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EVALUATION OF DRAINAGE WATER QUALITY FOR IRRIGATION BY INTEGRATION BETWEEN IRRIGATION WATER QUALITY INDEX AND GIS

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Abstract: The basic reason behind the need to monitor water quality is to verify whether the examined water quality is suitable for intended usage or not. This study is conducted on Al -Shamiya al- sharqi drain in Diwaniya city in Iraq to make valid assessment for the level of parameters measured and to realize their effects on irrigation. In order to assess the drainage water quality for irrigation purposes with a high accuracy, the Irrigation Water Quality Index (IWQI) will be examined and upgraded (integrated with GIS) to make a classification for drainage water. For this purpose, ten samples of drainage water were taken from different ten location of the stuay area. The collected samples were analyzed chemically for different elements which affect water quality for irrigation.These elements are : Calcium(Ca^{+2}), Sodium(Na^{+}), Magnesium(Mg^{+2}), Chloride(Cl^{-}), Potassium(K^{+}), Bicarbonate(HCO3), Nitrate(NO3), Sulfate(SO_4), Phosphate(PO_4), Electrical Conductivity(EC), Total Dissolved Solids (TDS), Total Suspended Solids (TSS) and pH-values (PH). Sodium Adsorption Ratio (SAR) and Sodium Content (Na%) have been also calculated. Results suggest that, the use of GIS and Water Quality Index (WQI) methods could provide an extremely interesting as well as efficient tool to water resource management. The results analysis of (IWQI) maps confirms that: 52% of the drainage water in study area falls within the "Low restriction" (LR) and 47%of study area has water with (Moderate restriction)(MR),While 1% of drainage water in the study area classified as (Sever restriction) (SR). So, the drainage water should be used with the soil having high permeability with some constraints imposed on types of plant for specified tolerance of salts.

Key words: Irrigation water quality index,GIS,Water quality.

I. INTRODUCTION

Increasing demands for water result from both increasing world population as well as improvements in standards of living. Agricultural demands for water are also still increasing as supplemental irrigation is adopted in regions where rainfall is not sufficient to met optimal crop water requirements. Water scarcity is a major constraint to expansion of agricultural production in many countries. Benefits of drainage water reuse in irrigation are expressed in agricultural production, the contribution of irrigation to aquifer recharge, saving in drainage water disposal cost and value of the saved fresh irrigation water. At the same time drainage water irrigation may be hazardous to the environment, since this water contains pollutants such as salinity, pathogens, trace and heavy metals, nutrients and pesticides. The use of marginal quality water has the potential of causing serious problems of soil degradation and reduction in crop productivity because of irrigation water quality[9,10]. Other problems such as human health hazards and quality degradation of groundwater are also involved. One of the ways to classify water quality is by adopting indices where a series of parameters examined are joined a single value to facilitate the interpretation of extensive lists of variables or indicators, to underlie water quality classification [6]. Water quality indices yield a quite simple as well as reasonable tool for the managers regarding the quality of irrigation water and its possible uses.

Drainage water quality analysis and geographic information system (GIS)-based mapping are significant sides for a strategy to plan drainage water. Analysis on the basis of hydrochemical studies may show potential contaminated zones and determines the suitability of water for drinking, irrigation, or other purposes. GIS can be adopted to identify the harmed areas by drainage water pollution and to get other reliable information over scenarios of current drainage water quality that can be basic side for the effective and productive implementation ofwater management programs [3].

II. STUDY AREA

AL-Shamiya al-sharqi drain is considered one of the most important and biggest drains of central and southern Iraq after AL-masab al-aam because it is the main drain for projects (Hilla-Kifil) , (Hilla-Diwaniya) ,(Kifil- Shinnafiah) and (Diwaniya-shafie). AL-Shamiya al-sharqi drain connected with AL-Forat al-sharqi drain, length of 261km at station (170+000)km. AL-Forat al-sharqi drain when passed at Al- Shamiya in the city of Diwaniya at road (Diwaniya - Najaf) called AL-Shamiya al-sharqi drain of 90km length. Al-Forat al-sharqi drain is the oldest drain that carried out by the government who started to work in 1942 and completed in 1946. It extends from south-west of the governorate of Babylon at the Kifil, passing land of Diwaniya-Mhenawiyah, where lands of Mhenawiyah and Saniya drain in. It passes Al-Shamiya at road (Diwaniya- Najaf) where the agricultural lands in the region drain in.Then, it deviates toward AL-Shinnafiah. It enters the administrative borders of AL-Samawa governorate to reach finally the marsh in DhiQar governorate. Al-Shamiya drain is located between (44◦61'-44◦69') eastern longitude and (31◦95'-31◦-99') northern latitude. The study area covers an area of 14531 dunums while AL-Forat al-sharqi drain covers an area of 1.5 million dunums.

III. SAMPLING AND LABORATORY WORKS

In the present study, a specified area of AL-Shamiya al-sharqi drain were selected to be evaluated for its drainage water quality. The study area is located between (44°61'-44°69') eastern longitude and (31°95'-31°99') northern latitude. Ten samples of drainage water were taken from different ten locations of the study area in (1/5/2014). These locations are shown in Figure (1). The collected samples were analyzed chemically for different elements which affect water quality for irrigation. These elements are : Calcium (Ca^{+2}), Sodium (Na^{+}), Magnesium (Mg^{+2}), Chloride(Cl^{-}) , Potassium (K^{+}) , Bicarbonate (HCO3), Nitrate(NO3), Sulfate (SO_4), Phosphate(PO_4) , Electrical Conductivity (EC) , Total Dissolved Solids (TDS), Total Suspended Solids (TSS) and pH-values (PH). Sodium Adsorption Ratio (SAR) and Sodium Content (Na%) have been also calculated.

