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Ministry of Higher
Education and
Scientific Research*



*University of Babylon
College of Engineering
Dept. of Civil Engineering*

EVALUATION OF SELECTED TRACE ELEMENTS IN SHATT AL - HILLA RIVER

A Thesis

*Submitted to the College of Engineering of the University of Babylon in
Partial Fulfillment of the Requirements for the Degree of Master of
Science in Civil Engineering*

*By
Higher Diploma*

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جمهورية العراق

وزارة التعليم العالي والبحث

تقييم عناصر نزره مختارة في نهر شط الحله

رسالة

مقدمة إلى كلية الهندسة في جامعة بابل كجزء من
متطلبات نيل درجة الماجستير في علوم الهندسة
المدنية

من قِبل

علي جليل عبد الكريم جابك

دبلوم عالي / هندسة مدنية

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ABSTRACT

The present study was conducted on Shatt Al-Hilla river and some drinking water treatment plants in Al-Hilla city in the aim of studying the concentration levels of some trace elements (Fe, Cu, Zn, Hg, Pb, and Cd) in addition to other physical and chemical characteristics of water.

Samples of raw and treated water were collected and analyzed from six locations and two water treatment plants during a period of eight months, starting from November 2007 until June 2008. The purpose is to assess the level of trace metals and their effects on the river and treated water quality.

The atomic adsorption technique was used for the determination of trace metals concentrations and the results were analyzed by statistical methods.

For Shatt Al-Hilla river, the investigation revealed significant seasonal, spatial and vertical variations in trace elements in the river.

Results showed that the maximum concentration of the metals (Fe, Cd, and Hg) did not meet the Iraqi system of maintenance for rivers and public waters from pollution No. 25, 1967 with last revisions. While the maximum concentration of the metals (Zn, Cu, and Pb) were met the mentioned standards.

For drinking water the maximum concentration of the metals (Fe, Hg, and Cd) of Al-Hilla Al-Kadeem treatment plant was exceeded the Iraqi standards during June. While the concentrations of copper and lead in June, and zinc in April were within the Iraqi standards. For Al-Hilla Al-Jadeed treatment plant,

the concentrations of Fe in June, Hg in March, and Cd in June were exceeded the allowable Iraqi standards for drinking water. While the concentrations of Cu and Pb in June, and Zn in March were within the Iraqi standards.

It was noticed that the maximum concentration of Fe in both treatment plants (Al-Hilla Al-Kadeem and Al-Hilla Al-Jadeed) exceeded the WHO standards by 97% and 90 % respectively, while the maximum concentration of Hg in Al-Hilla Al-Kadeem and Al-Hilla Al-Jadeed treatment plants exceeded the WHO standards by 81% and 41 % respectively.

This study showed that the mean concentrations of Fe, Zn, Cu, Pb, Cd, and Hg in raw water were (521, 51.94, 49.17, 4.55, 3.61, and 1.487) $\mu\text{g/l}$ respectively.

In the present work, it was found that the most related parameters affecting trace metals distribution in Shatt Al-Hilla river were: Turbidity, hydrogen ion, Temperature, dissolved oxygen, and total suspended solids, and in lower degree with parameters chlorides, sulphates, electrical conductivity, and alkalinity. While total hardness, calcium, and total dissolved solids parameters have low significant affect on trace metals concentrations.

بِسْمِ اللَّهِ الرَّحْمَنِ الرَّحِيمِ

(أَفْرَاءٌ □ يَتَمُّ □ لِمَاءِ الَّذِي

ت □ شَرِبُونَ □ عَائِتُ □ م

أَنْزَرَ □ لَتَمُوهُ مِنْ

□ لِمُنْزِرٍ □ نِ أَمْ □ نَحْنُ □ لِمُنْزِلُونَ، لَوْ

نَشَاءُ جَعَلْنَاهُ أَجَا جَا فُلُوًا

تَشْكُرُونَ))

صدق الله العظيم

الواقعة

آيات (68-70)

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Ali Jalil Abdul Kareem Chabuk

2008

CERTIFICATE

We certify that we have read this thesis, entitled "*Evaluation of Selected Trace Elements in Shatt Al - Hilla River*", and as examining committee, examined the student "*Ali Jalil Abdul Kareem Chabuk*" in its contents and in what is connected with it, and that in our opinion it meets the standard of a thesis for the degree of Master of Science in Civil Engineering.

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TABLE OF SYMBOLS

Symbol	Definition
ICP-AES	Inductivity coupled plasma atomic emission spectroscopy
ICP-MS	Inductivity coupled plasma metal spectroscopy
Sb	Antimony
Sr	Strontium
Rb	Rabidium
Mo	Molybdenum
Mn	Manganese
U	Uranium
Ba	Barium
Cr	Chromium
Ni	Nickel
Co	Cobalt
EPA	Environment protect agency
WHO	World health organization
µg/l	micro gram / liter
mg/l	mille gram / liter.....
pph	Part / hindered (mg/kg)
ppb	Part / billion (mg/tonne)
pH	Hydrogen ion
T.H.	Total hardness
TDS	Total dissolved solid
DO	Dissolved oxygen
TSS	Total suspended solid
TU	Turbidity
Cl	Chlorides
SO ₄	Sulphates
Ec	Electrical conductivity
Ca	Calcium
Alkal.	Alkalinity
Temp.	Temperature
Cd	Cadmium.....
Fe	Iron
Cu	Copper
Hg	Mercury.....
Pb	Lead
Zn	Zinc
AAS	Atomic absorption spectrometry.....
CVAAS	Cold -vapor atomic absorption spectrophotometer...

RE	Removal efficiency of turbidity $\times 100$
RE _{HKM}	Removal efficiency of turbidity $\times 100$ in al- hilla al-kadeem treatment plant for metals
RE _{HJM}	Removal efficiency of turbidity $\times 100$ in al- hilla al-jadeed treatment plant for metals.....
RE _{HKP}	Removal efficiency of turbidity $\times 100$ in al- hilla al-jadeed treatment plant for water quality parameters
RE _{HJP}	Removal efficiency of turbidity $\times 100$ in al- hilla al-jadeed treatment plant for water quality parameters

Table (4-2) : Maximum, and Range of Concentration, and Percentage of Exceeding Health Limits of Drinking Water (µg/l) .

Cd		Cu	Zn	Hg	Pb	Fe	Elements
5	1000	500	1	50	300	WHO for drinking water 2007	
3.74	58.2	57.7	1.81	4.9	592	Max.	Al- Hilla Al- Kadeem Treat ment plant
Zero%	Zero%	Zero%	81%	Zero%	97.3%	Health exceed- ing limit %	
(1.95-3.74)	(28.1-58.2)	(50-57.7)	(0.59-1.81)	(2.5-4.9)	(402-592)	Range	
4.33	51	58	1.41	4.7	570	Max.	Al- Hilla Al- Jadeed Treat ment plant
Zero%	Zero%	Zero%	41%	Zero%	90%	Health exceed- ing limit %	
(2.03-4.33)	(28.9-51)	(41.4-58)	(0.69-1.41)	(2.1-4.7)	(3222-570)	Range	

Chapter One

Introduction

1-1 General Introduction:

Water is one of the main sources for human, animal and plant life, therefore; civilizations have been created in the places where water is available. Most residential and agricultural projects and industrial facilities are built on banks of rivers and near water sources usually due to their importance in sustaining these activities, and because of these activities water sources can be severely polluted due to the disposal of industrial, agricultural and domestic discharges (Al-Taee,1999). Iraq has abundant natural water sources represented by the rivers Tigris and Euphrates and their tributaries and other water bodies, which are the main sources of water for various domestic, agricultural and industrial uses in the country, since more than 95% of the water needs in Iraq relies on surface water (Al-Samarrai, 1999).

1-2 Water Pollution with Heavy Metals:

The aquatic environment with its water quality is considered the main factor controlling the state of health and disease in both man and animal. Nowadays, the increasing use of the chemical waste and agricultural drainage systems represents the most dangerous chemical pollution. The most important heavy metals from the point of view of water pollution are Zn, Cu, Pb, Cd, Hg, Ni and Cr. Some of these metals (e.g. Cu, Ni, Cr and Zn) are essential trace metals to living organisms, but become toxic at higher concentrations. Others, such as Pb and Cd have no known biological function but are toxic elements (Nageeb, 2000).

Water pollution of heavy metals becomes a question of considerable public and scientific concern in the light of evidence of their extreme to

human health and to biological system (**Anazawa, et al., 2004**). The growing public concern over the deteriorating quality of the environment has led to generalized use when referring to trace elements, other terms such as (trace metals), (trace inorganics) and (heavy metals) are synonymous with the term trace elements (**Al-Kattan,1989**).

The term (heavy metals) and (metals) are interchangeable and generally interpreted to include those metallic elements from periodic table groups IIA through VIA. At trace levels, many of these elements are necessary to support life. However, at elevated levels they become toxic, may build up in biological systems, and become a significant detriment to aquatic life (**Maryland Department of Environment, 2003**). Elements can be divided into two groups in terms of their density: heavy elements which are those elements with a density higher than 5g/cm^3 , and atomic number more than 20, and light elements, which are elements with a density less than 5g/cm^3 . Heavy elements are also called trace elements because they occur in small quantities in the earth's crust which do not exceed (0.1%), (**Tucker et al., 2003**).

Trace metals have been referred to as common pollutants, which are widely distributed in the environment with sources mainly from the weathering of minerals and soils. However, the level of these metals in the environment has increased tremendously in the past decades as a result of human inputs and activities (**Awofolu, et al., 2005**).

A further special feature of toxic metals is that they are not biodegradable. Instead they undergo a biogeochemical cycle with substantially different residence times in the various spheres and compartments of the environment (**Lasheen, 1987**). Within this cycle they will be taken up also by man, predominantly from food and drinking water. In this respect toxic metals constitute a particular risk, because, although a certain fraction of the ingested amount is again excreted, they have a tendency to accumulate in vital organs. Thus, they will exert progressively

growing toxic actions over long periods of the lifespan depending also on the cumulative magnitude of the dose as a function of the long term exposure of the individual to its particular environment. The toxicity of metals in water depends on the degree of oxidation of a given metal ion together with the forms in which it occur.

1-3 Source of Pollution with Metals:

Metals have many sources from which they can flow into the water body, these sources are (Nageeb, 2000) :

- 1. Natural Sources:** Metals are found throughout the earth, in rocks, soil and introduced into the water body through natural processes, weathering and erosion.
- 2. Industrial Sources:** Industrial processes, particularly those concerned with the mining and processing of metal ores, the finishing and plating of metals and the manufacture of metal objects. Metallic compounds which are widely used in other industries as pigments in paint and dye manufacture; in the manufacture of leather, rubber, textiles, paint, paper and chromium factories which are built close to water for shipping.
- 3. Domestic Wastewater:** Domestic wastewater contains substantial quantities of metals. The prevalence of heavy metals in domestic formulations, such as cosmetic or cleansing agents, is frequently overlooked.
- 4. Agricultural Sources:** Agricultural discharge contains residual of pesticides and fertilizers which contains metals.
- 5. Mine runoff and solid waste disposal areas.**
- 6. Atmospheric pollution:** Acid rains containing trace metals input to the water body will cause the pollution of water with metals.

1-4 Entrance Mechanism of Heavy Metals into Aquatic Environment:

There are several mechanisms by which heavy elements enter into aquatic environment **Matagi et al., 1998**, these mechanisms are:

1- Ion exchange capacity & adsorption: This process occurs by adsorption of oxides and hydroxide of iron and manganese on the outside surfaces of the fine particles especially particles of mud and organic substances and this is due to the ability of sediments entering the water system to adsorb heavy elements from the water.

2- Co-precipitation: Occurs during weathering of rocks in the presence of various ions of iron and manganese and solutions containing oxygen. This process includes sedimentation of iron oxides, iron and manganese hydroxide along with fine sediments. This is often called the packaging metal where the metal particles are surrounded by a cover of iron and manganese ions during sedimentation forming a part of sediment generated that can be dissolved once again under minimalist conditions and move from sediment to the water column.

3- Organic Link: Heavy elements are secondary components of organic matter with a simple percentage. Some of these elements can transform from inorganic to organic form such as the transformation of inorganic mercury to organic mercury.

4- Metal Link: Heavy elements are found within the crystalline metallic structure of sediment grains as primary or secondary components. Oxygen, sulphur, and siliceous mineral links are more prevalent.

1-5 Selected Trace Elements Present in Rivers:

Some of trace metals present in rivers with summarized descriptions of their uses, applications health effects and treatment methods are mentioned below :

1-5-1 Iron:

Iron (Fe) is the first element in Group VIII of the periodic table; it has an atomic number of 26, an atomic weight of 55.85, and common valences of 2 and 3 (and occasionally valences of 1, 4, and 6) (APHA, 1998). The average abundance of Fe in the earth's crust is 6.22 %; in soils Fe ranges from 0.5 to 4.3 %; in streams it averages about 0.7 mg/l; and in groundwater it is 0.1 to 10 mg/l. Iron occurs in the minerals hematite, magnetite, taconite, and pyrite. It is widely used in steel and in other alloys.

The solubility of ferrous ion (Fe^{+2}) is controlled by the carbonate concentration. Because groundwater is often anoxic, any soluble iron in groundwater is usually in the ferrous state. On exposure to air or addition of oxidants, ferrous iron is oxidized to the ferric state (Fe^{+3}) and may hydrolyze to form red, insoluble hydrated ferric oxide. In the absence of complex-forming ions, ferric iron is not significantly soluble unless the pH is very low. Elevated iron levels in water can cause stains in plumbing, laundry, and cooking utensils, and can impart objectionable tastes and colors to foods. The United Nations Food and Agriculture Organization recommended level for irrigation waters is 5 mg/l. The U.S. EPA secondary drinking water standard maximum contaminant level is 0.3 mg/l.

Iron occurs naturally in ground waters in three forms, ferrous iron (clear water iron), ferric iron (red water iron), and heme iron (organic iron). Each can exist alone or in combination with the others, ferrous iron, or clear water iron as it is sometimes called, is ferrous bicarbonate ([http://www. good water company. com](http://www.goodwatercompany.com)). The water is clear when drawn

but turns cloudy when it comes in contact with air. The air oxidizes the ferrous iron and converts it to ferric iron. Ferric iron, or ferric hydroxide, is visible in the water when drawn; hence the name "red water iron". Heme iron is organically bound iron complexed with decomposed vegetation. The organic materials complexed with the iron are called tannins or lignins. These organics cause the water to have a weak tea or coffee color. Certain types of bacteria use iron as an energy source. They oxidize the iron from its ferrous state to its ferric state and deposit it in the slimy gelatinous material which surround them. These bacteria grow in stringy clumps and are found in most iron bearing waters.

1-5-2 Copper:

Copper (Cu) is the first element in Group IB in the periodic table; it has an atomic number of 29, an atomic weight of 63.54, and valences of 1 and 2. The average abundance of Cu in the earth's crust is 68 mg/l; in soils it is 9 to 33 mg/l; in streams it is 4 to 12 $\mu\text{g/l}$; and in groundwater it is less than 0.1 mg/l (APHA, 1998). Copper occurs in its native state, but is also found in many minerals, the most important of which are those containing sulphates compounds (e.g., chalcopyrite), but also those with oxides and carbonates. Copper is widely used in electrical wiring, roofing, various alloys, pigments, cooking utensils, piping, and in the chemical industry. Copper salts are used in water supply systems to control biological growths in reservoirs and distribution pipes and to catalyze the oxidation of manganese. Copper forms a number of complexes in natural waters with inorganic and organic ligands. Among the common aqueous species are Cu^{+2} , $\text{Cu}(\text{OH})_2$, and CuHCO^{+3} . Corrosion of copper-containing alloys in pipe fittings may introduce measurable amounts of copper into the water in a pipe system. Copper is an essential trace element for plants and animals and plays a direct role in the construction of tissues and the process of protein building in the body of an organism

The lack of copper results in the infection of many diseases, especially blood diseases in humans (**Crawford & Bhattachary, 1985**) Some compounds are toxic by ingestion or inhalation. The United Nations Food and Agriculture Organization recommended maximum level for irrigation waters is 200 $\mu\text{g/l}$.

Copper (Cu^{+2}) (<http://www.goodwatercompany.com>) in drinking water can be derived from rock weathering, however the principal sources are the corrosion of brass and copper piping and the addition of copper salts when treating water supplies for algae control. Copper is required by the body for proper nutrition. Insufficient amounts of copper lead to iron deficiency. However, high doses of copper can cause liver damage or anemia. The taste threshold for copper in drinking water is (2-5) mg/l . The US EPA has proposed a maximum contaminant level of 1.3 mg/l for copper.

1-5-3 Cadmium:

Cadmium (Cd) is the second element in Group IIB of the periodic table; it has an atomic number of 48, an atomic weight of 112.41, and a valence of 2. The average abundance of Cd in the earth's crust is 0.16 mg/l ; in soils it is 0.1 to 0.5 mg/l ; in streams it is 1 $\mu\text{g/l}$, and in ground waters it is from 1 to 10 $\mu\text{g/l}$ (**APHA, 1998**). Cadmium occurs in sulfide minerals that also contain zinc, lead, or copper. The metal is used in electroplating, batteries, paint pigments, and in alloys with various other metals. Cadmium is usually associated with zinc at a ratio of about 1 part cadmium to 500 parts zinc in most rocks and soils. The solubility of cadmium is controlled in natural waters by carbonate equilibrium. Guidelines for maximum cadmium concentrations in natural water are linked to the hardness or alkalinity of the water (i.e., the softer the water, the lower the permitted level of cadmium). It is nonessential for humans, plants and animals.

EPA has found cadmium to potentially cause the following health effects when people are exposed to it at levels above the maximum contaminant level for relatively short periods of time: nausea, vomiting, diarrhea, muscle cramps, salivation, sensory disturbances, liver injury, convulsions, shock and renal failure (**EPA, 2008**). While the long-term exposure to cadmium at levels above the maximum contaminant level has the potential to cause the following effects: kidney, liver, bone and blood damage.

Nations Food and Agriculture organization recommended maximum level for cadmium in irrigation waters is 10 µg/l.

Cadmium enters the environment through a variety of industrial operations, it is an impurity found in zinc (**[http://www. good water company. com](http://www.goodwatercompany.com)**). By products from mining, smelting, electroplating, pigment, and plasticizer production can contain cadmium. Cadmium emissions come from fossil fuel use. Cadmium makes its way into the water supplies as a result of deterioration of galvanized plumbing, industrial waste or fertilizer contamination.. The US EPA Primary Drinking Water Standards lists maximum contaminant level for cadmium with a 0.005 mg/l.

1-5-4 Lead:

Lead (Pb) is the fifth element in Group IVA in the periodic table; it has an atomic number of 82, an atomic weight of 207.19, and valences of 2 and 4. The average abundance of Pb in the earth's crust is 13 mg/l; in soils it ranges from 2.6 to 25 mg/l; in streams it is 3 mg/l, and in ground waters it is generally less than 0.1 mg/l. Lead is chiefly obtained from galena (PbS). It is used in batteries, ammunition, solder, piping, pigments, insecticides, and alloys (**APHA, 1998**). Lead was also used in gasoline for many years as an anti-knock agent in the form of tetraethyl lead.

The common aqueous species are Pb^{+2} and hydroxide and carbonate complexes. Lead in a water supply may come from industrial, mine, and smelter discharges or from the dissolution of plumbing and plumbing fixtures. Tap waters that are inherently non corrosive or not suitably treated may contain lead resulting from an attack on lead service pipes, interior plumbing, brass fixtures and fittings, or solder pipe joints.

Lead is nonessential for plants and animals. It is toxic by ingestion and is a cumulative poison. The Food and Drug Administration regulates lead content in food and in house paints. Under the lead-copper rule.

Lead (Pb^{+2}) found in fresh water usually indicates contamination from metallurgical wastes or from lead-containing industrial poisons. Lead in drinking water is primarily from the corrosion of the lead solder used to put together the copper piping. Lead in the body can cause serious damage to the brain, kidneys, nervous system, and red blood cells. The US EPA considers lead to be a highly toxic metal and a major health threat. The current level of lead allowable in drinking water is 0.05 mg/l (<http://www.goodwatercompany.com>).

1-5-5 Zinc:

Zinc (Zn) is the first element in Group IIB in the periodic table; it has an atomic number of 30, an atomic weight of 65.38, and a valence of 2. The average abundance of Zn in the earth's crust is 76 mg/l; in soils it is 25 to 68 ppm; in streams it is 20 $\mu\text{g}/\text{l}$, and in ground waters it is less than 0.1 mg/l. The solubility of zinc is controlled in natural waters by adsorption on mineral surfaces, carbonate equilibrium, and organic complexes (APHA, 1998). Zinc is used in a number of alloys such as brass and bronze, and in batteries, fungicides, and pigments. Zinc is an essential growth element for plants and animals but at elevated levels it is toxic to some species of aquatic life. Zinc plays an important role in the transformation of acid

HCO₃ to gas CO₂ by the enzyme (carbonic anhydrase) and it is essential in the process of protein building as it is a component of the enzyme DNA-RNA Polymerase. (**Crawford & Bhattachary, 1985**).

The United Nations Food and Agriculture Organization recommended level for zinc in irrigation waters is 2 mg/l. The U.S. EPA secondary drinking water standard maximum contaminant level is 5 mg/l. Concentrations above 5 mg/l can cause a bitter astringent taste and an opalescence in alkaline waters. Zinc most commonly enters the domestic water supply from deterioration of galvanized iron and dezincification of brass. In such cases lead and cadmium may also be present because they are impurities of the zinc used in galvanizing. Zinc in water may also result from industrial waste pollution.

1-5-6 Mercury:

Mercury (Hg) is the third element in Group IIB in the periodic table; it has an atomic number of 80, an atomic weight of 200.59, and valences of 1 and 2. The average abundance of Hg in the earth's crust is 0.09 mg/l; in soils it is 30 to 160 µg/l; in streams it is 0.07 µg/l, and in ground waters it is 0.5 to 1 µg/l. Mercury occurs free in nature, but the chief source is cinnabar (HgS) (**APHA, 1998**). Mercury is used in amalgams, mirror coatings, vapor lamps, paints, measuring devices (thermometers, barometers, manometers), pharmaceuticals, pesticides, and fungicides. It is often used in paper mills as a mold retardant for paper.

The common aqueous species are Hg⁺², Hg(OH)₂, Hg, and stable complexes with organic ligands. Inorganic mercury can be methylated in sediments when sulfides are present to form dimethyl mercury, (CH₃)₂Hg, mercury is considered nonessential for plants and animals. Mercury is a potential neurotoxin, which means it attacks the body's central nervous system. It can also harm the brain, kidneys and lungs. It can cross the

blood-brain barrier as well as the placenta. Methyl mercury from contaminated fish easily crosses the placenta and enters the brain of the developing fetus. their infants demonstrated nervous-system damage (**Mercury & Health, action@essential.org www.EssentialAction.org**).

The maximum contamination level for mercury set by the US EPA is 0.002 mg/l.

Mercury is one of the least abundant elements in the earth's crust. It exists in two forms, an inorganic salt or an organic compound (methyl mercury). (**[http://www. good water company. com](http://www.goodwatercompany.com)**).

1-6 Water quality standards:

A water quality standard is the combination of a designated use for a particular body of water and the water quality criteria designed to protect that use (**Maryland Department of the Environment, 2005**). Designated uses include support of aquatic life, primary or secondary contact recreation, drinking water supply. Water quality criteria consist of narrative statements and numeric values designed to protect the designated uses. The criteria developed to protect the designated use may differ and are dependent on the specific designated uses of a water body. Table (3-1) illustrates a comparison between the standards of several environmental world organizations with respect to the maximum allowable limits of trace elements in drinking water

Table (1-1): Iraqi and global parameters for concentration of heavy elements in river and drinking water ($\mu\text{g/l}$) (<http://www.almyah.com/ht/wgude.htm>)

Elements	parameters Iraqi system maintenance of river and public water from pollution NO.25 1967	Iraqi standards For drinking water (417) 2001	WHO for drinking water 2007	European standards for drinking water 2007	USEPA for drinking water 2007	Japanese for drinking water 2007	Russian for drinking water 2007	Canadian standards for drinking water 2007
Hg	1	1	1	1	2	-	0.5	1
Cd	5	3	5	5	10	10	1	5
Cu	1000	1000	1000	1000	1000	40	1000	1000
Pb	50	10	50	50	50	10	30	50
Fe	300	300	300	300	300	-	500	300
Zn	500	3000	500	3000	5000	-	1000	5000

1-7 Description of the Study Area:

Shatt Al-Hilla river as shown in Fig. (1-1) is a branch of the Euphrates river. It branches from the Euphrates river at km 602 in Saddaat Al-Hindiah town with a discharge of 200 m³/s during summer and 245 m³/s during winter. The length of Shatt Al-Hilla river passing through Babylon governorate equals to 101km. 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. There are 36 main channels 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).**

Like many rivers, Shatt Al-Hilla 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 spring season and during this period, ice dissolving water is the main source of river water.
- 2) Rain water: Rainy period occurs in winter season and during this period, rain water represents the main source of river water.
- 3) Stored water: Storage period occurs in 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 on the quality of the river water.

Shatt Al-Hilla river passes through many towns and villages thus it represents the main source for different uses such as:

- 1) Irrigation: The river is the main source of the irrigation for large agricultural areas locating on both sides of the river.
- 2) Water supply systems: The river represents the supply source for many water treatment plants such as Al-Hilla AL-Jadeed and Al-Hilla 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 to the river on both sides.
- 2) Municipal wastes: Municipal wastes are discharged from wastewater treatment plants such as Al-Muameerah wastewater treatment plant.
- 3) Industrial wastes: Many industries discharge wastewater to the river such as Al-Furat company for chemical industries, Al-Sada cement factory, Hilla textile industry, public slaughter houses.

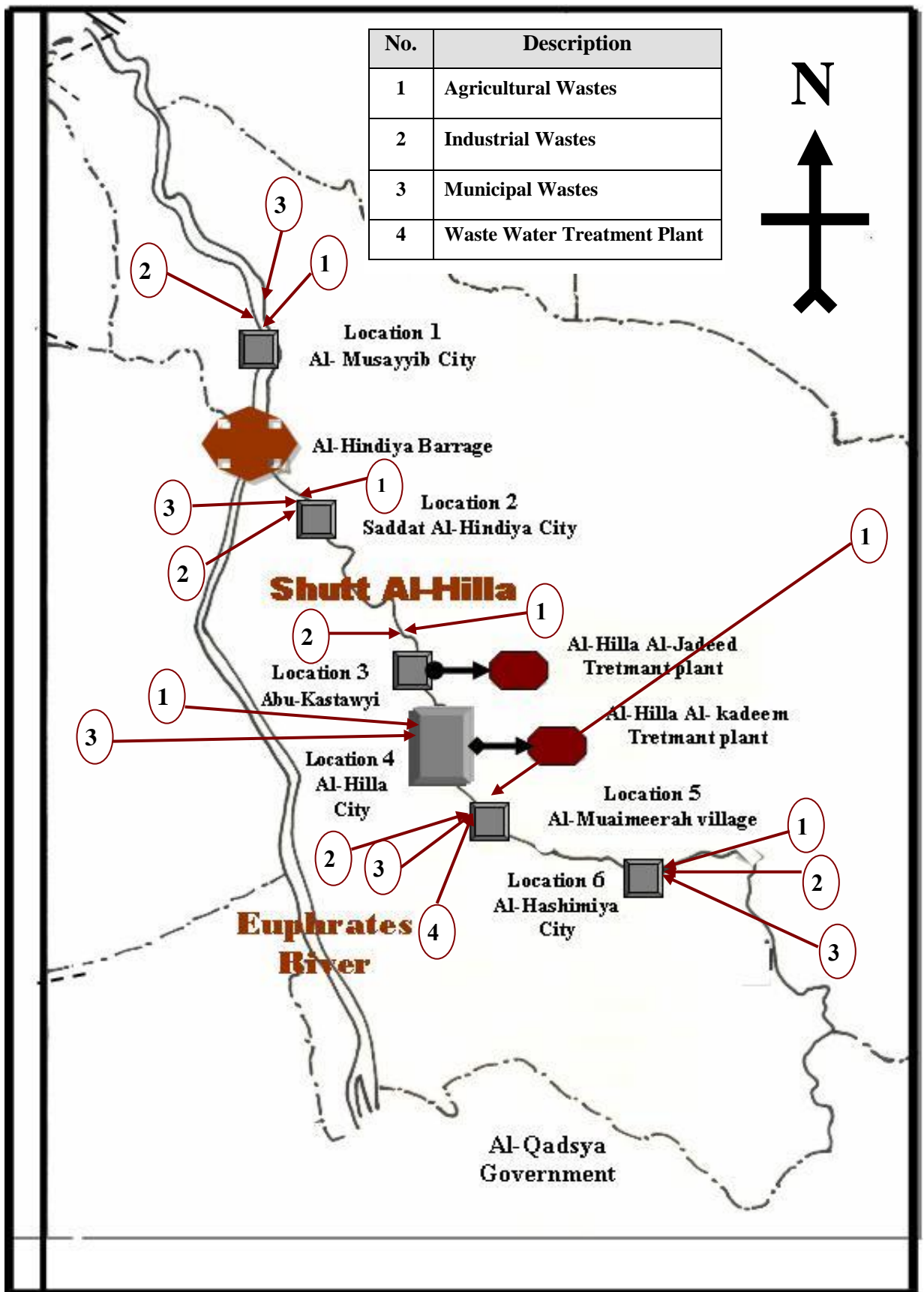


Fig. (1-1) Sampling Locations on Shatt Al-Hilla River and Sites of Water Treatment Plant

1-8 Objectives of the Study:

The presence of trace elements in natural waters is a problem of increasing importance because of the increase of man's activities that attributes to the continuing increase in their level of occurrence. The aesthetic and health importance of trace element justify the study of their origin of generation as well as their concentration in natural and modified water system.

