REUSE AND RECYCLE OF INDUSTRIAL WASTEWATER IN HILLA TEXTILE FACTORIES

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By

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جامعة بابل
كلية الهندسة
قسم الهندسة المدنية

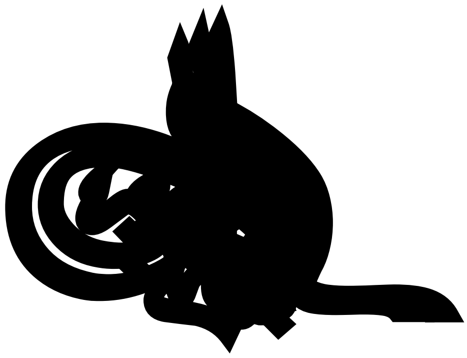
إعادة استخدام وتدوير فضلات المياه الصناعية في معامل نسيج الحلة

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

أعدت من قبل المهندسة

رشا صلاح القزويني

2003



أَفَرَأَيْتُمُ الْمَاءَ الَّذِي تَشْرَبُونَ 68 ءَأَنْتُمْ
أَنْزَلْتُمُوهُ مِنَ الْمُزْنِ أَمْ نَحْنُ الْمُنْزِلُونَ 69
لَوْ نَشَاءُ جَعَلْنَاهُ أُجَاجًا فَلَوْلَا
تَشْكُرُونَ 70

صدق الله العلي
العظيم

سورة الواقعة

المستخلص

أن الهدف الرئيس من هذا البحث هو تقويم أداء محطة معالجة المياه الصناعية في معامل نسيج الحلة. بالإضافة إلى ذلك فان البحث يهدف إلى أيجاد الطريقة المناسبة لمعالجة مياه الفضلات الصناعية للحصول على مياه مناسبة لاعادة الاستخدام ولطرحها إلى النهر وفق القوانين العراقية لطرح المياه.

في الجانب الأول من الدراسة وهو تقويم أداء محطة المعالجة القائمة، فقد وجد بان نسبة إزالة المواد العالقة الكلية(TSS) =(27-73%) ، المتطلب الكيميائي للأوكسجين (COD)=(20-54%) و المتطلب البايوكيميائي للأوكسجين (BOD_5) = (17-57%) .
وهذه النسب ليست مطابقة للمواصفات العراقية أو الأمريكية .

الجانب الثاني شمل الدراسة المختبرية التي تضمنت العمليات الفيزيوكيميائية لاختيار الجرعات المناسبة للمعالجات المطلوبة . وتمت الدراسة بواسطة فحوصات الجرة لاختيار الجرع المثلى من الشب والبولي الكترولايت و الكربون المنشط المسحوق(PAC) . بالإضافة إلى ذلك تمت تجارب معادلة الحامضية قبل إضافة الشب لمعرفة النسبة المثلى للرقم الهيدروجيني (pH) لكفاءة التخثير. وقد وجد من الجانب الأول لفحوصات الجرة إن النسب المثلى للشب هي (250mg/l) وللبولي الكترولايت هي (1.5mg/l)وذلك عند قيمة لل pH تساوي (8.5).

آما الجانب الثاني من فحوصات الجرة فتضمن ا ستخدام الكربون المنشط المسحوق لتعزيز كفاءة الإزالة وكمرحلة أخرى لمعالجة المياه المتدفقة ولمعرفة النسبة المثلى للكربون والتي كانت (20mg/l) .

وعند تطبيق النسب المثلى من الشب ,البولي الكترولايت الكربون المنشط المسحوق على الماء المتدفق تم التوصل إلى كفاءات إزالة مطابقة للمواصفات العراقية والأمريكية إذ وصلت كفاءة إزالة كل من نسبة المواد العالقة الكلية(TSS) الى (83-96%) ، المتطلب الكيميائي للأوكسجين (COD) الى (73-80%) و المتطلب البايوكيميائي للأوكسجين (BOD_5) الى (73-85%) واللون الى (80-98%) .

وبناءا على هذه التجارب، وجد آن الماء الناتج من المحطة يمكن إعادة استخدامه لاغرا ض غسل المكائن ا و التنظيف العام. بالإضافة إلى ذلك بالإمكان تعقيم المياه بواسطة الكلور قبل طرحها وذلك لحماية البيئة من أي فضلات خطرة. والمخطط الذي تم اختياره لمعالجة المياه الصناعية اقترح لتطويرات أخرى في المستقبل .

الإهداء

إلى ...

من بكته ملائكة السماء

إلى ...

الذي تحت قبته يستجاب الدعاء

إلى ...

سيد الشهداء

إلى ...

جدي الأمام الحسين (ع)

إلى...

من أوصى بهم ربي خيرا
أمي و أبي

إلى ...

ذخري وسندي في الحياة
اخوتي سيف و علي

إليهم جميعا اهدي ثمرة ما وفقني الله إليه

Acknowledgement

Praise be to “**ALLAH**”, to his prophet “**Mohammed**” and “**ALLAH’S**” guardian “**ALI**”. This research has been completed under their benediction.

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I record my sincere gratitude to my family for their encouragement and support during the period of preparing this work.

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I am also indebted to the faculty of the Civil Engineering Department and the College of Engineering for all the facilities they supplied me with.

Many others who are not mentioned explicitly here, their efforts are equally appreciated.

RASHA

2003

CERTIFICATE

We certify that we have read this thesis, titled “ ***Reuse and recycle of industrial wastewater in Hilla textile factories*** ”, and as examining committee examined the student “ ***Rasha Salah Al-Kizwini***” 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 Environmental Engineering.

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List of tables

Chapter One 1

INTRODUCTION

1.1: WATER QUALITY

1.1.1: Source of water

With the future need to safeguard the quality of fresh water supplies and reduce fresh water usage by the introduction of reclamation schemes, the control of industrial discharges will become of great importance. In many instances the wastes that industry discharges to the sewers are detrimental to the production of a high quality reclaimed water (***Hart et al., 1983).***

There are many sources of water. Table (1-1) lists those sources and also provides general comments regarding each of these sources. Most individuals and industry in U.S.A.obtain their water from surface waters (streams, rivers, lakes, reservoirs) and groundwater. However, in other parts of the world, (e.g., the Middle East), construction of desalination plants has allowed the use of seawater as a source of drinking water. Reclaimed water is obtained from the treated effluent from a wastewater treatment plant. While it is technically feasible to pipe treated wastewater effluent into a drinking water treatment plant, most municipalities who utilize this option first discharge the treated wastewater effluent into a reservoir for a set period of time, after which the reservoir can then be used as a source of drinking water (***Mihelcic and Hand, 1999***).

Table (1-1): Different sources of water (Mihelcic and Hand, 1999)

Source of water	Comments
Surface water	High flows, easy to contaminate, relatively high suspended solids (SS), turbidity, and pathogens. In some parts of the world, rivers and streams dry up during the dry season.
Groundwater	Fifty percent of U.S.A. population use groundwater as a source for their drinking water. Lower flows but has natural filtering capacity that removes suspended solids (SS) and turbidity. May be high in total dissolved solids (TDS) including Fe, Mn, Ca and Mg (hardness). Difficult to clean up after contaminated.
Ocean	Energy intensive; so costly compared to other sources. Desalination can occur by distillation, reverse osmosis, electrodialysis, freezing, and ion exchange. Of these, multistage distillation and reverse osmosis are the two technologies most commonly used (they account for approximately 87 percent of worldwide desalination capacity). There are more reverse osmosis plants in the wold; however, they are typically smaller in capacity than distillation plants.
Reclaimed water	Technically feasible. More likely to be unacceptable to the public.

1.1.2:Water pollution

Table (1-2) shows the range of wastewater contaminants produced from industry. The type, number and concentration of undesirable compounds depend on the industrial process. Many of these pollutants resist degradation by the self-purification processes of the water environment as well as the controlled environment of the conventional biological treatment works and eventually find their way into potable water supplies.

Table (1.2): Effects of specific types of pollution in industrial waste discharges (Hart et al., 1983)

Water pollutants	Industries and industrial activities responsible	Adverse effects
Color	Pulp and paper, textiles, abattoirs, steel, dairy.	Visually objectionable.
Solids	Pulp and paper mills, textile factories, tanning, canning, breweries, steel mills, boiler-house operations, mining (drainage from mine dumps), abattoirs.	Blockage of sewer lines and equipment, damage to rivers by deposit of solids and depletion of oxygen.
Oil and grease	Abattoirs, wool-washers, tanneries, metal finishing, dairy plants, steel mills, oil refineries, railway workshops, locomotive, truck and aircraft washing, engineering works.	Blockage of sewer lines and equipment, floating scum on water which prevents transfer of oxygen, anaerobic conditions, unpleasant smell and attraction of flies.
Organic wastes	Pulp and paper, textiles, abattoirs, tanneries, canning, brewery, starch and yeast factories.	Overloading of conventional sewage treatment plants, depletion of oxygen in rivers.
Insecticides, Pesticides	Chemical, food and textile factories.	Toxic to bacterial and aquatic life; puts sewage treatment works out of action.
Heavy metals **Cyanide**	Pickling, plating. Metal finishing, plating, coking, refineries.	

Table (1 – 2) – Continued

Chemical wastes	Coking, synthetic dyes, chemicals, plastics, solvents, textile finishing, kraft and sulphite pulp.	Unpleasant taste and odor; toxic to aquatic life.
Acids (mineral and organic)	Steel pickling, chemicals, food processing, acid mine drainage.	Corrosion of concrete structures.
Alkalis, sodium	Metal finishing, plating, textile and pulp mills, tanneries, water softening, ion-exchange installations	Toxic to fish, rendering water unsuitable for irrigation by causing brackish conditions due to imbalance of ions
Nitrogen, phosphorus	Fertilizer plants, synthetic detergents	Rapid growth of aquatic organisms, algae, *Sphaerotilus natans*
Carbohydrates	Fruit and vegetable canning, sugar milling.	
Heat	Cooling, all processes.	Stimulates organic growth and reduces oxygen in water.
Detergents	Textiles , metal finishing.	Foaming.
Pathogens, viruses, worm	Hospitals, abattoirs.	Spreading of disease.

1.2: INDUSTRIAL WASTEWATER

Industries consume large quantities of water in different types. This water could be raw taken from natural sources like rivers or could be taken from drinking water nets. Whatever the sources are, its destination will be to the sewage nets or to the sources of water. In both cases, these waters must be treated before disposing it. Such treatments are of different types due to the different pollutants. Such different pollutants are always accompanied with high cost for the treatment process.

Recycle and reuse of water will minimize the consumption of water, saving some water that could be used for drinking.

1. 3: OBJECTIVES OF THE RESEARCH

The main objectives of the present work are:

1. Assessment of a physio-chemical treatment for textile wastewater from a plant that mainly manufactures rayon, velvet and jacquard fabrics, aiming at obtaining the most appropriate doses of coagulants for treatment of the wastewater
2. Assessment of the water quality of the treated wastewater using a combination of physio-chemical treatments with the addition of powder activated carbon (PAC).
3. Performing a scope for reuse of the treated wastewater.

1.4: THESIS LAYOUT

This thesis comprises six chapters.

Chapter Two presents the recent and relevant studies on textile industry. The different industrial wastewater treatment methods are presented in Chapter Three.

Discussion of a case- study is presented in Chapter Four. Chapter Five includes the results of experiments and their relevant analyses.

Finally, conclusions and recommendations for future studies are presented in Chapter Six.

Chapter Two 2

LITERATURE REVIEW

Most industries require water for various operations, e.g., washing raw materials, washing and cleaning, cooling, chemical processes, etc. These uses result in industrial wastewaters that are complexes of cast-off materials from the various manufacturing processes. Industrial wastewaters vary both in quantity and in quality. The wastewaters carry with them small quantities of processed materials, and the wastewater from one type of industry is usually very different from the wastewater of another industry. The treatment of industrial wastewater is generally unique for a particular industry (***AL-Layla et al., 1980***).

Industrial wastewater may contain inorganic or organic substances or both. Toxic substances may be present and may adversely affect the biological activity in streams.

2.1: TEXTILE INDUSTRY

The problem of treating textile industry wastewater is very complex because the processed raw materials and the manufactured intermediate products vary greatly in their nature and composition and many different manufacturing processes are employed (***Rudolfs, 1953***).

Howard et al. (1934) showed that the (flax retting waste) has a BOD of (2200mg/l), TSS of (4200 mg/l) and pH of (4.8).

Rudolfs (1953) concluded that effluents from the desizing process and wastes from kier boiling exert the greatest influence on the BOD_5 of the total wastes of the finishing cotton mill. These two effluents account for (40.5-66.0%) of the BOD of the combined wastes from the finishing mill and (15.4-32.0%) of their alkalinity. Effluents from the mercerizing process contribute (24.7-62.9%) of the alkalinity but only (1.3-5.7%) of the BOD.Wastes from the dye-house account for (5.5-33.60%) of the total BOD. Rudolfs showed that wool industry wastes were brown and turbid due to their content of grease emulsions and other organic compounds. He also showed that flax textile industry wastes contain no oxygen at all and the wastes became acidic with a pH between (4.2 - 5.6), a total solids content of (300-1000 mg/l), a suspended solids content of (80-180 mg/l), and a BOD_5 of (3800 mg/l).

Smith (1965) [qouted from (Bond and Straub, 1974)] stated that pH value of the effluent from typical synthetic fibers processing equals (6-7) with a BOD concentration of (200 mg/l) and TSS of (122 mg/l).

Eckenfelder (1970) studied textile industry with wool, cotton, and synthetic-textile waste in the scouring, dying, bleaching and special finishing processes as shown in Table (2-1). He also stated that the treatment of textile wastes usually employed biological treatment processes by pretreatment for neutralization, grease removal and other purposes. The various treatment processes and average efficiencies are summarized in Table (2-2).

Table (2-1): Percentage of BOD in textile processes (Eckenfelder.,1970)

Process	**Wool**	**Cotton**	**Synthetic**
Scouring	(50-75)	(50-75)	<50
Dying	(3-10)	(15-35)	(5-80)
Bleaching	<5	<5	<5
Special finishing	(5-15)	(5-15)	(5-15)

Table (2-2): Waste-treatment processes and efficiencies (Eckenfelder.,1970)

Treatment process	**BOD**	**Color**	**Alkalinity**	**SS**
Sedimentation	$30\text{-}50^{b}$ $5\text{-}15^{c,d}$	$10\text{-}50^{b}$	$10\text{-}20^{b}$	$50\text{-}65^{b}$ $15\text{-}60^{c,d}$
Chemical	$20\text{-}85^{b}$	$<75^{b}$		
Coagulation	$25\text{-}60^{c}$			<90
Lagoons	$<85^{b}$ $<80^{c}$	$<30^{b}$	$<20^{b}$	$<70^{b}$ $<80^{c}$
Aerated lagoons	$<95^{c,d}$			$<95^{c,d}$
Activated sludge	$<90^{b}$ $<95^{e,d}$	$<30^{b}$	$<30^{b}$	$<95^{b}$ $<95^{e,d}$

- Designation of superscripts:

b= Wool finishing ; c= Cotton finishing ; d= Synthetic fibers ;

e= H_2SO_4+alum

Bond and Straub (1974) studied the treatment methods and the removal efficiency of the two types of textile mills, namely, wool and cotton. Their findings are given in Tables (2-3) and (2-4), respectively.

Table (2-3): Wool processing treatment and removal efficiency (Bond and Straub, 1974)

	Normal reduction %			
Treatment method	**BOD**	**Grease**	**Color**	**SS**
Sedimentation	30-50	80-90	10-50	50-65
Flotation	30-50	95-98	10-20	50-65
Chemical coagulation (alum)	20-65		75	80-95
Chemical coagulation (lime+$CaCl_2$)	60	97		80-95
Activated sludge	85-90	0-15	10-30	90-95
Trickling filtration	80-95		10-30	90-95

Table (2-4): Cotton mill waste treatment and removal efficiency (Bond and Straub, 1974)

	Removal efficiency %		
Removal method	**BOD**	**SS**	**TDS**
Chemical precipitation	25-60	30-90	0-50
Trickling filter	40-85	80-90	0-30
Activated sludge	70-95	85-95	0-40

Callely et al. (1977) showed that the effluents from cotton woven fabrics have a pH of (8-12), total solids of (500-2000 mg/l), suspended solids of (50-250 mg/l), COD of (200-1000 mg/l) and BOD of (100-500 mg/l). They also showed that the wool woven fabrics have a pH of (7-10), total solids of (1000-5000 mg/l), suspended solids of (50-500 mg/l), COD of (200-2000 mg/l) and BOD_5 of (100-1000 mg/l).

Hart et al. (1983) studied the overall wastewater characteristics of the dry-processing mills and the woven fabric-finishing mills. Their results for the two types of mills are summarized in Tables (2-5) and (2-6), respectively.

Table (2-5): Effluent produced from dry processing mills (Hart et al., 1983)

Parameter	Units	ATMI		NCWQ
		Avg.	Std. Dev.	Avg.
BOD	**mg/l**	274	123	300
TSS	**mg/l**	87	163	150
COD	**mg/l**	871	230	950
Oil and grease	**mg/l**	-	-	-
Sulphide	**mg/l**	8.00	-	-
Color		-	-	-
PH	**(units)**	11.53	5.78	6 – 11
Temperature	**°C**	-	-	24
Water use	**(l /kg)**	12.6	12.7	12.5

Table (2-6): Effluent produced from woven fabric finishing mills (Hart et al., 1983)

Parameter	Units	ATMI		NCWQ
		Avg.	**Std. Dev.**	**Avg.**
BOD	**mg/l**	592	392	550
TSS	**mg/l**	313	533	185
COD	**mg/l**	1 093	513	1 850
Oil and grease	**mg/l**	14	-	-
Sulphide	**mg/l**	2.72	4.57	2.72
Color		-	-	325
pH	**(units)**	-	-	-
Temperature	**°C**	-	-	42
Water use	**(l /kg)**	151	83	112

- ***ATMI (American Textile Manufactures Institute).***
- ***NCWQ (National Commission on Water Quality).***

AL-Tufaily (1995) studied the disposal of industrial wastewater from Hilla textile factories of the State Company for Textile Industries and its effect on the water of Shatt-Al-Hilla. The study involved the determination of the following parameters: temperature, pH, alkalinity, total suspended solids, calcium, magnesium, total hardness, chloride, sulfate, phosphate, nitrate, dissolved oxygen, biochemical oxygen demand, and heavy metals (chromium, lead, nickel, zinc, cadmium and copper). The researcher found that these effluents had an alkaline nature with a low organic load as expressed in terms of BOD but high levels of suspended and dissolved solids. A high concentration of chloride was also recorded.

The effluents disposed to Shatt Al-Hilla were found to have high concentrations of lead. Multiple regression procedure was adopted to find the regression equations, which were used to describe the spread of pollutants in Shatt Al-Hilla. For this purpose, the following quality parameters were used: dilution factor, pollutants concentrations at disposal point, pollutants concentrations in the water-waste mixture, and the distance along the river starting from the disposal and down-stream.

Al-Hashmi and Al-Kizwini (1999) measured the levels of heavy metals, BOD and COD of the industrial wastes that were disposed off from the Hilla textile factory of the State Company for Textile Industries and their effect on the water of Shatt-Al-Hilla.Test of samples taken from five different river locations indicated that all parameters were found to be within the allowable limits except the BOD value which was high. This was attributed to insufficient aeration of the industrial water. It was suggested that a large aeration tank is to be used in order to reduce the BOD value.

2.2: REUSE AND RECYCLE OF INDUSTRIAL WASTEWATER

The available literature on this subject is scarce as this subject was of minor importance due to the availability of ample quantities of good water in the past. Nowadays, the increased need to water and numerous sources of pollution of water, particularly in industry, gave the subject an advanced importance which sometimes rises to a priority.

In Tunisia a wastewater pretreatment plant of a textile factory was optimized where up to (0.5 m^3/h) of the effluent was treated by photocatalysis in a pilot (Flow Film Reactor) with an area of ($50m^2$). The influence of different types of processed waters and the kind of pretreatment on the photocatalytic oxidation was investigated. Tests of (TiO_2) in different concentrations were conducted in order to understand the characteristics determining the photocatalytic operation and to obtain guidelines to improve efficiency. By optimization of the flocculation and coagulation processes on a laboratory scale, the elimination of (63%) of the COD, (50%) of BOD_5, over (97%) of suspended solids (SS) and (100%) of dissolved solids (DS) were achieved. The substitution of an organic acid by an inorganic acid in the neutralization step reduced the recontamination of the pretreated water. Different methods for immobilizing the catalyst by minimizing the loss in photo catalytic activity were tested. In all cases decolorization of the effluent was possible ***(http://www, 2001)***.

