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DISTRIBUTION OF SULFATE CONTENT AND ORGANIC MATTER IN AN-NAJAF AND AL-KUFA CITIES' SOIL USING GIS

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ABSTRACT

AN-Najaf city is located 61 meters above the sea level in the dry desert of Iraq. It is one of the most important cities in Iraq due to religious tourism and continuously developing urban areas by constructing multi-storey buildings, bridges and shopping malls. This study aims to create a mapping database for sulfate in An-Najaf soil (Najaf centred and Al-Kufa cities' soil). To evaluate the spatial variability of data, 464 boreholes and in situ tests were selected and analysed using Geographic Information System ArcGIS 10.2.1. The adopted method consisted of four steps: (1) data collection; (2) geotechnical data georeferencing; (3) interpolation methods and (4) establishment of maps. Nine maps were produced for depths 0-35 m for sulfate content in soil. In addition to two maps for sulfate content in groundwater and organic matter content for depths 0-2. Results showed that all the study area and for depths 0-2 meter has very high sulfate content in the soil. Sulfate values varies between 0.36%- 14% where all the results were higher than the permissible limit which is 0.2%. The sulfate content decreases with the depth yet still effective in some areas. Therefore, precautions have to be adopt to avoid risks. One of the precautions is to use sulfate resistance Portland cement (SRPC) for all concrete works that have contact with soil. Groundwater sulfate content in the study area was ranging between 84-239 %. These values were ineffective because they are lower than the permissible limit, which is 1460%. The organic matter content values vary between 0.05-2.34, the greatest part of the study area was lower than the permissible limit 1% and therefore ineffective. The PH values indicate that all the study area was alkaline so it is uninfluential.

KEYWORDS: Geographic Information System (GIS); Sulfate content; pH Content; Organic matter; AN-Najaf province.

1. INTRODUCTION

The attack of sulfate on concrete is one of the structural problems facing the concrete armatures. It has raised the interest of researchers after the impact of this problem has appeared on many structures (Yahya, 2002).

Sulfate is soluble (easily dissolved) in water, thus found at high concentrations in surface water and groundwater. Massive amount of sulfur releases to the atmosphere by combustion of fossil fuels. Sulfur in the atmosphere is transform to sulfate by oxidization then deposited with precipitation or through dry deposition. Sulfate can move in groundwater because it exist as a dissolved ion. It occurs in a variety of oxidation states that affect its behaviour in the environment (Minnesota Pollution Control Agency, 1999). There are many potential sources sulfate. Gypsum is an important source in many aquifers having high concentrations of sulfate. In the past century, atmospheric fallout has become an important source of sulfate to soils and, eventually, to ground water. Other sources of sulfur include decomposition of organic matter fertilizers and natural sources, such as volcanoes. Since sulfate is mobile in soil, inputs to soil will affect shallow ground water (Minnesota Pollution Control Agency, 1999). The attack of sulfate on concrete is one of the structural problems facing the concrete body. It has attracted the interest of researchers after the impact of this problem has appeared on many structures (Yahya, 2002). The presence of sulfate salts at high rates negatively affects the hardened cement paste due to the formation of additional quantities of Ettringite where a large volume increase in the hardened cement paste leads to internal stresses causing cracks in the concrete mass, which affect their resistance (Soroka and Abayneh, 1986).

Table 1 outlines the level of risk associated with stabilizing soils with varying sulfate concentrations (Dallas and Syam, 2009). The acceptable limit for sulfate is 0.2% (Kezdi, 1974).

Table 1. Level of risk associated with soluble sulfate concentrations (Dallas and Syam, 2009).

Risk Involved	Soluble Sulfate concentrations	
	Parts per million	Percent dry weight
Low Risk	< 3000 ppm	< 0.3%
Moderate Risk	3000 - 5000 ppm	0.3% - 0.5 %
Moderate - High Risk	5000 - 8000 ppm	0.5% - 0.8%
High - Unacceptable Risk	> 8000 ppm	> 0.8%
Unacceptable Risk	> 10000 ppm	>1.0%

Note that all units used in the tests of this paper are in percentage dry weight because it is the standard unit used in all investigation laboratories. In addition, it is the unit used by experts to evaluate the soil.

Organic Matter normally exists at shallow depths, and in some cases at greater depths because of earth crust movement, earthworms and other possible reasons (Bakir, 1998). From engineering view, the organic matter is undesirable because of its harmful effects, which are increasing the possibility of Swelling and Shrinkage because of water content changing where the organic matter can adsorb water 5 times the weight it took leading to soil swelling (Scott, C. R., 1974). The organic matter content can be said high when it is greater than 1%. (Shikhal et al., 1999).

The purpose of measuring pH for soil is because it affects foundation concrete corrosion. The concrete is an alkaline-based material (pH is 13), therefore it is in danger of nearby acid's attack, where calcium hydroxide interacts with the acid and the result is dissolvable material (Salman, 1996).

The recent study is collecting, classification and analysis of the information for sulfate content, organic matter and pH in 464 boreholes in the study area and for depths 0, 2, 4, 6,8,10,12,14,16 and 35 meters. Eleven Geotechnical maps using ArcGIS software program have been produced to facilitate the soil primary investigation for the new construction works.

2. METHODOLOGY

2.1. Selected Study Area

AN-Najaf governorate is located at the southwest of Iraq away from the capital Baghdad of about 161 km southwest, Fig. 1. This study cover parts of An-Najaf and Kufa districts and located between the coordinates 44° 17’00” and 44° 25’0” Eastwards and 32° 7’0”and 31° 56’0” latitudes Northwards by degree system, Fig. 2. This area considered one of the most continuously developing urban areas. It is located at the southwestern tip of the north section of the plain and on the edge of the desert from the western side of the Euphrates River, which is 10 km away. It has an area of about 29000 km^2 and constitutes approximately 7% of Iraq's total area (Kadhim and Ahmed, 2016).

2.2. Data Collection

The data used in this research was taken from the National Center for Construction Laboratories& Researches (NCCLR)/Babylon laboratory reports. Babylon laboratory

represents a branch of the National Center for Construction Laboratories& Research (NCCLR), which is part of the Ministry of Construction and Housing authority.

The laboratory (NCCLR) conducting geotechnical tests for the Middle Euphrates region in addition to the testing of construction materials since its founding in 1977. The data were taking from 464 boreholes distributed in AN-Najaf and AL-Kufa cities and for depths of 0.5, 2, 4, 6, 8, 10, 12, 14, 16 and 35 meters. Locations of boreholes are shown in Fig. 2. The coordinates of the boreholes have been obtained by GPS.

2.3. Selected Software Program

To produce the sulfate distribution maps, first the data have to sorted and categorized in Excel, which includes the name of the site studied and the site's features, as well as tables containing the data that we will use in the analysis process. Then we call this file in the GIS program "ArcGIS 10.2.1" for the purpose of data analysis and production of maps using a set of tools for this aspect. Eleven geotechnical maps were prepared in this paper by ArcGIS 10.2.1 program, which is the latest version of the program that issued in 2014.

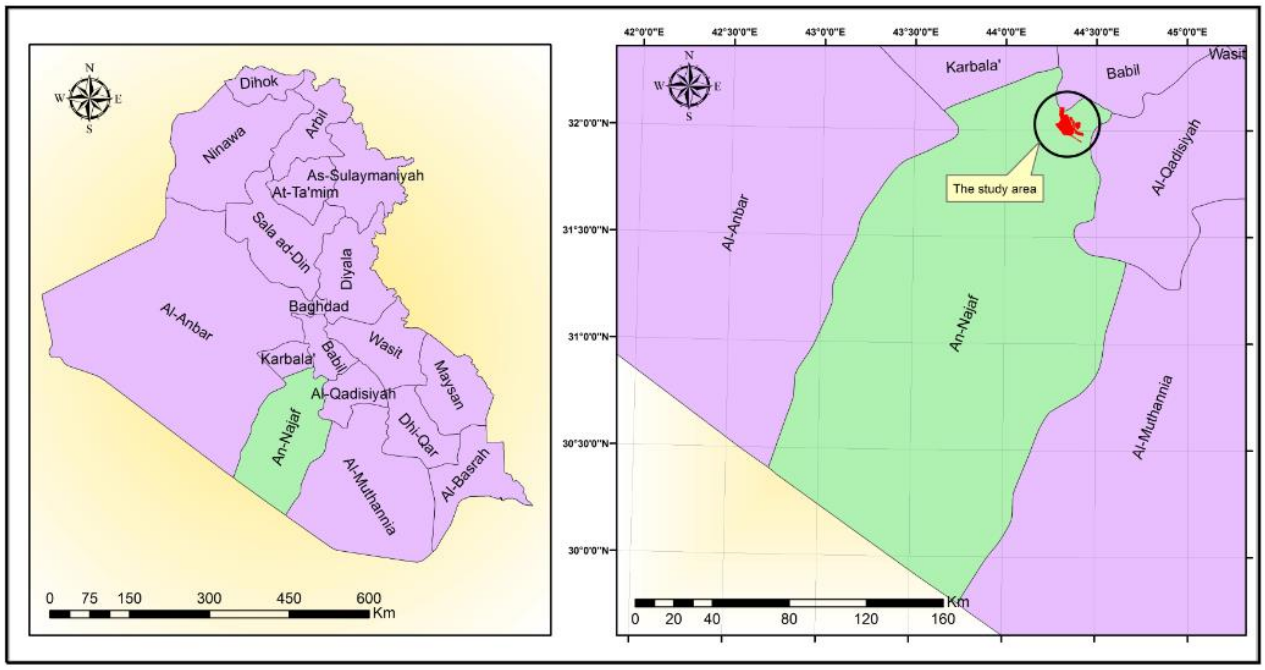


Fig. 1. Location of an- Najaf city.

