

# Evaluation of Wastewater in Drainage Network of Al-Kut City, Iraq by Using GIS Techniques

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**Abstract**— With the increase in urbanization and degradation of the urban environment, sanitation is becoming a predominant challenge within the short run. High resolution satellite imagery gives the first conception of polluted drainage sites, whether by the river or in residential areas. This helps in studying the seriousness of pollutants and their causes. The main objective of this research was to evaluate the pollutants in wastewaters received at pump stations in Al-Kut city in Wasit governorate, Iraq by using GIS data and techniques. Water samples were collected from 24 geo-referenced pump stations distributed within the studied area before being discharged into the river. Three water samples were collected in each of the following months: February, March and April in 2015. Samples were analyzed for (BOD, COD,  $PO_4^-$ ,  $NO_2^-$ ,  $NO_3^-$ , TDS, TSS,  $H_2S$ , and EC). The spatial distribution of these pollutants within the studied area was carried out using Ordinary Kriging (OK). The results revealed an increase in the concentrations of the studied pollutants when compared with Iraqi standards. The mean concentrations were: 247.54, 8.96, 0.59, 2.92, 1557.58, 232.79, 21.55, 2164.58, and 283.63  $mg\ l^{-1}$  for BOD,  $PO_4^-$ ,  $NO_2^-$ ,  $NO_3^-$ , TDS, TSS,  $H_2S$ , EC and COD, respectively. These concentrations were attributed with the human activities and land use in the studied area.

In conclusion, wastewater in Al-Kut city has to be treated before being directly discharged into the river due to its heavy load of pollutants and its impact on resident's health.

**Keywords:** Waste water, Sanitary, Pollutants, Pump Stations, GIS, Kriging

## 1 Introduction

Many serious diseases are associated with discharging of untreated wastewater into aquatic environments. This problem is propagating worldwide and specifically in developing countries mainly due to inadequate wastewater management. About eighty million people were exposed to cholera in Africa and about sixteen million cases of typhoid infections were also recorded (Kootatep et al., 2004).

Temperature and solid concentration are the most important physical characteristics in wastewater treatment. However, the most critical chemical characteristics are alkalinity, biochemical demand (BOD), chemical oxygen demand (COD), dissolved gases, nitrogen compounds, pH and phosphorus (Spellman, 2003). BOD is a measure of water contamination with organic materials. BOD is the amount of dissolved oxygen that is required for biochemical decomposition of organic compounds and oxidation of some inorganic materials such as iron and sulfites (Patil et al., 2012).

Nowadays, GIS plays an important role in facilitating the representation and analysis of water-related phenomena. It is widely used in tracking wastewater contamination and management. It helps in mapping, modeling,

facilities management, work-order management, and short- and long-term planning (Chandresh, 2014). Hydrological GIS models, were also developed for rainfall, runoff, stream flow, flooding and water quality (Hatzopoulos, 2002). About 90% of the water utilities in the U.S. were using GIS technology by the end of the year 2000 as reported by the American Water Works Association (AWWA). GIS softwares are developing on a daily bases to support the different applications in water and wastewater utilities (Mohsen, 2011 and Mohamed, 2012). GIS is also integrated with commonly used water utility systems such as work order, computerized maintenance, and enterprise asset management (Esri, 2010).

Remote sensing (RS) data also provide an informative and visual analytical tools that have been widely applied in monitoring and conservation of water-resources and evaluating changes in environmental conditions (Ulugtekin et al., 2005, De Leeuw et al., 2010 and Umbarkar et al., 2014 ). RS and GIS can be integrated to provide thematic maps for spatial features and their attributes. RS data can also be used in the classification of clean water and wastewater reservoirs. However, these data are not likely be

able to differentiate between different levels of pollutants in wastewaters (Gitelson, 1997). Therefore, these data have to be integrated with lab analysis of collected water samples from wastewaters.

Wastewater treatment and management are one of the most serious problems in Iraq. Most of wastewater drainage networks were combining both human wastes and rainfall. These waters were being discharged into the rivers without any treatment before 2003. Al-Kut city, which is the area of study in this work has three types of wastewater drainage networks. These networks are: a-sewage network, b- rainfall drains and c-combined drains (sewage and rainfall). Wastewater from the combined drains is being directly discharged into the river without any treatment, which cause a severe water pollution problem.

The objectives of this work was to evaluate wastewater received at the pumping stations in Al-Kut city based on the analysis of some pollutants. This is in addition to studying the spatial distribution of these pollutants in the drainage network.

## 2 MATERIAL AND METHODS

### 2.1 Description of study area

The study area is located in Al-Kut city, which is the capital of Al-Kut district in Wasit Governorate, Iraq. It is bounded between these coordinates 45°46'00" to 45°53'20" E and 32°27'00" to 32°34'00" N as represented in Figure 1. It has an area of about 85 km<sup>2</sup>. Al-Kut city is located along the main highway connecting Baghdad with Amarah and Basrah in the south, about 150 km south-east of Baghdad and 150 km north-west of Amarah city. The population of Al-Kut city is about 390,000 people according to 1997 census data with an annual growth rate of about 3% (MMPW and COSIT, 2006). The topography of the city is mostly flat and the ground elevation ranges between 15 and 25 m above the sea level.

The studied region is represented by semi-arid climate, which is characterized by dry, hot and long summers and relatively wet, cold winters with short and mild springs. Large difference in temperature between day and night and between winter and summer were observed. The maximum

temperature varies from 45 to 40 oC, where July and august are the hottest months. The minimum tempertaure ranges between 8 and 6, where December and January are the coldest months(COSIT,2013). The prevailing winds for most parts of the year are from north to west direction and usually reach their maximum speed in June (about 5.5 m S<sup>-1</sup>).