AL-Mallah (2002) studied the treatment of industrial wastewater from Baghdad Textile Factory. He found that the removal efficiency of chemical coagulation treatment using (alum+polymer) in concentrations (60+1.75 mg/l) gave a removal of (32-76.6%) of TSS and (1.5-9%) of turbidity. However, a removal efficiency of (28.2-70.4%) of TSS and (8.3-20%) of turbidity was obtained with concentrations of (80+1.75 mg/l). Moreover, a removal efficiency of (21.2-85.5%) of TSS and (43.7-85%) of turbidity was obtained with concentrations of (100+2 mg/l). He concluded that with the use of (25mg/l) of activated carbon a removal of (93.75-94.6%) of color, (96-96.35%) of turbidity, (74-77.2%) of TSS, (12-14.9%) of TDS, (87.4-87.6%) of BOD, (1%) of hardness and (3-5%) of alkalinity were possible.

Chapter Three 3

INDUSTRIAL WASTEWATER TREATMENT PROCESSES

3.1:WATER USED IN TEXTILE INDUSTRY

Water is considered a very important element in any principal process for textile and spinning industry like washing, dyeing, and finishing. Besides, it supplies the steam boilers in order to get vapor which is necessary in productive processes, supplying the cooling units during summer, and other works like cleaning.

According to **(Peters, 1967)** the industry of textile and spinning faces many challenges and problems associated with the kind of water. Among them are:

1. Providing water with certain specification suitable to the processes of producing textile
2. Providing certain water suitable for steam boilers and power producing station.
3. Preventing corrosion in the pipes and tanks, which is produced by the type of water.

Because of the many needs which are sensitive to the quality of water, the subject of the research on the quality of the water used in the industry of textile and spinning is considered very important in providing enough quantities of water in a good quality **(Peters, 1967).**

The pollutants that result from textile industry can be included under the following items:

A- Biological oxygen demand (BOD)

The biological oxygen demand is an important index of water pollution that indicates the degree of water pollution based on organic substances. Oxygen is consumed in proportion to the amount of the organic substances in the same way as the human metabolism works. As stated in **(Inoue, 2003):"**With BOD, clean and sufficiently aerated water is put in a sealed glass bottle along with N, P, Mg and other nutrients, and sufficiently. Another bottle is put. A fixed quantity of the polluted water and microbes are also added in the bottle. After 5 days of still standing, the oxygen content (dissolved oxygen) of the bottle is measured to get the value of the organic pollution in the polluted water. Usually, the bottle remained for 5 days at 20-C. The obtained value is the "BOD_5" **".**

B- Chemical oxygen demand (COD)

Chemical Oxygen Demand, COD, differs form BOD in that it measures the oxygen demand needed to decompose organic substances in polluted water, using a strong oxidizer such as potassium permanganate or potassium dichromate. Whereas BOD indicates the concentration of biochemical easy-to-decompose substances, COD indicates the concentrations of substances that can be readily decomposed "chemically". Consequently, COD measurement does not indicate sources of microbe nutrients such as iron sulfate (-2) and nitrous acid, but it does indicate a high value when water contains substances that readily and chemically bind with oxygen. However, acetic acid and other similar preferred sources of microbes nutriment can be measured by BOD but not by COD. Therefore, BOD and COD produce completely different values; nonetheless, both are used as pollution indicators today (**Inoue, 2003).**

The BOD, COD, and other pollutants are shown schematically in Fig. (3.1)

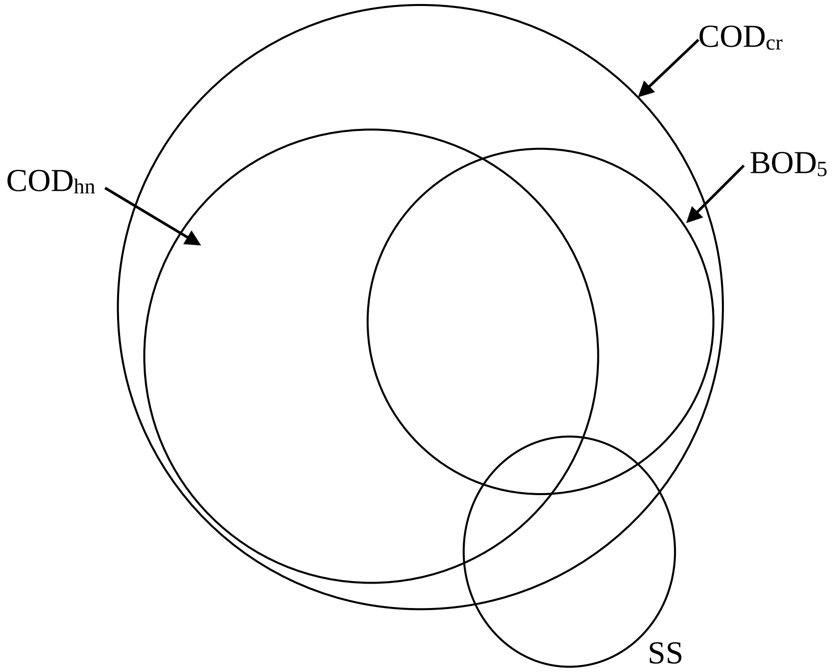

Fig. (3.1): Pollutant model for textile dyeing wastewater (Inoue, 2003)

3.2: MISCELLANEOUS WASTEWATER TREATMENT METHODS

Wastewater is treated to remove and decompose substances that are harmful to the natural environment. The substances are either directly decomposed or first separated and then decomposed, by using or promoting natural purification action. In other words, a treatment plant is built on separation and decomposition technologies as shown in Fig. (3.2).

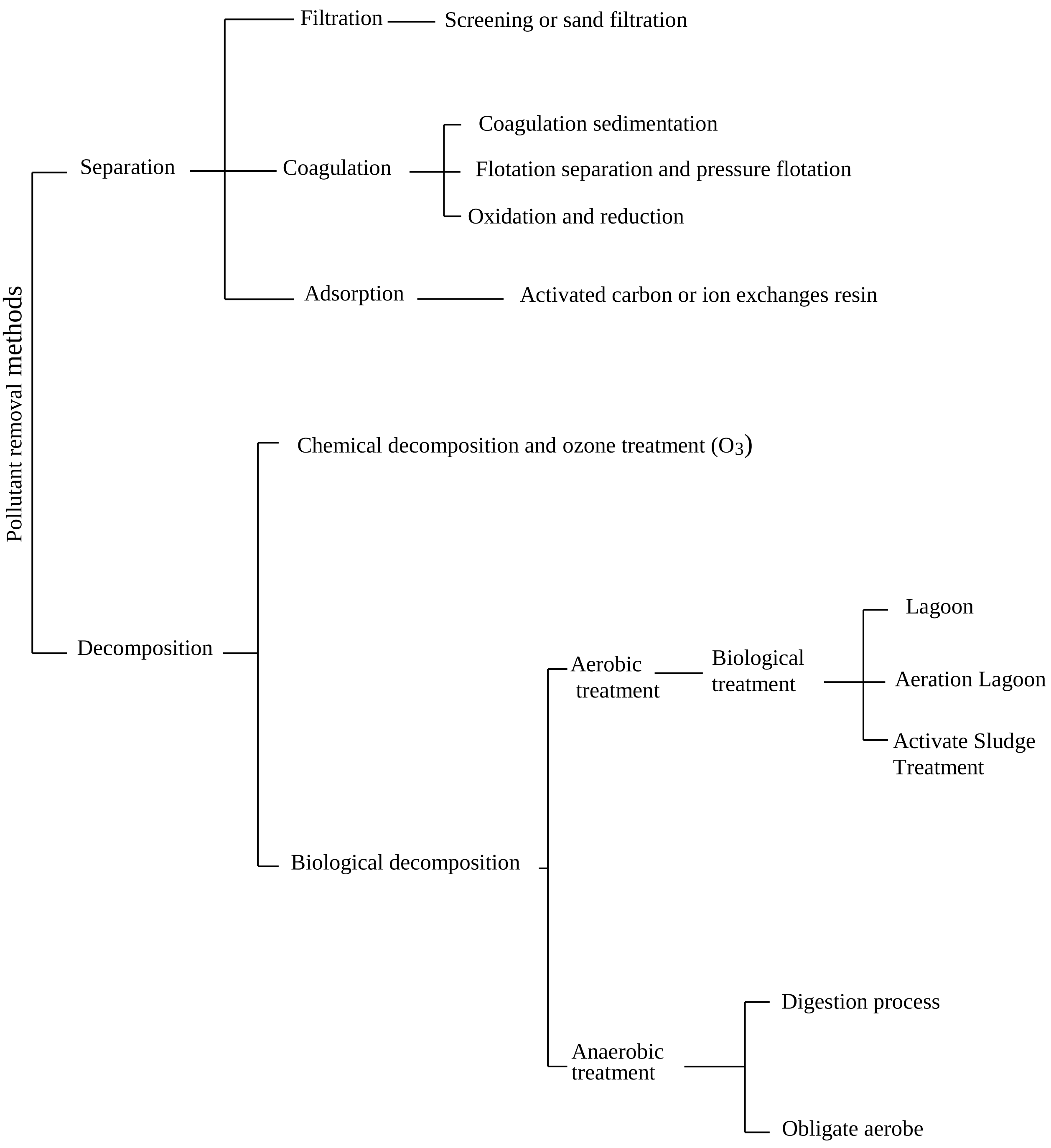

Fig. (3.2): Pollutant removal methods (Inoue, 2003)

The processes of treating wastewater are usually divisible into many principal sections. The divisions, according to **(Peirce et al., 1998),** are.

A-Primary treatment stage

This stage involves physical processes that remove nonhomogenizable solids and homogenize the remaining effluent. This stage contains several steps; among them are:

1-Screens

A screen in a modern treatment plant removes materials that might damage equipment or hander further treatment.

2- Comminutor

This is a circular grinder designed to grind the solids coming through the screen into pieces about (0.3cm) or less in diameter.

3- Grit chamber

The objective of a grit chamber is to remove grit or sand from the wastewater without removing organic material.

B- Secondary treatment stage

This stage involves biological processes that remove most of the biochemical demand for oxygen.

C- Tertiary treatment stages

This stage involves physical, biological, and chemical processes to remove nutrients like phosphorus and inorganic pollutants, to deodorize and decolorize effluent water, and to carry out further oxidation.

Figure (3.3) shows the stages of industrial wastewater treatment from textile and spinning industry **(Jorgensen, 1979).**

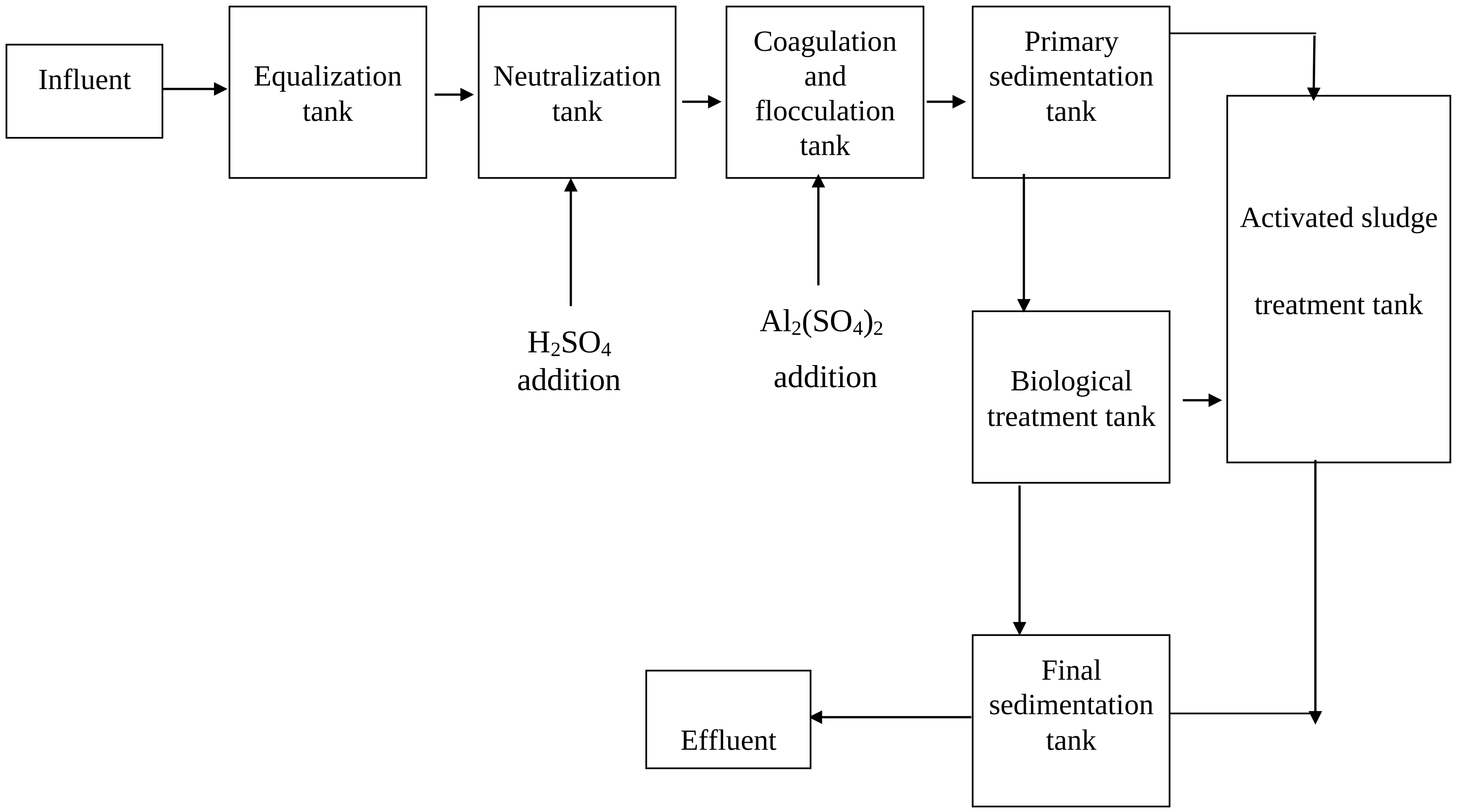

Fig. (3-3): Industrial water treatment stages in a textile factory (Jorgensen, 1979)

3.3: BASIC TREATMENT METHODS USED IN TEXTILE FACTORIES

The basic treatment methods used in textile factories are coagulation, flocculation and activated carbon. These methods are discussed hereinafter.

3.3.1: Coagulation and flocculation

Coagulation is the process of driving together small or colloidal particles by chemical forces into larger particles. Rapid mixing is used and the reaction occurs very fast.

Flocculation is the assembling of coagulated particles. Flocculation basin is used to provide slow mixing **(Mihelcic and Hand, 1999).**

Coagulation and flocculation are used together to remove particles that can impart color to a water source, create turbidity, and retain bacteria and viral organisms. Also, some of these small particles may be pathogenic organisms themselves. The process of coagulation and flocculation is used to treat small particles in the size range of (0.001 to 1.0 micrometer).

In coagulation theory, some of the mechanisms of destabilization include electrostatic attraction, interparticle bridging, and enmeshment (or sweep floc).

In electrostatic attraction, particles can be destabilized by electrostatic attraction. This occurs when surfaces are oppositely charged. This can be promoted by adsorption of specific ions on the surface of the particles. A reduction of the pH or addition of specifically adsorbed ions can lead to charge-neutralization and destabilization.

Interparticle bridging refers to long chain polymers that carry negative charges that can form bridges between particles thus destabilizing the suspension. The mechanism has also been shown to be the major factor controlling the aggregation of bacteria and algae suspension.

Enmeshment (also referred to as sweep floc) occurs when massive amounts of some coagulants are added to the water. As the voluminous and three dimensional polymers form, the colloids are trapped within the floc. The solids remain trapped within the settling floc and appear to be swept from the water **(Mihelcic and Hand, 1999).**

The primary function of coagulant chemicals is to destabilize particles and strengthen flocs to reduce floc breakup. Selection of the proper coagulant depends upon: the characteristics of the coagulant, particulates, water quality, cost, and dewatering characteristics of the solids that are produced.

The types of coagulant include aluminum sulfate (also referred to as alum), , ferric sulfate ($Fe_2 (SO_4)_3$ or ferric chloride ($FeCl_3$), lime (CaO), and synthetic cationic polymers, anionic polymers, and nonionic polymers.

The most commonly used coagulant is alum which has the chemical formula ($Al_2(SO_4)_3 . 14H_2O$) (with a molecular weight of 594). Addition of Al^{3+} in the form of alum (or ferric iron in the form of the ferric salts mentioned hereinbefore) at concentrations less than the solubility limit for the metal hydroxide, results in the formation of the metal hydroxide that adsorbs onto particles causing destabilization by charge neutralization. Addition of aluminum and iron salts at concentrations greater than the solubility limit of the metal hydroxide will result in the formation of the hydroxide precipitate. In this situation, both charge neutralization and enmeshment in the precipitate contribute to coagulation **(Culp et al., 1978**).

The reaction may be represented by the following equation:

$$\mathbf{Al_2(SO_4)_3.14H_2O + 3Ca(HCO_3)_2 \longrightarrow 2Al(OH)_3 + 3CaSO_4 + 14H_2O + 6CO_2} \quad \mathbf{[3\text{-}1]}$$

Hydrogen ions are liberated by the addition of alum and will react with the water’s natural alkalinity. Note in the above equation that alkalinity (as $Ca\ (HCO_3)_2$) is consumed. Theoretically, using the stoichiometry of the above reaction, (1mg/l) of alum will consume approximately (0.50mg/l) of alkalinity (as $CaCO_3$) and produce (0.44mg/l) of carbon dioxide. If the natural alkalinity of the water is not sufficient to react with the alum and buffer the pH, it may be necessary to add alkalinity to the water in the form of lime or soda ash (Na_2CO_3). In addition, the formation of an aluminum precipitate, Al $(OH)_3$ is charged at certain pH, and when the aluminum hydroxide is positively charged, it will neutralize the negatively charged naturally occurring particles **(Mihelcic and Hand, 1999).**

The minimum dose of alum is (5mg/l) but the average dose commonly encountered in practice lies in the range (15-50mg/l). If the water is very turbid the dose might be even more but there is no straight-line correlation. Results can be obtained only by jar tests (**Smethurst, 1997)**.

The characteristics of coagulation are discussed hereinafter.

3.3.1.1 Jar test for optimum coagulation dosage

Coagulation is not yet an exact science, although recent advances have been made in understanding the mechanics of the process. Therefore, selection and optimum dosage of coagulant are determined experimentally by the jar test instead of quantitatively by formulas. The jar test must be performed on any water that is to be coagulated and must be repeated with each significant change in the quality of that water.

