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# Total Maximum Daily Load (TMDL) as a Planning Tool to Achieve Water Quality of Euphrates River

*A research*

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2022 A.D

1443 A.H

بِسْمِ اللَّهِ الرَّحْمَنِ الرَّحِيمِ

(فَأَمَّا الزَّبَدُ فَيَذْهَبُ جُفَاءً وَأَمَّا مَا يَنْفَعُ النَّاسَ فَيَمْكُثُ فِي الْأَرْضِ

كَذَلِكَ يَضْرِبُ اللَّهُ الْأَمْثَالَ)

بِسْمِ اللَّهِ الرَّحْمَنِ الرَّحِيمِ

سورة الرعد- آية (١٧)

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## Dedication

To my parents.....

my sisters and my brothers.....

my dear husband (**Maher**)....

my daughter (**Malath**), my baby (**Hussein**)....

my department (**Civil Engineering**) ....

and to everyone I had learned from him in my life....

*I dedicate this modest effort.*

**Surour 2022**

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**Surour qais marza**

**2022**

## Abstract

The effects of pollution sources on receiving water quality are diverse and depend on the type and concentration of pollutants. In a river basin, there can be multiple water quality limited sections. The Total Maximum Daily Load (TMDL) of a pollutant must be calculated for each section, moving from the most upstream one to the most downstream one. There may be many combinations of a point source and a non-point source that can't meet the water quality criterion. Multiple feasible solutions can provide an opportunity for the regulator and stakeholders to find the most agreeable TMDLs.

The present study was conducted on the Euphrates River. The aim of study was the estimation of the TMDL. Raw water data which were obtained from the Ministry of Environment, Environment Directorate and Ministry of Water Resources, Water Directorate were collected and analyzed from Euphrates River five stations ( $S_1$ ,  $S_2$ ,  $S_3$ ,  $S_4$ ,  $S_5$ ) during the period starting from January to December of the year 2021. The purpose is to assess the level of parameters measured and their effects on the river. Statistical analysis was used to describe the relations between TMDL and parameters and a regression analysis was performed by "Excel" Program Software.

Fourteen parameters were collected from the Euphrates River. Use only eight parameters in order to determine the TMDL, these parameters were: Nitrate ( $\text{NO}_3$ ), Total Phosphate ( $\text{PO}_4$ ), Calcium (Ca), Magnesium (Mg), Potassium (K), Chloride (CL), Nitrogen (N), and Sulfate ( $\text{SO}_4$ ). The average values of TMDL for the study area are as follow: 82.22 kg/day for  $\text{NO}_3$ , 62.28 kg/day for  $\text{PO}_4$ , 271.69 kg/day for Ca, 90.57 kg/day for Mg, 76.16 kg/day for K,

862.89 kg/day for CL, 318.56 kg/day for N, and 1011 kg/day for SO<sub>4</sub> respectively.

The study showed that discharging domestic sewage and industrial wastewater from adjacent areas, caused contamination of levels more than Iraqi standards. The highest values of TMDL were recorded in station one (S1) and the most polluting element of Euphrates River is Sulfate.

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### Table of Abbreviations

Symbol	Description
CAFOs	Concentrated Animal Feeding Operations
CFR	Code of Federal Regulations
CWA	Clean Water Act
DDT	Dichloro Diphenyl Trichloroethane
EPA	Environmental Protection Agency
FAO	World Health and Food
FWPCA	Federal Water Pollution Control Act
LAs	Load Allocations
MDE	Maryland Department of the Environment
MOS	Margin Of Safety
NPDES	National Pollution Discharge Elimination System
NPS	Non-Point Source
NRC/ NAS	National Research Council of the National Academy of Sciences
PAHs	Polycyclic Aromatic Hydrocarbons
PS	Point Source
QAPP	Quality Assurance Project Plan
TMDL	Total Maximum Daily Load
TMDLs	Total Maximum Daily Loads
USEPA	United States Environmental Protection Agency
WEF	Water Environment Federation
WLAs	Waste Load Allocations
WQLS	Water Quality Limited Sections
WQSs	Water Quality Standards

**Table of Nomenclature**

<b>Unit</b>	<b>Definition</b>
day	Day
kg	Kilogram
km	Kilo Meter
L	Liter
m	Meter
m <sup>2</sup>	Square Meter
m <sup>3</sup>	Cubic Meter
mg	Milligram
s	Second

**Table of Subscripts**

<b>Symbol</b>	<b>Meaning</b>
Al	Aluminum
As	Arsenic
Ca	Calcium
Cd	Cadmium
CL	Chloride
DO	Dissolved Oxygen
F	Fluorides
Fe	Iron
Hg	Mercury
K	Potassium
K	Potassium
Mg	Magnesium
N	Nitrogen
Na	Sodium
NO <sub>3</sub>	Nitrate
pH	Potential of hydrogen
PO <sub>4</sub>	Phosphates
SO <sub>4</sub>	Sulfate
TDS	Total Dissolved Solids
TH	Total Hardness

# **CHAPTER ONE**

# **INTRODUCTION**

# CHAPTER ONE

## INTRODUCTION

### 1.1 General

Water is the major resource for the world to work and is very important for its sustenance. With increasing in developmental activities all over the world, there is an increase in rate of negative exploitation of this very major resource. Due to increase in the industrial activities the ground water and surface waters are getting polluted to the extent that it cannot be used for the domestic purpose without treatment, [Mustafa, 2021].

Water, is used for many purposes associated with human activity. In its natural state it occurs in and on the ground in subsurface and surface reservoirs. The quality and reliability of a water source will vary considerably, both in time and space. This means that characteristics (chemical, physical, and biological) will differ greatly depending upon the location and type of the source. It also means that a given source may vary over the seasons of the year, [Pfafflin and Ziegler, 2006].

Water pollution can be defined as the presence in water of enough harmful or objectionable material to damage the water's quality, [Pankratz, 2001]. Water pollutants are categorized as point sources or nonpoint sources (Fig. 1.1), the former being identified as all pollutants that enter watercourses through pipes or channels. Storm drainage, even though the water may enter watercourses by pipes or channels, it is considered a nonpoint source of pollution. Another nonpoint source comes from agricultural runoff, construction sites, and other land disturbances, [Weiner and Matthews, 2003].

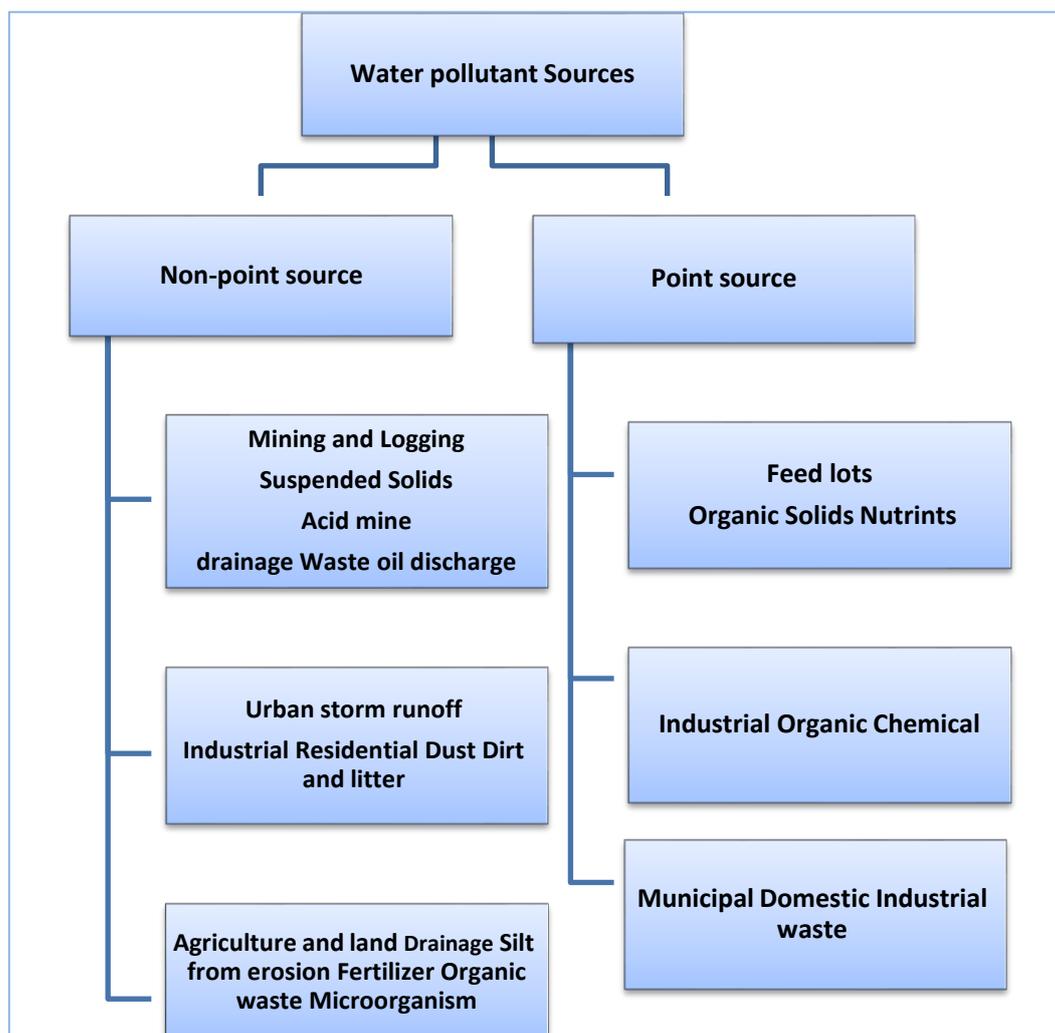


Fig. 1.1: The sources of water pollutant, [Zaidi and Demonsabent, 2014]

## 1.2 Heavy Metals Pollutants

River sediments are a major carrier of heavy metals in the aquatic environment. Sediments are mixture of several components of mineral species as well as organic debris, representing an ultimate sink for heavy metals discharged into the environment. Chemical leaching of bedrocks, water drainage basins and runoff from banks are the primary sources of heavy metals. Mining operations, disposal of industrial wastes and applications of biocides for pest are other anthropogenic sources. Heavy metals are serious pollutants

because of their toxicity, persistence and non-degradability in the environment. Polluted sediments, in turn, can act as sources of heavy metals, imparting them into the water and debasing water quality, [Emad and Tahseen, 2012].

An important issue in recent years is surface water pollution. A primary global objective is reducing pollution of the aquatic systems. The contaminant's behavior in the aquatic environment depends on some factors: chemical, physical, hydrodynamic, and biological. Pollution is that pressure influences the state of the aquatic ecosystems. Sources of the pollution of the aquatic systems are different surface water often degrade after using it for pesticides and agricultural fertilizers and heavy metals present in water, [Mustafa, 2021].

### **1.3 Total Maximum Daily Load (TMDL)**

Total Maximum Daily Load (TMDL) is the maximum amount (load) of a water quality parameter that can be carried by a water body without causing an exceedance of surface water quality standards. Expressed as mass/time (i.e. kg/day), TMDLs are approved or disapproved by EPA. If disapproved, EPA develops the TMDL, [<https://www.epa.gov/tmdl/overview-total-maximum-daily-loads-tmdls>].

Study the TMDL of toxic contaminants concentration in the river and its effectiveness in evaluating river pollution, in addition to some chemical and physical water quality parameters provide the department of water resources with a clear and important scientific vision to control the river's pollution in the future affected by changing the chemical and physical properties of the river, as accurately as possible.

TMDL is developed by using a range of techniques, from simple mass balance calculations to complex water quality modeling methods. The degree of

analysis varies based on various factors including the water body type, density of flow conditions, and pollutant causing the weakening, [<https://www.epa.gov/tmdl/overview-total-maximum-daily-loads-tmdls>].

## 1.4 Problem Statement

The Iraqi natural environment has been marked by a major decline twenty years ago, from air pollution to soil and water pollution. As Iraq passes through a stage of weakening with the quality of water in Iraq as a result of multiple sources of pollution in it, [Montadher, 2009].

Euphrates River has a large importance for Iraqi environmental researchers because of the detrimental effect of pollutants resulting from treated and untreated domestic wastewater, treated and untreated industrial wastewater and farming and agricultural pollutants. A large number of populations of Iraq reside along the banks of Euphrates and Tigris Rivers so the utility of such water for bathing and recreation purposes cannot be aesthetically good. The polluted water is also difficult to be easily treated and it is found that the treatment plants have to be increased in handling such water, [Hussein, 2013].

The study area water requirements have been provided by the Euphrates River. Euphrates River water is being provided to the cities after conservative treatment (coagulation, sedimentation, filtration, and chlorination) by water treatment plants. These plants are located on the banks of the Euphrates River.

One of the most important problems of this study is the pollution of the Euphrates River with wastewater and the resulting health and environmental problems and because many dangerous pollutants that it contains like harmful microbes and bacteria.

## **1.5 Objectives of The Study**

The main objectives of this study were summarized as follows :

1. An identification of the causes and sources (point and non-point) need to be controlled to achieve and estimate the load reductions expected and other goals identified in the base plan, for the management measures to be implemented.
2. Determine the loading capacity of a waterbody of Euphrates River (TMDL) and allocate that load among different pollutant sources so that the appropriate control actions can be taken and the water quality standards achieved.
3. Improving the water quality of Euphrates River by using the TMDL as a link between the water quality standards and the implementation of control actions designed to achieve the standards.
4. Use the general equation to compute the TMDLs for several pollutants to track changes and increases in water quality which depend on the varying conditions, and predict water quality in the future.

## 1.6 Outline of Thesis

The outline of the present work is as follows:

1. **Chapter one:** Includes a general introduction about water, water pollutants, heavy metals pollutant, TMDL, Euphrates River Basin, and illustrates the objectives and the problems of the study.
2. **Chapter two:** Includes a general description of pollution sources and the effects of physical and chemical parameters on water quality. It also includes water quality standards, what the Total Maximum Daily load means and the equation which use to determine it, and a literature review.
3. **Chapter three:** This chapter includes site descriptions, research methodology, collection and sampling conditions and measurement of physical and chemical variables of water.
4. **Chapter four:** Includes the results of the computing Total Maximum Daily Load and the discussion of it.
5. **Chapter five:** The main important points depending on the results and recommendations for future work are presen.