The specific objectives of this study are :-

1. To assess the effect of the physiochemical characteristics on the distribution of the trace metals.
2. To assess the trace metals concentration and their effects on water quality of the river.
3. To understand the role of treatment in the elimination and decreasing of the trace metals concentration.

Chapter Two

Literature Review

2-1 River Water:

Many studies were carried out for different rivers in the world in different forms. In Black Warrior river at Tuscaloosa, Alaska, **Williams, et al., 1973**, found that there was no correlation between stream flow and soluble concentration of the selected heavy metals. The heavy metals most often were associated with suspended and colloidal particles in significant concentration.

Stiff, 1971, pointed that much of Cu present in river waters is associated with suspended solids and soluble would consist almost entirely of complexed forms.

Leckie, 1979, concluded that the adsorption of Cu in natural systems was very strongly dependent upon the type and concentration of inorganic and organic ligands.

Oshea and Nancy, 1978, pointed that the complexation of Cu, Pb with hydroxo and carborato-ligands found in a carbonate medium had been observed to generally increase with increasing pH, neither calcium nor magnesium affect these interactions. Calcium was found to be more effective than magnesium in inhibiting trace-organic complexation.

In the upper Mississippi river **Eisenreich, 1980**, found that Al, Fe, and Mn were transported primary in the particulate phase at all sites, although a significant fraction (10-30%) was associated with the dissolved phase. The transport of Cu and to a lesser extent Pb was controlled by the dissolved phase (30-70%). The fraction of trace metals in the dissolved phase increased with decreasing suspended solids in the river. The solid organic phase of metal transport increased at the sites receiving sewage input.

Snodgrass, 1980, found in their study that Pb was likewise partitioned between soluble and solid-associated forms, the ratio of which depended upon the capability of a particular water for maintaining particulates in suspension, as well as the chemical factors which influence the form of Pb.

Steinberg, 1980, concluded from his study of the species of dissolved metal derived from oligotrophic hard water that all metals were bounded by organic molecules to a measurable degree. Pb.

The study of **Polprasert, 1982**, on the heavy metals pollution in the Chao Phraya river indicated that the accumulation of Cu, Cr, and Pb in water in the river mouth vicinity was significant, which might have a long term impact on the aquatic environment through precipitation of heavy metals to the bottom sediment.

In another study on the same river **Salino, et al., 1980**, found that the average of the mean concentrations exceeded 10 ug/l for Cu and 5 µg/l for lead at: (1) the mouth of river, (2) the area with high population density, (3) heavy traffic area and (4) industrialized area.

Fytianes, et al., 1986, investigated the deviation from the average to high metal contents in rivers in northern Greece in 1983. There was generally an indicative of anthropogenic contamination of water systems. Such deviation was particularly frequent and extensive with reference to zinc and iron.

The total flux, distribution and fate of Cu, Cr, Zn, Mn. and Pb were studied in Brazil by **Delacerda, et al., 1987**. For most of metals, transport through the river to the bay was mainly by suspended particulate matter; most metals transported by suspended particulate matter were in weakly bound forms.

In parts of Rbone river **Ngoc, et al., 1987**, found that Zn content appeared to be medium or low as compared with other rivers and standards and they showed also that Zn was carried as dissolved, adsorbed, and non-desorbable with approximately equal amounts.

In Guadiamar river, Spain, **Cabrera, et al., 1987**, studied heavy metal pollution mainly extended by the drastic changes in the river flow and the dissolving, adsorbing and complexion ability of organic effluents. Most heavy metals were precipitated in a distance of less than 13 km downstream from mine effluents.

Morrison, 1987, showed that heavy metals in natural waters may occur as organic and inorganic complexes of varying sizes, or be associated with colloidal or particulate material of a heterogeneous nature.

The field observations results conducted by **Allard, et al., 1987**, showed that the total concentration of dissolved trace metals was minimum at pH (7-8). The fraction of the metals that were associated with particulate matter (retained by filtration through 0.4 μm filter) maximum at pH (7-8) in the order $\text{Al} > \text{Fe} > \text{Pb} > \text{Cu} > \text{Zn}$. In the study of the specific sorption of Cu, Pb, by inorganic particulates the uptake was subsequently increasing steadily with increasing pH.

In the study conducted by **Aualitia and Pickering, 1987**, to investigate the specific sorption of Cu, Pb, by inorganic particulates, the uptake was subsequently increasing steadily with increasing PH. In general, affinity and relative uptake values followed the sequences $\text{Pb} > \text{Cu}$ and $\text{Mn (IV) oxides} > \text{Fe III oxides} > \text{Al(OH)}_3 > \text{clays}$.

Driscoll, et al. 1988, showed that the concentrations of Pb and Fe were highly correlated with dissolved organic carbon in soil solution and stream water suggesting that mobilization / immobilization of Pb and Fe were predominately controlled by transfer of dissolved organic carbon through complexation reactions formed the most stable complexes. Complex stability decreased for the other metals as follows: Al > Cr > Fe > Mg > Mn > Zn > Cu > Ni .

The distribution of 22 major and trace elements was examined in water in the upper Illinois river basin in Illinois, Indiana, and Wisconsin in the Chicago area as part of a pilot National Water-Quality Assessment project done by the **Faith, 1990**, from 1987 through 1990. Cd, Cr, Cu, Fe, Pb, Hg, Ag, and Zn concentrations in water exceeded USEPA at acute or chronic water-quality criteria at several sites in the Chicago area.

Masoud, et al., 1991, studied the distribution of trace elements in the Nile river. They found that the concentration of trace metals increased from south to north direction and the distribution of trace elements was affected by the physico-chemical parameters such as pH, dissolved oxygen, transparency, carbonate and bicarbonate, phosphate and suspended matter.

The results indicated that the concentration of the different metal ions was Fe > Mn > Zn > Cu. Also they found that the concentration of iron in the Nile water is higher during June and decreased during December and fluctuated between (42-550) µg/l. Manganese, zinc, copper concentrations varied between (18-65) µg/l, (9-56) µg/l, and (2-28) µg/l respectively. The level for all metal ions in the Nile water was found below that set by the United States Environmental Protection Agency (EPA) as harmless to the aquatic life.

In a study on the river Waihou in New Zealand, **Webster, 1995**, found that some of the heavy elements such as copper, lead and arsenic existed combined with suspended solids more than their existence in a dissolved form. The tendency for deposition of the iron in these forms of oxides was also found, leading to increased concentration of iron in the sediment.

Shiller and Hebert, 1998, found in their study of the elements dissolved in the Mississippi river in east Carolina and the river Loch in Colorado, that the concentration of these elements varies according to the different seasons of the year where it was noted that copper was increased during spring more than in other seasons while the iron was increasing during fall and winter and then started decreasing during spring.

Yilmazer and Yaman, 1999, studied the water pollution with heavy metals in Ceyhan river in Turkey. The concentrations of Al, Mn, Pb, Co, Cd, Cr, Ni, Cu, were determined. It was concluded that the highest concentrations of these elements were in suspended phase.

Gerhardt, et al., 2000, have examined trace elements distribution, partitioning, and speciation at 15 sites in the Patuxent in river watershed in U.S.A from May 1995 through October 1997 to determine possible sources of trace elements to the river and estuary, and to examine the relationship of the trace element discharges to freshwater discharges as well as to land use and geographic region, to validate previous estimates of loadings to the river, and to provide baseline data for trace elements in the Patuxent river watershed and estuary. Six freshwater sites were examined, representing different basins and geographic provinces, and nine sites along the estuarine salinity gradient. Subregions within the watershed varied considerably in concentrations and areal yields for some elements. Concentrations of As, Cd, Ni, Pb, and Zn were elevated in the Coastal Plain sites compared to the

Piedmont sites, while Cu and Hg were more evenly distributed. Cadmium, Cu, Hg, Ni, Pb, and Zn showed overall positive correlations with river flow while As and methyl Hg (meHg) showed negative correlations with river flow. Concentrations of trace elements in the estuarine portion of the river were found generally low, and consistent with mixing between Patuxent river water with elevated concentrations and the lower concentrations of the Chesapeake bay.

Jeffrey, 2001, studied the trace metals distribution during the Fall of 1998 and the Spring of 1999. 131 water samples were collected from the Spokane Aquifer, Spokane river, Coeur d'Alene river and Littler Spokane river in USA. Water samples were analyzed 25 elemental concentrations, which include major elements Ca, Mg, Na and K and trace elements Ag, As, B, Ba, Be, Cd, Co, Cr, Cu, Fe, Mn, Mo, Ni, Pb, Rb, Sb, Sr, Tl, U, V and Zn. Water samples were also analyzed for five water quality parameters that include specific conductance, nitrate as N, pH, temperature and hardness. Dissolved concentrations of major and trace elements in the Spokane Aquifer are very low compared to U.S. EPA drinking water standards. Low concentrations of trace elements are attributed to the geochemistry of host rocks in the Spokane Aquifer. Concentrations of major and trace elements found in the Spokane Aquifer are very similar to concentrations found in the Little Spokane river. Concentrations of major and trace elements in the Spokane river are influenced by the Coeur d'Alene river, which exhibits higher concentrations of Cd, Fe, Mn, Pb, Sb and Zn compared to the Spokane Aquifer. With the exception of trace elements mentioned above, most of the major and trace elements in the Spokane river are lower than in the Spokane Aquifer. Elements that exhibit large seasonal variations are major elements Ca, Mg,

Na, K and trace elements As, Ba, Cd, Cr, Fe, Mn, Mo, Pb, Rb, Sb, Sr, U and Zn. Fluctuations in dissolved trace elements Cd, Fe, Mn, Pb, Sb and Zn in the Spokane river are attributed to spring run-off. Variations in elements Ca, Mg, Na, K, As, Ba, Mo, Rb, Sr and U in the Spokane river are attributed to changes in river flow.

Oltmann, et al., 2003, studied the concentration of seven elements (Zn, Pb, Ni, Hg, Cu, Cr, and Cd) in different river systems in the state of Baden-Wuerttemberg in Germany. The results showed that the concentration of these elements depends on the wastes discharged from cities, erosion, and the flow of groundwater.

Taha, et al., 2004, found that the cities and industrial projects built near sources of water had the main impact in increasing the concentration of heavy elements in surface water and groundwater.

Anazawa, et al., 2004, studied the concentration of some elements in rivers Higashiyamatani, Kawata, and Yoshino in the Shikoku, Japanese. They found that the concentration of dissolved elements depended on the concentration in the sediment.

Rengasamy and Jing, 2005, studied the trace metal geochemistry in Indian and Chinese rivers in the Asian region to understand its variation on a global scale in terms of climate, ecological conditions and anthropogenic impact. They found that the average particulate trace metal concentration of Indian rivers ranged from (300–1000 mg/g) and was higher than that of Chinese and global rivers which ranged from (150–300 mg/g) and (170–350 mg/g) respectively. Elevated levels of lead in Chinese rivers and of cobalt and zinc in Indian rivers indicated anthropogenic inputs of these heavy metals.

Gaur, et al, 2005, investigate the impacts of domestic/industrial wastes on the water of river Gomti in India with special reference to heavy metals in different seasons (summer, winter and rainy) for seven sampling sites: Gaughat, Mohan Meakin, Martyrs Memorial, Hanuman Setu, Nishatganj bridge, Pipraghat and Malhaur.

Samples of water were collected in all the three seasons. Six metals Cd, Cr, Cu, Ni, Pb, and Zn were analyzed by ICP-AES. They noticed high concentrations of all metals in rainy season as compared to summer and winter. Because in rainy season runoff from open contaminated sites, agricultural field and industries, directly comes into the river without any treatment. The concentration of zinc was maximum (91 µg/l) while the concentration of cadmium (1 µg/l) was minimum.

Awofolu, et al., 2005 studied the variation of trace metals Cd, Pb, Co, Zn Cu and Ni in water from the Tyume river in South Africa. They found that higher levels of Cd (0.038 ± 0.004 to 0.044 ± 0.003 mg/l) and Pb (0.021 ± 0.004 to 0.035 ± 0.001 mg/l) may be detrimental to the “health” of the aquatic ecosystem and the rural communities that utilize the river water for domestic purposes without any treatment.

Ryan, 2005, conducted a monitoring program for characterizing ambient water quality concerning the trace metals concentrations at Birchbank and Waneta in the lower Columbia river in Canada. Samples were collected using standard sampling protocols and analyzed using (ICP-MS). All trace metals measured at Birchbank were below provincial water quality objectives and Canadian Council of Ministers of the Environment guidelines for the protection of aquatic life over the course of the study. At Waneta, cadmium often exceeded objectives, and lead occasionally exceeded guidelines during the 1996-1997 study period. Cd, Cu, Mn, Pb,

Th, and Zn were all significantly higher at Waneta than at Birchbank. This study demonstrated that when conducting a monitoring program for characterizing ambient water quality, it is essential to use analytical methods with method detection limits that are capable of detecting the target variables at concentrations observed in the environment.

High concentrations of heavy elements such as Fe, As, Cr, Hg, and Pb were found in river Abo in Nigeria by **Ezeronye and Ubalua, 2005**, in their study conducted on this river. Western water textile mills, detergents and cosmetics industries in addition to the high traffic density were found to be the main source of the river contamination. No moral relationship between increasing concentration of heavy elements and the bacterial organisms in the river mentioned was found.

Liu and Han, 2007, carried out a systematic study in China to evaluate the effects of human activities on the Wujiang river valley. This study was concerned mainly with the trace elements composition of river water. They found that Mn and Sr are strongly concentrated relative to other elements in river water, while Rb, Pb, Zn and Ni are relatively depleted, indicating that the process of chemical weathering has led to the differentiation of different elements between water body and weathered crust.

In Iraq, various water bodies such as (Shatt Al-Arab river, Shatt Al-Hilla river, Euphrates river, Tigris river, and others) were studied in a trial to investigate the pollution levels in these rivers.

The distribution of ten elements in Shatt al-Arab river Zn, V, Pb, Ni, Mn, Fe, Cu, Cr, Co, Cd was studied by **Abaychi and Doubul, 1985**. They recorded low concentrations of these elements in the waters and Plankton. Seasonal fluctuation in the levels of these elements was also

found in addition to the high concentration of Pb in the suspended solids of the river. Analyses were carried out, using a flameless AAS instrument. The mean concentrations of the dissolved species were as follows expressed in mg/l 0.25 Cd, 0.9 Cu, 716 Fe, 1.3 Mn, 0.3 Pb, 0.2 V and 1.8 Zn. Mean concentrations of Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb, V and Zn in the particulate matter were 55.2, 6.0, 188, 77, 31 472, 1731, 3807, 93, 207 and 77 mg/g respectively.

Musa, et al., 1985, showed that wastewater discharged by textile industries in Baghdad city causes the contamination of Tigris river with Cr, Pb, Cd, Zn and Cu.

Kassim, et al., 1997, found that some heavy metals such as Cu, Cd, and Pb, are present in the water and the Plankton of the Euphrates river in the western region of Iraq (the upper Euphrates).

The concentration and distribution of ten trace metals in dissolved and particulate form of Shatt Al-Hilla river were investigated by **Al-Taee, 1999**. Her study was conducted during the period from winter 1997 to winter 1998. She found that the mean concentrations of Cd, Co, Cr, Cu, Fe, Hg, Mn, Ni, Pb, and Zn in dissolved phase of water were, 1.11, 3.27, 5.27, 1.81, 6.74, 105.72, 0.96, 0.27, 4.21 and 8.73 $\mu\text{g/l}$ respectively. While their concentrations in particulate phase were, 3.59, 35.4, 114.02, 51.61, 76302.15, 710.43, 623.43, 21.84, 53.18 and 205, 05 $\mu\text{g/g}$ in dry weight respectively.

Seasonal variation showed highest Hg level in both dissolved and particulate phases, even it was more than standards.

Al-Tufaily, et al., 2000, conducted a study to find the levels of heavy metals (Cr, Pb, Ni, Zn, Cd) of the liquid

industrial wastes that disposed from Hilla-fine textile factory and their effects on the river water of Shatt Al-Hilla, from September 1994 to August 1995.

They found that these effluents were within the permissible levels of these metals except Pb which exceeded the allowable limits.

In a study conducted on the southern parts of the rivers Tigris, Euphrates, Shatt Al-Arab and Khor Al-Zubair, **Al-Imarah, et al., 2000**, showed that the levels of heavy elements were higher than the maximum allowable limits allowed by the World Health Organization (WHO) and by the Iraqi river protection system for year 1967.

In another study conducted on Shatt al-Arab river by **Al-Khafaji, 1996**, Pb concentration was found high due to the increase in municipal wastes and vehicles exhausts.

Al-Lami, 2002, has studied the distribution of five heavy elements in the Diwaniyah river Cd, Cu, Pb, Mn, Zn and found that the Zn concentration level in the river was the highest while Cd level was the lowest between all the elements studied.

The study showed that the mean concentrations of Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb and Zn in dissolved phase in water were (2.14, 1.16, 0.075, 2.48, 105.69, 6.12, 0.07, 0.10, and 10.50) $\mu\text{g/l}$ respectively, while their concentrations in particulate phase were (10.22, 8.09, 0.245, 13.65, 660, 33.71, 0.193, 0.50, and 59.98) $\mu\text{g/g}$ respectively.

In a study on the Euphrates river at Nasiriyah city in the southern region of Iraq, **Al-Khafaji, 2005**, found that certain elements such as Mn, Pb, Cu and Cd were present in high concentrations and this resulted from high traffic density and industrial activities in the city. To indicate the

possible environmental effects on Euphrates river from Al-Hindia dam to south of Al-Kufa city (a distance of 15 kilometers) in the middle of Iraq, **Jassim, 2006**, conducted a study to determine the physical and chemical water properties as well as concentration and distribution of some heavy metals Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb, and Zn in both dissolved and particular phase in the water in seven selected sites along this area.

2-2 Drinking water:

Ensuring the safety of our drinking water is one of the most fundamental, and most critical, responsibilities of modern public health. In fact, safe drinking water has been a key ingredient in some of the greatest public health achievements of the last half-century, including the dramatic reductions in disease and improvements in longevity that we now tend to take for granted. Along with other basic public health measures like immunization, drinking water protection has played a crucial role in building a safer and healthier society (**Faith, et al., 1990**).

Barnett, et al., 1968, showed that at three water works near Denver, Colorado, which apply alum dosing a substantial reduction in the concentrations of copper, iron, and manganese was observed, whereas lead and zinc were only eliminated to a small degree.

Pem, and Durum, 1973, showed that alkalinity and pH are of primary importance in limiting the solution of Pb in surface water. As a result of the processes used in water treatment plants in increase the pH, super saturation with respect to Pb carbonate on hydroxide may be reached. The supersaturated solution may deposit the excess Pb possibly as Pb carbonate on the surface of filter media or elsewhere at a solid liquid interface in the system.

Coagulation and flocculation with alum will result in effective lead removal only at pH level of 8-9, not at near natural pH values **Naylor and Dajue, 1975**.

The effectiveness of Cu, Zn removal from solution by alum coagulation was measured by **Truitt and Weber, 1978** the greatest losses of metal ion generally occurred in solutions with the high level of alum (50%) mg/l and high pH of (7). The metal ion removed ranged from (6–96) % for Cu, from (7–82) % for Zn. The

practical implication of the results is that strong complexes between natural water organic matter and metal ions entrance their removal by the alum coagulation process.

Zemansky, 1979, concluded that water treatment plants studied were capable of removing Fe, Mn, and Zn to a high degree as well as copper and nickel to a lesser degree. At the same time, it was evident that chromium and lead were only slightly removed.

With aluminum flocculation, **Forstner and Wittman, 1979** found that the water from three German drinking water reservoirs was treated in the same way and a reduction in the zinc content of (50-80) % was accomplished. Over a large range of initial concentrations lead exhibited a reduction of 30 %, iron over 75% and Mn between 30 % and 90%.

Sandhu, et al., 1979, found that Potable water in south Cardina metallic contamination was quite common and in certain cases the levels of Fe, Mn, were far above acceptable limits, Cu, Pb, Zn were found in; most of water samples but their concentrations were always low. Generally, investigations at various water works using traditional methods of purification show deviating results.

The fate of heavy metals in the Ruhr basin is described from factory to drinking water by **Imboff and Koppe, 1980**, by flocculation and filtration applied as pretreatment in a water work close to the river mouth less than 50% of heavy metals are removed on average.

The concentration of trace elements in drinking water depend upon its source of origin and treatment at water-purification plants. In the study conducted by **Azcue, et al., 1987**, to determine the heavy metals in drinking waters from the Paraiba Do Sul-Guandu river system in Brazil, Fe and Mn had the highest concentrations in tap water treatment plants.

Nora, S. J. et al., 1987, pointed that both Coagulation, flocculation and pH adjustment give a marked improvement in water quality with respect to lead.

Al-Hashimi, et al., 1985, in his research on the effect of different purification stapes on the removal of trace element found that there is correlation between the high removal during high turbidity levels and the removal of elements having high concentrations specially during sedimentation and the higher removal is at high concentration of these elements in the raw water. The average percentage of the total removal of elements was in sequence as follows: Fe, Mn, Cr, Pb, Cu, Zn. In sedimentation was: Fe, Mn, Zn, Cr, Cu, Pb. while in filtration was Cd, Pb, Mn, Zn, Cr, Cu, Fe. An increase in the concentrations of Zn was observed in the reservation stage due to the desolation of the element from the pipes and armatures as mentioned.

Chapter Three

Experimental Work

3-1 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:

Location One:

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

Location Two:

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

Location Three:

This station is located at the northern entrance to Al-Hilla city near Abu-Kastawi area at a distance of about 25 km away from the second location and upstream of the water intake of Al-Hilla Al-

Jadeed water treatment plant. There are different industrial, agricultural, and human activities that may have a potential impacts on water quality of the river in this location.

Location Four:

The location is located at the centre of Al-Hilla city. As it is known, Al-Hilla city is characterized by a high population density and presence of some agricultural areas. It was observed that the river section in this location was narrow 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.

Location Five:

It is located beyond the southern borders of Al-Hilla city at a distance about 12 km away from the city centre and Downstream of Al-Muameerah wastewater treatment plant. This region is characterized by industrial activities in addition to the agricultural, and human activities.

Location Six :

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

3-2 Drinking Water Treatment Plant Evaluated:

In order to evaluate the effect of treatment on the concentration of trace elements in water, analysis for Fe, Cu, Zn, Cd, Pb, Hg was performed on finished water for of Al-Hilla Al-Jadeed treatment plant which is located at the main north entrance of Al-Hilla city, and Al-Hilla AL-Kadeem treatment plant located in the city centre.

Other water quality parameters such as hydrogen ion (pH), turbidity (TU), electrical conductivity (Ec), sulfate (SO₄), chloride (Cl⁻), alkalinity, total hardness (TH), calcium (Ca), temperature (T°C), Total Dissolved Solid (T.D.S), total suspended solids (T.S.S), and dissolved oxygen (DO) were measured according to the standard method for examination of water and waste water. (APHA, 1998).

3-2-1 Al-Hilla Al-Jadeed Treatment Plant:

Al-Hilla Al-Jadeed treatment plant is located at the main northern entrance of Al-Hilla city, 100 km away to the south of Baghdad. In 1993 the plant was put into operation with feeding areas of Al-Hilla city and Abi-Gharak town with capacity of 10470 m³/hr. The raw water is treated by conventional treatment and treated water is stored before being pumped to the consumer. The following sections describe units and processes of Al-Hilla Al-Jadeed treatment plant.

The raw water intake comprises a river bank intake. Two low lift pumps with capacity of 1635 m³/h and six submerged pumps with capacity of 1200 m³/h (one as a standby) each, discharge to two raw water pipelines (each pipe represents a stream in the plant) with diameter of 1400 mm each. Raw water flows then to the flash mixing unit.

3-2-2 Al-Hilla AL-Kadeem Treatment Plant: Plant:

Al-Hilla AL-Kadeem treatment plant is the first water treatment plant constructed on Shatt Al-Hilla river in Al-Hilla city Fig.(1-1). It is located at the city center and the plant was established in 1954 and put into first operation in 1959 and it had many technical problems upon which it has subjected to necessary maintenance in (1999). Before this maintenance, it was serving Tayara AL-Jadeed pumping location and the network. After this maintenance, this plant started serving Tayara AL-Jadeed pumping station only, with capacity 1200 m³/h.

The raw water is drawn from Shatt Al-Hilla river and treated by conventional treatment. Treated water is stored before being pumped to the consumers.

The raw water intake comprises a river bank intake. Four low lift pumps (one as standby) with capacity of 400 m³/hr each, discharging to three raw water pipelines with 350 mm diameter each.

3-3 Sampling:

3-3-1 Samples collection:

Rivers are characterized by uni-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 much variations. Few locations with sufficient number of samples to define the results in terms of statistical significance are much more reliable than many stations with only a few samples at each (**APHA, 1998**).

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 at 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 (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 Dewaniya city, while

the other samples were analyzed in the laboratory of Babylon water office.

A locally made apparatus shown in Plate (3-1), 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.



Plate (3-1): The samples collection unit

3-3-2 Sample Handling:

Samples were acidified at the time of collection with a concentrated nitric acid (1.5 ml HNO_3 /l sample) to achieve a pH of 2 or less to keep the metals in solution and to minimize their adsorption on the container wall (APHA, 1998).

3-3-2-1 Sample Pretreatment and Analysis:

River and drinking water samples likely, contain suspended materials and require pretreatment before analysis. Pretreatment may require additional acid aliquots to preserve the sample and certainly require a digestion step to destroy organic matter and bring all metals into solution.

For total metal analysis, a 100 ml of well-mixed sample was transferred to a beaker, 5 ml concentration HNO_3 were added and then placed on a hot plate and evaporated to near dryness, making sure that the sample does not boil. After cooling another 5 ml acid were added, covering the beaker with a watch glass and placing it on a hot plate. Increasing the temperature until a gentle refluxing action occurred, continuing heating and adding additional acid as necessary until digestion is completed. Then 1 to 2 ml concentration nitric acid were added and warred slightly to dissolve the residue. The beaker walls and watch glass were washed down, with de-ionized water, filtered to remove silicate and other insoluble materials, and the volume was adjusted to original volume (APHA, 1998). The Fe, Cu, Cd, Pb and Zn contents were determined by an atomic absorption spectrophotometer type (BUCK/210VGP, USA). While the Hg content was determined by a spectrophotometer type (PERKIN-ELMER-GERMANY).

3-4 Analytical Techniques:**3-4-1 Metal Analysis by Atomic Absorption:**

Atomic absorption spectrometry (AAS) is an analytical technique that measures the concentrations of trace elements.

Quantification is based on light absorption by metal atoms at their ground state. The technique use the wavelengths of light specifically absorbed by an element. They correspond to the energies needed to promote electrons from one energy level to another, higher energy level. It is specially indicated for the determination of alkaline elements, alkaline-earth and heavy metals present in any type of sample, previously dissolved. Attainable levels range from pph to ppb (1 mg/tonne). The service is requested by firms, research departments in universities, research public organisms and individuals. The technique of atomic absorption is complemented by the techniques of elemental analysis with inductively coupled plasma linked to mass spectrometry and optic plasma. A diagram of an AAS is shown in Fig. (3-1), and a photo of the spectrophotometer type (BUCK/210VGP, USA) used for the determinations of metals is given in plate (3-2).

