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Assessment of Water Quality Along Shatt Al-Hillah River in Iraq Using GIS Software

A project submitted to the Department of Environmental Engineering, Babylon University as partial fulfillment of the requirement of the degree of Bachelor of Science in Environmental Engineering

By

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بسم الله الرحمن الرحيم

﴿وَقُلِ ٱعْمَلُوا۟ فَسَيَرَى ٱللَّهُ عَمَلَكُمْ

وَرَسُولُهُۥ وَٱلْمُؤْمِنُونَ ۖ وَسَتُرَدُّونَ إِلَىٰ عَـٰلِمِ ٱلْغَيْبِ

وَٱلشَّهَـٰدَةِ فَيُنَبِّئُكُم بِمَا كُنتُمْ تَعْمَلُونَ ﴿١٠٥﴾﴾

صدق الله العلي العظيم

سورة القصص الآية (١٠٥)

Certification

We certify that we have read this project an "**Assessment of Water Quality Along Shatt Al-Hillah River in Iraq Using GIS Software**" and as an examining "**Aya Alaa Hadi, and Hassan Hadi**" committee, examined the students in its content and in what is connected with it, and that in our opinion it meets the standard of a graduated project for the degree of Bachelor of Science in Environmental Engineering.

Signature:

Name: Dr. Ali Jalil Chabuk

Date: / / 2022

CERTIFICATION

We certify that we have read this project entitled "**Assessment of Water Quality Along Shatt Al-Hillah River in Iraq Using GIS Software**" and as an examining committee, examined the students "**Aya Alaa Hadi, and Hassan Hadi**" in its content and in what is connected with it, and that in our opinion it meets the standard of a graduated project for the degree of Bachelor of Science in Environmental Engineering.

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شكر وتقدير

الشكر الى الله تعالى بارئنا ومصورنا اولا واخرا
الى والدينٌا الذينٌ سهرا على تربيتٌنا وتعليمٌنا
الى معلمونا الاوائل الذي لم يدٌخروا جهدا من اجلنا
الى كل من علمنا حرفا انار به عمولنا وابصرنا به طريقٌنا
الى كل الزملاء والاصدقاء الذينٌ رافقونا في مسيرٌة الحياٌة
الى استاذنا الفاضل(الدكتور علي جليل جابك)
الذي تفضل بالاشراف على هذا المشروع فجزاه الله عنا كل خيرٌ وله منا كل التقديرٌ والامتنان

طلبة المشروع:

اية علاء هادي

حسن هادي

الإهداء

الى صاحب الحضرة النبوية والرسالة الالهية، وحامل هموم البشرية، والناصح الأمين، وهادي البشر, والسراج المنير، مصباح الظلمة، وينابيع الحكمة، والداعي الى الحرية، والخلاص من العبودية.

(وَيَضَعُ عَنۡهُمۡ إِصۡرَهُمۡ وَٱلۡأَغۡلَٰلَ ٱلَّتِي كَانَتۡ عَلَيۡهِمۡ)

سيد الانبياء والمرسلين ابي القاسم

محمد صلى الله عليه وعلى اله الطيبين الطاهرين

Abstract.

The global interest in the water bodies due to the water scarcity crisis encourages researchers to study the details of the water environment in different aspects. Consequently, this study's objective is to evaluate the water quality in Shatt Al-Hillah River by adopting eleven physic-chemical parameters measured at six locations along the river in 2015. In this study, the water quality index method (WQI) was calculated using the weighted arithmetic method through applied series of equations. Eleven physical-chemical parameters were comprised of calcium (Ca), magnesium (Mg), dissolved oxygen (DO), Hydrogen Ion (pH), chloride (Cl), sulfate (SO_4), total hardness (TH), total dissolved solids (TDS), turbidity (Tur), Alkalinity, and electric conductivity (EC). For the selected locations along the river, the measured values of all tested parameters in the year 2015 along the Shatt Al-Hillah River were decreased gradually from the location (L-1) in Al-Musayyib to the location (L-6) in Al-Hashimiya, and the clear decrease was at the part of the river from location (L-4) to the location (L-6) for all chosen parameters. According to the resulted WQI values for the six locations, these values ranged from 272 to 280 (with a range of 200 – 300) and were rated as very poor water quality. The average value of the WQI classified all water of Shatt Al-Hillah River as very poor water quality. In this study, the distributing map of (WQI) for drinking uses for Shatt Al-Hillah River, Iraq was output in ArcGIS 10.8 using the interpolation model of Inverse-Distance-Weighting (IDW).

الخلاصة.

نظرلاهتمام العالمي بالمسطحات المائية بسبب أزمة ندرة المياه شجع الباحثين على دراسة تفاصيل البيئة المائية من جوانب مختلفة. نتيجة لذلك، إن هدف هذه الدراسة هو تقييم نوعية المياه في نهر شط الحلة من خلال اعتماد أحد عشر معيارًا فيزيائيًا كيميائيًا تم قياسها في ستة مواقع على طول النهر في عام 2015.

في هذه الدراسة ، تم حساب طريقة مؤشر جودة نوعية المياه (WQI) باستخدام طريقة الحساب الموزون (weighted arithmetic method) من خلال سلسلة المعادلات التطبيقية. العناصر الاحدى عشر فيزيائية ـ كيميائية التي تم اعتمادها في هذه الدراسة هي: الكالسيوم (Ca)، والمغنيسيوم (Mg)، والأكسجين المذاب (DO)، وأيونات الهيدروجين (pH) ، والكلوريد (Cl)، والكبريتات (SO4)، والصلابة الكلية (TH)، والمواد الصلبة الذائبة الكلية (TDS)، العكورة (Tur)، القاعدية، والتوصيل الكهربائي (EC).

بالنسبة للمواقع المختارة على طول النهر الأنهار، فإن القيم المقاسة لجميع المعلمات المقاسة في عام 2015 انخفضت تدريجياً من الموقع الاول (L-1) في المسيب إلى الموقع الثاني (L-6) في الهاشمية ، وكان الانخفاض الواضح في جزء النهر من الموقع الرابع (L-4) إلى الموقع السادس (L-6) ةلجميع المعلمات المختارة. وفقًا لقيم WQI الناتجة للمواقع الستة ، تراوحت هذه القيم من 272 إلى 280 (ضمن نطاث المدى 200 إلى 300) وتم تصنيفها على أنها ذات جودة مياه رديئة جدًا.

صنف متوسط قيمة مؤشر جودة المياه لكل مياه نهر شط الحلة على أنها ذات نوعية مياه سيئة للغاية.

في هذه الدراسة ، تم إنتاج خريطة توزيع (WQI) لاستخدامات الشرب لنهر شط الحلة ، العراق في ArcGIS 10.8باستخدام نموذج الاستيفاء الخاص بالوزن العكسي للمسافة (IDW).

CHAPTER ONE

Introduction

Chapter One Introduction

1. Introduction

Water is an essential requirement of human and industrial development, and it is the most significant part of the environment (Das and Acharya 2003). Water quality deals with the physical, chemical, and biological characteristics concerning all other hydrological properties (Atulegwu and Njoku 2004). The increasing population, the expansion of economic activities, and urban sprawl are leading to increased demand for water. The overuse of surface water and groundwater is jeopardizing numerous resources because of the reduction of the available quantities and the deterioration of their quality (Massoud 2012; Sahoo et. al 2015).

The deteriorated quality of surface water is becoming a serious issue in many countries (Witek et. al 2009) and water quality monitoring is among the highest priorities in resources protection policy (Simeonov et. al 2002). Thus, recently developing countries have intensified efforts to evaluate the quality of rivers (Kannel et. al 2007). The assessment of water quality is a prerequisite for the implementation of water protection policies and the optimal allocation of different water sources according to their uses. Indeed, surface water has often been evaluated using norms (Rosemond et. al 2009). However, sources of pollution are diverse: urban, industrial, and agricultural pollution (diffuse or point source). Water quality (WQ) is defined as the set of variables that limit water use; each user has some common requirements for some variables.

The water quality is affected by nature, such as geological, hydrological, and climate, and various anthropogenic such as discharge of municipal and industrial sewage water, and agriculture drainage (Alam and Laishram 2017; Meybeck et. al 1996). Water quality assessment (WQA) is a process of determining the physicochemical and biological properties. The water quality indices (WQI) aimed to give individual values to know the WQ in a simple and easier expression to interpret control data (Bhart and Katyal 2011). Hoseinzadeh, et al. (2014) used different WQ indices to assess the Aydughmush River in Iran. They found similar results of indices except for the river pollution index. The Euphrates River is the main water resource for the Western (Ramadi Province) and southern parts of Iraq.

Many agro-industrial activities threaten the water quality along the mainstream (Hassan and Shaawiat 2015). Many studies in Iraq used the CCME-WQI to evaluate the WQ in Tigris and Euphrates Rivers.

2. Scope of Work

The research is interested in studying the suitability of the Shatt Al-Hillah River for drinking and household uses by measuring the available variables at six locations along the river starting from upstream of the river at Al-Musayyib to the near the downstream of the river at Al-Hashimiya.

This study aims to create the prediction map for Shatt Al-Hillah River using the water quality index model for drinking uses (WQI). Then, the values of (WQI) will enter within the interpolation technique IDW in the GIS to produce the prediction map.

The purpose of creating a new map of water quality for drinking uses is that the study zone does not have a map for groundwater. The study zone has been affected by the Global Warming problem which led to searching for another way to cover the shortage.

The map will be a document to help the researchers and the specialists. Also, the future of plan for the Governorate is to secure additional drinking water sources when necessary and help with future suburbs of the city. Moreover, the map is an easy way to show the water river to users.

CHAPTER TWO

Previous Studies and Study Area

Chapter Two Previous Studies and Study Area

2.1 Previous Studies

Many researchers studied the water quality index for water bodies, especially for rivers.