**CHAPTER TWO**

**THEORETICAL**

**CONCEPTS AND**

**LITERATURES**

**REVIEW**

## **CHAPTER TWO**

### **THEORETICAL CONCEPTS AND LITERATURES REVIEW**

#### **2.1 Background**

Water is the basis of life after oxygen. It is one of the most important natural resources on which the development and well-being of human civilization depends. Oldest civilizations have developed near natural water sources. Water is a part of the content of living organisms and also extends to all areas of economic life. Thirty two million cubic meters of water, but does not exceed (2.8%) the proportion of water which benefit to humans in drinking, agriculture and industry, rest is (2%) of fresh water is frozen, leaving only 0.8% of fresh water. Therefore, man is living with water in a real crisis because the available quantity for human use is very low and no longer commensurate with the population and it is needs, [<https://search.mandumah.com/Record/927082>].

Understanding the interrelationships among the physical, chemical, biological, and habitat characteristics of water resources and the management and use of land in the watershed is essential to fully restoring and protecting water quality. For example, a narrow focus on reducing chemical and physical pollutant loads in response to a watershed management plan, without recognition of the roles these pollutants play as ecological stressors could result in only partial success where load reduction targets are met but water quality goals as measured by biological and habitat criteria are not achieved, [Donald, et al., 2013].

Measurement of TMDL for surface water is an important component of most water quality monitoring projects. Flooding, stream geomorphology, and aquatic life support are all directly influenced by streamflow, and runoff and streamflow drive the generation, transport, and delivery of many nonpoint source (NPS) pollutants. Calculation of pollutant loads requires knowledge of water flow, [<https://www.coursehero.com/file/44446577/00-Surface-Water-Flow-Measurement-forpdf/?cv=1>].

The natural ecology of the watershed is a dynamically balanced system that can be disturbed by any external force, such as human intervention. If a system such as this is exposed to any disturbance may significantly affect one or more of the watershed functions. The removal of external forces which cause disturbance of equilibrium will allow for the restoration of original conditions, this state If the watershed was dynamically stable, [Black, 1996].

Federal Clean Water Act (CWA) Section 303(d) states need to develop the management plans for Total Maximum Daily Load (TMDL) for water bodies determined to be water quality limited. The amount of a pollutant a waterbody can assimilate without violating applicable water quality standards was documented by the TMDL. In 40 Code of the Federal Regulations (CFR) Part 130 a TMDLs are defined as the sum of the individual load allocations (LAs) for nonpoint sources, waste load allocations (WLAs) for point sources, and a margin of safety (MOS), [Kristen and Julie, 2002].

In some cases, the reduction of point-source loading further may be cost-prohibitive. For a cost-effective solution to the remaining water quality problems, it may be necessary to include non-point-source control in watershed management plans, [Carl, et al., 1999].

## 2.2 Water pollution

The release of substances into streams, rivers, estuaries, groundwater or into lakes, and oceans, which are harmful to living beings may be defined as water pollution. If the concentration of the substances naturally present in water increases then also the water is said to be polluted. The population explosion and industrialization are two important factors for water pollution. When one or more of the following parameters below exceed a specific concentration in the water, water is considered pollutant, these parameters are:

[<http://www.spcollege.co.in/lectures/636265138779828979.pdf?cv=1>]

- **Chemical parameters:** These include the amounts of chlorides, carbonates, sulfates, nitrates, fluorides, and metal ions. These chemicals form the total dissolved solids present in water.
- **Physical parameters:** Constitutes the physical parameters are good indicators of pollution like turbidity, color, taste, odor, electrical conductivity, and temperature.
- **Biological parameters:** These parameters include matter like fungi, viruses, algae, and bacteria. The presence of pollutants affects the life forms in water. The presence of such pollutants in the water causes a decrease in the population of both lower and higher plant and animal lives.

## 2.3 Sources Types of Water Pollutants

The following types are the different sources types of water pollutants:

- **Municipal and Domestic Pollutants:** The sewage contains human excreta, waste food, detergents, soaps, and garbage and it's one of the largest sources of water pollution. Through sewage, the microorganisms (bacteria, protozoa, fungi, algae) pathogenic

(disease-causing) enter the water system making it infected. Drinking such water causes diseases such as typhoid, gastroenteritis, cholera, and dysentery. Other viruses and bacteria which cannot grow by themselves, where it is reproduced in the cells of host organisms may certain found in water polluted by sewage. Plant nutrients are the other contents that enter the various water bodies, i.e. phosphates and nitrates. They support the growth of algae, commonly called algal bloom (blue-green species), [Mohammed, 2019].

- **Industrial Pollutants:** Near rivers or freshwater streams, many industries are located, which discharges their untreated effluents into rivers like highly toxic heavy metals such as chromium, lead, mercury, arsenic, etc. along with organic and inorganic wastes (e.g., alkalis, acids, cyanides, chlorides, etc.). Most of these pollutants are called non-biodegradable pollutants (microorganisms can't break down it), therefore damaging the growth of crops, [Mohammed, 2019]. Factories that produce plastic, caustic soda, and some fungicides and pesticides release mercury (a heavy metal) along with other effluents in nearby water bodies. Due to mercury consumption, fish died and the people who ate fish were affected by mercury poisoning and many of them died, [<https://1library.net/document/q76d3dpek-available-online-www-ksaer-com.html?cv=1>].
- **Agricultural Waste:** Wastes from farms slaughterhouse, poultry farms, fertilizers, manure, pesticides, salts and silt are drained as run-off from agricultural lands. Large quantities of fertilizers (phosphates and nitrates or manures) are received in the water body and then becomes rich in nutrients which leads to consequent depletion of dissolved oxygen result of eutrophication . The

consumption of like this water rich in nitrates is bad for human health especially for small children. Pesticides (Aldrin, DDT, malathion, dieldrin, carbaryl etc.) are used to eliminate insect and rodent pests. Through the food chain (biomagnification) or drinking water, toxic pesticide residues enter the human body even in minute amounts may lead to cancer and can cause hormonal imbalance, [Mohammed, 2019].

- **Physical Pollutants:** The physical pollutants can be of different types like Sediments, Radioactive Wastes, and Thermal Sources, [<http://www.spcollege.co.in/lectures/636265138779828979.pdf?cv=1>].
- **Petroleum Products:** These products are widely used for plastics manufacturing, fuel, lubrication, etc. and in nature, they happen to be toxic. The water receives the petroleum products (crude oil and other related products) generally by unintentional spillage from pipelines, tankers, ships, etc. Besides these unintentional spills, different water bodies pollute by oil exploration sites, oil refineries, and automobile service centers. The float of an oil slick on the water surface severely affects the ecosystem of the ocean and causes the death of marine organisms, [<http://www.spcollege.co.in/lectures/636265138779828979.pdf?cv=1>].

## 2.4 Sources of Water Pollution

A water pollutant is any substance capable of causing (chemical, physical or biological) a change in a water body. It has a big effect on living organisms, so it is an undesirable change. The domestic, agricultural, and industrial water with some unwanted impurities in it is discharged in to the waterbody. And this leads to freshwater pollution.

Entry of pollutants into the river, stream, or lake give rise to surface water pollution, [Depoint, et al., 2004]. And surface water pollution has a number of sources. These can be characterized as: [<http://www.spcollege.co.in/lectures/636265138779828979.pdf?cv=1>]

- **Point and Non-point Sources**

The well-defined sources that emit pollutants or effluents directly into different water bodies of fresh water are called point sources. Domestic and industrial waste are examples of this type. The point sources of pollution can be effectively checked. On the other hand, the non-point sources of water pollution are scattered or spread over large areas. This type of sources deliver pollutants indirectly through environmental changes and account for majority of the contaminants in streams and lakes. For example, the contaminated water that runs off from agriculture farms, construction sites, abandoned mines, enters streams and lakes. It is quite difficult to control non-point sources.

- **Natural and Anthropogenic Sources**

As mentioned earlier, an increase in the concentration of naturally occurring substances is also termed pollution. The sources of such an increase are called natural sources. Siltation (which includes soil, sand and mineral particles) is one such natural source. It is a common natural phenomenon, which occurs in most water bodies. Indiscriminate deforestation makes soil loose and flood waters bring silt from mountains into streams, rivers and lakes. On the other hand, the human activities that result into the pollution of water are called anthropogenic or manmade sources of water pollution. For example, domestic (sewage and waste water), industrial and agricultural wastes that go into the rivers, lakes, streams and seas are anthropogenic

sources. Certain materials that are leached from the land by run-off water and enter the various water bodies also belong to this category.

## **2.5 Nonpoint Sources vs. Point Sources**

The term "nonpoint source" (NPS) is defined to mean any source of water pollution that does not meet the legal definition of "point source" in section 502 (14) of the Clean Water Act. The term "point source" means any discernible, confined and discrete conveyance, including but not limited to any pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container, rolling stock, concentrated animal feeding operation, or vessel or other floating craft, from which pollutants are or may be discharged. This term does not include agricultural storm water discharges and return flows from irrigated agriculture, [Lindsay, 2020].

Nonpoint Sources (NPS) pollution generally results from land runoff, precipitation, atmospheric deposition, drainage, seepage or hydrologic modification. NPS pollution, unlike pollution from industrial and sewage treatment plants, comes from many diffuse sources. NPS pollution is caused by rainfall or snowmelt moving over and through the ground. As the runoff moves, it picks up and carries away natural and human-made pollutants, finally depositing them into lakes, rivers, wetlands, coastal waters and ground waters, , [Hussein, 2014].

Nonpoint source pollution can include: [Borah, et al., 2019]

- Excess fertilizers, herbicides and insecticides from agricultural lands and residential areas.
- Oil, grease and toxic chemicals from urban runoff and energy production.
- Sediment from improperly managed construction sites, crop and forest lands, and eroding stream banks.

- Salt from irrigation practices and acid drainage from abandoned mines.
- Bacteria and nutrients from livestock, pet wastes and faulty septic systems.
- Atmospheric deposition and hydro-modification.

States report that nonpoint source pollution is the leading remaining cause of water quality problems. The effects of nonpoint source pollutants on specific waters vary and may not always be fully assessed. However, we know that these pollutants have harmful effects on drinking water supplies, recreation, fisheries and wildlife, [Kufman, 2014].

## **2.6 Water Quality Standards**

As said by sanitary engineering, water quality refers to an exact location in terms of health for humans, counting illnesses transmitted through water. Water quality is defined from the point of view of specialists in water management, by human uses, such as irrigation, drinking water, industrial, or transportation use, power generation, [Goudie and Cuff, 2002].

Water Quality Standards (WQSs) are the basis of the water quality-based regulator database mandated by the Clean Water Act (CWA). The criteria form the lawful foundation for controls on the quantity of pollution from sources such as wastewater treatment plants, industrial facilities, and storm sewers. Criteria are also the technical root for decreasing runoff from urban and rural areas. A standard can contain either narrative or numeric limits for a specific chemical or physical parameter of raw water as shown in Table 2.1 according to Iraqi standard specification. Finally, a water quality standard is industrialized to assistance look after and maintaining water quality necessary to meet and

uphold selected or assigned uses, such as recreation, public water supply, swimming, and/or river life, [WHO, 2015].

**Table 2.1: Standard specifications for raw water (Iraqi standard limit), (Environment department of Karbala, 2010).**

Parameters	Maximum limits (Raw Water)
Alkalinity (ALK), mg/L	200
Calcium, (Ca), mg/L	50
Dissolved Oxygen, (DO), mg/L	< 0.4
Electrical Conductivity (EC), $\mu\text{mhos/cm } 25^{\circ}\text{C}$	1000
Magnesium, (Mg), mg/L	50
pH	6.5-8.5
Phosphate, ( $\text{PO}_4$ ), mg/L	>5
Potassium, (K), mg/L	12
Sodium, (Na), mg/L	200
Sulfates, ( $\text{SO}_4$ ), mg/L	400
Temperature, $^{\circ}\text{C}$	30
Total dissolved solids, mg/L	1500
Total hardness, mg/L (ac $\text{CaCO}_3$ )	500
Turbidity, N.T.U	5

## 2.7 Load Estimation

For any given watershed, the best approach for estimating loads will be determined on the basis of the needs and characteristics of the watershed. The critical principle at work is that nonpoint source pollutant concentrations are usually highly correlated with flow (i.e., high concentrations occur during high flows), [<http://docplayer.net/32539705-Models-quantify-the-total-maximum-daily-load-process.html?cv=1>].

Different methods of load estimation can result in substantially different estimates of pollutant load. Select the preferred method based on project objectives and monitoring resources [Donald, et al., 2013].

## **2.8 Sampling**

Good load estimates are usually derived from continuous flow data and intermittent data on pollutant concentration. Both flow and pollutant concentrations are highly variable. Generally, continuous flow measurement and frequent water quality samples are needed to accurately and reliably capture the true load pattern. Although sampling frequency requirements vary by the system monitored and the accuracy desired, quarterly concentration observations are generally inadequate, monthly observations probably not yield reliable load estimates, and even weekly observations may not be satisfactory, especially if very accurate load estimates are required to achieve project objectives, [Kaufman, et al., 2014].

Water quality sampling for load estimation must capture periods of high flows and pollutant concentrations. Flow-proportional sampling will often provide the most accurate and cost-effective data for load estimation, frequency, timing, and stratification are important considerations for fixed-interval sampling programs. Computational and statistical techniques appropriate to nonpoint source load estimation include: [Donald, et al., 2013]

- Numeric integration to compute load as the product of flow and concentration over a sequence of observations.
- Regression to estimate un-sampled concentrations based on flow.
- Ratio estimators to adjust individual unit loads based on flow conditions at the time of sampling.

## 2.9 Purposes of Flow Measurement

Flow data can be used for a variety of purposes, including problem assessment, watershed project planning, assessment of treatment needs, targeting source areas, design of management measures, and project evaluation. Nonpoint source management projects generally focus on reducing either flow, availability of pollutants, or both. It is often easier and less expensive to document changes in flow than in pollutant levels as a measure of project effectiveness. The selection of appropriate flow variables depends on the specific purpose and situation. The relationship between discharge and pollutant concentrations is often used in both the planning and assessment phases of watershed projects. It may be possible to develop a preliminary understanding of the relative importance of various point and nonpoint sources by observing the relationship between water quality variables and discharge. Pollutant loads are critical elements of TMDL development and implementation, and reduction in pollutant load is often an important measure of success in nonpoint source watershed projects, [Donald, et al., 2013].

## 2.10 Total Maximum Daily Load (TMDL) Calculation

A Total Maximum Daily Load (TMDL) is the calculation of the maximum amount of a pollutant allowed to enter a water body so that the water body will meet and continue to meet water quality standards for that particular pollutant. A TMDL determines a pollutant reduction target and allocates load reductions necessary to the source(s) of the pollutant, [<http://docplayer.net/32539705-Models-quantify-the-total-maximum-daily-load-process.html?cv=1>].