Soil of Wasit were developed on the Tigris sedimentations (Powers, 1954). These soils close to the river banks are characterized by coarse grains mixed with silt and they have low salt content. They are considered as the most fertile soils for agricultural production. However, soils far away from the rivers banks have a high salt content and high clay content. They aslo have a high lime content (about 25%). Tigris River is the main source of water in Wasit in addition to Al-Garraf River that branching from Tigris at Al-Kut city. The Tigris River runs from the north to south and a number of dams were built on it to control the flow of water and irrigation of agriculture lands in the governorate.

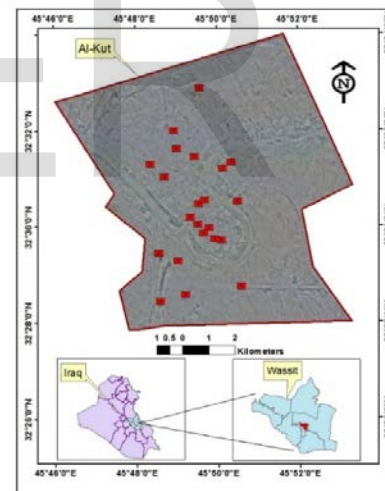


Figure (1.a) Location map of the study area and wastewater pumping stations.

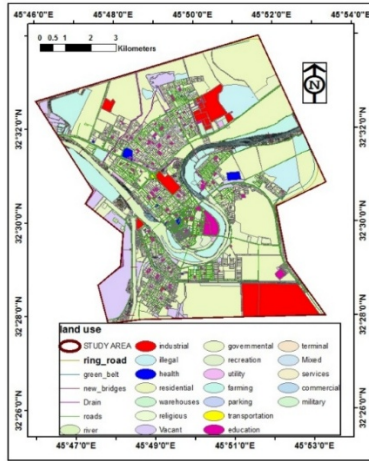
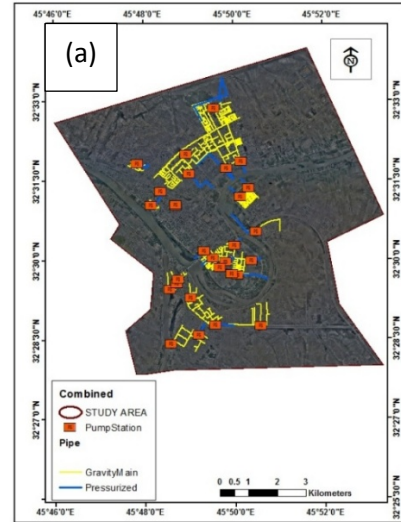
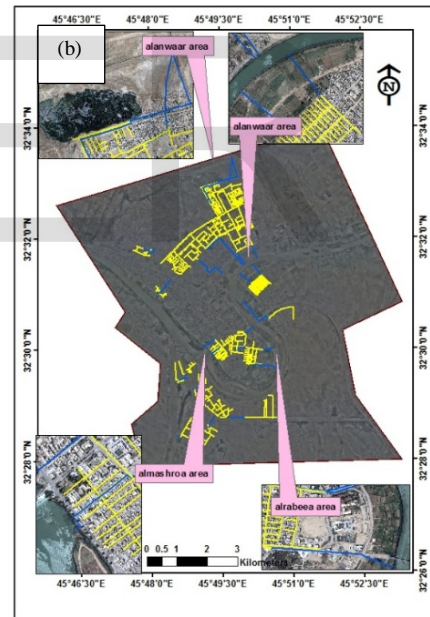


Figure (1. b) Land use map of the study area.



## 2.2. Wastewater networks in the studied area

Wastewater network in the studied area consists of three types of drains, which are: 1- sewage network, 2- rainfall drains and 3- combined drains (sewage and rainfall) as represented in Figure (3). The sewage network was built in 2007 to serve about 50% of the populated area. It collects wastewater from human and industrial areas. These wastes have to be treated before being discharged into the river. However, the treatment stations are running to treat about 99% of these wastewaters, the rest goes directly into the river. The rain network covers about 50% of the area served, where it is also constructed at the same with the sewage networks. Wastewater collected by this network is not polluted because it acts only on rain water. The combined network was first built as rain drains but later it was illegally used by the citizens in these areas as sewage drains. Therefore, these drains collected both sewage and rain water. Wastewater from the combined drains is being directly discharged into the river without any treatment, which cause a severe water pollution problem.



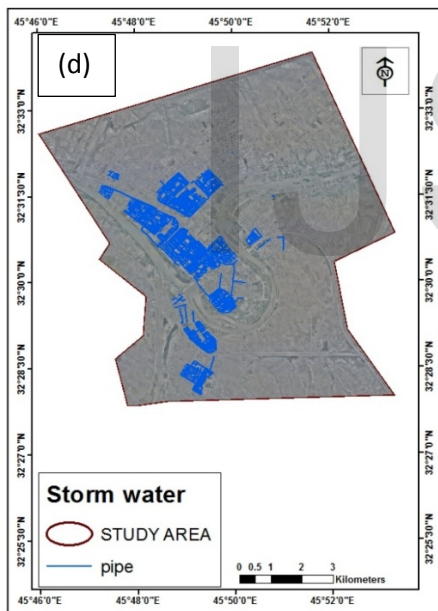
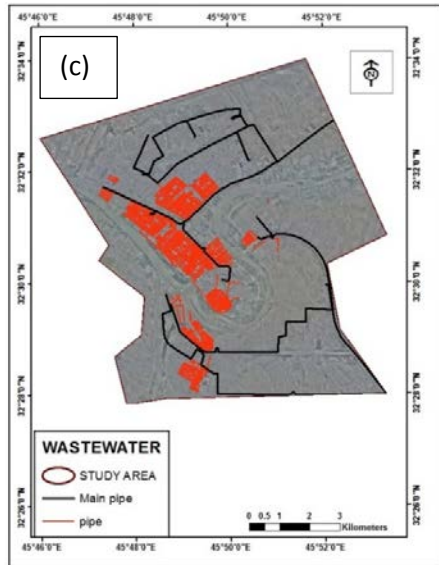


Figure (2). Wastewater drainage networks in Al-Kut City (a) sewage drains, (b) rainfall drains, (c) combined drains, (d) dumping areas.