Nawar (2018) study the water quality of the Diyala River in Iraq using the Bhargava method. Diyala River covers a total distance of 445 km (275 miles). 32600 km^2 is the area that drains by the Diyala River between the Iraq-Iran borders. This research aims to evaluate the water quality index WQI of the Diyala River, where three locations were chosen along the river. These locations are D12 at Jalawlaa City at the beginning of the Diyala River, the second station is D15 at Baaquba City at the mid-distance of the river, and the third station is D17 which is the last station before the confluence of the Diyala River with Tigris River at Baghdad city. Bhargava method was used to evaluate the water quality index for both irrigation and drinking uses. The results show that the first station at Jalawlaa city after the Iraqi Iranian borders has excellent water quality for irrigation and good water quality for drinking because it is the nearest point to the river origin and few populations beside it. The second station at the mid-distance of Diyala River in Baquba city has good water quality for irrigation but severely polluted water for drinking, this city is considered as Diyala province center, and many agricultural and industrial wastes are discharged directly to the river. The last station located at Baghdad city before the meeting of Diyala River with Tigris River, the river has acceptable water quality for irrigation but severely polluted water for drinking, we can conclude that the river is heavily polluted with various wastes and high concentration of BOD values affected on river water quality.

Haritash et al. (2016) say that the water samples were collected from River Ganga in Rishikesh in December 2008 to assess its suitability for drinking, irrigation, and industrial usage using various indices. Based on the values obtained and suggested designated best use, water in the upper segment can be used for drinking but after disinfection (Class A); organized outdoor bathing in the middle segment (Class B) and can be used as a drinking water source (Class C) in the lower segment in Rishikesh. All the parameters were within the specified limits for drinking water quality except E. coli. The indices of suitability for irrigation and industrial application were also evaluated. The irrigation quality ranged from good to excellent at almost all places except for percent sodium. The abundance of major ions followed $K^+ > Ca^{2+} > Cl^- > HCO^{3-} > Na^+ > Mg^{2+} > CO_3^{2-}$ trend. The major cations suggested that the water is alkaline (Na + K) than the alkaline earth

(Ca + Mg) type. The heavy metals (Pb, Cu, Zn, Ni) were found either absent or within the limits specified. The results indicated that the water quality of the river Ganga was good at most of the locations in Rishikesh town. The upper segment of Ganga had good quality water to be used for drinking with minimal treatment but after disinfection. Even the concentration of heavy metals was either non-detectable or within the safe limits. The middle and lower segments had higher levels of pollutants, especially the TDS, organic matter, and MPN. Such areas may be dedicated to organized outdoor bathing for tourists and pilgrims. Night soil disposal in riverbeds and wastewater discharge through open channels need immediate attention to control MPN and organic load. MPN was found to be a critical parameter that needs regular monitoring and measures to control. The addition of phosphate from wastewater channels is of concern since it may lead to eutrophication, particularly at the time of year when the flow is lean.

Hussein (2012) study the Euphrates River water quality in Al-Kufa Station. Euphrates river passes several large cities with rural areas and receives various types of waste that may affect the quality of its water and therefore the living organisms in it. Data for Euphrates River in Al Kufa station were collected, from the period extended from January to December 2008. These data represent the Phosphate (PO_4), Nitrate (NO_3), Monthly Rain Totals (Ra), Hydrogen Ion concentration (pH), turbidity unit (N.T.U.), Chloride (Cl), precipitated dust particles (PM), Ambient Temperature (T), and Monthly Percent of Sandstorm occur (S.ST) as independent variables, Biological Oxygen Demand (BOD), as the dependent variable. The statistical models have described the relations between parameters of water quality. The regression analysis was done by using the "Data Fit" program version 9.0 software. The results show that BOD is the amount of oxygen required for the biological decomposition of the organic matter under aerobic conditions (Duggal, 2008). So, this correlation may be indicating the indirect effects of wet and moist precipitated particulates on water rivers. Nitrates indicate the presence of fully oxidized organic matter (Punmia and Jain, 1998), major sources of nitrogen components include municipal wastewater discharges, runoff from animal feedlots, chemical fertilizers, and nitrogen-decomposition from the atmosphere (Masters and Ela, 2008), Phosphate (PO_4) is one of the phosphorus compounds, in organic form. It is released during anaerobic decomposition is very soluble in water and does not bind to metal ions or sediments. Soluble phosphate is easily taken up by plants and used as a nutrient (Weiner and Matthews, 2003), NO_3 has a moderate positive correlation with PO_4 and ambient temperature, apparently because of nutrients found in domestic sewage that is discharged to the Al Kufa river from Northern drainage of Al-Kufa (2 km/north) and raw wastewater discharged from Al Jimaah zone at 1 km/north of the station.

Alssgeer et. al (2017) study the physicochemical, biological condition, and water classification of the Nerus River, to identify the spatial-temporal relationship between water quality and pollution by using statistical techniques. The methodology of the study starts with analyze 13 parameters of water quality such as temperature, pH, DO, conductivity, TDS, salinity, turbidity, TSS, COD, BOD, NH_3-N, and E. coli. A total of three sampling locations (6, 7, and 11) were selected and sampling was carried out during dry and wet seasons from 2005 to 2010. The results show that Variation in water quality was mainly related to the seasonal changes in rainfall and inflow from upstream and saltwater intrusion. High tides increase the movement of seawater further upstream and affect the pH, salinity, and concentration of the river. This is due to the concentration of high dissolved salts, which later also increase water's ability to conduct electricity. The land-use activities such as land clearing, forest fire, and soil erosion usually take place before the wet season time which increases the pollutants load into the river by flash out during the rainfall.

Sarah and Afrah (2019) present a study conducted to demonstrate the effect of organic matter on the characteristics of the Euphrates River at the center of Al-Nasiriyah city and its feasibility for domestic, industrial, and agricultural uses. [This index is an efficient and successful method for descriptive and quantitative assessment of organic pollution in different aquatic systems]. Four locations were selected, the first station near Al-Sharif, the second station near the thermal electric power, the third station near the Zaytoon Bridge in the city center, and the fourth station near the wastewater treatment station, the samples were collected from water monthly starting October 2017 Until September 2018. Some physical and chemical properties were measured: Biological oxygen demand (BOD_5), Nitrate (NO_3), phosphate (PO_4), and Ammonium (NH_4).

Ioryue et al. (2018) present that River Mkomon which is one of the tributaries of River Benue serves as an excellent disposal agent for some of the communities at the riverbank and farmers. The objective of the study was to investigate the seasonal variation in Physico-chemical and bacteriological characteristics of River Mkomon water at four different sampling locations of the river. Analyses of river water quality containing 16 parameters were done during dry and rainy seasons in the year 2015. Results revealed deterioration in water quality with seasonal changes between the sites. The data have been compared with the norms for River water of the World Health Organization (WHO), National Environmental Standards and Regulations Enforcement Agency (NESREA), and standard organization of Nigeria (SON). The results obtained revealed enhanced level of water temperature (28.8 ± 0.08) ^{o}C, turbidity (8.5 ± 0.15) NTU, cadmium (0.087 ± 0.00) mg/l, lead (0.299 ± 0.00) mg/l, chromium (0.521 ± 0.00) mg/l, total coliform (159.1 ± 24.9) CFU and decrease or normal levels in phosphate (3.7 ± 0.05) mg/l, chloride (55.2 ± 1.35) mg/l, electrical conductivity (56.2 ± 0.49) µS/cm, biological oxygen demand (3.3 ± 0.08) mg/l, suspended solid (48.9 ± 0.31) mg/l, pH (6.5 ± 0.07), dissolved oxygen (4.0 ± 0.09) mg/l, total dissolved solids (47.7 ± 0.15) mg/l and total hardness (83.2 ± 1.13) mg/l. The bacterial counts detected were above the permissible limits for drinking water in all the sampled locations. Data suggested the importance of greater attention to household contamination, environmental sanitation control, and awareness about water contamination. Improvement in water quality and availability will aid hygienic practices and interrupt the transmission of enteric pathogens through contaminated water in the studied areas. Provision of sewerage systems and public health education aimed at improving personal, household, and community hygiene is imperative.

2.2 Study Area (Shatt Al-Hillah River)

Shatt Al-Hillah River as shown in Fig. (2-1) is a branch of the Euphrates River. It branches from the Euphrates River at km 602 in Saddat Al-Hindiya town with a discharge of 200 m^3/s during summer and 245 m^3/s during winter. The length of the Shatt Al-Hillah River passing through Babylon governorate is equal to 101 km. Discharge fluctuates according to the agricultural needs in the three governorates of Babylon, Qadisiya, and Al-Muthanna, with a total area of 420 thousand hectares. Thirty-six main channels are branching from both banks of the river (inside Babylon governorate boundaries) with a total length of 511.6 km. (**Water Resources Office of Babylon Governorate).**