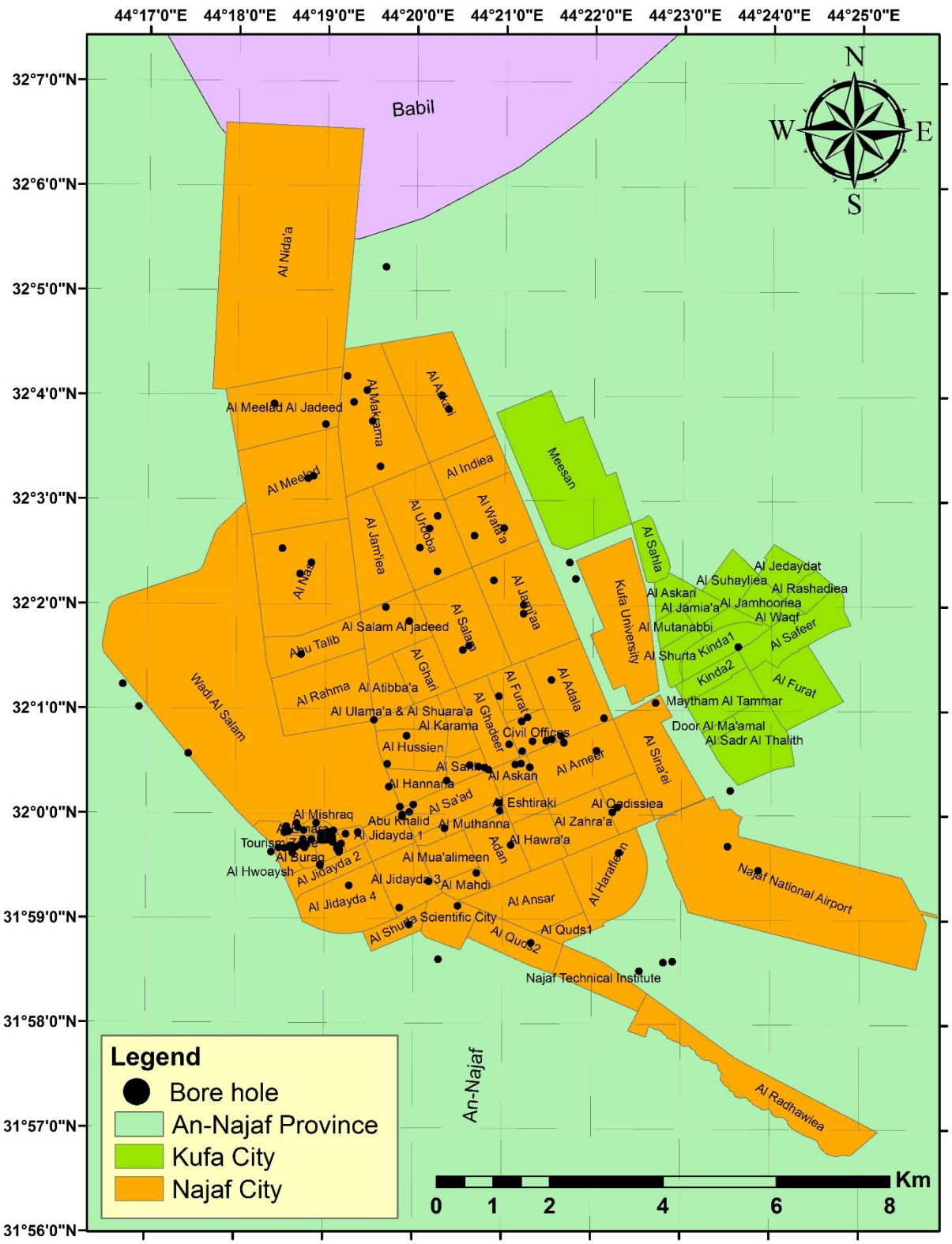


Fig. 2. Boreholes distribution in the study area.

3. AN-NAJAF CITY SOIL DESCRIPTION

In general, sand represents 50% - 85% of the soil composition, with few layers of clay and silty clayey soil at different depths. High values of SPT test, which exceeds 50 blows, are dominated on most of the region. Dense to very dense sand, and cemented sand are the most existing soil conditions. Angle of Internal friction Ø exceeds 35o in most of the region. The bearing capacity form SPT values exceeds 10 Ton/m2 in most studied region. Sulfate content reaches to 10%. Gypsum content is very high, it exceeds 25% in some locations. (Jassim and Goff, 2006).

4. AN-NAJAF CITY CLIMATE DESCRIPTION

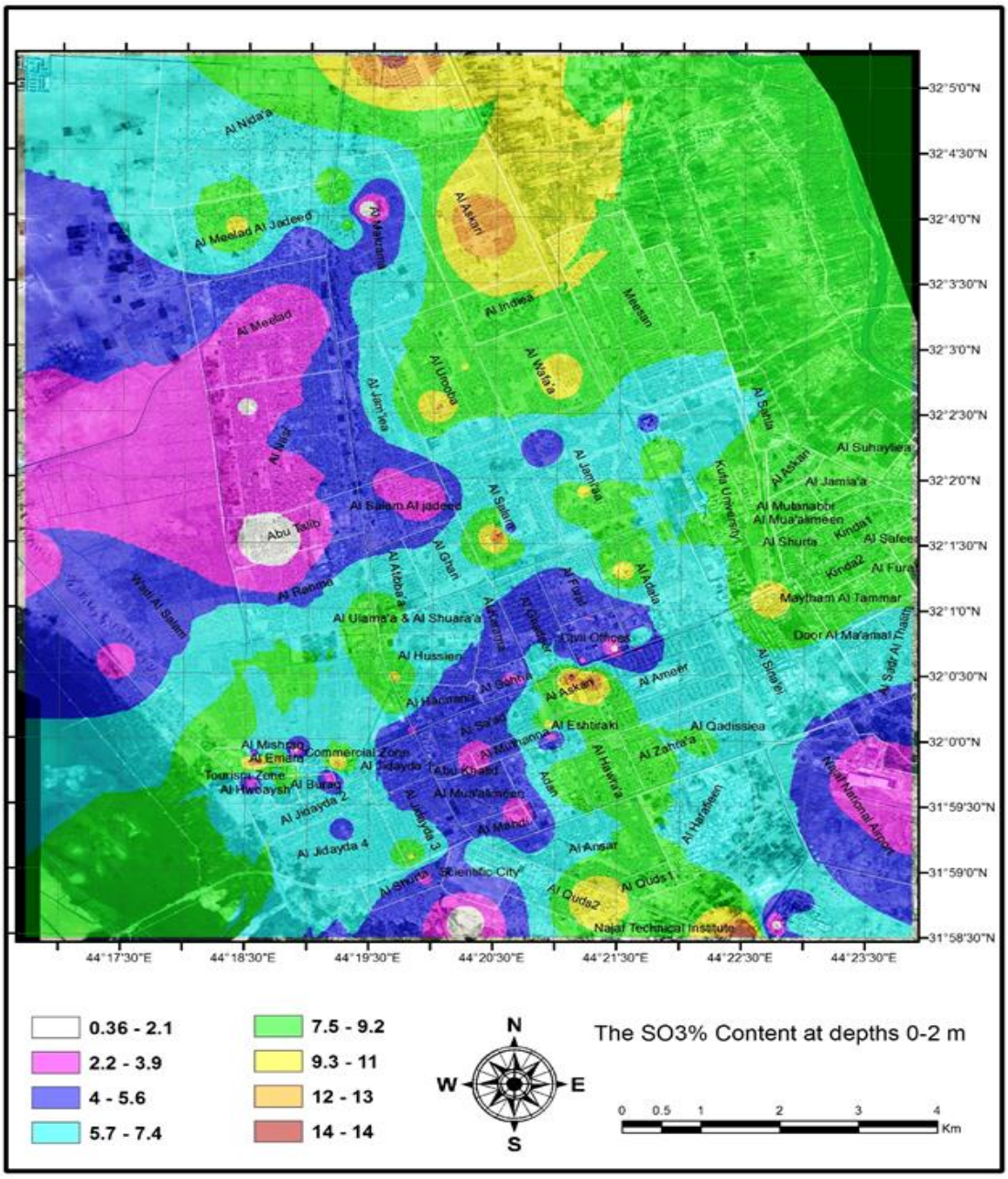
The climate naturally affects the formation of cities, regardless of their geographical location to the surface of the earth. The climate is directly or indirectly involved in the formation of the earth's surface. AN-Najaf province location has been developed within the desert climate, which is characterized with a hot dry summer, cold winter, the large difference in the daily temperature and rule of the Northwest wind. Summer temperatures rise to 41.2 in June, 43.9 in July and 43.4 in August. The main reason for this is the angle of fall of the sun, which is semi-vertical, causing the intensity of solar radiation in summer. Temperatures decrease in winter, as follows: in December, 5.1 in January, 3.9 and 5.6 in February. This difference is due to the period of solar radiation, where the sun rises to 11.9 hours per day in July while in December rises to 5.7 hours / day. This variation resulted in a great thermal range between the summer and winter months and between night and day. The rainfall in AN-Najaf, like other cities in Iraq, follows the Mediterranean system, as it increases in the winter and absent in the summer, where rainfall is restricted from October to May and distributed unevenly. The total annual amount of rainfall is 101,112.3,121 ml / cm2 (Environmental Statistics Report, Iraqi Ministry of Planning).

5. RESULTS AND DISCUSSION

Maps 1 to 9 were drawn for sulfate concentration in soil for different depths. While map 10 shows sulfate concentration in groundwater and map 11 shows organic matter content in the soil. Relationship between the sulfate concentration and the percentage of sulfate concentration were drawn to highlight the seriousness of each concentration for all depths as shown in Figs. 3 to 11. In addition, the relationship between the sulfate content and the percentage of the sulfate content in groundwater were drawn in Fig. 12. As well as the relationship between organic matter content and percentage of organic matter content in Fig. 13.