### 2.3. Sample collection and analysis

Water samples representing the different types of wastewaters in the studied area were collected from the pumping stations. The locations of pumping stations within the studied area are illustrated in Figure 1. Samples were collected

during the period from February 1<sup>st</sup> to April 25, 2015. These samples were sent to the Lab and analyzed for Samples were analyzed for BOD, COD, PO<sub>4</sub><sup>-</sup>, NO<sub>2</sub><sup>-</sup>, NO<sub>3</sub><sup>-</sup>, TDS, TSS, H<sub>2</sub>S, and EC. The test results for each parameter was compared with the standard values reported by the Italian Environment Law No. 152, 2006 as represented in Table 1.

Table 1. Limitations of pollutant concentrations in both sewers and water bodies (Italian Environment Law No. 152, 2006.

| ID | Concentrations                        | Unit               | Discharges into water bodies | Discharges into sewage |
|----|---------------------------------------|--------------------|------------------------------|------------------------|
| 1  | pH                                    | 5,5-9,5            | 5,5-9,5                      |                        |
| 2  | Temperature                           | °C                 | ≤30                          | ≤35                    |
| 3  | TSS                                   | mg l <sup>-1</sup> | ≤80                          | ≤200                   |
| 4  | BOD <sub>5</sub> (as O <sub>2</sub> ) | mg l <sup>-1</sup> | ≤40                          | ≤250                   |
| 5  | COD (as O <sub>2</sub> )              | mg l <sup>-1</sup> | ≤160                         | ≤500                   |
| 6  | Cl                                    | mg l <sup>-1</sup> | ≤0.2                         | ≤0.3                   |
| 7  | H <sub>2</sub> S                      | mg l <sup>-1</sup> | ≤1                           | ≤2                     |
| 8  | SO <sub>4</sub> <sup>2-</sup>         | mg l <sup>-1</sup> | ≤1000                        | ≤1000                  |
| 9  | Total phosphorus (TP)                 | mg l <sup>-1</sup> | ≤6                           | ≤12                    |
| 10 | Nitrate-N as N                        | mg l <sup>-1</sup> | ≤15                          | ≤30                    |
| 11 | Nitric-N as N                         | mg l <sup>-1</sup> | ≤0.6                         | ≤0.6                   |

### 2.4. GIS data and analysis

The physical data of the drainage networks within the studied area were collected from the geographic information system department in Wassit Provincial Council (WPC). These data include: pipe (diameter, materials), manhole (shape, invert level, ground level and facility IDs), wet wells (name, shape, area, maximum elevation storage and minimum elevation storage) and pump stations (name, design flow and design head).

The concentrations of the studied pollutants were spatial distributed by using the ordinary Kriging (OK) method in ArcGIS software package (ver. 10.3) approach. Kriging has been widely used as an important interpolation method at different scales, especially in soil pollution (Hani et al. 2010). It can efficiently analyze the relationships between geographic position and sample characteristics. (Hammoumi, et al., 2013).

The Kriging method is generally represented by the following equation:

$$Z^*(x_p) = \sum_{i=1}^n \lambda_i Z(x_i) \quad (1)$$

Where,  $Z(x_i)$  indicates the value of observable  $Z$  variable at  $x_i$ ,  $\lambda_i$  indicates the weight of a given ratio to  $Z$  variable at  $x_i$ , and  $n$  is the number of observations. After drawing an

## 1. Results and discussions

### 3.1. Chemical Characteristics of wastewaters in Al-Kut city

#### 3.1.1. pH values

The concentrations of the studied pollutants are represented in Table (2). The spatial distribution of pH in wastewater samples collected from the studied area is illustrated in Figure 3. The pH values varied from 6.1 to 7.5 with an average value of 6.85. These values are considered around the neutral range, which could be attributed to the decomposition of organic matter and release of organic acids into wastewater (Chandrakiran and Kuldeep, 2013). The lower values were observed in most of the studied area. However, the higher values were recorded in the north eastern parts of the study area.

The pH is very important in determining the corrosive nature of water on the pipe materials. It also determines if there a need to remove heavy metals in the pumping station or not. Accordingly, the obtained results revealed that there isn't a possible corrosive effect on the pipe materials (for concrete , aspst and GRP pipes) and there is no need to establish new units for removing heavy metals from waste waters.

Table(2). Studied pollutants and their concentrations within Al-Kut City.

experimental variogram, four models (including circular, spherical, exponential, and Gaussian) were fitted for each data set (Uyan and Cay, 2010).

In this work, validation models and estimations were evaluated by calculating the root mean squar

(RMS) criteria and the standard root mean square (SRMS) values.