The jar test is performed using a series of glass containers that hold at least (1liter) and are of uniform size and shape. Normally, six jars are used with a stirring device, Fig. (3-4), that simultaneously mixes the contents of each jar with a uniform power input. Each of the six jars is filled to the (1-liter) mark with water whose turbidity, pH, and alkalinity have been predetermined. One jar is used as a control while the remaining five are dosed with different amounts of coagulant at different pH values until the minimum values of residual turbidity are obtained. After chemical addition, the water is mixed rapidly for about (1 min) to ensure complete dispersion of the chemicals, then mixed slowly for (15 to 20 min) to aid in the formation of flocs. The water is next allowed to settle for approximately (30min), or until clarification occurs. Portions of settled water are then removed and tested to determine the remaining turbidity. Test results are used to calculate the type and quantity of coagulant to be used in the water-treatment plant **(Peavy et al., 1986).**

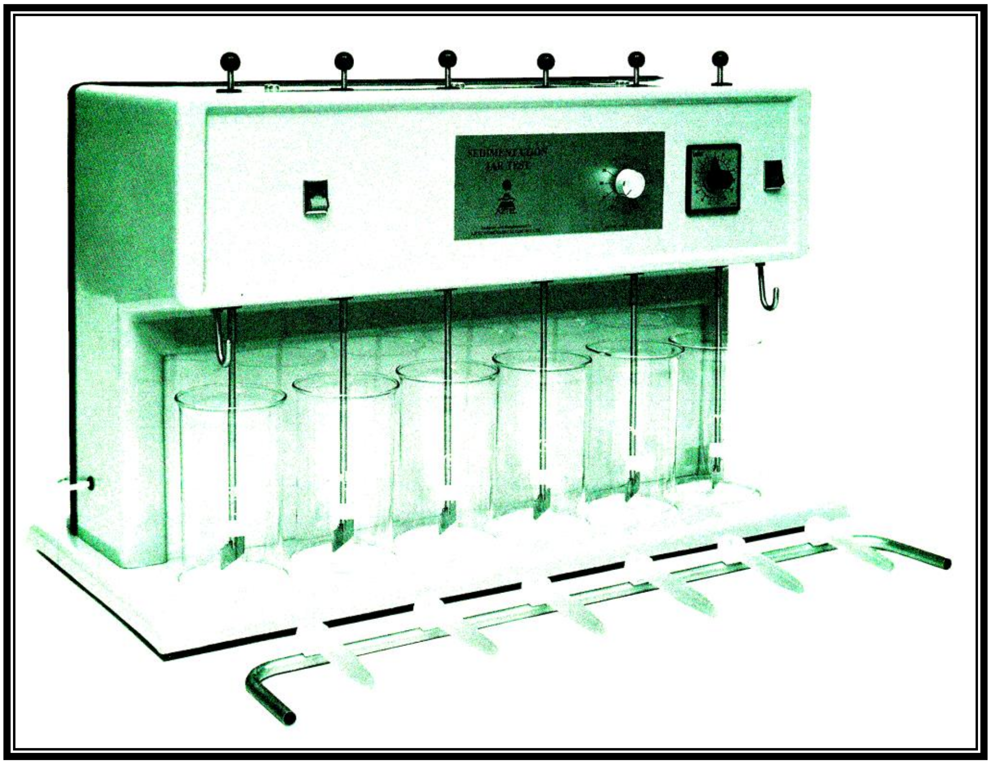

Fig. (3-4): Jar test apparatus (AZTEC, 2003)

3.3.1.2: Alkalinity- coagulation relationships

As noted from Eq.(3-2),the coagulation of metallic salts releases hydrogen ions as well as coagulant species. These hydrogen ions neutralize alkalinity. Hydrogen resulting from the addition of (1mg/l) of alum will neutralize (0.5mg/l) of alkalinity. If the initial alkalinity of water is low, further reduction will destroy its buffering capacity and the pH will drop rapidly. Since optimum pH values must be maintained for best coagulation and since alkalinity must be present for hydroxide floc formation, low alkalinity waters must be artificially buffered. This is usually accomplished by the addition of lime ($Ca(OH)_2$) or soda ash (Na_2CO_3) **(Peavy et al., 1986).**

$$\mathbf{Al_2(SO_4)_3.18H_2O + 3Na_2CO_3+3H_2O \longrightarrow 2Al(OH)_3 +3Na_2SO_4+ CO_2+18\ H_2O} \quad \textbf{[3-2]}$$

3.3.1.3: pH-coagulation relationships

Aluminum sulfate, the most commonly used coagulant in water purification, is most effective in the pH range (5.0 and 7.5). Ferric chloride, effective down to pH (4.5), and ferrous sulfates, effective only above pH (9.5), are sometimes used. Although less expensive than alum, these coagulants can cause color problems if the precipitate is not removed completely. It is sometimes advantageous to use synthetic polymers in addition to alum. These polymers bind small flocs together to make larger masses for faster settling **(Peavy et al., 1986).**

3.3.1.4:Coagulant aids - polyelectrolytes

Clay, activated silica, and organic polymers have been used often as coagulant aids. Polymers and polyelectrolytes are extensively used for modern high-rate filters, with success. A great deal of current interest is focused on the use of polymers and polyelectrolytes as coagulants or as coagulant aids because, as stated by **(Kawamura, 1976),** they**:**

1- Reduce the sludge volume produced by the treatment process.
2- Prove effective in very small amounts.
3- Improve the sludge-dewatering process, compared with alum or ferric salts sludge.
4- Are generally more readily biodegradable than alum or iron salts sludge and ease sludge digestion by microorganisms.

5- Are easy to handle.

6- Are nontoxic in nature.

7- Minimize alkali dosage for final pH control because practically no pH reduction occurs compared with the pH reduction following the use of alum or iron salts as coagulants.

8- Minimize chemical residual such as sulfates in treated waters .

The ability of natural substances such as starch, gelatin, vegetable gum, and sodium alginate to act as coagulant aids has long been known. In contrast, synthetic polyelectrolytes have been introduced in rather recent years

Polyelectrolyte is defined as those organic polymers that consist of long chain molecules having ionized sites along their chains. There are two types of polyelectrolytes-cationic and anionic-that are used in the water-treatment field. Nonionic polymers are also used.

In the water-treatment field, anionic and nonionic polymers are mostly used as coagulant aids or filter aids, whereas the cationic polymers, which are usually in the liquid form, are normally used as coagulant or filter aids. Anionic or nonionic polymers, however, are sometimes effectively used as coagulants, especially for the flocculation of raw sewage and partially treated sewage. It is important to recognize, however, that an overdose of any polyelectrolytes will result in an adverse effect on coagulation. It is also important to point out that not all waters can be treated with equal success with the same polymers or the same dosage. Jar-test studies are recommended to determine both the proper types of polymer or polyelectrolyte to be used and optimum dosage rates **(Kawamura, 1976)**.

3.3.2: Activated Carbon Adsorption:

Activated carbon comes in two forms: powdered activated carbon (PAC), and granular activated carbon (GAC). Both forms effect removal by physically adsorbing compounds. In the past, (PAC) was employed more frequently, primarily for color, taste and odor control. (PAC) reportedly was first used in the United States in 1929. However, both (PAC) and (GAC) are generally viewed as a reliable last recourse for removal of color, taste and odors particularly from industrial sources **(Montgomery, 1985).**

In order to understand how activated carbon accomplishes adsorption, an explanation of how it is produced would be appropriate. Activated carbon is manufactured from wood, coal, bone char, coconut shells, or some other carbon source. The carbon source is heated in the absence of air to carbonize it, then activated by oxidation to remove noncarbon impurities. This activation burns away some carbon layers and produces a pore structure. According to **(Qasim et al., 2000),** activation is accomplished by heating to a high temperature (between 200 and 1000 ^{o}C) in the presence of steam and carbon dioxide, and air or wet chemical treatment at lower temperature, using such agents as concentrated phosphoric acid, potassium hydroxide, or zinc chloride. The result is a highly porous carbon surface with specific adsorption properties. Pore–size distribution and adsorption characteristics are strongly influenced by the carbon source and the activation method employed.

It is the high porosity and large surface area that gives activated carbon its unique adsorption properties. Surface area in excess of (2000m^2/gm) and a dry weight density of (500 kg/m^3) can be achieved. However, economics generally limits the use of carbon with a surface are a between (500 and 1500 m^2/gm) in water applications **(Qasim et al., 2000).**

The large surface area available enhances the physical adsorptive properties of the carbon. In this process, water-borne solute molecules (adsorbates) pass through the maze of rough surface and irregular fissures of the activated carbon, or adsorbent .The molecules are removed by Van der Waals force (physical adsorption) and by very weak bonding between adsorbent and adsorbate. For this reason, the adsorbate is approximately at equilibrium with the solute concentration in solution. Any change in solute concentration, therefore, affects the amount of chemicals that can remain adsorbed.

In water treatment, the major consideration in selection of activated carbon are:

1-The form of activated carbon (PAC or GAC).

2-The adsorptive capacity.

3-The rate of adsorption.

(PAC) is normally more economical for treatment of seasonal or mineral taste and odor problems whereas (GAC) may be desirable for more severe and persisted conditions. Both (PAC and GAC) are marketed with specific adsorptive properties **(Qasim et al., 2000).**

3.3.2.1: The removal efficiency of adsorption process by activated carbon

The adsorption process by activated carbon is able to remove color, odor, and taste. It is also capable to remove dissolved organic materials, detergent, grease, oil, phenols and hydrocarbonate. The value of BOD is changed from (200mg/l) to (1mg/l) whereas the value of COD is changed from (200mg/l) to (20 mg/l) by using activated carbon **{Besseliver et al., 1978[qouted from (Al - Mallah, 2002)]}.**

The removal efficiency by activated carbon compared with other treatments are tabulated in Table (3-1) **(AICE and EPA, 1976).**

Table (3-1): Efficiency of activated carbon compared with other treatments (AICE and EPA, 1976)

Pollutant	Removal efficiency %		
	Chemical treatment	Biological treatment	Activated carbon
1.BOD_5 mg /l	50-70	70-95	60-95
2.COD mg/l	50-70	30-70	60-95
3.TSS mg /l	80-98	30-90	60-90
4.Color	80-90	10-80	80-98
5.Alkalinity mg /l	0-20	10-20	5

The table shows that the removal efficiency by activated carbon is very high, but the industrial waste must be treated by chemical and biological treatments first and the remainder of the pollutants is then removed by activated carbon **(AICE and EPA, 1976).**

3.3.2.2:Granular activated carbon (GAC)

The contact system for granular activated carbon (GAC) consists of a cylindrical tank which contains a bed of the material. The water is passed through the bed with sufficient residence time allowed for completion of the adsorption process. The system may be operated in either a fixed-bed or moving-bed mode. Fixed-bed systems are batch operations that are taken off the line when the adsorptive capacity of the carbon is used up **(Peavy et al., 1986).**

.

Although fixed granular carbon beds can be cleaned at site with superheated steam, the most common practice is to remove the carbon for cleaning in a furnace. The regeneration process is essentially the same as the original activation process. The adsorbed organics are first burned at about (800°C) in the absence of oxygen. An oxidizing agent, usually steam, is then applied at slightly higher temperatures to remove the residue and reactivate the carbon **(Peavy et al., 1986).**

In a moving-bed system, spent carbon is continuously removed from the bottom of the bed, with regenerated carbon being replaced at the top. Most modern applications use the removing-bed system with a countercurrent flow; that is, the water is introduced at the bottom of the bed and moves upward against the flow of carbon **(Peavy et al., 1986).**

The design of a granular-activated- carbon systems is based on the flow rates and contact times. Flow rates of (0.08 to 0.4 $m^3/m^2.min$) and contact times of (10 to 50 min) are based on empty-tank cross section and volume, form a common practice **(Peavy et al., 1986).**

The effectiveness of (GAC) in removing color, taste and odor can be expressed by the following equation **(Qasim et al., 2000).**

$$\mathbf{Ln\ ((C_o/C_e)-1) = Ln\ (e^{K\ NoD\ /\ v}-1) - KC_ot} \qquad \mathbf{[3\text{-}3]}$$

where:

C_o = influent concentration, mg/l;

C_e = allowable effluent concentration, mg/l;

K= constant rate, $m^3/kg.h$;

No = adsorptive capacity, kg solute/m^3 carbon;

D= depth of bed, m;

V= linear flow rate, m/h;

t= service time, h.

3.3.2.3: Powdered Activated Carbon (PAC)

Powdered activated carbon (PAC) cannot be used in a fixed-bed arrangement because of the tiny size of its particles and subsequent high head loss that would result from passing water through it. Powdered activated carbon is contacted with the water in open vessels where it is maintained in suspension for the necessary contact time and then removed by conventional solids-removal processes.

Powdered activated carbon is much more difficult to regenerate than granular. In wastewater treatment, powdered activated carbon is added to the aeration basin and removed with the biological solids in the secondary clarifiers. In this case, both refractory and biodegradable organics are adsorbed **(Peavy et al., 1986)**. Carbon dosages may vary from (20 to 200 mg/l) depending on the results desired **(Ekenfelder, 1989**).

The Freundlich equation is expressed by Eq. (3-4) **(Qasim et al, 2000).**

$$X/M=kC^{1/n} \qquad [3\text{-}4]$$

where:

X= adsorbate actually adsorbed by carbon, mg/l ($X=C_o-C$);

Co = initial concentration of adsorbate, mg/l;
C= final or equilibrium concentration of the adsobate, mg/l;
M = carbon dose, mg/l;
k= empirical constant;
n= slope – inverse constant,
where the value of (k) and (n) are abstracted from the drawn log-log curve.

Chapter Four 4

THE CASE STUDY

4.1:GENERAL

The Hilla textile factories of the State Company for Textile Industries have been taken as the case study. The factories complex is located in the southern part of Hilla City and within its municipal limits. The complex was established in (15/ 10 / 1967). In 1980, a new section (factory), namely, the velvet and jacquard section, has been established.

The factories complex produces the following fabrics :

1. Cotton fabric and blending.
2. Velvet and jacquard fabric.
3. Synthetic fabric for special uses as blanket base.

The complex constitutes several productive, technical, and administrative sections. The present basic industrial sections are:

1.The spinning section

2.The preparation section

3.The textile or weaving section.

4. The finishing section

5.The velvet and jacquard section.

Those that have relations to the quality, use, and consumption of water, and consequently to the subject of this research, are briefly discussed hereafter.

4.2: WATER SUPPLY AND DISTRIBUTION

The total daily water consumption in Hilla Complex is nearly ($3500 m^3$/day). Of this, about ($1500 m^3$/day) is used for industrial purposes, and the remainder is for drinking and sanitary services, as shown in Fig. (4.1). The soft water (influent) and industrial wastewater (effluent) limits are summarized in Tables (4.1) and (4.2), respectively. However, the capacity of the existing treatment plant is ($438 m^3$) per working shift (7 hours)

4.3: THE PRODUCTIVE SECTIONS

4.3.1: Finishing section (Factory No 1)

This section is the one that uses the largest quantity of water among other sections, which represent about (55%), of the water used in production. Moreover, it is the one that produces the most polluted effluent.

The finishing process constitutes the following sub-processes:

1.Scouring and bleaching:

Scouring with hot alkali removes the natural waxes and pectins from the cotton together with spinning oils. Bleaching with hydrogen peroxide is used to whiten the fabric. Many chemicals are used in this stage, such as NaOH, caustic soda and sodium silicate. Steam is used to raise the temperature and increase moisture.

2.Dyeing and printing:

Cloth is colored to customers requirements by either dyeing or printing. Final finishing in the form of easy care or handle finish is often carried out prior to the sale of the cloth. Chemical materials in different doses are used in this respect.

The pollutants produced in this section are as follows.

a) Colors:

Colors are caused by different kinds of dyes such as direct, disperse and reactive dyes.

b) Suspended solids (TSS):

Such a contaminant results from cleaning machines, the remainder of fabric and sludge.

c) Oil and grease:

They are produced because of the use of oil in industrial operations. Grease is used in maintenance of machines. It is used continually.

d) High alkalinity and pH:

It is the result of using chemical materials like sodium hydroxide, which is used in large amount in the industrial processes.

e) High rate of organic materials:

It is the result of removing the starch and the use of organic colors. These materials cause an increase in the biochemical oxygen demand (BOD_5).

f) Small amounts of chlorides and sulfates:

It is the result of using some materials that contain chloride ion and sulfates like sodium chloride and colors that contain sulfates.

g) Large amounts of soaps, bleach, and detergents:

They are used too much in this section before and after the processes of dyeing and in the processes of coloring.

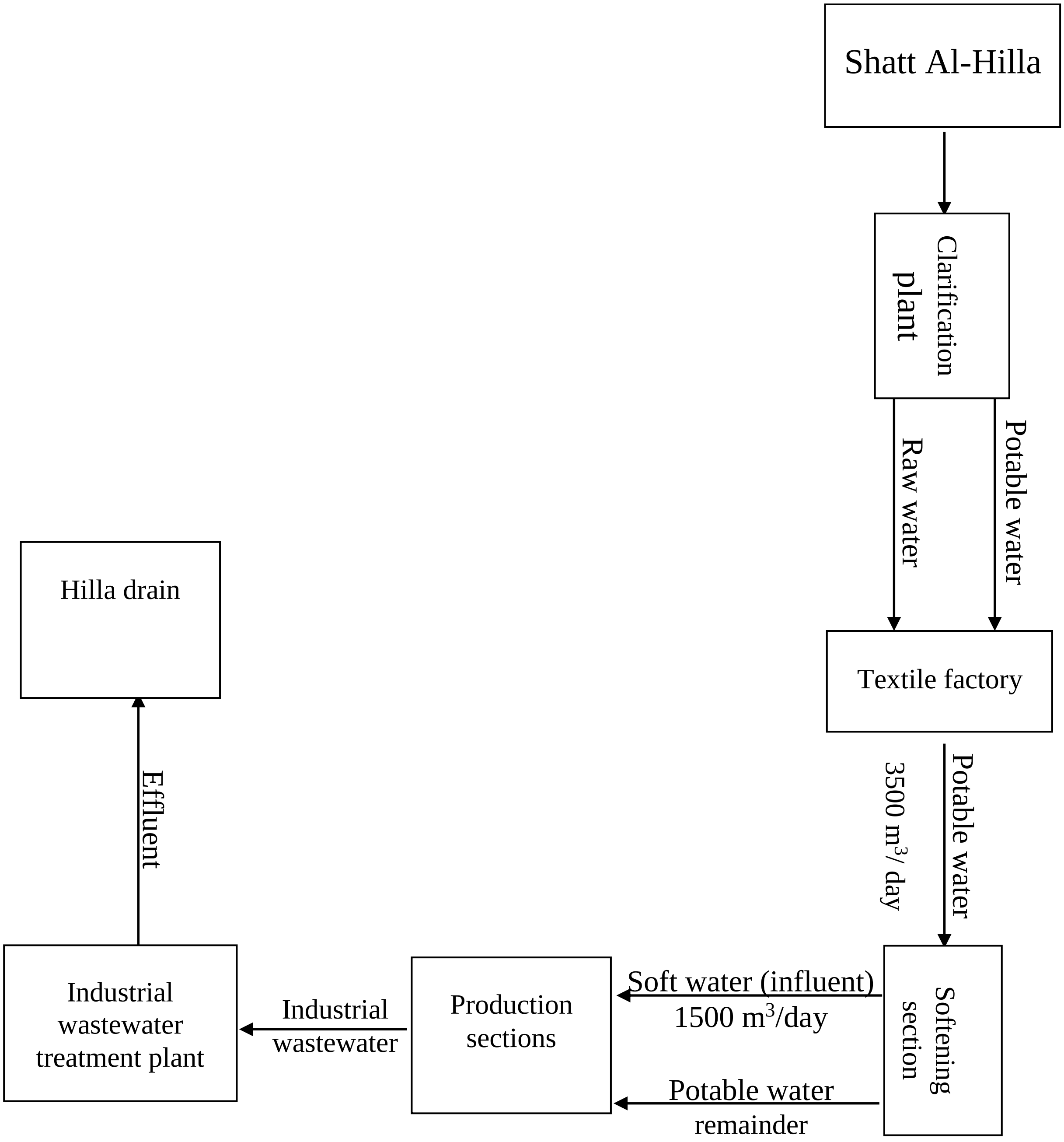

Fig. (4.1): Schematic illustration of water supply and distribution of Hilla factories of the State Company for Textile Industries

Table (4-1): The standard influent limits of soft water in textile industry (SCTI, 2003)

Parameter	Limit
pH	7.5-8.5
Cl^-	600 mg/l
SO_4^{--}	400 mg/l
Hardness	(0-1mg/l)
Conductivity	(1000-1500 ms/cm)
TDS	(500-1000 mg/l)

Table (4-2): The standard effluent limits of industrial water in textile industry (SCTI, 2003)

Parameter	**Limit**
pH	6-9.5
Cl^-	600 mg/l
SO_4^{--}	400 mg/l
TSS	60 mg/l
BOD	40 mg/l
COD	100 mg/l

4.3.2: Velvet and jacquard section (Factory No 2)

This section contains three units

1. Preparations :No industrial water is contributed.
2. Textile :No industrial water is contributed.
3. Finishing: It forms the principal user of the industrial water in the velvet and jacquard section. As for pollution, this section uses about (60 m^3) of water per day. Its pollution is less than the processing section (factory No1). However, pollution in this section is the result of using alkaline colors and chemical materials as used in the bleaching processes; (H_2O_2) and (NaOH) are used with (pH) equals (9).

4.4: THE INDUSTRIAL WASTEWATER TREATMENT PLANT

The industrial wastewater that is produced from the productive sections is collected through a pipe network that ends to a special treatment plant. The treatment plant comprises the following basic units: The primary mixing tank, the sedimentation tank, the biological treatment tank, filters, the final sedimentation tank, and the final mixing tank, as shown in Fig. (4-2). A brief discussion of each unit is given hereinafter.

4.4.1: The primary mixing tank

This tank is the first stage of the treatment. The process of receiving industrial water here may be considered as an equalization process. The tank has a square cross-section with (4m) length, (2m) width and (2m) depth. Water entering this tank contains salts, dyes, grease and other suspended and dissolved organic materials. The tank is preceded by screens manhole. Grease, fats and oil are partially removed in this tank. The wastewater in this tank is then pumped by a set of submersible pumps to the primary sedimentation tank. Figure (4.3) shows a plate photograph of the primary mixing tank.

4.4.2: The primary sedimentation tank

This is a circular tank [Fig. (4.4)]; its diameter is (25m), its depth is (1.6m), and its capacity is about (700 m^3). The tank is used as a sedimentation tank. It is equipped with a revolving bridge with a scraper mechanism at the bottom that removes sludge from the lower part of the tank. Sludge is pumped from there to sludge drying beds. Water then flows by gravity to the chemical treatment tanks.

4.4.3: The chemical treatment tanks

These are five tanks. Alum and lime are added in the tanks. Each tank has a square cross-section (2x2m) and a length of (2.5m). Residual grease is removed here. (20%) of the flow is then sent to the biological treatment units, while the rest is sent directly to the final sedimentation tank. Figure (4.5) shows a plate photograph of the chemical treatment tanks.

4.4.4: The biological treatment tank

The tank has an oval- circular shape. Its capacity is (200-250 m^3). Mechanical brushes are used in aerating the wastewater in this tank. Figure (4.6) shows a plate photograph of the biological treatment tank.

4.4.5: The final sedimentation tank

The tank is (20m) long, (9.5m) wide and has a depth between (1 to 3.5m). The tank is equipped with a revolving bridge with a scraper mechanism. Sludge is pumped from this tank to the sludge drying beds. . Figure (4.7) shows a plate photograph of the final sedimentation tank.