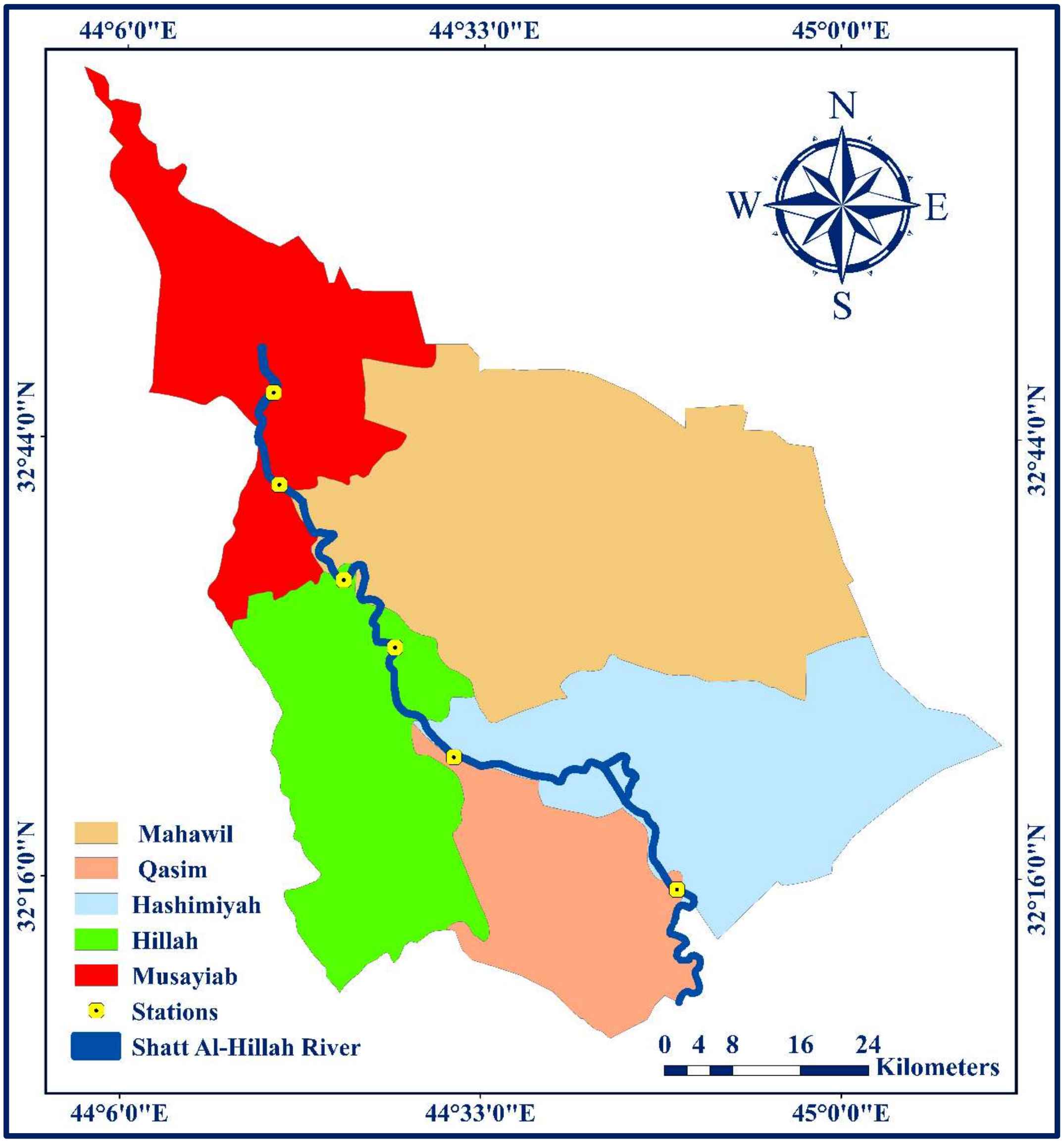

Figure 2.1: Map of Shatt Al-Hillah River.

Like many rivers, the Shatt Al-Hillah River source varies during the year. According to the information that was supplied by Babylon Irrigation Administration. The main sources of the river water are:

1) Ice dissolving water: The dissolving period occurs in the spring season and during this period, ice dissolving water is the main source of river water.

2) Rainwater: Rainy period occurs in the winter season and during this period, rainwater represents the main source of river water.

3) Stored water: The storage period occurs in the summer and autumn seasons. During this period, the river mainly depends on lakes and reservoirs as a source of river water.

Euphrates river is supplied with water from natural sources coming from outside Iraq's borders, this water is usually loaded with silt and other suspended solids. Another quantity of water is added to the river from low-Tharthar lake, Al-Habbaniya lake, and Saddat Al-Qadisiya lake (Haditha), carrying sands, lichens, and seeds into the river and this is reflected in the quality of the river water.

Shatt Al-Hillah River passes through many towns and villages, the main sources for different uses are**:**

1) Irrigation: the river is the main source of irrigation for large agricultural areas located on both sides of the river.

2) Water supply systems: The river represents the supply source for many water treatment plants such as Al-Hillah Al-Jadeed and Al-Hillah Al-Kadeem water treatment plants.

3) Industrial purposes: The river represents the main source for all industrial activities in the area.

In addition to these main uses, the river receives many pollutants discharged by different sources, including:

1) Agricultural wastes: Wastes of animals and plants from agricultural areas are discharged into the river on both sides.

2) Municipal wastes: Municipal wastes are discharged from wastewater treatment plants such as the Al-Muaimeerah wastewater treatment plant.

3) Industrial wastes: Many industries discharge wastewater into the river such as Al-Furat company for chemical industries, Al-Sadat cement factory, Hillah textile industry, and public slaughterhouses.

2.2.1 Description Selected Locations:

Six locations on the river were chosen in the present study Fig. (1-1). The following is a brief description of these locations:

1. Location One.

Location one is located on the main Euphrates River, upstream of Saddat Al-Hindiya dam in the vicinity of Al-Furat company for chemical industries located at Saddat Al-Hindiya town. This location is characterized by its high-water levels, wide section area, and being surrounded by dense agricultural areas.

2. Location Two.

Location two is located about 5 km downstream of Saddat Al-Hindiya town about 15 km away from the first location. The river at this location falls under the influence of human, industrial, and agricultural activities of Saddat Al-Hindiya town. During the study period, some small islands resulting from the sedimentation process were noted in the river at this location. There are also some small drainage channels along with all the chosen locations in this study, these drainages are discharging into the river from neighboring agricultural lands.

3. Location Three.

This location is situated at the northern entrance to Al-Hillah city near the Abo Khstawyi area about 25 km away from the second location and upstream of the water intake of the Al-Hillah Al-Jadeed water treatment plant. There are different industrial, agricultural, and human activities that may have a potential impact on water quality in this location.

4. Location Four.

Location four is located at the center of Al-Hillah city. Al-Hillah city is characterized by a high population density and the presence of some agricultural areas. It was observed that the river section in this location was narrowly leading to an increase in the river velocity. This section is located upstream of many water intakes of some of the main drinking water treatment plants in the city.

5. Location Five.

Location five is located beyond the southern borders of Al-Hillah city at a distance of about 12 km away from the city center and downstream of the Al-Muaimeerah wastewater treatment plant. This region is characterized by industrial activities in addition to agricultural, and human activities.

6. Location Six:

This location represents the last section studied in this work and it is located in Al-Hashimiya town at a 15 km downstream from the fifth location.

2.2.2 Population

Iraq has a population of approximately 41 million inhabitants with a growth rate of 2.5% in 2019. Most of the population settles in the north, center, and eastern parts of the country. Along with wide parts of the Tigris and Euphrates Rivers, several of the larger urban agglomerations are established. Great parts of the western and southern areas are either lightly populated or uninhabited, due to a hard environment and lack of welfare facilities (Central Intelligence Agency 2019).

Babylon Governorate covers an area of **5,337** km^2, including the cities of Babylon Governorate. In 2017, Babylon Governorate had a population of approximately 2,200,000 inhabitants distributed throughout sixteen cities (Iraqi Ministry of Planning, 2017). The governorate is divided administratively into five major cities, referred to as **districts or (Qadhaa).** The five districts are Al-Hillah, Al-Qasim, Al-Musayyab, Al-Mahawil and Al-Hashimiyah. Sixteen smaller cities, called Nahiahs, belong to these major cities.

2.2.3 Climate

The climate of Iraq is divided mainly into three types. These are continental, subtropical semi-arid, and Mediterranean (Jaradat, 2002). According to FAO (2003), Iraq is divided into four zones of agro-ecological which are (Frenken, K., 2009):

1) The arid and semi-arid zones with a Mediterranean climate covered mainly the governorates in northern parts of Iraq.
2) The desert zone is extended from the north of Baghdad to the borders of Saudi Arabian and Jordan, where the climate in this zone is distinguished by extreme temperatures in summer and the annual rainfall is less than 200 mm.
3) The steppe zone is located between the Mediterranean and desert zones, where the annual rainfall in the cold winter is between 200–400 mm and the temperatures in summer are very hot.
4) The irrigation area zone is located between the rivers of Tigris and Euphrates and extended from the north of Baghdad to the south of Basra.

The rainfall takes place during winter in most parts of Iraq (from December to February), while in mountains from November to April. The annual quantities of rainfall from the south and southwest to the north range from less than 100 mm to more than 1000 mm. The mean daily temperature is 16°C and at night, the temperature drops to 2°C. During the Summer, the climate is hot to the so hot and dry (without rainfall), where the daily temperature during the hottest months July and August reaches over 43°C in the shade and decreases to 26°C at night (Jaradat, 2002).

Babylon Governorate locates in the arid hot region and in the irrigation areas which are covered in the zone from the north of Baghdad to Basra Governorate in the south of Iraq (between the rivers of Tigris and Euphrates) (Frenken, K., 2009; Kadhim and Ali, 2011). The climate in the governorate changes dramatically with the seasons' changes and between a day and a night. The prevailing wind in the governorate comes from the northwest and blows throughout the year, with an annual average wind speed of 7.2 km/h. Temperatures during the summer season can reach more than 50 ˚C, with an average of approximately 12 hours of sunlight/day and usually with no rainfall. The winter is cold and rainy, with approximately 6.8 hours/day of sunlight. Although temperatures normally remain above 0 ˚C, they can decrease below freezing on some nights. The average annual rainfall is 102 mm while the average annual relative humidity is 45.8% (Al Khalidy et al., 2010; Iraqi Ministry of Municipalities and Public Works, 2009, CEB, 2012; Iraqi Ministry of transportation constitutions, 2017). Generally, the average annual rainfall in Iraq is decreasing due to climate change. In some years, the rainfall happens in a very short period causing floods (Osman et al. 2017; Al-Ansari et al., 2014).

2.2.4 Topography

Topographically, the Iraq region can be divided into seven sub-regions, they are Thrust zone; High folded zone (mountains of sedimentary rock); Low folded zone (hills of sedimentary rocks); Al-Jazira zone (plains of sedimentary rocks); Mesopotamia zone (vast flat plain of fluvial sediment); Western Desert zone (flat region of sedimentary rocks with rare gypsum); and Southern desert zone (an extension to the Arabian Peninsula mainly sedimentary rocks) (Al-Jiburi and Al-Basrawi 2015; Al-Madhlom et al. 2019).