| ID | Name             | COD | TSS | TDS  | Cl  | SO4 | H2S  | PO4  | NO2  | NO3  | pH   | EC   | B |
|----|------------------|-----|-----|------|-----|-----|------|------|------|------|------|------|---|
| 1  | AL-DUJEAL        | 69  | 70  | 1000 | 147 | 270 | 3    | 1    | 0.1  | 0.6  | 6.1  | 1400 |   |
| 2  | ALSHUHADAA       | 512 | 377 | 2166 | 415 | 890 | 38   | 17   | 1.11 | 5.5  | 7.5  | 3000 |   |
| 3  | AL-ZAHRAA        | 154 | 120 | 1230 | 187 | 370 | 10   | 3.5  | 0.2  | 1.2  | 6.4  | 1650 |   |
| 4  | AL-JEHAAD        | 163 | 135 | 1250 | 208 | 400 | 12   | 4.5  | 0.3  | 1.4  | 6.5  | 1750 |   |
| 5  | AL-TYRAAN        | 465 | 337 | 2070 | 377 | 790 | 34.5 | 15.7 | 1.01 | 5    | 7.35 | 2800 |   |
| 6  | AL-HUSSAIN       | 190 | 155 | 1350 | 230 | 462 | 14.5 | 5.7  | 0.35 | 1.75 | 6.55 | 1850 |   |
| 7  | AL-HORAH         | 210 | 197 | 1370 | 239 | 472 | 16   | 6.1  | 0.4  | 2    | 6.66 | 1900 |   |
| 8  | AL-KHAKYA        | 215 | 203 | 1385 | 247 | 488 | 16.5 | 6.4  | 0.45 | 2.1  | 6.69 | 1950 |   |
| 9  | AL-JEHAAD2       | 235 | 212 | 1397 | 251 | 500 | 17   | 7    | 0.49 | 2.3  | 6.7  | 2000 |   |
| 10 | ALKAREAMYAH      | 247 | 221 | 1402 | 255 | 517 | 18   | 7.8  | 0.5  | 2.4  | 6.7  | 2050 |   |
| 11 | AL-150           | 353 | 291 | 1802 | 333 | 698 | 29.5 | 12.5 | 0.82 | 4.2  | 7.14 | 2500 |   |
| 12 | CommercialCenter | 423 | 297 | 1807 | 339 | 720 | 30.1 | 12.9 | 0.84 | 4.4  | 7.15 | 2550 |   |
| 13 | AL-DEEWAAN       | 453 | 320 | 1890 | 360 | 772 | 33.1 | 14.5 | 0.94 | 4.7  | 7.3  | 2700 |   |
| 14 | TownGames        | 430 | 317 | 1830 | 351 | 744 | 31.4 | 13.4 | 0.89 | 4.4  | 7.2  | 2550 |   |
| 15 | AL-FLAHYAH       | 304 | 260 | 1605 | 301 | 620 | 25.3 | 10.1 | 0.67 | 3.3  | 7    | 2300 |   |
| 16 | AL-ANWAAR1       | 320 | 277 | 1662 | 311 | 640 | 26.4 | 10.4 | 0.7  | 3.5  | 7.1  | 2350 |   |
| 17 | AL-ANWAAR2       | 330 | 281 | 1704 | 319 | 688 | 27   | 11.2 | 0.72 | 3.5  | 7.1  | 2350 |   |
| 18 | SAAHTALAAMEL     | 341 | 286 | 1718 | 320 | 690 | 28   | 11.4 | 0.75 | 3.8  | 7.1  | 2400 |   |
| 19 | TAMMOZ           | 255 | 231 | 1496 | 265 | 550 | 20   | 8.1  | 0.55 | 2.7  | 6.8  | 2080 |   |
| 20 | AL-SALAAM        | 290 | 242 | 1577 | 277 | 591 | 21   | 9.2  | 0.59 | 2.8  | 6.8  | 2100 |   |
| 21 | AL-EZZAH OLD     | 288 | 255 | 1599 | 289 | 616 | 23.5 | 9.6  | 0.62 | 3    | 6.9  | 2200 |   |
| 22 | ALKAREAMYAHOLD   | 263 | 246 | 1592 | 282 | 612 | 22   | 9.4  | 0.6  | 2.9  | 6.9  | 2120 |   |
| 23 | SABEA-BNKHAMEES  | 177 | 147 | 1280 | 215 | 415 | 13   | 4.7  | 0.32 | 1.6  | 6.55 | 1800 |   |
| 24 | Al-kFaouT        | 120 | 110 | 1200 | 177 | 329 | 7.5  | 3    | 0.15 | 1.1  | 6.3  | 1600 |   |

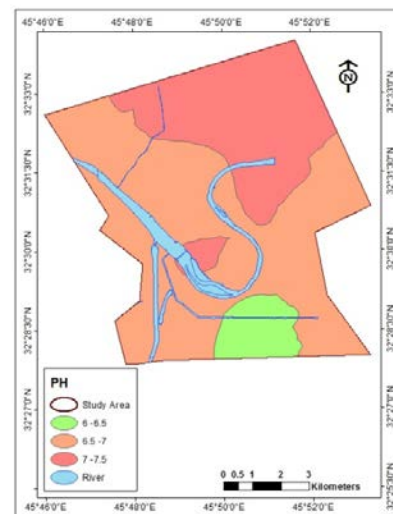


Figure (3): Spatial distribution of pH in wastewaters within Al-Kut city.

### 3.1.2. Electrical Conductivity (EC)

EC values in wastewaters varied greatly from 1400 to 3000  $\mu\text{S cm}^{-1}$ , with an average value of 2165  $\mu\text{S cm}^{-1}$ . These values are considered high according to the US salinity Laboratory. Accordingly, that water can't be used in crop irrigation even after being treated. The spatial distribution of these values within the studied area is demonstrated in Figure 4. The higher values were observed in the northeastern and middle parts of the studied area (i.e, Al-Shuhadaa, Al-150, Al-Tyraan and Al-Deewaan), which could be attribute to the agricultural drainage form the salt-affected soils and certain industries in these areas. The lower values were noticed in the north-western and south parts of the city, which are close to the rivers in the study area.

