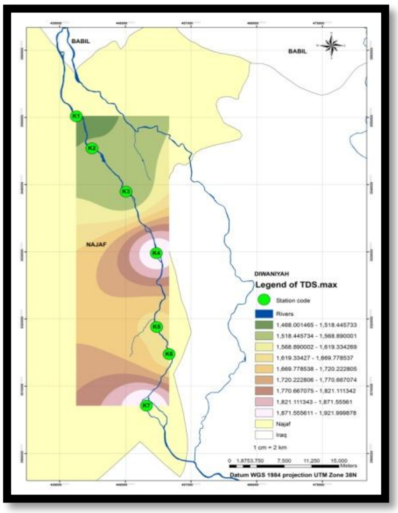

Figure 21 TDS maximum

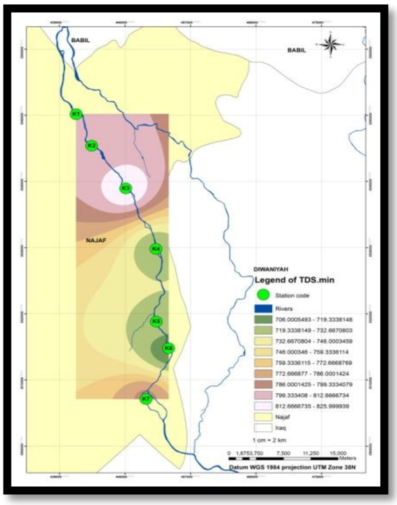

Figure 22 TDS minimum

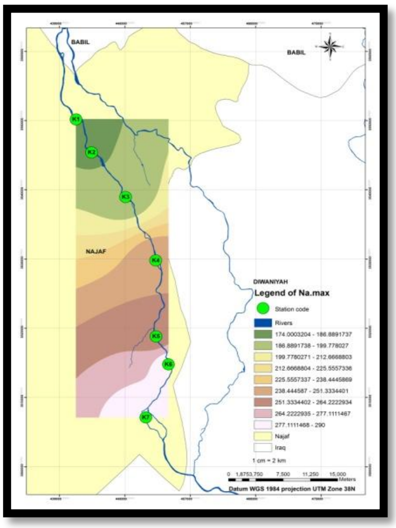

Figure 23 Na^+ maximum

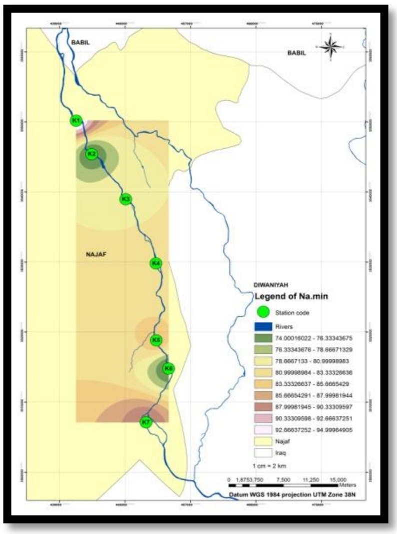

Figure 24 Na+ minimum

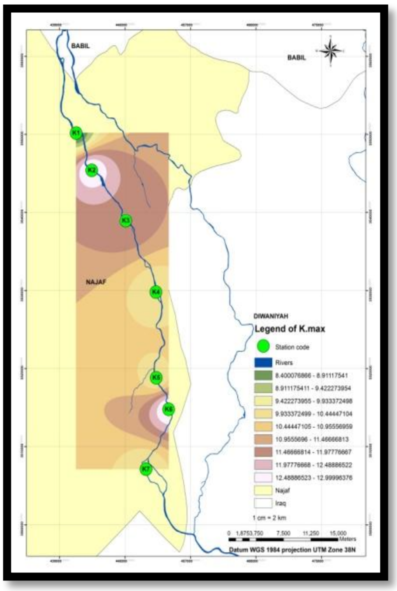

Figure 25 K^+ maximum

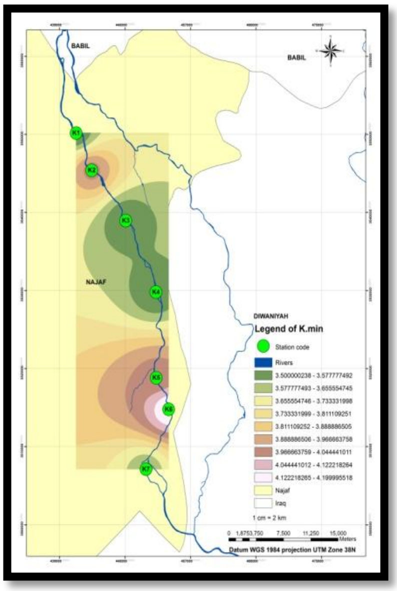

Figure 26 K^+ minimum

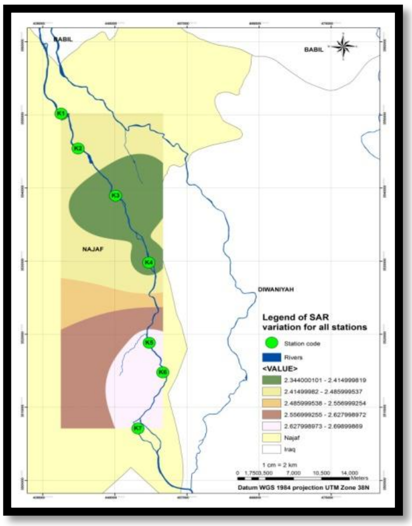

Figure 27 SAR values

4. CONCLUSIONS

- The maximum concentrations of (Cl^-, Ca^{+2}, Mg^{+2}, Ec, TH, Na^+, Alk., K^+, SAR and TDS) for surface water were during winter season especially in December 2013 because of heavy rainfall on agricultural land surrounding the river which led to the increased concentrations of dissolved ions that seeping into the river.
- The deterioration increased of water quality of Al-Kufa River during 2013-2014 because there are many agricultural drainages surrounding the river. In addition to the wastewater treatment plant non-efficient because of an old plant and receive discharges higher than the design capacity of the plant.
- The results showed that the maximum values of (Turb, Ca^{+2}, Ec, TH, Na^+, K^+, and TDS) were exceeded Iraqi standards for drinking water, No.417, 2001. This means that the water is certainly unfit for drinking purposes (without treatment).

- According to the standards of FAO (1997), Al-Kufa River is considered acceptable to be used in irrigation. And based on (SAR) classification, the test results showed that there is no harmful effects from sodium on plants.
- According to the standards of Maas (1972), Al-Kufa River is considered unacceptable to be used in food and plastic industries.
- The spatial distribution of various physico-chemical parameters are developed by using (GIS) facilitated in identifying the potential zones of drinking water quality, irrigation and industry, where GIS is an efficient tool to the decision makers in order to be able to understand the status of the surface water quality.

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