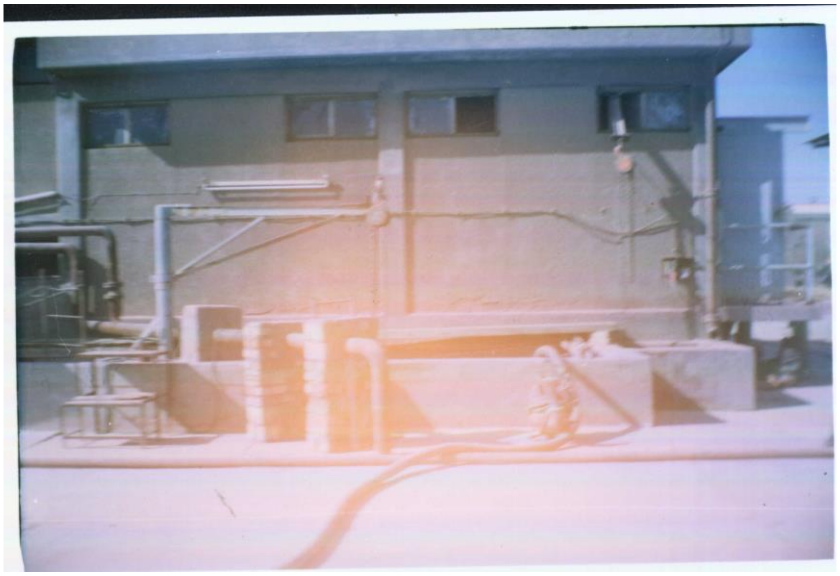

Fig. (4.3): The primary mixing tank

Fig. (4-4): The primary sedimentation tank

Fig. (4-5): The chemical treatment tanks

Fig. (4.6): The biological treatment tank

Fig. (4.7): The final sedimentation tank

4.4.6: Filters

The plant involves five filters. Two of these are used to dry the primary sludge, while the other three are used to filter the combined effluent from the final sedimentation tank. The dimensions of each filter are (20x10x1.5m). A cross-section through a filter shows a layer of (35 cm) of sand resting on a layer of gravel of (35cm) in which the gravel is (5-18mm) in size .At the bottom, a final layer of gravel of (20cm) in height is placed on a drainage system of perforated pipes. The gravel of this layer has a size of (18-50mm). The drainage water from these filters is pumped by (3) pumps to the Hilla drain. Figures (4.8) and (4.9) show plate photographs of the sand filters and the sludge drying beds, respectively.

Fig. (4.8): The sand filter

Fig. (4.9): The sludge bed filter

4.4.7: The final mixing tank

The tank is (4m) long, (8m) wide and (6.5m) deep. Final disposal of industrial wastewater effluent is pumped from this tank to the Hilla drain. Figure (4.10) shows a plate photograph of the final mixing tank.

Fig. (4.10): Final mixing tank

4.5: EVALUATION OF THE PERFORMANCE OF THE INDUSTRIAL WASTEWATER TREATMENT PLANT

To evaluate the performance of the treatment plant, ten samples were taken from the primary and the final mixing tanks as indicated in Table (4.3). The samples were tested for pH, TSS, SO_4, BOD_5, COD, hardness, and alkalinity according to (AWWA, 1985). The results of the tests are summarized in Table (4.4).

The results indicate that the different units were not operating efficiently compared with (AICE and EPA) specification { As given in Table (3-1)} as seen by the individual removal efficiency of each parameter, e.g., TSS, BOD_5, and COD.This is believed to be due to lack of maintenance and overloading of the treatment plant.

Table (4-3): Sampling for the evaluation of performance of the existing treatment plant

Location	**Sample No**	**Date of sampling**
The primary mixing tank (before treatment)	**1-A** **2-A** **3-A** **4-A** **5-A**	**12/10/2002** **16/11/2002** **3/12/2002** **4/1/2003** **1/2/2003**
The final mixing tank (after treatment)	**1-B** **2-B** **3-B** **4-B** **5-B**	**12/10/2002** **16/11/2002** **3/12/2002** **4/1/2003** **1/2/2003**

Table (4-4): Quality of the industrial water of Hilla Textile Factories before and after treatment

Sample No.(1)							
The tests	pH	TSS	SO_4	BOD_5	COD	Hardness as $CaCO_3$	Alkalinity as $CaCO_3$
		mg/l					
1-A	9	149	272	130	250	318	355
1-B	8	46	252	71	125	245	279
The efficiency		69%		45%	50%		
Sample No.(2)							
The tests	pH	TSS	SO_4	BOD_5	COD	Hardness as $CaCO_3$	Alkalinity as $CaCO_3$
		mg/l					
2-A	7.5	210	350	278	320	410	300
2-B	8.4	110	425*	150	252	290	222
The efficiency		47.6%		46%	21.3%		
Sample No.(3)							
The tests	pH	TSS	SO_4	BOD_5	COD	Hardness as $CaCO_3$	Alkalinity as $CaCO_3$
		mg/l					
3-A	8	450	333	50	123	220	607
3-B	9	310	532*	33	73	165	310

The efficiency		31%		34%	41%		

Sample No.(4)

The tests	pH	TSS	SO_4	BOD_5	COD	Hardness as $CaCO_3$	Alkalinity as $CaCO_3$
		mg/l					
4-A	9.5	110	280	90	225	222	320
4-B	10	80	310*	75	180	185	279
The efficiency		27%		17%	20%		

Sample No.(5)

The tests	pH	TSS	SO_4	BOD_5	COD	Hardness as $CaCO_3$	Alkalinity as $CaCO_3$
		mg/l					
5-A	9.5	350	290	60	87	232	330
5-B	8	95	240	26	40	185	292
The efficiency		73%		57%	54%		

* Increase of (SO_4) after treatment is due to residual Alum (which constitutes SO_4)

Chapter five

5

TREATMENT METHODS AND ANALYSIS OF RESULTS

5.1:THE TESTING PROCEDURE

The tests in this study are carried out in two steps. In the first step a physio-chemical treatment is applied to wastewater in order to reduce (COD) and total suspended solids (TSS). In the second step activated carbon is used to improve the quality of the effluent from the physio-chemical treatment.

5.1.1: The physio-chemical test

Physio-chemical treatments were carried out using a multiple stirrer (jar-test) apparatus. The tests were conducted in the laboratory of the Hilla textile factories of the State Company for Textile Industries. Tests were performed using $Al_2(SO_4)_3.18H_2O$ as coagulant and polyelectrolytes as coagulant aid in a conventional jar test analysis.The influences of (pH), coagulant and coagulant aid concentrations were investigated. The coagulant concentration was varied between (10-500 mg/l) and the polyelectrolyte concentration between (0.5-2.5mg/l). Finally, the (pH) values were adjusted to (7.5,8,8.5,9,9.5) before alum addition [as suggested by J. D Walker **(Jeffcoat and Singley, 1975)**]. The (pH) of the samples was changed by the addition of HCl (0.1N) or NaOH (0.1 and 0.5 N).

Nine samples were taken from the primary mixing tank to determine the optimum value of pH, alum and polyelectrolyte concentration as indicated in Table (5-1). The samples were tested for COD and TSS according to **(AWWA,1985)** as shown in the following:

5*.1.1.1: Effect of pH value on COD and TSS of treated water*

Figure (5.1) shows the variation of (COD) values of the clarified water after (jar-testing) using three different doses of ($Al_2(SO_4)_3$).

With the (100mg/l) alum dose, the best result is obtained at (pH = 8) and initial COD of (287 mg/l) is reduced to (152 mg/l), i.e., a (47%) removal efficiency. After that the (COD) is seen to increase gradually with pH increase.

With the (250mg/l) alum dose, the best result is obtained at (pH =8.5) and initial COD of (450 mg/l) is reduced to (222 mg/l), i.e., a (52.2%) removal efficiency. However, as the pH increases, the removal efficiency is not significantly altered with an alum dose of (250 mg/l).

The (500mg/l) alum dose results in increasing COD removal. with the increase of pH.

Figure (5.2) shows the variation of (TSS) values of the clarified water after jar-testing using two doses of ($Al_2(SO_4)_3$) .

With the (100mg/l) alum dose, the best result is obtained at (pH=7.5) and initial TSS of (98 mg/l) is reduced to (38 mg/l), i.e., a (61%) removal efficiency. After that the (TSS) is seen to increase gradually with pH increase.

With the (250mg/l) alum dose, the best result is obtained at (pH =8.5) and initial TSS of (281 mg/l) is reduced to (107 mg/l), i.e., a (62%) removal efficiency. After that the (TSS) is seen to increase gradually with pH increase.

Table (5-1): Sampling for physio-chemical treatment

No of sampling	**Date of sampling**	**tests**	**Location**	**Fig. No**	**Comments**
1	9/2/2003	COD,TSS	The primary mixing tank	(5.1),(5.2)	To determine the optimum of (pH)
2	12/2/2003	COD,TSS	The primary mixing tank	(5.1),(5.2)	To determine the optimum of (pH)
3	15/2/2003	COD	The primary mixing tank	(5.1)	To determine the optimum of (pH)
4	18/2/2003	COD,TSS	The primary mixing tank	(5.3),(5.4)	To determine the optimum dose of alum
5	22/2/2003	COD,TSS	The primary mixing tank	(5.5),(5.6)	To determine the optimum dose of alum
6	25/2/2003	COD,TSS	The primary mixing tank	(5.7),(5.8)	To determine the optimum dose of alum
7	3/3/2003	COD,TSS	The primary mixing tank	(5.9),(5.10)	To determine the optimum dose of polyelectrolyte,
8	8/3/2003	COD,TSS	The primary mixing tank	(5.11),(5.12)	To determine the optimum dose of polyelectrolyte,
9	15/3/2003	COD,TSS	The primary mixing tank	(5.13),(5.14)	To determine the optimum dose of polyelectrolyte,

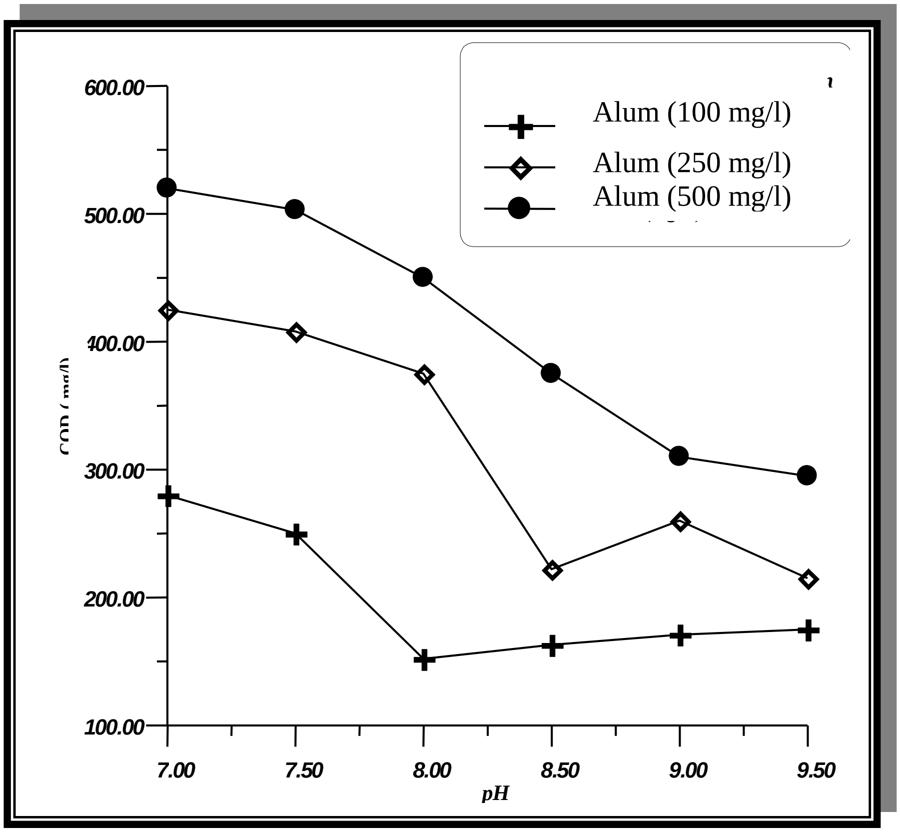

Fig.(5.1) : Influence of wastewater pH on COD of treated water using different concentration of alum

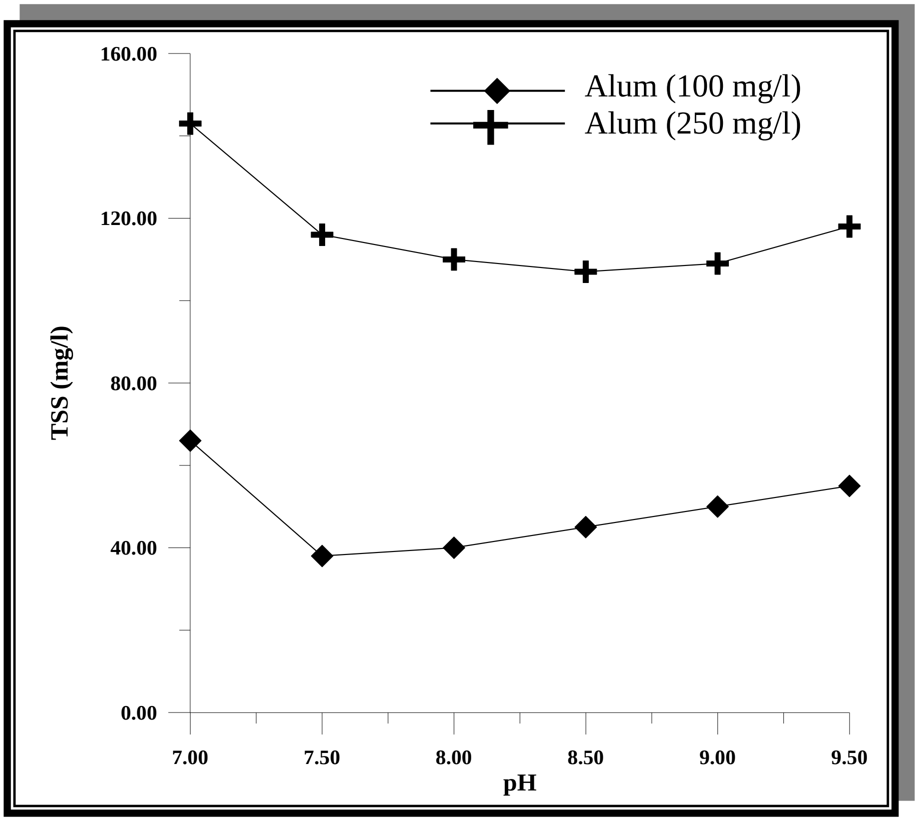

Fig.(5.2) : Influence of wastewater pH on TSS of treated water usina different concentration of alum

5.1.1.2: Effect of alum and polyelectrolyte doses concentrations on COD and TSS of treated water

Figures (5.3) and (5.4) show that the best results (18% COD removal and 45% TSS removal) are obtained at a dose of (50 mg/l) of alum with an initial COD of (130mg/l) reduced to (107mg/l) and TSS of (226 mg/l) reduced to (125mg/l) at (pH =7.5).

Figures (5.5) and (5.6) show that the best results (24% COD removal and 50% TSS removal) are obtained at a dose of (100 mg /l) of alum with an initial COD of (360mg/l) reduced to (273mg/l) and TSS of (102 mg/l) reduced to (51mg/l) at (pH =8).

Figures (5.7) and (5.8) show that the best results (36.4% COD removal and 65% T.S.S removal) are obtained at a dose of (250 mg/l) of alum with an initial COD of (354mg/l) reduced to (225mg/l) and TSS of (230mg/l) reduced to (81mg/l) at (pH =8).

Figures (5.9) and (5.10) show that the best results (45.5% COD removal and 79.4% TSS removal) are obtained at a dose of (500 mg/l) of alum with an initial COD of (244 mg/l) reduced to (133mg/l) and TSS of (437mg/l) reduced to (90mg/l) at (pH =9).

It was observed that coagulation concentration higher than (250 mg/l) hardly improved the COD removal efficiency.

Figures (5.11) and (5.12) show the effect of adding (100 mg/l) of alum and polyelectrolyte. The best results (49% COD removal and 69% TSS removal) are achieved with (2 mg/l) of polyelectrolyte with an initial COD of (350 mg/l) reduced to (180mg/l) and TSS (145 mg/l) reduced to (45mg/l) at (pH =8).

Figures (5.13) and (5.14) show the effect of adding (250mg/l) of alum and (0.5-2.5 mg/l) of polyeletrolyte. The best results (52%COD removal and 58.4% TSS removal) are achieved with (1.5 mg/l) of polyelectrolyte with an initial COD of (410 mg/l) reduced to (195mg/l) and TSS of (108 mg/l) reduced to (45mg/l) at (pH =8.5).

At higher polyelectrolyte concentrations, COD and TSS concentration increase. This is due to the restabilization of colloidal matter in water, which contribute to the COD and TSS of the clarified water.

Thus, the experiments show that the optimum operating condition for the physio-chemical treatment of the textile wastewater are: [pH =8.5, alum $Al_2(SO_4)_3$= 250 mg/l and polyelectrolyte = 1.5-2mg/l].

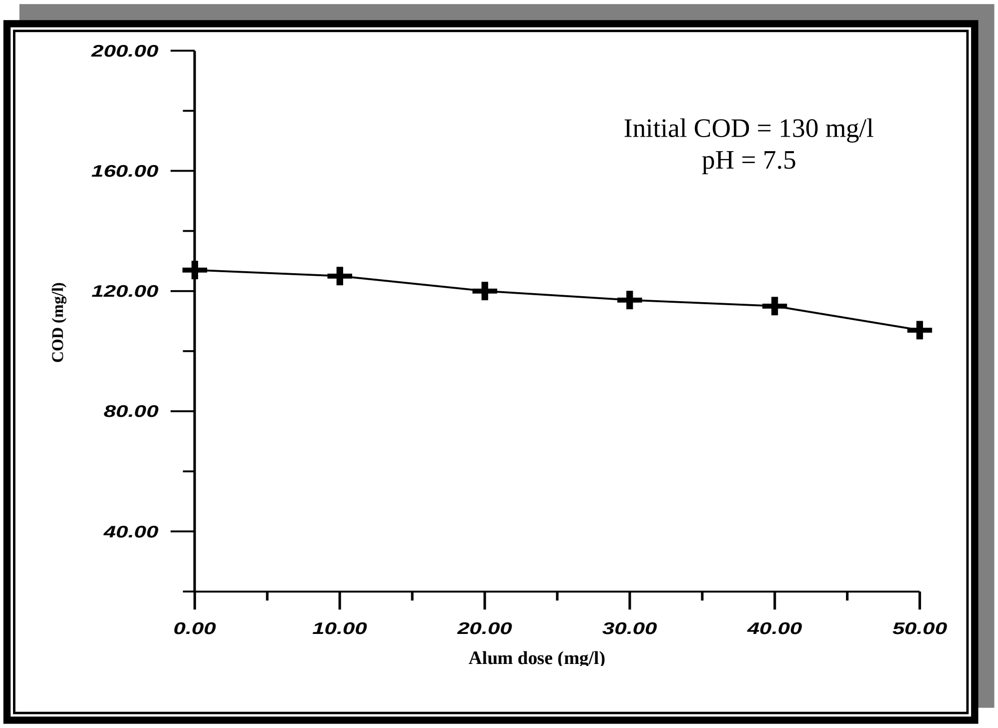

Fig. (5-3): Influence of (10 – 50mg/l) alum concentrations on COD of treated water

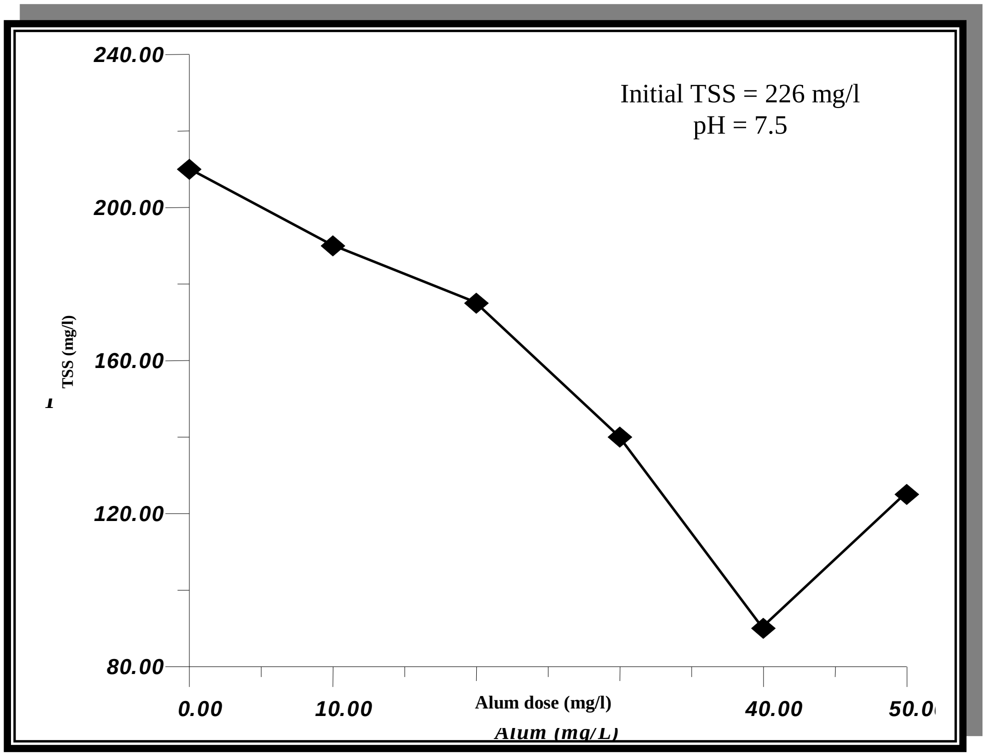

Fig. (5-4): Influence of (10 – 50mg/l) alum concentrations on TSS of treated water