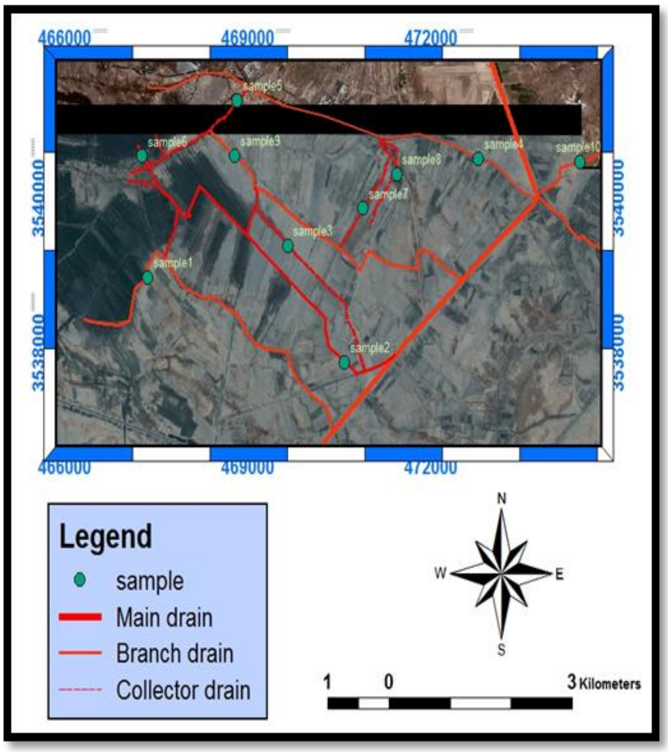

Fig.(1) Water sampling sites in the studied area

IV. IRRIGATION WATER QUALITY CRITERIA

The kind and amount of salt determine the suitability of irrigation water. Potential severity problems expecting to progress over a long-term use verdict water quality or suitability for use. [1]. In general and as mentioned by [2], there are main groups for limitations which are associated with the quality of irrigation water:

1- Soluble salts total concentration (Salinity hazard)
2- Sodium relative proportion to the other cations (sodium hazard).
3- pH values and concentrations of bicarbonate and nitrate (Diverse effects)
4- Specific ions toxicity, such as Chloride, Sodium, and trace elements.

Appropriateness of water irrigation in addition to the probability of plant toxicity can be defined by the amounts and combinations of these substances [4].

A. The Salinity Hazard

There are dissolved salts in all major water irrigation sources.To describe the concentration of (iconic) salt species, the term salinity is used [8]. The Salinity hazard can happen when salts accumulates in the zone of the crop root to reduce the sum of water existing at the roots.The available amount of the reduced water occasionally hits such levels that are adversely affecting the crop yield. Plant's growth gets slow rate and drought-like symptoms begins to build up when this water pressure is extended [2]. A high osmotic potential is caused by high salinity in water (or soil solution). Plants roots can be burnt and/ or foliaged by some salts with a toxic effect. The elevated rates of some metals may intervene with proportional availability and plant absorbtion of other micronutrients [8]. Salinity of water irrigation is expressed in terms of both indicators of Electrical Conductivity (EC) and Total Dissolved Solids (TDS).

1. Electrical Conductivity (EC)

EC is used to measure the electricity conducted by water. It is closely related to Total Dissolved Solids (TDS) due to the function of the ionic solutes concentrations. It is commonly reported that it is a quick and easy measurement to make in the field. EC, is determined by the passage of an electrical stream through a water sample and records the impedance in mmhos/cm or dS/m [5].The usual range of EC as mentioned by [1] is between 0-3000 (µS/cm).

2. Total Dissolved Solids (TDS)

TDS is another expression used in describtion water quality that is used to assess the mass concentration of soluble components in water. It is usually calculated in units of milligrams per liter (mg/l) or parts per million (ppm). Usual range of TDS for irrigation water as mentioned by [1] is between 0-2000 ppm.

B. Sodium Hazard

There are large amounts of sodium in the irrigation of water which is of special concerns because of sodium affects on the soil and forms a sodium risk [4]. A problem to occur with the high sodium concentrations when the infiltration rate is reduced to such a rate that the availability of the water for a crop is not enough or when the hydraulic accessibility of the soil profile is very low to supply sufficient drainage. An excess of Na could cause other problems to the crop such as formatting crusting the beds of seed, temporal saturation of soil surface, escalated pH and the more potential for diseases, weeds, soil corrosion, scarcity of oxygen and insufficient nutrient obtainability. There are several factors related to these problems such as the rate of salinity and soil type. For example, the soil of sandy type (which comprise most study area) may be different from other soils in getting the damage when it is irrigated with water of high Na concentration. Sodium Hazard is usually expressed in terms of Sodium Absorption Ratio (SAR) and Soluble Sodium Percent (SSP) [4].

1. odium Content (Soluble Sodium Percent (SSP))

SSP means the ratio of sodium in meq/l (miliequivalents per liter) to the sum cations (meq/l) multiplied by100.When water with a Soluble Sodium Percent more than 60 percent it product in sodium cumulation that will give rise to a collapse in the physical properties of soil [4].

$$Na\%=SSP=\frac{(Na+K)}{(Na+K+Ca+Mg)}\times 100 \qquad (1)$$

2. Sodium Absorption Ratio (SAR)

The proportional concentrations of sodium is considered as the most public water quality factor that influences the common amended of permeation of water, magnesium and calcium ions in water. The role of Calcium and magnesium is important to maintain constitution of soils that contain clay. Applying water with excessive rate of sodium and low rate of calcium and magnesium is common to clay soils. Sodium, on the other hand, tends to move calcium and magnesium on clay particles to result in collapse of components, deposition of organic substance, and decreased permeability. The sodium adsorption ratio (SAR) represents relative concentration of sodium, magnesium and calcium ions in water and it can be defined as:

$$SAR = \frac{Na}{\sqrt{(Ca+Mg)/2}} \qquad (2)$$

What SAR provides a beneficial pointer of water irrigation potential detrimental effects on soil structure and permeability. The concentration of the constituents is expressed in (meq/l).