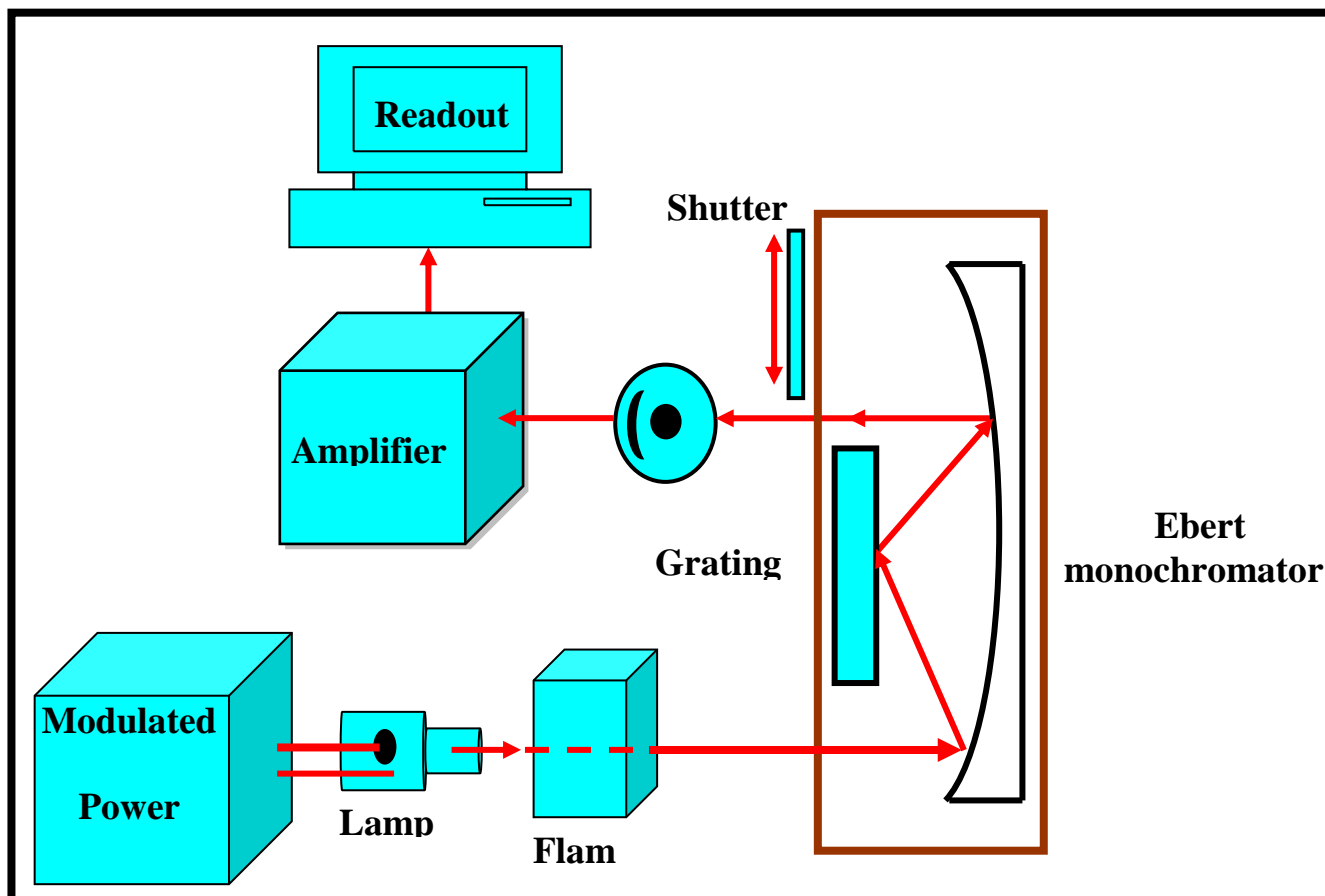


Fig. (3-1) : Diagram of Atomic Absorption Spectrophotometer



Plate (3-2): Atomic Absorption Spectrophotometer

3-4-2 Cold -Vapor Atomic Absorption Spectrophotometer:

A spectrophotometer type (PERKIN-ELMER) was used for the determination of mercury by the cold vapor technique. The flameless AAS procedure is a physical method based on the absorption of radiation at 253.7 nm by mercury vapor. The mercury is reduced to the elemental state and aerated from solution. The mercury vapor passes through a cell positioned in the light path of an atomic absorption spectrophotometer Cold Vapor Atomic

Absorption Spectrophotometer (CVAAS). Absorbance (peak height) is measured as a function of mercury concentration and recorded in the usual manner. A photo and a diagram of the spectrophotometer type (PERKIN-ELMER) used for the determinations of mercury metal are given in Fig. (3-3) and plate (3-2) respectively.



Plate (3-3) : Cold -Vapor Atomic Absorption Spectrophotometer

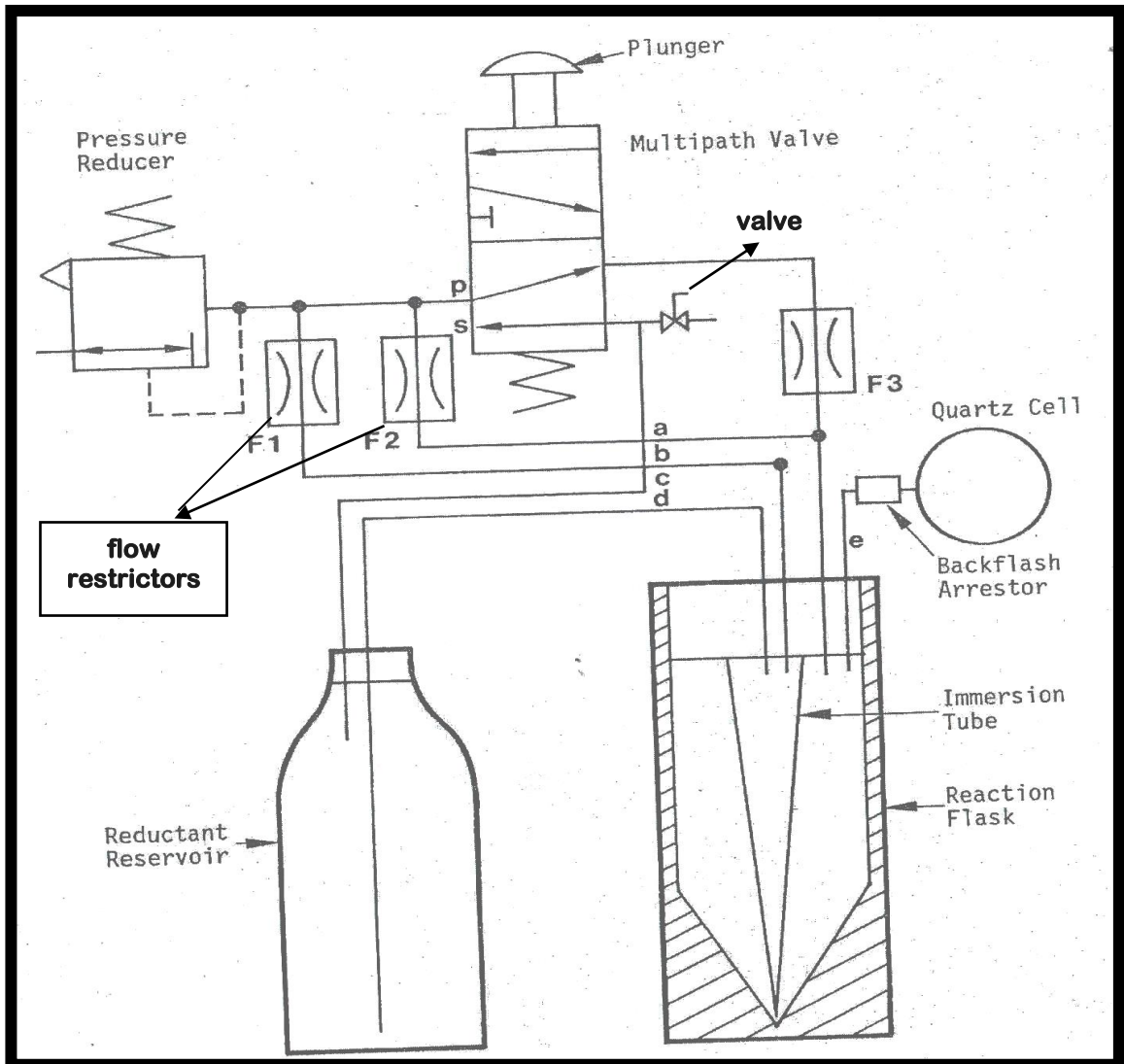


Fig. (3-2): Diagram of Cold-Vapor Atomic Absorption Spectrophotometer

3-4-3 Other Water Quality Parameters:

The standard methods for examination of water and waste water (APHA, 1998) were employed for all water quality measurements and these were:

1-Temperature(T):

Measured at sampling locations by simple thermometer (0-100) °C.

2- Hydrogen Ion (pH):

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

3-Turbidity (TU):

Nephelometric method by using electronic device (Turbidity model 2100 A HACH).

4- Total Suspended Solids(TSS):

A well- mixed sample is filtrated through a weight standard glass-fiber filter and residues retained on the filter is dried to constant weight at 103 to 105°C. The increase in weight of the filter represents the total suspended solid.

$$\text{Total suspended solid (mg/l)} = (A - B) * 1000 / \text{Sample volume, ml} \quad \dots\dots(3-1)$$

Where:

A = weight of filter + dried residue, mg, and

B = weight of filter, mg.

5- 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 solid.

$$\text{Total dissolved solid mg / l} = (A - B) * 1000 / \text{Sample volume, ml} \quad \dots\dots(3-2)$$

Where:

A = weight of dried residue + dish, mg, and

B = weight of dish, mg.

6-Conductivity (EC):

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

7-Sulphates (SO₄):**Gravimetric Method with Ignition of Residue :**

Sulfate is precipitated in a hydrochloric acid (HCl) solution as barium sulfate (BaSO₄) by the addition of barium chloride (BaCl₂).

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 BaSO₄.

$$\text{Sulfates SO}_4^{2-} \text{ mg /l} = \text{mg BaSO}_4 * 411.6 / \text{Sample volume, ml} \dots\dots\dots(3-3)$$

8- Chlorides (Cl⁻):**Argentometric method with AgNO₃:**

25 ml (sample) + chromate potassium K₂Cro₄ (1-3) drop + titration with AgNO₃.

$$\text{Chlorides (Cl}^-) \text{ mg/l} = \text{A} * 35.45 * 1000 / \text{Sample volume, ml} \dots\dots\dots(3-4)$$

A= titer for standard mg AgNO₃ /ml.

9-Total Hardness(TH):**EDTA titration method:**

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

$$\text{Hardness EDTA as (mg CaCO}_3\text{/l) = A*B*1000 / sample volume, ml} \dots\dots(3-5)$$

Where:

A: ml titration for sample and

B: mg CaCO₃ equivalent to 1ml EDTA titrant.

10- Alkalinity:**Titration with standard 0.02 H₂SO₄**

50 ml (sample) + Methyl (1-3)drop + Phenolphthalein (1-3) drop + titration with 0.02 H₂SO₄

$$\text{Alkalinity, (mg CaCO}_3\text{ / l) = A* t * 1000 / sample volume, ml} \dots\dots\dots(3-6)$$

Where:

A= ml standard acid used and

t= titer for standard acid, mg CaCO₃ / ml.

11-Calcium (Ca):**EDTA titration method**

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

$$\text{Calcium (Ca) mg / l} = A * B * 1000 / \text{sample volume,} \dots\dots\dots(3-7)$$

Where:

A: ml titration for sample and

B: mg CaCO₃ equivalent to 1ml EDTA titrant at the calcium indicator end point.

12- Dissolved Oxygen (DO):

Electronic DO meter devise (DO model **HACH / sens ion 6**).

Chapter Four

Results and Discussion

4-1 General:

The present study was conducted on Shatt Al-Hilla river and some drinking water treatment plants in Al-Hilla city in the aim of studying the concentration levels of trace elements (Fe, Cu, Zn, Hg, Pb, Cd) in addition to other physical and chemical characteristics of the river and drinking water. Samples were collected and analyzed from six locations for a period of eight months, starting from November 2007 until June 2008.

The atomic absorption technique was used for the determination of trace metals concentrations. The relationship between the concentration of metals in drinking water and river water was determined and was represented by curves using statistical fit. The relationship of each metal with the different physical and chemical characteristics was also plotted using statistical fitting. The best fit was determined by obtaining the coefficient of determination (R^2).

4-2 The Physical and Chemical Characteristics of the River Water:

4-2-1 Temperature(T °C):

Temperatures ranged in all stations throughout the study period between (10-30) °C. The highest value recorded was (30 °C) in the stations No. (5&6) in June, but the lowest value was (10 °C) during January at the Stations No. (1,2,3,&4). The variation of temperature level in Shatt Al-Hilla river during the period of the

study is given in Fig. (4-1).

The results obtained showed a slight difference in temperature between the samples collected at the same time from all stations, while there were clear differences in temperature for samples collected during separate times.

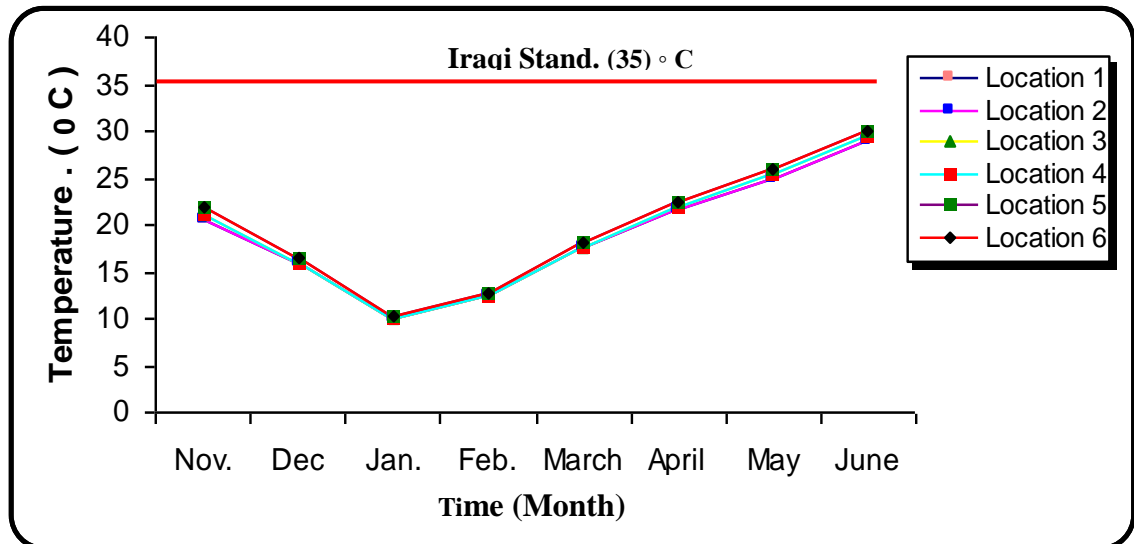


Fig.(4-1): Variation of the temperature with date

4-2-2 Hydrogen Ion Concentration (pH) :

The pH values at all stations were between (7.74-8.3). The highest pH value recorded was (8.3) at station No.(1&2) in February, while the lowest value was (7.74) in the station No.(6) in June. Fig. (4-2) presents the variation of hydrogen ion concentration in river water during the period of the study.

The pH value of water was decreases as the content of CO₂ increases, while it increases as the content of bicarbonate alkalinity increases. The narrow scope of pH values in rivers due to buffer capacity which enables the river to resist fluctuation in pH. Therefore, there was a narrow scope in pH value in Shatt Al-Hilla river and this agreed well with the result obtained by (Hassan, 2004; and Mohammad, et al., 1990).

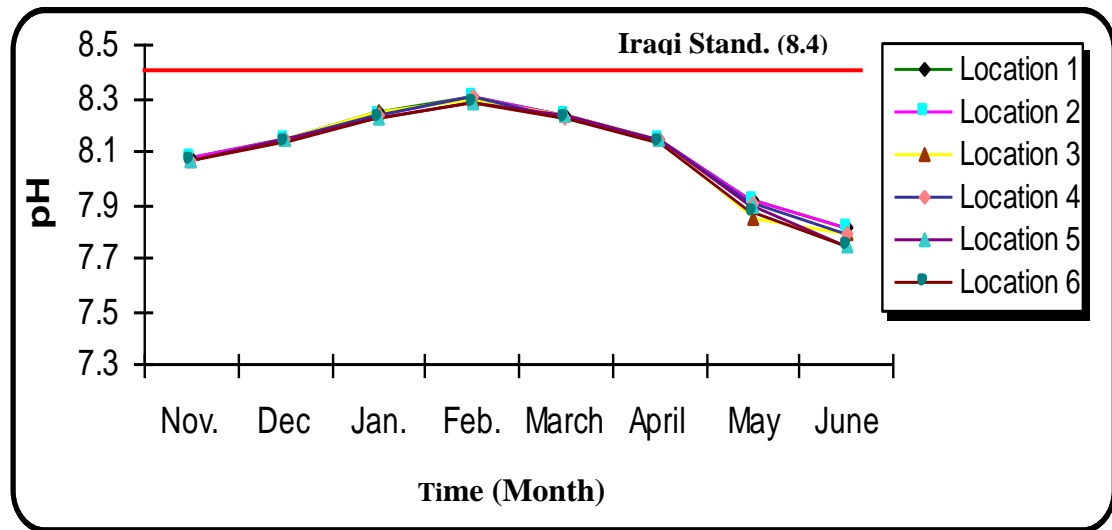


Fig.(4-2): Variation of the pH concentration with date

4-2-3 Total Hardness (T.H.):

Fig. (4-3) shows the variation of total hardness levels in the river water during the period of the study. These values ranged between (252-737) (mg/l) and the highest value of 737 (mg/l) was obtained in the station No.5 in February. The lowest value of 252 (mg/l) was obtained in the station No.2 in May.

The results of total hardness during February month in all stations were higher than the allowable Iraqi standard limits. This attributed to weathering processes during rain seasons, the disposal of industrial, municipal and agricultural wastes in to river. Many previous studies agreed with the present study that total hardness values are high in Iraqi waters such as (Alkam, et al., 2002).

This result agreed well with the finding of the present study concerning the hard nature of Shatt Al-Hilla river water at all chosen stations.

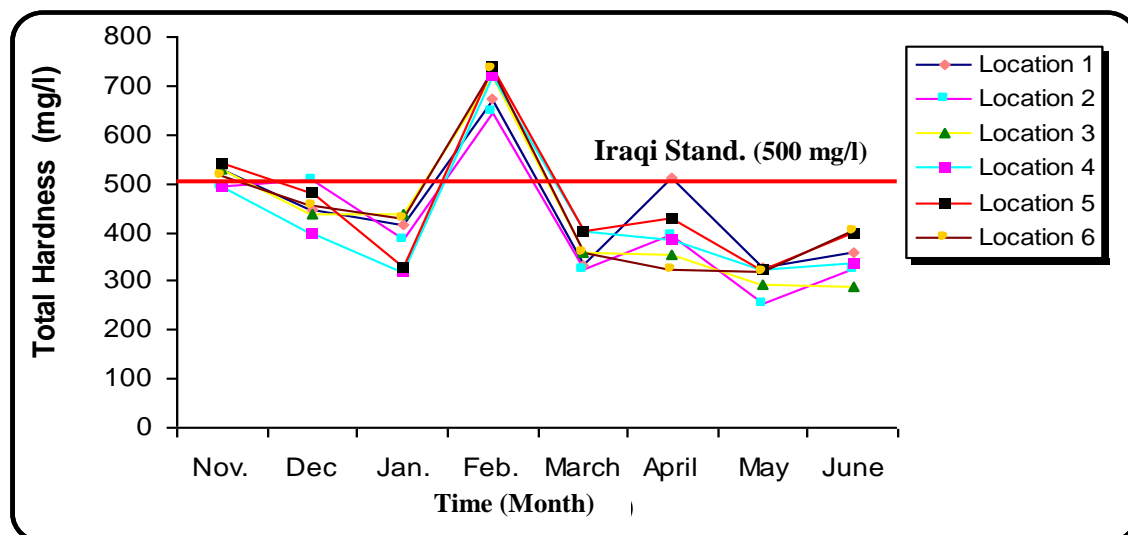


Fig.(4-3): Variation of the total hardness concentration with date

4-2-4 Alkalinity:

The highest alkalinity value was 164 (mg/l) at the station No.5 in January, and the lowest value was 92 (mg/l) at the Station No.2 in June. Fig. (4-4) 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 the major part of alkalinity due to the study which 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. Water level in rivers has a great effect on the alkalinity values, and this explain the monthly fluctuation of alkalinity values recorded during the present study. The results agreed with these obtained by many researchers such as (Smith, 2004; and Jassim, 2006).

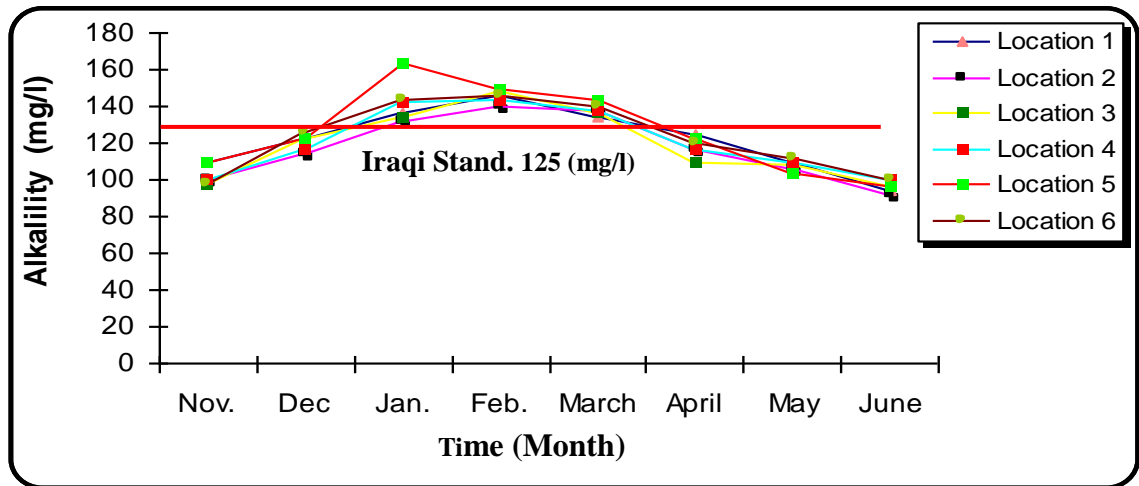


Fig. (4-4) Variation of the alkalinity concentration with date

4-2-5 Total Dissolved Solids (TDS):

TDS values throughout the period of the study at all the stations ranged between (592-1089) (mg/l) with a highest value of 1089 (mg/l) in the station No.6 in January, and a lowest value of 592 (mg/l) in the station No.3 in May. Fig. (4-5) shows that all results with allowable limit and the variation of total dissolved solid concentration in the river water during the period of the study.

A slight difference was observed in TDS values for the samples collected from the different stations 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 sulphates. 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 winter season months (January and February) this due to the washing of soil by rain water and as a result of the flow of drainage water from lands nearby the river. The found results agreed with the results obtained by (Al-Lami, et al., 2001).

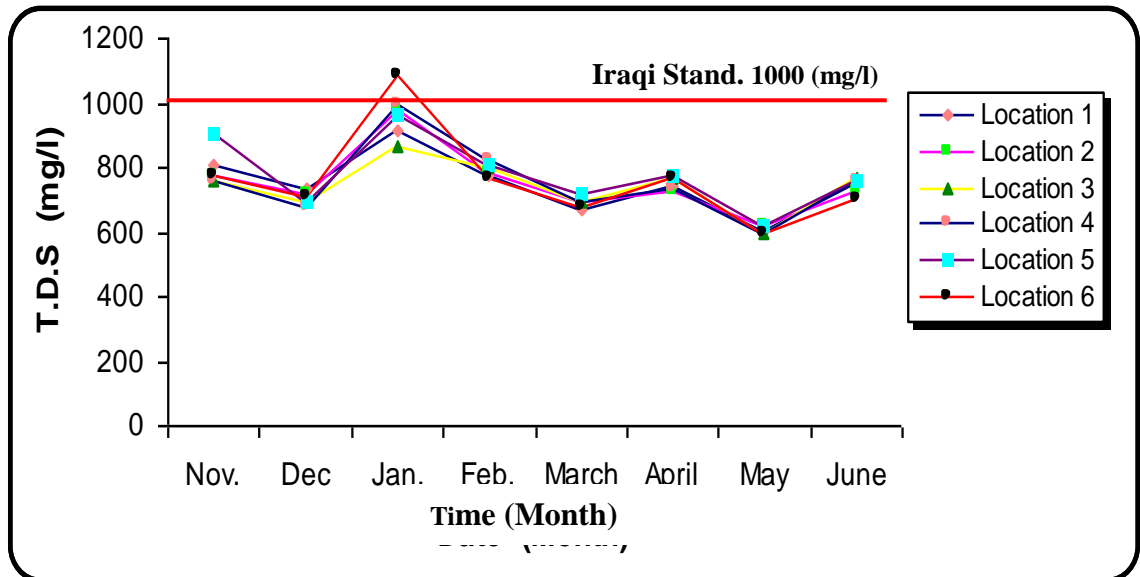


Fig. (4-5): Variation of the TDS concentration with date

4-2-6 Dissolved Oxygen (DO):

High levels of DO were recorded at most of the stations. The values recorded in the selected stations were ranging from (7.31-9.31), (7.28-9.22), (7.07-8.18), (7.24-10.27), (7.12-8.89), and (7.23-8.81) mg/l at the stations No. (1, 2, 3, 4, 5, & 6) respectively. The highest value was 10.27 (mg/l) recorded in the station No.4 in January due to good aeration, continuous mixing of water and dense zooplankton and phytoplankton which result in high levels of dissolved oxygen. While the lowest DO level in the river water was 7.07 (mg/l) at the station No.3 in June. This can be attributed to the biological degradation of the organic materials or the low water level at these stations, the same conclusion was found by (**Jassim, 2006**). Fig. (4-6) shows the variation of dissolved oxygen levels in the river during the period of the study.

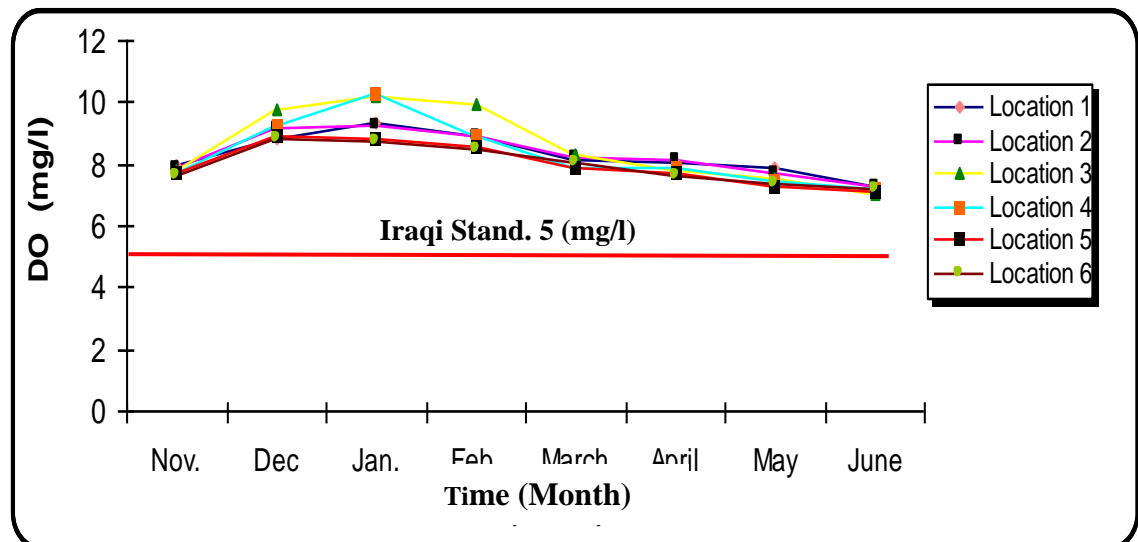


Fig. (4-6): Variation of the dissolved oxygen concentration with date

4-2-7 Total Suspended Solid (TSS):

TSS values in the river ranged between (24.86-50.76) (mg/l). The highest value obtained was (50.76) mg/l in the station No.3 in June, but the lowest value was (24.86) mg/l at the Station No.4 in January. A graph of Total suspended solid concentration versus time is given in Fig. (4-7). At a given river station turbidity can often be related to TSS, especially where there are large fluctuations in suspended matter which consists of silt, clay, fine particles of organic and inorganic matter, soluble organic compounds, plankton and other microscopic organisms.