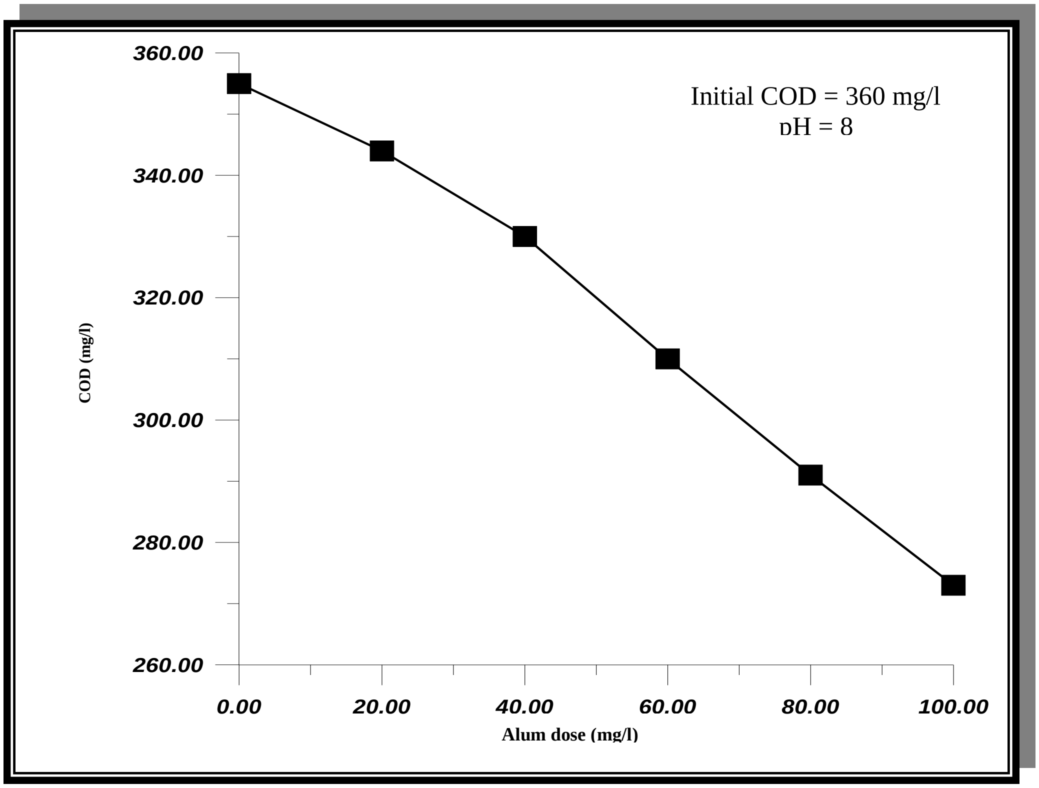

Fig. (5-5): Influence of (20 – 100mg/l) alum concentrations on COD of treated water

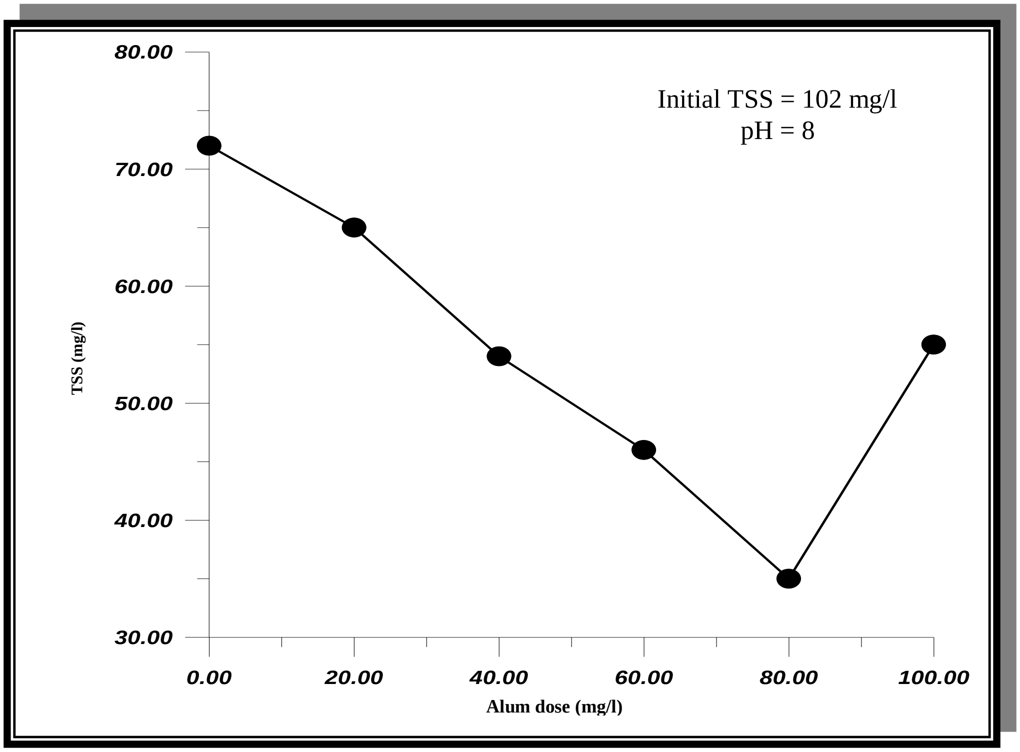

Fig. (5-6): Influence of (20 – 100mg/l) alum concentrations on TSS of treated water

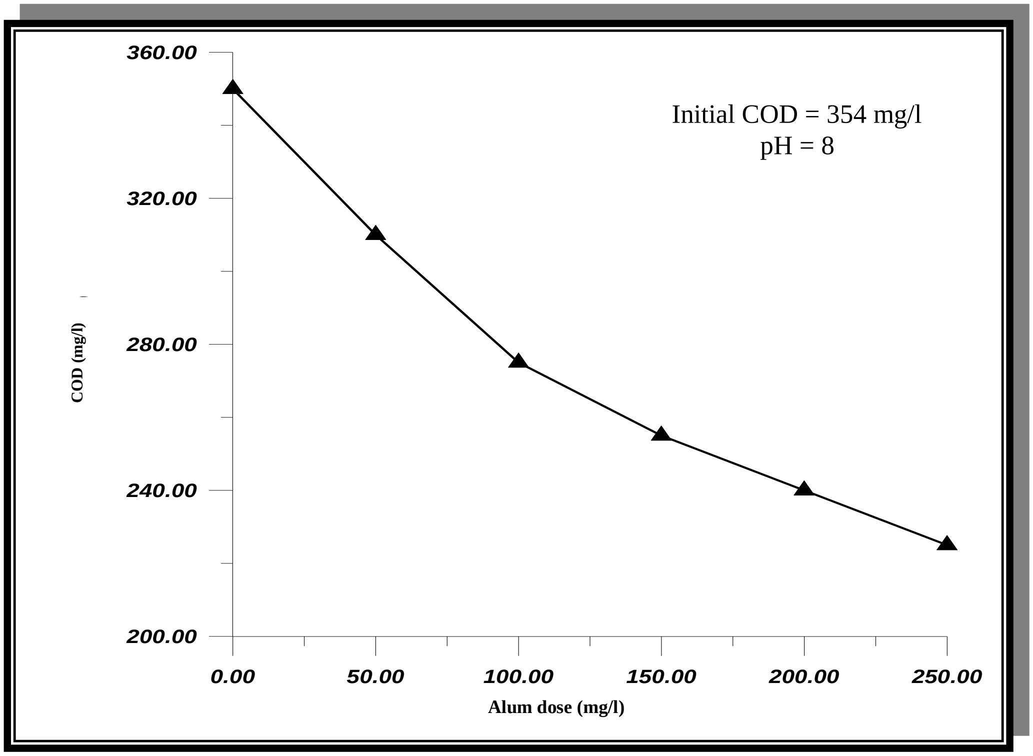

Fig. (5-7): Influence of (50 – 250mg/l) alum concentrations on COD of treated water

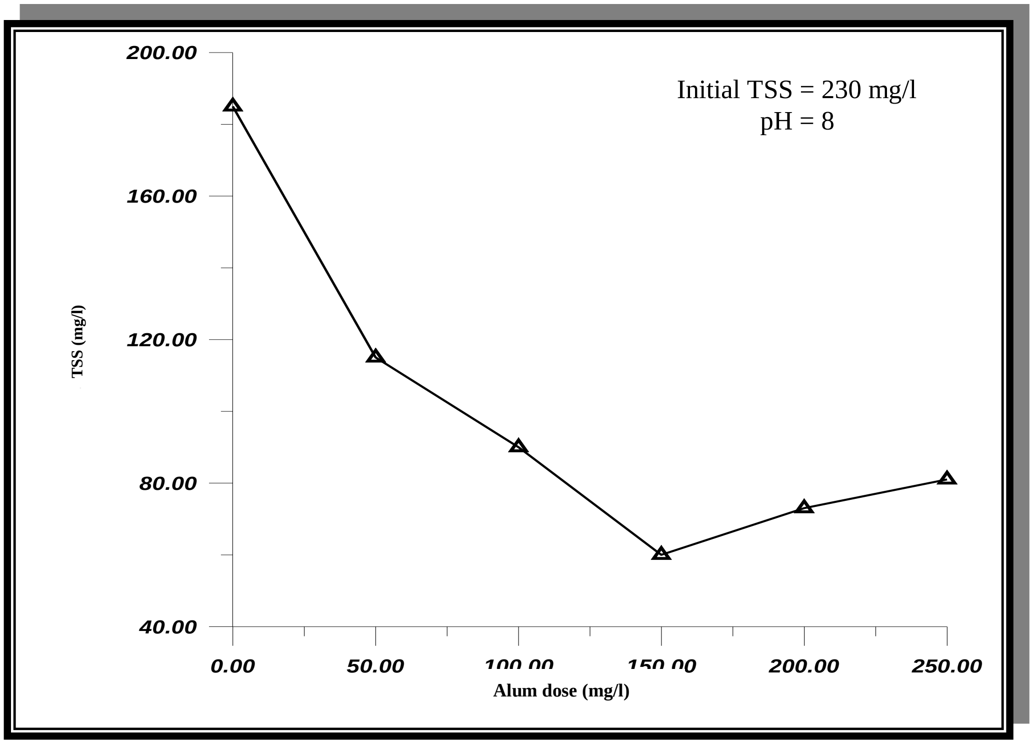

Fig. (5-8): Influence of (50 – 250mg/l) alum concentrations on TSS of treated water

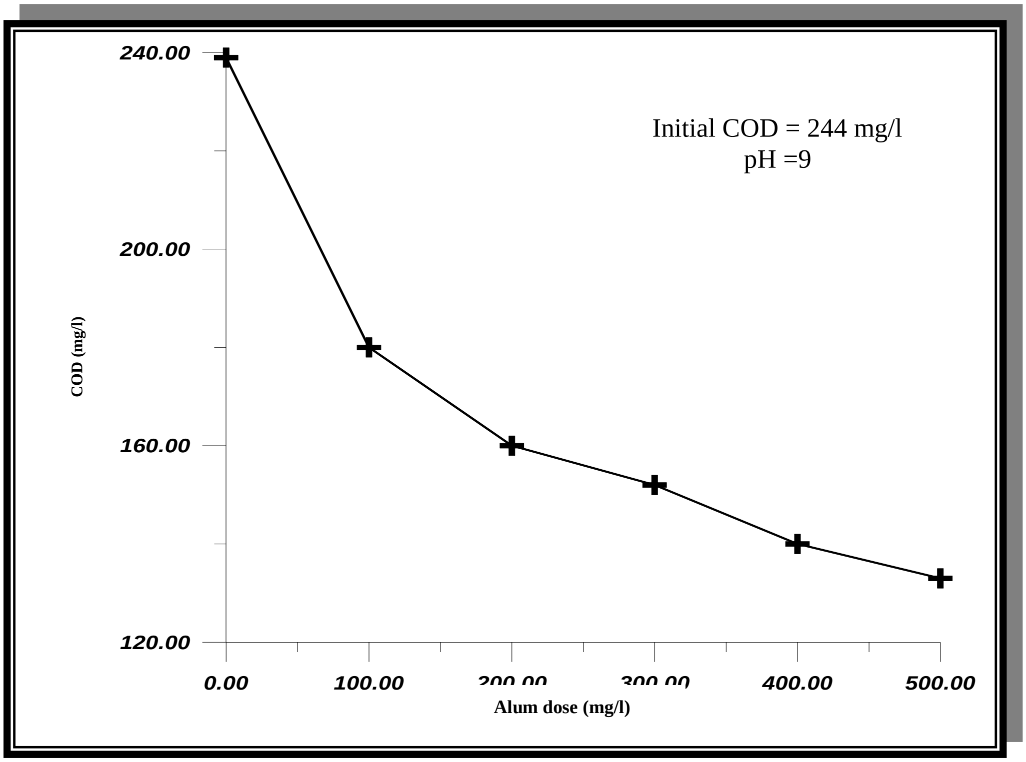

Fig. (5-9): Influence of (100 – 500mg/l) alum concentrations on COD of treated water

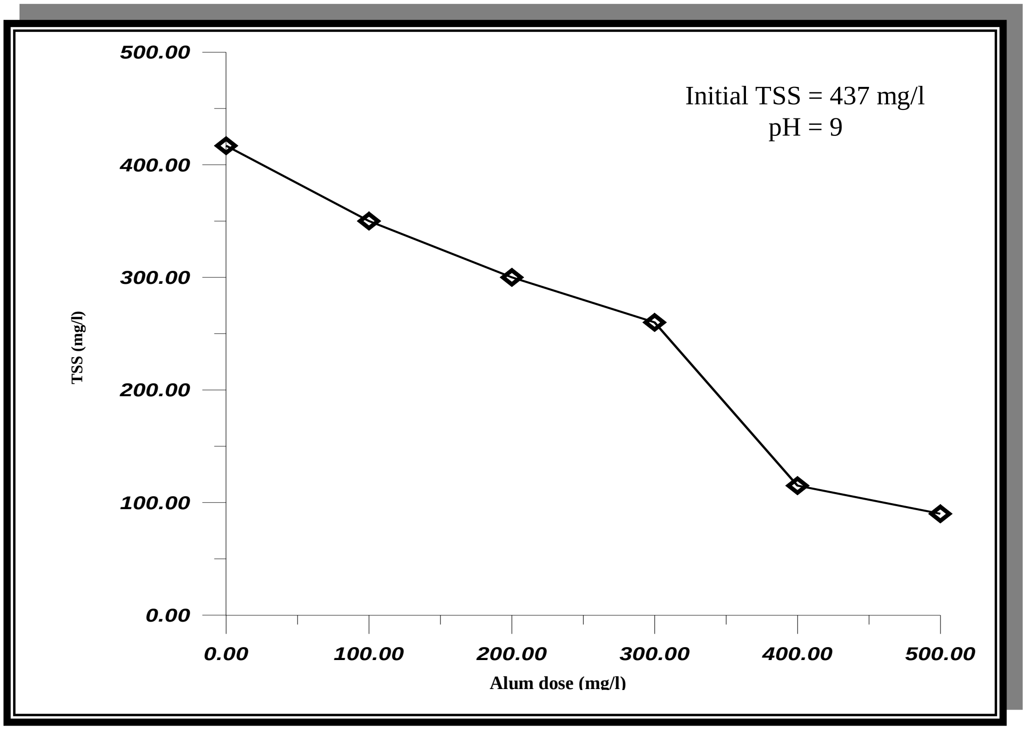

Fig. (5-10): Influence of (100 – 500mg/l) alum concentrations on TSS of treated water

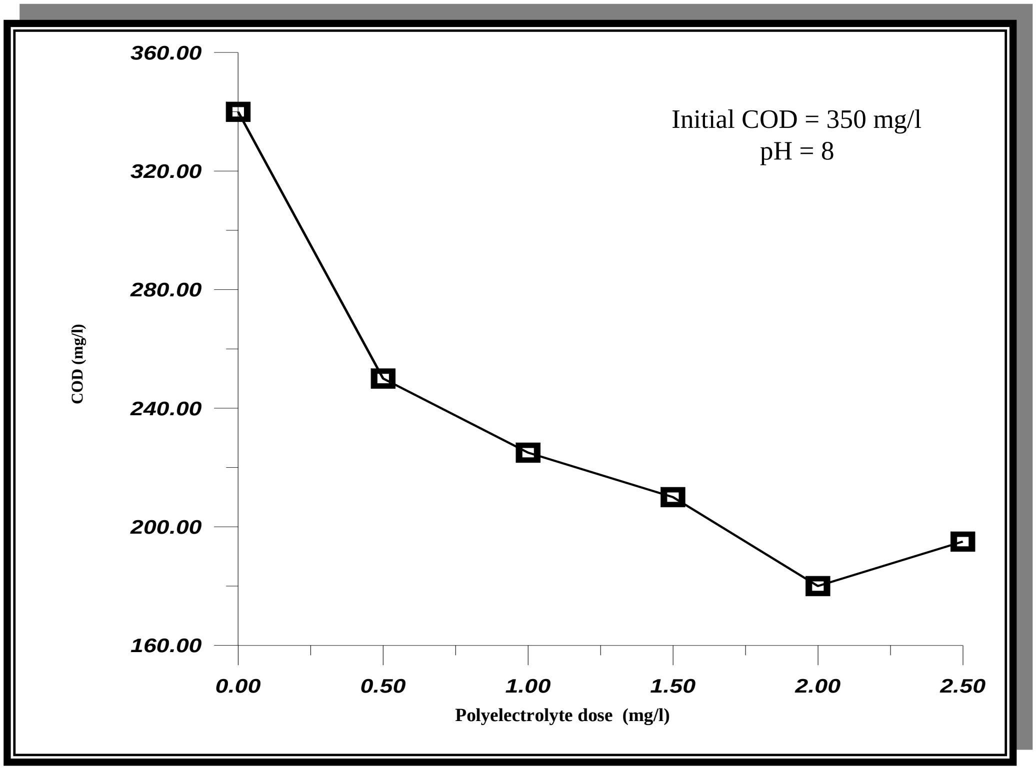

Fig. (5-11): Influence of (0.5 – 2.5mg/l)of polyelectrolyte concentration and addition of (100mg/l) alum on COD of treated water

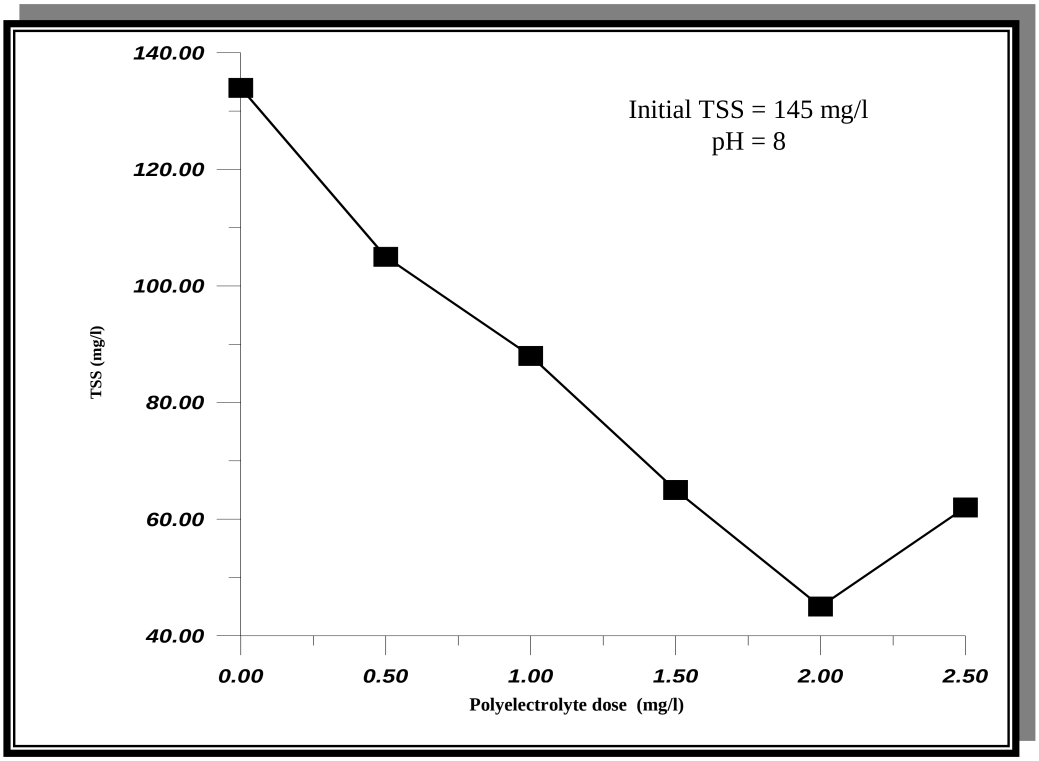

Fig. (5-12): Influence of (0.5 – 2.5mg/l) of polyelectrolyte concentration and addition of(100mg/l) alum on TSS of treated water