Pollutant sources are characterized as either: Point sources that receive a Waste Load Allocation (WLA), or nonpoint sources that receive a Load Allocation (LA). For purposes of assigning WLAs, point sources

include all sources subject to regulation under the National Pollutant Discharge Elimination System (NPDES) program, e.g. wastewater treatment facilities, some storm water discharges and Concentrated Animal Feeding Operations (CAFOs). For purposes of assigning LAs, nonpoint sources include all remaining sources of the pollutant as well as natural background sources, [<https://www.epa.gov/tmdl/overview-total-maximum-daily-loads-tmdls>].

A Federal Clean Water Act (FCWA) requires states to recognize water stream or bodies sections that don't meet water quality standards and designated uses then place them on the United States Environmental Protection Agency (USEPA) impaired waters list. If it is listed, the State is required to measure the total of a specific pollutant that a listed water body can accept without violating applicable water quality standards and to apportion that allowable load among the sources of the selected pollutant. The maximum acceptable pollutant quantity is mentioned as the TMDL, [Minnesota Pollution Control Agency Wisconsin Department of Natural Resources, 2012].

### **2.11 Margin of safety**

Determination of a margin of safety (MOS) is required as part of the TMDL development process. The MOS component of a TMDL accounts for any uncertainty about the relationship between the pollutant loads and the quality of the receiving water body. The MOS is divided into two components, implicit and explicit, that when combined form the overall MOS. The challenge in determining the MOS for TMDLs comes with the estimation of each component in a consistent and well documented manner. The implicit component of the MOS consists of conservative estimates used throughout the calculations of the loads in the TMDL document. The explicit component of the MOS consists of data variability, equipment error, model accuracy, etc. One factor in

determining the MOS is to quantify uncertainty based on sampling and equipment. Uncertainty associated with lab and field meter data is quantified through a Quality Assurance Project Plan (QAPP), [NMED and SWQP, 2001].

Many TMDLs are drafted with only an implicit MOS, using conservative assumptions in calculations. Some TMDLs use an implicit MOS that is incorporated by adjusting a water quality standard to reflect a percentage MOS, [Kristen and Julie, 2002].

## **2.12 Mathematical Calculation for Total Maximum Daily Load (TMDL)**

Mathematical models of watersheds and receiving water bodies are often an integral part of the total maximum daily load (TMDL) process. All water bodies that have been placed on the state 303(d) priority water body list require the development of a TMDL, [NRC/NAS, 2001].

The TMDL process requires the determination of the point source (PS) waste load and nonpoint source (NPS) load allocations for a water body that is necessary to meet specified water quality objectives. This determination must be made such that there is a margin of safety between the allocated PS and NPS loads and the assessment of the maximum total daily load of a pollutant that the water body can receive and still meet the water quality criteria for its designated uses (i.e., its assimilative capacity), [Water Environment Federation (WEF), 2001].

One of the best tools available for determining the quantitative relationship between pollutant sources and water quality criteria is a water quality model. Models can serve multiple purposes in the TMDL process. They can be used to calculate watershed loads for existing conditions, relate loads to water quality response, and evaluate the effectiveness of proposed control alternatives in reducing loads and improving water

quality to meet standards. But, many in the water quality field believe that TMDL modeling is not being properly implemented, and that improvements are needed. In general, the abuse of models in the TMDL process often occurs because of limited data, budget, and schedule inherent to the current TMDL process, coupled with poor training and inadequate experience on the part of model users, [U.S. EPA, 2002].

TMDLs must also account for seasonal variations in water quality, and include a margin of safety (MOS) to account for uncertainty in predicting how well pollutant reductions will result in meeting water quality standards. Expressed mathematically, the TMDL equation is:

[ <https://www.epa.gov/tmdl/overview-total-maximum-daily-loads-tmdls> ]

$$\text{TMDL} = \Sigma\text{WLA} + \Sigma\text{LA} + \text{MOS} \dots\dots\dots 2.1$$

Where:

\*WLA: is the sum of waste load allocations (point sources)

\*LA: is the sum of load allocations (nonpoint sources and background)

\*MOS: is the margin of safety.

Then the Load Allocation and the Waste Load Allocation are calculated by the equations:

$$\text{LA} = Q \times \text{Con.} \times \text{Conv. F} \dots\dots\dots 2.2$$

$$\text{WLA} = Q \times \text{Con.} \times \text{Conv. F} \dots\dots\dots 2.3$$

Where:

\*Q: is the flow of the river

\*Con.: is the concentration of the parameter

\*Con. F.: is the Conversion Factor from ( mg/L \*m<sup>3</sup>/sec) to (kg/day)

Each pollutant causing a water body to be impaired or threatened is referred to as a water body/pollutant combination, and typically a TMDL is developed for each water body/pollutant combination. For example, if one water body is impaired or threatened by three pollutants, three TMDLs might be developed for the water body. However, in other cases, a single TMDL document may be developed to address several water body/pollutants combinations. Neither the Clean Water Act (CWA) nor Environmental Protection Agency (EPA's) regulations define or limit the scale of TMDLs. Some states have been developing TMDLs on a watershed-scale basis. Such state TMDLs may also cover multiple watersheds, [<https://www.epa.gov/tmdl/overview-total-maximum-daily-loads-tmdls>].

### **2.13 Literatures Review**

The term TMDL, or Loading Capacity, is defined as the maximum amount of a pollutant that a waterbody can receive and still achieve water quality objectives. TMDLs also establish the pollutant load allocation necessary to meet the water quality standards established for a waterbody based on the relationship between pollutant sources and water quality conditions in the waterbody, [Zaidi, et al., 2014]. TMDLs should clearly identify the links between the water body use impairment, the causes of impairment, and the pollutant load reductions needed to meet the applicable water quality standards, [<http://docplayer.net/32539705-Models-quantify-the-total-maximum-daily-load-process.html?cv=1>]. A short overview of the Total Maximum Daily Load is given below:

**[The Arizona Department of Environmental Quality (ADEQ), 1999]**, has developed the TMDL to account for all impacts from point and non-point sources of phosphorus and nitrogen pollution for the Oak Creek Basin. TMDL has been calculated based on real and simulated loads

using the equation (2.1) Appropriate TMDLs in the Oak Creek watershed was for Nitrogen 440 kg/day and for phosphorus was 58 kg/day.

**[Final Approved Total Maximum Daily Load (TMDL) for the RIO HONDO, 2004]**, were documented the development of a Total Maximum Daily Load (TMDL) to address impairments of water quality standards for Total Phosphorus and Total Nitrogen in the Rio Hondo (South Fork of Rio Hondo to Lake Fork Creek). The study was for twelve months. And by using the general equation for calculating TMDL and 5% as an explicit margin of safety. The results for total Phosphorus and total Nitrogen were 195 kg/day for each pollutant.

**[Gary and Lewis, 2013]**, were used the Phase 5.3 Watershed Model to simulate the Chesapeake watershed land use, the river flows, and the associated transport and fate of nutrient and sediment loads to the Chesapeake Bay. The Phase 5.3 Model, in conjunction with models of the Chesapeake airshed and estuary, provides estimates of management actions needed to protect water quality, achieve Chesapeake water quality standards, and restore living resources. The Phase 5.3 Watershed Model tracks nutrient and sediment load estimates of the entire 166,000 km<sup>2</sup> watershed.

**[Oklahoma Department of Environmental Quality Water Quality Division, 2013]**, were documented the data and assessment methods used to establish total maximum daily loads (TMDL) for Lake Thunderbird. They established waste load allocations (WLA) and load allocations (LA) determined to be necessary for reducing turbidity and chlorophyll-a levels and maintaining sufficient oxygen levels in Lake to attain water quality targets. The calibrated lake model was used to evaluate the water quality response to reductions in the watershed loading

of sediment and nutrients. Observed Data and Model Results were Aggregated Over the Whole Lake for the Period (2008 - 2009). The TMDLs for the study parameter (Suspended solids (TSS), CBOD, Total Phosphorus (TP), Total Nitrogen (TN)) were (76,950.8 kg/day , 2,480.8 kg/day, 158.4 kg/day, 807.7 kg/day) respectively.

[**Robert, et al., 2014**], were prioritized total maximum daily load (TMDL) development starts by considering the scope and severity of water pollution and risks to public health and aquatic life. Used the quantitative assessments of in-stream water quality as methodology and it is appropriate and effective for a point source (PS) dominated discharge, but less so in watersheds with mostly nonpoint source (NPS) related impairments. The study found that assessments of ecological function could be used to generate leading (early) indicators of water quality degradation for targeting pollution control measures, while traditional in-stream water quality monitoring lagged in response to the deterioration in ecological functions.

[**United States Environment Protection Agency, 2019**], addressed the water quality impairments in the Waikele watershed in Hawaii due to each of turbidity, total nitrogen and nitrite +nitrate nitrogen during both wet (November through April months) and dry (May through October months) seasons. Turbidity is included on the section 303(d) list due to turbidity measurements exceeding only the wet season (November through April months) water quality criterion. The total nitrogen and nitrite +nitrate nitrogen listings are due to measurements of these nutrients exceeding both the Waikele Stream's associated wet and dry season (year-round) water quality criteria.

# **CHAPTER THREE**

## **EXPREIMENTAL METHODOLOGY**

## **CHAPTER THREE**

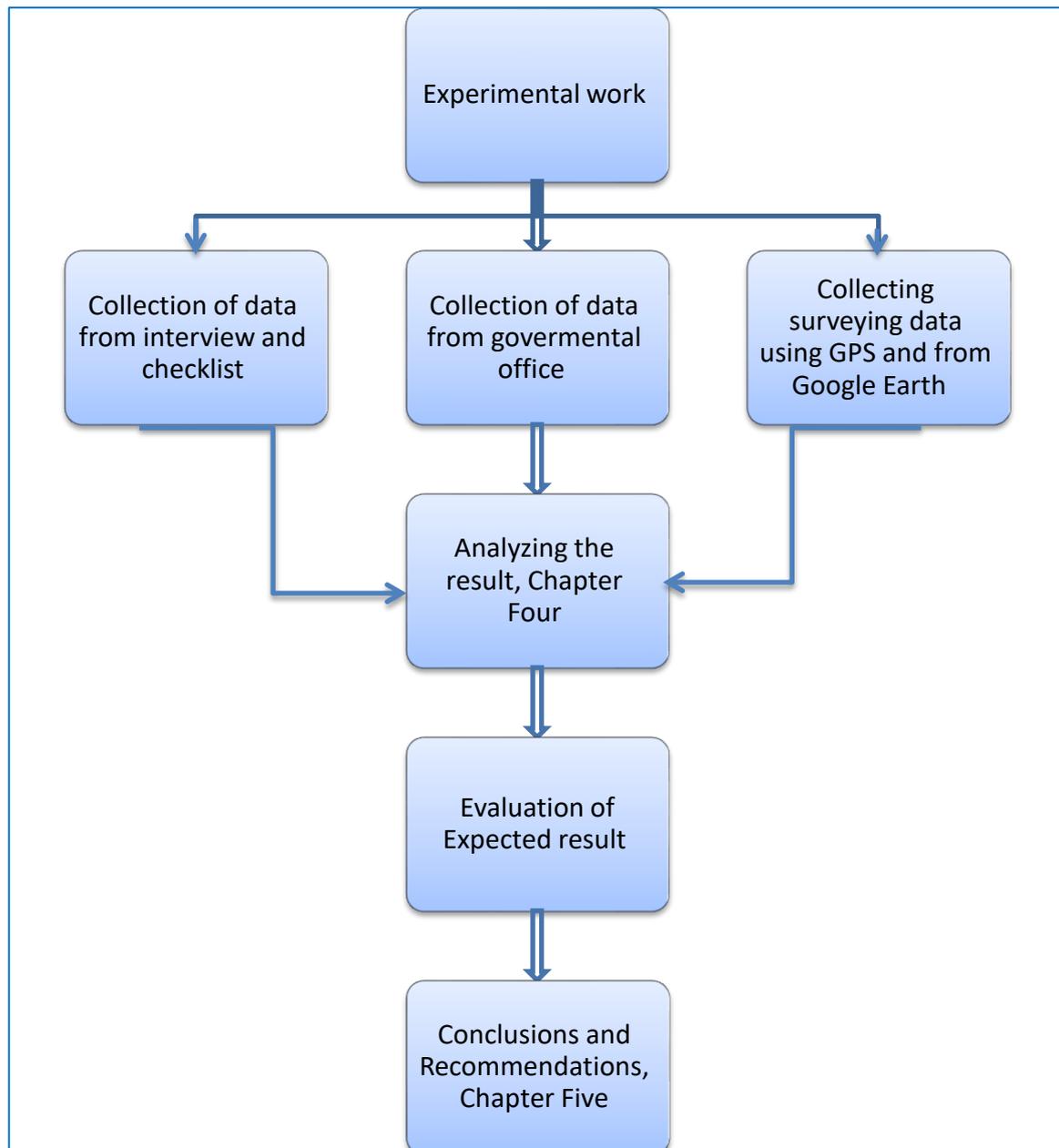
### **EXPERIMENTAL METHODOLOGY**

#### **3.1 Introduction**

One of the ways that are used to solve problems of surface water pollution is equations, variations that take place in surface water and associated water quality parameter. On the other hand, it depends on available data sets, namely results of the measurement of water quality indicators and on which the estimation of parameters. In recent years, computer simulation methods are becoming popular in scientific research, particularly as far as the research on the aquatic environment quality is concerned, Methods of computer analysis have become an independent branch of research, which substantially increases the research capabilities of modern eco-engineers, [Holnicki et al., 2000]. Total Maximum Daily Loads of metals were determined to achieve water quality standards. In this work using a mathematical equation for assessment of water quality through identification of the TMDL of Euphrates River. In this chapter all the data were obtained from the Ministry of Environment, 2021 and from the Ministry of water resources, 2021.

#### **3.2 Experimental Plan**

The experimental plan initially has various observation and assessment on water quality and quantity, distribution of point and non-point source of pollution, and the tributaries and braches of the river. The data collecting system was systematically obtained sequentially for effective work.



**Fig. 3.1: The research experimental plan.**

### 3.3 Study area

The longest river in southwest Asia is the Euphrates River. 2786 km its total length and have an area which it estimated at about 440000 km<sup>2</sup> distributed in five countries. These countries are: 47% in Iraq , 28% in Turkey, 22% in Syria, 2.97% in Saudi Arabia as shown in Table 3.1. The people of the catchment area is estimated to reach 23 million they are shared by (7.13) in Turkey, (5.75) in Syria, and (10.12) in Iraq, [ESCWA, 2013].

The Euphrates originates in Turkey and movements south toward to Syria and to Iraq. It joins with Tigris River in the southern part of Iraq at Qurna, [Nadhir, et al., 2008].