The present study showed that concentrations of total suspended solids were higher during summer and spring seasons. This can be attributed to the fact that the main source of water in Shatt Al-Hilla river during both spring and summer seasons is the water stored in dams and caused by erosion runoff and discharges. This was asserted by (Al-Tufaily, 1995; Al-Tae, 1999; and Jassim, 2006).

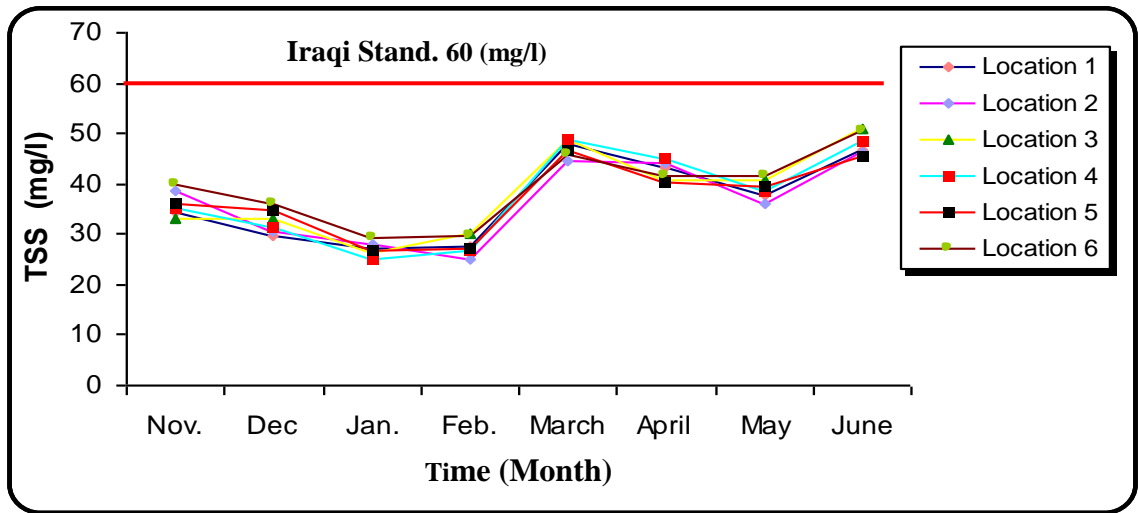


Fig. (4-7):Variation of the TSS concentration with date

4-2-8 Turbidity(TU):

Water turbidity in the river ranged between (15-30.2) (NTU). Wide differences were observed in turbidity levels from location to another and from time to time. The highest turbidity value recorded was 30.2 (NTU) at the station No.3 in June. On the other hand, the lowest value was (15) (NTU) in the station No. (2&4) in February and January. Fig. (4-8) shows the variation of turbidity concentration in the river water during the period of the study.

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.

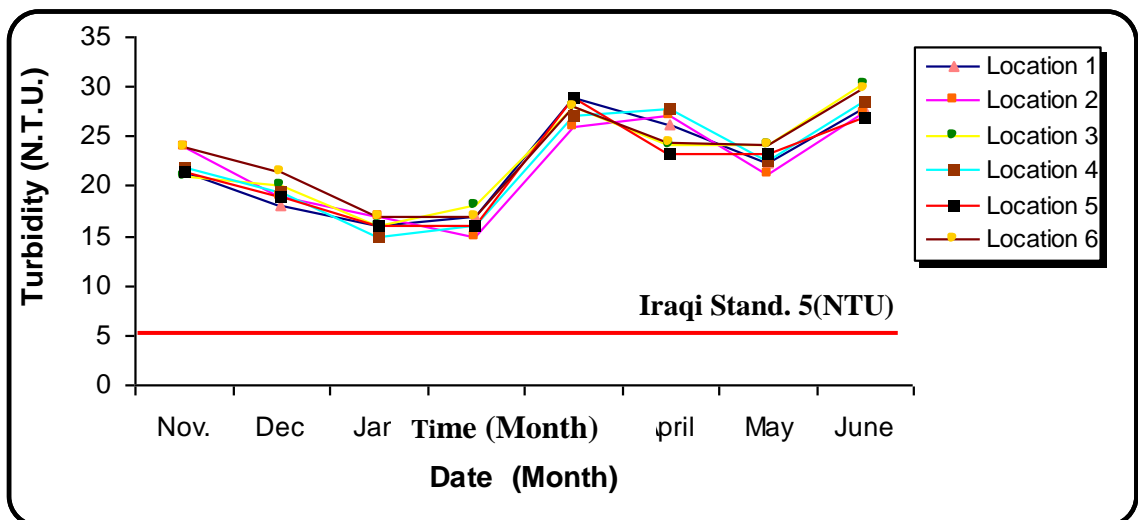


Fig. (4-8):Variation of the turbidity concentration with date

4-2-9 Chlorides (Cl⁻):

Chloride levels in shut Al-Hilla river were ranging from 140 to 226 mg/l, a highest value of 226 mg/l at the station No.2 in January, and a lowest value of 140 (mg/l) at the station No.4 in June. It can be observed that chlorides level in the river meets the Iraqi system of maintenance of rivers and public waters from pollution No. 25, 1967 with last revisions of 200(mg/l). The variation of chlorides level in Shut Al-Hilla river during the period of the study is shown in Fig. (4-9).

This Fig. shows an increase in chloride levels during winter and spring in most stations. This 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).

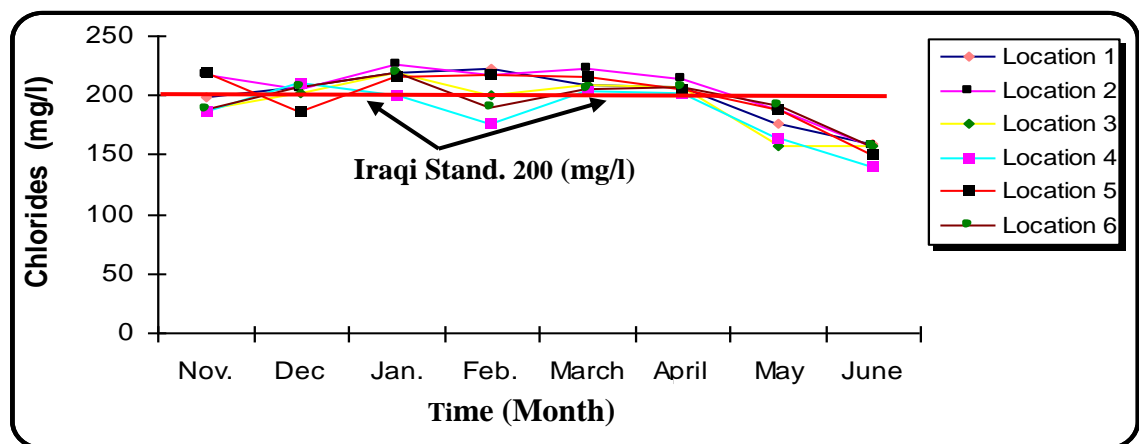


Fig. (4-9):Variation of the chlorides concentration with date

4-2-10 Sulphates (SO₄):

Throughout the period of the present research it was found that sulphates concentration ranged between (191.8-391.8) (mg/l). The highest value obtained was 391.8 (mg/l) in the station No.6 in January, and the lowest value was 191.8 (mg/l) at the Station No.5 in November. Fig. (4-10) gives the variation of sulphate levels in

the river water during the period of the study.

Results of the current study show that the values of sulphate during winter season is higher than other seasons and higher than the allowable Iraqi standards. This due to present of Sulphate in natural surface water as sulphate minerals (gypsum) or sulphide minerals (pyrite) from sedimentary rocks, industrial discharges and atmospheric precipitation, which agreed very well with the results of the previous study carried out by (Talk, 2004).

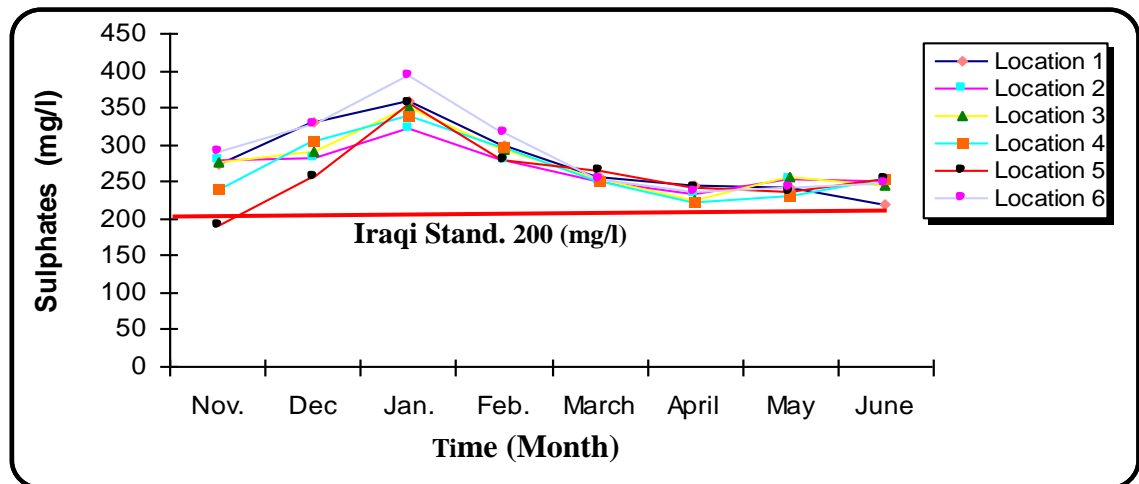


Fig. (4-10): Variation of the sulphates concentration with date

4-2-11 Electrical Conductivity (Ec):

Conductivity values throughout the period of the study at all the stations ranged from (838) ($\mu\text{s}/\text{cm}$) to (1613) ($\mu\text{s}/\text{cm}$). The highest value was 1613 ($\mu\text{s}/\text{cm}$) in the station No.6 in January, while the lowest value was 838 ($\mu\text{s}/\text{cm}$) at the Station No.3 in May. The variation of conductivity level in river water during the period of the study shown in Fig.(4-11). The results show clear seasonal differences in conductivity values.

High values were recorded in the winter season, this due to the washing of soil by rain water and as a result of the flow of salinity water from drainages nearby the river. This was asserted by the increase in value rates of soluble and suspended solid substances in river water. This was in agreement with other studies conducted by (Al-Mussawi, et al., 1995; Al-Lami, et al., 2001; and Jassim, 2006).

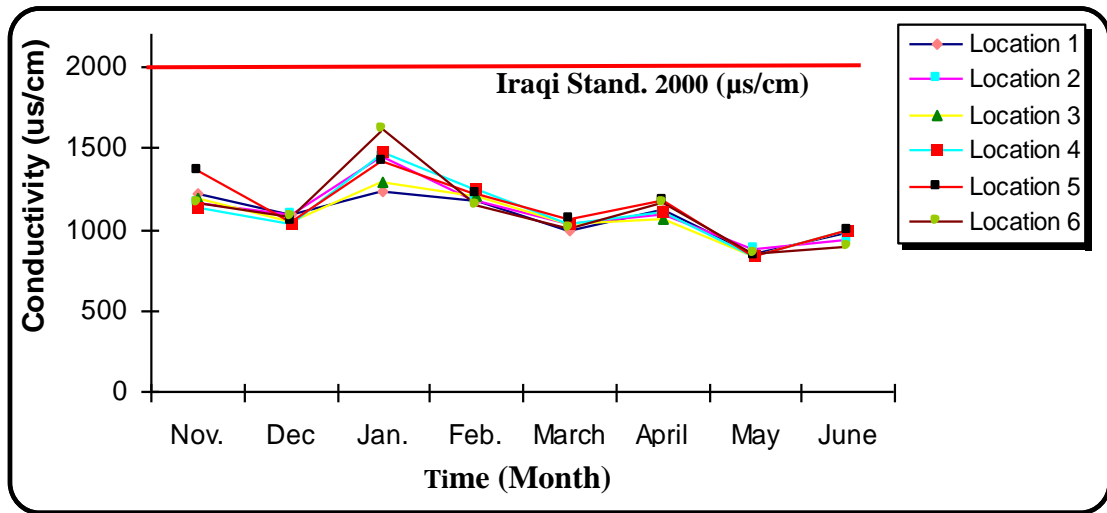


Fig. (4-11): Variation of the conductivity concentration with date

4-2-12 Calcium (Ca):

Calcium levels in shut Al-Hilla river water were ranging (42-117) (mg/l). The highest value obtained was 117 (mg/l) in the station No.4 in February, while the lowest value was 42 (mg/l) at the station No.4 in April. A graph of calcium concentration versus date is given in Fig. (4-12).

This Fig. shows that calcium concentrations were high during most seasons of the study this 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).

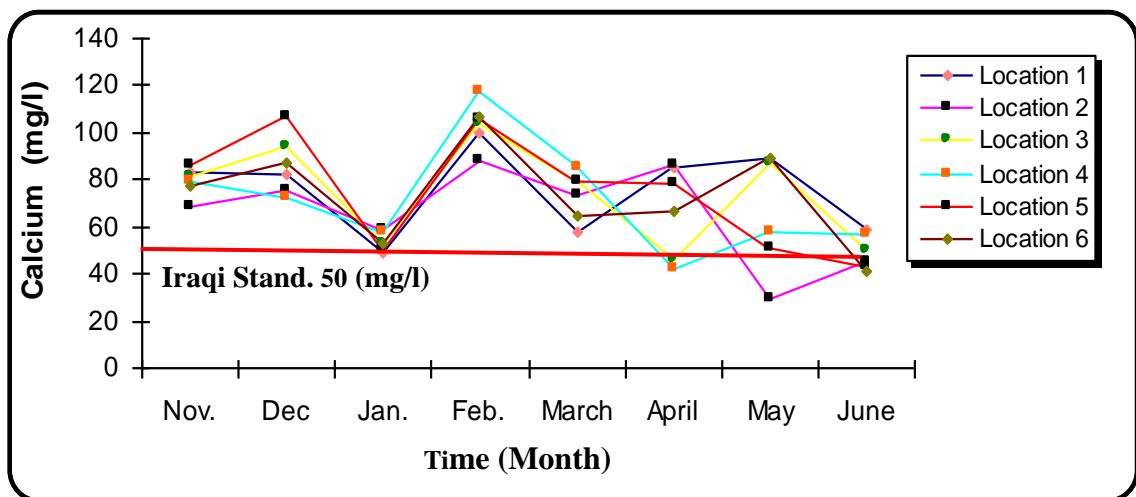


Fig. (4-12): Variation of the calcium concentration with date

4-3 Heavy Metals in River:

4-3-1 Cadmium (Cd):

The highest value of cadmium in the river water was (6.5) ($\mu\text{g/l}$) at the station No.(1 and 5) during June and the lowest value was (2.14) ($\mu\text{g/l}$) at station No.4 during February. The variation of cadmium level in Shatt Al-Hilla river water during the period of the study is shown in Fig. (4-13).

Statistical results showed that there was negative correlation between cadmium level and hydrogen ion concentration, dissolved oxygen, chlorides, sulphates, and conductivity values but, the positive correlation was found with each of total suspended solids, temperature, turbidity, iron, copper, lead, and mercury. Also significant negative correlation was recorded between cadmium and dissolved oxygen because the increase of dissolved oxygen leads to precipitation of cadmium at high value of hydrogen ion. On the other hand, cadmium was found to be precipitated due to the negative correlation with hydrogen ion and positive correlation with suspended matter, which leads to the adsorption of cadmium onto hydrous oxides which acts as scavenger for cadmium and finally to the precipitation of cadmium. Results showed that maximum cadmium concentration levels in river water were higher Iraqi system of maintenance for rivers and public waters from pollution No. 25, 1967 with last revisions as shown in Table (1-1).

It was noticed that cadmium level increases during summer months as compared with other months of the year because of storage water which is stored in dams which represent the main source of Shatt Al-Hilla river during summer season. Also, high concentrations of suspended solids during summer and spring caused by many factors such as floating materials which increases

the concentrations of trace metals in water. Chemical compounds which are used in agricultural purposes such as commercial fertilizers and pesticides, contain some trace elements, while phosphate fertilizers contain different concentrations of cadmium. So, these compounds comprise one of the reasons of the increase in the cadmium concentration in the river.

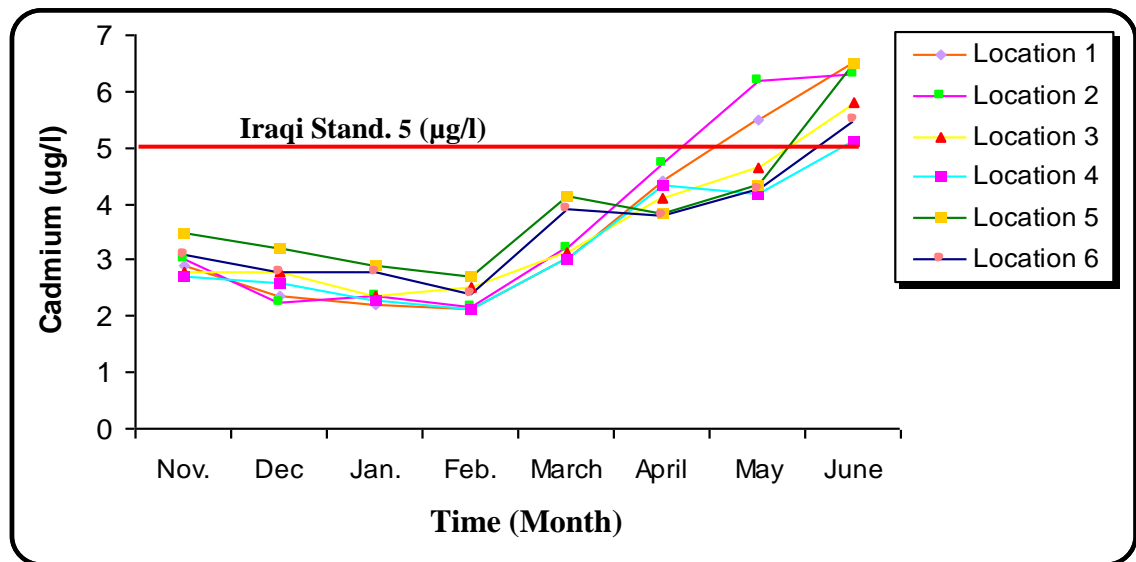


Fig.(4-13): Variation of the cadmium concentration with date

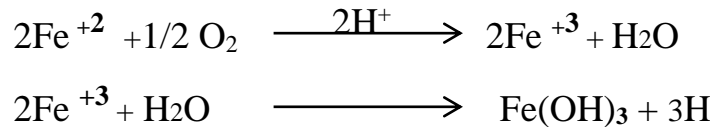
4-3-2 Iron (Fe) :

Results showed that the highest value of iron was (640) ($\mu\text{g/l}$) at the station No.3 in June, while the lowest value was (452) ($\mu\text{g/l}$) at the station No.2 in January. Fig. (4-14) shows the variation of iron concentration in the river water during the period of the study.

Statistical results showed that iron was negatively correlated with hydrogen ion concentration, dissolved oxygen, conductivity, sulphates, and chlorides and positively correlated with total suspended solids, temperature, turbidity, copper, mercury, cadmium.

Maximum iron concentration levels at all stations measured in river water were higher than Iraqi system of maintenance of rivers and public waters from pollution No. 25, 1967 with last revisions.

It was noticed that the level of iron concentrations increases in May and June compared to other months, and this may be related to the low level of dissolved oxygen which is not enough to precipitate $\text{Fe}(\text{OH})_3$ in May and June, while during other months high concentration of oxygen leads to oxidize iron from +2 to +3 followed by hydrolysis to form $\text{Fe}(\text{OH})_3$



The negative correlation between iron concentration and hydrogen ion concentration supports the above suggestion.

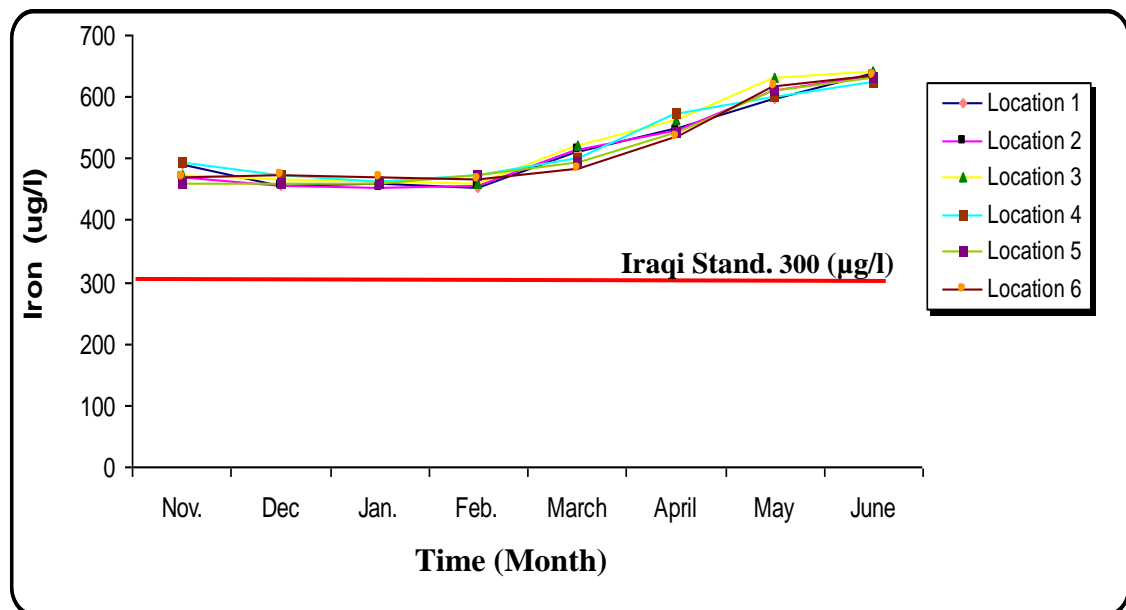


Fig.(4-14): Variation of the iron concentration with date

4-3-3 Copper (Cu) :

The highest value of copper was (64) ($\mu\text{g}/\text{l}$) at the Station No.3 in June and the lowest value was (38.7) ($\mu\text{g}/\text{l}$) at stations No.1 in February. A graph of copper concentration versus date is given in Fig. (4-15).

Statistical analysis shows that copper has negatively correlated with each of hydrogen ion, dissolved oxygen, also, the chloride concentration and copper has positively correlated with iron, mercury, cadmium, turbidity, total suspended solids and temperature. Results showed that maximum copper concentration levels in river water were within allowable Iraqi system of maintenance of rivers and public waters from pollution No. 25, 1967 with last revisions.. The negative relation between Copper and hydrogen ion concentration leads to precipitation of copper as basic copper carbonate $\text{CuCO}_3 \cdot \text{Cu}(\text{OH})_2 \cdot \text{H}_2\text{O}$ at $\text{pH} > 7$. The significant negative correlation obtained between copper and dissolved oxygen is a result of the formation of insoluble copper oxide. This can be considered as a reason for the increase in the concentration of copper in the river water during summer months and decreased in all results recorded during the period of the study due to sediment of metal.

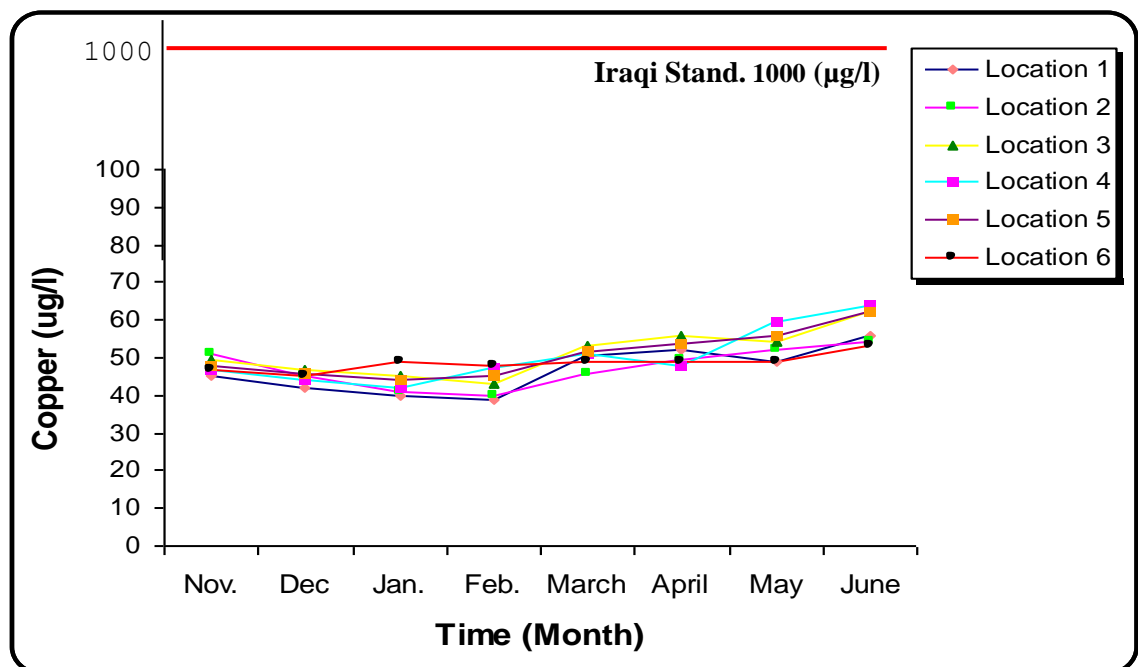


Fig.(4-15): Variation of the copper concentration with date

4.3.4 Mercury (Hg):

It was found that the highest value of mercury is (3.44) ($\mu\text{g/l}$) at the Station No.5 in June and the lowest value is (0.79) ($\mu\text{g/l}$) at stations No.6 in February. The results ranged between (0.79-3.44) ($\mu\text{g/l}$) as shown in Fig. (4-16).

Statistical results showed that there was negative correlation between mercury and hydrogen ion, dissolved oxygen, and chloride, and positive correlation with total suspended solids, temperature, turbidity, zinc, iron, cadmium and copper. It was found that maximum mercury concentration levels in river water were higher than allowable Iraqi system of maintenance of rivers and public waters from pollution No. 25, 1967 with last revisions. Like the previous elements, mercury concentration levels increased in May and June compared to other months. The highest mercury levels found in this study were less than that recorded by the previous study on Shatt Al-Hilla river conducted by **(Al-Taee, 1999)** and this attributed to the decrease in industrial activities and wastewater discharged by many industries located on the upstream of the river especially in Al-Musyab and Al-Eskendria city such as (Al-Qa'aqaa and Hateen company). The high mercury levels at most stations during study period caused by seepage of mercury to river from polluted areas which are located near the sources of pollution and lie near the banks of Shatt Al-Hilla river and attributed to the presence of many companies and factories that discharge waste directly into river such as Al-Furat company for chemical industries. The high concentration at some locations, due to natural sources coming from the erosion of sediment participates by water current because of the turbulence of flow at any location which cause high turbidity.

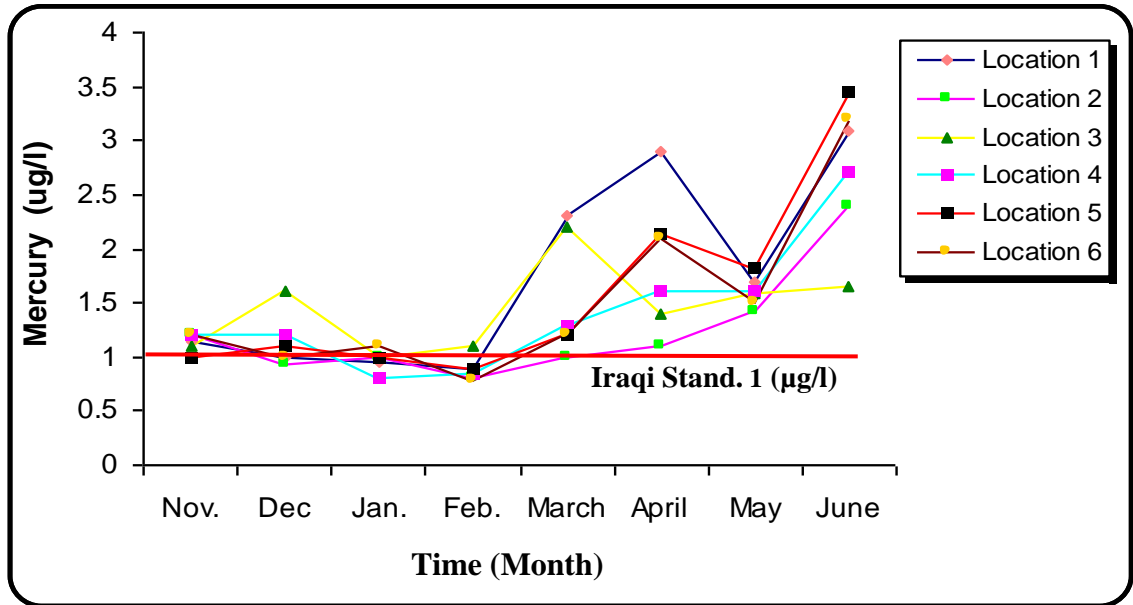


Fig.(4-16): Variation of the mercury concentration with date

4.3.5 Lead (Pb):

In this study it was found that the highest value of lead was (7.2) ($\mu\text{g/l}$) at the station No.4 in April and the lowest value was (3.2) ($\mu\text{g/l}$) at station No.3 in January. Fig. (4-17) gives the variation of lead levels in the river during the period of the study.