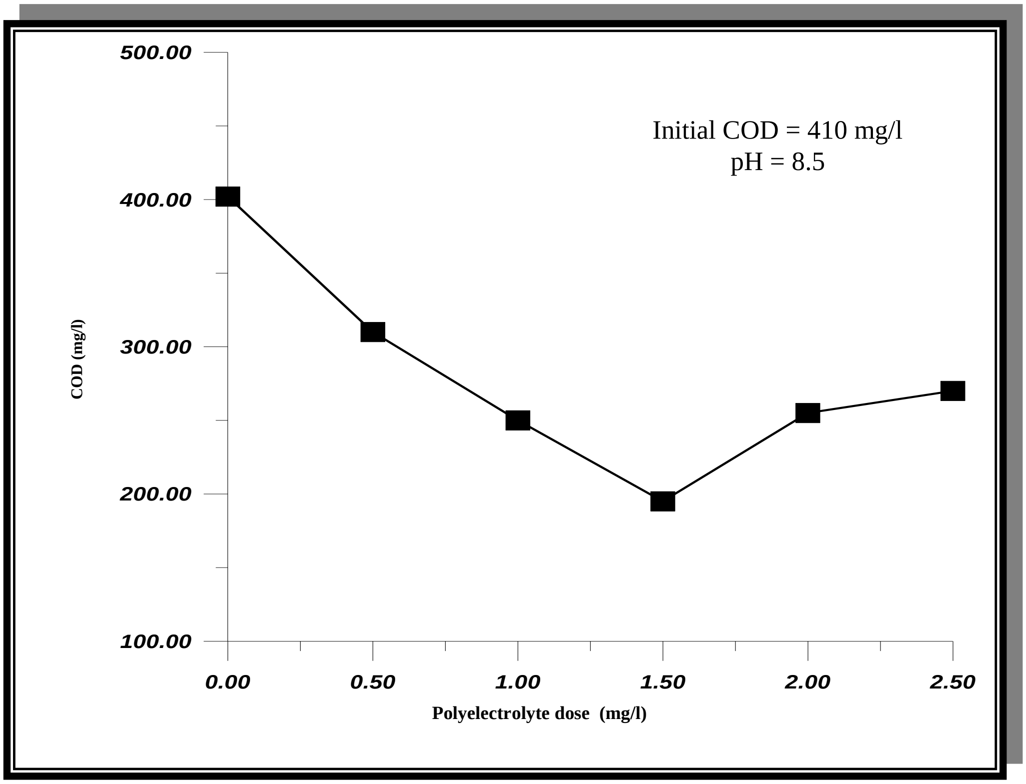

Fig. (5-13): Influence of (0.5 – 2.5mg/l) of polyelectrolyte concentration and addition of (250mg/l) alum on COD of treated water

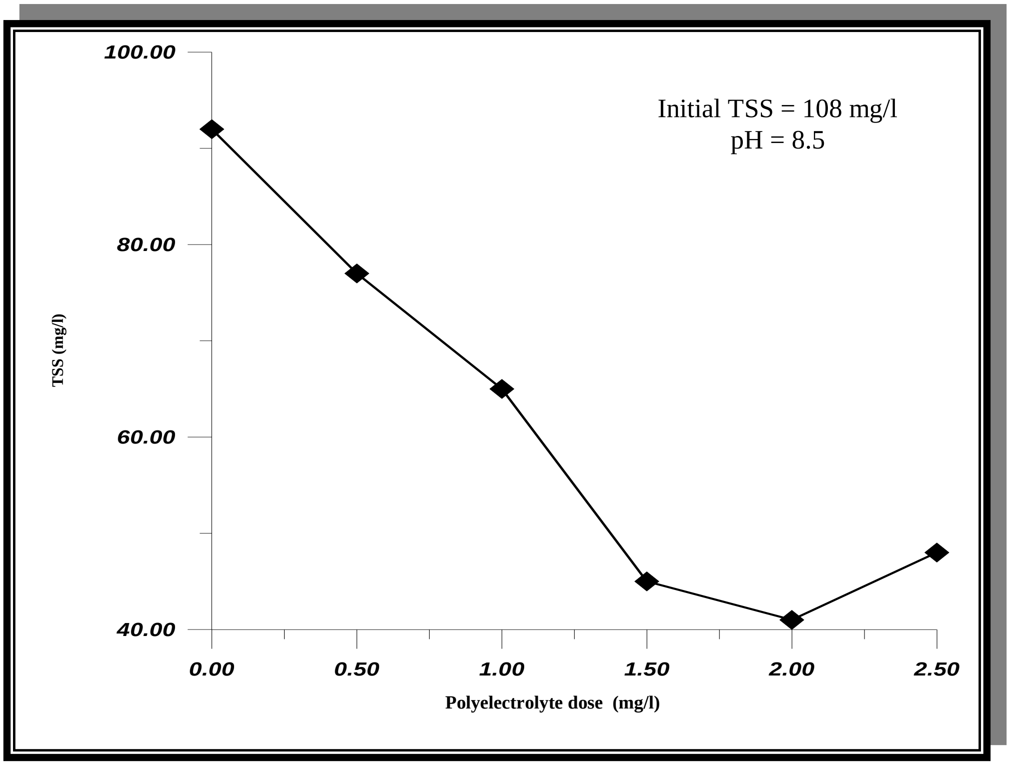

Fig. (5-14): Influence of (0.5 – 2.5mg/l) of polyelectrolyte concentration and addition of (250mg/l) alum on TSS of treated water

5.1.2: Activated carbon adsorption

The jar-test experiments were used to determine the optimum doses of activated carbon (PAC). The PAC is of the quality traditionally available in the market (which is of unique quality). The amount of carbon used may vary from (5 to30 mg/l) depending upon the quality of the water to be treated and the results expected **(Ismail, 1996).** Four samples were taken from the primary mixing tank. For these samples colors and suspended solids concentrations were determined before and after the addition of powdered activated carbon. Each sample after the activated carbon addition is filtered on cellulose acetate membrane.

Figures (5.15) and (5.16) show that the best results (98% color removal and 73% TSS removal) are obtained at doses of (250 mg/l) of alum (1.5 mg/l) of polyelectrolyte and (25mg/l) of PAC with an initial color of (145mg/l) reduced to (8 mg/l) and TSS of (100 mg/l) reduced to (27mg/l) at (pH =8.5).

Figures (5.17) and (5.18) show that the best results (95% color removal and 74% TSS removal) are obtained at doses of (250 mg/l) of alum, (1.5mg/l) of polyelectrolyte and (2omg/l) of PAC with an initial color of (102mg/l) reduced to (5mg/l) and TSS of (73 mg/l) reduced to (19mg/l) at (pH =8.5).

Figures (5.19) and (5.20) show that the best results (92% color removal and 78% TSS removal) are obtained at doses of (250 mg/l) of alum, (1.5 mg/l) of polyelectrolyte and (25mg/l) of PAC with an initial color of (86mg/l) reduced to (7mg/l) and TSS of (230 mg/l) reduced to (51mg/l) at (pH =8.5).

Figures (5.21) and (5.22) show that the best results (89% color removal and 79% TSS removal) are obtained at doses of (250 mg/l) of alum, (1.5mg/l) of polyelectrolyte and (20mg/l) of PAC with an initial color of (74mg/l) reduced to (8mg/l) and TSS of (57 mg/l) reduced to (12mg/l) at (pH =8.5).

All the aforementioned figures show clearly that the optimum dose of (PAC) is (20mg/l). The removal efficiency by optimum doses of (PAC) is (89-95%) color and (70-79%) TSS.

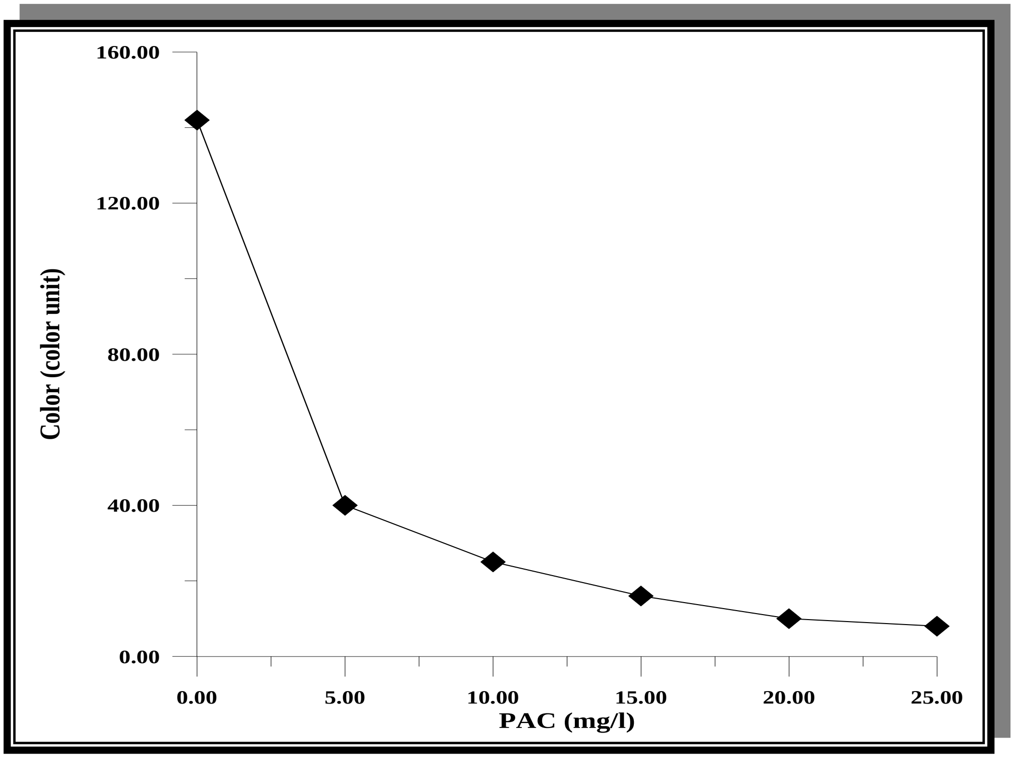

Fig. (5-15): Influence of PAC concentration on color of treated water (with initial color = 145 unit)

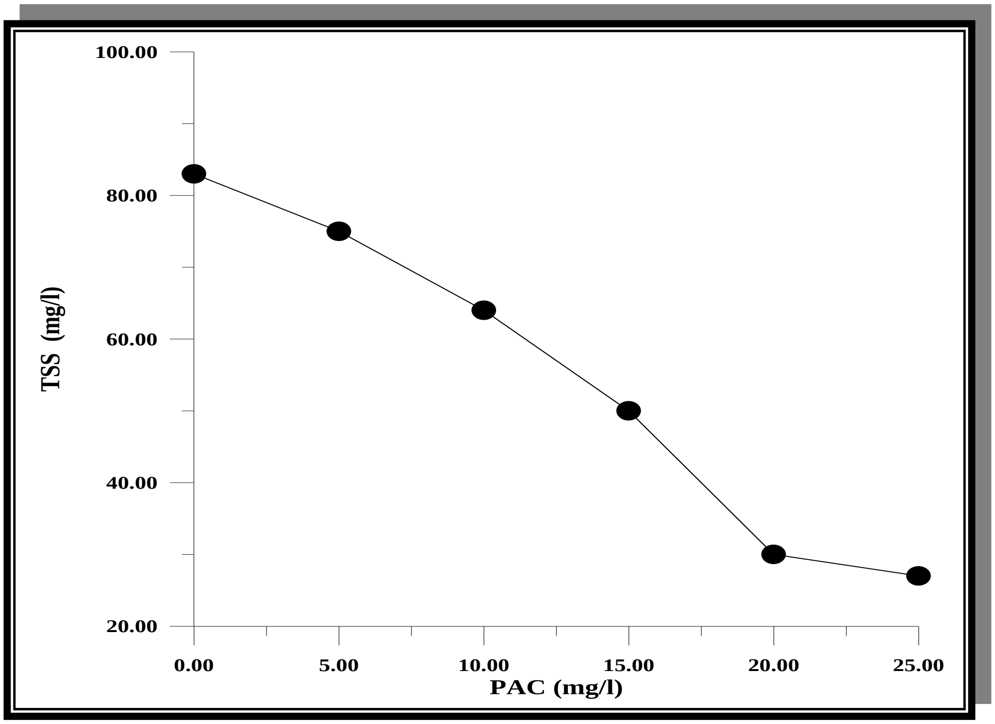

Fig. (5-16): Influence of PAC concentration on TSS of treated water (with initial TSS = 100 mg/l)

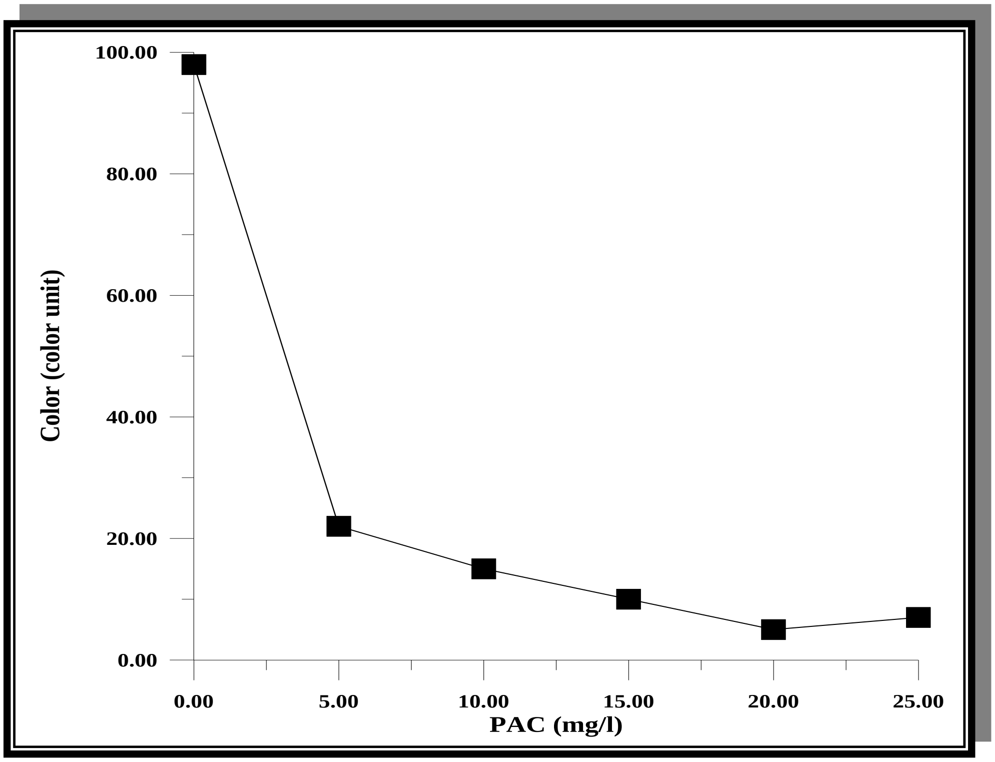

Fig. (5-17): Influence of PAC concentration on color of treated water (with initial color = 102 unit)

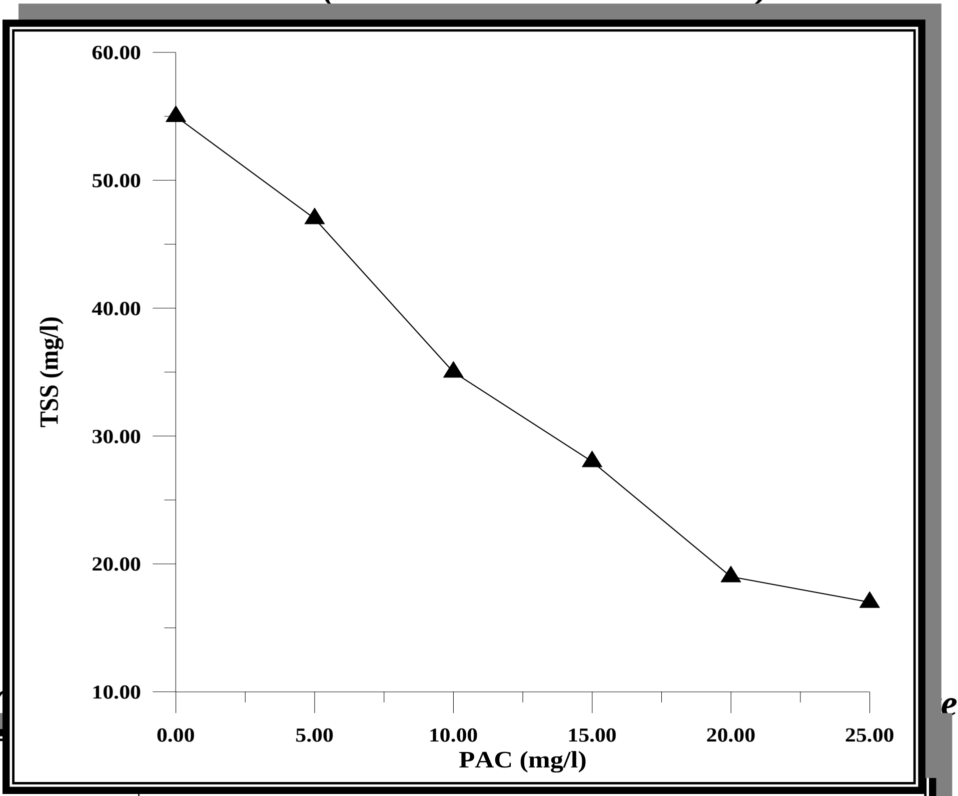

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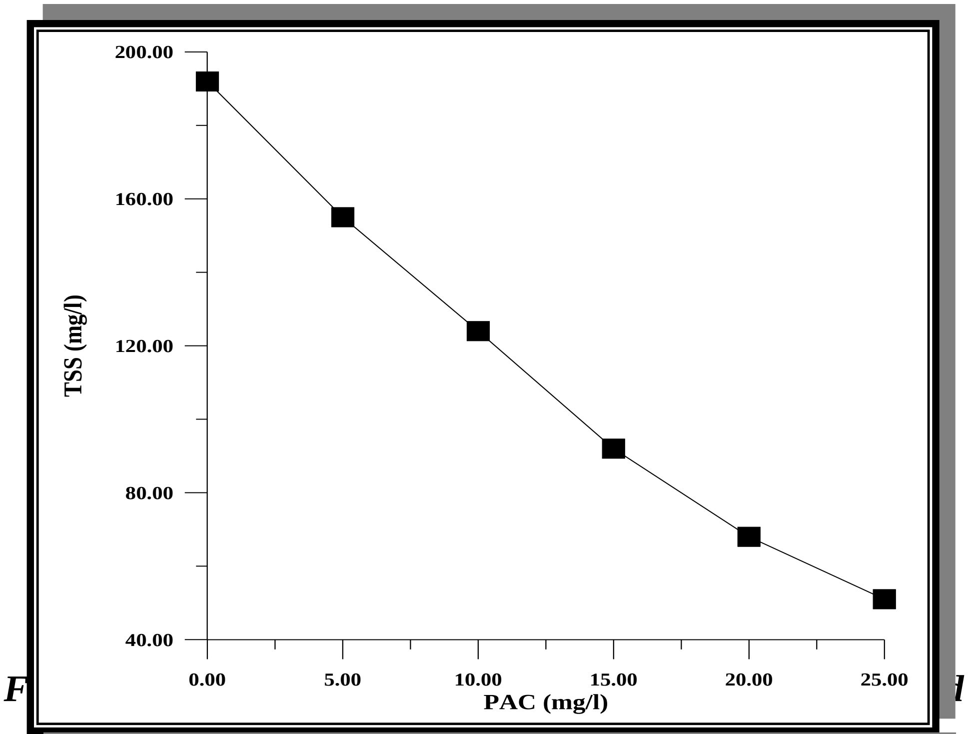
Fig. (5-19): Influence of PAC concentration on color of treated water (with initial color = 86 unit)