From maps 1 to 11 listed below, we can see:

1. At depth 0-2 meters the sulfate concentration in soil varies between 0.36-14 %, where the highest concentrations found in the north and east north areas of AN-Najaf city. While sulfate concentration in Al-Kufa city range between 7.5- 9.2%. These values are higher than the acceptable limit 0.2%.
2. At depth 2-4 meters the sulfate concentrations in soil vary between 0.1-18 %, yet the values 0.2-6 % are more prevailing on most of the study area. These values are higher than the limit 0.2%. and dangerous on construction foundations.
3. At depth 4-6 meters the sulfate concentrations in soil rang between 0.1-18 %. The most dominate values are between 2.4-8.8 % which spread over most of the city, while at the northern part in Al-Gadeer neighbourhood the concentration reach to 18%.
4. At depth 6-8 meters the sulfate concentrations in soil vary between 0.021-20 % and the most dominate concentrations ranges between 0.2-8 %.
5. At depth 8-12 meters the sulfate concentrations in soil varies between 1.8-6.3 % which spread over the study area.
6. At depth 12-16 meters the sulfate concentrations in soil ranges between1.2-4.1 for all the study area except for a residential area in the centre of AN-Najaf city (New Al-Salam neighbourhood) where the concentrations reach up to 7.3%.
7. At depth 16-35 meters the sulfate concentrations in soil ranges between 1.7-5.6 for all the study area except for an industrial zone in the southern of AN-Najaf city, where the concentrations reach 12%.
8. Groundwater sulfate content in the study area range was 84-239 %. Where the dominated values ranged between (150-200) with a percentage of 52% (figure12). These values were ineffective because they are under the permissible limit 1460% (Which were identified in the Iraqi standards).
9. In the study area, the organic matter contents of soil were 0.05-2.34, the greatest part of the study area was lower than the permissible limit (1%) Which were identified in the Iraqi standards and therefore ineffective.
10. It has been deduced that the highest pH value is 8.08 that means the soil is alkaline (because pH values are more than 7), while the average lowest value is 7.48 which is also alkaline and, therefore uninfluential.



Map 1. The SO_3% Content at Depths (0-2) m.

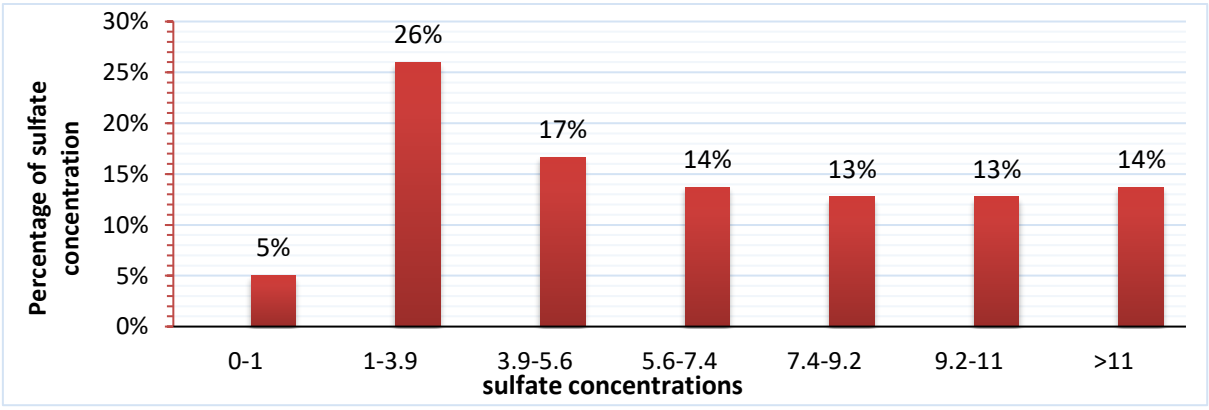
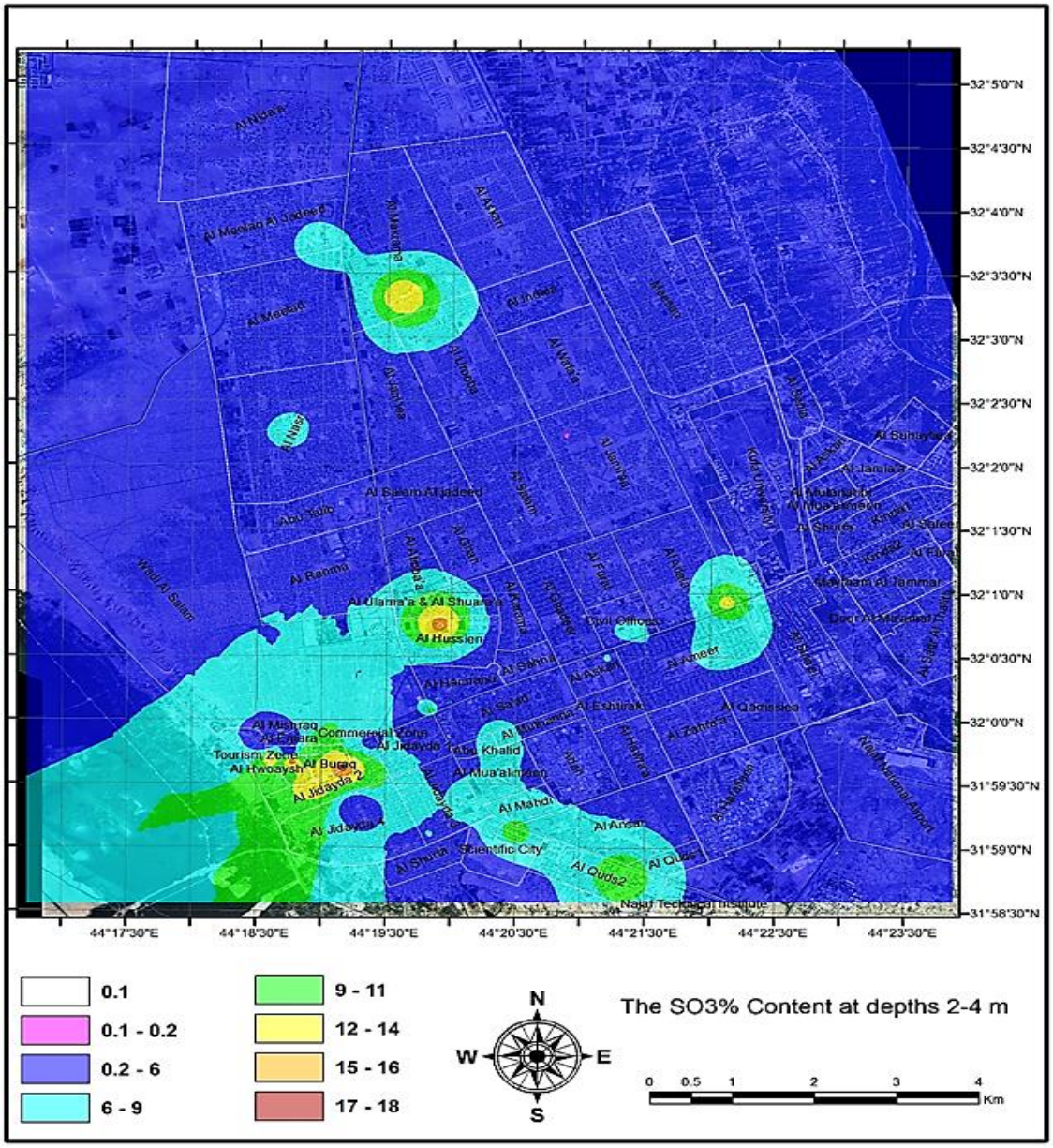


Fig. 3. Percentage of sulfate concentration at Depth (0-2)m



Map 2. The SO3% Content at Depths (2-4) m

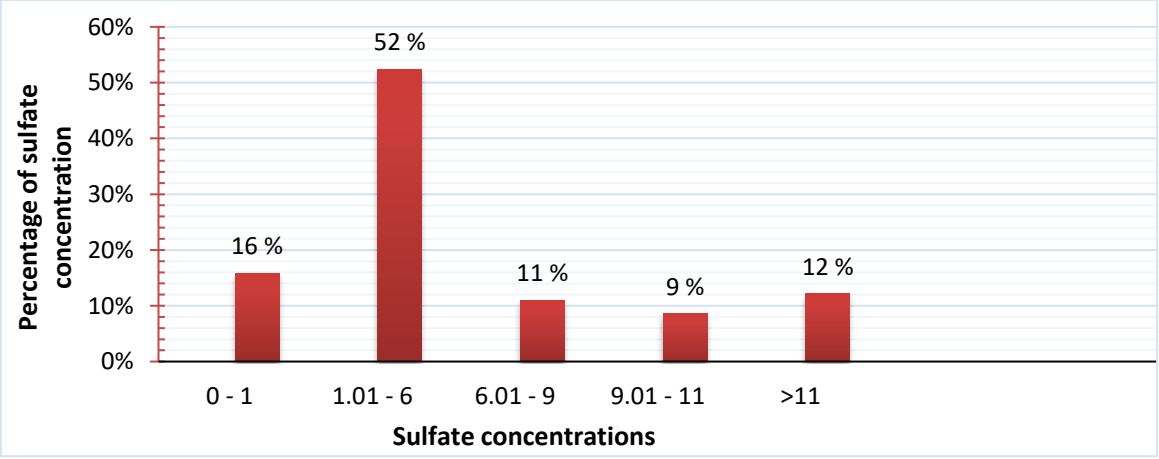
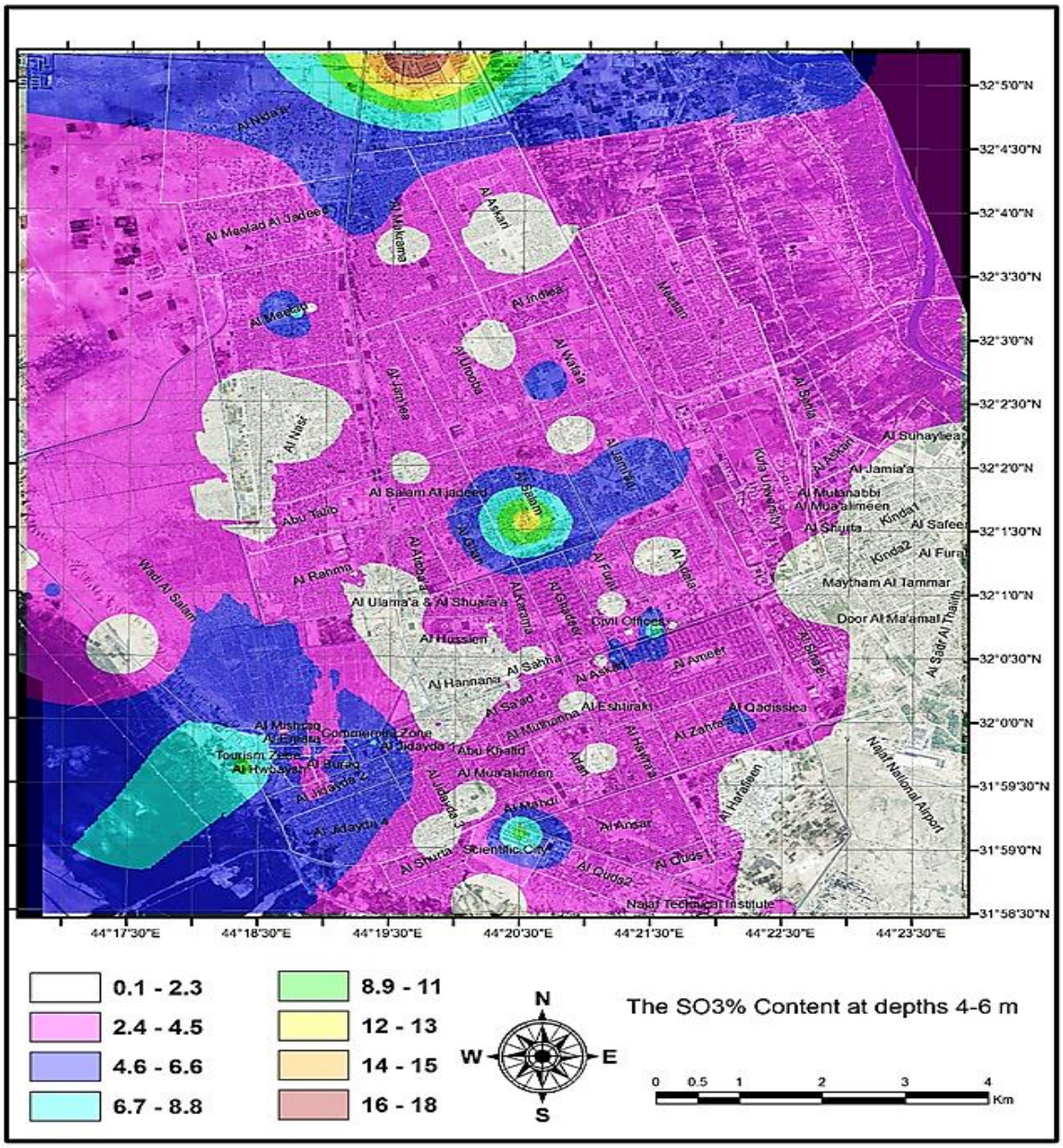