CHAPTER THREE

Methodology

ChapterThree Methodology

3.1 Methodology

The methodology of this article consists of three approaches, they are field measurements; GIS mapping; and calculations and equations. Below is the description of each one. The description of the schematic diagram of the methodology can be seen in **Figure 3.1.**

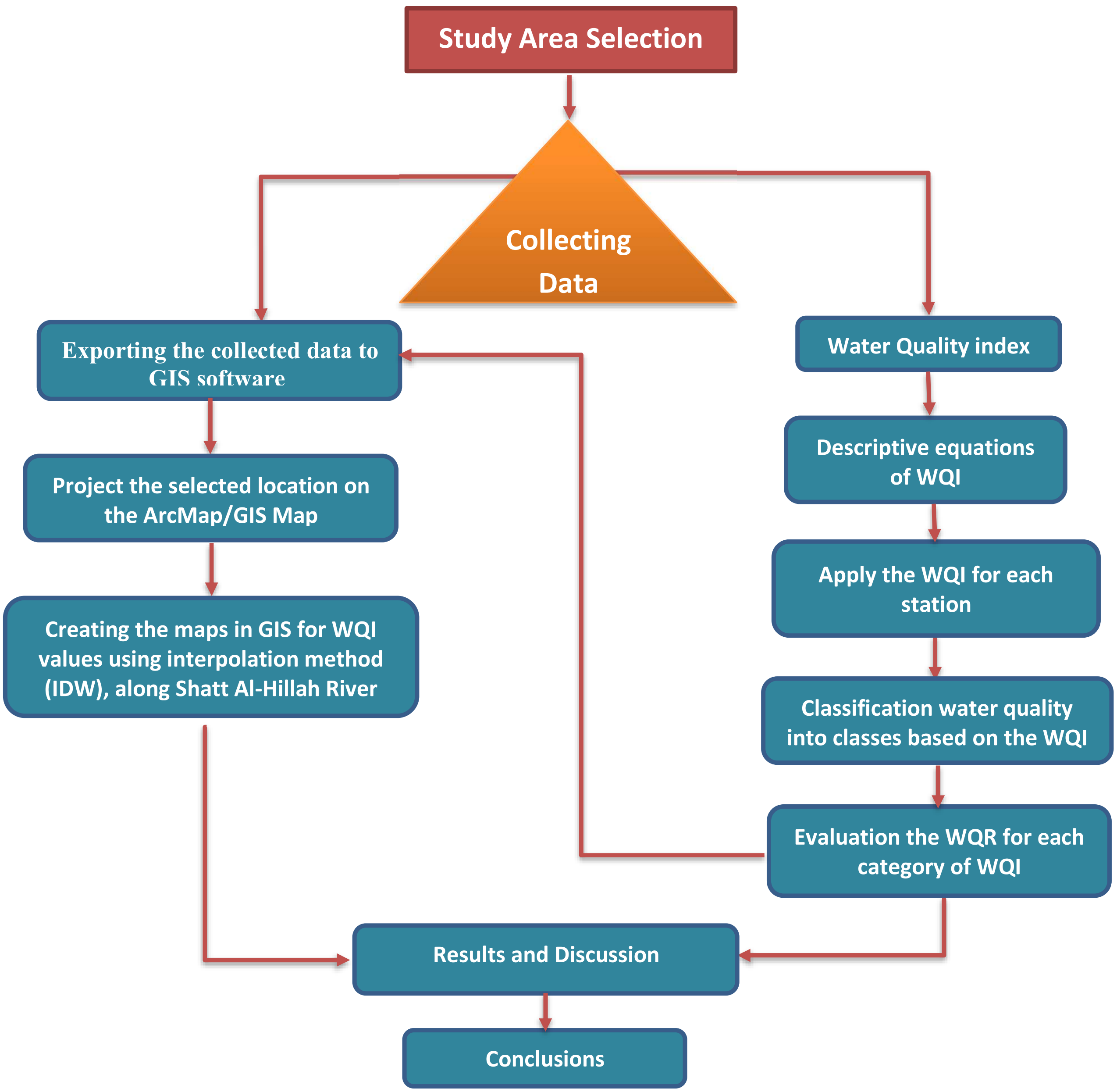

Figure 3.1: Schematic diagram for research methodology.

3.2 Samples Collection:

In general, rivers are characterized by an un-directional current with a relatively high, average flow velocity ranging from (0.1-1) m/s. The river flow is highly variable in time, depending on the climatic situation and the drainage pattern. In general, thorough, and continuous vertical mixing is achieved in rivers due to the prevailing currents and turbulence. Lateral mixing may take place only over considerable distances downstream of major confluences **(Deborah, 1996)**.

Rivers are dynamic systems and are subjected to many variations. Few locations with enough samples to define the results in terms of statistical significance are much more reliable than many locations with only a few samples at each **(APHA, 1998)**.

In this study, samples were collected from six sites located across the length of the river. These sites were chosen due to their potential environmental impacts on the river including industrial, agricultural, and human activities. At each site, five samples were taken at different depths (two samples on both sides and three samples at the center of the river) and then mixed to get one sample from the mixture with a (10) liters volume to represent the actual picture of the water quality in that site. Samples for trace metals and Water Quality Parameters were placed in a well-sealed plastic bottle with (2) liters volume for each and (1) liter volume for dissolved oxygen to preserve the sample until it was analyzed. The samples of trace metals were tested in the private laboratory in Diwaniya city, while the other samples were analyzed in the laboratory of the Babylon water office.

A locally made apparatus shown in **Figure 3.2**, was used for the collection of the samples from different sites. This apparatus consisted of a metallic arm of a (3.5) m length, a container fixed at the end of the arm where a stainless-steel pan was placed, and a cover for the pan opened by an iron chain at the desired depth.

Figure 3.2: The samples collection unit.

3.3 Water Quality Assessment

Along the Shatt Al-Hillah River, eleven parameters were measured from six locations selected in the year 2015. The selected locations are (Al-Musayyib city, Al-Hindiya, Al-Hillah city, Abu Khstawyi, Al-Maamera, and Al-Hashimiya) **Table 3.1** shows the average concentrations for the selected parameters in 2015.

Table 3.1: The concentrations for the measured parameters in the selected locations along Shatt Al-Hillah River in 2015.

Location	Location	Ca	Mg	DO	pH	Cl	SO4	TH	TDS	Tur	EC	Alkal.
L.1	Al-Musayyib	126.2	69.0	8.00	7.95	204	368	495	937	22.21	1463	118
L.2	Al-Hindiya	125.2	65.3	8.02	7.94	206	360	495	941	22.06	1470	116
L.3	Abu Khstawyi	122.9	58.3	8.02	7.93	197	362	497	939	22.70	1467	117
L.4	Al-Hillah city	122.2	60.9	8.02	7.93	191	364	493	952	22.29	1487	118
L.5	Al-Maamera	122.6	73.3	7.94	7.91	203	369	484	954	21.86	1490	119
L.6	Al-Hashimiya	119.7	73.9	7.91	7.91	199	383	475	957	23.25	1495	118

3.4 Water Quality Parameters Analysis

The standard methods for the examination of water and wastewater **(APHA, 1998)** were employed for all water quality measurements.

1. Hydrogen Ion (pH).

Electronic pH meter with temperature compensation adjustment (Model CORNING PINNACLE "545").

2. Turbidity (TU).

The nephelometric method by using an electronic device (Turbidity model 2100 A HACH**).**

3. Electrical Conductivity (EC).

Self-contained conductance instruments by using an electronic device (model CORNING PINNACLE "541").

4. Total Dissolved Solids (TDS).

A well-mixed sample is filtrated through a weight standard glass-fiber filter, and filtrated is evaporated to dryness in a weight dish and dried to constant weight at 180°C. The increase in dish weight represents the total dissolved solids.

$$\text{Total dissolved solid mg / l} = (A - B) * 1000 / \text{Sample volume, ml} \quad (3.1)$$

where: **A** = weight of dried residue + dish, mg, **B** = weight of dish, mg.

5. Sulfates (SO4).

Gravimetric Method with Ignition of Residue.

Sulfate is precipitated in hydrochloric acid (HCl) solution as barium sulfate ($BaSO_4$) by the addition of barium chloride ($BaCl_2$). The precipitation is carried out near the boiling temperature, and after a period of digestion, the precipitate is filtered, washed with water until free of Cl^-, ignited or dried, and weighed as $BaSo_4$.

$$\text{Sulfates } SO4^{-2} \text{ mg /l} = \text{mg } BaSo_4 * 411.6 / \text{Sample volume, ml} \quad (3.2)$$

6. Chlorides (Cl^-).

Argentometries method with $AgNo_3$.:

25 ml (sample) + chromate potassium K_2Cro_4 (1-3) drop + titration with $AgNo_3$.

$$\text{Chlorides } (Cl^-) \text{ mg/l} = A * 35.45 * 1000 / \text{Sample volume, ml} \quad (3.3)$$

where: **A**= titer for standard mg $AgNo_3$ /ml.

7. Total Hardness (TH).

EDTA titration method:

25 ml + Eriochrome Black T (1-2) drop + 1 ml ammonia buffer solution + titration with EDTA.

$$\text{Hardness EDTA as (mg } CaCo_3/l) = A*B*1000 / \text{sample volume, ml sample} \quad (3.4)$$

where: **A:** ml titration for sample, **B:** mg $CaCo_3$ equivalent to 1ml EDTA titrant.

8. Alkalinity.

Titration with standard 0.02 H2So4:

50 ml (sample) + Methyl (1-3) drop + Phenolphthalein (1-3) drop + titration with 0.02 H_2So_4

$$\text{Alkalinity, (mg } CaCo_3 / l) = A* t * 1000 / \text{sample volume, ml} \quad (3.5)$$

where: **A**= ml standard acid used, **t**= titer for standard acid, mg $CaCo_3$ / ml.