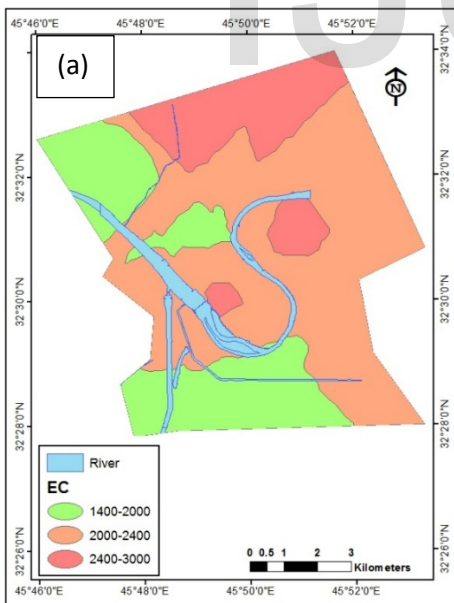


Figure (4): Spatial distribution of EC in wastewaters within Al-Kut city.

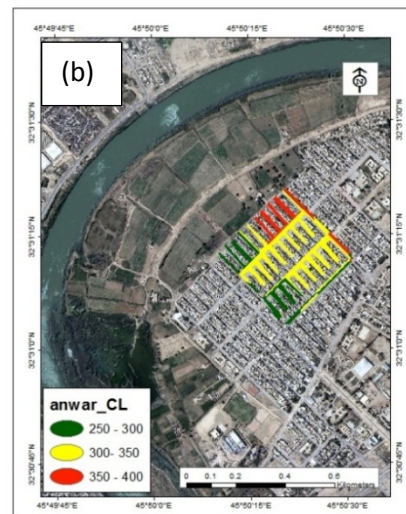
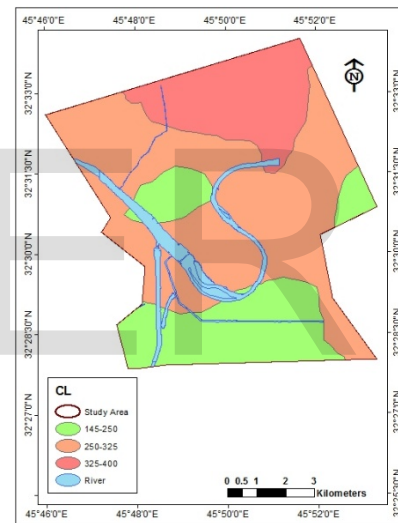
### 3.1.3. Chlorides (Cl<sup>-</sup>)

Chloride concentrations in wastewaters varied from 147 to 415  $\text{mg l}^{-1}$  with a mean value of 279  $\text{mg l}^{-1}$ .

1<sup>-1</sup>. The spatial distribution of Cl<sup>-</sup> in wastewaters within the studied area and its distribution within Al-Anwar network is represented in Figure (5). It took the same trend as the EC values, where there is a very high correlation between both of them ( $r=0.99, p=0.0001$ ) We note the values in the table 3.

Table 3. Studied pollutants and their concentrations within Alanwaar in Al-Kut City.

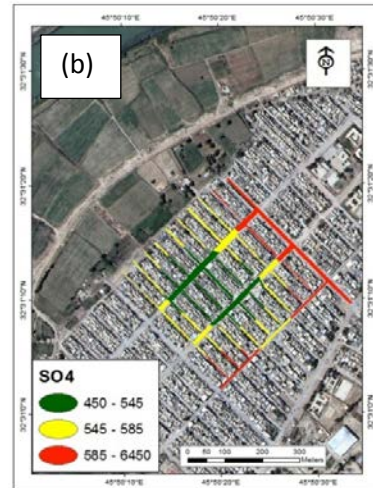
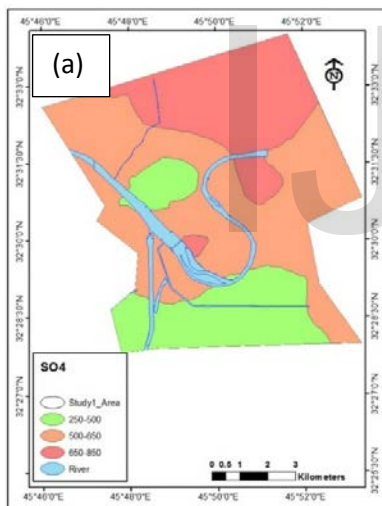
| X | Y          | Name        | COD       | TSS | TDS | Cl   | SO4 | H2S | PO4  |      |
|---|------------|-------------|-----------|-----|-----|------|-----|-----|------|------|
| 1 | 578879.458 | 3598568.906 | Alanwaar1 | 320 | 277 | 1662 | 400 | 640 | 26.4 | 10.4 |
| 2 | 578982.490 | 3598468.387 | Alanwaar2 | 320 | 150 | 1500 | 300 | 640 | 15   | 6    |
| 3 | 579057.469 | 3598377.920 | Alanwaar3 | 150 | 250 | 1660 | 400 | 650 | 26.4 | 10.4 |
| 4 | 578706.063 | 3598395.511 | Alanwaar4 | 140 | 150 | 1400 | 311 | 500 | 26.4 | 10.4 |
| 5 | 578839.251 | 3598327.661 | Alanwaar5 | 160 | 150 | 1500 | 350 | 450 | 10   | 7    |
| 6 | 578881.971 | 3598566.393 | Alanwaar6 | 320 | 150 | 1500 | 300 | 640 | 15   | 6    |



**Figure (5):** Spatial distribution of  $Cl^-$  in a) wastewaters within Al-Kut city and b) Al-Anwar drainage network.

### 3.1.4. Sulphates ( $SO_4^{2-}$ )

The concentrations of sulphates in wastewater samples were higher than those for chloride in the same samples. Sulphates varied from 270 to 890  $mg\ l^{-1}$  with a mean value of 577  $mg\ l^{-1}$ . The spatial distribution of  $SO_4^{2-}$  in wastewaters within the studied area and its distribution within Al-Anwar network is represented in Figure 6. Sulphates also took the same trend as both the EC and the  $Cl^-$  values. Also, a very high correlation was found between the EC and  $SO_4^{2-}$  values ( $r=0.99, p=0.0001$ ).