C. Diverse Effects

Besides the risks and consequences considered in the former sections, there are another parameters and, the existence of such parameters should be estimated strictly in water irrigation. These parameters are thought to be inside the field of diverse effects to sensational crops and involve pH value plus the concentrations of bicarbonate and nitrate ions [11].

1. pH

The pH value affects the carbonate stability, weighty mineral content, and the proportional rate of nitrogen constituents that consequently influence on the quality of soil and plant development. In acidic waters, aluminum, magnesium, and calcium are not assimilated appropriately by plants while essential water grant the best climate for plants absorption of many minerals and nutrients. Therewith, essential waters are also in charge of calcium carbonate collection that affects the physical constitutes of water [11]. In general, the major use of pH in a water analysis is to detect unusual water. The normal range of pH for water irrigation is from 6 to 8.[1].

2. Bicarbonate

Bicarbonate (HCO_3^-) and Carbonate (CO_3^{2-}) ions are the main component of alkalinity and in charge for large pH values (more than 8.5).

3. Nitrate

It can safely be said that nitrate is the fundamental exporter of nitrogen to most plants as it is generally employed as a compost. In spite of that, using immoderate amounts of nitrate could reduce the yield or the crop quality because it delays the crop ripeness, untimely growing or unsightly deposits on the fruit or plants leaves. A proper fertilizer and irrigation management can solve many of these problems. Furthermore, applying nitrate to soils must be prepared with maximum attention because it could readily result in nitrate defilement for the resources of local groundwater [11].

D. Specific Ions Toxicity

Specific ions such as sodium and chloride as well as boron are causing problems of toxicity for plants when their concentrations are at high rates in water or soil. In case the plant takes up such ions until they get accumulated at high concentrations, the ions will cause crop damage or reduction and they will be labeled as toxic. Toxicity level depends on plant type and its rate of uptake.The crops that permanent and perennial have more sensitivity to such kind of toxicity as compared to the crops of yearly types. It is a famous fact that toxicity caused by ion is regularly co-occur with other hazards such as salinity and permeation [2].The toxicity risks can be more categorized as troubles that are linked with certain ions and hazards connected with the trace elements and weighty metals. Despite the fact that chloride is vital for plants in very little amounts, it may cause toxicity to sensitive crops in case of its availability with high concentrations. The immediate toxic effects include leaf burns or leaf tissue deaths. As in the case with sodium, high concentrations of chloride lead to additional problems when applied with sprinkler irrigation.

V. PROPOSED WATER QUALITY EVALUATION MODEL

The objective of this study is to develop the IWQI which established by [7] through integrated it with GIS in order to identify places with the best water quality for irrigation by maping irrigation water quality index (IWQI). GIS-integrated method is built on combining five varied groups of parameters used to assess irrigation water quality that may have negative consequences or hazards on both the quality of soil and crop productivity. All five groups, In this technique, are at once involved in the analysis, and combined to form a single index value meant to be assessed to identify the irrigation water suitability.

IWQI model was applied based on the results of samples were taken from a drainage water of the study area. This model was developed by [7] via conducting two steps. The first step involves identifying the parameters that participate in causing most variability of irrigation water quality. For the sake of developing the suggested WQI; The EC, Na^+, Cl^-, HCO_3^-, and SAR parameters were adopted. The best water quality are defined through these major factorial load. The second step witnesses defining quality mensuration values (Q_i) and accumulation weights (w_i). Values of (Q_i) are to be implied according to every parameter value, based on the criteria recognized by Ayers and Westcot (1999), as listed in Table (1).By using a non-dimensional number, water quality parameters were represented; the highest the value, the best water quality.

Table (1): Limiting values of Parameter for quality measurement (Q_i) calculation [7].

HCO_3^-	Cl^-	Na^+	SAR $(meq/l)^{1/2}$	EC (µs/cm)	Qi
meq/l					
1≤HCO3<1.5	1≤Cl<4	2≤Na<3	2≤SAR<3	200≤EC<750	85-100

1.5≤HCO3<4.5	4≤Cl<7	3≤Na<6	3≤SAR<6	750≤EC<1500	60-85
4.5≤HCO3<8.5	7≤Cl<10	6≤Na<9	6≤SAR<12	1500≤EC<3000	35-60
HCO3<1 or HCO3≥8.5	1<Cl≥10	Na<2 or Na≥9	2<SAR≥12	EC<200 or EC≥3000	0-35

Values of Qi were estimated depending on Equation (3), according to tolerance limits as in Table(1) and results of water quality as appear in lab:

$Q_i=Q_{imax}-[(x_{ij}-x_{inf})*Q_{iamp})/x_{amp}]$ (3)

where

Q_{imax}= comes as the maximal value of q_i for the category;

x_{ij} = comes as the parameter spotted value;

x_{inf} = is the value that corresponds to the minmal border of the category to each parameter;

Q_{iamp} = is category ampleness;

x_{amp} = is category ampleness to each parameter.

To estimate x_{amp}, of the final category of every parameter, the uppermost border was viewed as the maximal value obtained in the physico-chemical and chemical examination of water samples. Every parameter weight used in the IWQI was gotten by [7] as shown in Table (2)

Table (2): Weights for the WQI parameters [7]

Parameters	w_i
Electrical Condutivity (EC)	0.211
Sodium (Na^+)	0.204
Bicarbonate (HCO_3^-)	0.202
Chloride (Cl^-)	0.194
Sodium Adsorption Ration (SAR)	0.189
Total	**1.000**

The w_i values were put on a normal footing such that their summation equals one. The water quality index was computed as:

$WQI=\sum_{i=1}^{n} Q_i w_i$ (4)

WQI is none dimensional parameter extending from (0 to 100);

Q_i comes as the quality of the parameter (i^{th}), a number from (0 to 100), assignment of its concentration or mensuration; and w_i is the stabilized weightiness of the parameter (i^{th}), and assignment of its relative significance to drainage water quality. The classes are divided according to the proposed index of water quality that is set by depending on available water quality indexes.The classes are introduced by seeing the danger of problems related to salinity, soil water permeation lowering, besides toxicity to plants as noticed in the categorizations submitted by Bernardo (1995) and Holanda and Amorim (1997). limitations to waste usage classes are described in Table (3).