9. **Calcium (Ca).**

EDTA titration method

50 ml (sample) + Murexied + 2 ml NaOH + titration with **EDTA**

$$\textbf{Calcium (Ca) mg /l} = A * B * 1000 / \text{sample volume, ml} \qquad (3.6)$$

where: A: ml titration for sample, **B**: mg $CaCo_3$ equivalent to 1ml EDTA titrant at the calcium indicator endpoint.

10. **Dissolved Oxygen (DO).**

Electronic DO meter device (DO model **HACH / Sens ion 6**).

3.5 Method of calculating Weights of Water Quality Index

In this study, the method of weighted arithmetic is employed to calculate the water quality index (WQI). eleven parameters (calcium (Ca), magnesium (Mg), dissolved oxygen (DO), Hydrogen Ion (pH), chloride (Cl), sulfate (SO4), total hardness (TH), total dissolved solids (TDS), turbidity (Tur), Alkalinity, and electric conductivity (EC). were used to determine the water quality index (WQI) for the selected six locations along the Shatt Al-Hillah River because these parameters are so significant to calculate the water quality index for different purposes. The water quality index (WQI) for each selected location in the Shatt Al-Hillah River was calculated using the following equations (3.7), (3.8), and (3.9) (Tyagi et al. 2013):

$$Qi = \left(\frac{N_i - N_0}{ST_i - N_0}\right) \times 100 \qquad (3.7)$$

$$Wi = \frac{1}{ST_i} \qquad (3.8)$$

$$WQI = \frac{\sum Qi \times Wi}{\sum Wi} \qquad (3.9)$$

where: Q_i is the sub-index of the i^{th} parameter, W_i is the inverse weight of the standard value (ST_i) of the i^{th} parameter, ST_i is the standard value of the i^{th} parameter (WHO 2017), Ni is the measured concentration value for the i^{th} parameter, N_0 is the ideal value for each parameter in water that has zero value, excluding the dissolved oxygen and pH values which are equal to 14.6 ppm and 7 respectively.

For each location along the Shatt Al-Hillah River, the water quality rating (QWR) was given the deserve classification based on the category of the WQI according to Alsaqqar et. al. 2015 (Alsaqqar et al. 2015; Ali 2017) (**Table 3.2**).

Table 3.2: Water quality rating based on WQI value (Alsaqqar et al. 2015; Ali 2017).

Value of WQI	Water quality rating (QWR)
< 50	Excellent
50 - 100	Good
100 - 200	Poor
200 - 300	Very poor
300 - 400	Polluted
> 400	Very polluted

3.6 GIS Prediction Maps Using the Interpolation Method (IDW)

The interpolation method Inverse Distance Weighted (IDW) was used to generate the interpolation map for each parameter. The interpolation in GIS software was done based on the shapefiles' maps of the Iraqi boundary and Shatt Al-Hillah River.

The IDW is a technique that reflects principally the first law of Waldo Tobler in geography (Hengl, 2009). The IDW method is based on a technique of accurate local deterministic interpolation (Watson and Philip 1985). The interpolation method (IDW) is used to estimate the unknown values at a specific location as an average value of the distance from known to neighboring locations. which are surrounding the unknown points (Longley et al. 2005).

In the IDW, the points nearer to the prediction location will have a greater effect on the predicted values than the points that are located farther away from them (Chang 2006; Panhalkar and Jarag 2015). This procedure was applied in this study to produce interpolation between the selected points or locations using the IDW method within the range of minimum and maximum values for each parameter.

According to (Panhalkar and Jarag 2015), the IDW method is considered more suitable than other methods (e.g., kriging and Topo to raster) (Tomislav 2009), where these methods generate an interpolation for the selected points with more deviation. The interpolation method IDW has adopted the following mathematical equation (3.10) (Panhalkar and Jarag 2015):

$$Z_0 = \frac{\sum_{i=1}^{n} Z_i \frac{1}{X_i^r}}{\sum_{i=1}^{n} \frac{1}{X_i^r}} \quad (3.10)$$

where: Zo is the estimated value of point zero; Zi is the Z value of known point i; Xi is the distance between point i and zero point; N is the number of known points used in estimation; r is the specified power > 1.

CHAPTER FOUR

Results & Discussion

Chapter Four **Results and Discussion**

4. Results and Discussion

4.1Concentrations Values of the Measured Parameters along River.

4.1.1 Calcium (Ca).

The variations of Ca along the Shatt Al-Hillah River in 2015 ranged from 89 in April to 140 mg/L in February at location (L-4), and the average value of Ca concentration was 123 mg/L. All readings for Ca measured at the selected locations in the river were higher than the permissible limit of 50 mg/L

Figure 4.1 shows that calcium concentrations were high during most seasons of the study this is attributed to calcium compounds are stable in water when carbon dioxide is present, but calcium concentrations can fall when calcium carbonate precipitates due to increased water temperature, photosynthetic activity, or loss of carbon dioxide due to increases in pressure as concluded by **(Deborah, 1996)**.

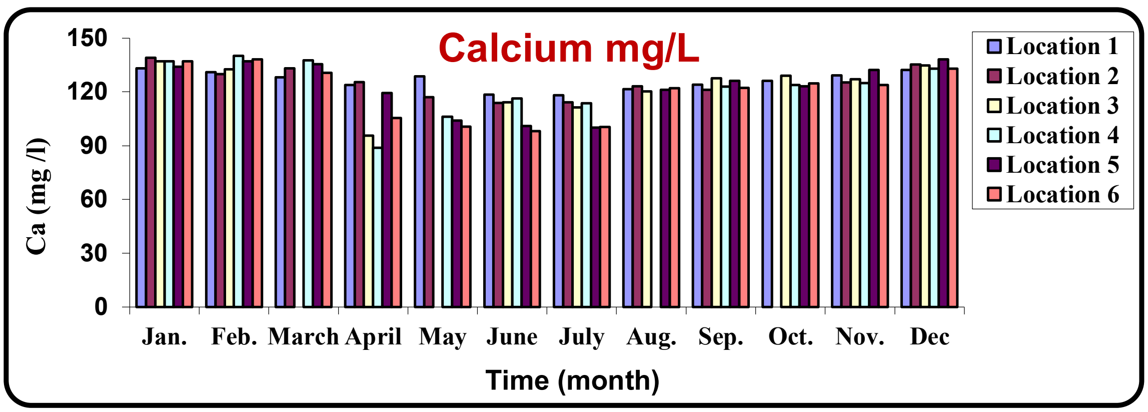

Figure (4.1): Concentrations of calcium along Shatt Al-Hillah River in 2015.

4.1.2 Magnesium (Mg).

The average concentration of Mg measured in the Shatt Al-Hillah River during this year was 66.8 mg/L. The highest and lowest reading of Mg concentration during the year ranged from 28 (May) to 107 (February) mg/L at the locations (L-3 and L-5) respectively (**Figure 4.2**). The most values of samples for Mg which were taken from all locations in Shatt Al-Hillah River were over the permissible limit of 50 mg/l (WHO 2017).

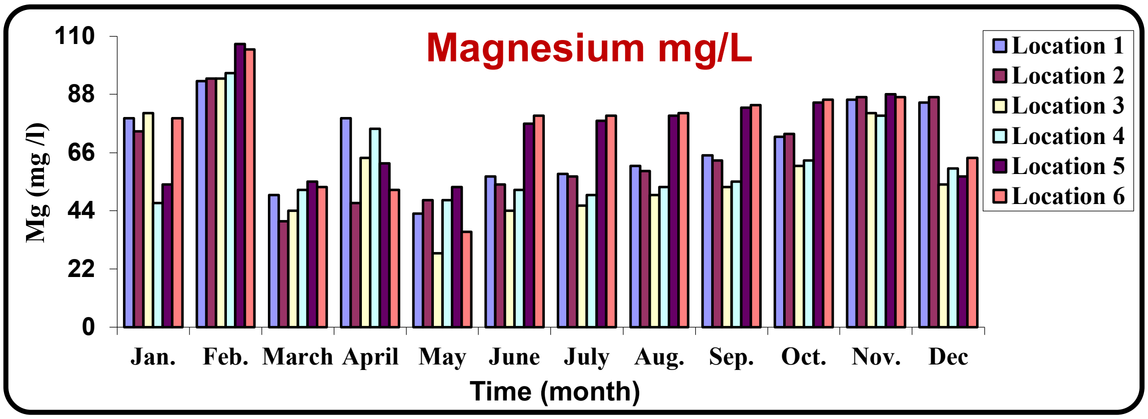

Figure (4.2): Concentrations of magnesium (Mg) along Shatt Al-Hillah River in 2015.

4.1.3 Chlorides (Cl).

The maximum value of chloride (Cl) concentration in 2015 was 239 mg/L respectively at location (L-2) in February, and the average value was 200 mg/L in that year. During the current year, the lowest value of Cl was 170 mg/L at location (L-4) in July (**Figure 4.3**). The value of chloride concentration which was measured along the Shatt Al-Hillah River was within the allowable limit of 250 mg/L (WHO 2017).

Figure 4.3 shows an increase in chloride levels during winter and spring in most locations. This is caused by weathering of some sedimentary rocks (mostly rock salt deposits), or by agricultural drainage wastes and road run-off. The salting of roads during winter periods can also be contributed significantly to chloride increase as concluded by **(Deborah, 1996)**.