Statistical results showed that lead was negatively correlated with each of sulphates, dissolved oxygen, and hydrogen ion and positively correlated with total suspended solids, temperature, turbidity, Copper, iron, and cadmium.

Maximum lead concentration levels met the allowable Iraqi system of maintenance of rivers and public waters from pollution No. 25, 1967 with last revisions.

Lead compounds in river resulted from the burning process of lead tetraethyl (used as anti-knock) in the internal combustion machines. This phenomenon has a significant effect on lead levels in river water especially after the great increase in the number of cars in the country after 2003.

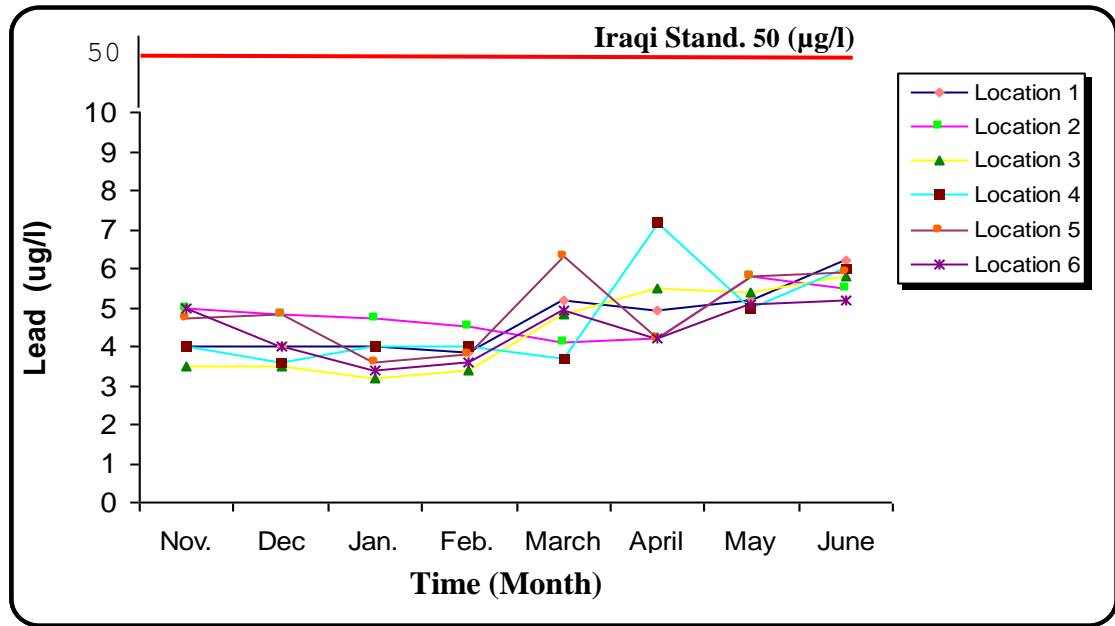


Fig.(4-17): Variation of the lead concentration with date

4.3.6 Zinc (Zn):

Results of the study recorded that the highest value of zinc was (64.2) ($\mu\text{g/l}$) at the station No.5 in June while the lowest value was (31.2) ($\mu\text{g/l}$) at the station No.1 in February. Fig. (4-18) shows the variation of zinc concentration of the river water during the study period.

Statistical negative correlation between zinc and dissolved oxygen and in lower degree with hydrogen ion, but positive correlation with total suspended solids, temperature, iron, mercury, copper, cadmium and turbidity. Maximum zinc concentration levels in Shatt Al-Hilla river met with the Iraqi system of maintenance of rivers and public waters from pollution No. 25, 1967 with last revisions. During summer months especially during June, zinc concentrations increased more than the others due to many factors such as many of the Euphrates and Shatt Al-Hilla river washed soil campaign like different chemical compounds which are used for agricultural purposes of fertilizers and pesticides, where great

amount of soil is drifted into water carrying with it different kinds of chemical compounds (salts of zinc). The increase of zinc concentrations is high in summer because of the source of water in the river of Euphrates and Shatt Al-Hilla. In this season the water stored in dams for irrigation purposes, thus, high concentrations of suspensions in summer and spring are attributed to floating materials, and high temperatures, leading to evaporator of water and therefore increase in concentrations. The significant negative correlation recorded between the zinc and dissolved oxygen, is attributed to the increase of the dissolved oxygen which leads to precipitate zinc as $Zn(OH)_2$ at high hydrogen ion. This explains the negative correlation between zinc and hydrogen ion. On the other hand, the highly significant positive correlation between zinc and suspended matter is related to adsorption of zinc onto anhydrous Fe_2O_3 which acts as scavenger for zinc. It was also found that there was a positive correlation with the rest elements in this study, with less extent with lead.

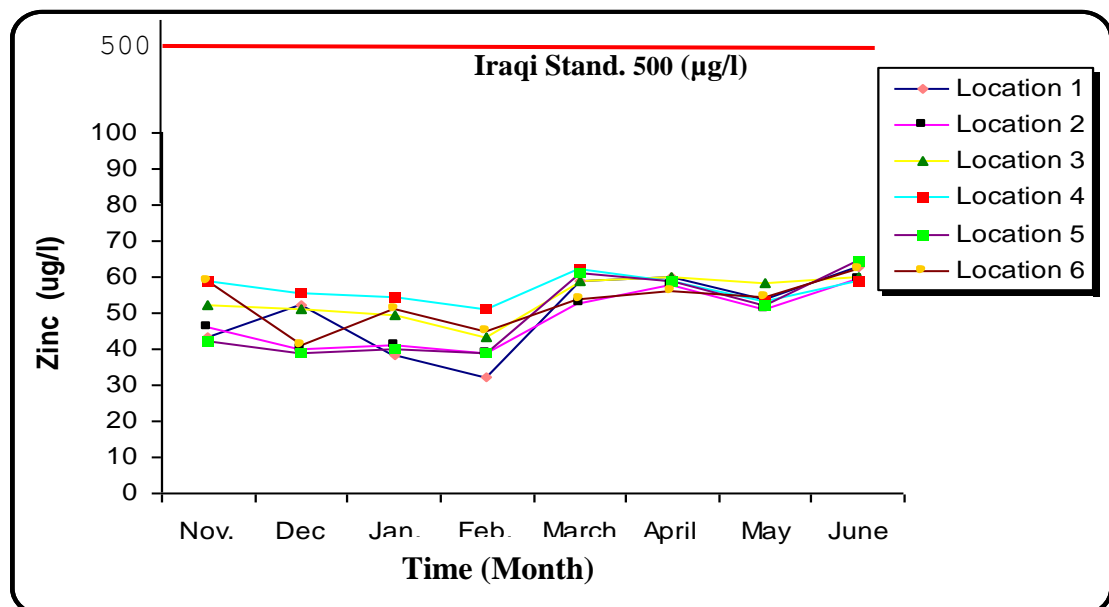


Fig.(4-18): Variation of the zinc concentration with date

4-4 Effects of water quality parameters on the levels of trace metals in the river:

There are many factors that can affect the pollution level of Shatt Al-Hilla river with traces metals. These factors are:

1. Presence of agricultural areas on both banks of the Euphrates and Shatt Al-Hilla river, since many of them washed soil campaign of different chemical compounds which are used for agricultural purposes of fertilizers and pesticides, where great amount of soil is drifted into water carrying with it different kinds of chemical compounds which are used in agricultural purposes such as fertilizers and pesticides. Pointed out that commercial fertilizers contain some traces of elements, while phosphate fertilizers contain different concentrations of cadmium ranging from (1-95) mg/kg. Other compounds, such as salts of zinc, copper, lead, and other organic metallic compounds are used as pesticides.

2. The river runs through a number of towns, suburbs, and villages such as Saddat-Al-Hindia, Al-Mahaweel, Al-Hilla, and Al-Hashmiya and other towns. These places add more pollutants to the river caused by the discharge of domestic and factory waste materials. These materials have a direct and indirect impact on the river.

3. In certain circumstances, elements which are present in sediments interact with water resulting in the formation of other sediments which cause dangerous effects in water. These sediments are a potential source of pollution. Also, the sudden change in water quality covering sediments may lead to the liberation of large quantities of elements accumulated in the contaminated area.

4. The increase of concentrations is higher in summer because the source of water in the river of Euphrates and Shatt Al-Hilla

river. In this season the water stored in dams for irrigation purposes. Thus, high concentrations of suspensions in summer and spring are attributed to floating materials.

5. There is a relation between the concentration of heavy elements and the water level. This was reflected clearly on the decrease or increase of concentration of elements in the Shatt Al-Hilla river during the period of the study.

6. The reason behind the low concentration of dissolved elements in some locations of the water river are due to the tendency of these elements to accumulate in the floating plants and other aquatic plants, or perhaps because of a tendency of heavy materials to be absorbed on sediment surfaces or the formation of compounds with organic materials.

Generally in the present work, it was found that the most related parameters affecting on trace metals concentration in Shatt Al-Hilla river were: turbidity, temperature, hydrogen ion, dissolved oxygen, and total suspended solids and in lower degree with parameters chlorides, sulphates, electrical conductivity, and alkalinity. while total hardness, calcium, and total dissolved solids parameters have low significant effect on trace metals concentrations in this study.

The range, mean and standard division of the selected trace metals and other water quality parameters in Shatt Al - Hilla river are shown in Table (4-1).

4-5 Drinking water:

concentrations of Fe, Cd, Cu, Hg, Pb, and Zn in treated water and the removal percentage of each element were studied in two treatment plants. The treatment processes used in Al-Hilla Al-Kadeem treatment plant and Al-Hilla Al-Jadeed treatment plant are: alum coagulation, sedimentation, filtration, and chlorination.

The concentration of trace elements in treated water is shown in Figs. (4-19 to 24 and from 4-25 to 30) for Al-Hilla Al-Kadeem treatment plant and Al-Hilla Al-Jadeed treatment plant respectively.

High concentrations in elements were observed in treated water with high turbidity or when the raw water contains high concentrations of heavy metals, while the low concentrations of elements occurs at low turbidity in treated water or when element concentration in the raw water is low. Therefore it is necessary to control the turbidity in treatment water for the two treatment plants because it plays a significant role in minimizing the concentration of most elements in treated water.

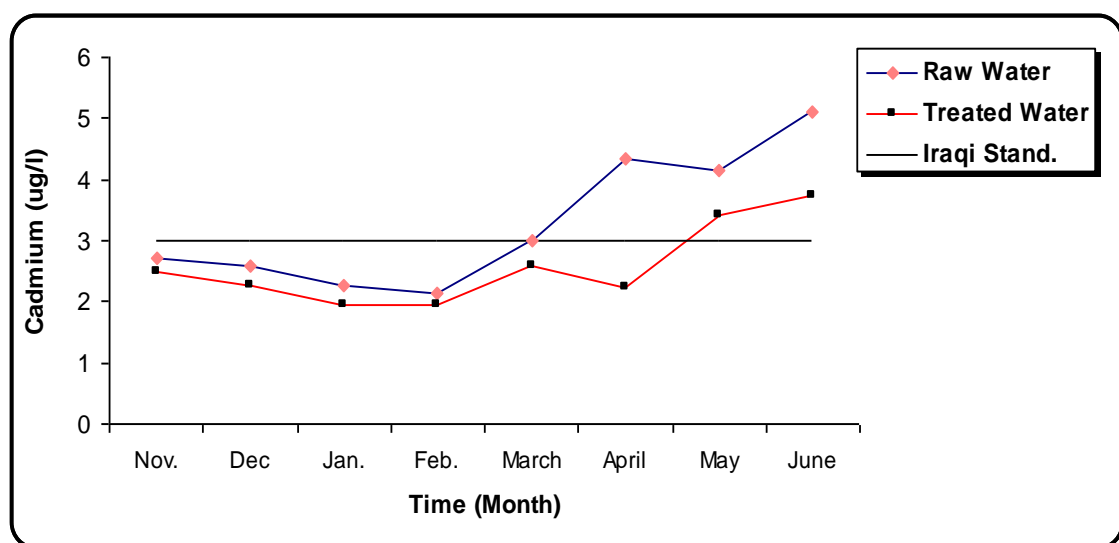


Fig. (4-19): Cadmium concentration in treated water at Al-Hilla Al-Kadeem treatment plant

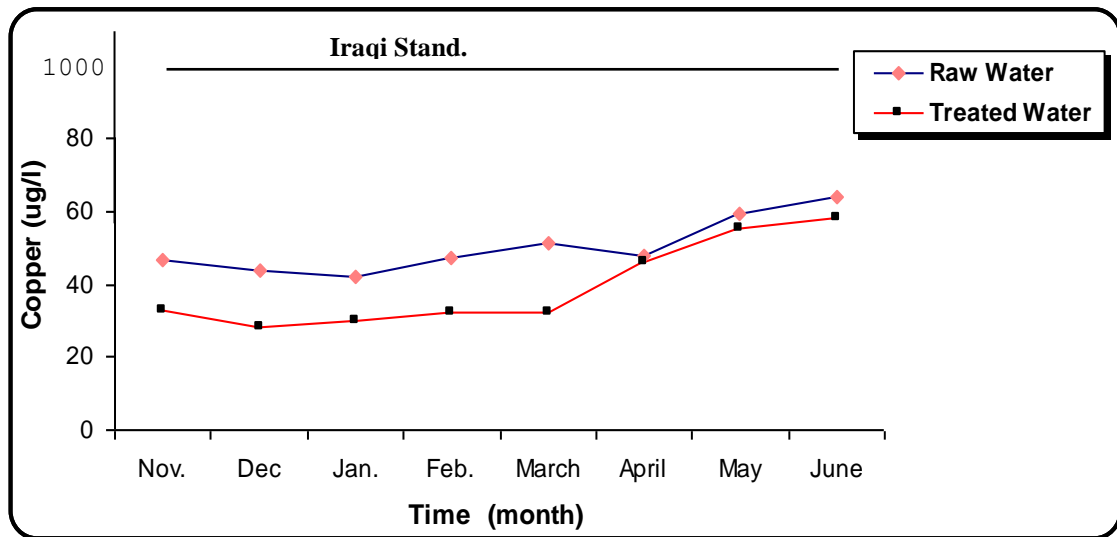


Fig. (4-20): Copper concentration in treated water at Al-Hilla Al- Kadeem treatment plant

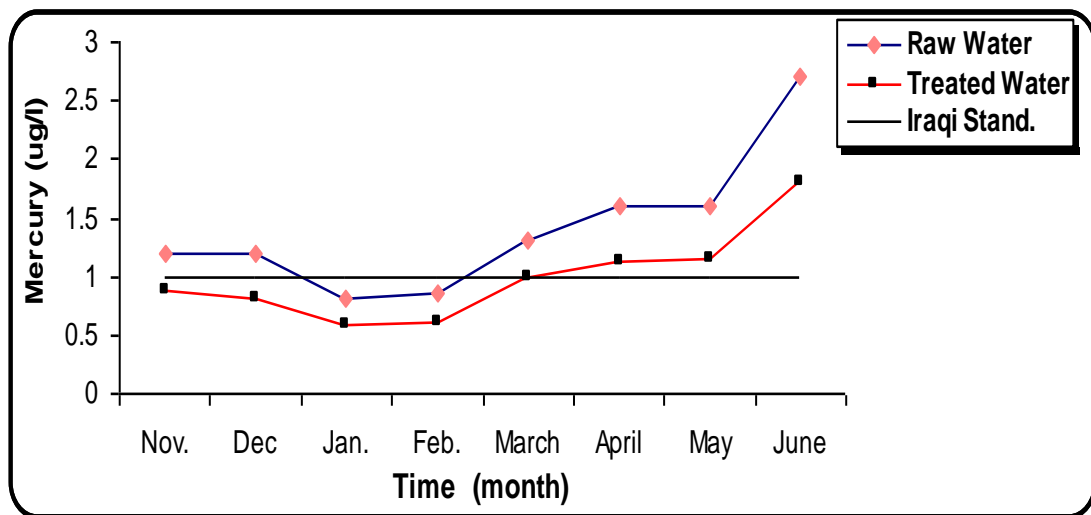


Fig. (4-21): Mercury concentration in treated water at Al-Hilla Al- Kadeem treatment plant

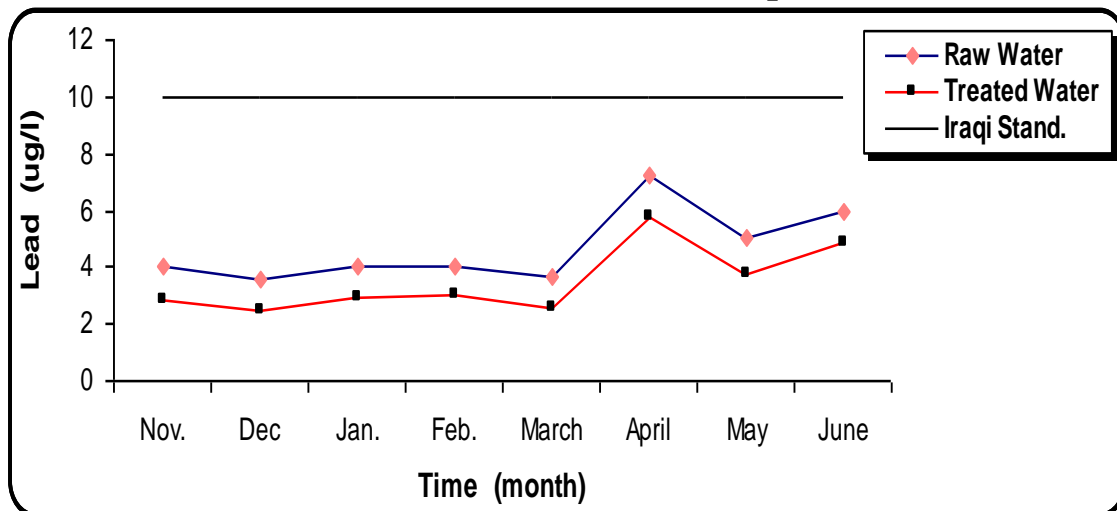


Fig. (4-22): Lead concentration in treated water at Al-Hilla Al- Kadeem treatment plant

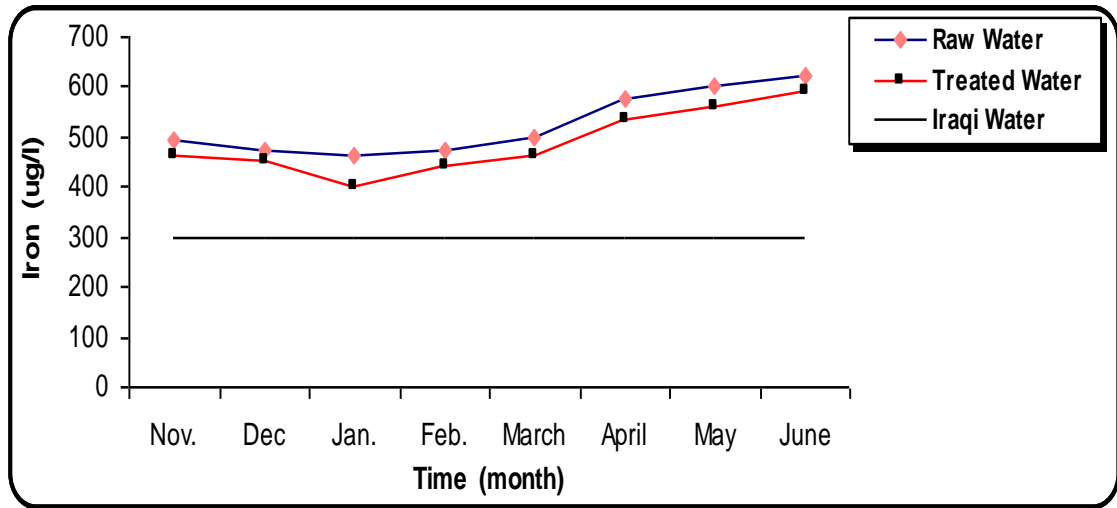


Fig. (4-23): Iron concentration in treated water at Al-Hilla Al- Kadeem treatment plant

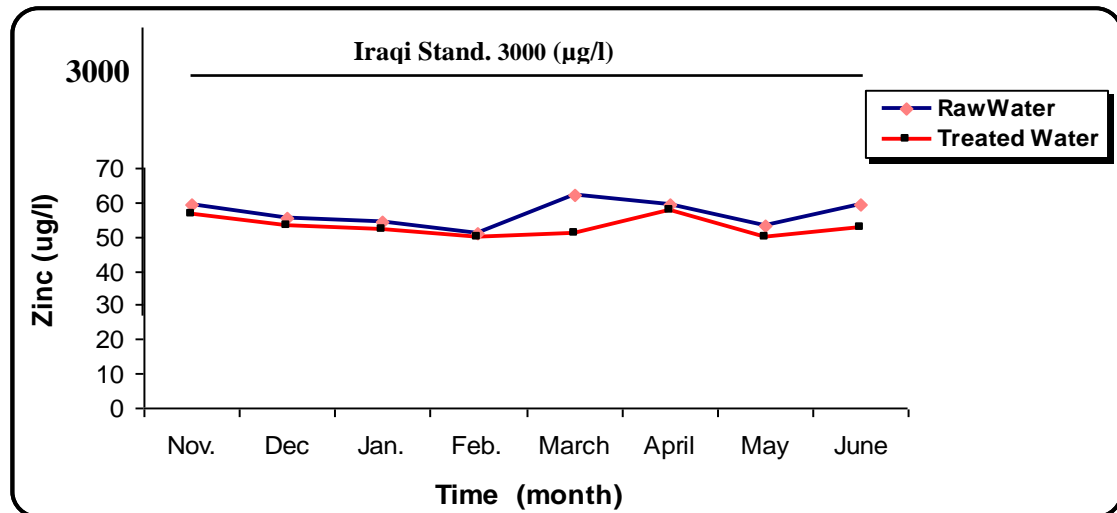


Fig. (4-24): Zinc concentration in treated water at Al-Hilla Al- Kadeem treatment plant

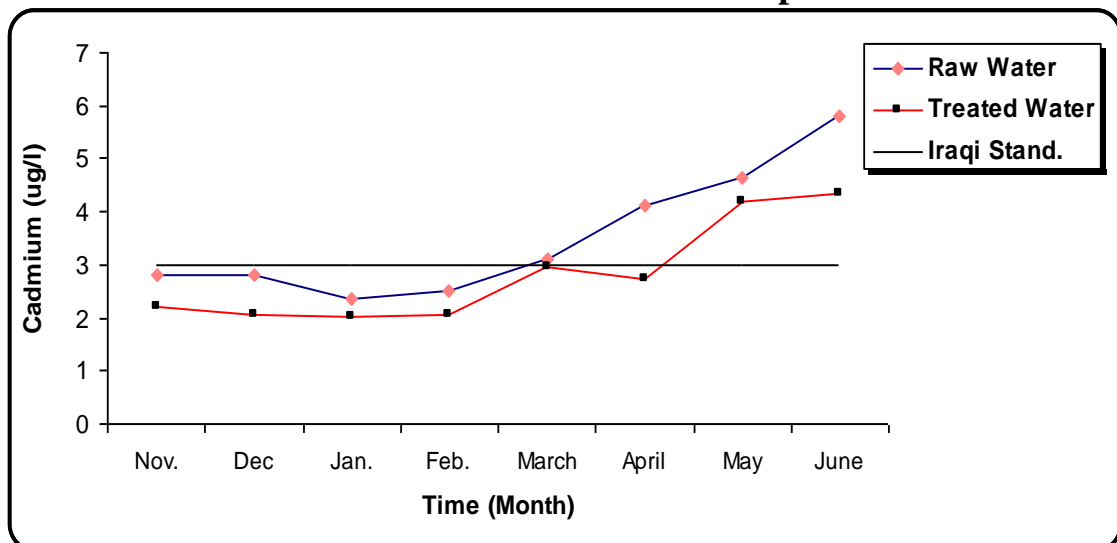


Fig. (4-25): Cadmium concentration in treated water at Al-Hilla Al- Jadeed treatment plant

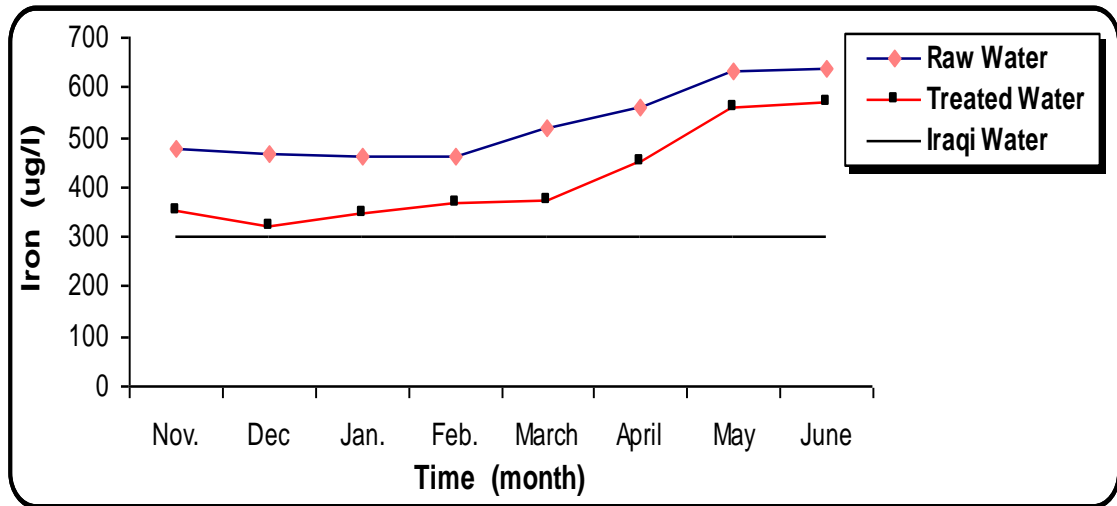


Fig. (4-26): Iron concentration in treated water at Al-Hilla Al- Jadeed treatment plant

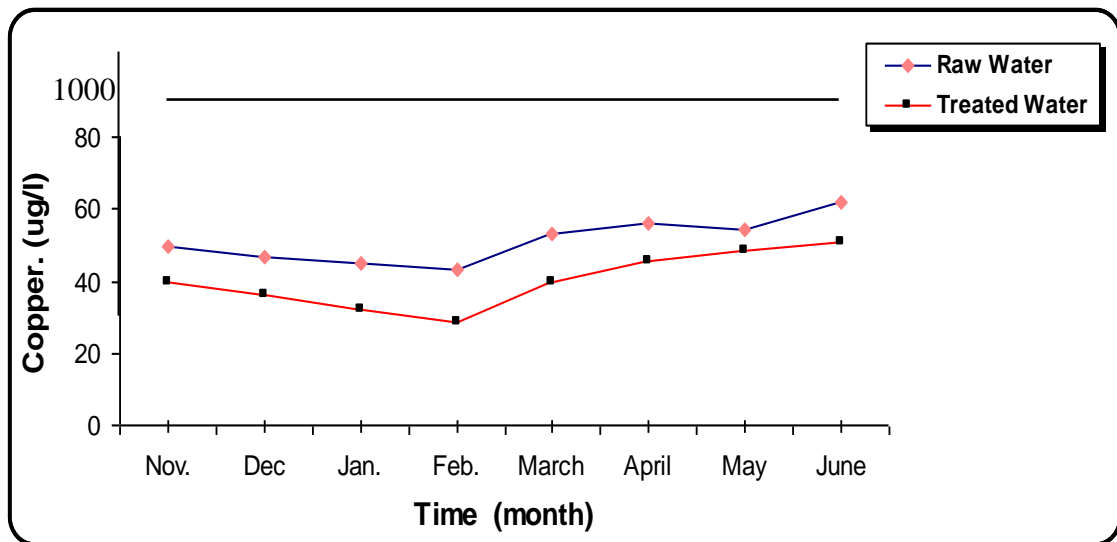


Fig. (4-27): Copper concentration in treated water at Al-Hilla Al- Jadeed treatment plant