Table (3): Water quality index characteristics [7].

IWQI	Water Use Restrictions	Recommendation	
		Soil	Plant
85-100	No restriction (NR)	May be used for the majority of soils with low probability of causing salinity and sodicity problems, being recommended leaching within irrigation practices, except for in soils with extremely low permeability.	No toxicity risk for most plants
70-85	Low restriction (LR)	Recommended for use in irrigated soils with light texture or moderate permeability, being recommended salt leaching. Soil sodicity in heavy texture soils may occur, being recommended to avoid its use in soils with high clay.	No toxicity risk for most plants
55-70	Moderate restriction (MR)	May be used in soils with moderate to high permeability values, being suggested moderate leaching of salts	Plants with moderate tolerance to salts may be grown
40-55	High restriction (HR	May be used in soils with high permeability without compact layers. High frequency irrigation schedule should be adopted for water with EC above 2000 µS cm-1 and SAR above 7.0.	Should be used for irrigation of plants with moderate to high tolerance to salts with special salinity control practices, except water with low Na, Cl and HCO3 values
0-40	Severe restriction (SR)	Should avoid its use for irrigation under normal conditions. In special cases, may be used occasionally. Water with low salt levels and high SAR require gypsum application. In high saline content water soils must have high permeability, and excess water should be applied to avoid salt accumulation.	Only plants with high salt tolerance, except for waters with extremely low values of Na, Cl and HCO3.

VI. RESULTS AND DISCUSSION

The water quality database measured in laboratory is transferred into GIS platform, grid datasets are created for each parameter within the domain of interest using inverse distance weight interpolation technique. The following Figures from (2) to (16) are showing the distribution of most elements that affect surface water quality for irrigation in the studied area.

