

**Republic of Iraq
Ministry of Higher Education
University of Technology
Building and Construction Dept.**



Select the Best Effect of Coagulate for Removal Nitrite and Nitrate in Row Water

**A project
Submitted as a partial Fulfillment of the
Requirements for
The Degree of (B.S.C) in civil Engineering**

By:

Ahmed Nasser

SUPERVISED BY:

Leacture. Ghydaa Yassen

2011

الاهداء

الى مثلي الاعلى...الوالد العزيز

الى القلب الذي حمل عني الهموماحب الناس الام

الحنون

الى ثاني اثنين لايشبعان :طالب مال وطالب علم

نهدي بحثنا المتواضع هذا

الطالب احمد ناصر

بسم الله الرحمن الرحيم

شكر و تقدير

نتقدم بالشكر الجزيل الى رئاسة قسم البناء و
الانشاءاتو الى الست (م. غيداء) للجهود التي
بذلها لإنجاز هذا المشروع و نشكر اساتذه القسم كافة
لمساهماتهم في اصالنا الى هذا المستوى العلمي ... و
الى جميع العاملين في مختبر الهندسه الصحيه للجهود
التي بذلوها في انجاز هذا البحث ..

احمد ناصر



جمهورية العراق
وزارة التعليم العالي
الجامعة التكنولوجية
قسم البناء و الانشاءات
فرع الهندسة الصحية و البيئية

اختيار تأثير افضل مخثر في ازاله النترات و النتريت من ماء النهر

مشروع مقدم الى قسم هندسة البناء و الانشاءات كجزء من
نيل درجة البكلوريوس في هندسة البناء و الانشاءات
(فرع الهندسة الصحية و البيئية)

بِسْمِ اللَّهِ الرَّحْمَنِ الرَّحِيمِ

سَبِّحْ إِسْمَ رَبِّكَ الْأَعْلَى ۝ ١ ۝ الذِّكْرُ خَلَقَ فَسَوَّى ۝ ٢ ۝

وَالذِّكْرُ فَتَرَفَقَ ۝ ٣ ۝

صدق الله العظيم

سورة الاعلى - 3

Table of Contents

Subject	Page
Dedication	I
Acknowledgement	II
Abstract	III
Table of Contents	IV
Chapter One: Introduction	
1.1 Introduction	1
1.2 water pollution	2
1.2.1 Types of water pollution	2
1.2.2 Sources of water pollution	2
1.3 object of this study	3
Chapter Two: Literature Review	
2.1 Introduction	4
2.2 Coagulation and flocculation	5
2.3 coagulant	6

Chapter Three:	
3.1-Introduction	10
3.2-Coagulation	10
3.3-Alum and ferric sulphate comparison	11
3.4-Alum and ferric chloride comparison	11
3.5-Flocculent	11
3.6-Particle Charge Prevents Coagulation	12
3.7-Microscopic Electrical Force the Double Layer	12
3.8-Double Layer Thickness	13
3.9-Zeta Potential	13
3.10-Zeta Potential vs. Surface Potential	14
3.11- Balancing Opposing Forces	14
3.12-Repulsion	14
3.13-Attraction	14

3.14- The Energy Barrier	15
3.15-Lowering the Energy Barrier	15
3.16-Compress the Double Layer	15
3.17-Lower the Surface Charge	16
3.18-Coagulate, and then Flocculate	16
3.19-Four Ways to Flocculate	16
3.19.1-Double Layer Compression	17
3.19.2-Charge Neutralization	17
3.19.3-Bridging	17
3.19.4-Colloid Entrapment	18
3.20-Time Tested Coagulants	18
3.21-Tools for Dosage Control Jar Test and Undervalued Tool	18

3.22- Jar Test Apparatus	19
Chapter Four:	
4.1- Introduction	20
4.2- sampling	20
4.2.1-Raw Water samples	20
4.3- Turbidity	21
4.4- Jar Tester	21

Chapter Five: Account and discussion	
5.1- Introduction. Account and discussion	25
Chapter Six: Conclusion	
6.1-Conclusions	31

List of table

Chapter four		
Table	Title	Page
4-1	Apparatus and Equipments	21
Chapter five		
Table	Title	Page
5-1	Results of the turbidity Removal by jar test after add (Alum, FeCl ₃ and FeSO ₄)	22
5-2	Results of the (Alum, FeCl ₃ and FeSO ₄) Obtained of Conventional Jar Test through Table (1)	22
5-3	Results of the turbidity Removal by jar test after add (Alum, FeCl ₃ and FeSO ₄)	23
5-4	Results of the (Alum, FeCl ₃ and FeSO ₄) Obtained of Conventional Jar Test through Table (3)	23
5-5	Results of the turbidity Removal by jar test after add (Alum, FeCl ₃ and FeSO ₄)	24
5-6	Results of the (Alum, FeCl ₃ and FeSO ₄) Obtained of Conventional Jar Test through Table (5)	24
5-7	Results of the turbidity Removal by jar test after add (Alum, FeCl ₃ and FeSO ₄)	25
5-8	Results of the (Alum, FeCl ₃ and FeSO ₄) Obtained of Conventional Jar Test through Table (7)	25
5-9	Results of the turbidity Removal by jar test after add (Alum, FeCl ₃ and FeSO ₄)	26
5-10	Results of the (Alum, FeCl ₃ and FeSO ₄) Obtained of Conventional Jar Test through Table (9)	26

Subject	Page
<i>References</i>	32
Abstract	33
Dedication	34

الخلاصة

الماء نعمة الله على الخلق حيث وفر لنا نهري دجلة والفرات التي تروي اراضيه والمعروف عن هذه الانهار انها تنقي نفسها بنفسها ولكن تدخل الانسان من خلال نشاطاته الصناعية والزراعية والتي خلفت كثير من المخلفات التي رميت دون درايه الى هذه الانهر احد مسببات التلوث , ولذلك اعتبرت محطات معالجة ماء الشرب ضرورة من ضروريات الحياة فلا بد من الاهتمام بهذا الجانب .

ان احواض الترسيب والتخثير باستعمال المخثرات المختلفة احد طرق معالجة مياه الانهار , وتعتبر كبريتات الالمنيوم المائية (الشب) , كبريتات الحديدوز , كلوريد الحديدك اكثرها شيوعا من هنا جاءت فكرة البحث هذا بايجاد افضل مخثر من هذه المخثرات السابقة والتي تعطي اعلى نسبة ازالة وكذلك قدرة على ازالة ايوني النترات والنترت من ماء النهر .

تناول الجانب العملي جمع عينات من نهر دجلة واجراء فحص pH والعكارة والنترات والنترت قبل المعالجة وبعد المعالجة بهذه المخثرات (كبريتات الالمنيوم المائية (الشب) , كبريتات الحديدوز , كلوريد الحديدك) ومن خلال اجراء فحص (jar test) .

توصلنا من خلال هذه الدراسة بان كبريتات الحديدوز افضل مادة مخثرة يليها الشب فكلوريد الحديدك في ازالة العكارة من ماء النهر , ورغم ان كلوريد الحديدك اقل مادة بتخثير العكارة ولكنه افضل مخثر لازالة النترات والنترت يليه الشب فكبريتات الحديدوز , كما لوحظ انخفاض بقيمة pH مع مرور الزمن مما وفر اجواء للتفاعل وكذلك زيادة في ازالة ايون النترت نتيجة ارتفاع لدرجات الحرارة كما وقلت العكارة مع الزمن نتيجة لسرعة جريان النهر ربيعا.

Abstract

Water the grace of God over creation as provided us with the Tigris and the Euphrates, which tells its territory and is known for these rivers they purify themselves, but human intervention through the activities of industrial, agricultural, and that left many of the waste thrown Without knowledge into this river one of the causes of pollution, and therefore considered treatment plants drinking water need of the necessities of life must be attention to this aspect.

The basins of sedimentation and coagulation using different coagulant one ways of addressing the rivers, and is aluminum sulfate (alum), ferrous sulfate, ferric chloride most commonly from here came the idea of this search to find a better rennet from this coagulant the former, which gives a higher percentage of removal, as well as able to remove Ionic nitrate and nitrite from the water of river.

Address the practical side of collecting samples from the Tigris River and an examination of pH and turbidity, nitrate and nitrite before treatment and sulfate, after treatment in this coagulant aluminum sulfate (alum), ferrous Reached ferric chloride) and through an examination of (jar test).

through this study that the ferrous sulfate best material coagulant followed by alum and ferric chloride in the removal of turbidity of water river, although the ferric chloride is less material coagulate the turbidity but the best coagulant for the removal of nitrate and nitrite, followed by alum ferrous sulfate, as noted a decrease of pH with the passage of time, providing suitable condition for interaction, as well as an increase in the removal of nitrite ion as a result of high temperature and turbidity, and I said with time due to the rapid flow of the river year-old.