Al-Hindiya dam plays a major part in the Euphrates river water allocation downstream and distributes the Euphrates flow among four branches. The largest one is the main channel of the Euphrates river which movements toward the south of Iraq. The second one is the Shatt Al-Hillah branch which flows toward the Babylon Governorate. The last two branches are the al-Musayab Canal which is used to water the farming land of the project of al-Musayab, and al-Hussiniah Canal which is used to water the agricultural land of Karbala Governorate, [Khayyun and Todd, 2009].

In antiquity, the Euphrates didn't join the Tigris River and the two rivers reached the Arabic Gulf separated. The evolution of the deltas of both rivers made a very large marsh area and creation of Shatt Al-Arab, [Kornfeld, 2008].

**Table 3.1: The area of the Euphrates Basin, [ESCWA, 2013].**

Countries	Euphrates River	
	Catchment area,(km <sup>2</sup> )	Catchment area,(%)
Turkey	125000	28.2
Syria	76000	17.1
Iraq	177000	39.9
Saudi Arabia	66000	14.9
Total	444000	100

The Euphrates River basin is categorized by the varies significantly of topography from it's source to the estuary of it. The foundation area is categorized by the Mediterranean climate, where it is dry and hot in summer and cold and wet in winter. Most of the mountains in the headwater area are covered with snow during winter. The mean annual precipitation reaches 1000 mm and gradually decreases toward the south, [Mahmoud, 2010; ESCWA, 2013].

When the Euphrates river reaches Syria, still affected by the Mediterranean climate prevails, but less than what it is in the first parts of the basin. Summer is also dry and hot and winter is wet, but, the annual mean precipitation is about 300 mm. The evapotranspiration reaches (2000 to 2800) mm/year and relative humidity varies from (45 to 55) %, [Mahmoud, 2010].

The portion of the Euphrates River that is situated within the Mesopotamian Plain is categorized by hot summer, where the temperature ranges (39-50)°C and the mean annual rainfall ranges from (150–200) mm/year additional south, the climate becomes drier and the mean annual rainfall decrease to less than 50 mm/year, [ESCWA, 2013].

Euphrates River passes through many towns and villages thus it represents the main source for different uses such as: [Hussein, 2013]

- Irrigation: Irrigation for large agricultural areas located on both sides of the river.
- Water supply systems: Water supply for many water treatment plants.
- Industrial purposes: 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: [Siders and Karl, 2020]

- Careless use of pesticides can contaminate water sources and make the water unsuitable for drinking. Wastes of animals and plants from agricultural areas are discharged into the river on both sides.
- Municipal wastes.
- Industrial wastes.

The study area (Fig. 3.2) is located between N 32°47'44" latitude and E 44°17'24" longitude at S<sub>1</sub> to S<sub>5</sub> with N 32°22'23.4" latitude and E 44°39'05" longitude.

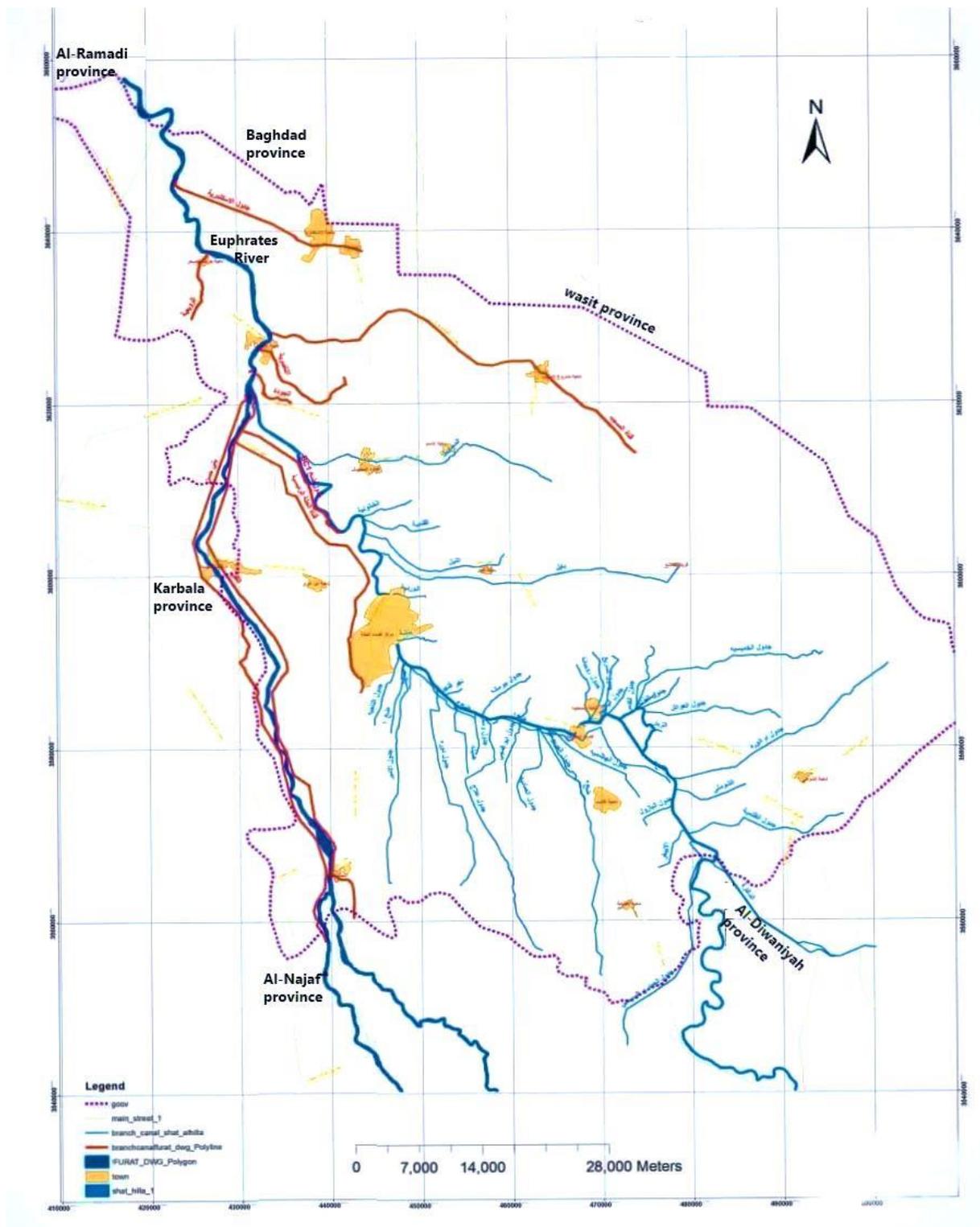


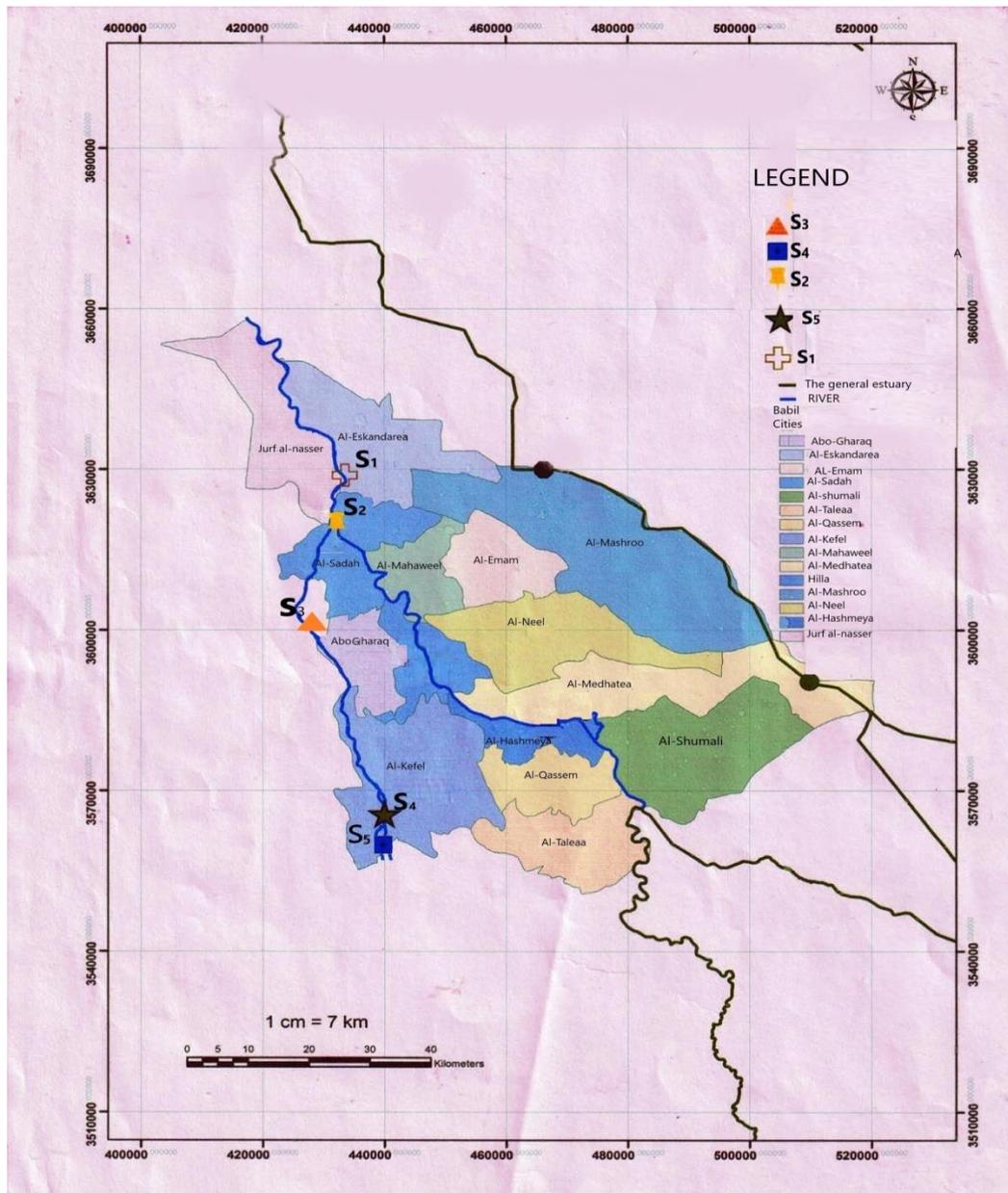
Fig. 3.2: Euphrates River branches and it's tributaries , [Ministry of Water Resources, 2021].

### 3.4 Stations

Sampling stations are classified as point and non-point sources of pollution. Point source of pollution stations are chosen after each stationary pollutant source and before any drinking water intakes. In this study, the point source of two stations ( $S_1$  at the electric power plant and  $S_2$  at the cement factory) and the non-point sources are in the stations ( $S_3$ ,  $S_4$ , and  $S_5$ ) as shown in Fig. 3.3. Table 3.2 summarizes samples location along the Euphrates River in the study area.

**Table 3.2: locations of samples in the Euphrates River, [Ministry of Environment, 2021].**

Stations	Longitude	Latitude
$S_1$	E 44°17'24"	N 32°47'44"
$S_2$	E 44°16'32.5"	N 32°42'42.6"
$S_3$	E 44°26'23.4"	N 32°28'32"
$S_4$	E 44°21'47.6"	N 32°13'33.2"
$S_5$	E 44°39'05"	N 32°22'23.4"



**Fig. 3.3: Administrative map showing the locations of samples along Euphrates River, [Ministry of Water Resources, 2021] .**

### 3.5 Raw Water Characteristics

The data of raw water characteristics were collected from five stations along the Euphrates River during the period of January to December from the year 2021. Tables 3.3 shows the physical, chemical and biological characteristics, [Ministry of Environment, 2021].

**Table 3.3: Raw Water Characteristics of Euphrates River at the study area, [Ministry of Environment, 2021].**

Station	Value	pH	Alk. mg/L	CL mg/L	Mg mg/L	K mg/L	N mg/L	SO <sub>4</sub> mg/L	NO <sub>3</sub> mg/L	DO mg/L	TDS mg/L	TH mg/L	Ca mg/L	PO <sub>4</sub> mg/L	Tur. N.T.U
1	Max.	7.9	164	187.3	45.95	6.45	150.2	348.9	2.115	10.6	1096	456.3	127.1	0.265	20.4
	Min.	7.35	98	143.9	28.06	3.25	108.1	235.9	0.725	5.55	607.3	343.9	94.35	0.16	5.75
	St. dev.	0.151	18.60	12.95	5.01	0.87	12.06	44.53	0.469	1.406	170.6	32.35	12.29	0.032	3.82
2	Max.	7.9	149	188.3	42.3	6.3	145.9	359.9	2	9.25	1109	464.1	124.8	0.27	16.35
	Min.	7	100	142.6	27.6	3.5	110.8	220.1	0.805	6.2	611.3	390	95.1	0.13	4.95
	St. dev.	0.278	16.55	15.75	4.62	0.78	11.43	49.85	0.413	0.785	169.4	21.23	10.11	0.036	4.15
3	Max.	8	166	183.4	44.6	6.45	143	454.9	1.8	12.22	1063	468	127.9	0.25	16.4
	Min.	7.5	92	135	29.4	3.55	102.5	229.4	0.78	6.1	626.8	306.1	88.4	0.145	3.6
	St. dev.	0.166	19.41	14.9	4.12	0.85	11.55	69.37	0.352	1.659	175.7	46.17	12.88	0.032	4.01
4	Max.	8	154	264.1	56.65	7.3	172.3	423.6	2.01	13	1142	501.5	129.5	0.255	18.4
	Min.	7.4	95	162.5	31.3	4.05	132.3	248.1	0.79	6.3	725.5	405.6	101.4	0.145	2.4
	St. dev.	0.205	12.03	26.43	7.17	0.19	14.01	50.15	0.419	1.895	141.4	28.53	8.94	0.032	4.38
5	Max.	8	147	208.9	48.1	6.9	157.7	439.3	1.8	12.6	1091	484.8	128.7	0.256	20.2
	Min.	7.5	99.5	150.5	32.6	3.8	81.7	249.4	0.8	6.2	676.1	355.9	97.3	0.18	7.02
	St. dev.	0.167	15.72	16.18	4.66	0.86	18.46	57.34	0.397	1.743	152.9	34.30	10.52	0.025	3.74

### 3.6 River Discharge

The annual water flow of the Euphrates River was decreases in Iraq, mainly due to the construction of dams in Turkey, Syria, and Iraq and due to climate changes.