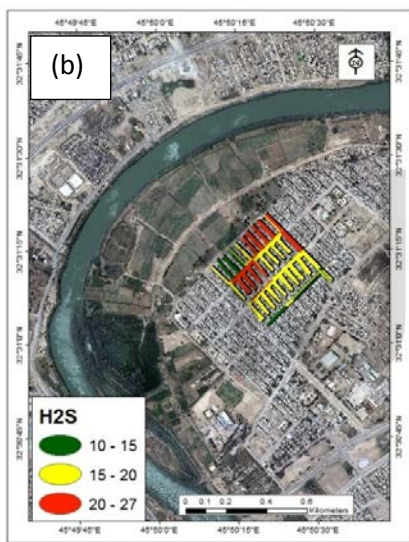
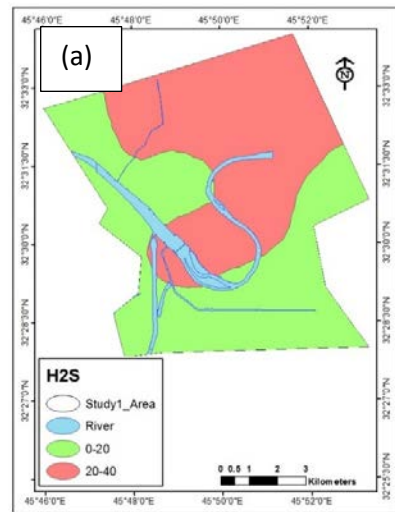


**Figure (6):** Spatial distribution of  $SO_4$  in a) wastewaters within Al-Kut city and b) Al-Anwar drainage network.

### 3.1.5. Hydrogen Sulfide ( $H_2S$ )

Hydrogen sulfide is a colorless, flammable, extremely hazardous gas with a “rotten egg” smell.

Some common names for the gas include sewer gas, stink damp, swamp gas and manure gas. Hydrogen sulfide in general is produced by bacterial breakdown of organic materials and human and animal wastes (e.g., sewage). The spatial distribution of  $H_2S$  in wastewaters within the studied area and its distribution within Al-Anwar network is demonstrated in Figure 7. The concentrations of  $H_2S$  in wastewater samples collected from Al-Kut combine drainage station varied from 3 to 38  $mg\ l^{-1}$  with a mean value of 22  $mg\ l^{-1}$ .



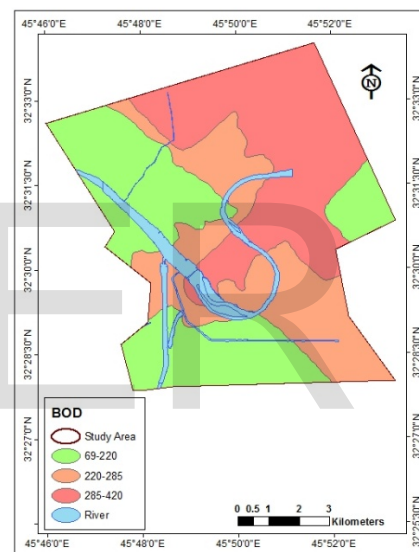
**Figure (7):** Spatial distribution of H<sub>2</sub>S in: a) wastewaters within Al-Kut city and b) Al-Anwar drainage network.

### 3.2. Biological Characteristics of wastewaters in Al-Kut city

#### 3.2.1 Biological Oxygen Demand (BOD)

Biological oxygen demand (BOD) is a direct indication of the extent of pollution in water bodies and it is a measure of organic material contamination. It refers to the amount of oxygen required by living aquatic organisms for their physiological processes. There are many sources of BOD in aquatic environment, which include leaves

and woody debris, dead plants and animals, animal manure, industrial effluents, wastewater treatment plants, feedlots, and food-processing plants, failing septic systems, and urban storm water runoff (Lokhande *et al.*, 2011). BOD in wastewater in Al-Kut city varied from 41 to 490 mg l<sup>-1</sup> with an average value of 248 mg l<sup>-1</sup>. The spatial distribution of these values in the studied area is illustrated in Figure 8. The highest values were observed in the eastern and middle parts of the study area. This could be attributed to the abundance of bacterial and microbial activities in these areas or the decomposition of organic wastes coming from slaughter houses and residential wastes (Fair yard and Al-Anwaar stations).



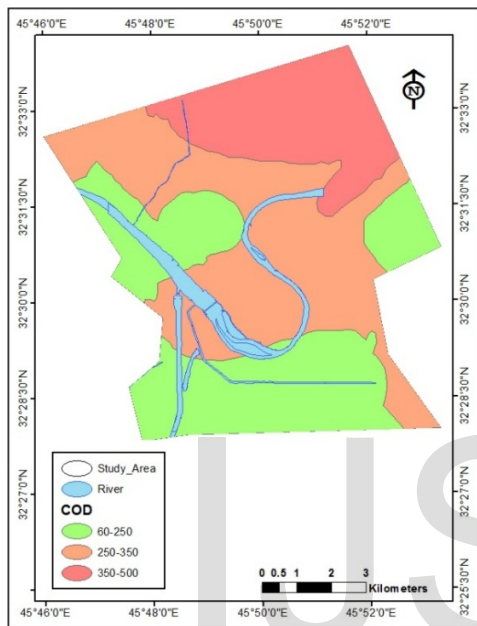
**Figure (8):** Spatial distribution of BOD in wastewaters within Al-Kut city.