Chapter one Introduction

1.1 Introduction

The removal of suspended matter from water is one of the major goals of water treatment. Only disinfection is used more often or considered more important. In fact, effective clarification is really necessary for completely reliable disinfection because microorganisms are shielded by particles in the water. Clarification usually involves:

- Coagulation
- Flocculation
- settling
- Filtration

This guide focuses on coagulation and flocculation: the two key steps which often determine finished water quality. Coagulation control techniques have advanced slowly. Many plant operators remember when dosage control was based upon a visual evaluation of the flocculation basin and the clarifier. If the operator's *eyeball* evaluation found deterioration in quality, then his common sense response was to increase the coagulant dose. This remedy was based upon the assumption that if a little did some good, then more ought to do better, but it often did worse.

The competency of a plant operator depended on his years of experience with that specific water supply. By trial, error and oral tradition, he would eventually encounter every type of problem and learn to deal with it. Reliable instruments now help us understand and control the clarification process. Our ability to measure turbidity, particle count, zeta potential and streaming current makes coagulation and flocculation more of a science, although art and experience still have their place. We make zeta meters and happen to be a little biased in favor of zeta potential. In this guide, however, we have attempted to give you a fair picture of all of the tools at your disposal, and how you can put them to work.

1.2 water pollution

Water pollution is one of the major environmental of our time : it is came about due to the industrial and urban growth over few decades the water body is polluted when containing an excessive amount of specific pollution which affects the quality of water body : than are dissolved or lie suspended in water whereby the quality of the water deteriorates , affecting aquatic ecosystems , and they cannot survive if their water load is loaded with toxic chemicals or harmful microorganisms (Hammer 1992)

The pollutants generally fall into two categories: nature and man-made. The first one (nature pollutants) includes water contaminants such as minerals (salts) and heavy metals and the second (man-made pollutants) is introduced into water sources by manufacturing plants, poor waste and disposal management, air pollution . Most often these pollutants are nutrients, sediment, pathogens, toxic metals, carcinogens, oxygen demanding materials.

1.2.1 Types of water pollution

The major water pollutants are physical, chemical, biological and physiological materials that degrade water quality due to improper human actives produced because of the discharge of industrial and domestics' wastewater into stream, so the pollution could concern public health (Klein 1957). These types are as follow:

1. Physical pollution, which causes change in the watercolor, turbidity, temperature, suspended solids, foam and radioactivity.
2. Chemical pollution caused by organic and inorganic chemicals and resulting in the change of pH value that increases toxicity by heavy metals and other toxic materials.
3. Physiological pollution is caused by several substances, particularly hydrogen sulfide and results in the change of taste and odor.
4. Biological pollution, caused by viruses, bacteria, protozoa, algae and helminthes.

1.2.2 Sources of water pollution

Water pollution in water body (rivers, lakes, and reservoirs) may come from non-point or point sources (Velz 1970 and Mitsch 1993)

1.3-object of this study

In this study collect two sample from Tiger river every two month (mid February, March, mid March, April, mid April) in clean bottle, NO_3 , NO_2 . Is tested in laboratory, in another hand used three coagulate (Alum, Ferric Sulfate, and Ferrous chloride) to study the best coagulate and the best dose can reduce effluence of this element from raw water through jar test.

Chapter tow

Literature Review

2.1- Introduction

One of the most important aspects related to sitting, planning, design, operation and long-term management of Municipal Solid Waste (MSW) landfill is the management of leachate. Leachate from MSW landfill sites are often characterized as heavily polluted wastewater. Leachate is a complex organic liquid formed primarily by the percolation of precipitation water through open landfill or through the cap of the completed site (Senior, 1995). Leachate may contain large amount of organic contaminants which can be measured as chemical oxygen demand (COD) and biological oxygen demand (BOD), ammonia, halogenated hydrocarbons, suspended solid, significant concentration of heavy metals and inorganic salts (Trebouet et al., 2000; Bagchi, 1990). If it was not treated and safely disposed, landfill leachate could be a potential source of surface and groundwater contamination, as it may percolate through soils and sub soils, causing pollution to receiving waters (Tatsi et al., 2003).

The specific composition of leachate influences its relative treatability and depends to a large extent on the contamination to be removed (Kreith, 1994). In general, the treatment of landfill leachate often involves a combination of various techniques. Several processes derived from water and wastewater treatment have been applied for the treatment of leachate. These include aerobic and anaerobic biological treatments, photo-oxidation and membrane processes, chemical oxidation and precipitation, activated carbon and adsorption and coagulation-flocculation (Trebouet et al., 2001; Marttinen et al., 2002; Wang et al., 2002; Enzminger et al., 1987; Lisk, 1991). Biological processes are quite effective for younger leachates (containing mainly volatile fatty acids), but less efficient for the treatment of stabilized leachate (Amokrane et al., 1997; Wang et al., 2002). However, leachate with low organic content is best treated with physical/chemical process (Baghi, 1990). Chemical precipitation using lime indicated that between 70 and 90% removal of color, turbidity,

suspended matter and dispersed oil could be achieved (Amokrane et al., 1997). Therefore, a combination of physical-chemical and biological methods is often required for the efficient treatment of leachate (Rautenbach & Millis, 1994). Now this waste water removal in the rivers and another source of water.

2.2-Coagulation and flocculation

Coagulation and flocculation is widely used in water and wastewater treatment and these techniques form an important step in the treatment process (Muhammad et al., 1998; Amokrane et al., 1997; AWWA, 1971). Coagulation process is effective for removing high concentration organic pollutants (Wang et al., 2002), heavy metals and some anions (Kreith, 1994). Aluminum and iron coagulants have been widely used as coagulants for the removal of humic substances from water (Lu et al., 1999; Wang et al., 2002; Amokrane et al., 1997; Koether et al., 1997; Ching et al., 1994). Chemical coagulants can destabilize colloidal particles by four distinct mechanisms: double layer compression; charge neutralization; enmeshment in a precipitate and inter-particle bridging (Al-Malack et al., 1999). Different coagulants provide different degrees of destabilization. The higher the valence of the counter-ion, the more will the destabilizing effect and the less amount of dose required for coagulation. Studies on the coagulation-flocculation processes for the treatment of landfill leachate have been reported by a few researchers (Sletten et al., 1995; Ehrig, 1984; Amokrane et al., 1997; Diamadopoulos, 1994). Alum, ferrous sulphate, ferric chloro-sulphate and ferric chloride were commonly used (Ehrig, 1984; Amokrane et al., 1997). Amokrane et al. (1997) reported that iron salts seem to be more efficient than aluminum. They reported that the addition of flocculants together with coagulants may enhance the flocs-settling rate. Additionally they reported that nonionic, cationic or anionic polyelectrolyte could be used as coagulant aids to increase flocs settling rate, without really improving the turbidity removal efficiency.

However, limited information exists on the efficiency of the coagulation-flocculation process, when applied for the removal of suspended solids, colour and COD from semi-aerobic landfill leachate. A semi-aerobic landfill is a system where semi-aerobic condition is maintained in the waste body through a convection process. It involves the

decomposition of organic matter inside the landfill and causes an increase in temperature. The difference in temperature between the inside and outside of the landfill generates a heat convection current in the landfill through the leachate pipe (Aziz et al., 2004). It was found that the leachate from semi-aerobic system has slightly lower organic contaminants compared with an anaerobic landfill in terms of BOD, COD, and other constituents (Basri et al., 2000; Aziz et al., 2004). This study focuses on the leachate generated from Pulau Burung Landfill Site (PBLs); which is situated within Byram Forest Reserve at 5° 24' N, 100° 24' E in Penang, Malaysia. The total area of the landfill is 23.7 ha and equipped with a leachate collection pond but without other treatments.

This site is contained by a natural marine clay liner. PBLs has a semi-aerobic system and it is one of the only three sites of its kind found in Malaysia. PBLs has been developed as a sanitary landfill Level II by establishing a controlled tipping technique in 1991. It was further upgraded to a sanitary landfill level III by employing controlled tipping with leachate recirculation in 2001. This site receives 1,500 tons of solid waste daily (Aziz et al., 2004).

2.3- coagulant

Ferric chloride is not new to the drinking water treatment industry and has been commercially available in the United States since the 1930's. However, it has only been in the past 15 years that a trend towards increased acceptance of ferric chloride for drinking water treatment has evolved. This is due in large part to significant improvements in product economics, quality and availability. Since 1986 there has been a ground swell in interest in ferric chloride not only for the treatment of turbidity but additionally for the removal of color, natural organic materials and arsenic from raw waters. California Water Technologies has been instrumental in helping Water Treatment Plants understand the extensive capabilities of this coagulant.

Ferric chloride is an interesting compound. It is produced as a solution from the oxidation of ferrous chloride with chlorine and it has the unusual distinction of being one of the purest and most concentrated forms of iron commercially available for water treatment. However, what is truly unusual is its chemistry is that ferric chloride not only functions as a reactant to

remove water impurities but it also functions as both a coagulant and a flocculant. Its versatility is enormous. The reactions of ferric chloride in water include an ability to form precipitates with hydrogen sulfide (H_2S), phosphate (PO_4), arsenic as arsenate (AsO_4) and hydroxide alkalinity (OH). In drinking water treatment, however, understanding ferric chloride's reaction with hydroxide alkalinity is the primary key to understanding its effectiveness as a coagulant/flocculent.