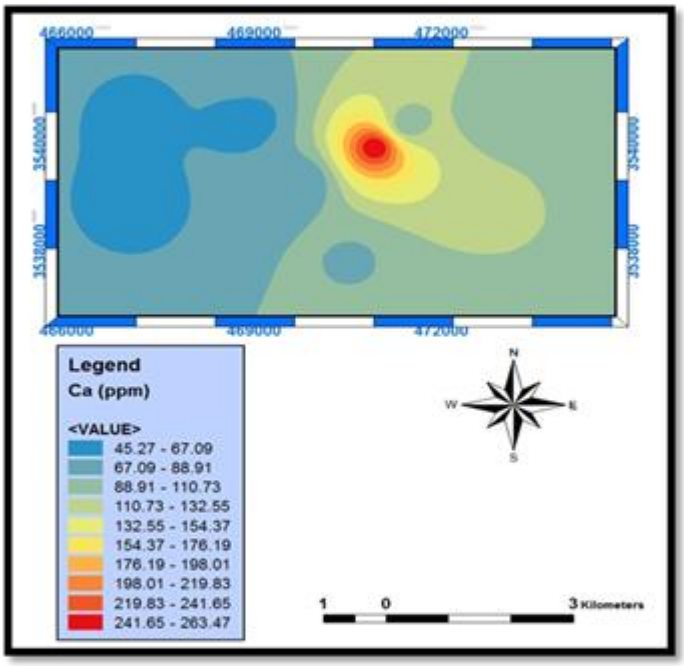

Fig.(2) Distribution map of Ca^{+2}

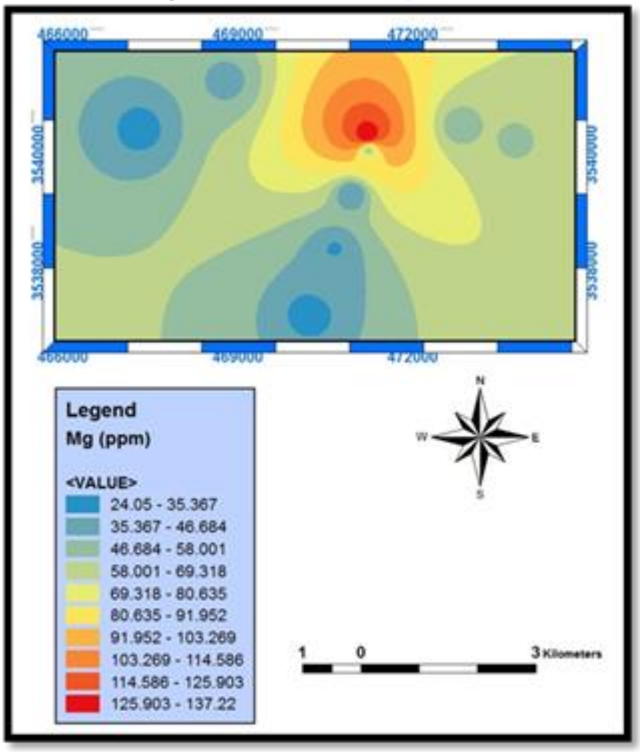

Fig. (3) Distribution map of Mg^{+2}

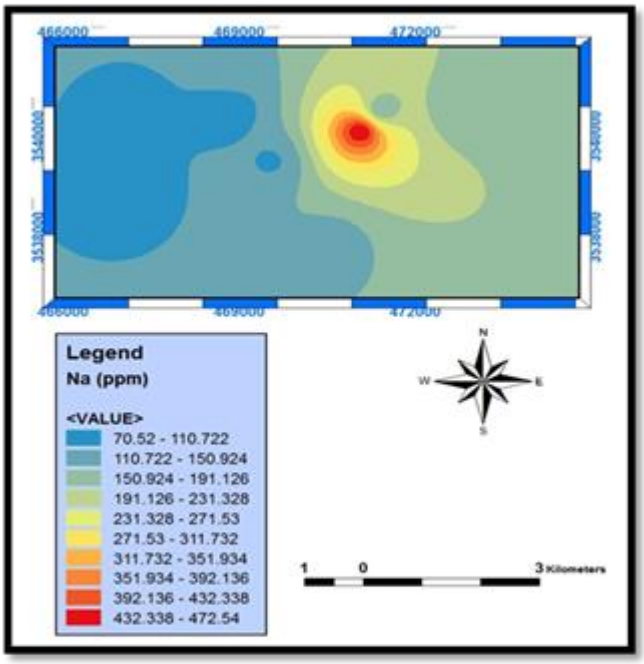

Fig. (4) Distribution map of Na^{+1}

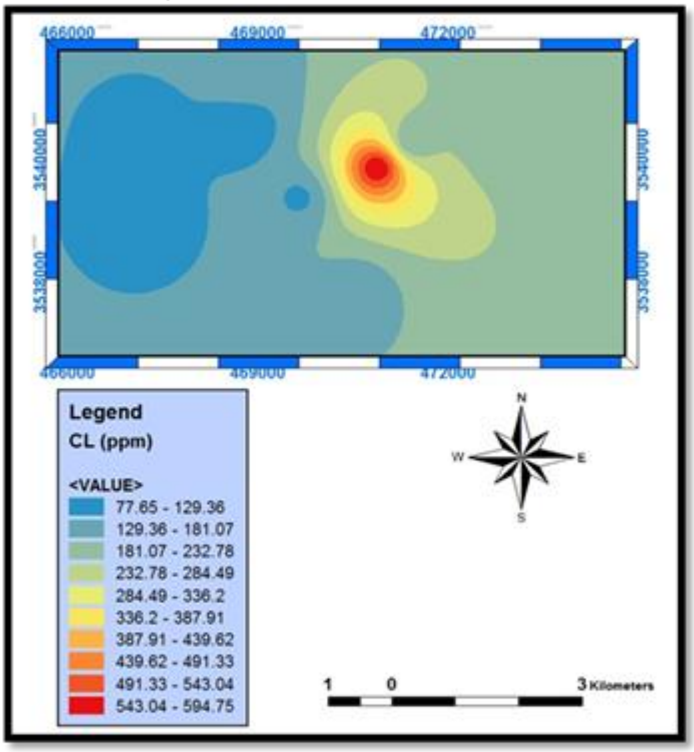

Fig. (5) Distribution map of CL

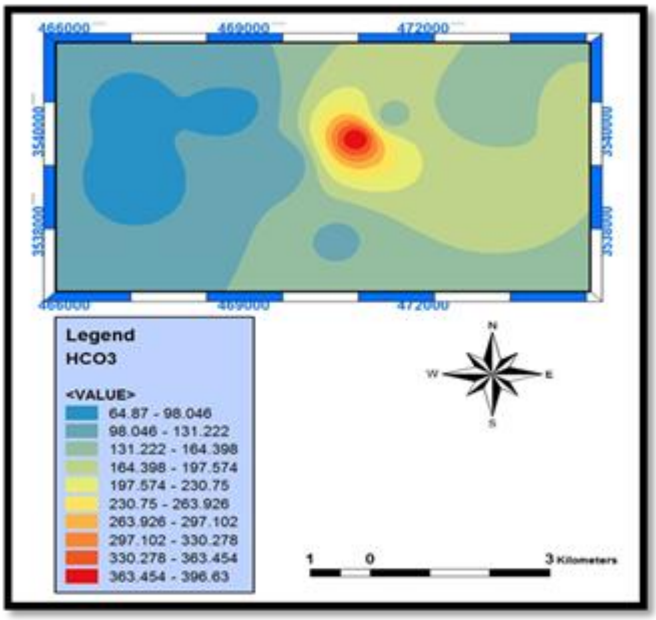

Fig. (6) Distribution map of HCO_3^-

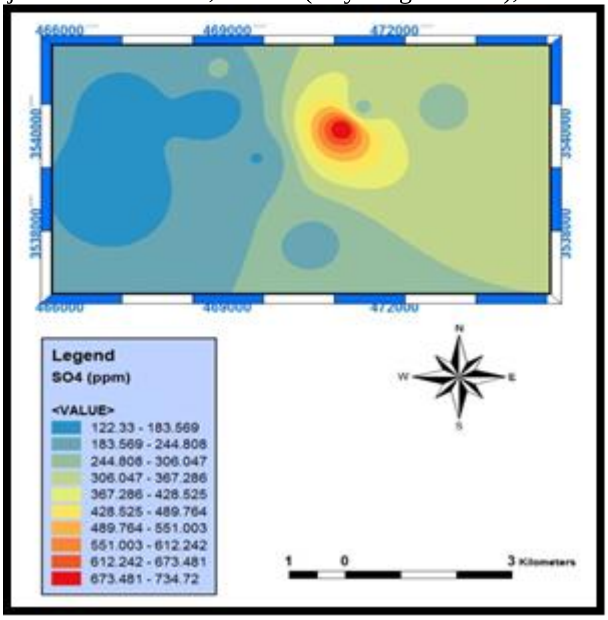

Fig.(8) Distribution map of SO4

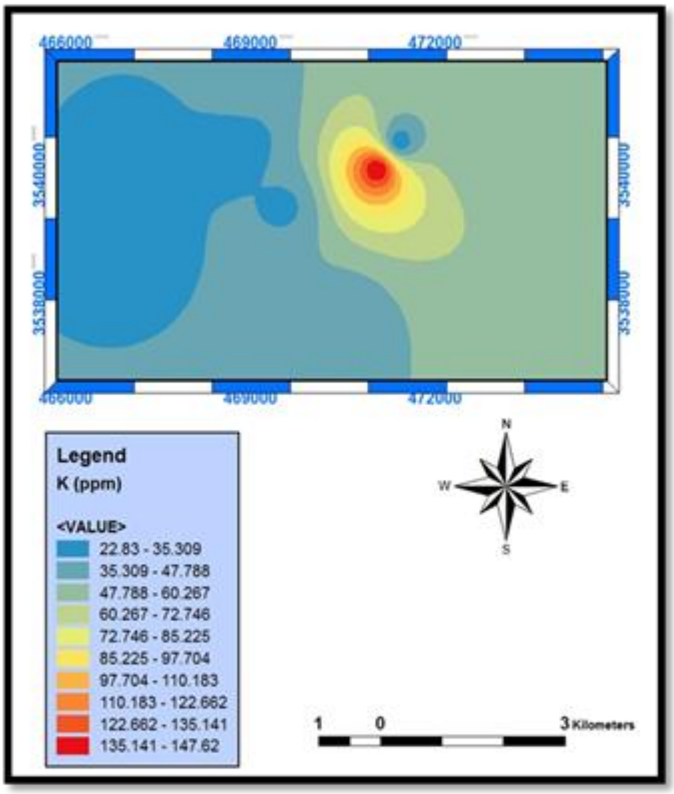

Fig. (7) Distribution map of K^+

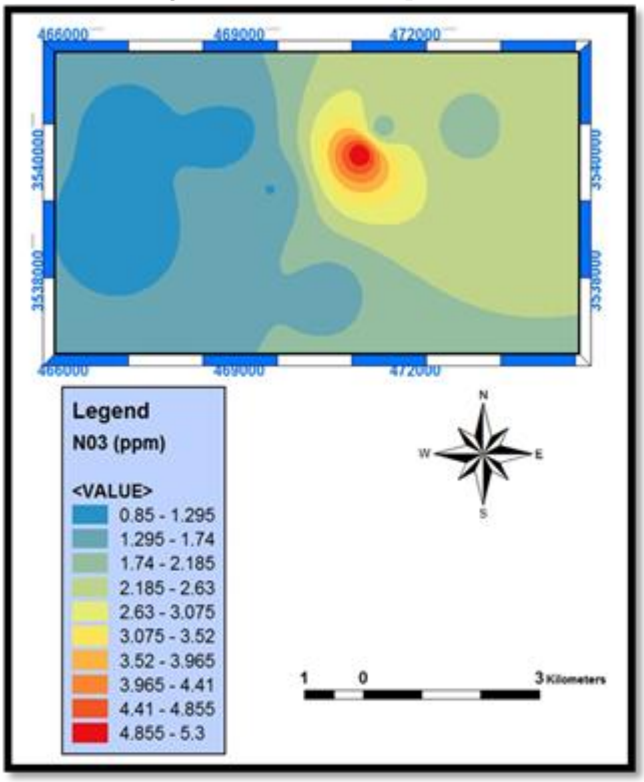

Fig.(9) Distribution map of NO3

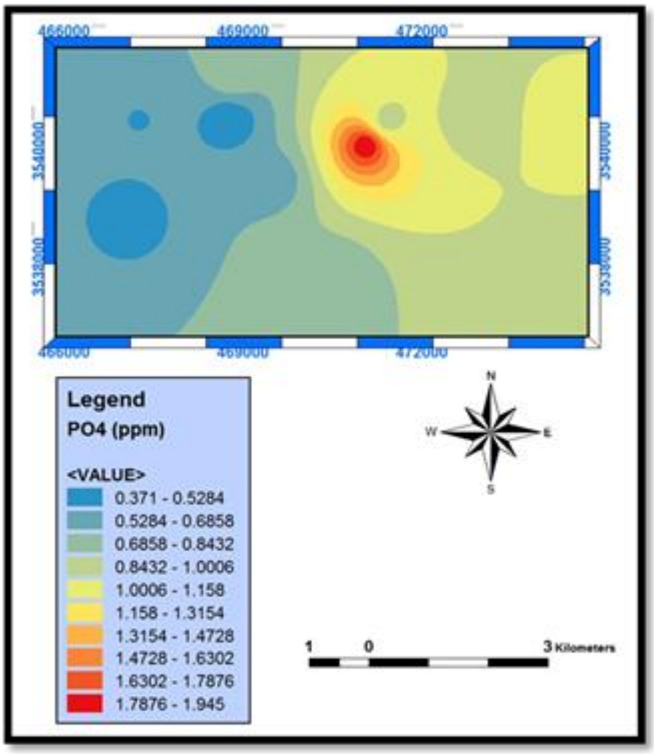

Fig.(10) Distribution map of PO4

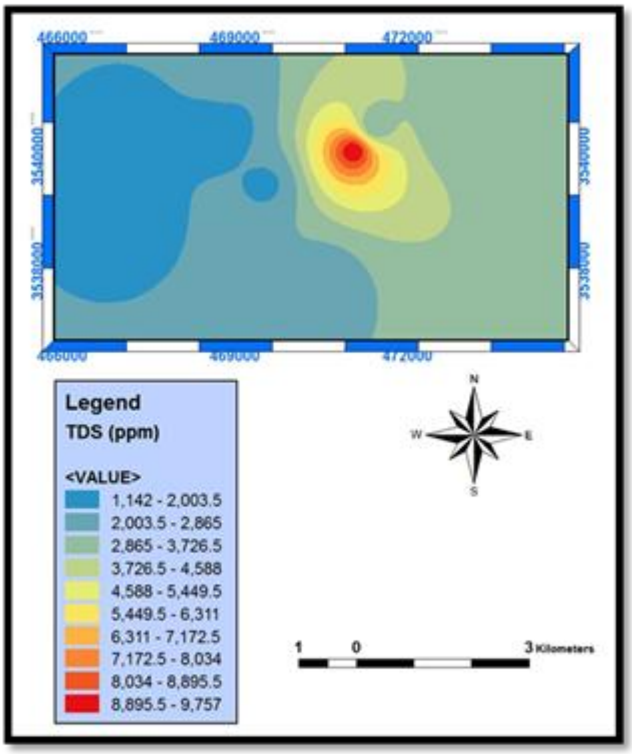

Fig.(12) Distribution map of TDS