Table 3.4 shows the flow variations of Euphrates River with the study area through the months in which the samples were taken, [Ministry of Water Resources, 2021].

**Table 3.4: Euphrates River Discharge Changes With The Study Area, [Ministry of Water Resources, 2021].**

Station	Max. m <sup>3</sup> /sec	Min. m <sup>3</sup> /sec	St. dev.
1	37	35	0.652
2	35	32	0.985
3	30	28	0.603
4	24	22	0.715
5	20	18	0.875

# **CHAPTER FOUR**

## **DATA ANALYSES AND DISCUSSION**

## **CHAPTER FOUR**

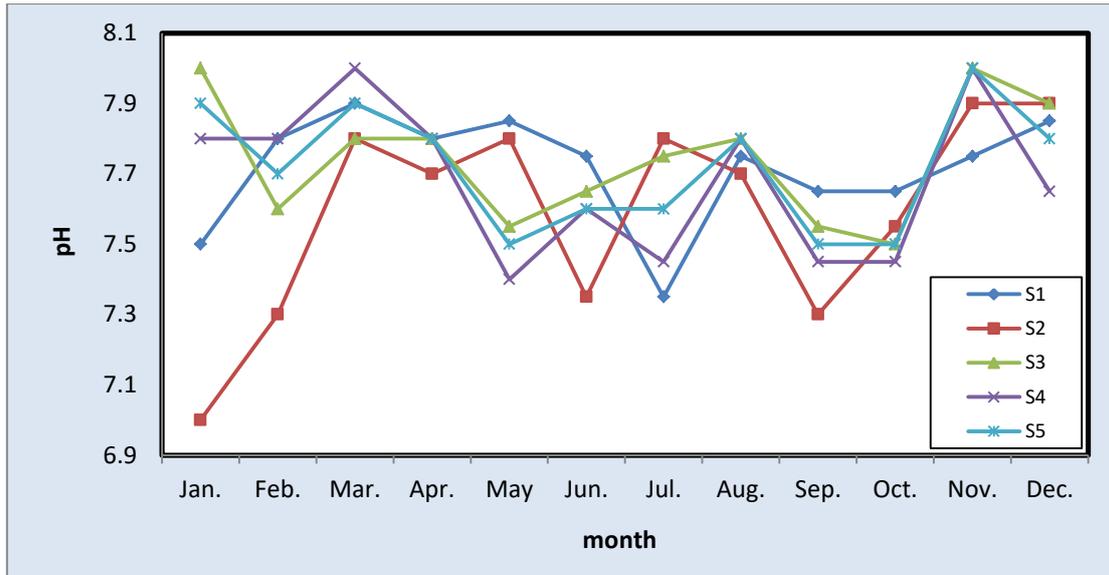
### **DATA ANALYSES AND DISCUSSION**

#### **4.1 Introduction**

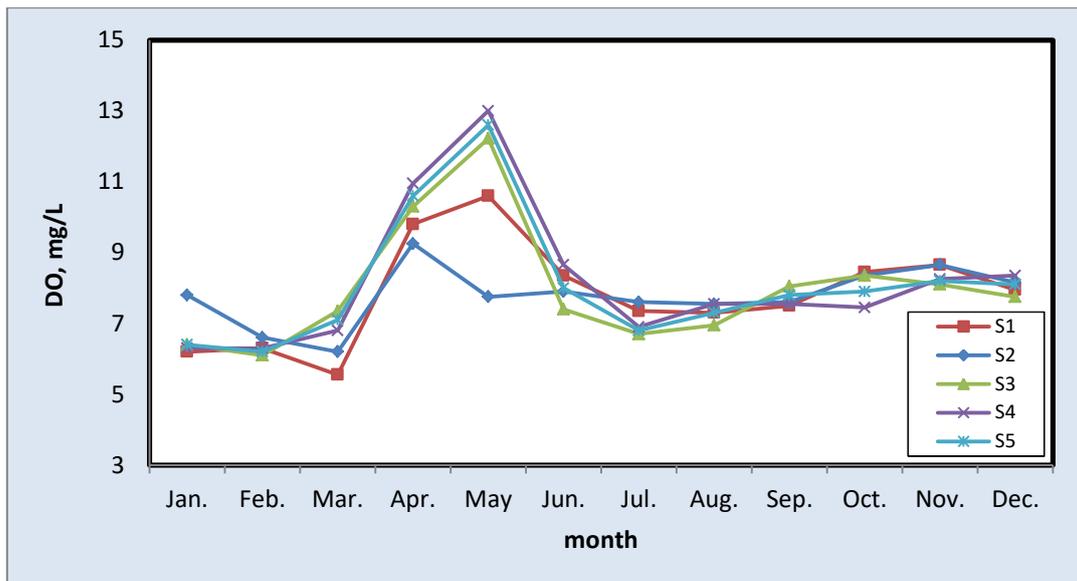
In this chapter, the results of Total Maximum Daily Loads of raw water characteristics for selected stations along the Euphrates River through the study area were determined and discussed. This chapter is divided into two sections. The first section represents the variation of physical and chemical water characteristics through the study period and the second section contained the calculation of the TMDLs for the parameters concentrations of the study (Ca, PO<sub>4</sub>, N, SO<sub>4</sub>, NO<sub>3</sub>, K, CL, and Mg).

#### **4.2 Variation of Parameters**

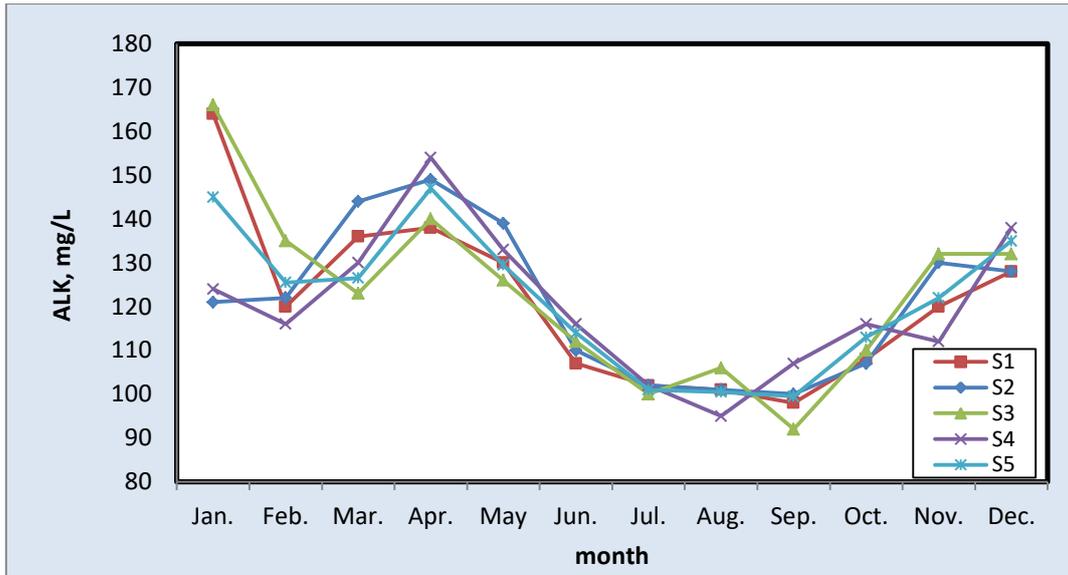
The concentrations and flow vary considerably over time, especially NPS situations. This varies according to the polluted source (point or non-point source) and according to the weather (hot or cold) through the seasons of the year. The study was conducted during the period from January to December of 2021. Figs. show the variations for each parameter during the study period.



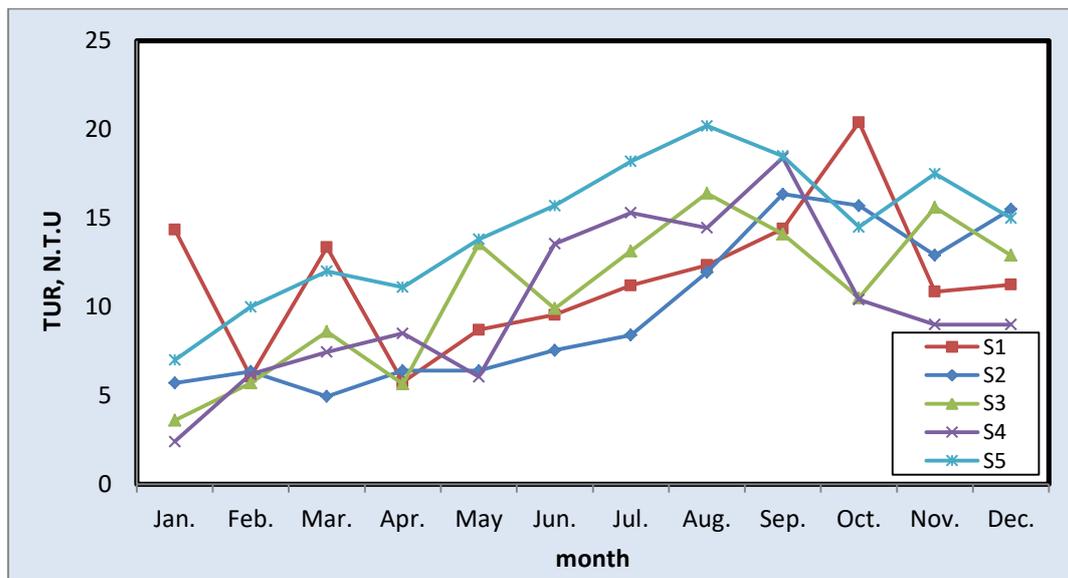
**Fig. 4.1: Variation of pH value at the selected stations during the study period.**



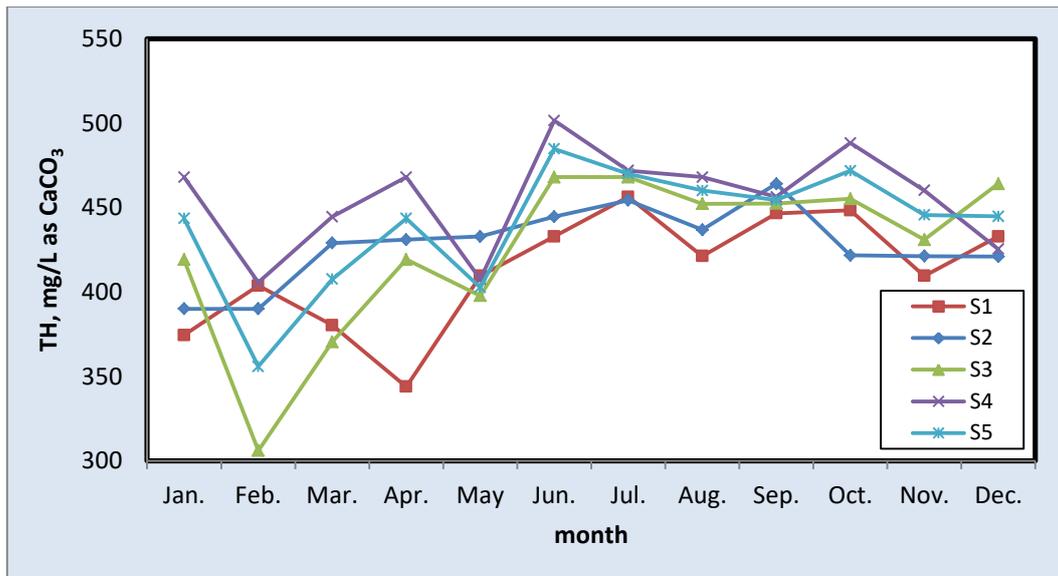
**Fig. 4.2: Variation of the dissolved oxygen at the selected stations during the study period.**



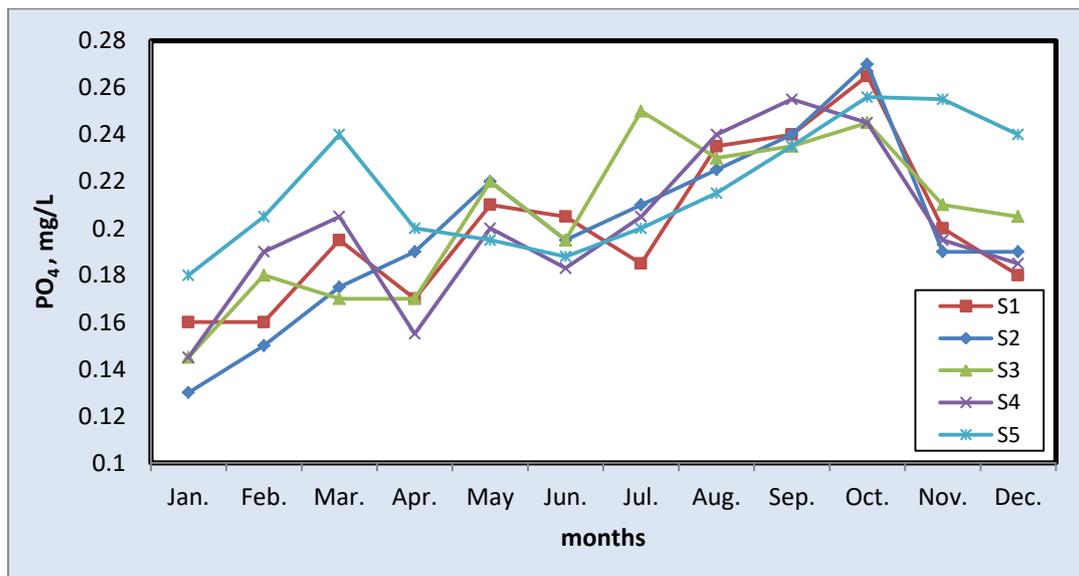
**Fig. 4.3: Variation of the alkalinities at the selected stations during the study period.**