Ferric chloride reacts in water with hydroxide alkalinity to form various hydrolysis products that incorporate $\text{Fe}(\text{OH})_3$. These compounds possess high cationic charge which allows them to neutralize the electrostatic charges found on colloidal compounds and also to bind to negatively charged particles, including the ferric hydroxide itself. This ability to bind to itself is the mechanism for the formation of floc aggregates and the basis for ferric chloride's flocculation abilities. The hydrolysis products from ferric chloride, nominally ferric hydroxide, are different from those of sulfate based ferric sulfate and aluminum sulfate (alum). The aggregates or floc particles of ferric hydroxide are physically more discrete and dense and have a higher cationic charge density. In contrast, the floc aggregates of ferric sulfate and aluminum sulfate tend to be less discrete and "fluffy" or cloud like, this apparently due to differences in the types of bonding of the hydrolysis products. These differences translate into characteristics and abilities for ferric chloride that set it far apart from the sulfate based coagulants. In typical plant situations one can expect to use about 30% less ferric chloride than aluminum sulfate (on a dry weight basis) to achieve similar results. Ferric Chloride forms a more discrete and dense floc that promotes faster sedimentation in general and specifically, better sedimentation in cold water. This dense floc has more available cationic charge that allows higher reactivity with colloidal solids. The high ratio of cationic charge to total mass also makes the ferric chloride hydrolysis products more reactive and adsorptive with emulsified and semi-emulsified organic matter; such as oils, fats, and other natural and synthetic organic matter. This would explain the ability of ferric chloride to remove TOC and other disinfection by product precursors (DBP's). The high density of the ferric hydroxide floc leads to another important benefit for the treatment plant. The settled sludge volume of the ferric (chloride) hydroxide ranges typically from 1/3 to 2/3 that of sulfate based coagulants. Additionally, the sludge developed through the use of ferric chloride is generally much more

dewaterable. So, although the ferric hydroxide molecule itself is heavier than the aluminum hydroxide molecule, this does not translate into more sludge to be disposed of. Instead, because sludge is disposed of on a wet basis rather than on a dry basis, the use of ferric chloride produces fewer wet tons of sludge and yields significant solids handling and disposal savings. One of the other characteristics of ferric chloride is its ability to form floc over a very wide pH range as is demonstrated in the accompanying charts. The charts also show the very low solubility of ferric hydroxide compared to aluminum hydroxide. The combination of these properties allow ferric chloride to function over a very wide pH range with little fear of carry over into downstream processes due to post precipitation. This ends up being very important for operations looking to flocculate at higher pH and alkalinity's while controlling corrosive factors in the water. Additionally, the low end of the pH range becomes especially important to enhanced coagulation processes. Although there is little formal data regarding the use of ferric chloride as a filtration aid there is much operational data that speaks to its ability to greatly enhance turbidity removal with both slow and rapid sand filter filtration. Additionally there are more recent reports that speak to the use of iron coated sand in the removal of manganese.

1. Potable Water Treatment Applications
2. Turbidity removal
3. Enhanced Coagulation
4. NOM, DBP precursor removal
5. Color removal
6. Arsenic reduction
7. Softening Solids Sedimentation Aid
8. Filtration Aid

Four coagulation chemicals and one coagulant aid are commonly used in water treatment plants. Selection of the right chemical depends on which coagulation method is used the coagulant is usually a metal salt, which reacts with alkalinity in the water to produce an insoluble metal hydroxide floc, which incorporates the colloidal particles. This fine precipitate is then flocculated to produce settleable solids. Coagulants are usually added as a concentrated solution, which can be dosed accurately using a positive

displacement-metering pump. (Tebbutt, 1998) Aluminum sulfate $\text{Al}_2(\text{SO}_4)_3 \cdot 14\text{H}_2\text{O}$, ferric chloride FeCl_3 , ferric sulfate $\text{Fe}_2(\text{SO}_4)_3$ and polyaluminum chloride are the primary chemicals used to treat drinking water. Powdered activated carbon (PAC), a coagulant aid, can be used in coagulation cells to enhance the removal of taste and odors compounds, and remove some organic carbon.

Chapter three Theory

3.1-Introduction

Coagulation is the formation process of clot by means of a coagulant reaction in contact with water. Coagulation objective is to transform impurities such as fine colloidal suspension, suspended solids and microorganisms, in bigger particles called flocks, which can be removed by sedimentation, flotation and/or filtration adsorption. The parameters that determine an efficient coagulation are pH, kind of coagulant, rapid mix of coagulant, water temperature, zeta Coagulation is the formation process of clot by means of a coagulant reaction in contact with water. Coagulation objective is to transform impurities such as fine colloidal suspension, suspended solids and microorganisms, in bigger particles called flocks, which can be removed by sedimentation, flotation and/or filtrationadsorption. The parameters that determine an efficient coagulation are pH, kind of coagulant, rapid mix of coagulant, water temperature, zeta

3.2-Coagulation

Coagulation is the electrochemical process of aggregating small particles into larger particles or "flocs" that settle more rapidly than individual particles due to their increased weight. It is also the most common first step in water treatment prior to treatment where by the removal of impure particulates can be achieved. In the process, coagulants are added to turbid water in order to destabilize particles and reduce antiparticle repulsion force. Destabilization increases the tendency of particles to coalesce on contact, resulting in heavier agglomerated particles and then settle out of solution (Degremont 1991).

Coagulation is accomplished by the addition of ions having the opposite charge to that of the colloidal particles. Since the colloidal particles are charged negatively usually, the added ions should be cations or positively charged. The coagulating power of an ion is dependent on its valency or magnitude of charge (Amirtharajah and O milia 1990)

3.3-Alum and ferric sulphate comparison

Many laboratory studies of cultured anabaena floc aquae in jar tests that were conducted with alum and ferric Sulphate at PH 6.0, William et al (1986), Briley, and Knappe (1998) found that alum and ferric Sulphate produced similar levels of turbidity. However, on a molar basis, ferric Sulphate required a higher dose to achieve a given streaming current value than alum, indicating that charge neutralization was more effectively accomplished with alum hydrolysis products.

3.4-Alum and ferric chloride comparison

Cheal and Field (1980) evaluated in a bench scale, jar test experiments four coagulants, $\text{Al}_2(\text{SO}_4)_3 \cdot 14\text{H}_2\text{O}$, ferric chloride FeCl_3 , ferric sulfate $\text{Fe}_2(\text{SO}_4)_3$, and two cationic inorganic coagulant were ineffective at destabilizing the sediment suspension and initiating floc formation in the relatively short rapid mixing period. As a result, conversely ferric chloride FeCl_3 performed well, exhibiting rapid floc formation and good solids settling characteristics and the optimum dosage for ferric chloride FeCl_3 , based on sediment and metals removal, was 15 mg/L as Fe while Kim (2000) performed on locally available alum from Nepal, alum and ferric chloride from the United States. Hadi (1990) and Feryad (2003) (alum and ferric chloride). They found through comparison to all coagulants studied that FeCl_3 requires the least amount of dosage to achieve the greatest amount of turbidity removal as well as comparable amounts of dosage show greater PH drops in FeCl_3 treated waters than in alum treated waters.

3.5-Flocculent

Degremont (1991), defined flocculation as the agglomeration of destabilized particles into microfloc, and later into bulky flocs, which can be settled, called floc.

Tchobanoglous and Schroeder (1985), stated that particles would gradually aggregate through per kinetic flocculation brought about by Brownian motion, but the process is very slow. The rate can be greatly enhanced by providing velocity gradients that bring about orthogenetic flocculation.

Kiely (1997), suggested detention times of 20 to 60 min are now

required to encourage the microfloc (pin floc) to agglomerate and produce larger flocs, therefore; the flocculation basin is about 50 times larger than the rapid mixing unit. Gentle agitation is required in this unit to promote thorough mixing. However, mixing should not be so strong as to cause breakup of the weak influent microfloc. In practice, Schemidtke (1983), illustrated variables such as the characteristics of particular water, the coagulant used, pH, and temperature as important factors that affect on the flocculation.

3.6-Particle Charge Prevents Coagulation

The key to effective coagulation and flocculation is an understanding of how individual colloids interact with each other. Turbidity particles range from about .01 to 100 microns in size. The larger fraction is relatively easy to settle or filter. The smaller, colloidal fraction, (from .01 to 5 microns), presents the real challenge. Their settling times are intolerably slow and they easily escape filtration. The behavior of colloids in water is strongly influenced by their electro kinetic charge. Each colloidal particle carries a like charge, which in nature is usually negative. This *like* charge causes adjacent particles to repel each other and prevents effective agglomeration and flocculation. As a result, charged colloids tend to remain discrete, dispersed, and in suspension. On the other hand, if the charge is significantly reduced or eliminated, then the colloids will gather together. First forming small groups, then larger aggregates and finally into visible floc particles which settle rapidly and filter easily.