#### 3.2.2. Chemical Oxygen Demand (COD)

Chemical oxygen demand (COD) is a measure of the oxygen equivalent of the organic matter content of water that is susceptible to oxidation by a strong chemical oxidant. Accordingly, COD is a reliable parameter for judging the extent of pollution in aquatic environments (Suarez, J. and Puertas, J., 2005 and Amirkolaie, 2008). There a direct positive relationship between COD of water and concentration of organic matter (Boyd, 1979). Chemical oxygen demand (COD) varied from 69 to 512 mg l<sup>-1</sup> with a mean value of 284 mg l<sup>-1</sup>. The spatial distribution of (COD) values in the studied

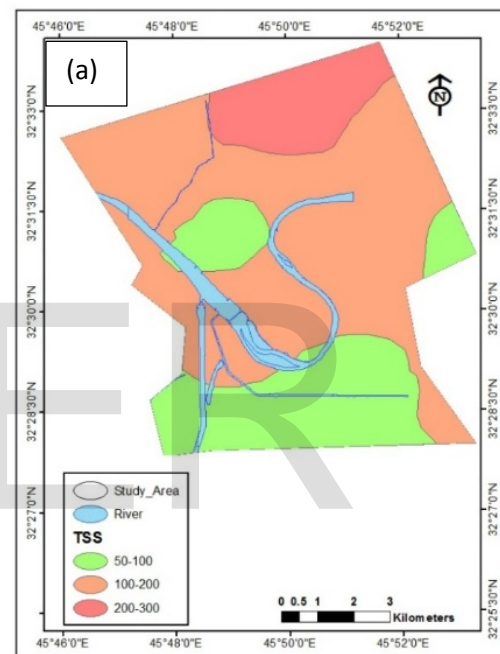


area is represented in Figure 9. The highest values were observed in the eastern and middle parts of the study area (Al-Shuhadaa, Al-Tyraan, Al-Deewaan, Commercial Center, Fair yard, Al-150, Saaht Al-Aamel and Al-Anwaar), which could be attributed to the high load of organic materials in sewage water.



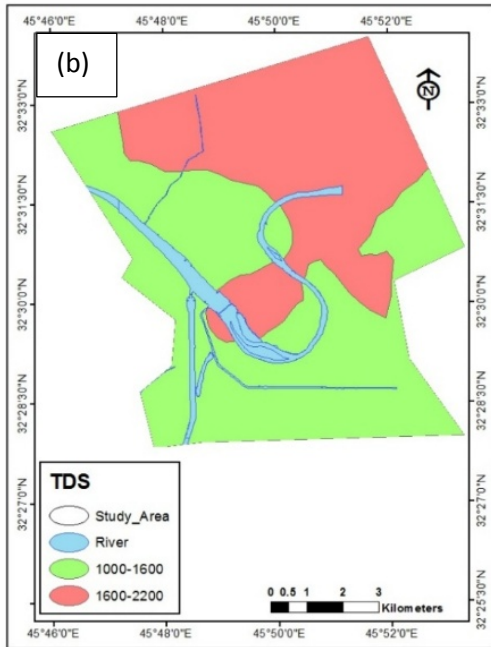
**Figure (9):** Spatial distribution of COD in wastewaters within Al-Kut city.

residues (hair, fats, flesh and guts) coming from slaughter houses. These concentration increase when the water level in the river decreases, which resulted in increasing mud and turbidity in the river at dumping areas. These materials must be precipitated in the first stages of wastewater treatment to eliminate their effects on followed treatment stages. The spatial distribution of both TSS and TDS in wastewaters within Al-Kut city is illustrated in Figure 10.



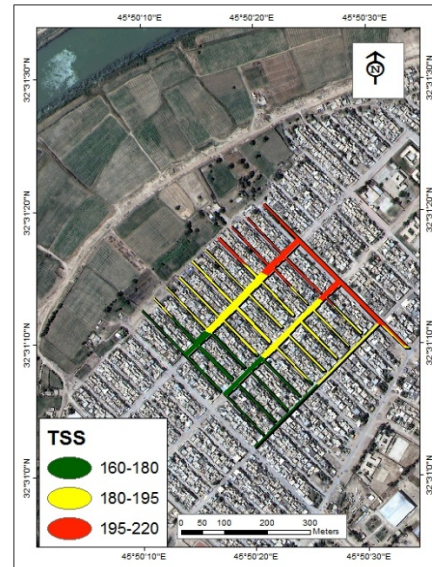
### 3.2.3. Total Suspended Solids (TSS) and Total Dissolved Solids (TDS)

The most important pollutant that must be studied after BOD is suspended solids either soluble (TDS) and non-soluble materials (TSS). TSS values in wastewater of Al-Kut city were varied from 70 to 377 mg l<sup>-1</sup> with an average of 233 mg l<sup>-1</sup>. On the other hand, the TDS values ranged between 1000 to 2166 mg l<sup>-1</sup> with an average of 1558 mg l<sup>-1</sup>. Both the TSS and TDS values were exceeded the standard limits and the highest values were recorded at Alshuhadaa pump station. These values could be resulted from the suspended materials like soil and fats in addition to animal



**Figure (10):** Spatial distribution of both a) TSS and b) TDS in wastewaters within Al-Kut city.

The spatial distribution of TSS concentrations was also studied in the drainage network of Al-Anwar pump station at certain points in the network as represented in Table 3 and demonstrated in Figure (11).