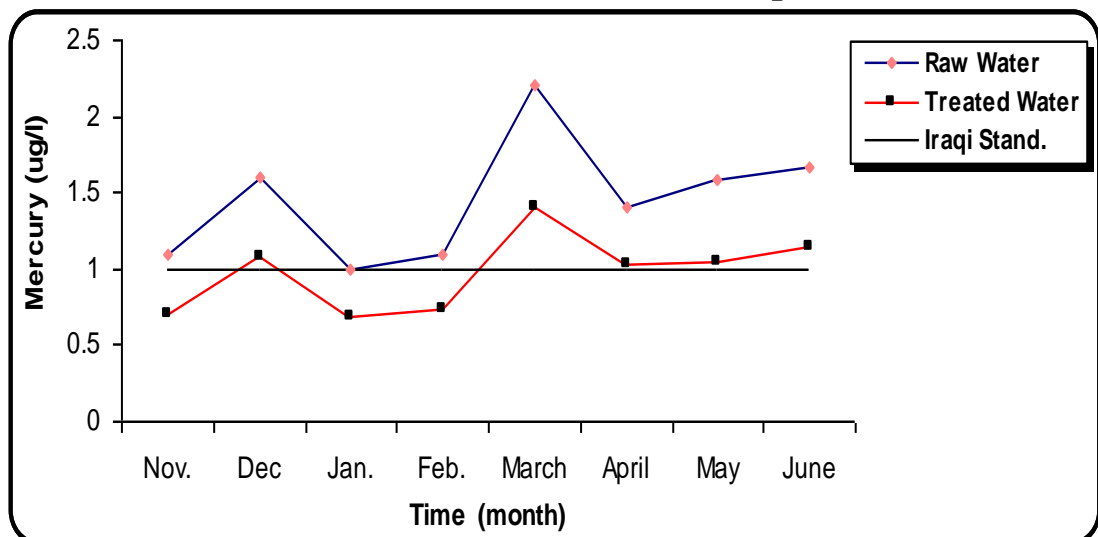


Fig. (4-28): Mercury concentration in treated water at Al-Hilla Al- Jadeed treatment plant

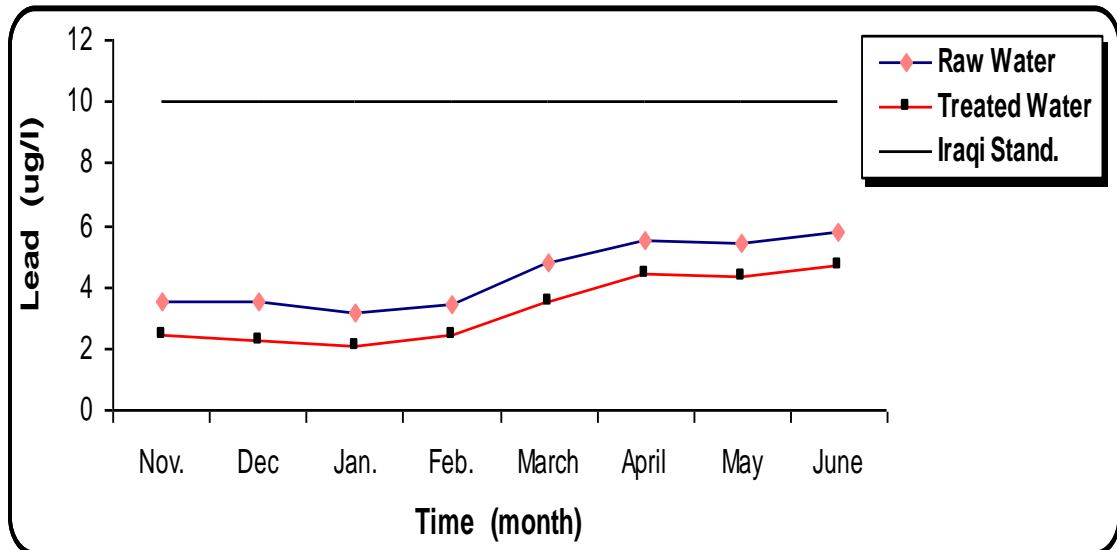


Fig. (4-29): Lead concentration in treated water at Al-Hilla Al- Jadeed treatment plant

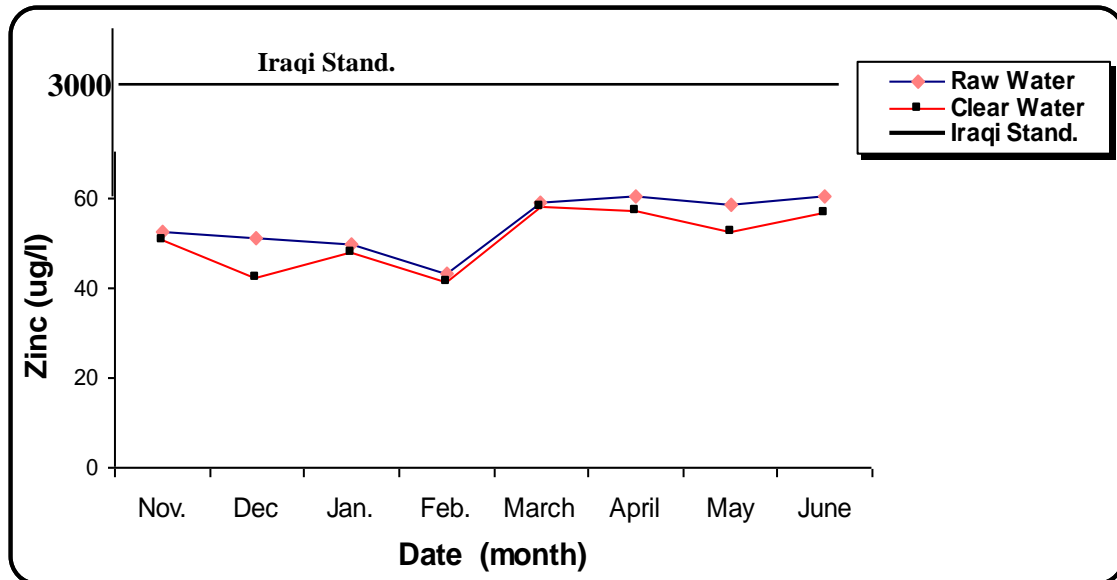


Fig. (4-30): Zinc concentration in treated water at Al-Hilla Al- Jadeed treatment plant

Results shown in the above Figs. insist the need of controlling the concentration of these elements in the raw water and/or increase their removal in the treatment plants. Generally, the percentage removal in Al-Hilla Al-Kadeem treatment plant was ranging from (5–38) for Cu, (3–18) for Zn, (4–13) for Fe, (18–31) for Pb, (23–33) for Hg, and (8–48) for Cd, while for Al-Hilla Al-Jadeed treatment plant was (10–33) for Cu, (3–17) for Zn, (10–26) for Fe, (19–34) for Pb, (21–36) for Hg, and (10–33) for Cd.

The results show that the maximum concentration of the metals (Fe, Hg, Cd) measured in drinking water of Al-Hilla Al-Kadeem treatment plant were (592, 1.81, and 3,74) $\mu\text{g/l}$ during June respectively. These metals exceeded the Iraqi standards for drinking water. While the concentrations of copper (51 $\mu\text{g/l}$), lead (4.9 $\mu\text{g/l}$) in June, and zinc (57.7 $\mu\text{g/l}$) in April were within the Iraqi standards. In drinking water of Al-Hilla Al-Jadeed treatment plant, the concentrations of Fe (570 $\mu\text{g/l}$) in June, Hg (1.41 $\mu\text{g/l}$) in March, and Cd (4.33 $\mu\text{g/l}$) in June were exceeded the allowable Iraqi standards for drinking water. While the concentrations of Cu (58.2 $\mu\text{g/l}$) in June, Pb (4.7 $\mu\text{g/l}$) in June, and Zn (57.7 $\mu\text{g/l}$) in March were within the Iraqi standards.

The physical and chemical characteristics of treated water are summarized in Figs. (4-31 to 54).

These characteristics included (hydrogen ion (pH), turbidity (TU), conductivity (Ec), sulfates(SO_4), chlorides (Cl), alkalinity, total hardness (TH), calcium (Ca), temperature (T), total dissolved solid (TDS), total suspended solids (TSS), and dissolved oxygen (DO).

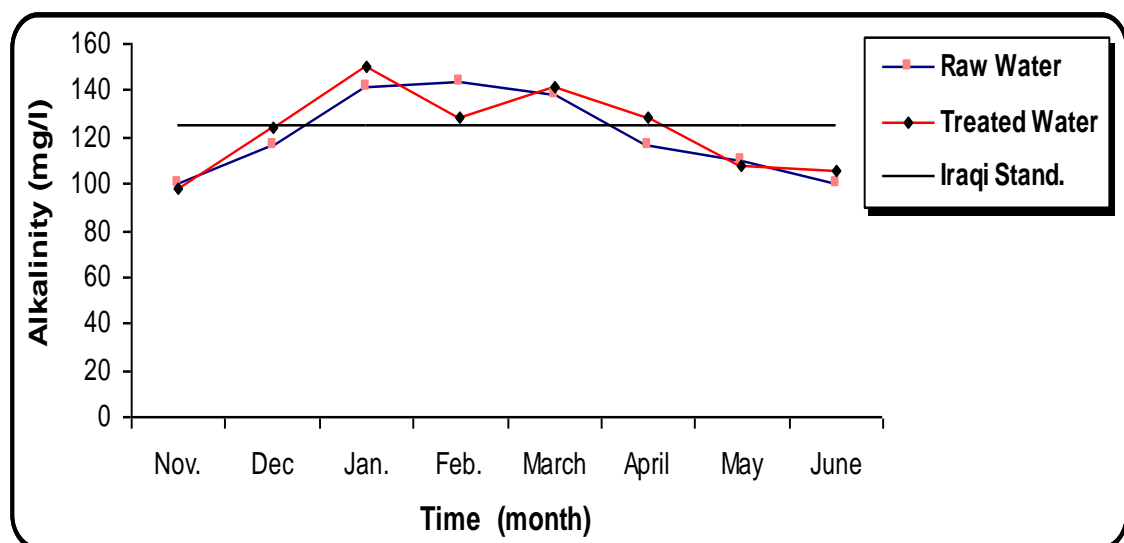


Fig. (4-31): Alkalinity concentration in treated water at Al-Hilla Al- Kadeem treatment plant

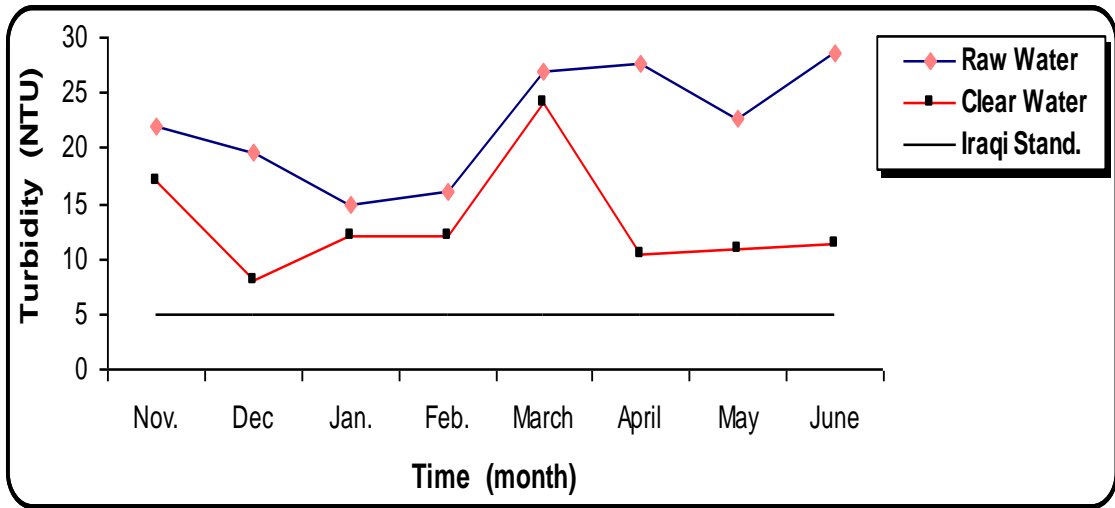


Fig. (4-32): Turbidity concentration in treated water at Al-Hilla Al- Kadeem treatment plant

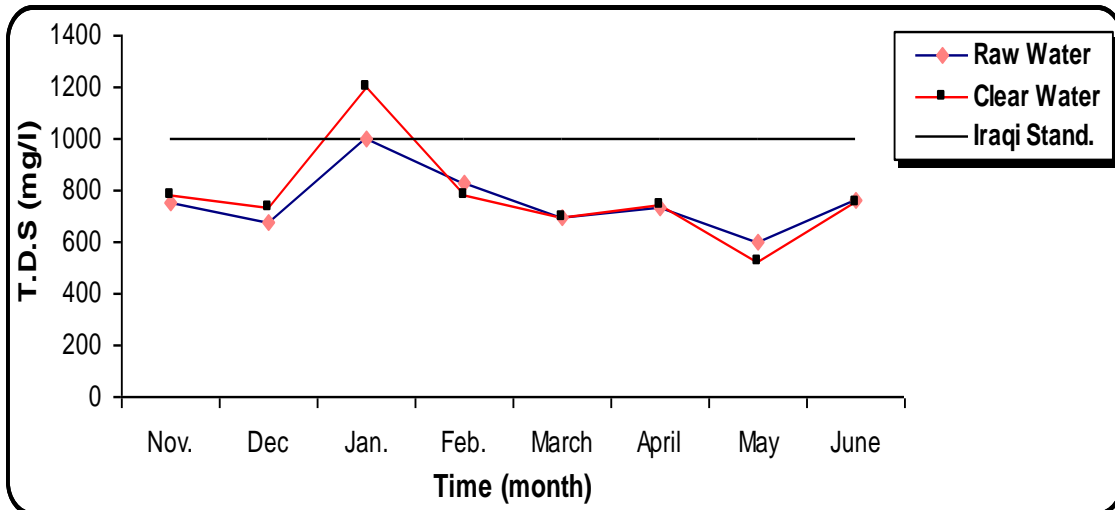


Fig. (4-33): Total dissolved solid concentration in treated water at Al-Hilla Al- Kadeem treatment plant

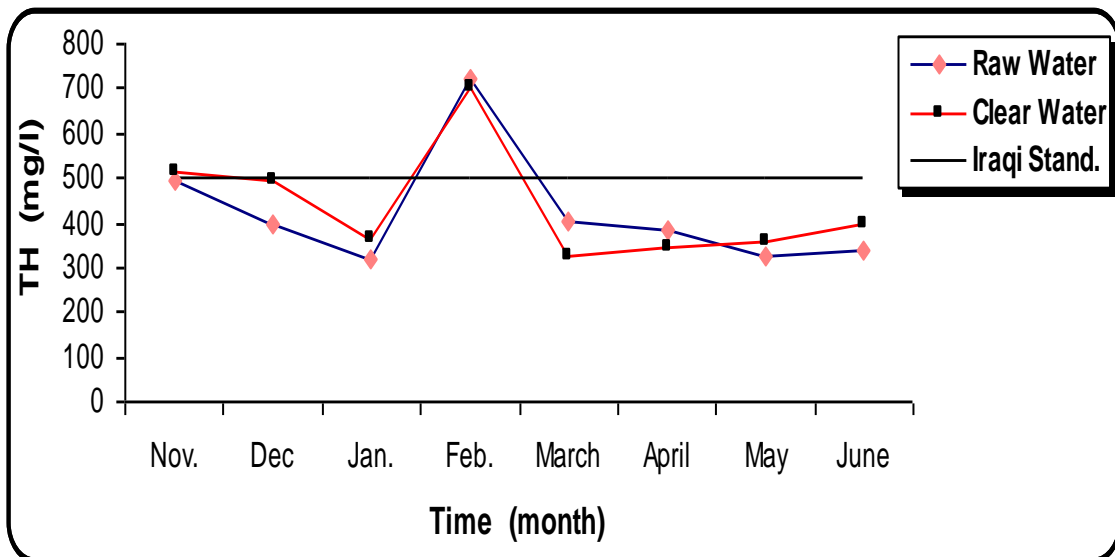


Fig. (4-34): Total hardness concentration in treated water at Al-Hilla Al- Kadeem treatment plant

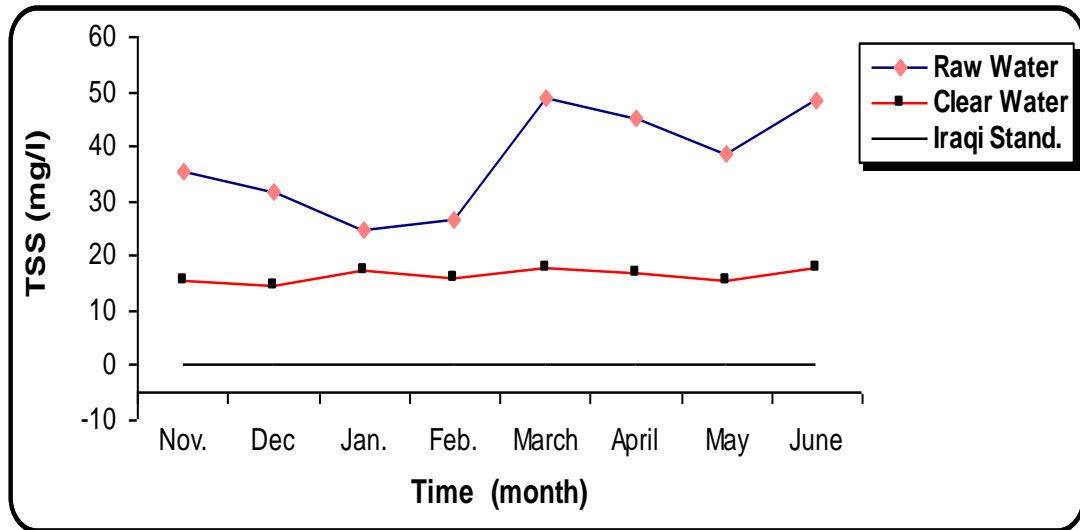


Fig. (4-35): Total suspended solid concentration in treated water at Al-Hilla Al- Kadeem treatment plant

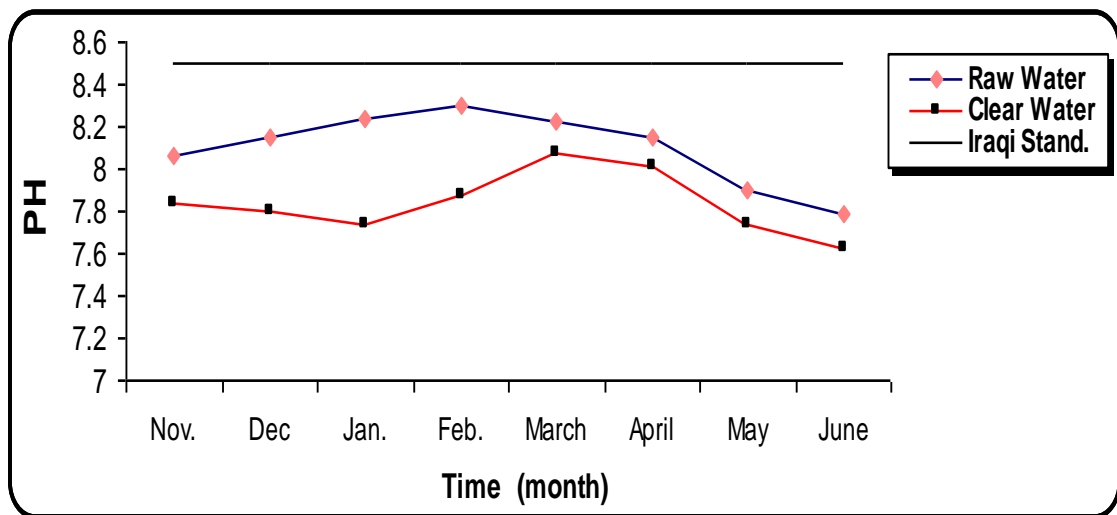


Fig. (4-36): Hydrogen ion concentration in treated water at Al-Hilla Al- Kadeem treatment plant

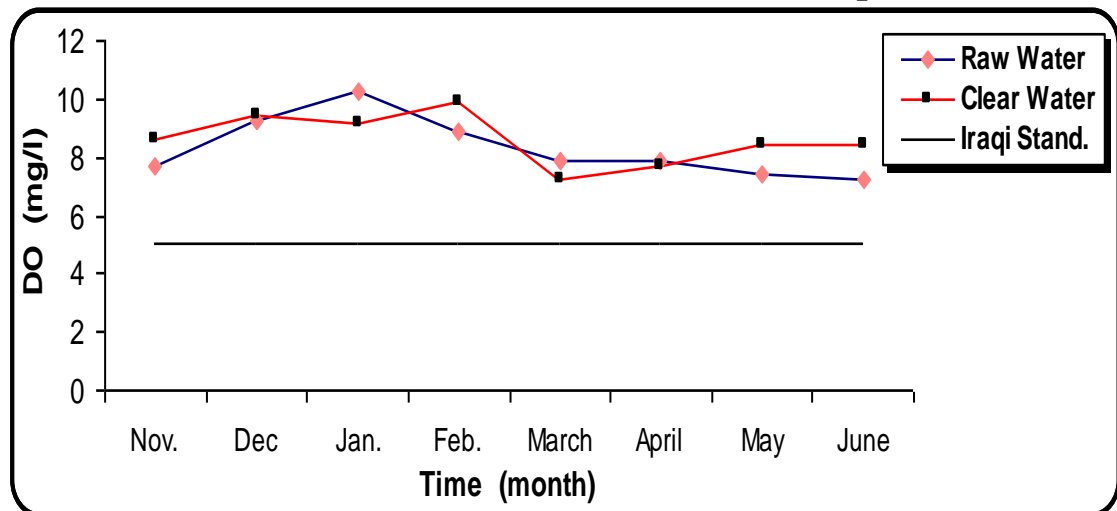


Fig. (4-37): Dissolved oxygen concentration in treated water at Al-Hilla Al- Kadeem treatment plant

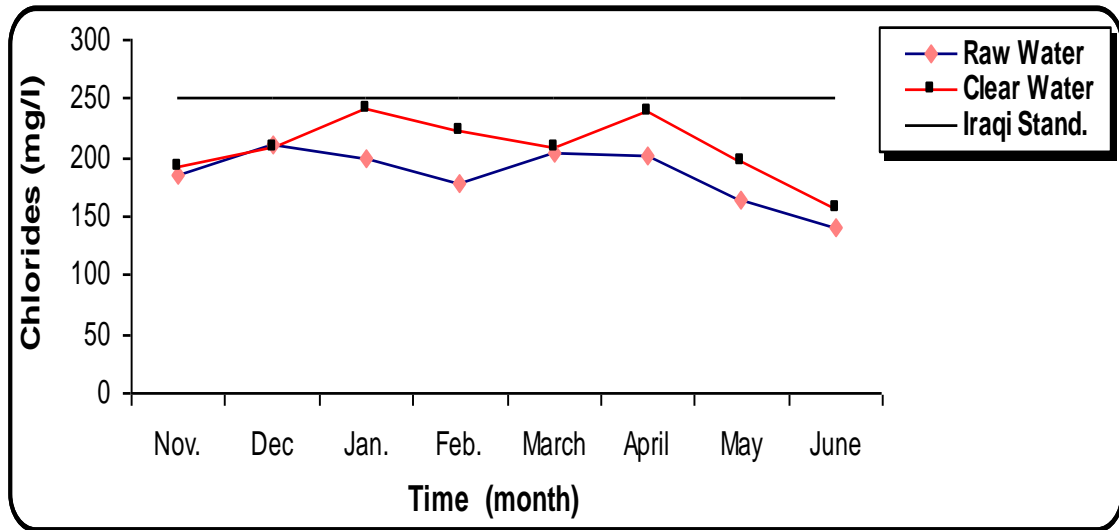


Fig. (4-38): Chlorides concentration in treated water at Al-Hilla Al- Kadeem treatment plant

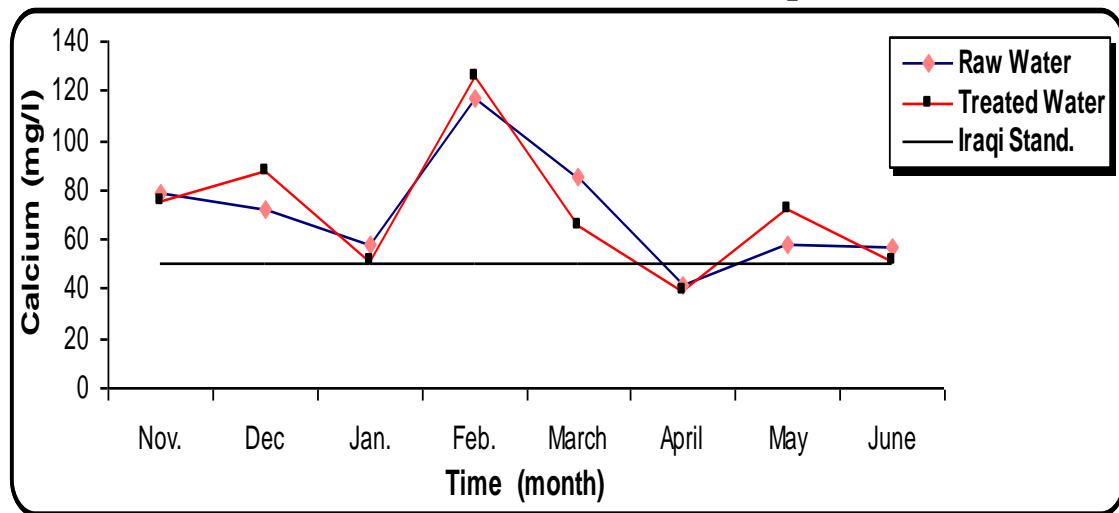


Fig. (4-39): Calcium concentration in treated water at Al-Hilla Al- Kadeem treatment plant

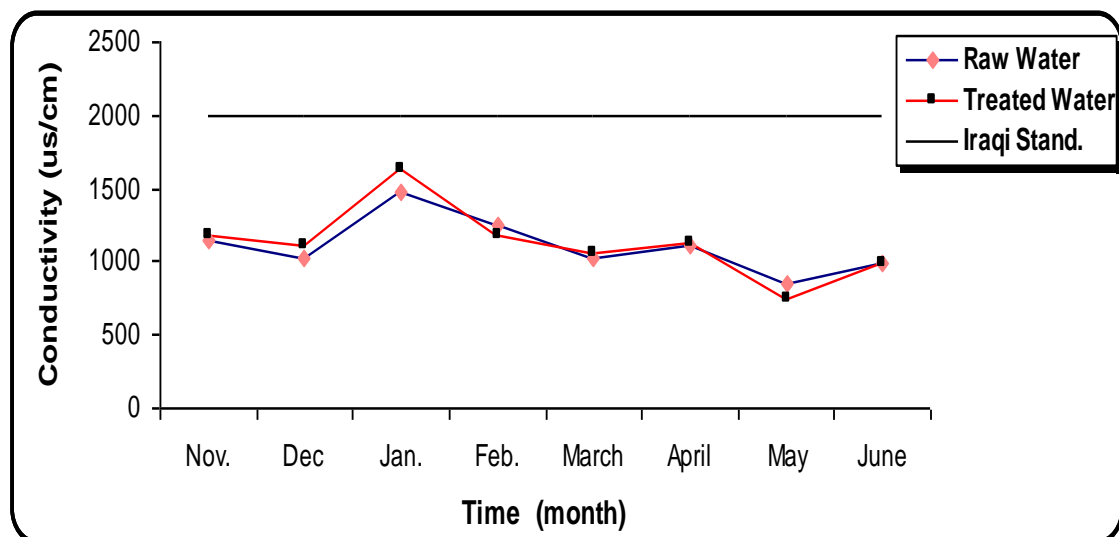


Fig. (4-40): Conductivity concentration in treated water at Al-Hilla Al- Kadeem treatment plant