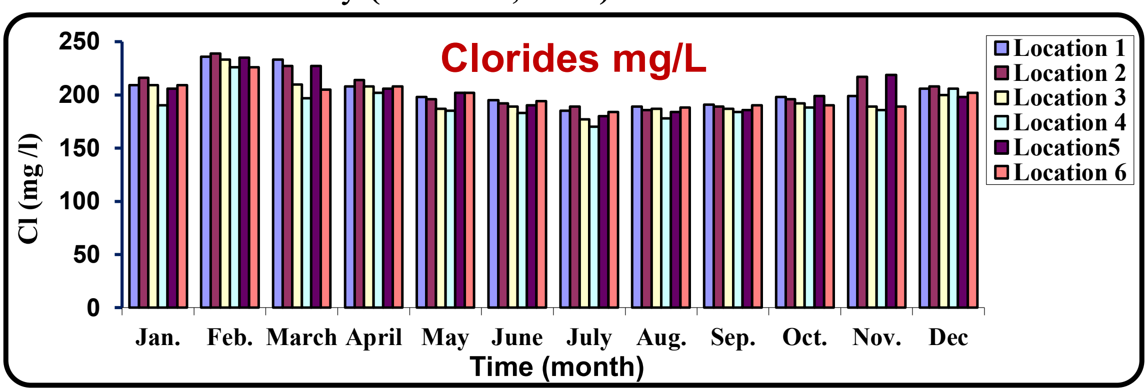

Figure (4.3): Concentrations of chloride (Cl) along Shatt Al-Hillah River in 2015.

4.1.4 Sulfate (SO_4).

Sulfate (SO_4) concentrations in 2015 varied between (332 - 451) mg/L at locations (L-2 and L-6) respectively with an average value of 367 mg/L. The values of sulfate (SO_4) concentrations measured at selected locations along the

Shatt Al-Hillah River were over the allowable limit of 250 mg/L during these years (WHO 2017) (**Figure 4.4**).

The results of this study show that the values of sulfate during the winter season are higher than in other seasons and higher than the allowable Iraqi standards. This is due to the presence of Sulphate in natural surface water as sulfate minerals (gypsum) or sulfide minerals (pyrite) from sedimentary rocks, industrial discharges, and atmospheric precipitation.

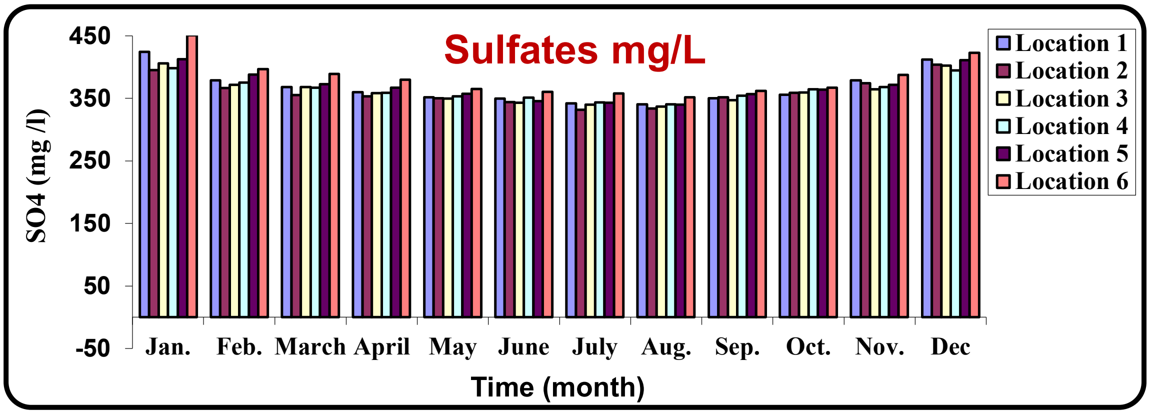

Figure (4.4): Concentrations of sulfate (SO_4) along Shatt Al-Hillah River in 2015.

4.1.5 Total Dissolved Solids (TDS).

For the TDS, the highest reading in 2015 was 1198 mg/l and found at location (L-6) in January, whilst the lowest reading was 871 mg/l at location (L-3) in August. The average value for TDS was 946 mg/L (**Figure 4.5**). In the current study, the readings of the (TDS) along the Shatt Al-Hillah River in the winter months of January, February, and December were over the allowable limit of 1000 mg/l (WHO 2017).

A slight difference was observed in TDS values for the samples collected from the different locations together at the same time but there was a much more difference in TDS values for the samples collected at separate times.

TDS are usually constituted of inorganic materials such as calcium, magnesium, sodium, bicarbonates, chlorides, and sulfates. The chemical composition of solids dissolved in rivers is affected by the areas that the rivers pass through. The major sources of dissolved solids in rivers are agricultural wastes, drainage, and industrial wastes. High values were recorded in the winter season months (January and February) due to the washing of soil by rainwater and as a result of the flow of drainage water from lands nearby the river.

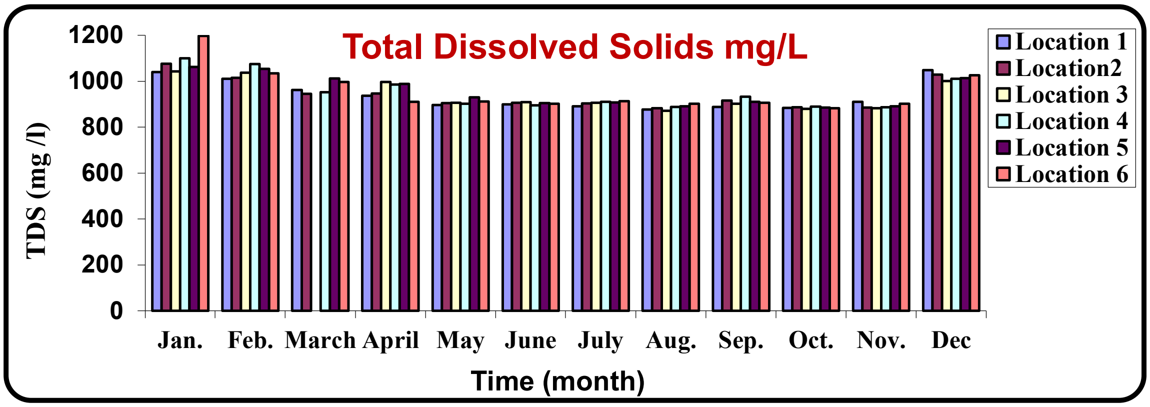

Figure (4.5): Concentrations of (TDS) along Shatt Al-Hillah River in 2015.

4.1.6 Electrical Conductivity (EC).

The average value of EC at all the locations was 1546 (µmhos/cm). The highest value was 1868 (µmhos/cm) at location (L-6) in January, while the lowest value was 1437 (µmhos/cm) at location (L-3) in September. The readings of the EC were more than the allowable limit of 2000 µmhos/cm (WHO 2017). The variation of conductivity level in river water during this study is shown in **Figure (4.6)**.

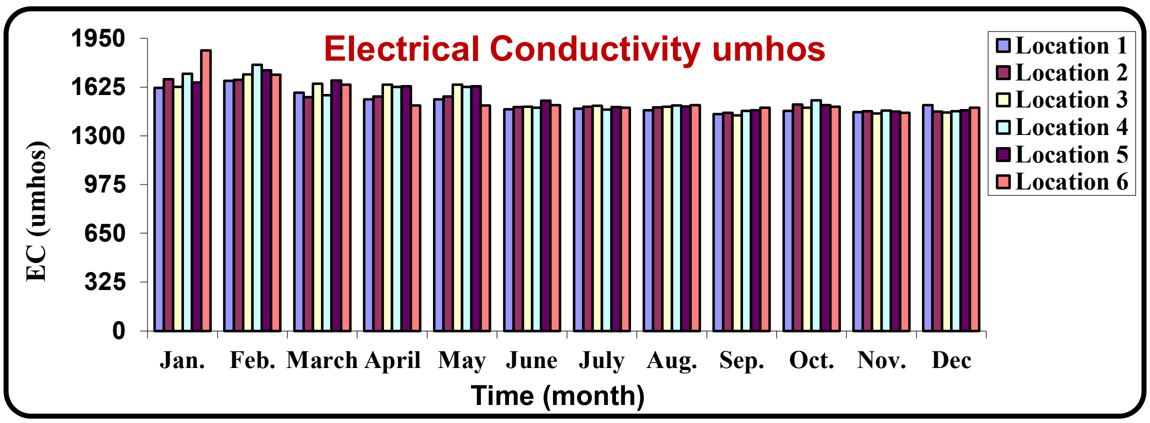

Figure (4.6): Concentrations of (EC) along Shatt Al-Hillah River in 2015.

4.1.7 Total Hardness (T.H.):

In this study, along the Shatt Al-Hillah River, the highest concentrations of total hardness (TH) in 2015 were equal to 560 mg/L at (L-4) in February. The lowest value of TH was 392.8 mg/L, and this value was recorded at (L-6) in June (**Figure 4.7**). Along the Shatt Al-Hillah River in 2015, the average value was 490 mg/L. The results of total hardness in January, February, March, and December at all locations were higher than the allowable limit of 500 mg/l (WHO 2017). This is attributed to weathering processes during the rainy season, and the disposal of industrial, municipal, and agricultural wastes into the river.

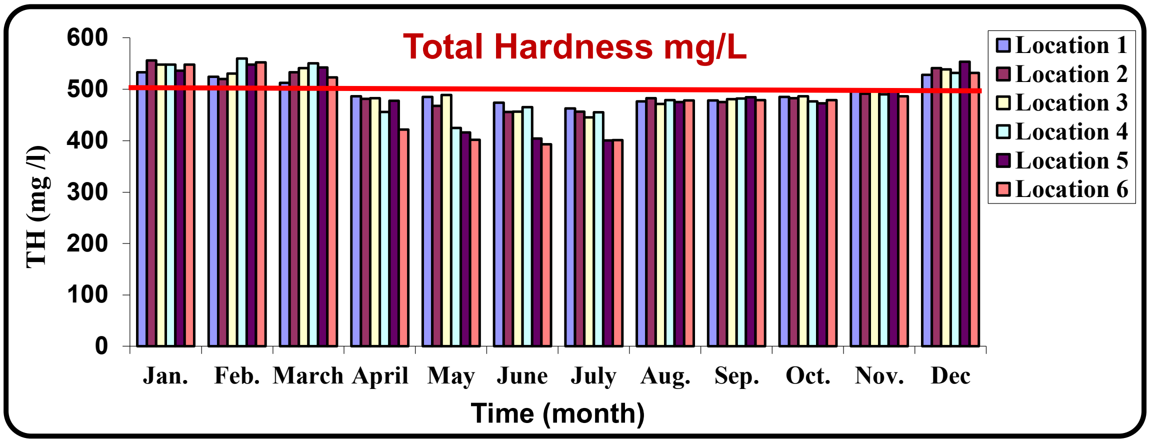

Figure (4.7): Concentrations of the (TH) along Shatt Al-Hillah River in 2015.