3.7-Microscopic Electrical Force the Double Layer

The double layer model is used and explains how electrical to visualizethe ionic environment in the vicinity of a charged colloid repulsive forces occur. It is easier to understand this model as a sequence of steps that would take place around a single negative colloid if the ions surrounding it were suddenly stripped away. We first look at the effect of the colloid on the positive ions, which are often called *counter-ions*. Initially, attraction from the negative colloid causes some of the positive ions to form a firmly attached layer around the surface of the colloid. This layer of counter-ions is known as the *Stern layer*. Additional positive ions are still attracted by the negative colloid but now they are repelled by the positive Stern layer as well as by other nearby positive ions that are also trying to approach the colloid. A dynamic equilibrium results, forming a diffuse layer of counter-ions. The diffuse positive ion layer has a high

concentration near the colloid which gradually decreases with distance until it reaches equilibrium with the normal counter-ion concentration in solution. In a similar but opposite fashion, there is a lack of negative ions in the neighborhood of the surface, because they are repelled by the negative colloid. Negative ions are called *co-ions* because they have the same charge as the colloid. Their concentration will gradually increase as the repulsive forces of the colloid are screened out by the positive ions, until equilibrium is again reached with the co-ion concentration in solution.

3.8-Double Layer Thickness

The diffuse layer can be visualized as a charged atmosphere surrounding the colloid. At any distance from the surface, its charge density is equal to the difference in concentration of positive and negative ions at that point. Charge density is greatest near the colloid and rapidly diminishes towards zero as the concentration of positive and negative ions merge together. The attached counter-ions in the Stern layer and the charged atmosphere in the diffuse layer are what we refer to as the *double layer*. The thickness of the double layer depends upon the concentration of ions in solution a higher level of ions means more positive ions are available to neutralize the colloid. The result is a thinner double layer. Decreasing the ionic concentration (by dilution, for example) reduces the number of positive ions and a thicker double layer results. The type of counter-ion will also influence double layer thickness. *Type* refers to the valence of the positive counter-ion.

3.9-Zeta Potential

The negative colloid and its positively charged atmosphere produce an electrical potential across the diffuse layer. This is highest at the surface and drops off progressively with distance, approaching zero at the outside of the diffuse layer. The potential curve is useful because it indicates the strength of the repulsive force between colloids and the distance at which these forces come into play. A particular point of interest on the curve is the potential at the junction of the Stern layer and the diffuse layer. This is known as the *zeta potential*. It is an important feature because zeta potential can be measured in a fairly simple manner, while the surface potential cannot. Zeta potential is an effective tool for coagulation control because changes in zeta potential indicate changes in the repulsive force between colloids. The ratio between zeta potential and surface potential depends on double layer thickness. The low dissolved solids level usually found in water treatment results in a relatively large double layer. In this case, zeta potential is a good approximation of surface potential. The situation

changes with brackish or saline waters; the high level of ions compresses the double layer and the potential curve. Now the zeta potential is only a fraction of the surface potential.

3.10-Zeta Potential vs. Surface Potential

The relationship between Zeta Potential and Surface Potential depends on the level of ions in solution. In fresh water, the large double layer makes the zeta potential a good approximation of the surface potential. This does not hold true for saline waters due to double layer compression.

3.11- Balancing Opposing Forces

The DLVO Theory (named after Derjaguin, Landau, Verwey and Overbeek) is the classic explanation of how particles interact. It looks at the balance between two opposing forces - electrostatic repulsion and Vander Waals attraction - to explain why some colloids agglomerate and flocculate while others will not.

3.12-Repulsion

Electrostatic repulsion becomes significant when two particles approach each other and their electrical double layers begin to overlap. Energy is required to overcome this repulsion and force the particles together. The level of energy required increases dramatically as the particles are driven closer and closer together. An electrostatic repulsion curve is used to indicate the energy that must be overcome if the particles are to be forced together. The maximum height of the curve is related to the surface potential.

3.13-Attraction

Vander Waals attraction between two colloids is actually the result of forces between individual molecules in each colloid. The effect is additive; that is, one molecule of the first colloid has a Vander Waals attraction to each molecule in the second colloid. This is repeated for each molecule in the first colloid and the total force is the sum of all of these. An attractive energy curve is used to indicate the variation in attractive force with distance between particles.

3.14- The Energy Barrier

The DLVO theory combines the van der Waals attraction curve and the electrostatic repulsion curve to explain the tendency of colloids to either remain discrete or to flocculate. The combined curve is called the *net interaction energy*. At each distance the smaller energy is subtracted from the larger to get the net interaction energy. The net value is then plotted - above if repulsive, below if attractive – and the curve is formed. The net interaction curve can shift from attraction to repulsion and back to attraction with increasing distance between particles. If there is a repulsive section, then this region is called the *energy barrier* and its maximum height indicates how resistant the system is to effective coagulation. In order to agglomerate, two particles on a collision course must have sufficient kinetic energy (due to their speed and mass) to *jump over* this barrier. Once the energy barrier is cleared, the net interaction energy is all attractive. No further repulsive areas are encountered and as a result the particles agglomerate. This attractive region is often referred to as an *energy trap* since the colloids can be considered to be trapped together by the van der Waals forces.

3.15-Lowering the Energy Barrier

For really effective coagulation, the energy barrier should be lowered or completely removed so that the net interaction is always attractive. This can be accomplished by either compressing the double layer or reducing the surface charge.

3.16-Compress the Double Layer

Double layer compression involves adding salts to the system. As the ionic concentration increases, the double layer and the repulsion energy curves are compressed until there is no longer an energy barrier. Particle agglomeration occurs rapidly under these conditions because the colloids can just about fall into the van der Waals “trap” without having to surmount an energy barrier. Flocculation by double layer compression is also called *salting out* the colloid. Adding massive amounts of salt is an impractical technique for water treatment, but the underlying concept should be understood, and has application toward wastewater flocculation in brackish waters.

3.17-Lower the Surface Charge

In water treatment, we lower the energy barrier by adding coagulants to reduce the surface charge and, consequently, the zeta potential. Two points are important here. First, for all practical purposes, *zeta potential is a direct measure of the surface charge* and we can use zeta potential measurements to control charge neutralization. Second, *it is not necessary to reduce the charge to zero*. Our goal is to lower the energy barrier to the point where the particle velocity from mixing allows the colloids to overwhelm it. The energy barrier concept helps explain why larger particles will sometimes flocculate while smaller ones in the same suspension escape. At identical velocities the larger particles have a greater mass and therefore more energy to get them over the barrier.

3.18-Coagulate, and then Flocculate

In water clarification, the terms *coagulation* and *flocculation* are sometimes used interchangeably and ambiguously, but it is better to separate the two in terms of function. ***Coagulation*** takes place when the DLVO energy barrier is effectively eliminated; this lowering of the energy barrier is also referred to as *destabilization*.

Flocculation refers to the successful collisions that occur when the destabilized particles are driven toward each other by the hydraulic shear forces in the rapid mix and flocculation basins. Agglomerates of a few colloids then quickly bridge together to form micro flocs which in turn gather into visible floc masses.

Reality is somewhere in between the line between coagulation and flocculation is often a somewhat blurry one. Most coagulants can perform both functions at once. Their primary job is charge neutralization but they often adsorb onto more than one colloid, forming a bridge between them and helping them to flocculate. Coagulation and flocculation can be caused by any of the following:

- Double layer compression
- charge neutralization
- bridging
- Colloid entrapment

3.19-Four Ways to Flocculate

In the pages that follow, each of these four tools is discussed separately, but the solution to any specific coagulation-flocculation

problem will almost always involve the simultaneous use of more than one of these. Use these as a check list when planning a testing program to select an efficient and economical coagulant system.

3.19.1-Double Layer Compression

Double layer compression involves the addition of large quantities of an indifferent electrolyte (e.g., sodium chloride). The *indifference* refers to the fact that the ion retains its identity and does not adsorb the colloid. This change in ionic concentration compresses the double layer around the colloid and is often called *salting out*. The DLVO theory indicates that this results in a lowering or elimination of the repulsive energy barrier. It is important to realize that salting out just compresses the colloid's sphere of influence and does not necessarily reduce its charge. In general, double layer compression is not a practical coagulation technique for water treatment but it can have application In industrial wastewater treatment if waste streams with divalent or trivalent counter ions happen to be available.