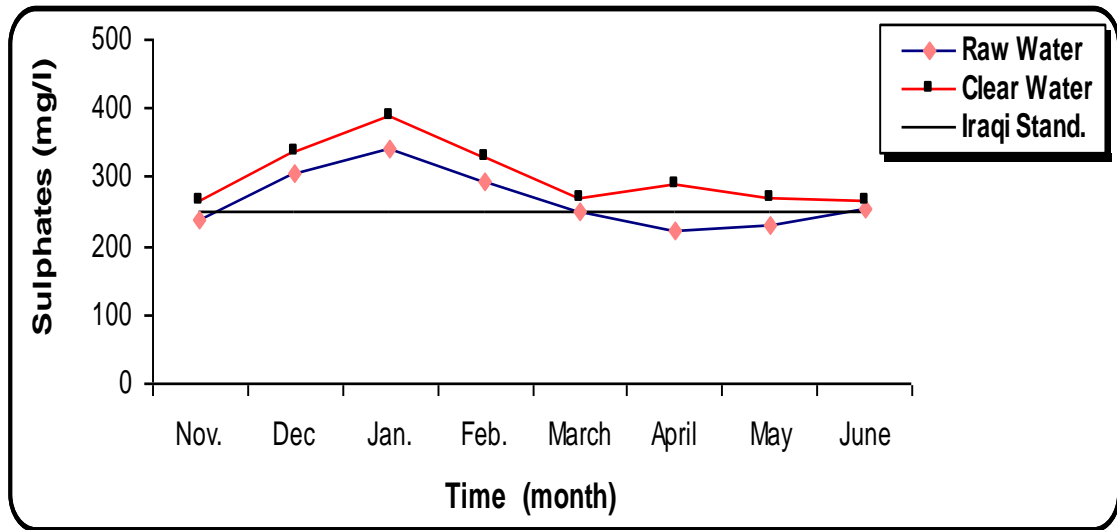


Fig. (4-41): Sulphates concentration in treated water at Al-Hilla Al- Kadeem treatment plant

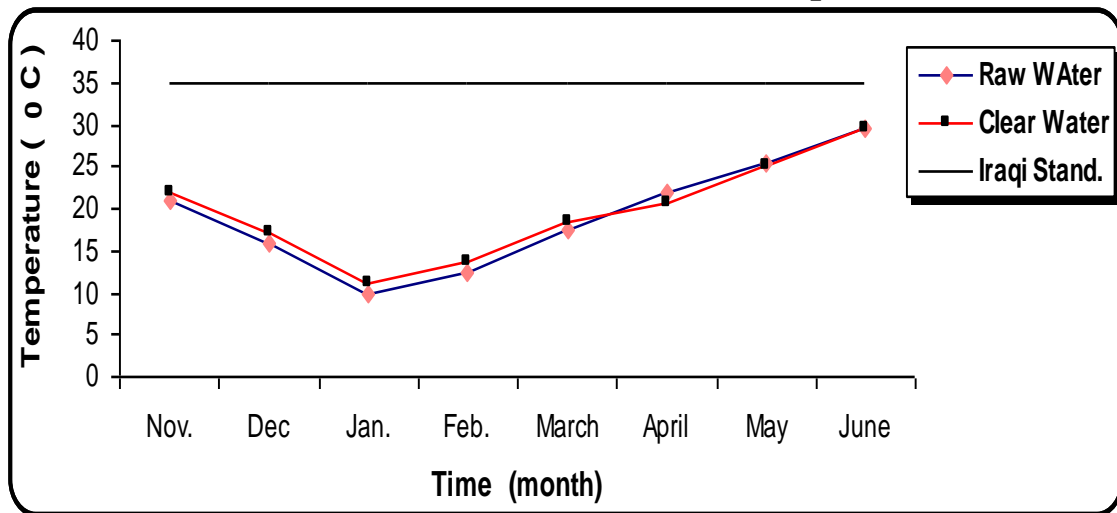


Fig. (4-42): Temperature concentration in treated water at Al-Hilla Al- Kadeem treatment plant

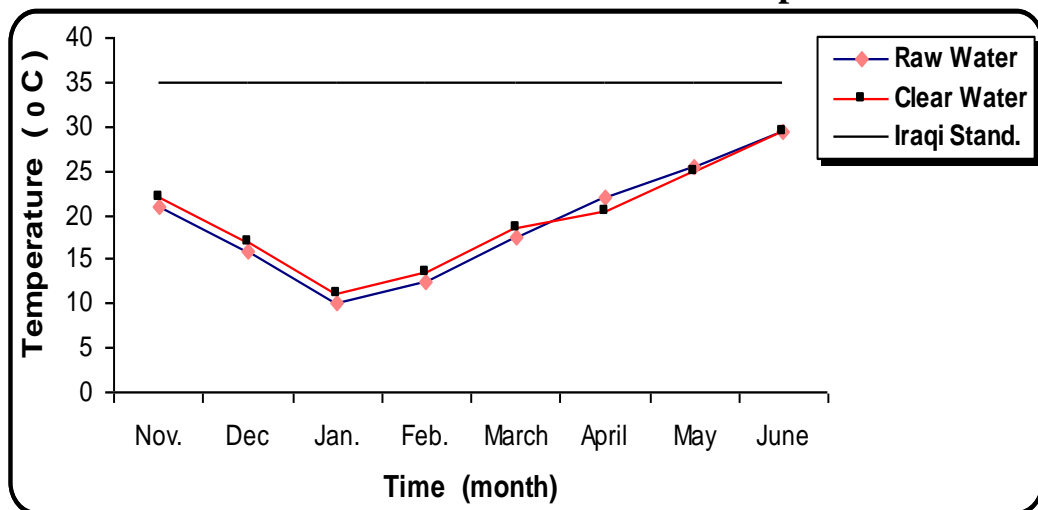


Fig. (4-43): Temperature concentration in treated water at Al-Hilla Al- Jaded treatment plant

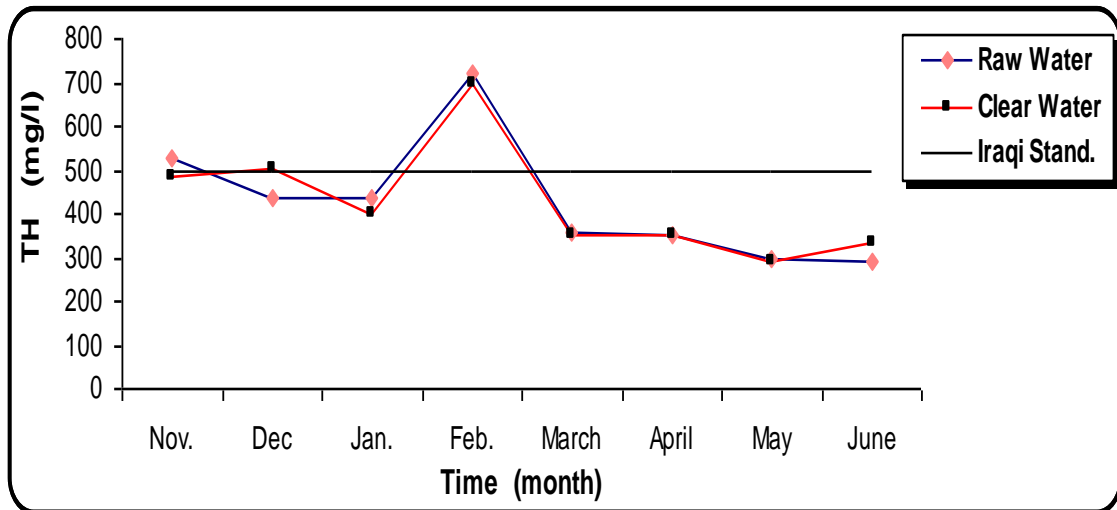


Fig. (4-44): Total hardness concentration in treated water at Al-Hilla Al- Jadeed treatment plant

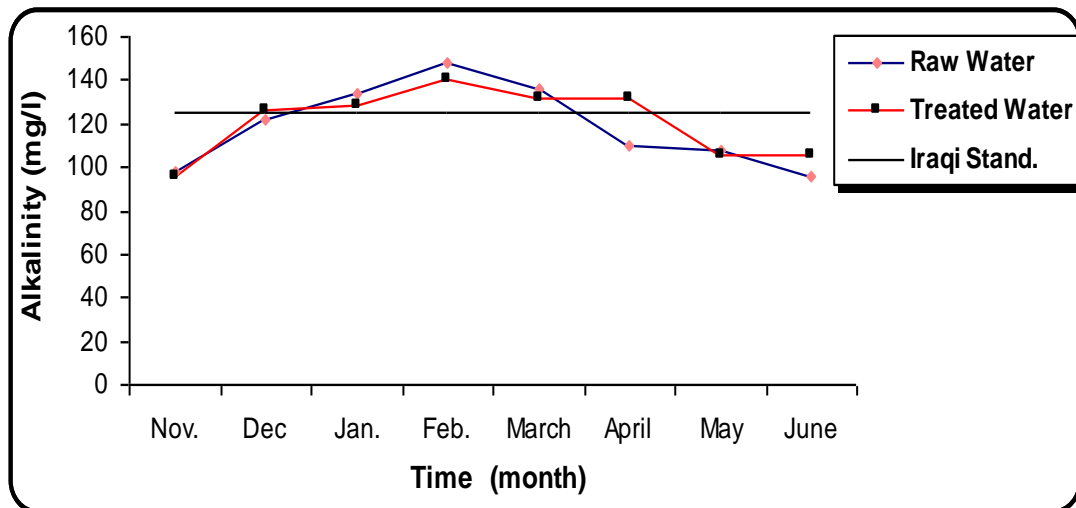


Fig. (4-45): Alkalinity concentration in treated water at Al-Hilla Al- Jadeed treatment plant

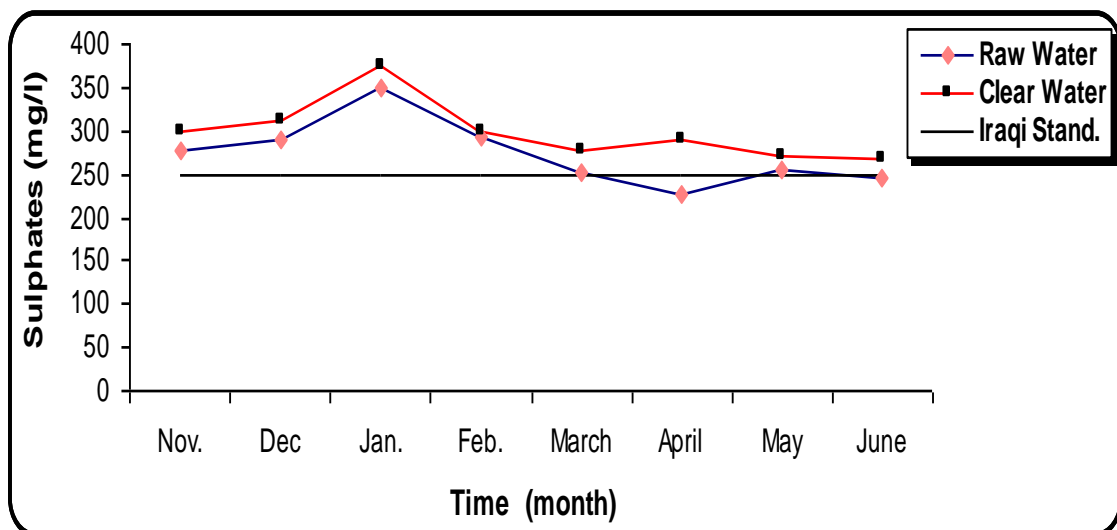


Fig. (4-46): Sulphates concentration in treated water at Al-Hilla Al-Jadeed treatment plant

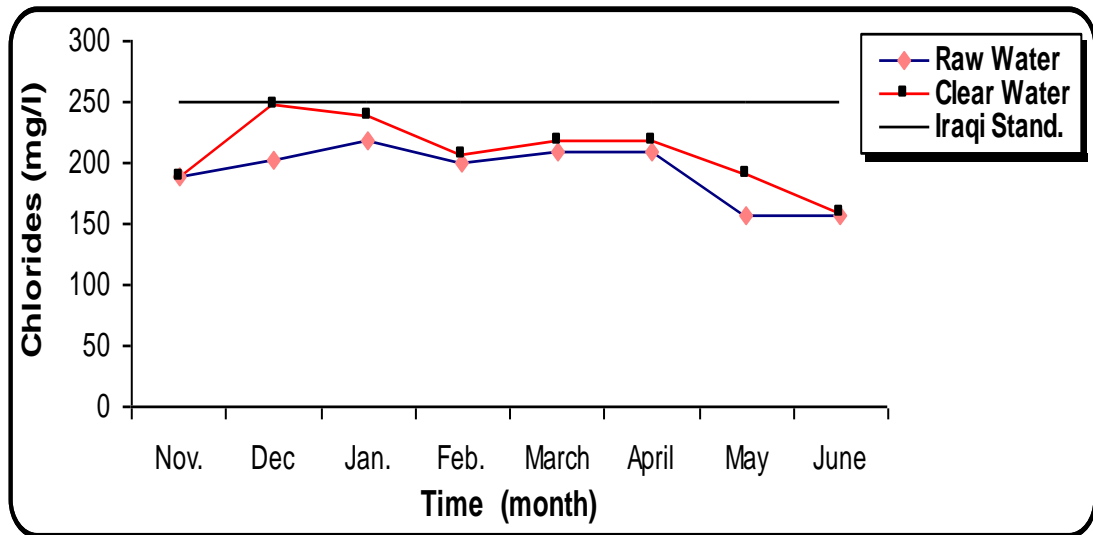


Fig. (4-47): Chlorides concentration in treated water at Al-Hilla Al- Jadeed treatment plant

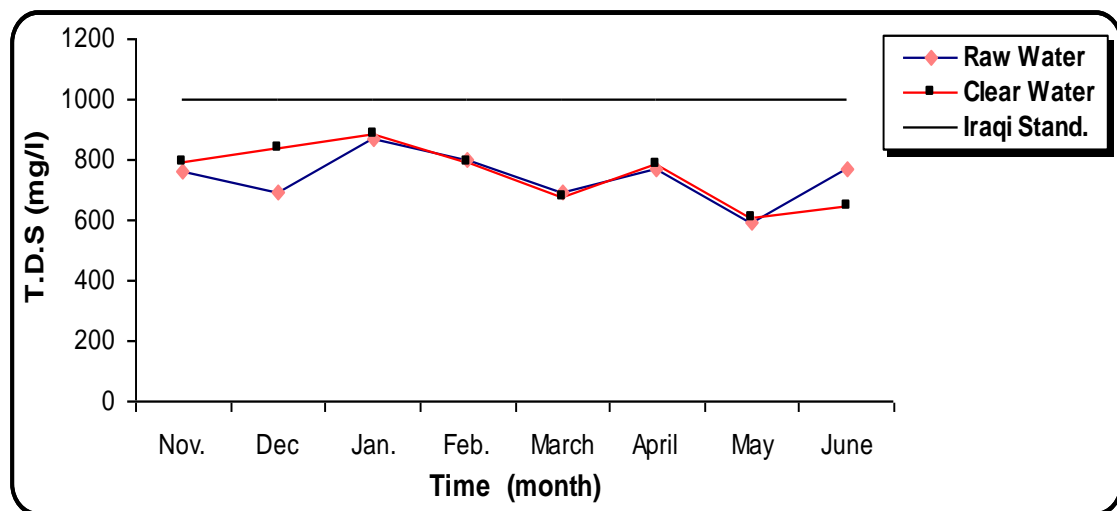


Fig. (4-48): Total dissolved solid concentration in treated water at Al-Hilla Al- Jadeed treatment plant

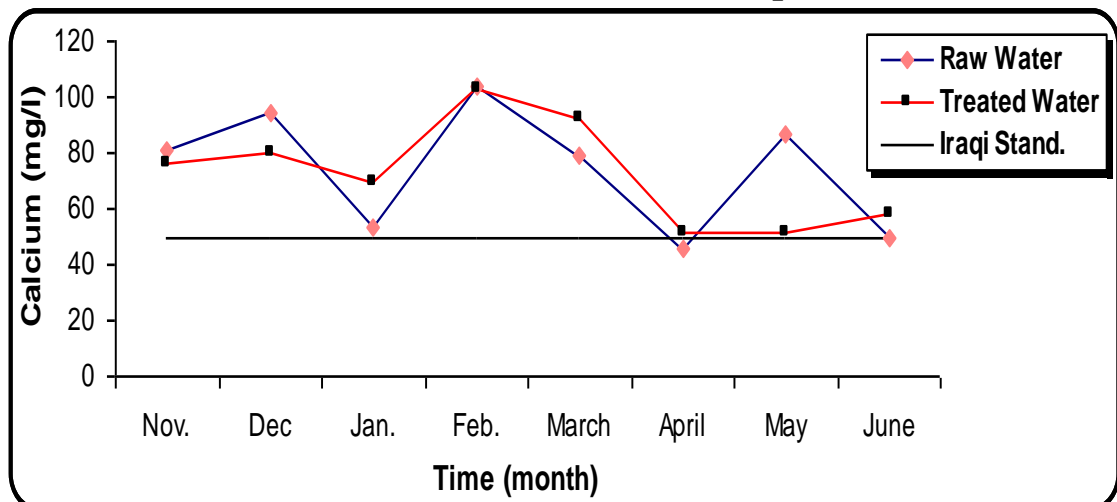


Fig. (4-49): Calcium concentration in treated water at Al-Hilla Al- Jadeed treatment plant

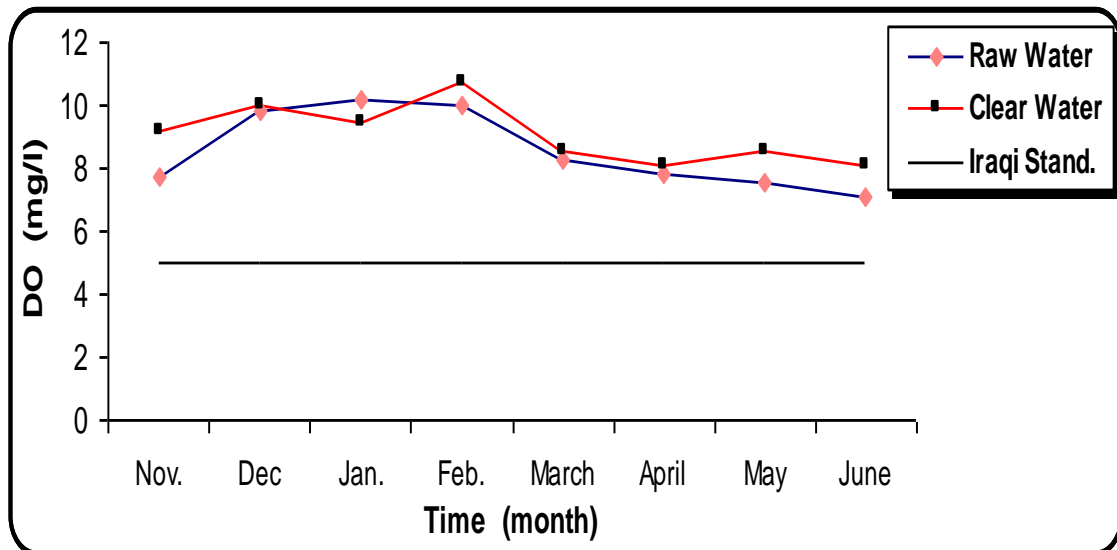


Fig. (4-50): Dissolved oxygen concentration in treated water at Al-Hilla Al- Jadeed treatment plant

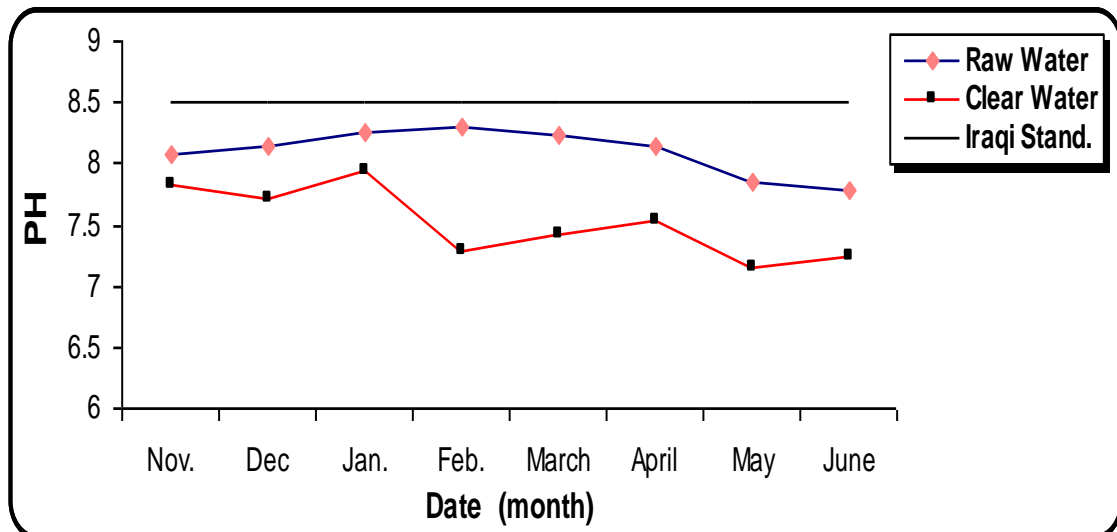


Fig. (4-51): Hydrogen ion concentration in treated water at Al-Hilla Al- Jadeed treatment plant

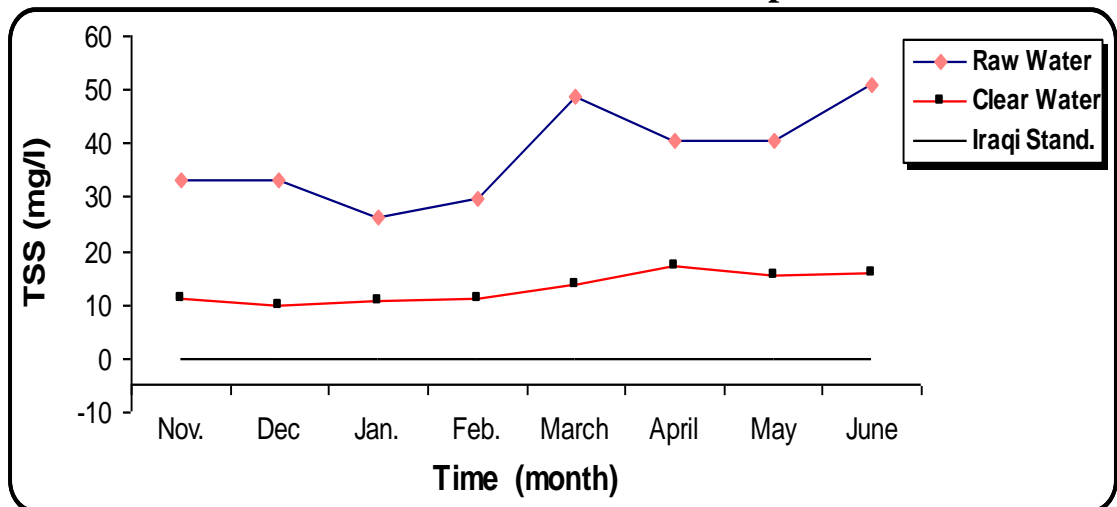


Fig. (4-52): Total suspended solid concentration in treated water at Al-Hilla Al- Jadeed treatment plant

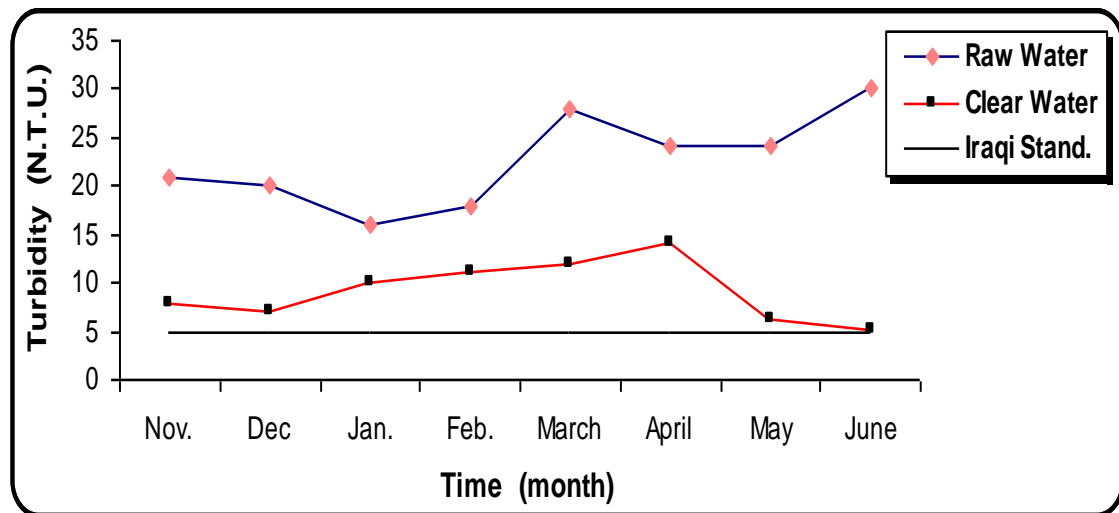


Fig. (4-53): Turbidity concentration in treated water at Al-Hilla Al- Jadeed treatment plant

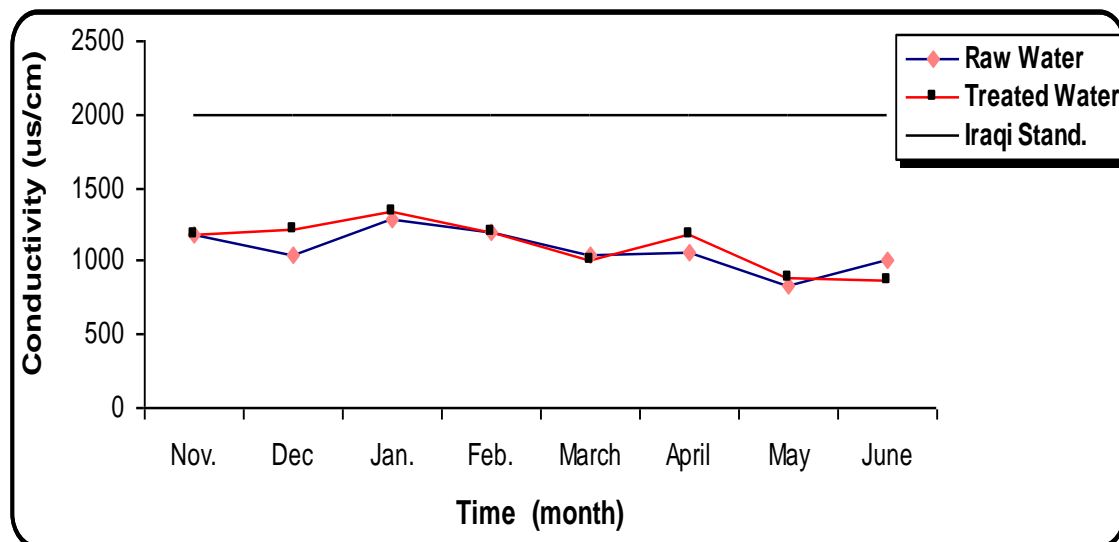


Fig. (4-54): Conductivity concentration in treated water at Al-Hilla Al- Jadeed treatment plant

In general, the maximum concentrations of (chlorides, conductivity, hydrogen ion, temperature, and dissolved oxygen) in Al-Hilla Al-Kadeem treatment plant were within the Iraqi and the WHO standards for drinking water, while the maximum concentrations of (alkalinity, calcium, sulphates, total suspended solids, total dissolved solids, total hardness, and turbidity) didn't meet the Iraqi standards and the WHO standards for drinking water. The maximum concentrations of (chlorides, conductivity, hydrogen ion, temperature, and dissolved oxygen, and total dissolved solids)

in Al-Hilla Al- Jadeed treatment plant were within the Iraqi and the WHO standards for drinking water, while the maximum concentrations of (alkalinity, calcium, sulphates, total suspended solids, total hardness, and turbidity) in Al-Hilla Al-Jadeed treatment plant were not within the mentioned standards.

The fluctuation of the physical and chemical parameters can be attributed to many factors such as the quality of water fed to the treatment plant or lack of the cleaning and maintenance process in the treatment plant. It was noticed that turbidity removal efficiency achieved in the treatment plants sometimes be low in spite of the low level of turbidity in river water because of the wrong addition of alum dosage or because of the high daily demand which makes the treatment process inefficient.

The range of concentration and percentage of samples exceeding health limits of drinking-water at the two treatment plants were given in Table (4-2).

It can be noticed from this Table (4-2) that the maximum concentration of Fe in both treatment plants (Al-Hilla Al-Kadeem and Al-Hilla Al-Jadeed) exceeded the WHO standards by 97% and 90 % respectively, while the maximum concentration of Hg in Al-Hilla Al-Kadeem and Al-Hilla Al-Jadeed treatment plants exceeded the WHO standards by 81% and 41 % respectively.

4.6 Statistical Analysis:

Multiple regression models were developed by using (Data Fit Version 9.0) program to simulate the experimental results.