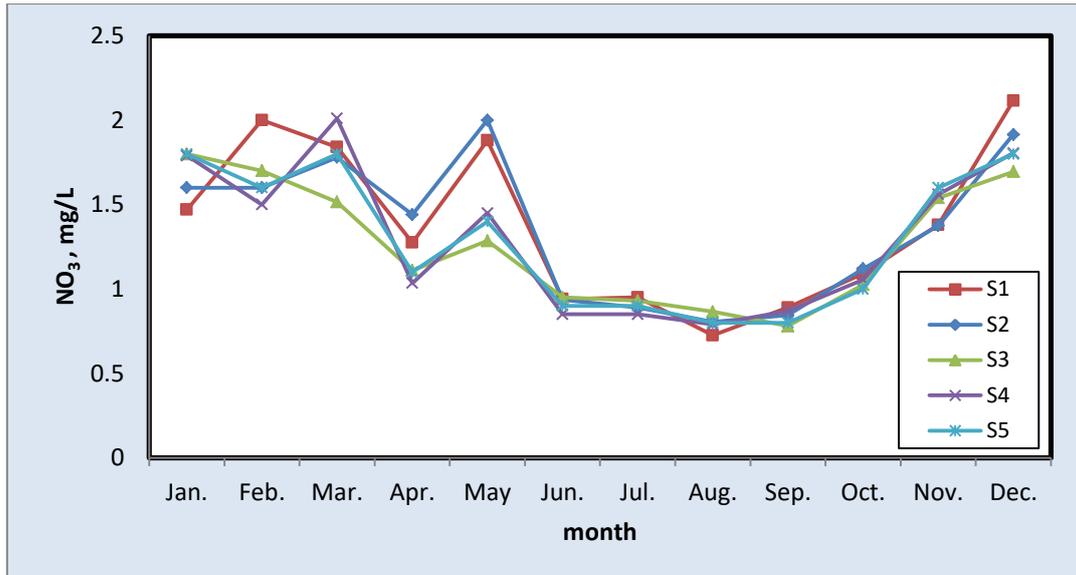
**Fig. 4.4: Variation of Turbidity at the selected stations during the study period.**



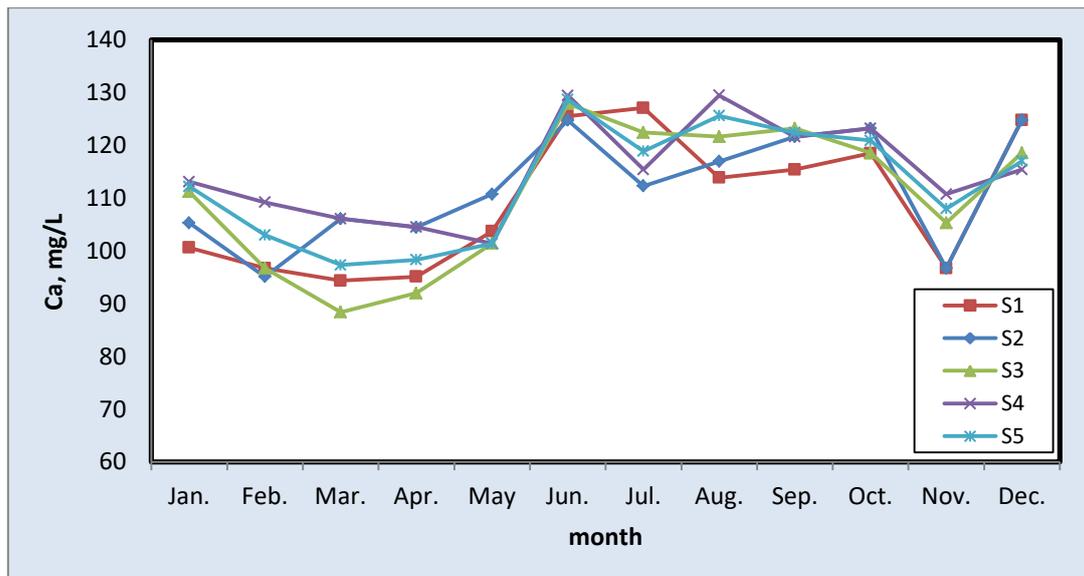
**Fig. 4.5: Variation of Total Hardness at the selected stations during the study period.**



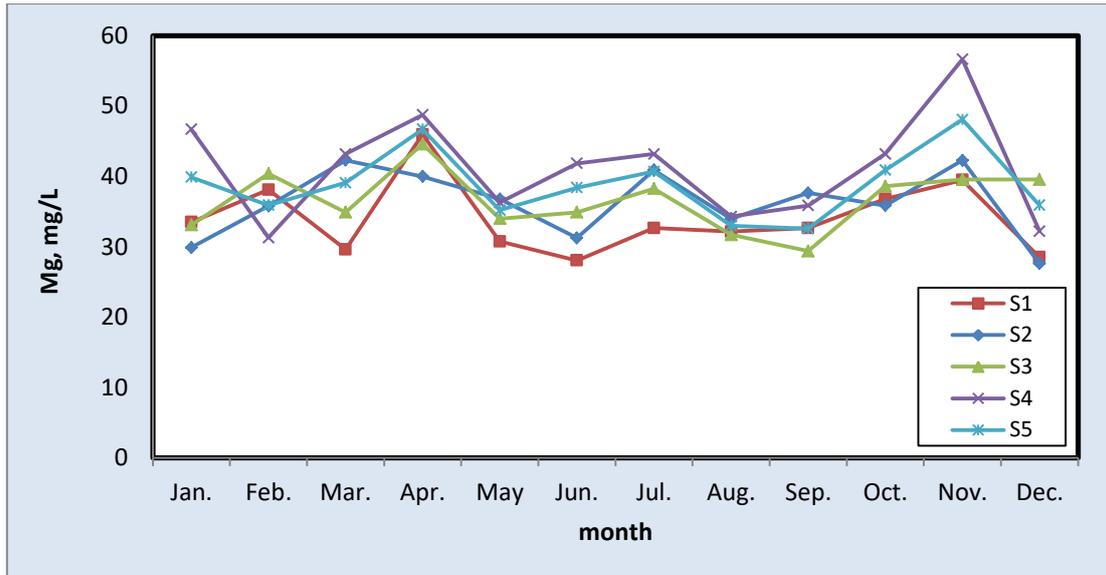
**Fig. 4.6: Variation of PO<sub>4</sub> at the selected stations during the study period.**



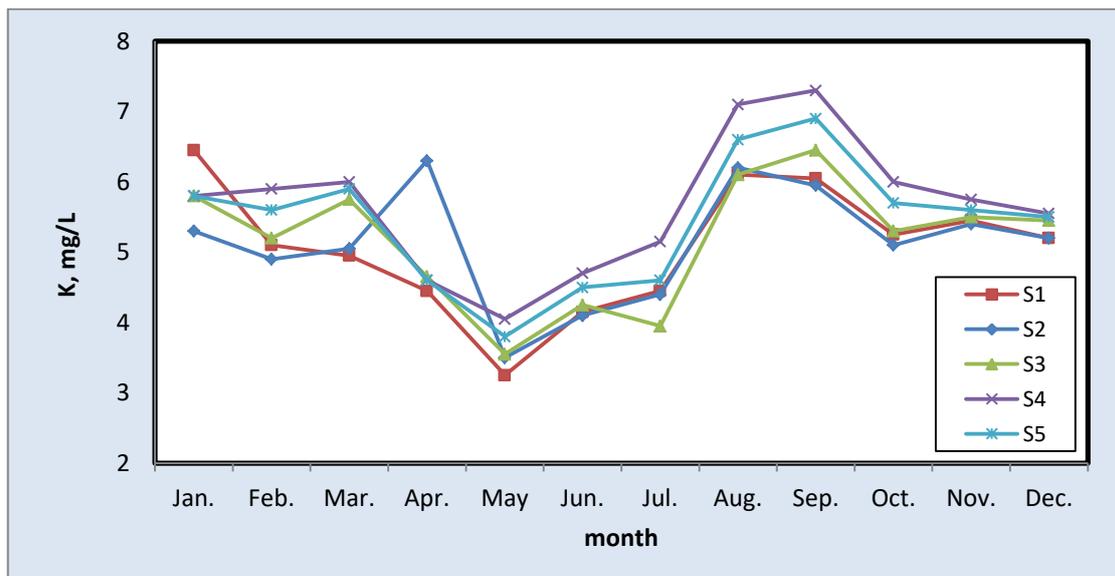
**Fig. 4.7: Variation of  $\text{NO}_3$  at the selected stations during the study period.**



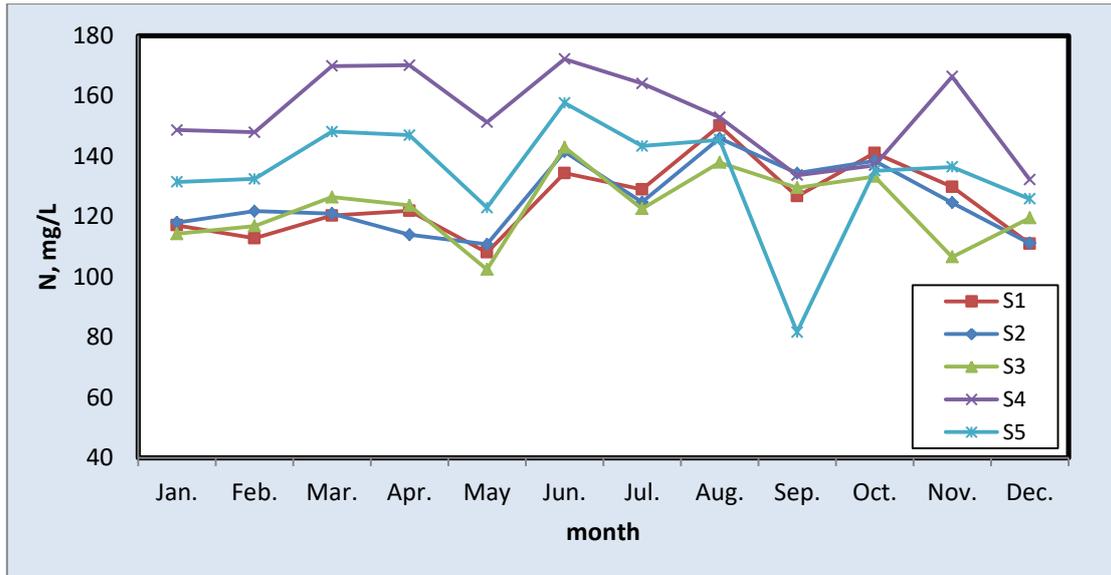
**Fig. 4.8: Variation of Ca at the selected stations during the study period.**



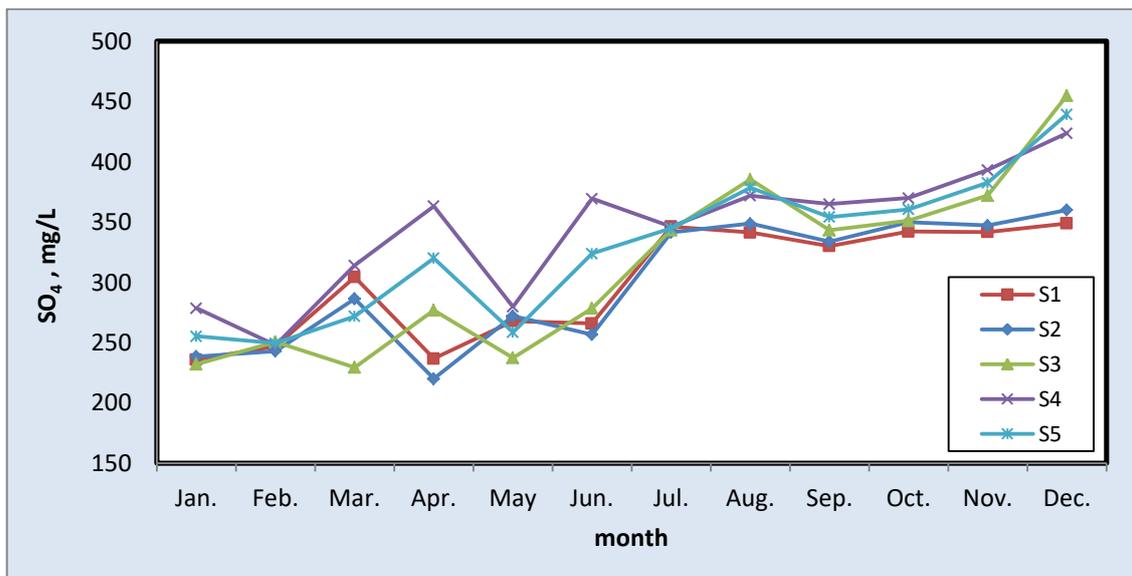
**Fig. 4.9: Variation of Mg at the selected stations during the study period.**



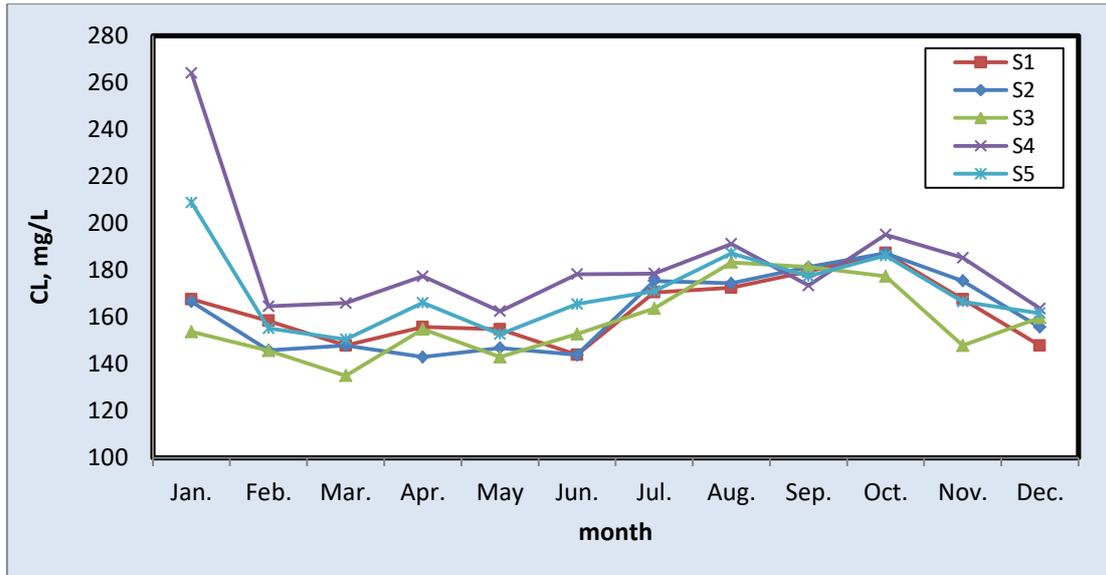
**Fig. 4.10: Variation of K at the selected stations during the study period.**