Fig. 4. Percentage of sulfate concentration at Depth (2-4)m



Map 3. The SO_3% Content at Depths (4-6) m

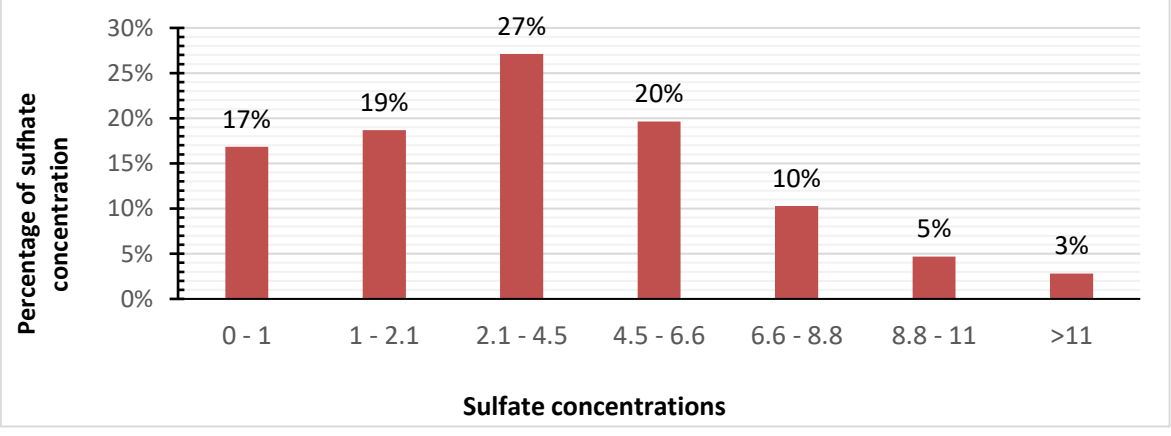
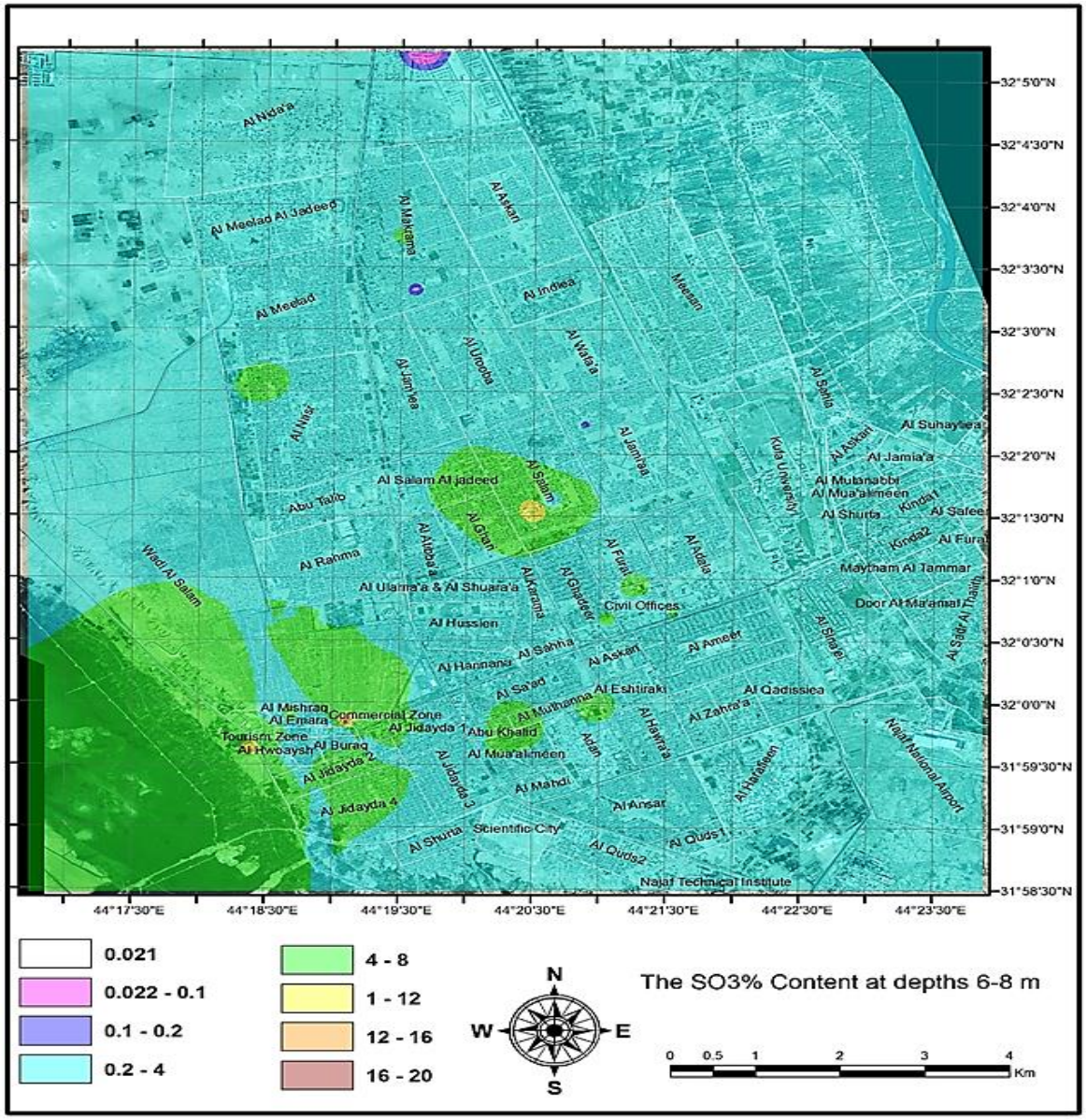