3.19.2-Charge Neutralization

Inorganic coagulants (such as alum) and cationic polymers often work through *charge neutralization*. It is a practical way to lower the DLVO energy barrier and form stable flocs. Charge neutralization involves adsorption of a positively charged coagulant on the surface of the colloid. This charged surface coating neutralizes the negative charge of the colloid, resulting in a near zero net charge. Neutralization is the key to optimizing treatment before sedimentation, granular media filtration or air flotation. Charge neutralization alone will not necessarily produce dramatic *macro flocs* (flocs that can be seen with the naked eye). This is demonstrated by charge neutralizing with cationic polyelectrolytes in the 50,000- 200,000 molecular weight range. *Microflocs* (which are too small to be seen) may form but will not aggregate quickly into visible flocs. Charge neutralization is easily monitored and controlled using zeta potential. This is important because overdosing can reverse the charge on the colloid, and redisperse it as a positive colloid. The result is a poorly flocculated system. The detrimental effect of overdoing is especially noticeable with very low molecular weight cationic polymers that are ineffective at bridging.

3.19.3-Bridging

Bridging occurs when a coagulant forms threads or fibers which attach to several colloids, capturing and binding them together. Inorganic primary coagulants and organic polyelectrolyte's both have the capability

of bridging. Higher molecular weights mean longer molecules and more effective bridging. Bridging is often used in conjunction with charge neutralization to grow fast settling and/or shear resistant flocs. For instance, alum or a low molecular weight cationic polymer is first added under rapid mixing conditions to lower the charge and allow microflocs to form. Then a slight amount of high molecular weight polymer, often an anionic, can be added to bridge between the microflocs. The fact that the bridging polymer is negatively charged is not significant because the small colloids have already been captured as microflocs.

3.19.4-Colloid Entrapment

Colloid entrapment involves adding relatively large doses of coagulants, usually aluminum or iron salts which precipitate as hydrous metal oxides. The amount of coagulant used is far in excess of the amount needed to neutralize the charge on the colloid. Some charge neutralization may occur but most of the colloids are literally swept from the bulk of the water by becoming enmeshed in the settling hydrous oxide floc. This mechanism is often called *sweep floc*.

3.20-Time Tested Coagulants

Aluminum and ferric compounds are the traditional coagulants for water and wastewater treatment. Both are from family called metal coagulants, and both are still widely used today. In fact, many plants use one of these exclusively, and have no provision for polyelectrolyte addition. Metal coagulants offer the advantage of low cost per pound. In addition, selection of the optimum coagulant is simple, since only a few choices are available. A distinct disadvantage is the large sludge volume produced, since sludge dewatering and disposal can be difficult and expensive. Aluminum and ferric coagulants are soluble salts. They are added in solution form and react with alkalinity in the water to form insoluble hydrous oxides that coagulate by sweep floc and charge neutralization. Metal coagulants always require attention to pH conditions and consideration of the alkalinity level in the raw and treated water. Reasonable dosage levels will frequently result in near optimum pH conditions. At other times, chemicals such as lime, soda ash or sodium bicarbonate must be added to supplement natural alkalinity.

3.21-Tools for Dosage Control Jar Test an Undervalued Tool

We usually associate the jar test with a tedious dosage control tool that seems to take an agonizingly long time to set up, run and then clean up

after. As a result the true versatility of the humble jar test is often overlooked. The following applications for jar testing may be more important than its use in routine dosage control. It is studies such as these where the jar test has its major value, since the results are worth the time and effort to do the test properly:

- Selection of primary coagulant
- Comparison of coagulant aids
- optimizing feed point for pH adjusting chemicals
- mixing energy and mixing time studies (rapid mix and flocculation)
- optimizing feed point for coagulant aids
- evaluating dilution requirements for coagulants
- estimating settling velocities for sedimentation basin sizing
- studying effect of rapid changes in mixing energy
- evaluating effect of sludge recycling

3.22- Jar Test Apparatus

Many commercial laboratory jar test units are in use today. The Phipps & Bird six place gang stirrer is very traditional. It has 1" x 3" flat blade paddles and is usually used with 1.5 liter glass beakers. A disadvantage is the large vortex that forms at high stirring speeds. Some provision is usually made for drawing off a settled sample from below the water surface. Siphon type draw-offs are frequently used for glass beakers.

Camp improved the Phipps & Bird design by using 2-liter glass beakers outfitted with vortex breaking stators. These were especially suitable for mixing studies because Camp developed curves for mixing intensity (G) versus stirrer speed using this design.

Gator or Wagner jars are a relatively recent improvement and are square Plexiglas jars with a liquid volume of 2 liters. These are now commercially available, and have several advantages over traditional glass beakers. First, they are less fragile and allow for easy insertion of a sample tap, thus avoiding the need for a siphon type draw-off. Their square shape helps dampen rotational velocity without the need for stators while their Plexiglas walls offer much greater thermal insulation than glass, thus minimizing temperature change during testing

Chapter four

Field work

4.1- Introduction:

Included In this chapter, all fields work sampling, testing and all table containing the result of this testing.

4.2- sampling

Grab water samples were taken during (15-2-2011 to 15-4-2011) form point selected for each test as follow fig (4.1) show sampling water:

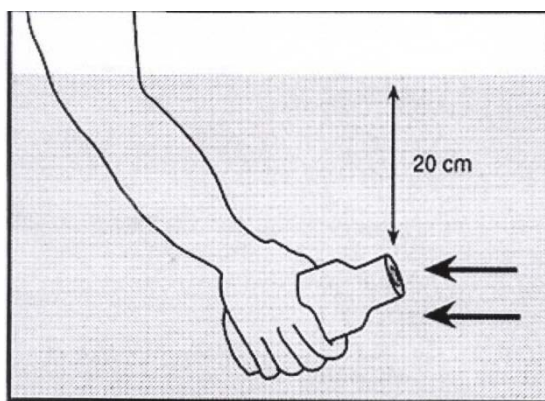


fig (4.1) show sampling water

4.2.1-Raw Water samples

Tigris raw water samples were taken from AL- Qadisiya WTP intakes at Baghdad city. The grab water samples were brought to the laboratory in plastic containers, within a short time not exceeding one hour and kept in cold pace (4°C) for testing , pH the first test show in fig (4.2) , for jar test investigation and this tests bellow.

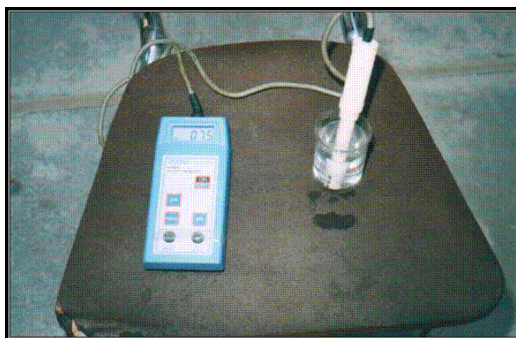


Fig (4.2): pH meter

4.3- Turbidity

Turbidity was determined in the laboratory with (portable Hanna Instruments HI93703) Microprocessor turbidity meter, manufactured in type which can be calibrated with standard solution (10, 100, 1000)

4.4- Jar Tester

A Jar test is "Hjc Floc Tester _ Holzle and chelives Co. " Table (4.1) was used to simulate coagulation and precipitation processes for raw water by using circular plastic jar shown in fig (4-3). The jar tester is electrically operated, 220 volts, power supply, single phase, it has six positions of paddles, each paddle has single blade, having dimensions of 5.2 cm long and 1.6 cm depth, under each paddle is a bay allowing beaker of one liter through the sample, admitting clear vision.

Table (4.1) Apparatus and Equipments

Item	Apparatus	Type and Manufacture
1	Turbidity meter	Hanna Instruments HI93703 Microprocessor turbidity meter Manufactured in Singapore
2	PH and Temperature meter	
3	Jar tester	Hjc Floc Tester _ Holzle and chelives Co

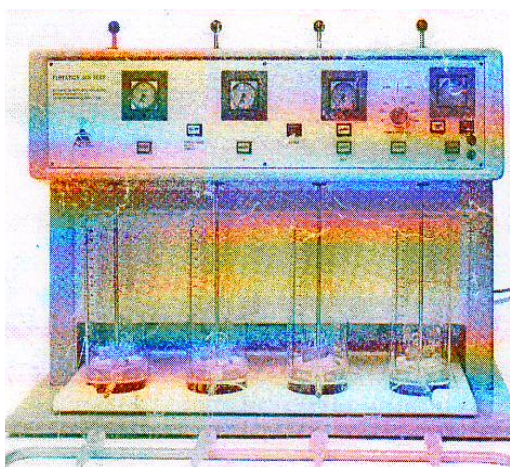


Fig (4.3): jar test instrument

Chapter five

Account and discussion

5.1- introduction

In this chapter, interest with account of the result of the experimental work and the result of all this tests show in tables bellow:

**Table (5-1), Results of the turbidity Removal by jar test after add
(Alum, FeCl₃ and FeSO₄)(15 February)**

D(Mg/l)	Alum	FeSO ₄	FeCl ₃
4	73.40	75.36	69.93
8	75.38	79.75	71.68
12	83.62	81.20	72.33
16	88.17	82.32	72.72
20	85.65	83.63	71.90
24	84.90	80.95	70.32

**Table (5-2), Results of the (Alum, FeCl₃ and FeSO₄) Obtained of Conventional Jar
Test through Table (1) (15 February)**