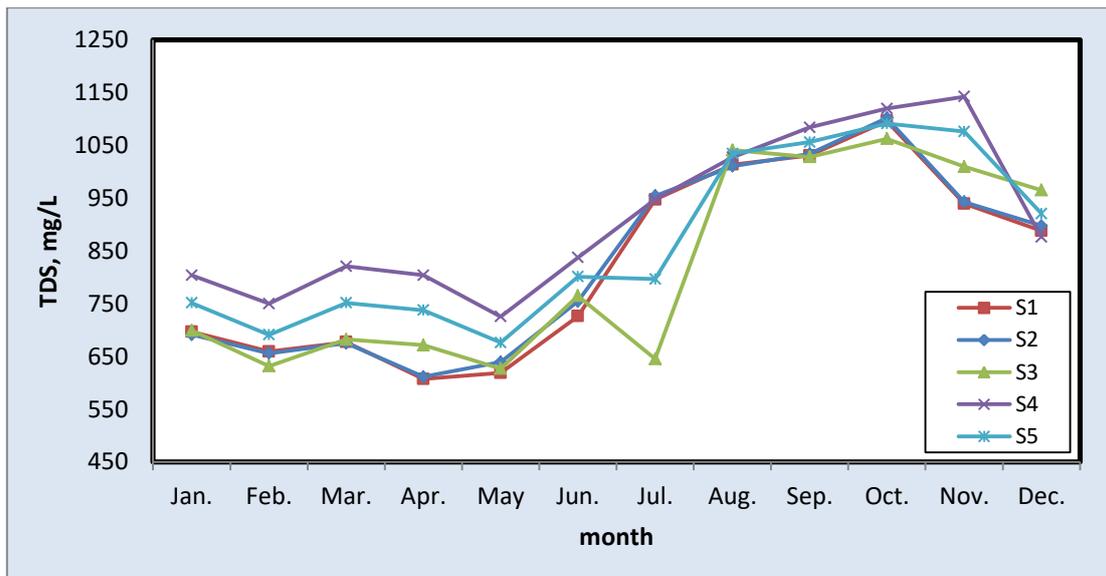
**Fig. 4.11: Variation of N at the selected stations during the study period.**



**Fig. 4.12: Variation of SO<sub>4</sub> at the selected stations during the study period.**



**Fig. 4.13: Variation of CL at the selected stations during the study period.**



**Fig. 4.14: Variation of Total Dissolved Solids at the selected stations during the study period.**

### 4.3 Total Maximum Daily Loads Calculation

TMDL calculations were developed for Nitrate, Total Phosphate, Calcium, Magnesium, Potassium, Chloride, Nitrogen, and Sulfate. TMDLs were calculated by using "Excel" program Software and applying equation 2.1 for parameters in each station. Using an explicit margin of safety of 5% based on previous studies. Load Allocation was calculated in three stations (3, 4, and 5) as non-point and Waste Load Allocation was calculated in two stations (1 and 2) as point sources.

Tables 4.1, and 4.2 show the TMDLs for point source and non-point source respectively. The TMDL in each station is the average of the TMDLs during the study period, Table 4.3 shows the average TMDLs for the five stations, during the study period.

**Table 4.1: TMDLs for point source locations during the study period.**

Station	Month	TMDL ( kg/day)							
		PO <sub>4</sub>	NO <sub>3</sub>	Ca	Mg	K	N	SO <sub>4</sub>	CL
1	Max.	78.05	95.16	389.02	146.01	85.67	454.65	1671.63	925.58
	Min.	60.71	77.15	294.82	87.01	76.22	339.21	956.03	867.38
	St. dev.	4.662	6.190	34.472	16.007	2.371	34.059	246.879	16.771
2	Max.	71.54	92.02	360.89	127.25	80.03	406.39	1387.36	958.68
	Min.	57.85	77.89	276.57	79.03	75.23	320.56	902.74	866.52
	St. dev.	3.602	5.240	24.841	14.087	1.576	26.797	129.623	28.639

**Table 4.2: TMDLs for non-point source locations during the study period.**

Station	Month	TMDL ( kg/day)							
		PO <sub>4</sub>	NO <sub>3</sub>	Ca	Mg	K	N	SO <sub>4</sub>	CL
3	Max.	69.85	96.22	313.95	114.87	78.63	366.47	1574.35	906.17
	Min.	58.61	76.68	229.85	72.61	73.59	255.45	885.15	834.98
	St. dev.	3.457	5.096	27.270	11.218	1.398	30.989	181.906	22.075
4	Max.	72.93	86.03	258.54	112.47	75.65	364.99	977.33	920.22
	Min.	53.25	75.11	209.99	63.89	73.02	260.05	882.74	812.35
	St. dev.	4.569	3.166	13.127	15.133	0.794	36.061	32.043	30.956
5	Max.	63.43	82.55	221.68	84.53	74.58	271.12	940.96	820.5
	Min.	49.25	74.02	175.49	52.23	72.12	132.63	834.42	800.22
	St. dev.	4.231	2.487	12.572	8.984	0.665	34.972	30.212	5.912

**Table 4.3: Average TMDLs for the study parameters during the study period.**

Station	TMDL ( kg/day)							
	PO <sub>4</sub>	NO <sub>3</sub>	Ca	Mg	K	N	SO <sub>4</sub>	CL
1	67.68	86.49	337.73	105.30	79.56	386.23	1201.69	896.62
2	64.63	84.65	322.60	100.42	77.73	361.98	1021.89	900.03
3	64.02	82.8833	275.56	91.41	75.93	309.10	1007.36	870.34
4	60.06	79.56	230.58	85.72	74.17	306.60	934.01	836.86
5	55.01	77.45	191.97	65.99	73.46	228.86	890.21	810.56

The change in TMDL results for each parameter during the study period for the five stations

### **4.3.1 Phosphate PO<sub>4</sub>**

TMDL of PO<sub>4</sub> ranges from (49.25 to 78.05) kg/day at the locations for point and non-point sources. It's highest average value during the study period was in station one (S<sub>1</sub>) which reached 67.68 kg/day and it's average in the Euphrates River in the study area was 62.28 kg/day.

### **4.3.2 Nitrate NO<sub>3</sub>**

TMDL value of NO<sub>3</sub> ranges from (74.02 to 96.22) kg/day at the locations for point and non-point sources. It's highest average value during the study period was in station one (S<sub>1</sub>) which reached 86.49 kg/day and it's average in the Euphrates River in the study area was 82.22 kg/day.

### **4.3.3 Calcium Ca**

TMDL value of Ca ranges from (175.49 to 389.02) kg/day at the locations for point and non-point sources. It's highest average value during the study period was in station one (S<sub>1</sub>) which reached 337.73 kg/day and it's average in the Euphrates River in the study area was 271.69 kg/day.

### **4.3.4 Magnesium Mg**

TMDL value of Mg ranges from (52.23 to 146.01) kg/day at the locations for point and non-point sources. It's highest average value during the study period was in station one (S<sub>1</sub>) which reached 105.30 kg/day and it's average in the Euphrates River in the study area was 90.57 kg/day.

### **4.3.5 Potassium K**

TMDL value of K ranges from (72.12 to 85.67) kg/day at the locations for point and non-point sources. It's highest average value during the study period was in station one (S<sub>1</sub>) which reached 79.56 kg/day and it's average in the Euphrates River in the study area was 76.16 kg/day.

### **4.3.6 Nitrogen N**

TMDL value of N ranges from (132.63 to 454.65) kg/day at the locations for point and non-point sources. It's highest average value during the study period was in station one (S<sub>1</sub>) which reached 386.23 kg/day and it's average in the Euphrates River in the study area was 318.56 kg/day.

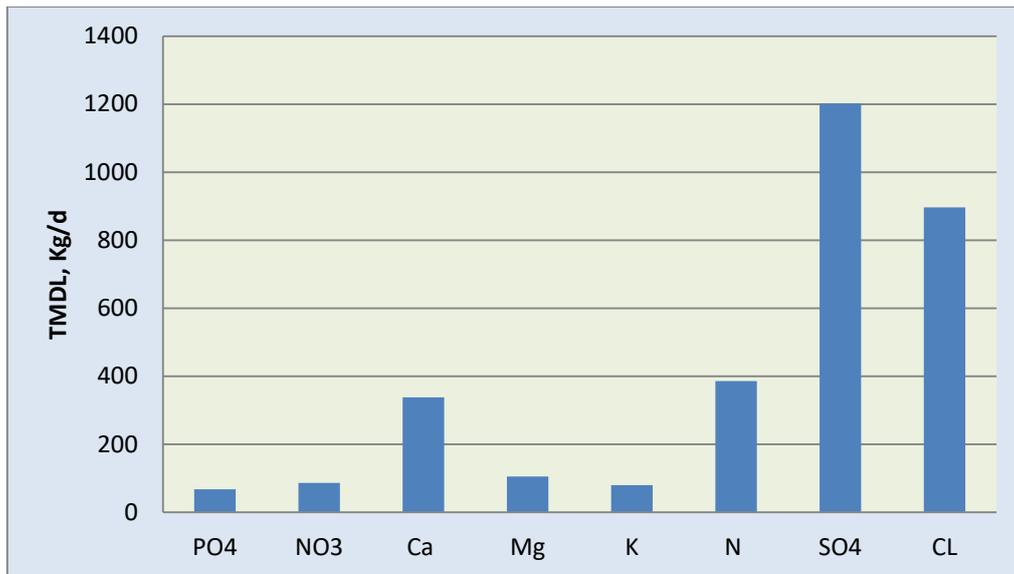
### **4.3.7 Sulfates SO<sub>4</sub>**

TMDL value of SO<sub>4</sub> ranges from (834.42 to 1671.63) kg/day at the locations for point and non-point sources. It's highest average value during the study period was in station one (S<sub>1</sub>) which reached 1201.69 kg/day and it's average in the Euphrates River in the study area was 1011.34 kg/day.

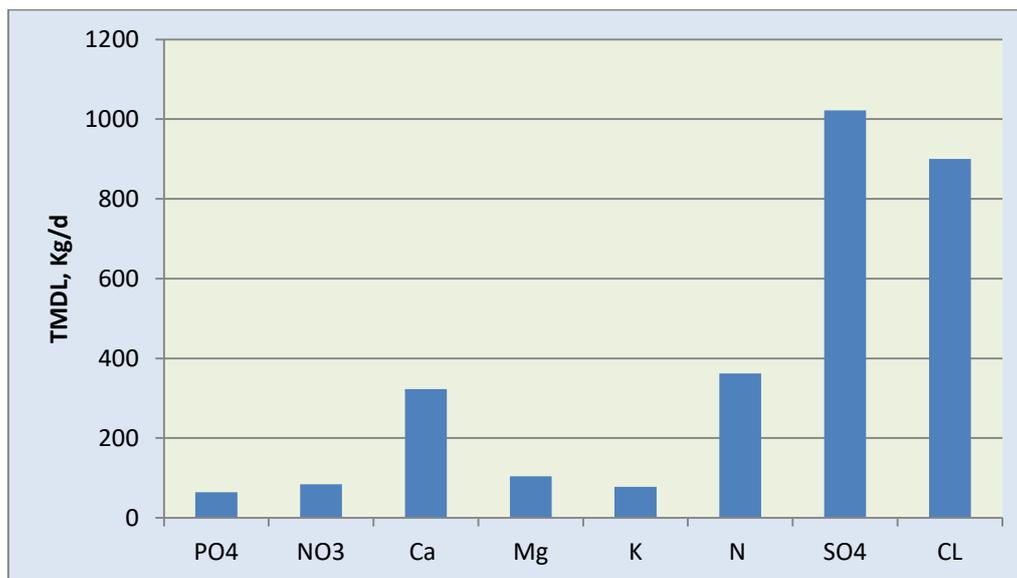
### **4.3.8 Chloride CL**

TMDL value of CL ranges from (800.22 to 958.68) kg/day at the locations for point and non-point sources. It's highest average value during the study period was in station two (S<sub>2</sub>) which reached 900.03 kg/day and it's average in the Euphrates River in the study area was 862.87 kg/day.

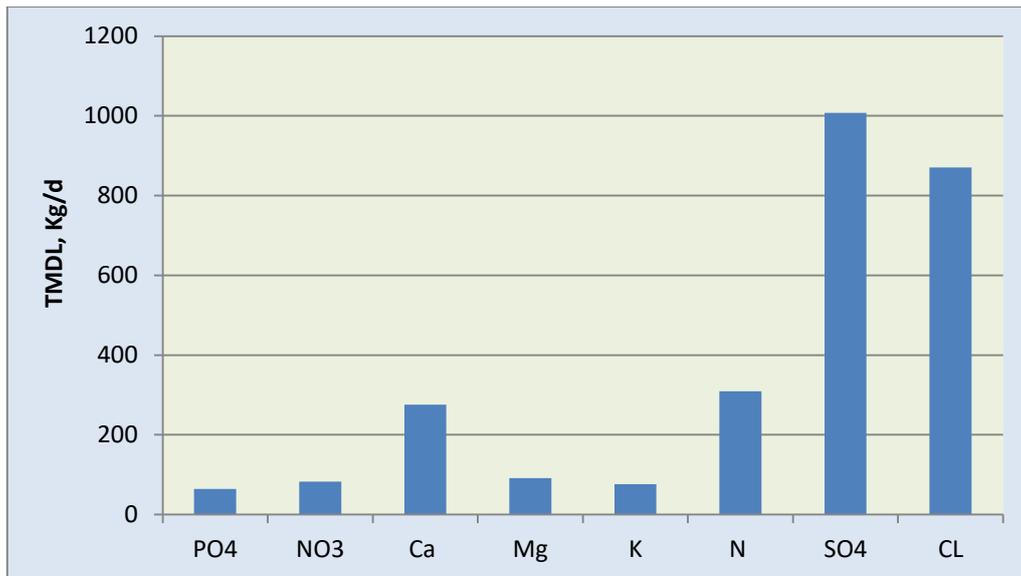
Figs. below explain the difference in the value of TMDL for the study parameters at each station.