Fig. 5. Percentage of sulfate concentration at Depth (4-6)m



Map 4. The SO3 % Content at Depths (6-8)m

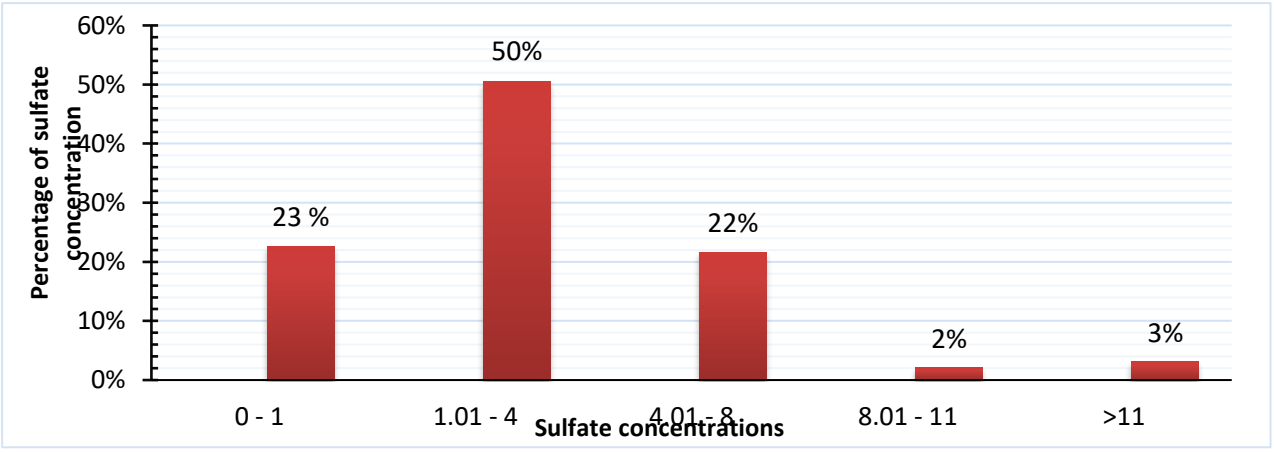
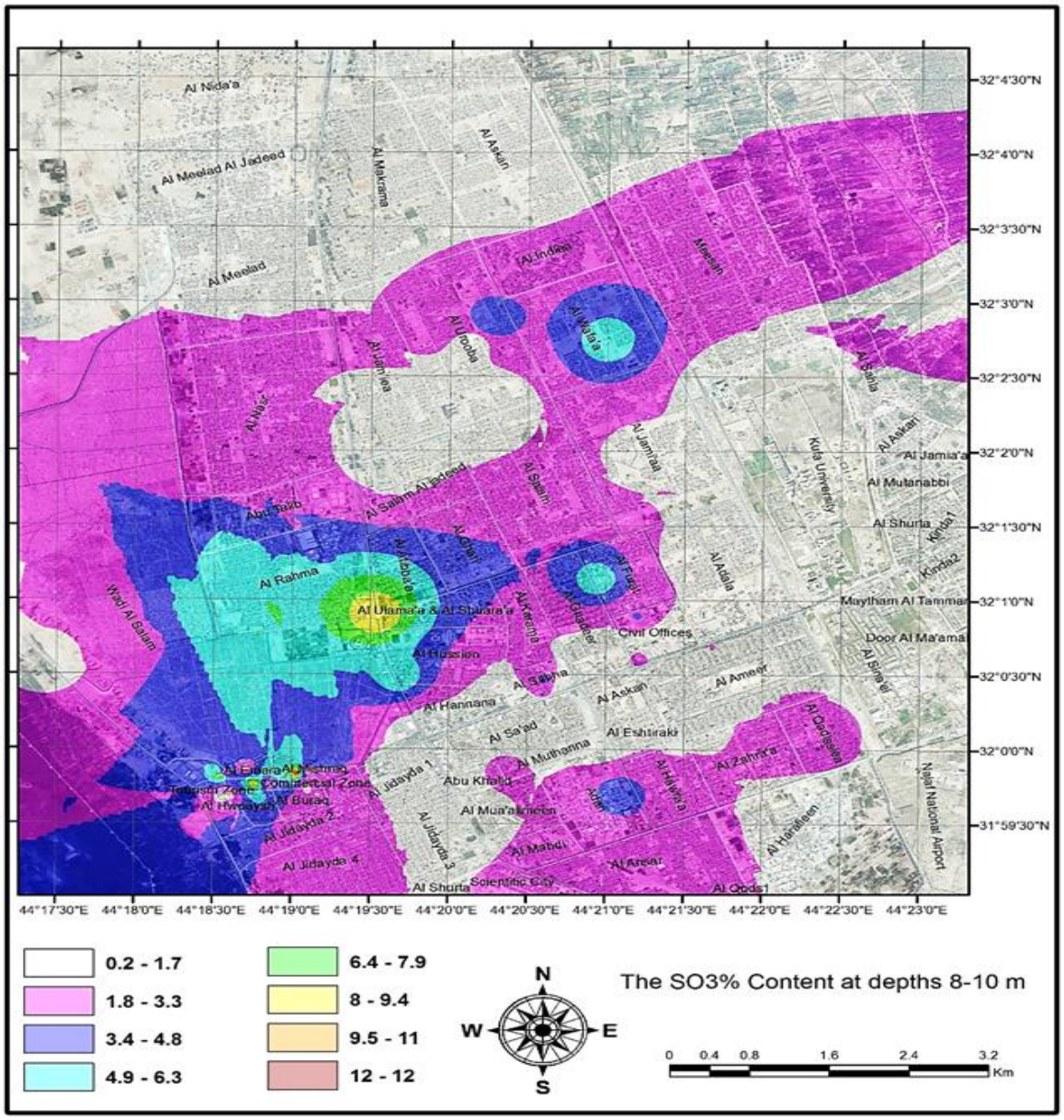


Fig. 6. Percentage of sulfate concentration at Depth (6-8)m



Map 5. The SO3% Content at Depths (8-10) m

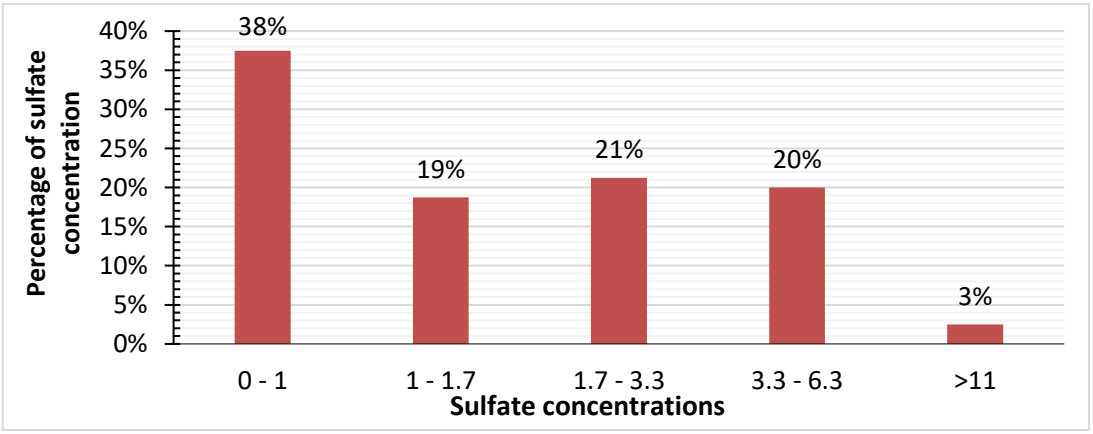
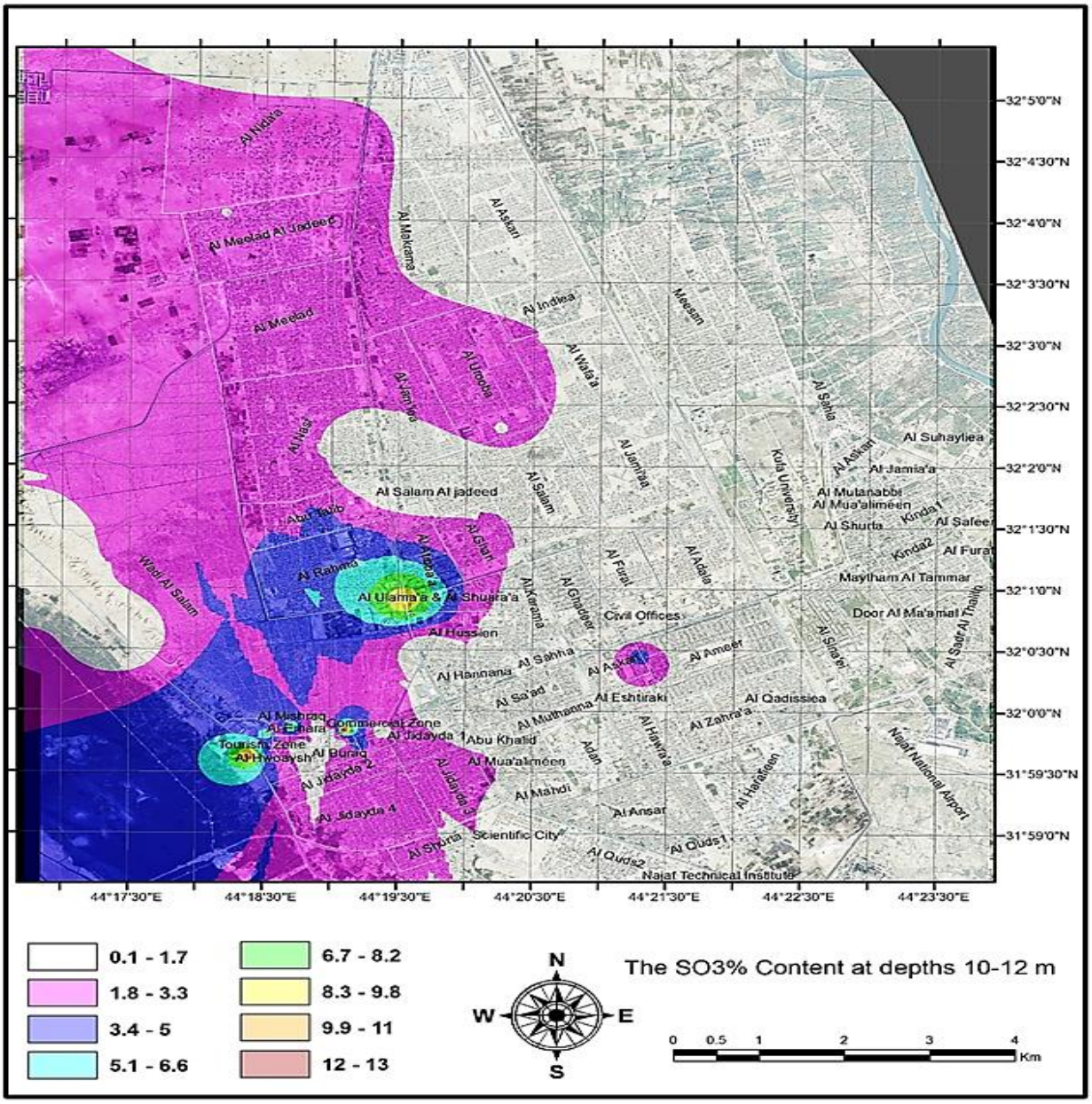