4.1.8 Dissolved oxygen (DO).

High levels of DO were recorded at most of the locations **(Figure 4.8)**. The highest value was 9.2 (mg/l) in location (L-4) in January due to good aeration, continuous mixing of water, and dense zooplankton and phytoplankton which result in high levels of dissolved oxygen. The lowest level of DO was 7.18 (mg/l) at the location (L-3) in July. This can be attributed to the biological degradation of the organic materials or the low water level at these locations.

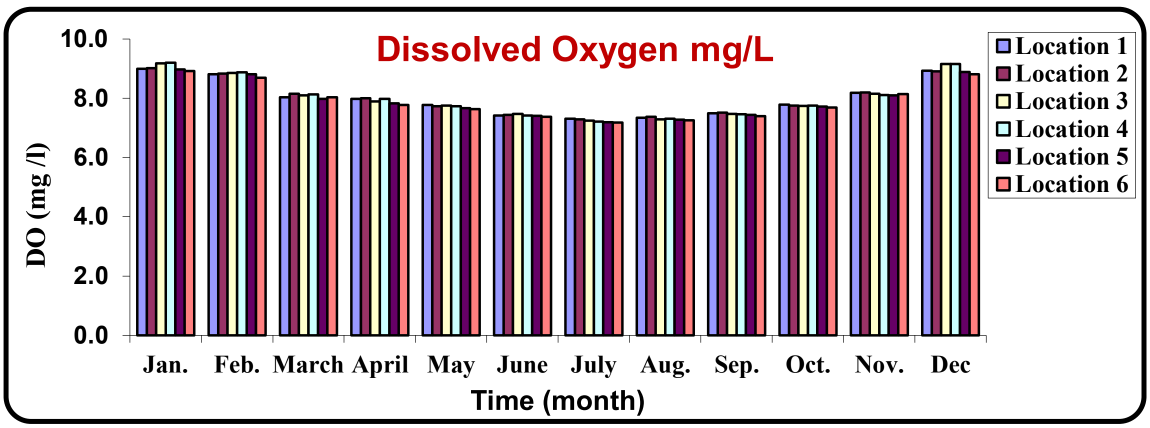

Figure (4.8): Concentrations of the (DO) along Shatt Al-Hillah River in 2015.

4.1.9 Alkalinity.

The highest and the lowest values of alkalinity were (respectively) 161 (mg/l) in January and 95 (mg/l) in July at location (L-5). The average value of alkalinity was 118 mg/l. **Figure (4.9)** gives the variation of alkalinity concentration in the river water during the period of the study.

Results obtained confirmed the alkaline nature of river water due to the presence of weak acid salts and strong and weak alkaline salts such as carbonates and bicarbonates that represent a major part of alkalinity due to the study conducted by **(Mohammad, et al.,1990).**

The results agreed well with previous studies that showed the predominant alkaline nature of Iraqi waters due to the presence of bicarbonates (HCO_3) in water and the surrounding soil.

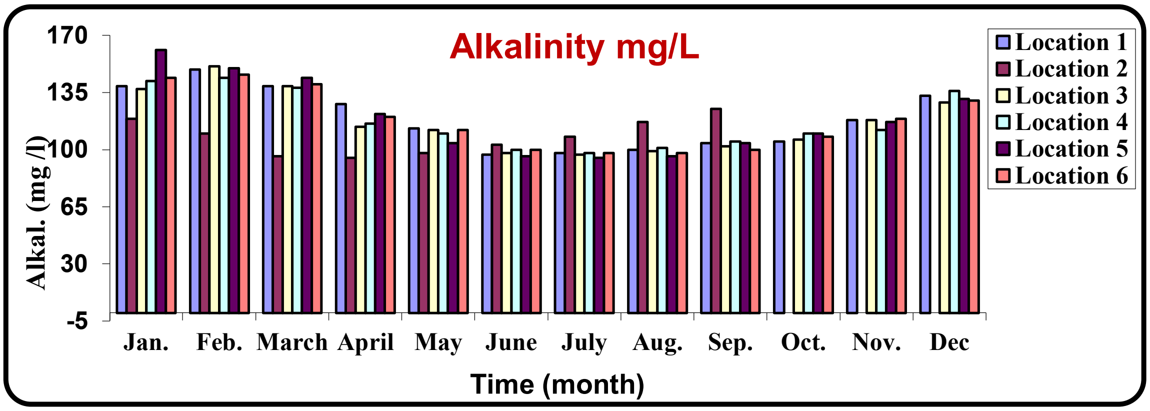

Figure (4.9): Concentrations of the Alkalinity along Shatt Al-Hillah River in 2015.

4.1.10 Turbidity.

The turbidity in the river ranged from 18 to 40 (N.T.U.). The highest turbidity value was 40 (N.T.U.) at location (L-4) in July. On the other hand, the lowest value was (18) (N.T.U.) at location (L-2) in February and at (L-4) in January. **Figure 4.10** shows the variation of turbidity concentration in the river water during the period of the study. The average value of turbidity of the Shatt Al-Hillah River was 28.8 (N.T.U.).

These variations vary seasonally according to biological activity in the water column and surface run-off carrying soil particles. Heavy rainfall can also result in hourly variations in turbidity.

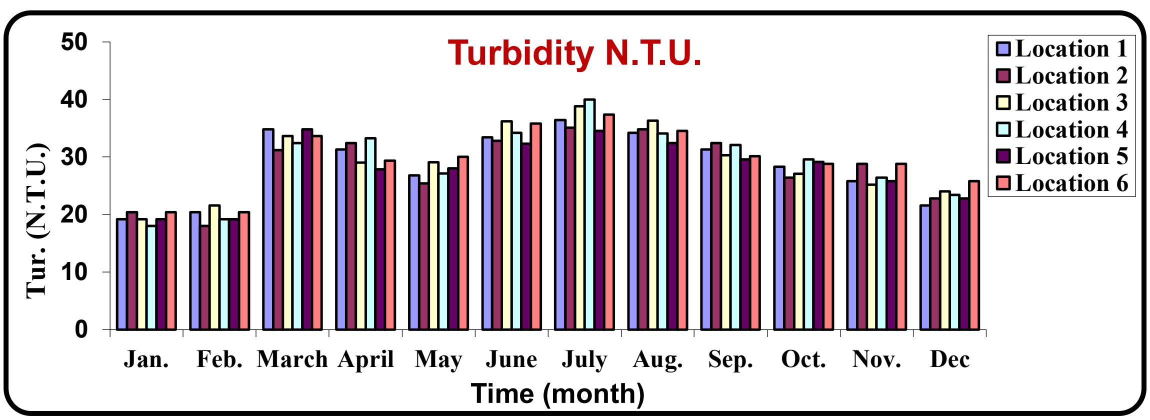

Figure (4.10): Concentrations of the Turbidity along Shatt Al-Hillah River in 2015.

4.1.11 Hydrogen Ion (pH).

The pH values at all locations were between 7.65 and 8.2. The highest pH value recorded was (8.3) at location (L-2) in February, while the lowest value was (7.65) at location (L-6) in July (**Figure 4.11).**

The pH value of water decreases as the content of CO_2 increases, while it increases as the content of bicarbonate alkalinity increases. The narrow scope of pH values in rivers due to buffer capacity enables the river to resist fluctuation of the pH. Therefore, there was a narrow scope in pH value in the Shatt Al-Hillah River (**Hassan, 2004; Mohammad, et al., 1990).**

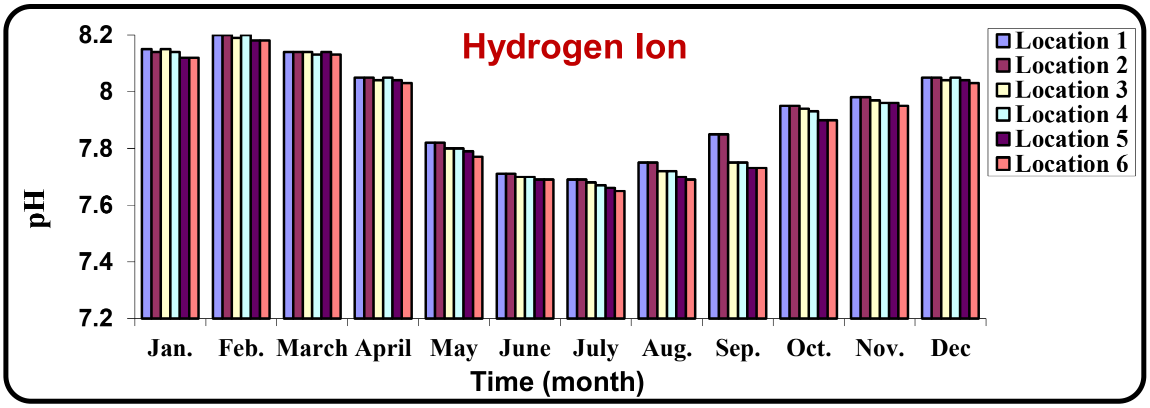

Figure (4.11): Concentrations of the pH along Shatt Al-Hillah River in 2015.

4.2 Water Quality Index

The method of weighted arithmetic water quality index was used to calculate the water quality index (WQI) at the selected location along the Shatt Al-Hillah River in 2015 based on **Equations** (3.7 – 3.9). Then, the water quality rating (WQR) was obtained for each location (six locations) along the Shatt Al-Hillah River (Alsaqqar et al. 2015) and based on the resulted values of WQI. **Table 4.1** shows the water quality value (WQI) and water quality rating (WQR) for the chosen locations along the Shatt Al-Hillah River in 2015.