**Figure (11):** Spatial distribution of TSS in drainage network of Al-Anwar pump station at Al-Kut city.

### 3.3. Nutrient content in wastewaters of Al-Kut city

#### 3.3.1. Nitrate ( $\text{NO}_3^-$ )

The excess usage of inorganic nitrogen fertilizers represents the main source of nitrate ions in the wastewaters. Also, the complete oxidation of nitrogen from the decay of organic materials in the surface water and in the sediment is an important factor in producing ammonia, nitrate and nitrite (Taha *et al.* 2004). Concentrations of nitrate in wastewaters in Al-Kut city varied from 0.6 to 5.5  $\text{mg l}^{-1}$  with an average value of 2.92  $\text{mg l}^{-1}$ . The maximum values of nitrates were higher than the limit set by the EEAA (1994), which is 0.56  $\text{mg l}^{-1}$  and the EPA (1991) standard limit (5  $\text{mg l}^{-1}$ ). Also the IPCB (1990) has set standards for nitrate not to exceed 10  $\text{mg l}^{-1}$  as nitrogen for public water-supply and food processing waters. The spatial distribution of  $\text{NO}_2^-$  values in wastewaters in Al-Kut city area is illustrated in Figure 12. The higher values could be attributed to the both agricultural drainage and decomposition of organic materials. This is in addition to the availability of bloods in sewage water coming from the slaughter houses in old commercial area.

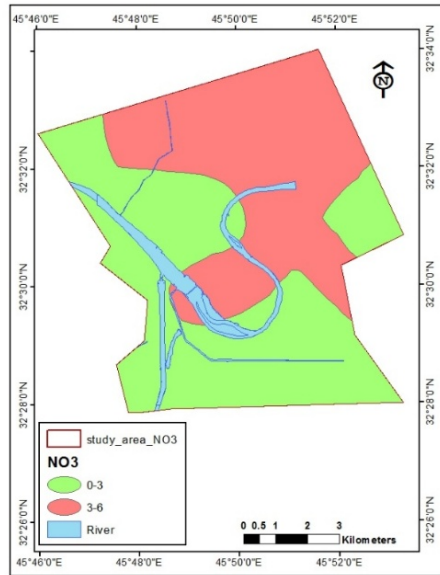


Figure (12): Spatial distribution of NO<sub>3</sub> in wastewaters within Al-Kut city.

Nitrite in wastewaters of Al-Kut city took similar trend as the nitrate. Nitrite values ranged between 0.1 to 1.11 mg l<sup>-1</sup> with an average value of 0.59 mg l<sup>-1</sup>. The spatial distribution of NO<sub>2</sub> values in wastewaters of Al-Kut city area is represented in Figure 13.

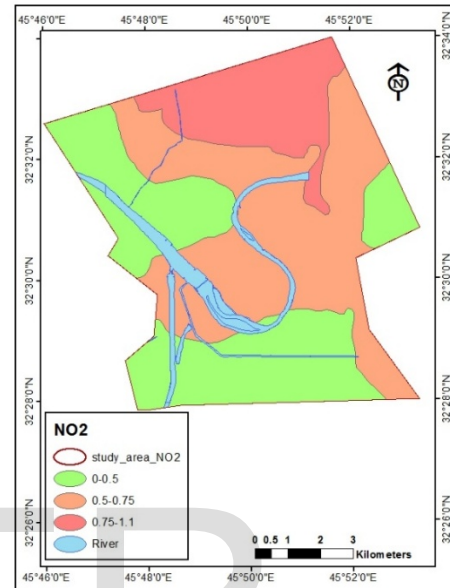
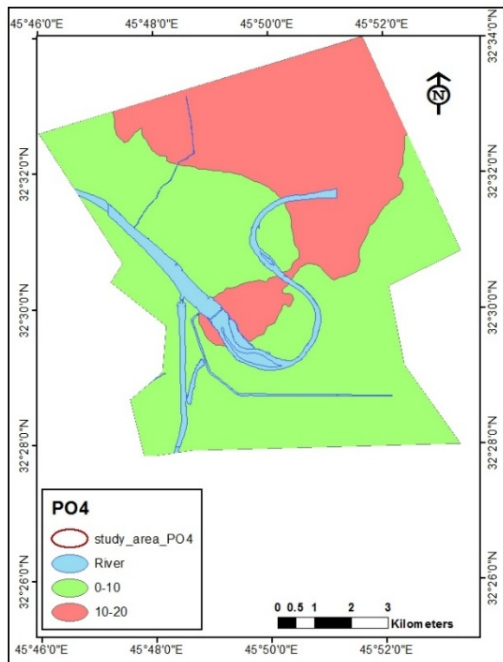


Figure (13): Spatial distribution of NO<sub>2</sub> in wastewaters within Al-Kut city.

### 3.3.2. Nitrite (NO<sub>2</sub><sup>-</sup>)

### 3.3.3. Phosphate (PO<sub>4</sub><sup>-</sup>)

Phosphate concentrations in wastewaters varied from 1 to 17 mg l<sup>-1</sup> with an average of 8.96 mg l<sup>-1</sup>. The spatial distribution of PO<sub>4</sub><sup>-</sup> values in wastewaters in Al-Kut city area is illustrated in Figure 14. The higher values may be attributed to agricultural wastes (Olila and Reddy, 1997). Also, Domestic detergent and industrial sewage effluents represent important sources of phosphorus in natural water (Taha *et al.*, 2004).



**Figure (14):** Spatial distribution of PO<sub>4</sub> in wastewaters within Al-Kut city.

## Conclusion

It could be concluded that the geostatistical analysis such as ordinary Kriging could be very helpful in studying the spatial distribution of pollutants in wastewaters throughout the

studied area and within the drainage network if there is plenty of accurate data. They help in predicting values at unmeasured locations with more credibility at low cost and time-wise. The obtained results indicated that wastewaters in Al-Kut city are highly polluted according to both the Iraqi and international standards. Pump stations are poorly managed and wastewater is almost being directly discharged into the river without any treatment. Accordingly, there is an urgent need to treat these wastewaters before being dumped into the river or used in other activities such as crop irrigation. Pump station should be supplied by highly effective treatment units and also hospitals and slaughter houses should be implemented with local treatment units. This is in order to protect both human health and the surrounding environment. Also, legislations and regulatory frameworks should be issued to prohibit the direct discharge of untreated wastewaters in fresh water bodies.

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