Fig. 7. Percentage of sulfate concentration at Depth (8-10)m



Map 6. The SO_3% Content at Depths (10-12) m

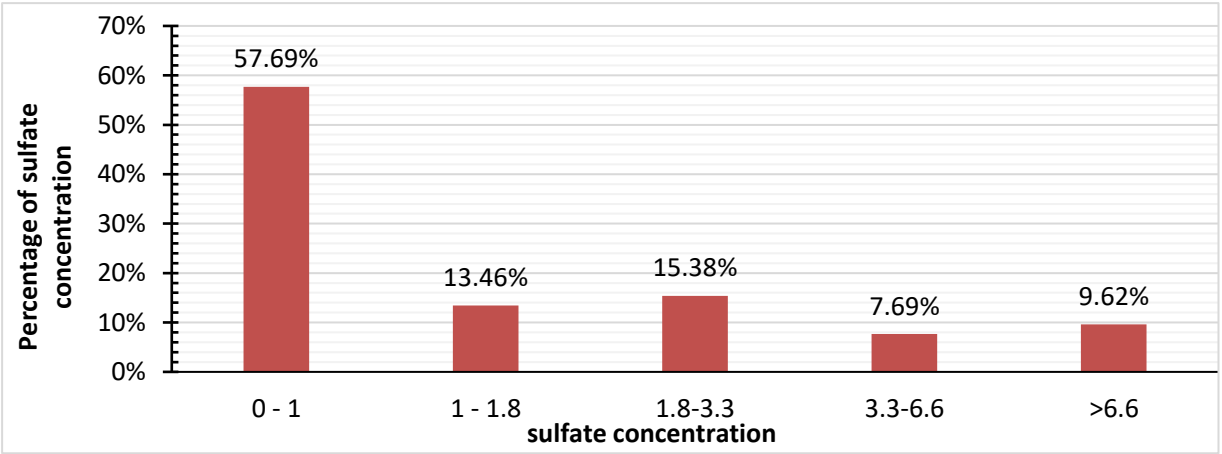
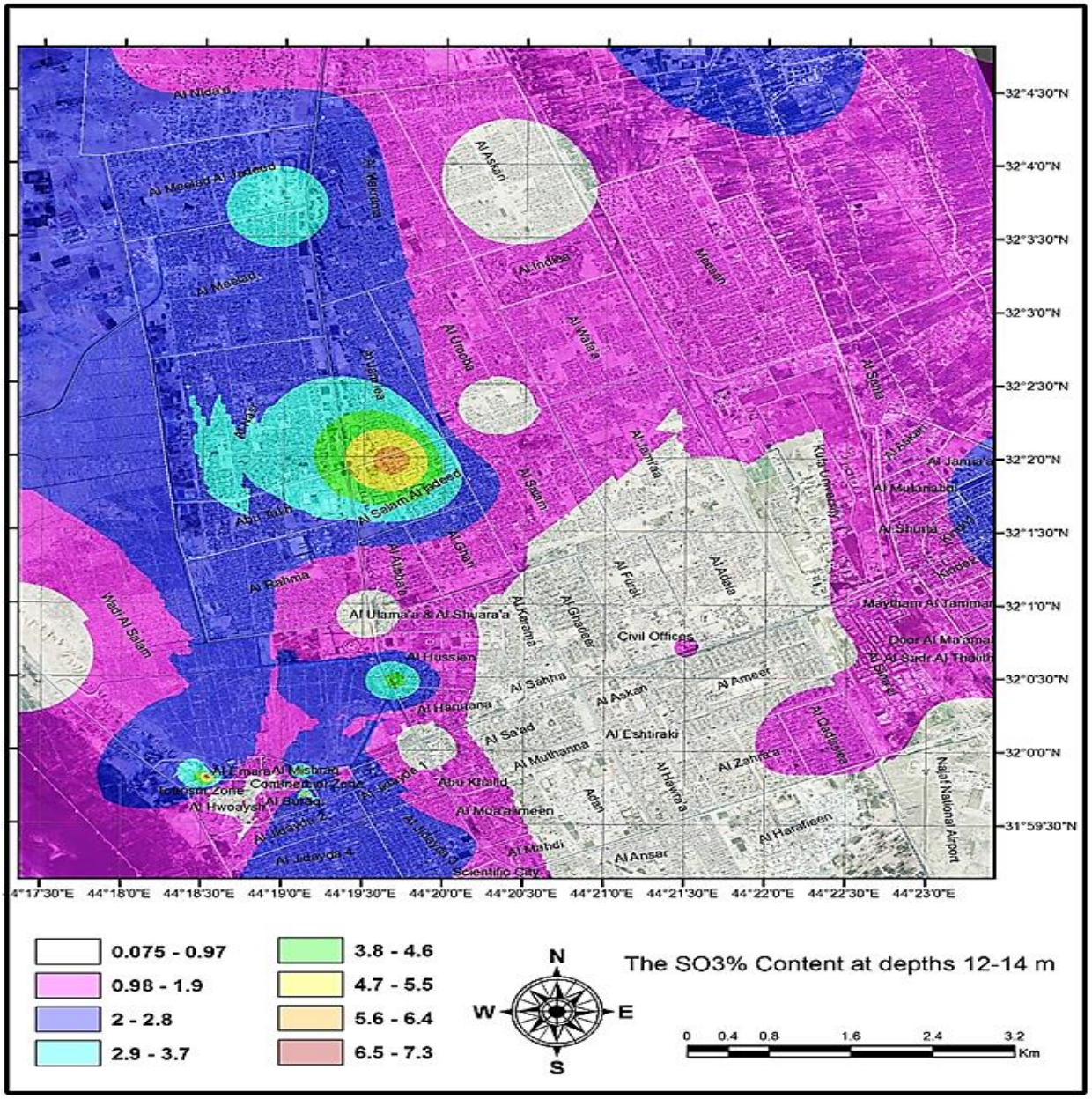


Fig. 8. Percentage of sulfate concentration at Depth (10-12)m



Map 7. The SO_3% Content at Depths (12-14) m

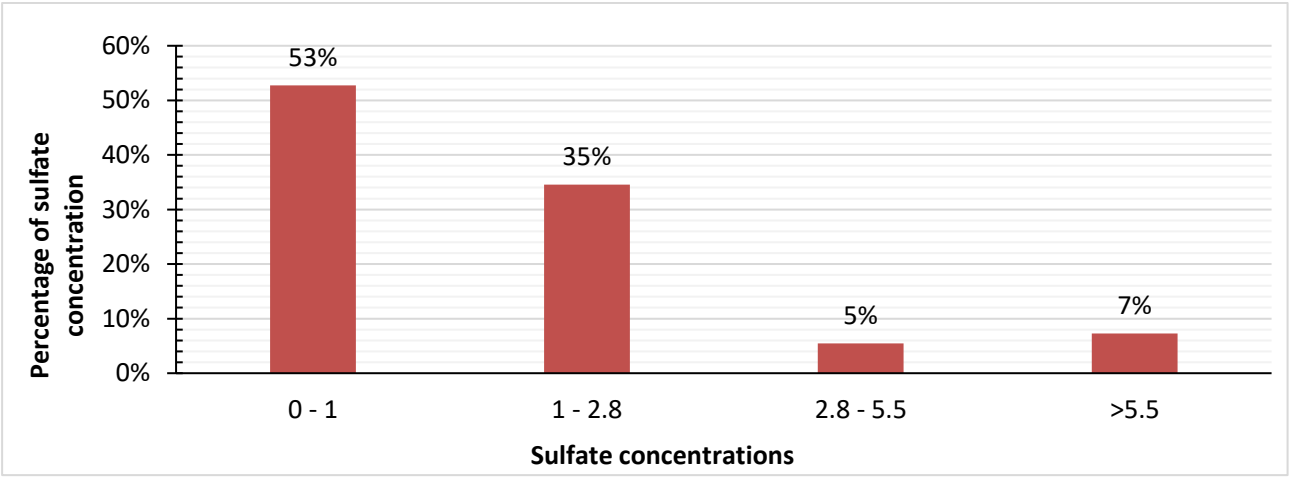
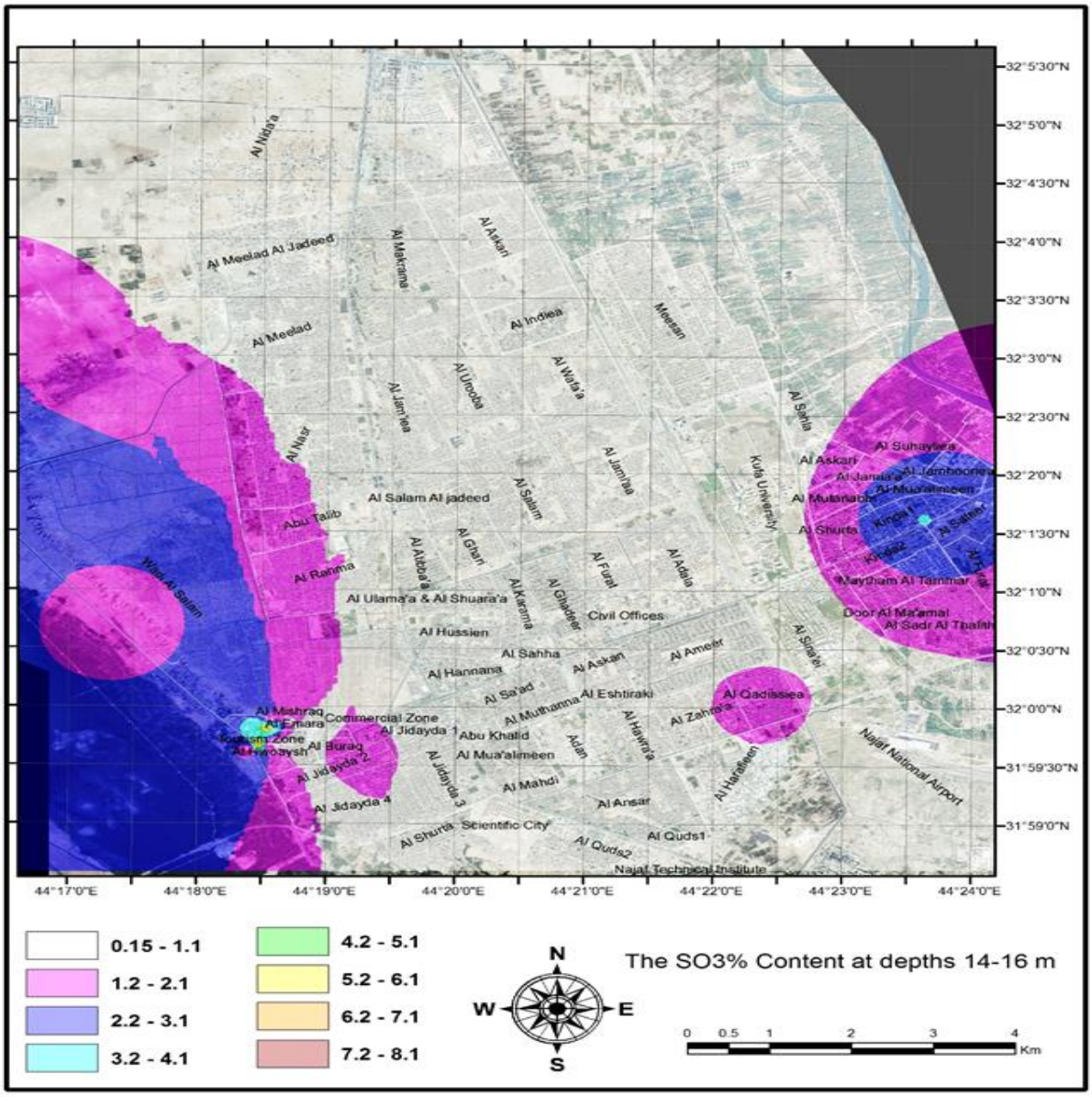