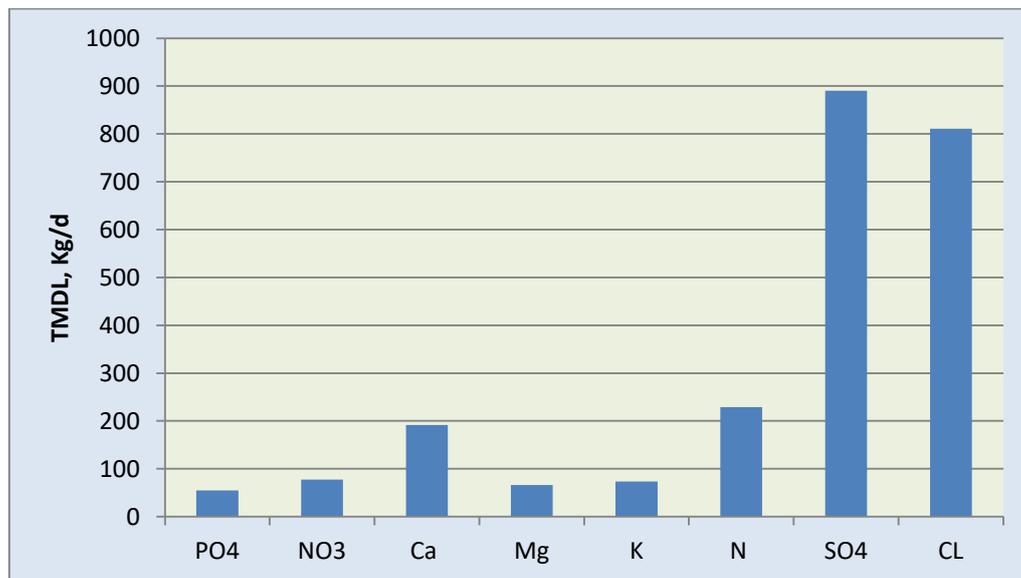
**Fig. 4.15: TMDLs for the study parameters in Euphrates River at station one (S<sub>1</sub>).**



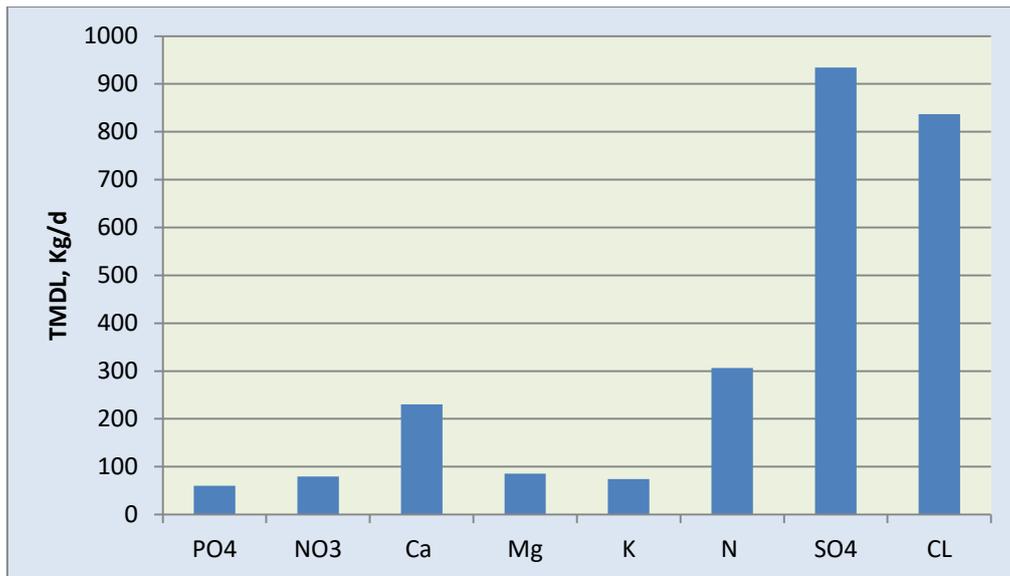
**Fig. 4.16: TMDLs for the study parameters in Euphrates River at station two (S<sub>2</sub>).**



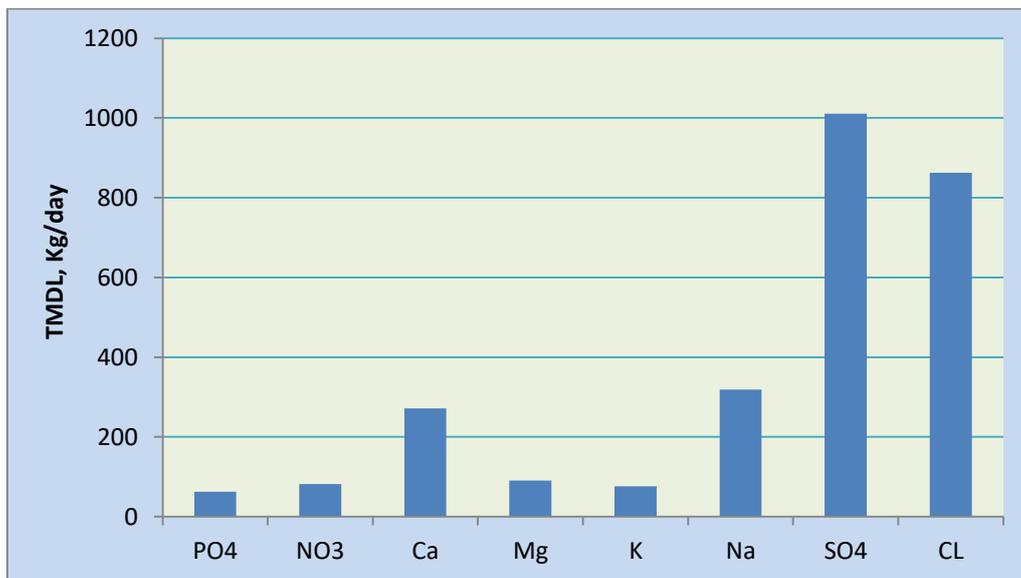
**Fig. 4.17: TMDLs for the study parameters in Euphrates River at station three (S<sub>3</sub>).**



**Fig. 4.18: TMDLs for the study parameters in Euphrates River at station four (S<sub>4</sub>).**



**Fig. 4.19:** TMDLs for the study parameters in Euphrates River at station five (S<sub>5</sub>).



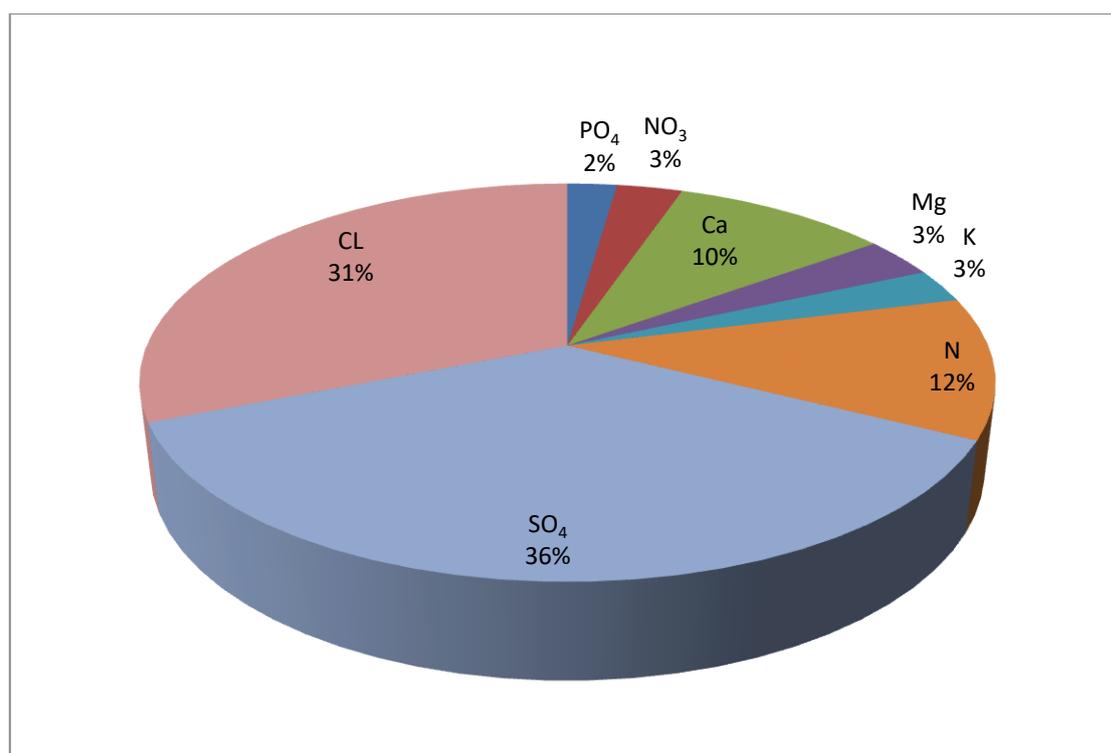
**Fig. 4.20:** TMDLs for the study parameters in Euphrates River at the study area.

In the results some concentrations were very high, especially for sulfates and chloride. These variations are due to the changes in flows of the Euphrates River during the study period, the type of pollution source (point or non-point) in the sampling stations, and due to the long beach of

Euphrates River and uncontrolled and direct disposing of different pollutants.

In general, the water of the Euphrates River was more polluted in station one (S<sub>1</sub>) and less in station four (S<sub>4</sub>) and station five (S<sub>5</sub>).

Based on previous results as a percentage, the highest values of the Euphrates River pollutants obtained in the study were sulfates, which reached 36%, followed by chlorine 31%, sodium 12%, and calcium 10%. while the other pollutants, their percentage was little (under 10%). These percentages explain in Fig. 4.21.



**Fig. 4.21: The percentages of pollutants in the Euphrates River during the study period.**

# **CHAPTER FIVE**

## **CONCLUSIONS AND RECOMMENDATIONS**

# CHAPTER FIVE

## CONCLUSIONS AND RECOMMENDATIONS

### 5.1 Conclusions

The following conclusions were reached by studying the results of this study:

1. TMDL highest average of  $\text{PO}_4$  value during the study period was in station one ( $S_1$ ) which reached 67.68 kg/day and its average in the Euphrates River in the study area was 62.28 kg/day.
2. TMDL highest average value of  $\text{NO}_3$  during the study period was in station one ( $S_1$ ) which reached 86.49 kg/day and its average in the Euphrates River in the study area was 82.22 kg/day.
3. TMDL highest average value of Ca during the study period was in station one ( $S_1$ ) which reached 337.73 kg/day and its average in the Euphrates River in the study area was 271.69 kg/day.
4. TMDL highest average value of Mg during the study period was in station one ( $S_1$ ) which reached 105.30 kg/day and its average in the Euphrates River in the study area was 90.57 kg/day.
5. TMDL highest average value of K during the study period was in station one ( $S_1$ ) which reached 79.56 kg/day and its average in the Euphrates River in the study area was 76.16 kg/day.
6. TMDL highest average value of N during the study period was in station one ( $S_1$ ) which reached 386.23 kg/day and its average in the Euphrates River in the study area was 318.56 kg/day.

7. TMDL highest average value of  $\text{SO}_4$  during the study period was in station one ( $S_1$ ) which reached 1201.69 kg/day and its average in the Euphrates River in the study area was 1011.34 kg/day.
8. TMDL highest average value of CL during the study period was in station two ( $S_2$ ) which reached 900.03 kg/day and its average in the Euphrates River in the study area was 862.87 kg/day.
9. Phosphate constitutes the lowest percentage among the other calculated parameters as its percentage was 2%. Where Nitrate, Potassium, and Magnesium constitute 3%. and higher than were the percentage for Calcium, Sodium, Chloride, and Sulfate which was 10%, 12%, 31%, 36% respectively.

## 5.2 Recommendations

The following recommendations were for future studies:

1. Establishing river water monitoring stations to show the water quality and its impact on various environmental factors.
2. Conducting periodic measurements of the level of concentrations of trace elements and the organic matter that is thrown into the Euphrates River without treatment.
3. Can use different methods of load estimation in considerably different estimates of pollutant load. Choose the preferred one built on project objectives and monitoring resources.
4. Both discharge and pollutant concentrations are very variable. Usually, continuous flow measurement and recurrent water quality samples are wanted to exactly and reliably determine the true load pattern.
5. This study can be applied to the Tigris River to calculate the maximum daily load.

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## الملخص

إن تأثير مصادر التلوث على جودة المياه المستقبلية متنوعة وتعتمد على نوع وتركيز الملوثات في حوض النهر. حيث إن إجمالي الحمل اليومي الأقصى للملوثات يجب أن يحسب لكل ملوث من تلك الملوثات، خلال عملية النقل والانتقال من المنبع إلى المصب. وقد يكون هناك العديد من المصادر النقطية والغير نقطية التي لا يمكن أن تقي بمعيار جودة المياه. هناك حلول ممكنة ومتعددة توفر فرصة للجهات التنظيمية وأصحاب الاختصاص لإيجاد إجمالي الحمل اليومي الأقصى المناسب والأكثر قبولاً.

أجريت الدراسة الحالية على نهر الفرات. وكان الهدف منها دراسة وتقدير إجمالي الحمل اليومي الأقصى للمنطقة. تم جمع وتحليل بيانات المياه الخام التي تم الحصول عليها من وزارة البيئة من خمس محطات لنهر الفرات ( $S_1, S_2, S_3, S_4, S_5$ ) خلال الفترة من كانون الثاني إلى كانون الأول من عام 2021. والغرض من ذلك هو تقييم وقياس مستوى المطروحات وتأثيراتها على النهر. تم استخدام التحليل الإحصائي لوصف العلاقات بين إجمالي الحمل اليومي الأقصى والملوثات وتم إجراء تحليل الانحدار بواسطة برنامج "Excel".

تم جمع أربعة عشر خاصية لمياه نهر الفرات. تم حساب إجمالي أقصى حمل يومي لثمانية منها فقط، وهذه المتغيرات هي: النترات ( $NO_3$ )، الفوسفات الكلي ( $PO_4$ )، الكالسيوم (Ca)، المغنيسيوم (Mg)، البوتاسيوم (K)، الكلوريد (Cl)، النيتروجين (N)، والكبريتات ( $SO_4$ ). وكانت متوسط قيم TMDL في منطقة الدراسة كما يلي: 82.22 كجم/يوم للنترات ، 62.28 كجم / يوم للفوسفات الكلي، 271.69 كجم/يوم للكالسيوم، 90.57 كجم/يوم للمغنيسيوم، 76.16 كجم/يوم للبوتاسيوم، 862.89 كجم/يوم للكلوريد، 318.56 كجم/يوم للنيتروجين ، و 1011 كجم/يوم للكبريتات على التوالي.

وأظهرت الدراسة أن تصريف مياه الصرف الصحي المنزلية ومياه الصرف الصناعي من المناطق المجاورة تسبب في مستويات تلوث أعلى من المعايير العراقية. وقد تم تسجيل أعلى قيم لـ TMDL في المحطة الأولى (S1) وكان العنصر الأكثر تلوثاً في نهر الفرات خلال فترة الدراسة هو الكبريتات.



جمهورية العراق  
وزارة التعليم العالي والبحث العلمي  
جامعة بابل / كلية الهندسة  
قسم الهندسة المدنية

# إجمالي الحمل اليومي الأقصى كأداة تخطيطية لتحقيق جودة مياه نهر الفرات

بحث

مقدم الى كلية الهندسة في جامعة بابل كجزء من متطلبات نيل درجة الدبلوم العالي  
في الهندسة / الهندسة المدنية / صحية

من قبل

سرور قيس مرزه حرش

(بكلوريوس هندسة مدنية – 2015)

إشراف

الأستاذ الدكتور علاء حسين الفتلاوي

2022 م

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