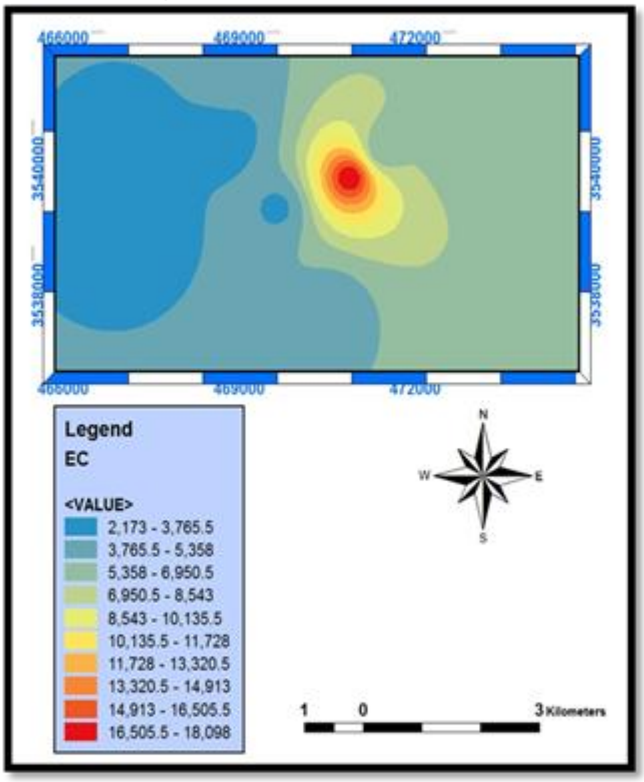

Fig. (11) Distribution map of EC

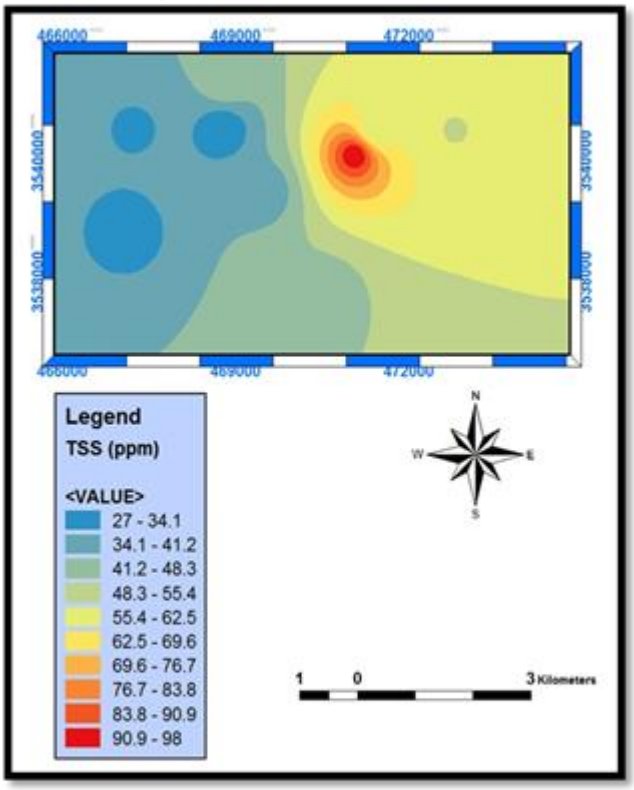

Fig.(13) Distribution map of TSS

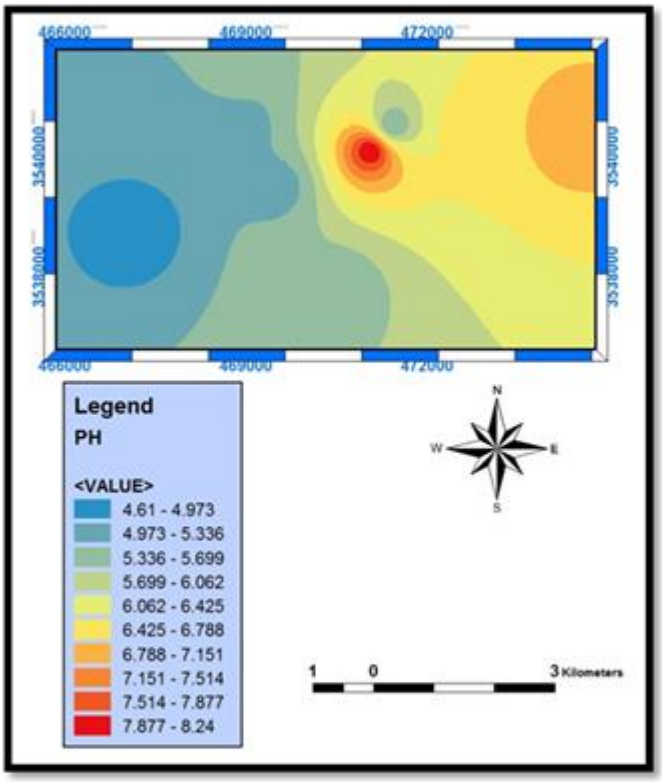

Fig. (14) Distribution map of PH

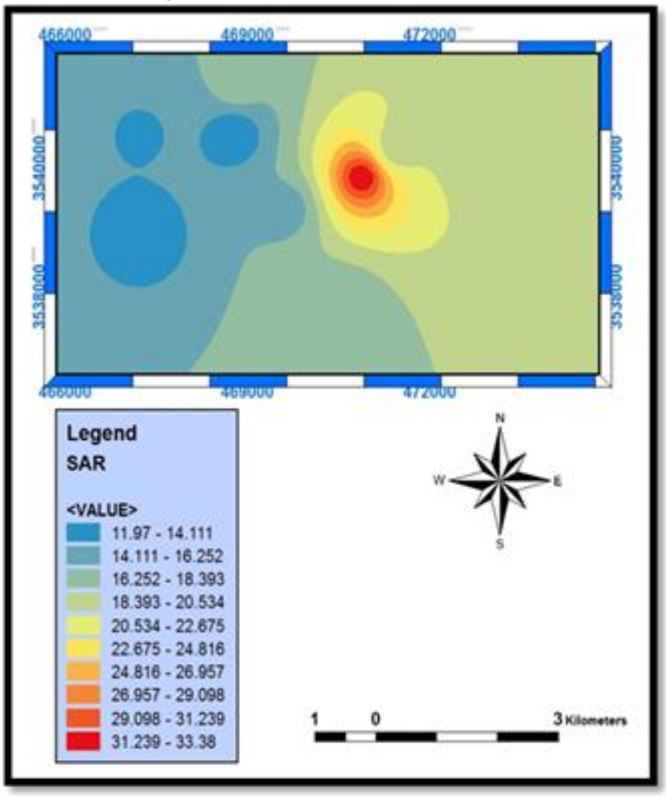

Fig. (15) Distribution map of SAR

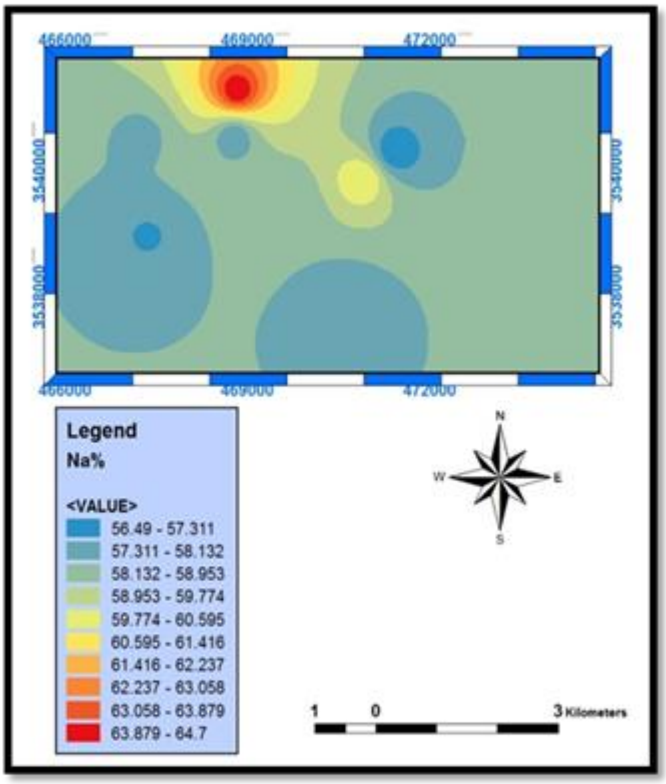

Fig.(16) Distribution mpa of Na%

(IWQI) map was produced by overlapping of the thematic maps (EC,SAR, Na, Cl and HCO3) as a result of geostatistical analysis. The spatial integration for drainage water quality mapping was carried out using ArcGIS Spatial Analyst extension according to Eq. (4). This integration gives the IWQ index map shown in Figure(17).This figure represents the spatial distribution of the IWQ index within the domain of interest and