Fig. 9. Percentage of sulfate concentration at Depth (12-14)m



Map 8. The SO_3% Content at Depths (14-16) m

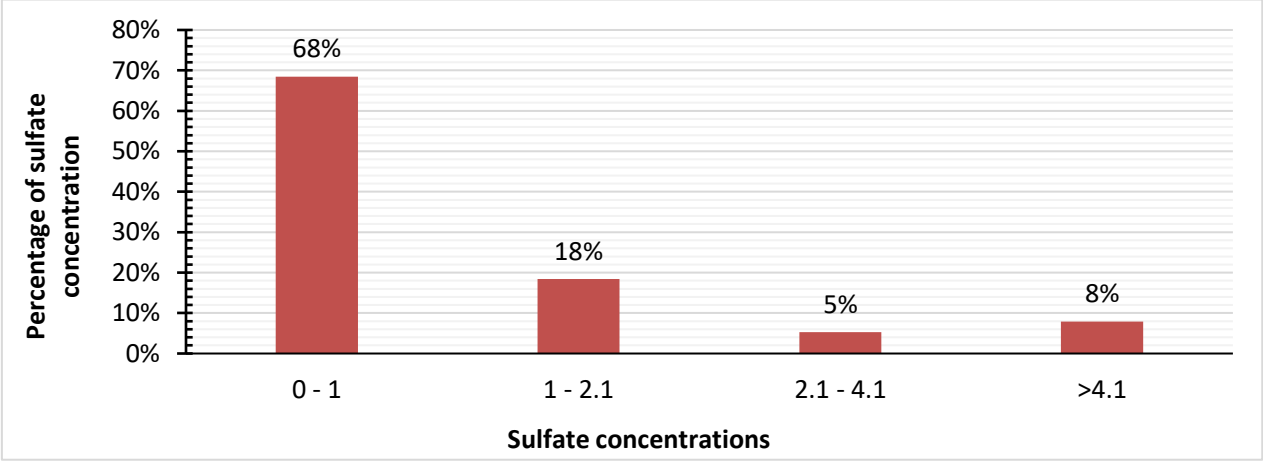
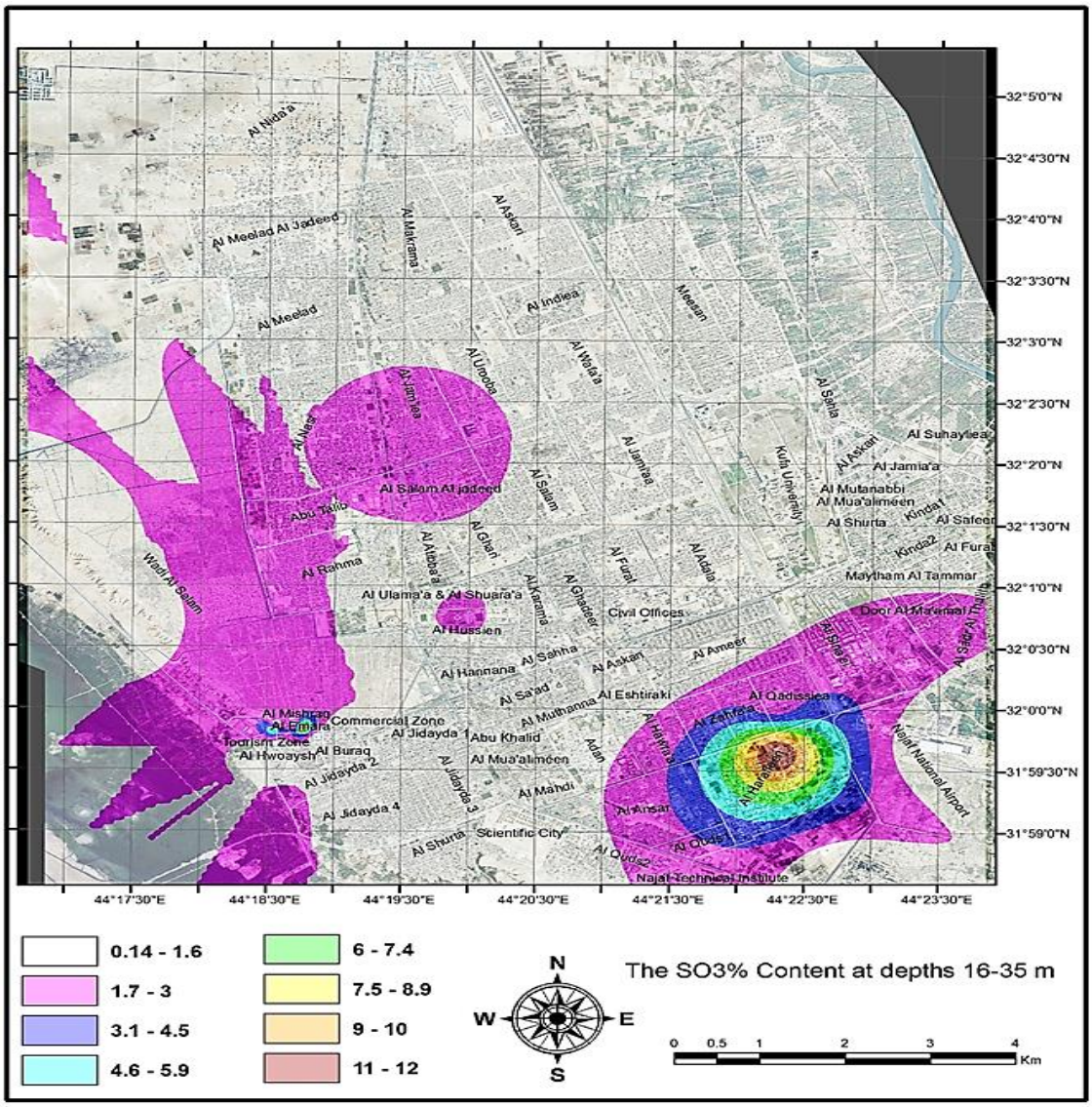


Fig. 10. Percentage of sulfate concentration at Depth (14-16)m



Map 9. The SO3% Content at Depths (16-35)m

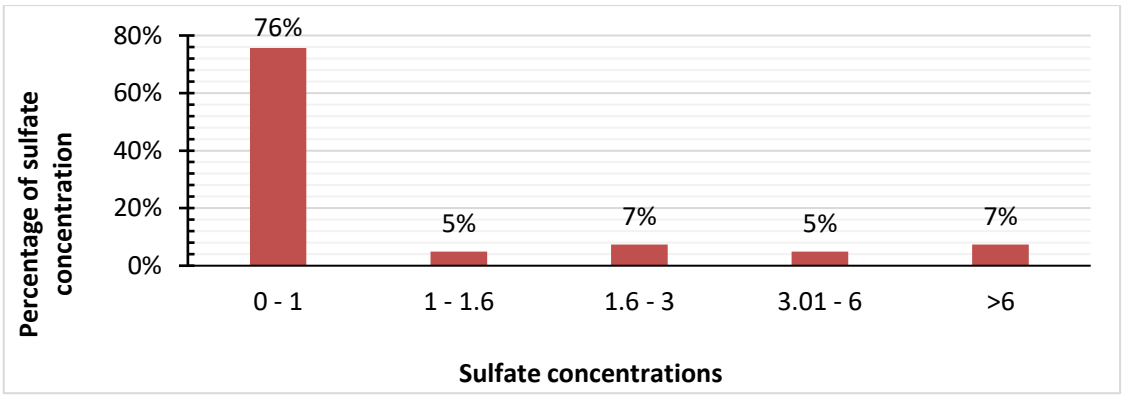
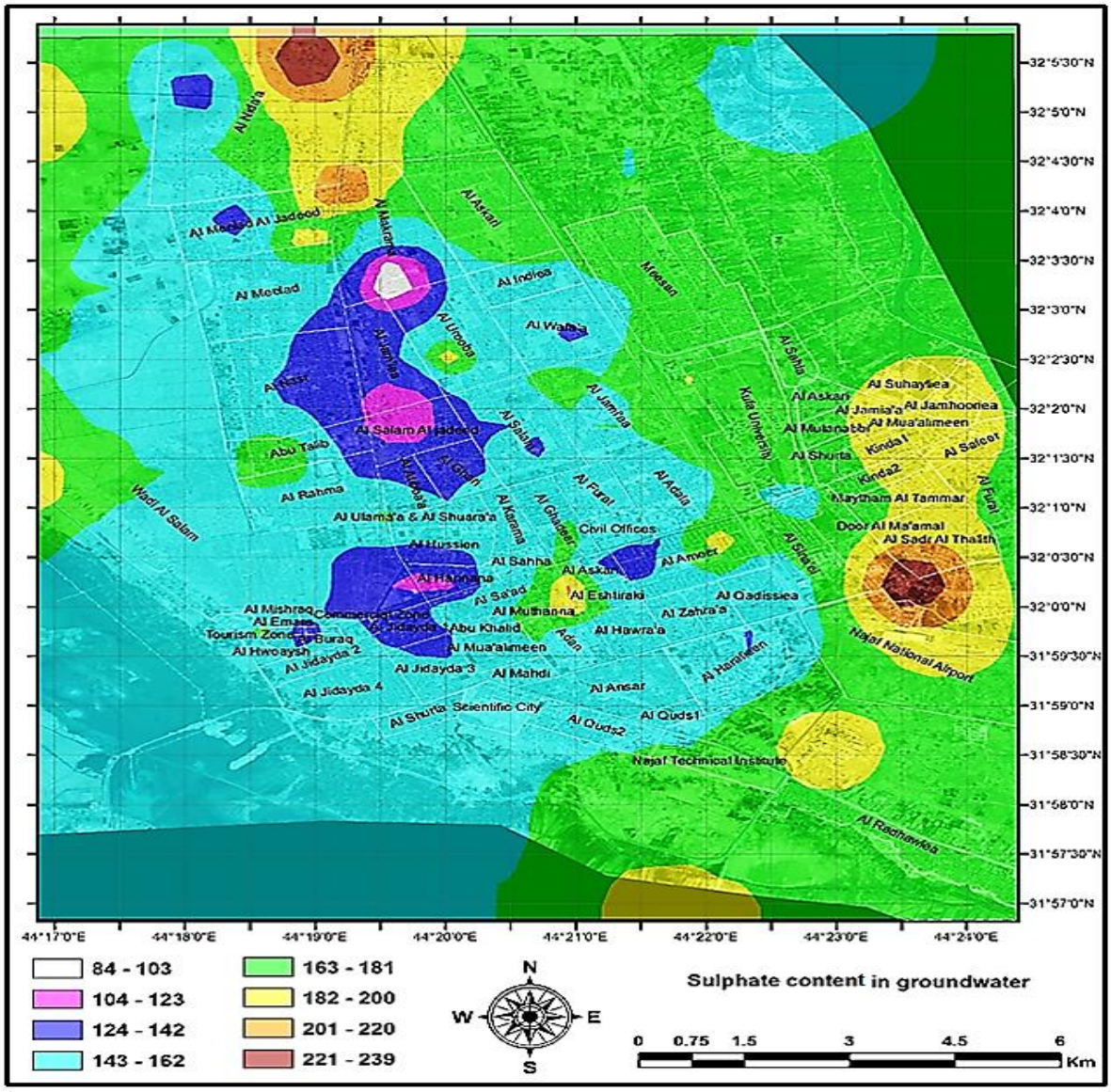


Fig. 11. Percentage of sulfate concentration at Depth (4-6)m

A geotechnical map for groundwater sulfate content in the study area were produced in map 10 below.