Date	Sample	Turbidity	pH	NO ₂	NO ₃
Before and after add alum	R.W	110	8.1	6.8	1190
	F.R.W	13.9	7.8	4.6	867
Before and after add FeSO ₄	R.W	110	8.1	6.8	1190
	F.R.W	18	7.6	5.0	820
Before and after add FeCl ₃	R.W	110	8.1	6.8	1190
	F.R.W	30	7.8	4.2	748

F.R.W: R.W after coagulation

Table (5-3), Results of the turbidity Removal by jar test after add (Alum, FeCl₃ and FeSO₄)(1-March)

D(Mg/l)	Alum	FeSO ₄	FeCl ₃
4	55.69	79.65	64.31
8	65.85	80.88	72.60
12	71.08	82.40	74.32
16	74.90	85.90	78.46
20	75.38	87.84	73.77
24	74.30	86.70	64.41

Table (5-4), Results of the (Alum, FeCl₃ and FeSO₄) Obtained of Conventional Jar Test through Table (3) (1-March)

Date	Sample	Turbidity	PH	NO ₂	NO ₃
Before and after add alum	R.W	95	8.1	9.9	875
	F.R.W	23.39	7.8	8.2	697
Before and after add FeSO ₄	R.W	95	8.1	9.9	875
	F.R.W	11.55	7.7	8.2	673.4
Before and after add FeCl ₃	R.W	95	8.1	9.9	875
	F.R.W	20.46	7.9	6.7	446

F.R.W : R.W after coagulation

Table (5-5), Results of the turbidity Removal by jar test after add (Alum, FeCl₃ and FeSO₄) (15-March)

D(Mg/l)	Alum	FeSO ₄	FeCl ₃
4	70.33	79.87	80.94
8	71.90	81.63	85.68
12	74.90	83.67	86.43
16	75.40	85.55	88.70
20	77.64	88.82	87.90
24	76.56	86.77	86.32

Table(5-6), Results of the (Alum , FeCl₃ and FeSO₄) Obtained of Conventional Jar Test through Table(5) (15-March)

Date	Sample	turbidity	pH	NO ₂	NO ₃
Before and after add alum	R.W	85	7.9	7.4	837
	F.R.W	19	7.8	6.2	500
Before and after add FeSO ₄	R.W	85	7.9	7.4	837
	F.R.W	9.5	7.6	5.6	473.8
Before and after add FeCl ₃	R.W	85	7.9	7.4	837
	F.R.W	9.6	7.8	5.26	464

F.R.W: R.W after coagulation

Table(5-7), Results of the turbidity Removal by jar test after add (Alum ,FeCl₃ and FeSO₄)(1-April)

D(Mg/l)	Alum	FeSO ₄	FeCl ₃
4	75.39	64.66	71.42
8	78.63	69.30	76.46
12	80.67	70.48	78.62
16	81.22	74.21	78.62
20	84.44	76.66	80.00
24	81.34	75.10	75.34

Table(5-8), Results of the (Alum , FeCl₃ and FeSO₄) Obtained of Conventional Jar Test through Table(7) (1-April)

Date	Sample	Turbidity	PH	NO ₂	NO ₃
Before and after add alum	R.W	57	8.1	8.3	885
	F.R.W	8.869	7.5	5.4	490
Before and after add FeSO ₄	R.W	57	8.1	8.3	885
	F.R.W	13.30	7.7	7.2	734
Before and after add FeCl ₃	R.W	57	8.1	8.3	885
	F.R.W	11.4	7.8	6.35	624

F.R.W: R.W after coagulation

Table (5-9), Results of the turbidity Removal by jar test after add (Alum, FeCl₃ and FeSO₄) (15-April)

D(Mg/l)	Alum	FeSO ₄	FeCl ₃
4	67.45	65.19	75.49
8	69.91	67.13	77.60
12	71.05	67.96	78.10
16	73.33	68.20	79.75
20	76.19	70.00	75.69
24	75.47	69.29	73.52

Table (5-10), Results of the (Alum, FeCl₃ and FeSO₄) Obtained of Conventional Jar Test through Table (9) (15-April)

Date	Sample	Turbidity	PH	NO ₂	NO ₃
Before and after add alum	R.W	60	8.1	9.5	110
	F.R.W	14.28	7.9	8.37	84.3
Before and after add FeSO ₄	R.W	60	8.1	9.5	110
	F.R.W	18	7.7	7.43	63.1
Before and after add FeCl ₃	R.W	60	8.1	9.5	110
	F.R.W	12.15	7.8	7.65	86

F.R.W: R.W after coagulation

5.2- Discussion of this result

Accounts were discussed by the following graphs:

In Figure (5-1), which shows the relationship between the proportion of removal rate and different models of mid-February found that the optimal dose at the removal rate of 88 is 16 mg / L when using alum as coagulant and rises to 20 mg / L ,of ferrous sulfate at the rate of removal of 84 and less than removal for up to 74% at a dose of 17 mg / L, and note from the table (5-2) that the pH value decreased when the use of all coagulants from 8.1 to reach the limits (6.7 to 8.7) and generated an suitable condition for chemical effective for coagulants interaction with suspended solids, causing low concentrations of nitrite The effect of nitrate and ferric chloride in removing these ions was great

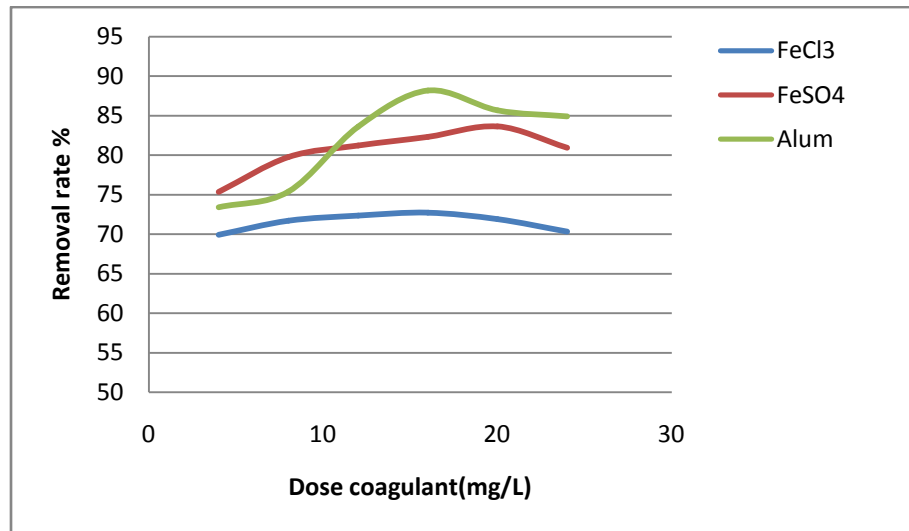


Figure.(5-1), percentage of removal rate with different doses at samples one in1 (15/2)

We note that the results varied for the models (1/3) is viewed as ferrous sulfate best coagulant and the percentage removal of 87% at a dose of 22 mg / L, followed by ferric chloride and Alum. And through the table (5-4) found that ferric chloride the best coagulant in the removal of these ions followed by alum.

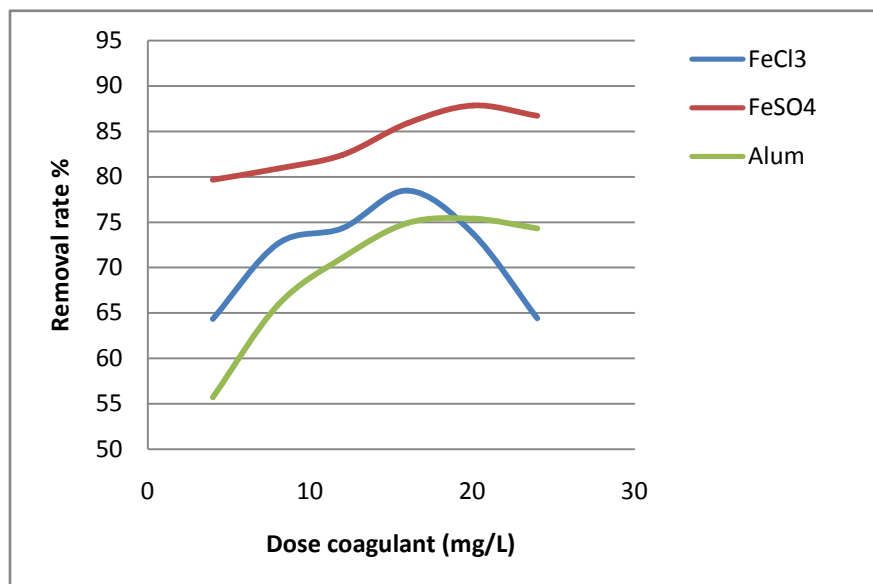


Figure. (5-2), percentage of removal rate with different doses at samples two in (1/3)