could be considered as a general suitability map for providing irrigation water from the studied area. Since the map shows the spatial distribution of drainage water quality in the plain as index values, it is now much easier for a decision maker to assess the quality of drainage water for irrigation purposes.

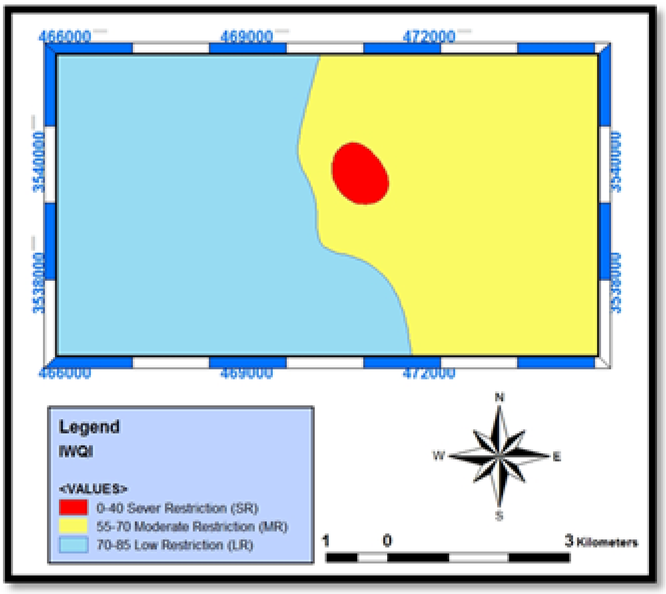

Fig. (17): Irrigation water quality index (IWQI) map for the studied area

VII. CONCLUSION

The primary objective of this study was to map and evaluate the drainagewater quality in AL-Shamiya al-sharqi drain in Diwaniya city in Iraq. Spatial distribution of drainage water quality parameters were carried out through GIS and irrigation water quality index techniques. The use of GIS and water quality index (WQI) methods could provide a very useful and an efficient tool to summarize and to report on the monitoring data to the decision makers in order to be able to understand the status of the drainage water quality. Based on the results of the irrigation water quality index (IWQI) map, left part of the studied area has water with (Low restriction)(52%) while the right part has water with (Moderate restriction)(47%) and small part in the middle of study area classified as (Sever restriction)(1%). According to the recommendations in Table (3), these types of water should be used only with the soil of high permeability, the drainage water could be used in irrigation with some constrains in type of plant with tolerance to salt as mentioned in Table (3).

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