Map 10. The SO_3% Content in Groundwater

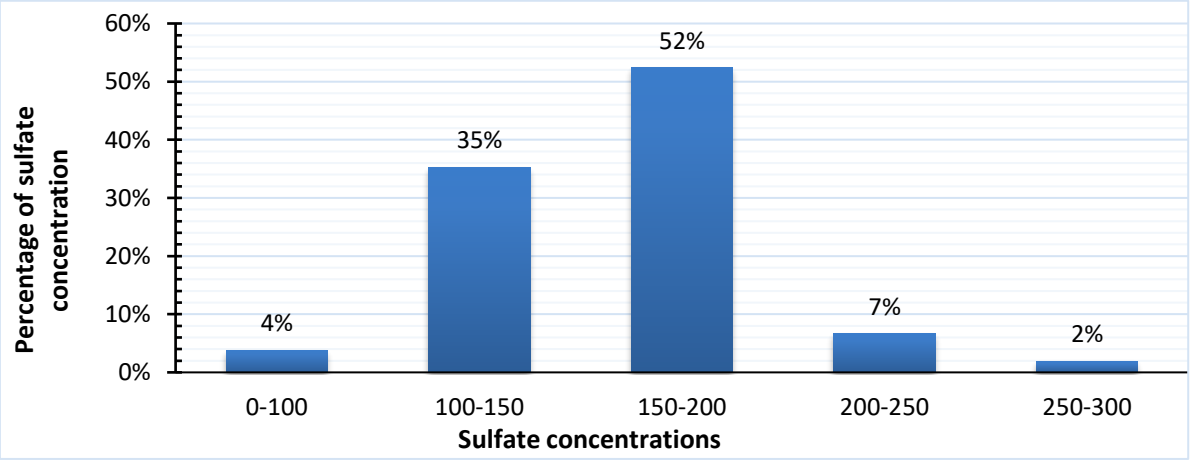
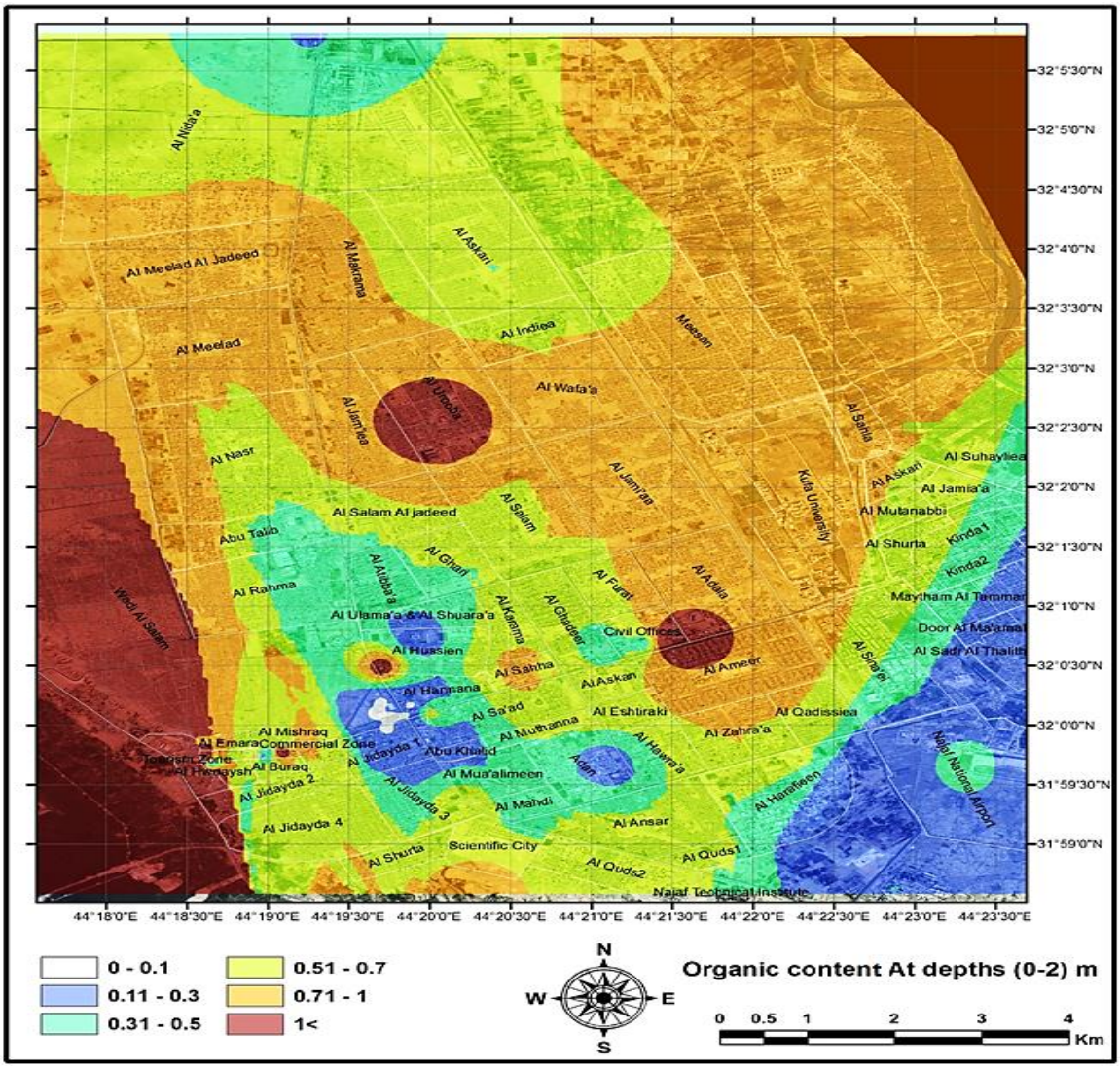


Fig. 12. Percentage of sulfate concentration in groundwater

A geotechnical map for the organic matter in the study area were produced in map 11. In addition, the relationship between the organic matter content and the percentage of the organic matter content were drawn in Fig. 13.



Map 11. Organic content at depths (0-2)m

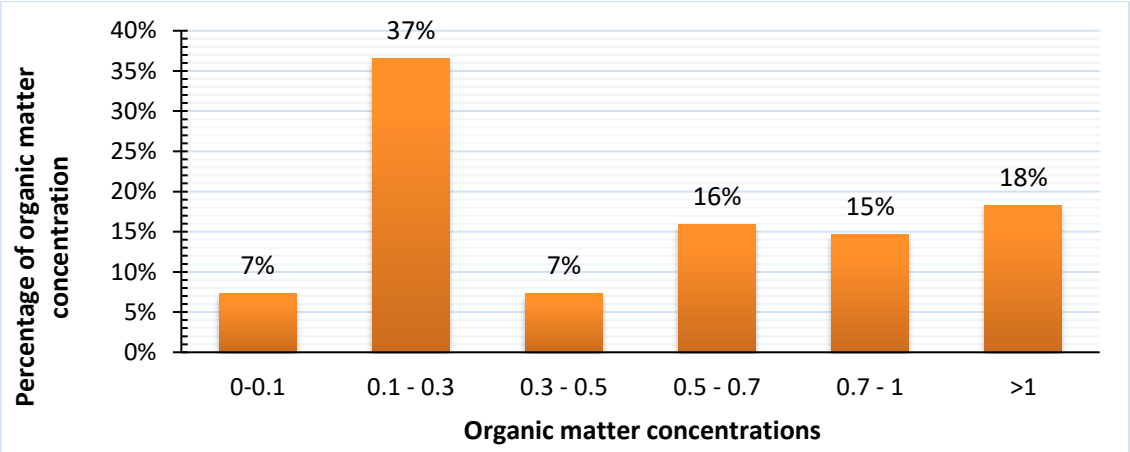


Fig. 13. Percentage of organic matter content at depth (0-2)m

6. CONCLUSIONS

1. Using Geographic Information System (GIS) to produce geotechnical maps provide a helpful way to predict the sulfate content in non-Spatial data areas.
2. Geotechnical maps produced for the study area represent a very powerful database and visual display of the collected data. Besides, using these maps will help save time cost and effort.
3. The produced maps can be used as a guidance for engineers and decisions makers to decide the suitability of any construction in the study area, the best foundation design and type of suitable treatment needed.
4. It has been concluded that all the study area and for depths (0-2) has very high sulfate content in the soil. Sulfate values varies between (0.36- 14) where all the results were higher than the permissible limit which is (0.2%). Therefore, precautions have to be adopt and sulfate resistance Portland cement (SRPC) should be used for all concrete works that have contact with soil
5. Groundwater sulfate content in the study area range was (84-239) %. These values were ineffective because they are under the permissible limit, which is 1460%.
6. The organic matter content values varies between (0.05-2.34), the greatest part of the study area was lower than the permissible limit (1%) and therefore ineffective.
7. The PH values indicate that all the study area was alkaline so it is uninfluential.

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