In shape (5-3) the effect of ferric chloride and ferrous sulfate equal in the degree of removal in terms of doses 20 mg / liter ferrous sulfate 16 mg / l for ferric chloride

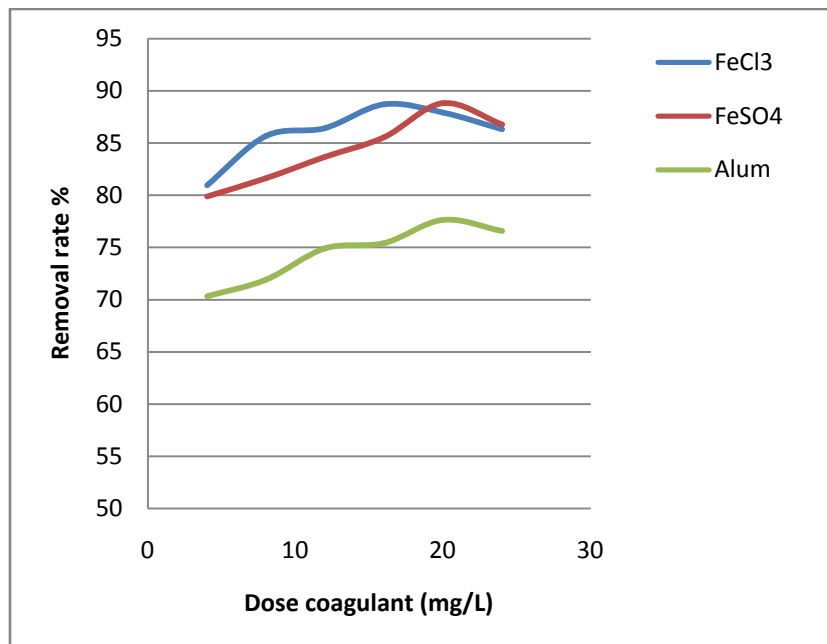


Figure. (5-3), percentage of removal rate with different doses at sample three in (15/3)

In the form (5-4) note the best dose of ferrous sulfate 20 mg / L is also for all coagulants that the removal rate for 81% ferric chloride and alum.

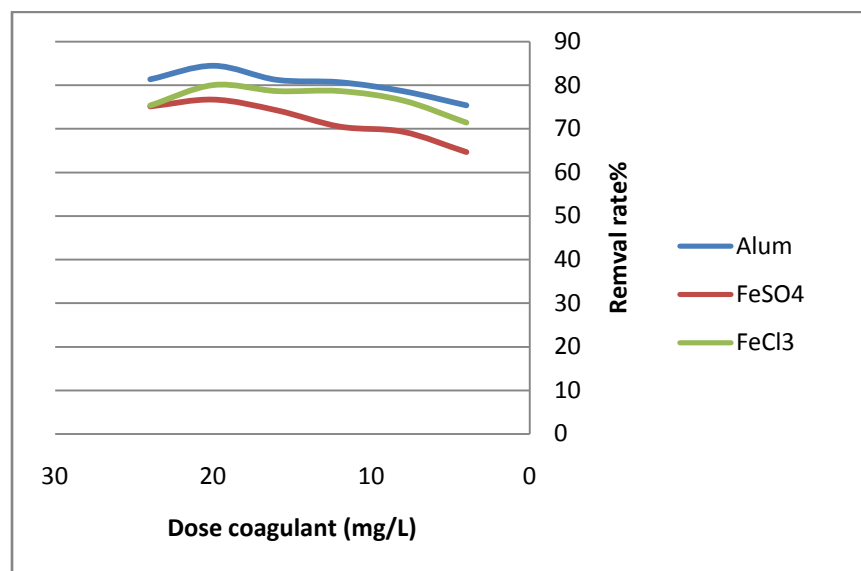


Figure. (5-4), percentage of removal rate with different doses at sample four in (1/4)

By (5-6) (5-8) (5-10) we found that the ferric chloride best coagulant removal for ionic nitrate and nitrite, followed by alum and ferrous sulfate. Although most of the ferrous sulfate in the previous data was the best material and coagulant dose of 20 mg / L, followed by alum ferric chloride, and due to the low value pH to the lower limit for all months of the other cases coagulant shown in Figure (5-6)

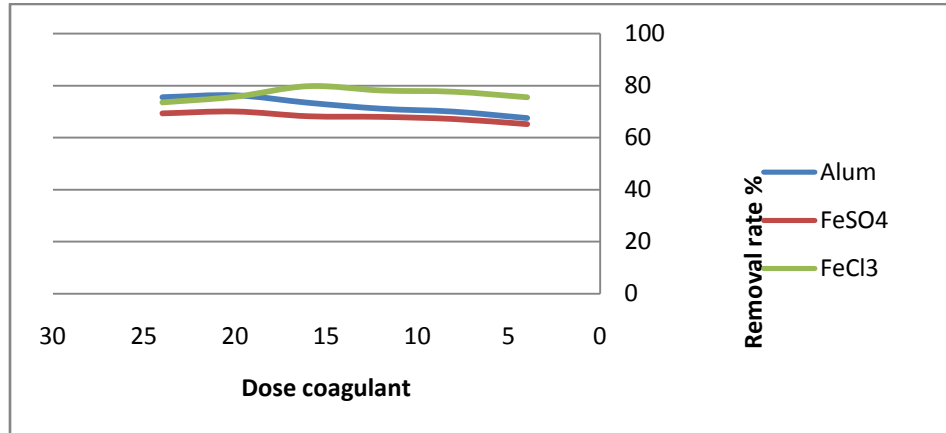


Figure. (5-5), percentage of removal rate with different doses at sample five in (15/4)

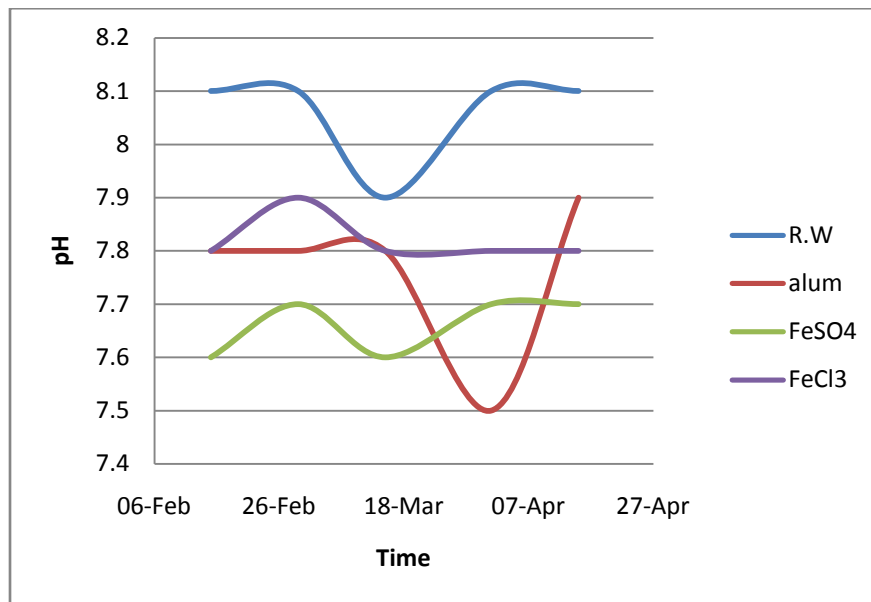


Figure (6) pH with different type and dose of coagulant at different time

Through Figure (7-5), which shows the relationship between turbidity and time note down the turbidity with the continuation of time caused by low suspended solids in raw water due

to the increasing speed of the river in the spring months resulting in the payment of the waves of sediment first, then the waves of water therefore the suspended solid less.

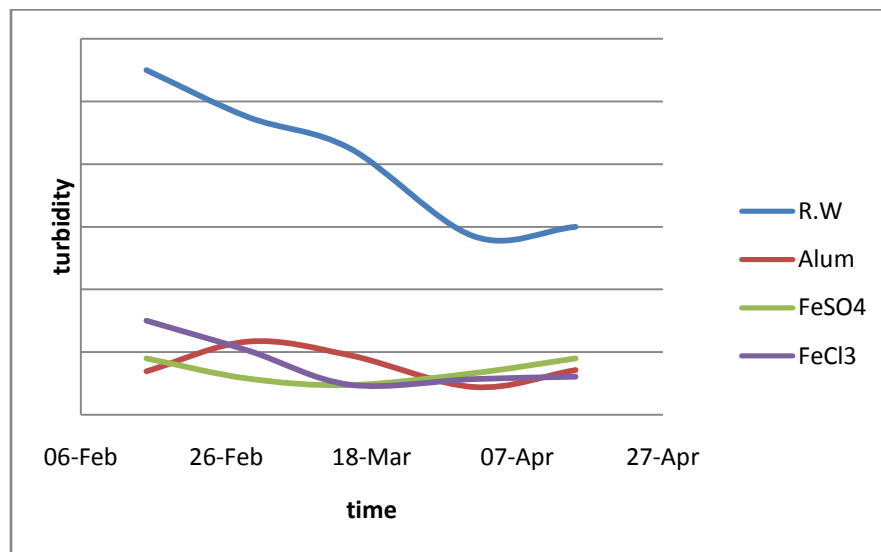


Figure (5-7), Removal turbidity with different type and dose of coagulant at different time

Note down the nitrate concentration with time and height in early April.