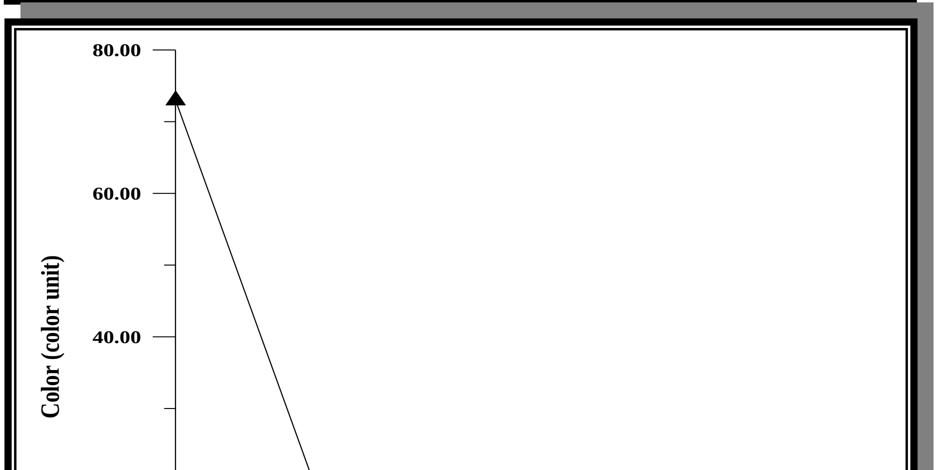


Fig. (5-21): Influence of PAC concentration on color of treated water (with initial color = 74 unit)

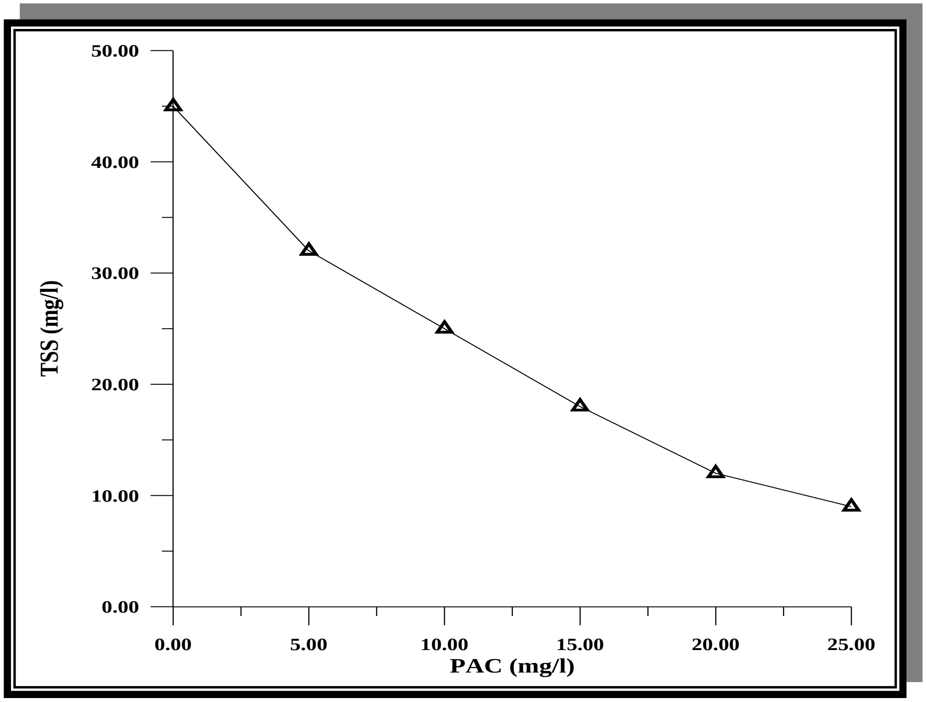


Fig. (5-22): Influence of PAC concentration on T.S.S of treated water (with initial TSS = 57 mg/l)

5.2: APPLICATION OF THE FREUNDLICH ISOTHERM EQUATION

The isotherm equation is an attempt to prove that the adsorption process by activated carbon is a linear relationship. Two samples were taken from the primary mixing tank for this purpose. According to **(Brault, 1991)**, the principal steps in establishing an isotherm curve are:

1. Measuring the initial concentration (Co) expressed in (mg/l).

2. Increasing dosages of carbon between (0-50mg/l) into the (6) jars, where each jar contains (1liter) of water sample.

3. Drying the carbon for (4 h) at (120) C° in a crucible.

4. After one hour of moderate stirring (30 to 40 rpm) at constant temperature, each sample is filtered on a cellulose acetate membrane.

5. Testing (1000ml) to determine the pollutant concentration remaining in the (6) jars.

6. Drawing the isotherm curve in log- log coordinates; the equilibrium concentration (C) expressed in (mg/l) on the X-axis and the pollutant weight (mg/g) of carbon (X/M) on the Y-axis and find (1/n) from the curve and (K) from equation of the isotherm curve.

The equation of isotherm curve, Eq. (3.4), in log-log would be:

$$\mathbf{Ln\,(X/M) = Ln\,(K) + 1/n\,Ln(C)} \qquad \mathbf{[5\text{-}1]}$$

The two samples were tested for the aimed goal. The basic data are given in Table (5-2).

Table (5-2): The data used in plotting the Freundlich isotherm equation

Sample No.1				
M (mg/l)	**Co**	**C**	**X = Co – C**	**X/M (l/mg)**
10	**109**	**55**	**54**	**5.4**
20	**109**	**40**	**69**	**3.45**

30	**109**	**31**	**78**	**2.5**
40	**109**	**27**	**82**	**2.05**
50	**109**	**22**	**87**	**1.72**
Sample No.2				
M (mg/l)	**Co**	**C**	**X = Co – C**	**X/M (l/mg)**
10	**210**	**125**	**85**	**8.5**
20	**210**	**85**	**125**	**6.25**
30	**210**	**60**	**150**	**5**
40	**210**	**45**	**165**	**4.13**
50	**210**	**35**	**175**	**3.5**

Figures (5-23) and (5-24) show the Freundlich isotherm plot. A clear linear relationship is apparent as (X/M= a+bC) with given as:

Fig. (5.23): a= 9.2172625; b= 8.5921751, r=0.99784855 and S=0.96414442

Fig. (5.24): a=-29.665063; b= 18.20034, r=0.99963427 and S =1.12588972.

Fig. (5-23) indicates (n=0.78) or (K=0.028) and Fig (5-24) indicates (n=1.45) or (K=0.298).

* a ,b= constant r = correlation coff. S= standard err.

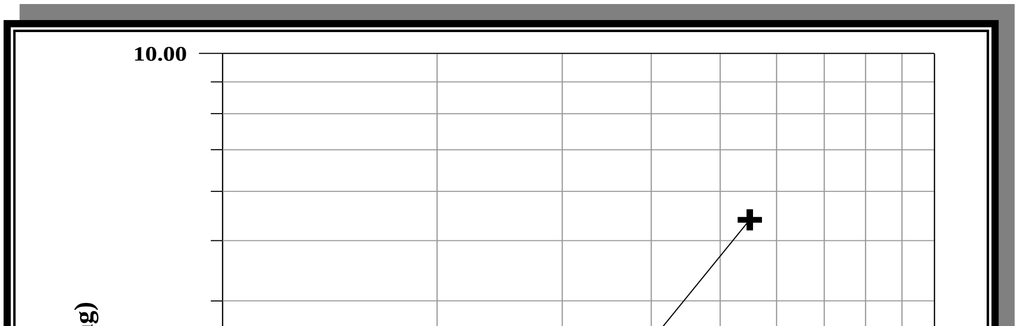


Fig. (5-23): Freundlich isotherm plot for test No.1, PAC adsorption of color

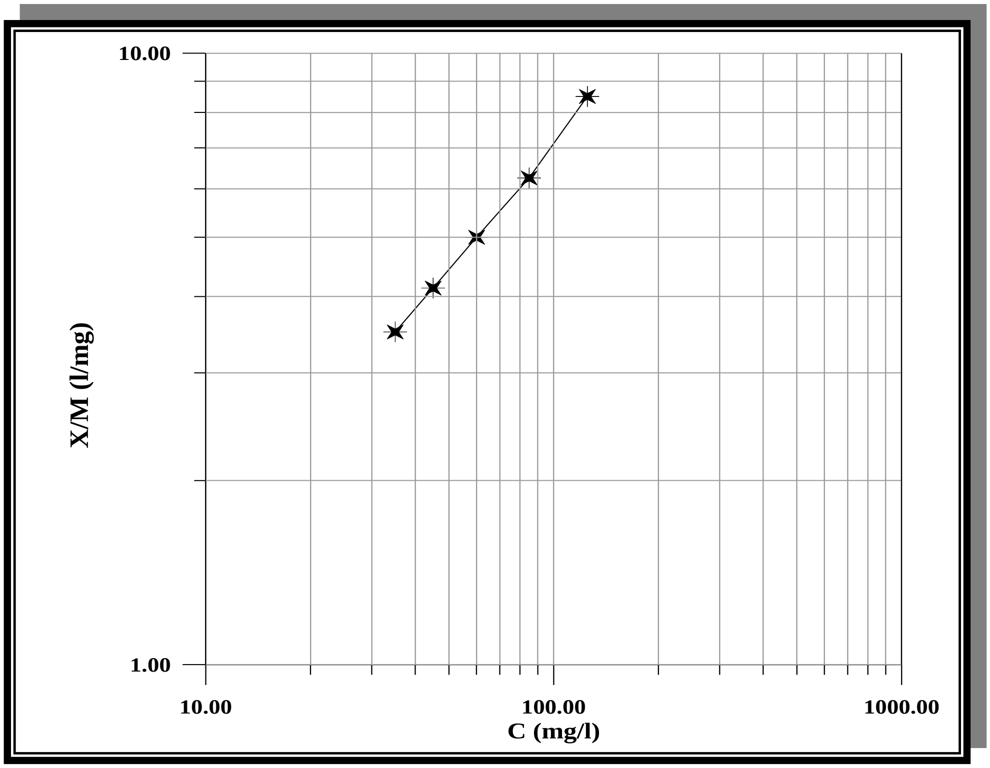


Fig. (5-24): Freundlich isotherm plot for test No.2, PAC adsorption of color

5.3: THE EFFECT OF THE OPTIMUM DOSAGES OF (ALUM+POLYELECTROLYTE+PAC) ON INDUSTRIAL WASTEWATER TREATMENT.

To delineate the effects of the optimum dosages of (alum + polyelectrolyte +PAC) at (pH=8.5) in the treatment of industrial wastewater as compared with the specification given by (AICE and EPA), five samples were taken from the primary mixing tank. The samples were tested for color, pH, TSS, COD and BOD_5 according to (AWWA, 1985). The results of the tests are given in Table (5-3). The results indicate that the efficiency of color removal is between (83-96%) which is within the (AICE and EPA) specification limits on the removal efficiency of color, that is (80-98%). The difference in the percentage removal efficiency is due to the different types of dyes used.

It is also observed that the removal efficiency of TSS of (73-80%) is within the (AICE and EPA) specification, which is (60-90%).

Furthermore, it is observed that the removal efficiency of both (BOD and COD) are between (69-84.4%) and (73-85%) respectively. These figures are well within the (AICE and EPA) specification, which call for an efficiency of (60-95%).

Table (5-3): Effects of the optimum doses of (Alum+polyelectrolyte+PAC) on treated industrial wastewater

Sample No.1					
Tests	**Color (unit)**	**PH**	**TSS (mg/l)**	**COD (mg/l)**	**BOD_5 (mg/l)**
Before addition	**90**	**8.5**	**45**	**285**	**85**

After addition	**4**	**7.4**	**12**	**44**	**25**
Removal efficiency	**96%**		**73.4%**	**85%**	**71%**
Sample No. 2					
Tests	**Color (unit)**	**PH**	**TSS (mg/l)**	**COD (mg/l)**	**BOD_5 (mg/l)**
Before addition	**110**	**8.5**	**102**	**110**	**55**
After addition	**15**	**7.65**	**20**	**18**	**15**
Removal efficiency	**86.4%**		**80%**	**78%**	**72%**
Sample No. 3					
Tests	**Color (unit)**	**PH**	**TSS (mg/l)**	**COD (mg/l)**	**BOD_5 (mg/l)**
Before addition	**55**	**8.5**	**95**	**135**	**66**
After addition	**6**	**7.75**	**22**	**25**	**10.3**
Removal efficiency	**89%**		**77%**	**82%**	**84.4%**
Sample No. 4					
Tests	**Color (unit)**	**PH**	**TSS (mg/l)**	**COD (mg/l)**	**BOD_5 (mg/l)**
Before addition	**210**	**8.5**	**130**	**210**	**103**
After addition	**15**	**7.5**	**35**	**40**	**28**
Removal efficiency	**92%**		**73%**	**81%**	**73%**
Sample No. 5					
Tests	**Color (unit)**	**PH**	**TSS (mg/l)**	**COD (mg/l)**	**BOD_5 (mg/l)**
Before addition	**98**	**8.5**	**98**	**85**	**32**
After addition	**17**	**8**	**22**	**23**	**10**
Removal efficiency	**83%**		**78%**	**73%**	**69%**

5.4: SUGGESTED TREATMENT SCHEME

Based on the results obtained so far and on the physical limitations of the site, the following diagram given in Fig.(5.25) summarizes the suggested treatment scheme. This scheme is expected to result in an effluent with the following average values:

Color = 11.5 units.

pH = (7.4-8),

TSS =22 mg/l,

COD = 30 mg/l

BOD_5 =17.66 mg/l,

It is to be noted that these figures are well within the Iraqi and American standards on industrial effluent discharges.

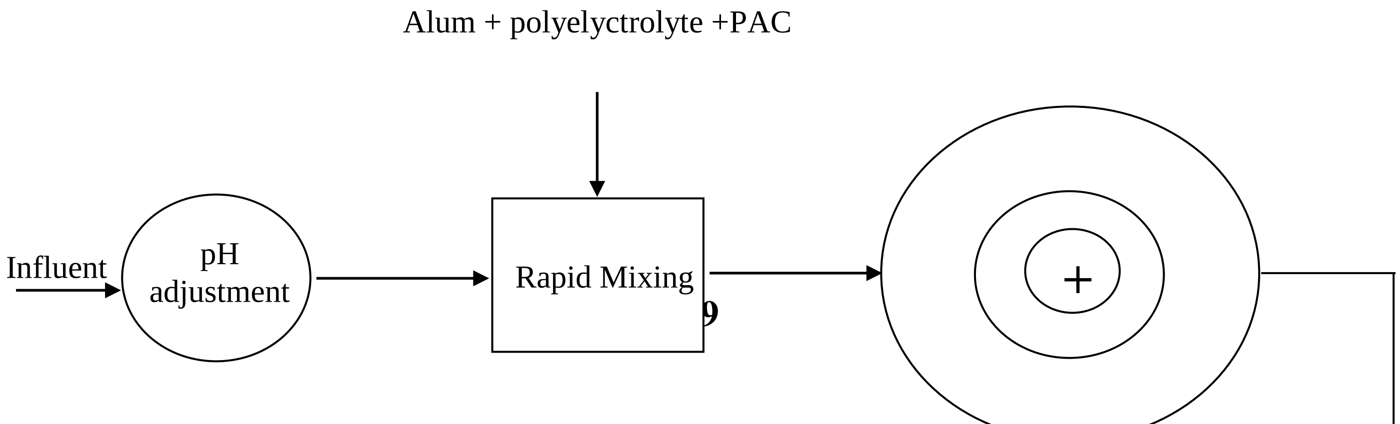


Fig. (5.25): Schematic illustration of the suggested treatment

Chapter Six 6

CONCLUSIONS AND RECOMMENDATIONS

6.1: CONCLUSIONS

Based on the obtained results, the following are the most important conclusions that are abstracted:

1. The existing wastewater treatment plant is not working efficiently. The removal efficiencies of the respective quality parameters were:

TSS = 27-73 %.
BOD = 17-57 %.
COD = 20-54 %.

2. The applied physio-chemical treatment which involved neutralization, addition of alum and polyelectrolyte achieved a (COD) removal efficiency of around (50%). The optimal values of the parameters are: (pH=8.5), (Alum $Al_2(SO)_4$= 250 mg/l), and (polyelectrolytes = 1.5–2 mg/l). The quality of the effluent water is still not good enough to be reused in the industry.

3. The optimum treatment method was achieved when using (250mg/l alum + 1.5mg/l polyelectrolyte + 20 mg/l PAC). This gave the following removal efficiencies:

Color = 83-96%.

TSS = 73-80%.

COD = 73-85%.

$BOD_{5.}$ = 69-84.4%.

4. It was found that the quality of the water is not good enough to be reused in the industry but could be reused for in–plant washing of machines, agriculture, cooling and general cleaning.

6.2: RECOMMENDATIONS

The following are recommended for future studies:

1. Studying the use of two (primary and final) sedimentation tanks instead of one sedimentation tank to remove more suspended solid organic materials.

2. Studying the feasibility of adding a centrifuge system to the treatment plant (mechanical dewatering of the sludge).

3. Using membrane technologies with two different plants of Ultrafiltration (UF) and Nanofiltration (NF) to remove fine suspended solids.

4. Studying the feasibility of using a layer of (granular activated carbon (GAC)) instead of using the (powdered activated carbon (PAC)) in the basic adsorption process in the treatments.

5. Investigation the problem of heavy metals in the effluent.

6. Performing an optimization to attain the best pH, alum, polyelectrolyte and activated carbon dose.

Chapter Four

4

The case study

4.1:GENERAL

The Hilla textile factories of (the State Company for Textile Industries) have been taken as the case study. The factories complex is located in the southern part of Hilla City and within its municipal limits.

The complex was established in (15/ 10 / 1967). The factories complex produces the following fabrics :

1. Cotton fabric and blending.
2. Velvet and jquard fabric.
3. Synthetic fabric for special uses as (blanket base).

In 1980, a new section (factory), namely, the (velvet and jquard section) has been established. The present basic industrial functions are:

1. The spinning section
2. The preparation section.
3. The textile or weaving section.
4. The finishing section.
5. The velvet and jquard section.

The complex constitutes several productive, technical, and administrative sections. Those that have relations to the quality, use, and consumption of water, and consequently to the subject of this research, are briefly discussed herein after.

4.2: WATER SUPPLY AND DISTRIBUTION

The total daily water consumption in Hilla Complex is nearly (3500m^3/day). Of this, about (1500 m^3/day) soft water is used for industrial purposes, and the remainder is drinking and sanitary services, as shown in Fig. (4.1). The soft water (influent) and industrial wastewater (effluent) are summarized in Table (4.1) and (4.2), respectively.