Table 4.1: WQI and WQR along Shatt Al-Hillah River in 2015.

Symbol	Location	WQI	WQR
L.1	Al-Musayyib	271.55	Very poor
L.2	Al-Hindiya	270.73	Very poor
L.3	Abu Khstawyi	277.30	Very poor
L.4	Al-Hillah city	277.01	Very poor
L.5	Al-Maamera	265.50	Very poor
L.6	Al-Hashimiya	280.27	Very poor

In this study, when all parameters were entered in the calculating of the WQI for Shatt Al-Hillah River, the values of the WQI were within the range of (200 – 300) and the water quality of the river was rated as very poor. In the case that excluded the turbidity parameter in the calculating of the WQI for the river, the WQI values for all locations along Shatt Al-Hillah River were within the range of (100 – 200) and they were classified as poor rating (**Figure 4.12**).

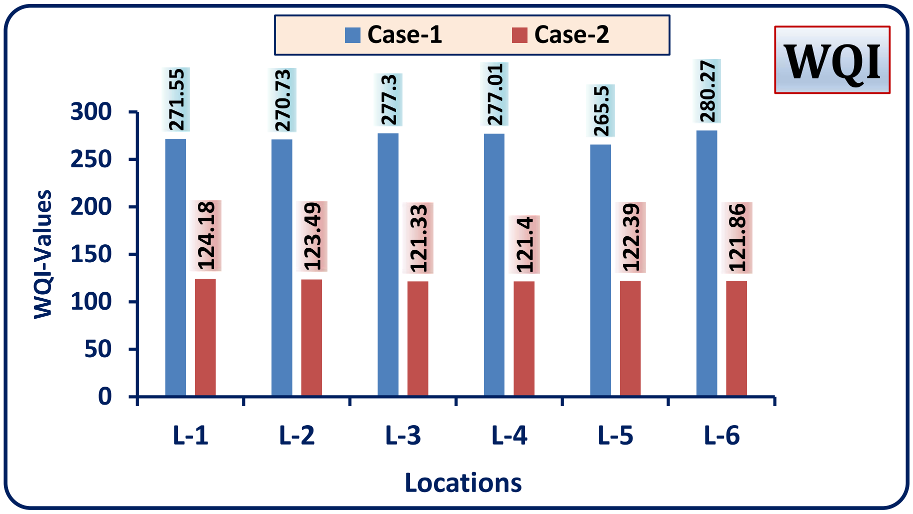

Figure (4.12): WQI values for six locations along the river (with and without turbidity).

The Water Quality Rating (QWR) was classified into five categories (see **Table 3.2**), based on the values of the water quality index value calculated using the method of weighted arithmetic according to Tyagi et al. (2013).

The values of WQI at Al-Musayyib (L-1), Al-Hindiya (L-2), Abu Khstawyi (L-3), Al-Hillah city (L-4), Al-Maamera (L-5), Al-Hashimiya (L-6), in 2015 were as follows: 285.95, 285.32, 292.87, 292.67, 280.47, and 295.62 respectively.

The values of the WQI (for all parameters) were within the range of (200 – 300) starting from the location (L-1) until the location (L-6). So, these locations were classified as very poor-quality water. This is due to the amount of the pollutants released into the river at these locations from different sources that have significant impacts on the water quality system, consequently, increasing the values of the WQI in the river.

The results showed that there was little difference in the WQI values at the selected locations along the Shatt Al-Hillah River, and this indicated the similar discharging pollutants into the water river system from different resources such as agricultural runoff, domestic sewers, and industrial waste discharges.

Generally, the originality of this paper included two parts. The first part studied the water quality using the water quality index (WQI) method for the whole length of the Shatt Al-Hillah River. Then, generating the interpolation maps for the values of the WQI for irrigation purposes along the river. Then, created the interpolation map for the WQI in the GIS software along the Shatt Al-Hillah River in 2015 (**Figure 4.13**).

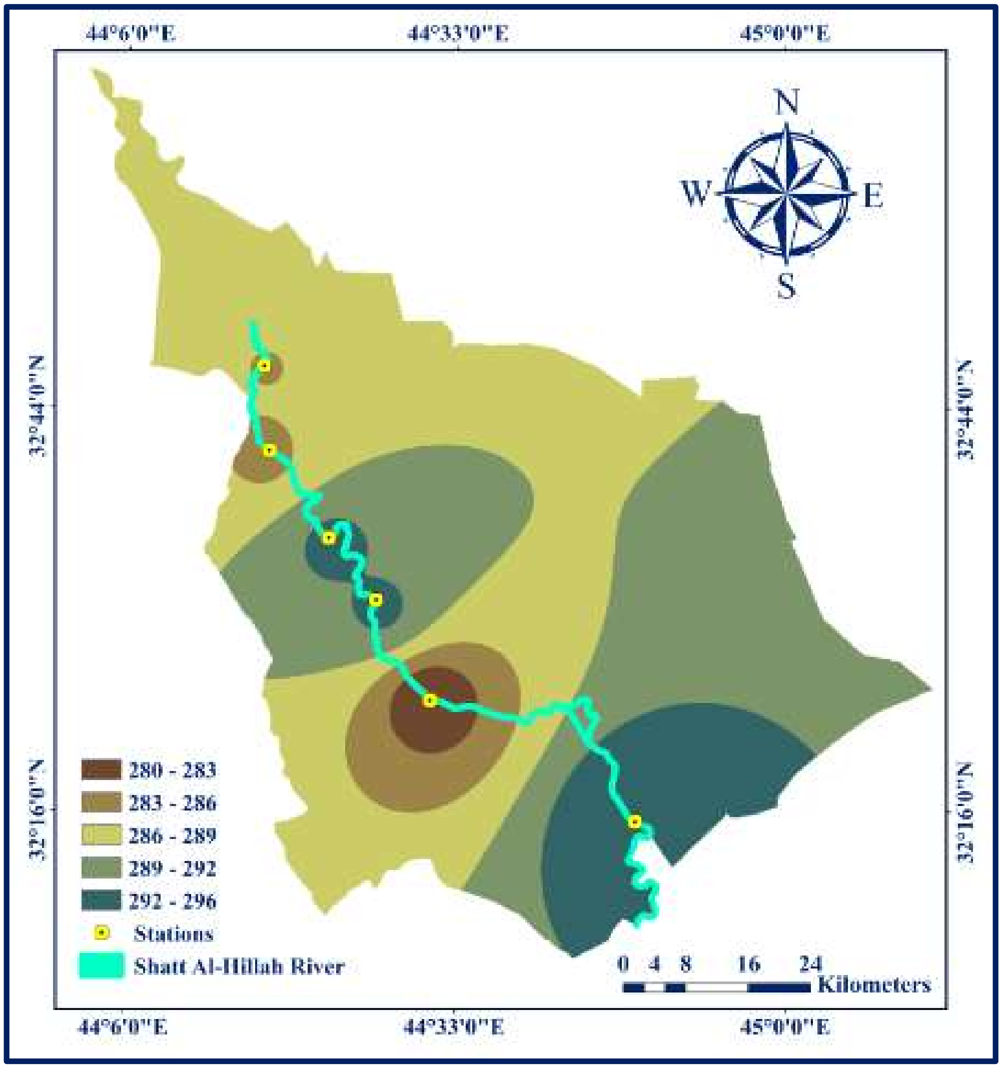

Figure (4.13): Distributing map of (WQI) for drinking uses for Shatt Al-Hillah River, Iraq.

CHAPTER FIVE

Conclusion
&
Future Works

Chapter Five	Conclusion and Future Works

5.1 Conclusions

Shatt Al-Hillah River represents one of the main sources of water for cities that located along the river. The recent water crisis in the region has prompted the necessity of assessing the quality of the river's water in 2015. Water samples were taken from six locations along the Shatt Al-Hillah River by measuring eleven physical and chemical parameters. These parameters are Ca, Mg, DO, pH, Cl, SO_4, TH, TDS, Alkalinity, turbidity, and EC.

The measured values of all tested parameters in the year 2015 along the Shatt Al-Hillah River were decreased gradually from the location (L-1) in Al-Musayyib to the location (L-6) in Al-Hashimiya. The in clearly decreased showed from location (L-4) to the location (L-6) for all selected parameters in these stations. The concentration of Ca was decreased gradually from location (L-1) to location (L-4) and then increased at location (L-5) then returned to decrease at the location (L-6).

The weighted arithmetic method was applied to compute the water quality index (WQI) for each selected station along the whole length of Shatt Al-Hillah River within the Iraqi borders in 2015 using a series of equations mentioned before. The results showed that the water quality index was approximately constant and stable for the selected stations along the Shatt Al-Hillah River from the upstream of the river (Al-Musayyib) toward the downstream (Al-Hashimiya).

The WQI from the location (L-1) until location (L-6) were calculated and they were given the rating of very poor water quality within the category of (200 – 300) based on the WQI value.

The clear degradation was related to several pollutants originating in human activities and natural phenomena factors occurring along the pathway of the river. Moreover, the computed WQI values indicated that the water quality of the river at these stations was invalid to use before treating the parameters concentrations (especially) with values more than allowable limits.

In this study, the IDW method of the spatial analyst extension in the ArcGIS 10.8 was used for mapping the water quality parameters within the catchment area. This will assist in identifying the sampling locations or areas along the river with high impairment levels which will in turn aid in the enforcement of standards and pollution control activities.

5.2 Future work

1. Evaluation of the Water Quality Index along Shatt Al-Hillah River by measuring more samples such as K, Na, and BOD besides the measured samples in the current study.
2. Producing the interpolation maps in the GIS for concentrations of each parameter along the Shatt Al-Hillah River.
3. Legislation of laws compels owners of facilities and factories to treat the materials and waste that are thrown into the river as a complete treatment or to be thrown away from the river to reduce the pollution of the river.
4. Increasing the efficiency of treatment plants that treat sewage water and providing them with advanced treatment technologies And the establishment of new treatment plants due to population increase and urban expansion.

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