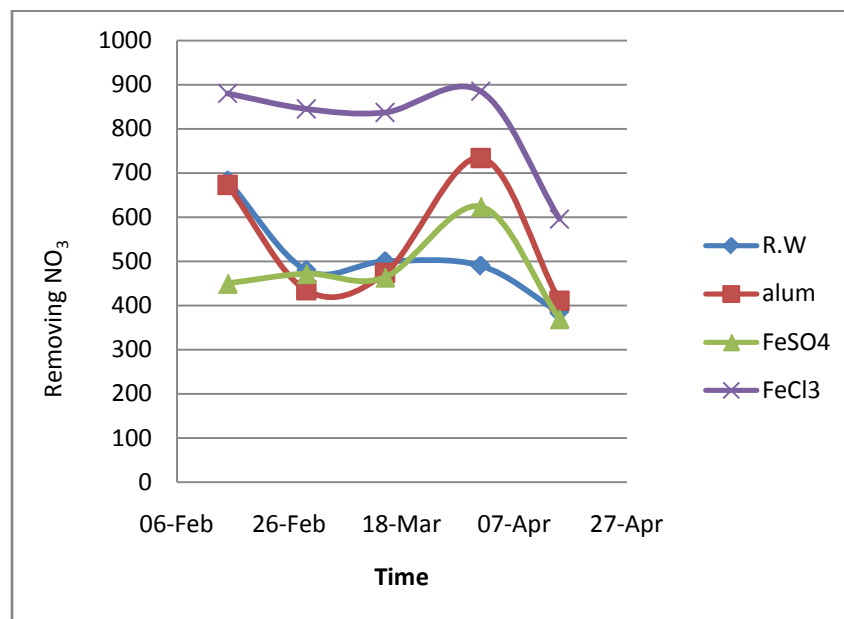


Figure (5-8), Removal Nitrate with different type and dose of coagulant at different time

In shape (9-5) shows the removal of nitrite with the passage of time and due to the high temperatures year-old and assistance for chemical processes.

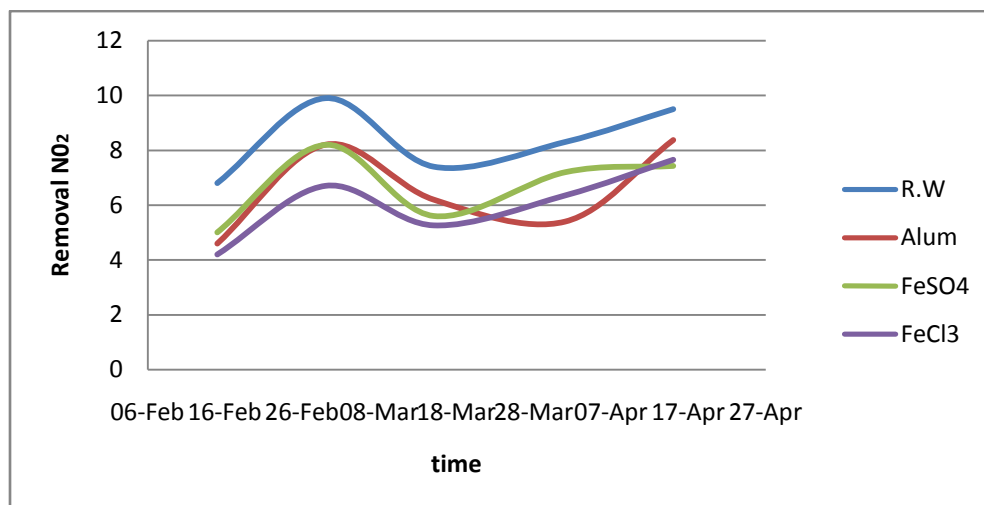


Figure (5-9), Removal Nitrite with different type and dose of coagulant at different time

Chapter six

Conclusion

6.1-Conclusions

Here are some of the conclusions from this study:

- 1 - ferrous sulfate is the best coagulant in the removal of turbidity, followed by alum and ferric chloride.
- 2 - ferric chloride is the best coagulant to remove the ionic nitrate and nitrite
- 3 - lower the value of pH constantly study which shows that there is scope for interaction and a broad
- 4 - Increase in the removal of nitrite ion with time due to higher spring temperatures, which generates the suitable condition to a chemical reaction
- 5 - lower the value of the turbidity with time due to increased speed of runoff-year-old

References

1. Amokrane A, Comel C. Landfill leachates pretreatment by coagulation flocculation. *Water Res.* 1997;31: 2775-82
2. AWWA. (1971) *Water quality and treatment: A Handbook of Public Water Supplies*, 3rd Edition., McGraw-Hill, New York.
3. Rautenbach, R. & Mellis, R. (1994) Wastewater treatment by a combination of bioreactor and nanofiltration. *Desalination*, 95, 171-188.
4. Kreith F. (1994) *Handbook of Solid Waste Management*, McGraw-Hill, Inc.
5. Wang, Z.P., Zhang, Z., Lin, Y.J., Deng. N.S., Tao, T. & Zhuo, K. (2002) Landfill leachate treatment by a coagulation-photooxidation process. *J. Hazardous Mater*, 95 (1/2), 153-159. Lu X., Chen Z. & Yang X. (1999) Spectroscopic Study of Aluminum Speciation in Removing Humic Substances by Al Coagulation. *Wat.Res.*, 33 (15), 3271-3280.
6. Marttinen, S.K., Kettunen, R.H., Sormunen, K.M., Soimasuo, R.M. & Rintala, J.A. (2002) Screening of physical-chemical methods for removal of organic material, nitrogen and toxicity from low strength landfill leachates. *Chemosphere*, 46, 851-858.
7. Trebouet, D., Schlumpf, J.P., Jaouen, P. & Quemeneur, F. (2001) Stabilized landfill leachate treatment by combined physico-chemical-nanofiltration processes. *Wat. Res.*, 35, 2935-2942.
8. Al-Malack, M.H., Abuzaid N.S. & El-Mubarak, A.H. (1999) Coagulation of Polymeric Wastewater Discharged by A Chemical Factory. *Wat. Res.*, 33 (2), 521-529.

9. Aziz, H.A., Yusoff, M.S., Adlan, M.N., Adnan, N.H. & Alias, S.(2004) Physico-chemical removal of iron from semi-aerobic landfill leachate by limestone filter. *Waste Manage Res.*, 22:371-375.
10. Senior E. (1995) *Microbiology of Landfill Sites*. Lewis Publishers
11. Sletten, R.S., Benjamin, M.M., Horng, J.J. & Ferguson, J.F. (1995) Physical-chemical treatment of landfill leachate for metals removal. *Wat. Res.*, 29 (10), 2376-2386.
12. Basri, D.R.H., Mohamed, A.A.K., Aziz, H.A. & Asaari, F.A.H. (2000) The Effectiveness of Cockle Shells in Treating Leachate Organic Pollutants' in ISWA International Symposium and Exhibition On Waste Management in Asian Cities, 23-25 October 2000, Hong Kong Convention and Exhibition Centre.
13. Trebouet, D., Schlumpf, J.P., Jaouen, P. & Quemeneur, F. (2001) Stabilized landfill leachate treatment by combined physico-chemical-nanofiltration processes. *Wat. Res.*, 35, 2935-2942.
14. Enzminger, J.D., Robertson, D., Ahlert, R.C. & Kosson, D.S. (1987) Treatment of landfill leachates. *J. Hazardous Materials*, 14, 83-101.
15. Blanc, F.C. & Navia, R. (1991) Treatment of dairy wastewater by chemical coagulation, *Proc. Ind. Waste Conf. West Lafayette (Indiana)*, 45th., 681-689.
16. Tatsi, A.A., Zouboulis, A.I., Matis, K.A. & Samaras, P. (2003) Coagulation-flocculation pretreatment of sanitary landfill leachates. *Chemosphere*, 53, 737-744.
17. Kreith F. (1994) *Handbook of Solid Waste Management*, McGraw-Hill, Inc.
18. Lisk, D.J. (1991) Environmental effects of landfill. *Sci. Total Environ.*, 100, 415-468.
19. Ching H.W., Elimelech M. & Hering J.G. (1994) Dynamics of Coagulation of Clay Particles With Aluminum Sulphate. *Journal of Environmental Engineering*, 120 (1), 169-189, 1994.

Reference

20. Diamadopoulos, E. (1994) Characterization and treatment of recirculation-stabilized leachate. Wat. Res., 28 (12), 2439-2445.
21. Ehrig, H.J. (1984) Treatment of sanitary landfill leachate: Biological treatment. Waste Manage. Res., 2, 131-152.