4.6.1 Selection of variables:

The first step in the development of the statistical analysis was the selection of the variables included in model prediction. The selection of these variables is based upon the reviewed literature and the availability of data for each one. The factors used to predict resilient modulus are numerous, according to the literature reviewed that is mentioned in this research and to the available data that can be calculated from testing results. The independent variables (trace metals, and water quality parameter) and dependent variable (removal efficiency of treatment plant, (RE)) were selected as shown in table (4-3), and table (4-4) respectively.

Table (4-3): Dependent and Independent Variables for Trace Metals

<i>Dependent variable</i>	<i>Independent variables</i>
(RE)	Cd, Hg, Pb, Cu, Fe , Zn

Table (4-4): Dependent and Independent Variables for Water Quality Parameter

<i>Dependent variable</i>	<i>Independent variables</i>
(RE)	Alkal., Cl, Cond., pH, SO ₄ , TDS, Temp., TH, TSS

Three models were examined to predict the concentration levels for heavy metals selected in this study by using this program. These models are shown in Table (4-5) below:

Table (4-5) Models Tested by Regression Analysis

No.	Model	Symbol
1	$\exp(a*x1+b*x2+c*x3+d*x4+e*x5+f*x6+g*x7+h*x8+i)$	A
2	$a*x1+b*x2+c*x3+d*x4+e*x5+f*x6+g*x7+h*x8+i$	B
3	$a*x1+b*x2+c*x3+d*x4+e*x5+f*x6+g*x7+h*x8$	C

4.6.2 Statistical Analysis Results:

Statistical analysis results were obtained by applying Data Fit analysis on the experimental results. The best models were selected on the basis of the higher coefficient of determination (R^2) value. These results are shown in Table (4-6):

Table (4-6): Statistical Analysis Results (Governing Models)

No.	Dependent Variable	Coefficient of determination R^2	Model Symbol	Standards error	Model
1	RE _{HKM}	0.987	B	3.075	$66102.4 \times \text{Cd} + 849.3 \times \text{Cu} - 1106.67 \times \text{Fe} - 4814.04 \times \text{Hg} + 7476.9 \times \text{Pb} - 671.8 \times \text{Zn} + 722.1$
2	RE _{HJM}	0.907	B	6.385	$14581.29 \times \text{Cd} + 1007.6 \times \text{Cu} + 227.8 \times \text{Fe} + 25934.47 \times \text{Hg} - 34403.65 \times \text{Pb} + 31.88 \times \text{Zn} - 69.37$
3	RE _{HKP}	1	C	1.83E-014	$-0.06 \times \text{Alkal.} - 0.26 \times \text{Cl} - 1.93 \times \text{Ca} + 3.92 \times \text{pH} + 0.71 \times \text{SO}_4 - 0.19 \times \text{TDS} + 0.86 \times \text{TSS} + 0.58 \times \text{Temp.} + 0.27 \times \text{TH}$
4	RE _{HJP}	1	C	2.6E-014	$-0.67 \times \text{Alkal.} - 0.45 \times \text{Cl} + 1.85 \times \text{Ca} - 0.78 \times \text{Ph} - 0.25 \times \text{SO}_4 + 0.4 \times \text{TDS} + 0.25 \times \text{TSS} - 1.71 \times \text{Temp.} - 0.26 \times \text{TH}$

Table (4-7): Correlation Coefficient Between Removal Efficiency (RE) and Trace Metals in Al-Hilla Al-Kadeem Treatment Plant.

Metals	RE
Cd	0.703455
Cu	0.6496
Fe	0.66272
Hg	0.516355
Pb	0.513954
Zn	0.538982
NTU	1

Table (4-8): Correlation Coefficient Between Removal Efficiency (RE) and Parameters in Al-Hilla Al-Kadeem Treatment Plant.

parameters	NTU
Alkalinity	-0.68541
Cl	-0.84478
Ca	0.035059
pH	-0.8703
SO ₄	-0.44344
TDS	-0.62682
TSS	0.623288
Temp.	0.795132
TH	-0.57173
NTU	1

Table (4-9): Correlation Coefficient Between Removal Efficiency (RE) and Trace Metals in Al-Hilla Al-Kadeem Treatment Plant.

Metals	NTU
Cd	0.697976
Cu	0.430929
Fe	0.655294
Hg	-0.40796
Pb	0.677837
Zn	-0.04524
NTU	1

Table (4-10): Correlation Coefficient Between Removal Efficiency (RE) and Parameters in Al-Hilla Al-Jadeed Treatment Plant.

parameters	NTU
Alkalinity	-0.68541
Cl	-0.84478
Ca	0.035059
pH	-0.8703
SO ₄	-0.44344
TDS	-0.62682
TSS	0.623288
Temp.	0.795132
TH	-0.57173
NTU	1

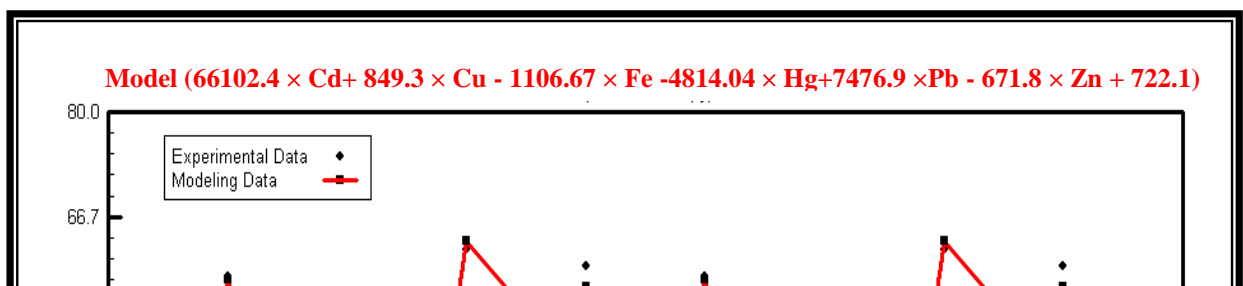


Fig. (4-55): Relationship between experiential data and modeling data of removal efficiency of trace metals in Al-Hilla Al-Kadeem treatment plant (RE)

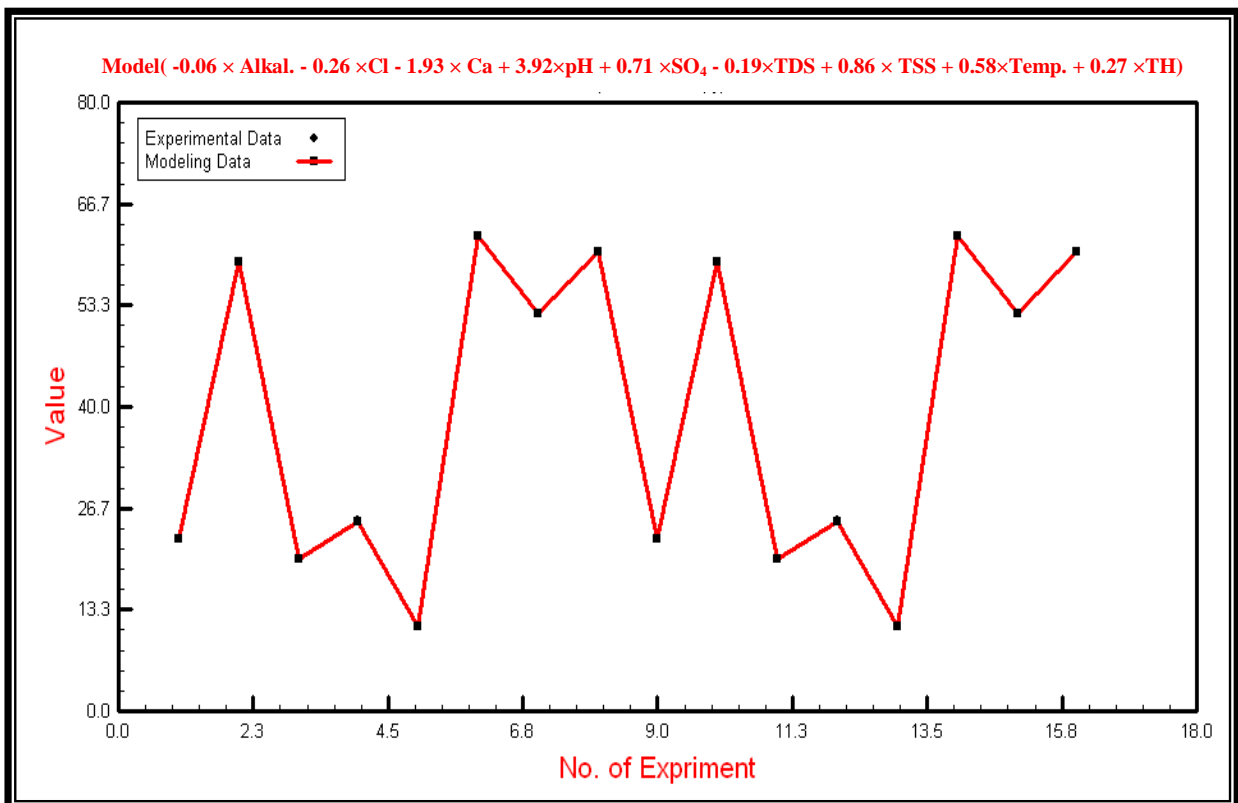


Fig. (4-56): Relationship between experiential data and modeling data of removal efficiency of parameters in Al-Hilla Al-Kadeem treatment plant (RE)

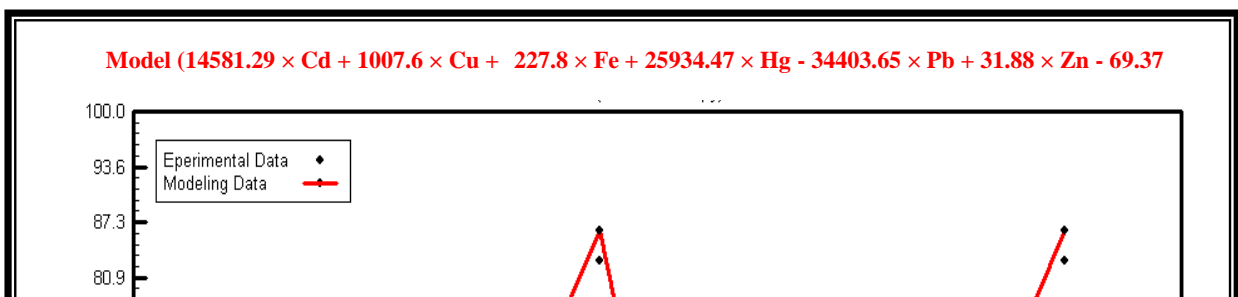


Fig. (4-57): Relationship between experiential data and modeling data of removal efficiency of trace metals in Al-Hilla Al-Jadeed treatment plant (RE)

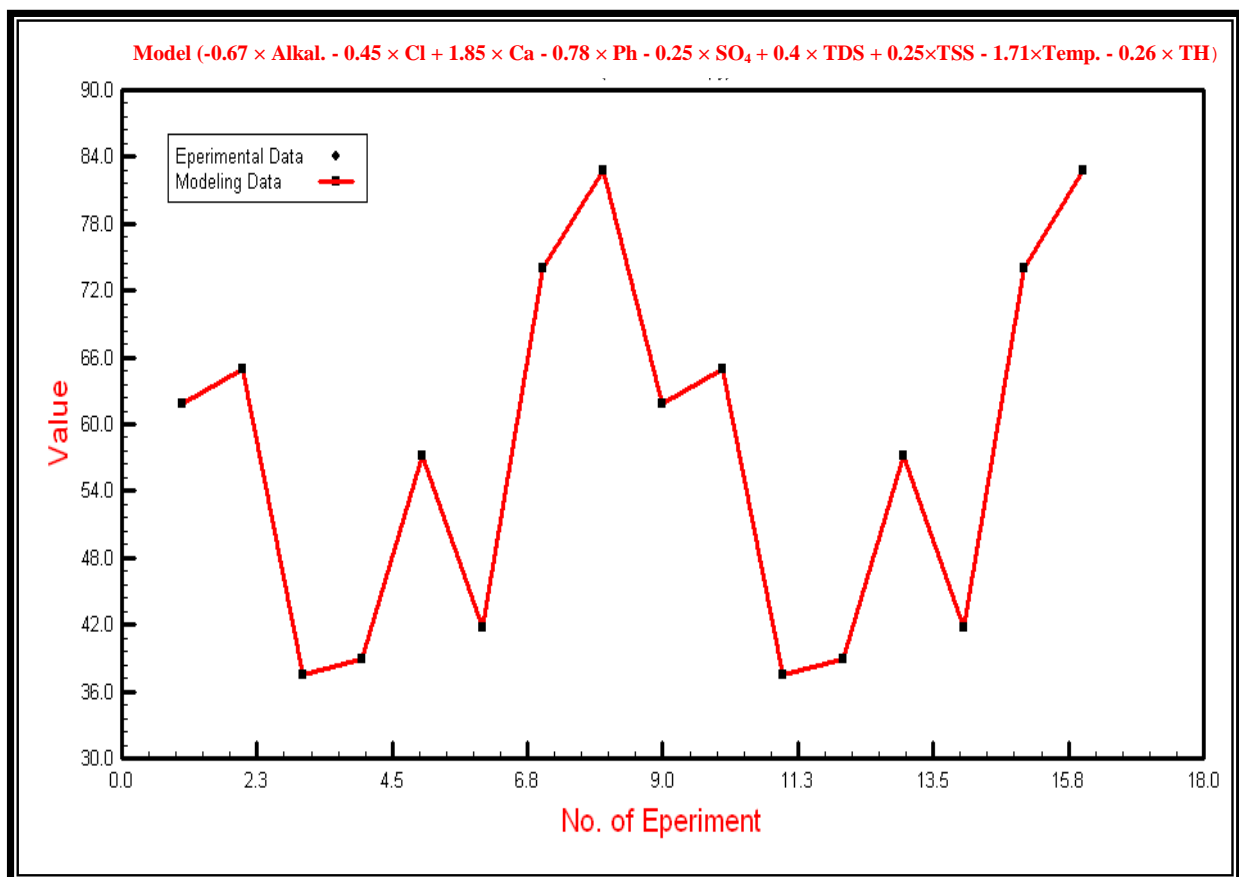


Fig. (4-58): Relationship between experiential data and modeling data of removal efficiency of parameters in Al-Hilla Al-Jadeed treatment plant (RE)

4.6.3 Verification of Regression Models:

selected models were verified with experimental data not included in models development and correlated as shown in Figs below:

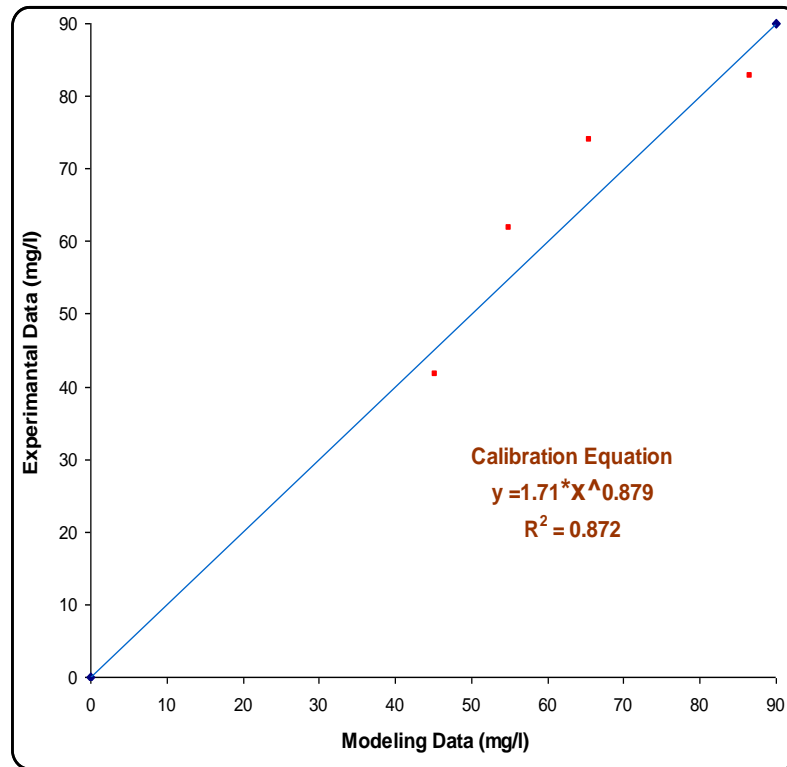


Fig. (4-59): Removal efficiency of trace metals in Al-Hilla Al-Jadeed treatment plant (RE) verification curve of regression model

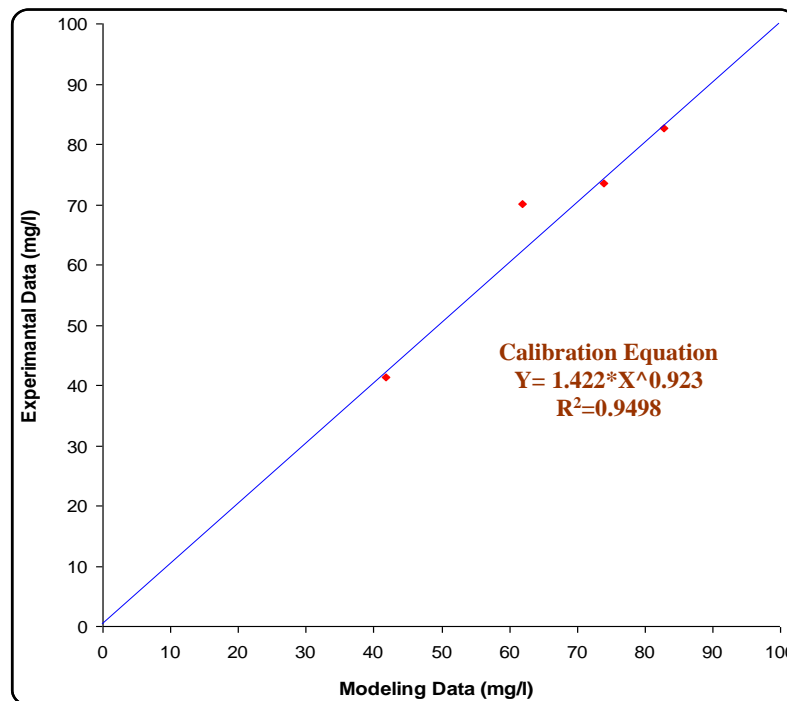


Fig. (4-60): Removal efficiency of parameters in Al-Hilla Al-Jadeed treatment plant (RE) verification curve of regression model

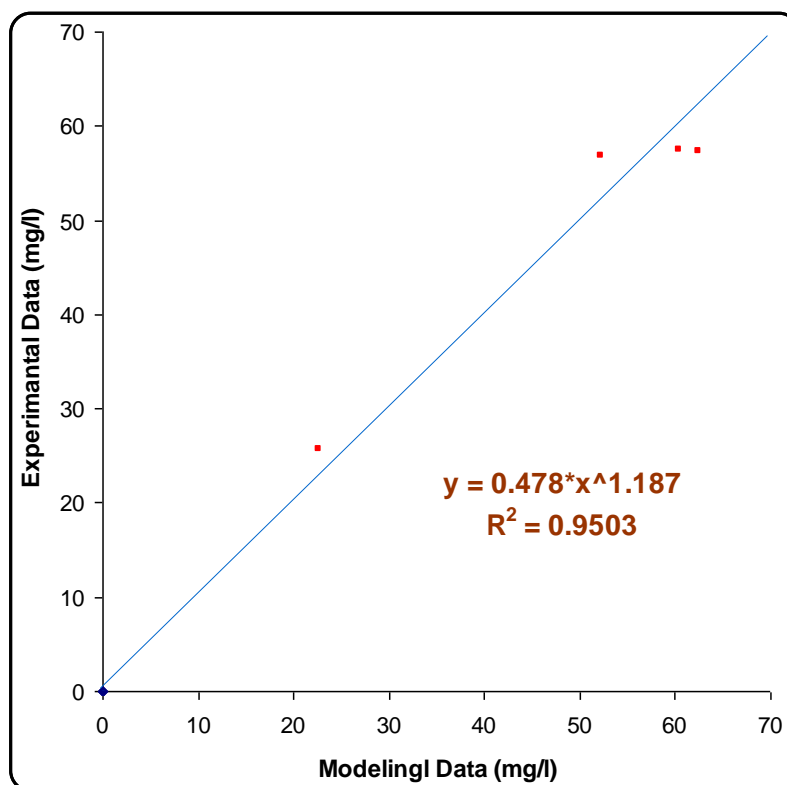


Fig. (4-61): Removal efficiency of trace metals in Al-Hilla Al-Kadeem treatment plant (RE) verification curve of regression model

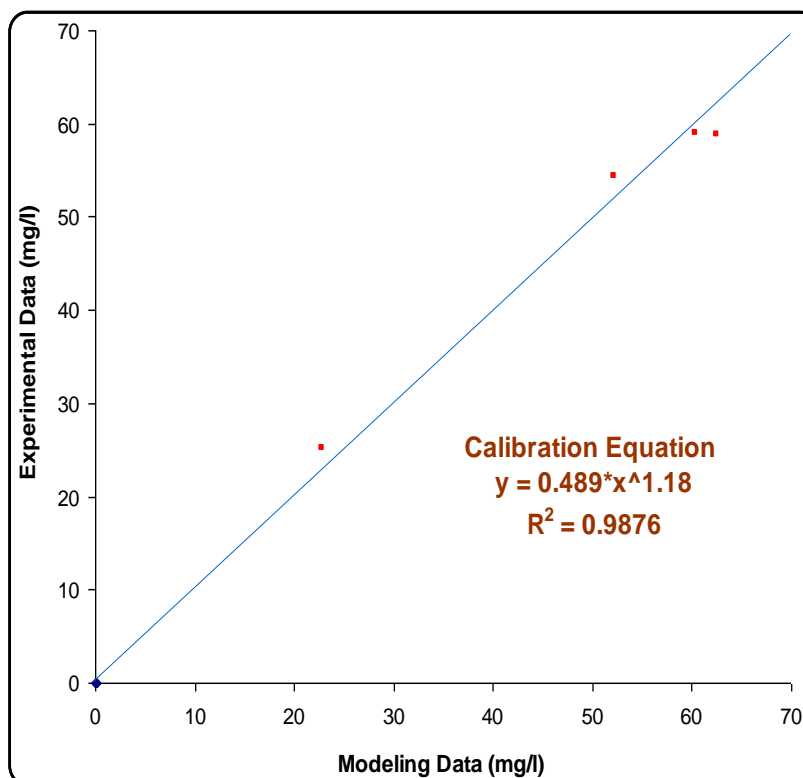


Fig. (4-62): Removal efficiency of parameters in Al-Hilla Al-Kadeem treatment plant (RE) verification curve of regression model

It can be shown from Figs. that the experimental data fits very well to all of the modeling data.

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Table (4-1): Range and mean concentration of selected trace metals in Shatt Al- Hilla river

Sample Location		Concentrations of Metal (ug/l)					
		Iron (Fe)	Mercury (Hg)	Zinc (Zn)	Lead (Pb)	Copper (Cu)	Cadmium (Cd)
Location 1	Range	(454-638)	(0.88-3.1)	(32.1-63)	(3.87-6.2)	(38.7-56)	(2.14-6.50)
	Mean	519.75	1.75	50.2	4.19	46.7	3.63
	STDVE	0.0694	0.00091	0.0112	0.0008	0.0062	0.0017
Location 2	Range	(452-636)	(0.81-2.4)	(38.9-59.3)	(4.12-5.8)	(40-54)	(2.15-6.32)
	Mean	518	1.23	48.3	4.83	47.375	3.77
	STDVE	0.0731	0.00051	0.008	0.00059	0.00518	0.00174
Location 3	Range	(460-640)	(1.2-2)	(43.2-60.2)	(3.2-5.8)	(43.1-62.1)	(2.35-5.8)
	Mean	527.4	1.46	54.2	4.39	51.2	3.52
	STDVE	0.07566	0.000396	0.00615	0.00109	0.00632	0.0012
Location 4	Range	(464-624)	(0.81-2.7)	(51.1-62)	(3.6-7.2)	(42-64)	(2.14-5.1)
	Mean	525,5	1.41	56.5	4.69	50.3	3.29
	STDVE	0.0637	0.00059	0.00369	0.00129	0.00764	0.0011
Location 5	Range	(460-630)	(0.89-3.44)	(38.7-64.2)	(3.6-6.3)	(44-62)	(2.7-6.5)
	Mean	516.13	1.57	49.5	4.89	50.7625	3.88
	STDVE	0.0698	0.00087	0.01083	0.00101	0.0062	0.0012
Location 6	Range	(468-636)	(0.79-3.44)	(41.2-62.2)	(3.4-5.2)	(45.2-53)	(2.4-5.5)
	Mean	519.25	1.51	52.9	4.44	48.675	3.56
	STDVE	0.06978	0.00079	0.00695	0.00071	0.0022	0.00101

Sample Location		Concentrations					
		SO4 (mg/l)	TDS (mg/l)	Temp. (°C)	TSS (mg/l)	Turbidity (NTU)	Cl (mg/l)
Location 1	Range	(220.1-358.4)	(606-917)	(10-29)	(26.94-47.94)	(16-27.8)	(160-223)
	Mean	277.8	750.25	19	36.835	22.213	200
	STDVE	47.486	92.985	6.313	8.469	5.020	21.632
Location 2	Range	(233.2-322.8)	(618-978)	(10-29)	(25.14-46.24)	(15.27.3)	(157-226)
	Mean	269.08	752.5	19	36.688	22.063	206
	STDVE	27.929	104.184	6.313	8.081	4.731	23.055
Location 3	Range	(244.3-350.8)	(592-869)	(10-29.5)	(26.32-50.76)	(16-30.2)	(157-219)
	Mean	273.53	742.75	19.23	37.927	22.7	193
	STDVE	38.880	82.737	6.514	8.785	4.869	23.585
Location 4	Range	(223.4-340)	(596-999)	(10-29.5)	(24.86-48.68)	(15-28.5)	(140-211)
	Mean	267.24	755	19.23	37.383	22.287	186
	STDVE	41.363	119.535	6.514	9.425	5.219	23.9105
Location 5	Range	(191.8-357.1)	(622-965)	(10.3-30)	(26.76-46.68)	(16-26.9)	(150-219)
	Mean	260.65	781	19.76	37.075	21.863	207
	STDVE	46.899	111.525	6.633	7.483	4.739	23.922
Location 6	Range	(236.2-391.8)	(594-1089)	(10.3-30)	(26.76-46-84)	(17-29.8)	(157-219)
	Mean	287.88	760	19.76	39.28	23.25	196
	STDVE	54.235	145.782	6.633	7.423	4.624	19.044

		Concentrations						
		Alkalinity (mg/l)	Ca (mg/l)	EC (mg/l)	DO (mg/l)	Mg (mg/l)	pH	T.H. (mg/l)
Location 1	Range	(94-146)	(45-88)	(884-1238)	(7.31-10.27)	(26-103)	(7.81-8.3)	(328-673)
	Mean	122.125	75.625	1082.5	8.29	63.25	8.11	448.8
	STDVE	16.889	17.935	132.617	0.6585	23.377	0.170	118.094
Location 2	Range	(92-140)	(46-104)	(878-1445)	(7.28-9.22)	(35-104)	(7.81-8.3)	(252-646)
	Mean	117.25	65.5	1103.88	8.32	61.75	8.11	415.9
	STDVE	17.886	20.284	172.563	0.7148	23.5175	0.1691	127.264
Location 3	Range	(96-148)	(46-104)	(838-1288)	(7.07-9.96)	(19-113)	(7.79-8.29)	(295-722)
	Mean	119	74.25	1083	8.55	59	8.09	427.5
	STDVE	19.034	21.855	140.634	1.236	29.189	0.1773	143.509
Location 4	Range	(100-144)	(42-117)	(844-1478)	(7.24-10.27)	(42-105)	(7.79-8.29)	(317-722)
	Mean	120.75	71	1108.13	8.33	60	8.10	422.6
	STDVE	18.172	23.152	190.384	1.045	21.421	0.1763	134.136
Location 5	Range	(96-164)	(43-106)	(840-1414)	(7.12-8.89)	(48-115)	(7.75-8.28)	(324-737)
	Mean	126.5	75	1140.38	7.99	65	8.09	454.7
	STDVE	23.946	24.946	192.468	0.6706	23.207	0.183	135.551
Location 6	Range	(100-146)	(41-107)	(848-1613)	(7.23-8.81)	(24-114)	(7.74-8.28)	(320-733)
	Mean	123.25	73.25	1115.25	7.99	63.25	8.08	442.2
	STDVE	19.092	21.205	233.974	0.6192	27.861	0.1828	135.501