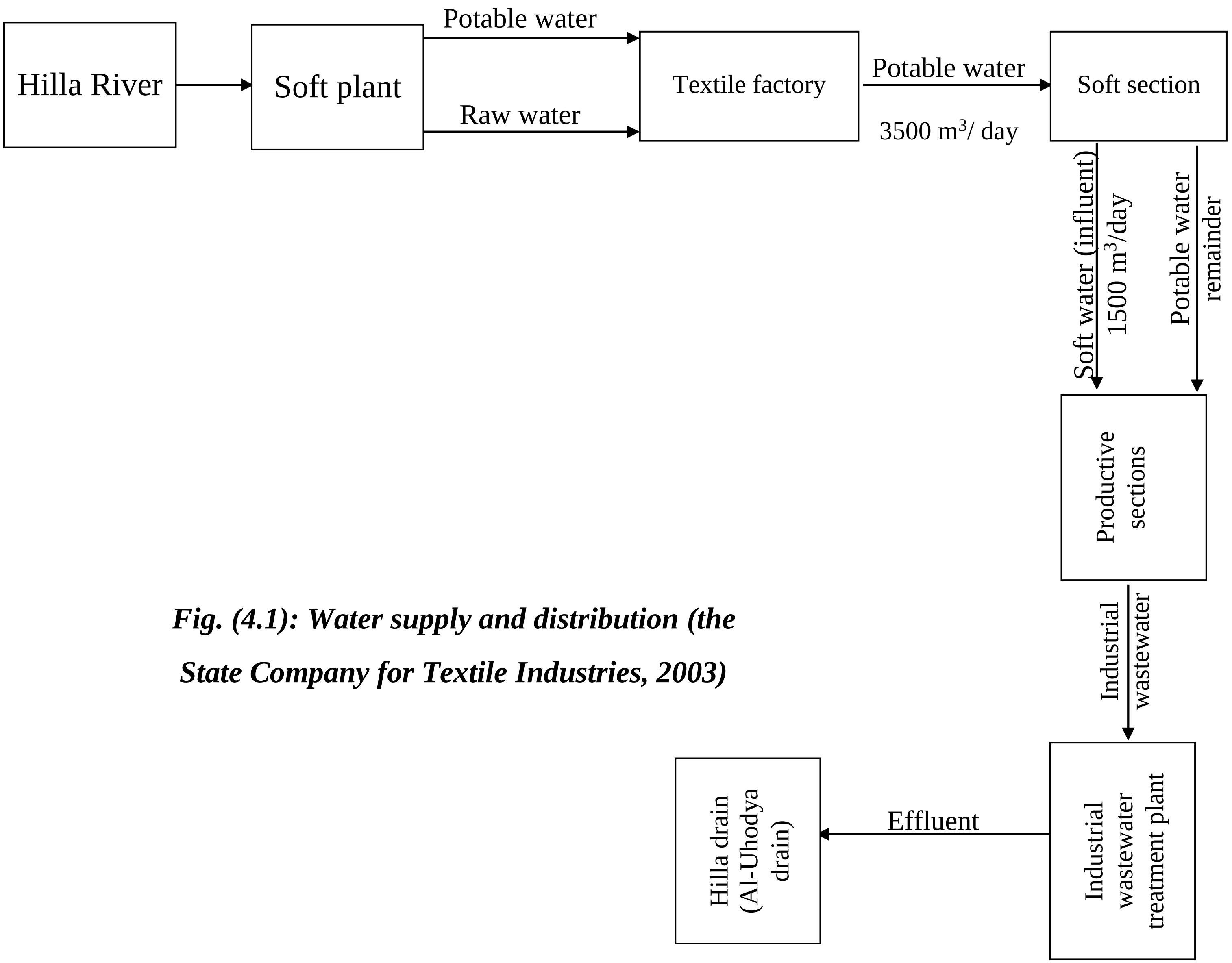


Fig. (4.1): Water supply and distribution (the State Company for Textile Industries, 2003)

Table (4-1): The standard influent limits of soft water in textile industry (the State Company for Textile Industries, 2003)

Parameter	Limits
pH	7.5-8.5
CL^-	600 mg/l
SO_4	400 mg/l
Hardness	(0-1mg/l)
Conductivity	(1000-1500 ms/cm)
T.D.S	(500-1000 mg/l)

Table (4-2): The standard effluent limits of industrial water in textile industry (the State Company for Textile Industries, 2003)

Parameter	**Limits**
PH	6-9.5
CL^-	600 mg/l
SO_4	400 mg/l
T.S.S	60 mg/l
BOD	40 mg/l
COD	100 mg/l

4.3:THE PRODUCTIVE SECTIONS

4.3.1: Finishing section (Factory No 1)

This section is the one that uses the largest quantity of water among other sections, which represent about (55%), of the water used in production. Moreover, it is the one produces the most polluted effluent.

The process constitutes the following sub-processes

1.Scouring and Bleaching

Scouring with hot alkali removes the natural waxes and pectins from the cotton together with spinning oils. Bleaching with hydrogen peroxide or hypochlorite is used to whiten the fabric. Many chemicals used in this stage, such as, 50% H_2O_2 ,NaOH and caustic soda as well as sodium silicate.Stream is used to raise the temperature and increase moisture.

2.Dyeing and printing

Cloth is colored to customers requirements by either dyeing or printing. Final finishing in the form of easy care or handle finish is often carried out prior to the sale of the cloth. Chemical materials are used in different doses. Different kinds of colors such (direct, disperse and reactive) as and fixtures are used.

The pollutants produced in this section are as follows.

(a) Colors are caused by dyeing colors, which come in different kinds.

(b) Suspended solid (T.S.S).

It is product of washing and cleaning and suspension materials. As pollutants to the waters of washing and cleaning.

(c) Oil and grease.

They are produced because of the use of oil in industrial operations. Grease is used in maintenance of machines. It is used continually.

(d) High value for alkalinity and pH.

It is the result of using chemical material like sodium hydroxide, which is used in large amount in the industrial processes.

(e) High rate of organic materials.

It is the result of removing the starch and of organic colors used. These materials cause an extra demand of biochemical oxygen demand (BOD_5).

(f) Small amounts of chlorides and sulfates.

It is the result of using some materials that contain chloride ion and sulfates like sodium chloride and different colors with sulfates.

(g) Large amounts of soaps, bleach and detergents.

They are used too much in this section before and after the processes of dyeing and in the processes of coloring.

From all of the above, it can be stated that the problem of pollutants are the product of the industrial wastewaters in the textile factory.

4.3.2: Velvet and Jquard section (Factory No 2)

This section contains three units

1. preparations: No industrial water is contributed
2. Textile :No industrial water is contributed
3. Processing: It forms the principal part of the industrial waters in the labour section. As for pollution, this section uses industrial waters in the amount of (60 m^3/day). Its pollution is less than the processing section (factory No1).

Pollution is the result of using alkaline colors and chemical materials as used in the bleaching processes; (H_2O_2) and (NaOH) are used with (pH) equals (9).

4.4: THE INDUSTRIAL WATER TREATMENT PLANT

The industrial wastewater that is produced from the productive sections is collected through a pipe network that ends to a special treatment plant. The treatment plant comprises the following basic units: The primary mixing tank, the sedimentation tank, the biological treatment tank, filters, the final sedimentation tank, and the final mixing tank, as shown in Fig. (4-1). Abrief discussion of each unit is given hereinafter.

4.4.1: The primary mixing tank

This tank is the first stage of the treatment. The process of receiving industrial water here may be considered as an equalization process. The tank has a square cross-section with (4m) length, (2m) width and (2m) depth as show in Fig. (4.3). Water entering this tank contains salts, dyes, grease and other suspended and dissolved organic materials. The tank is preceded by screens manhole. Grease, fats and oil are partially removed in this tank.

The wastewater is with draw from this tank a set of submersible pumps to the primary sedimentation tank.

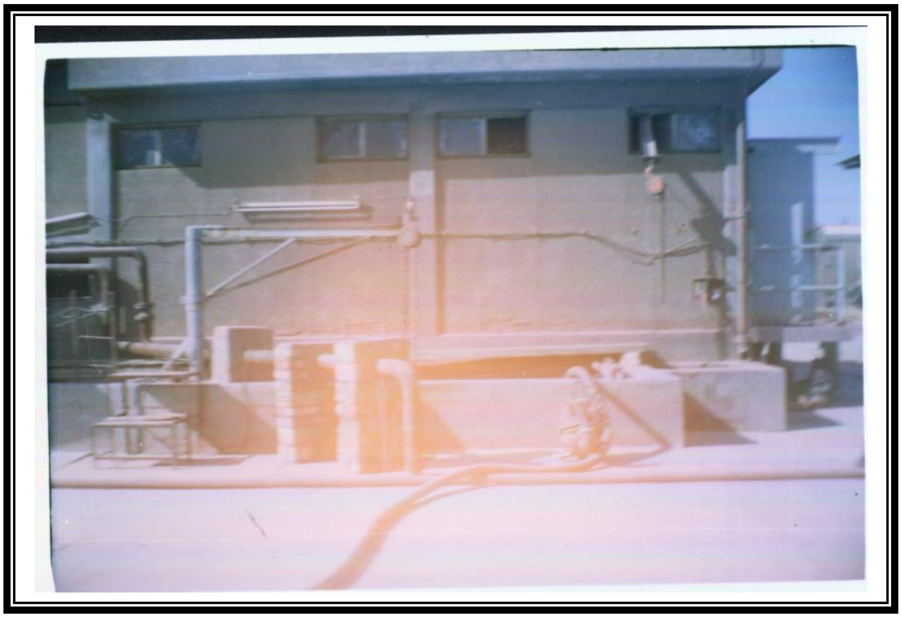


Fig. (4.3): The primary mixing tank

4.4.2: The primary sedimentation tank

This is circular tank, its diameter is about (25m) and its depth is nearly (1.6m) as show in Fig. (4.4). The capacity is about (700 m^3). Its is used as a sedimentation tank. This tank is equiped with a revolving bridge with a scraper mechanism at the bottom that removes sludge from the lower part of the tank. Sludge is pumped from there to sludge drying beds. Water then flows by gravity to the chemical treatment tanks.

Fig. (4-4): The primary sedimentation tank

4.4.3: Chemical treatment tanks

They are five tanks. (Alum +Lime) is added in these tanks. Each tank has a square cross-section with (2x2x2.5m). Residual grease is removed here. (20%) of the flow is then sent to the biological treatment units, while the rest is sent to directly to the final sedimentation tank. Fig. (4.4) shows a plate photograph of the chemical treatment tanks.

Fig. (4-5): The chemical treatment tanks

4.4.4: The biological treatment tank

The tank has an oval- circular shape. Its capacity is (200-250 m^3). Mechanical brushes are used in aerating the wastewater in this tank. Fig. (4.5) shows a plate photograph of the biological treatment tank.

Fig. (4.6): The biological treatment

4.4.5: The Final sedimentation tank

The tank is (20m) length, (9.5m) width and depth between (1 to 3.5m) as shown in Fig. (4.7). The tank is equiped with a revolving bridge with a scraper mechanism. Sludge is pumped from this tank to the sludge drying beds.

Fig. (4.7): The final sedimentation tank

4.4.6: Filters

There are filters, (2) of which are used to dry the primary sludge, while the other three are used to filter the combined effluent from the final sedimentation. The dimension of each filter is (20*10*1.5m). A cross-section through a filter has a layer of (35 cm) of red sand resting on a layer gravel of (35cm) has a size of (5-18mm) .At the bottom, a final layer of gravel of (20cm) in height is placed on a drainage system of perforated pipes. The gravel of this layer has a size of (18-50mm). The drainage water from these filters is pumped by (3) pumps to the Hilla drain (AL-Uhodya drainage canal). Figs (4.8), (4.9) show plates photograph of the sand filters and the sludge drying bed, respectively.

Fig. (4.8): The Sand filter

Fig. (4.9): The sludge filter

4.4.7: The final mixing tank

The tank is of (4m) length, (8m) width and (6.5 m) in depth. Final disposal of industrial wastewater effluent is pumped from this tank to the Hilla drain canal. Fig. (4.10) shows plates photograph of the final mixing tank.

Fig. (4.9): Finally mixing tank

4.5: EVALUATION OF PERFORMANCE INDUSTRIAL WATER TREATMENT PLANT IN HILLA

Many samples were taken from both (primary and finally mixing tanks) in order to determine the efficiency of the industrial water treatment plant. Table (4.3) shows the characteristic of the industrial wastewater before and after the treatments.

Table (4-3): The product of industrial water for Hilla – textile factory before and after the treatment

Test no.(1)

The tests	PH	TSS	So_4	BOD_5	COD	Hardness as $CaCo_3$	Alkalinity
		mg/L					
Before treatment	9	149	272	130	250	318	355
After treatment	8	46	252	71	125	245	279
The efficiency		69%		45%	50%		

Test no.(2)

The tests	PH	TSS	So_4	BOD_5	COD	Hardness as $CaCo_3$	Alkalinity
		mg/l					
Before treatment	7.5	210	350	278	320	410	300
After treatment	8.4	110	425	150	252	290	222
The efficiency		47.6%		46%	21.3%		

Test no.(3)

The tests	PH	TSS	So_4	BOD_5	COD	Hardness as $CaCo_3$	Alkalinity
		mg/l					
Before treatment	8	450	333	50	123	220	607
After treatment	9	310	532	33	73	165	310
The efficiency		31%		34%	41%		

Test no.(4)

The tests	PH	TSS	So_4	BOD_5	COD	Hardness as $CaCo_3$	Alkalinity
		mg/l					
Before treatment	9.5	110	280	90	225	222	320
After treatment	10	80	310	75	180	185	279
The efficiency		27%		17%	20%		

Test no.(5)

The tests	PH	TSS	So_4	BOD_5	COD	Hardness as $CaCo_3$	Alkalinity
		mg/l					
Before treatment	9.5	350	290	60	87	232	330
After treatment	8	95	240	26	40	185	292
The efficiency		73%		57%	54%		

List of symbols and abreviations

Symbol	*Definition*
AICE	American Institute of Chemical Engineers
ATMI	American Textile Manufacture Institute
BOD_5	Biochemical oxygen demand at 5days
COD	Chemical oxygen demand
EPA	Environmental Protection Agency
GAC	Granular activated carbon
NCWQ	National Commission on Water Quality
PAC	Powdered activated carbon
pH	Hydrogen number
SS	Suspended solids
TDS	Total dissolved solids
TSS	Total suspended solids

x

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- ***AICE and EPA*** [(American Institute of Chemical Engineers) and (Environmental Protection Agency Technology Transfer).,(1976):"Water reuse".American Institute of Chemical Agency.
- ***AWWA*** (American Water Works Association), (1985):"Standard methods for the examination of water and wastewater"; 16th ed., American Public Health Association, Washington, U.S.A.
- ***AZTEC Environmental control LTD***., (2003):"Sedimentation Jar- tester". Manufacturers of specialist instrumentation and jar equipment; Oxon, UK.
- ***BOND, R.G. and STRAUB, C.P.,*** (1974):"Handbook of environmental control". Vol.4, wastewater, treatment and disposal, CRC press.
- ***BRAULT, J.L.,*** (1991):"Water treatment handbook". 6th ed., Lavoisier Publishing, France.
- ***CALLELY, A.G., FORSTER, C.F., and STAFFORD, D.A.,*** (1977): "Treatment of industrial effluents". London. England.
- ***CULP, R.L., WESNER, G.M., and CULP, G.L***.,(1978):"Handbook of advanced wastewater treatment".Van Nostrand Reinhold, New York. U.S.A.
- ***ECKENFELDER, W.WELSY.,*****(**1970):" Water quality engineering for practicing engineering ".Barnes and Noble , Inc ., New York. U.S.A.
- ***ECKENFELDER, W.W., JR.,*** **(**1989):" Industrial water pollution control". McGraw- Hill publishing company., New York. U.S.A.

📖 ***HART, O.O., GROVES, G.R., BULKLEY, C.A. AND SOUTHWORTH, B.,*** (1983): “Aguide for the planning, design and implementation of wastewater treatment plants in the textile industry”. (Part One: Closed loop treatment) Recycle system for textile sizing /Desizing effluents; ***[INTERNNET: 2003].***

📖 ***HTTP:// WWW.,*** (2001) A pilot study in textile industry ”Waste water recycling and reuse by solar catalytic treatment”., Tunisia..

📖 ***INOUE, KIYOMI***.,(2003):”Textile dyeing wastewater treatment and activated sludge treatment”.kanebo Spring Corporation,No.2; ***[INTERNNET;2003]***.

📖 ***ISMAIL, K.I.,*** (1996):” A study into the use of black alum in treatment water”. MSc. Thesis, Dep. of Building and Constructing Eng., Iraq.

📖 ***JEFFCOAT, W.B. and SINGLEY, J.E.,*** (1975):”The effect of alum concentration and chemical- addition time on coagulation”. J.AWWA, Vol.67, No.4, U.S.A.

📖 ***JORGENSEN, S.E.,*** (1979):” Industrial waste water management”. Elsevier Scientific Publishing Company, New York.

📖 ***KAWAMURA, S.,*** (1976):”Consideration on improving flocculation". J.AWWA, Vol.68, No .6,U.S.A.

📖 ***Al-HASHMI, M.A. and Al-KIZWINI, S.S.,*** (1999):”The evaluation of industrial waste treatment that disposal from Hilla-fine textile factory to the Shatt Al-Hilla”. Journal of Babylon University., Vol.7,No.3,Iraq.

📖 ***Al-LAYLA, M.A., AHMED, S., AND MIDDLEBROOKS, E.J.,*** (1980):”Handbook of wastewater collection and treatment: Principles and practice ". Garland Publishing, Inc., New York.

📖 ***LLAH, W.E.R.***,(2002):“Astudy of treatment and recycling of industrial wastewater disposed from Baghdad textile factory”. MSc. Thesis, Dep. of Building and Constructing Eng., Iraq.

- ***MIHELCIC, J.R. and HAND, D.W.,*** (1999):”Water supply and treatment”. John Wiley, New York, U.S.A.; ***[INTERNNET; 2002].***
- ***MONTGOMERY, J.M., INC.,*** (1985):”Water treatment principles and design”. John Wiley and Sons, New York.
- **PEAVY, H.S., ROWE, D.R., AND TCHOBANOGLOUS, G.,** (1986):”Environmental engineering “. McGraw-Hill Book company.
- ***PEIRCE, J.J., WEINER, R F., AND VESILIND, P.A.,*** (1998) “ Environmental pollution and control ”. 4th edition. Butterworth – Heinemann, U.S.A.
- ***PETERS, R.H.,*** (1967):”Textile Chemistry”. Elsevier Publishing Company, New York.
- ***QASIM, S.R., MOTLY, E.M., and ZHU, G.,*** (2000):”Water works engineering”. Prentice-Hall, Inc., U.S.A.
- ***RUDOLFS, WILLEM.,*** (1953) ”Industrial wastes, their disposal and treatment “. Reinhold publishing corporation.,New York.
- ***SCTI*** (the State Company of Textile Industries)., (2003) { Personal connections}.
- ***SMETHURST, G.***, (1997):”Basic water treatment for application world wide “; 2th ed., Thomas-Telford, London.
- ***Al-TUFAILY, M.A.***,(1995):”The characteristic of the liquid industrial waste that disposal from Hilla-fine textile factory to the Shatt Al-Hilla”. M.Sc. Thesis, College of Engineering, University of Babylon, Iraq, {In Arabic}.

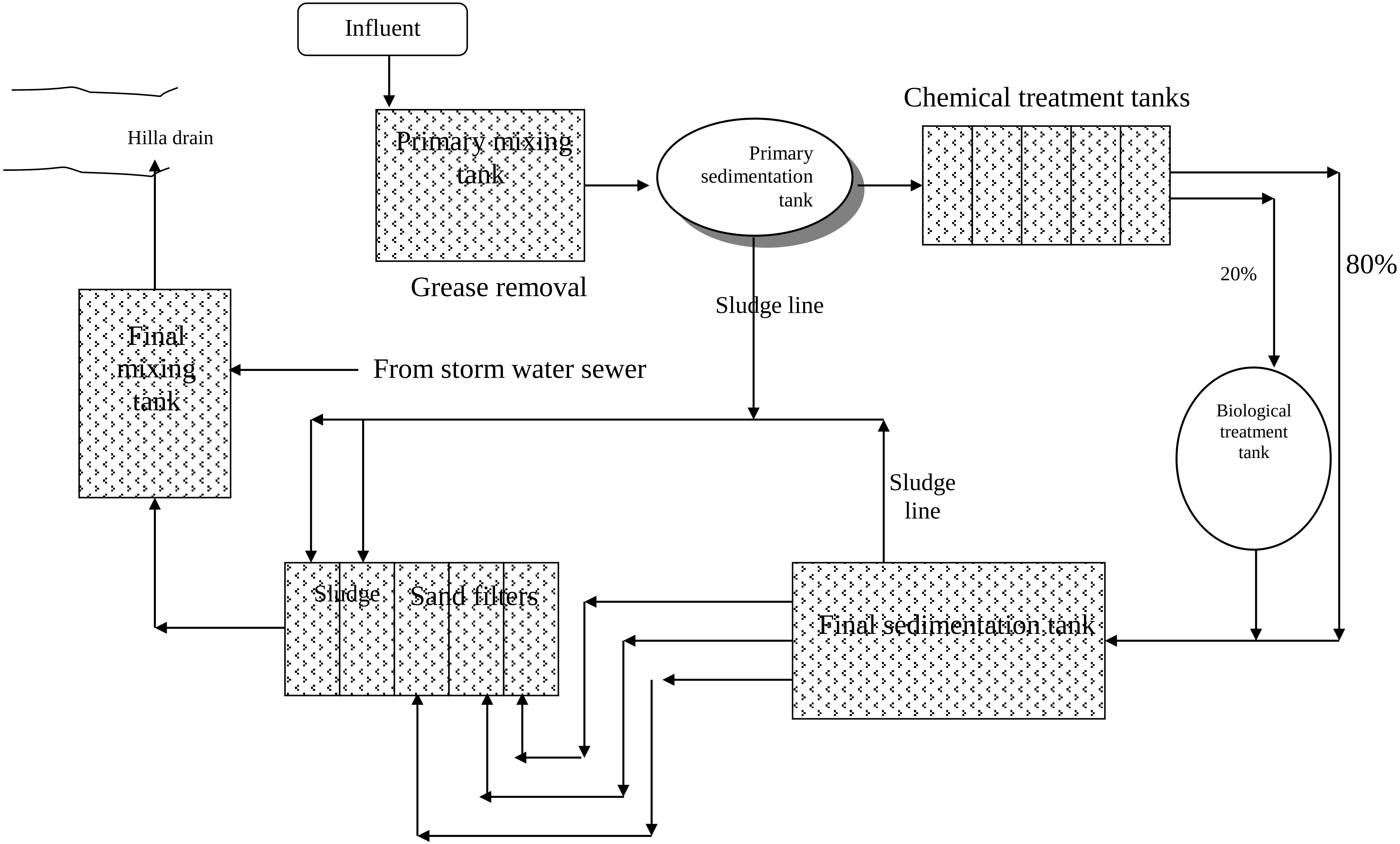

Fig. (4-2): Industrial water treatment plant unit of the Hilla textile factory