

**İSTANBUL YENİKAPI DESARJ ATIKSULARININ
KİMYASAL ÇÖKTÜRME İLE ARITILABİLİRLİĞİ**

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**ANA BİLİM DALI : ÇEVRE MÜHENDİSLİĞİ
PROGRAMI : ÇEVRE MÜHENDİSLİĞİ**

TEMMUZ, 1991

**TREATABILITY OF ISTANBUL YENIKAPI DISCHARGE
WASTEWATER BY CHEMICAL PRECIPITATION**

**MASTER OF SCIENCE THESIS
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DATE OF SUBMISSION: JUNE 10th, 1991

DATE OF APPROVAL : JULY 4th, 1991

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JULY, 1991

PREFACE

I would like to personally thank to all my professors, especially to my supervisor, Professor Olcay Tunay for his great contributions to my study.

I would also like to thank to Mrs Isık Kabdaslı, Miss Ruya Taslı, Mr. Cengiz Baske, Mr. Kadir Alp, Mr. Hurrem Bayhan, Mr. Suleyman Sakar, Mrs. Nursen Eldem and Mr. Hakan Kalender who helped me in making my thesis. Without their helps I wouldn't be able to achieve the profit.

I would also like to thank to my friends; Selcuk Buyukmurat, Sertac Tokta, Banu Ozcan, Hale Poyraz and the others for their helps.

I would like to personally thank to Mr. Osman Egeli for his great helps.

I would also like to thank to Zet Research Corp.

As a last word I would like to thank to my mother and brother for their great supports in making my thesis.

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TREATABILITY OF ISTANBUL YENIKAPI DISCHARGE WASTEWATER BY CHEMICAL PRECIPITATION

SUMMARY:

In the treatment of wastewaters, besides the removal of organic constituents from the water, nutrient control is essential especially in the case of discharging the wastewater into a receiving water that is incapable of diluting the wastewaters.

Marmara Sea and Istanbul Bosphorus are the receiving waters for Istanbul wastewaters. They are already contaminated and cannot dilute the discharges. Thus, nitrogen and phosphorus that are the main nutrients are to be treated from the water.

Chemical precipitation achieves a good removal efficiency in phosphorus. It is adequate to control one of the primary nutrient in aquatic growth.

In the first chapter, the scope and the object of this study are explained and it is stated that nutrient control be essential for the treatment of Istanbul wastewaters. The second chapter contains the theoretical approaching and the applications of chemical precipitation. In the third chapter, the role of nitrogen and phosphorus, and the removal processes are discussed. The fourth chapter explains the treatment requirement of Istanbul. In the fifth chapter, experimental study and the results are taken place. The sixth chapter explains the performance of chemical precipitation.

İSTANBUL YENİKAPI DEŞARJ ATIKSULARININ KİMYASAL ÇÖKTÜRME İLE ARITILABİLİRLİĞİ

TURKÇE ÖZET :

Atıksuların arıtılmasında en çok kullanılan proseslerden biri biolojik arıtma prosesleridir. Biolojik arıtma proseslerinin bugün kullanılan birçok değişik türü mevcuttur; klasik aktif çamur sistemleri, damlatmalı filtreler, dönen biolojik diskler, nitrifikasyon-denitrifikasyon prosesleri bunlar arasında sayılabilirler.

Biolojik arıtma sistemleri organik kirleticilerin giderilmesinde etkili olurlarken, nütrient gideriminde, nitrifikasyon-denitrifikasyon sistemi hariç, etkili değildirler.

Nütrient giderimi alıcı ortamlar için son derece önemlidir, zira su yaşamı için gerekli olan nütrientlerin, fazla olduğu durumlarda su yaşamında istenmeyen koşullar meydana getirdikleri bilinmektedir. Su yaşamında istenmeyen bu koşullar aşağıdaki şu alt başlıklarda toplanabilir :

- 1) Azot alıcı ortamlardaki oksijeni tüketerek çözünmüş oksijen seviyesini düşürür, ortamı anoksik yapar.
- 2) Azot ve fosfor temel besin maddesi oldukları için sudaki canlıların aşırı şekilde büyümelerine neden olur ve ötrofikasyon problemini meydana getirir.
- 3) Azot klor dezenfeksiyonun verimini etkiler.
- 4) Atıksuların yeniden kullanılmalarını engeller.

Nütrientlerin arıtılmasında azot ve fosforun ayrı ayrı ele alınmasında fayda vardır, zira ikisi de birincil besin maddeleri olmalarına karşın giderilme sistemleri farklıdır.

Azotun giderilmesi çeşitli yöntemlerle sağlanır. Bu yöntemler, nitrifikasyon-denitrifikasyon yönteminde olduğu gibi azotun önce nitrite daha sonra da nitrata dönüştürülmesinden sonra azot gazı olarak atmosfere verilmesi şeklinde olabilir, veya klor aminler oluşturarak dezenfeksiyon verimine etki ederek uzaklaştırılır.

Kimyasal olarak azotun giderilmesi serbest amonyak haline dönüştürülerek, yüksek miktarda havayla amonyak gazının sudan uzaklaştırılması sağlanır. Kullanılan diğer yöntemler ise ters osmos, ion değişimi ve arazide arıtma olarak sayılabilir.

Fosforun sudan giderilmesi, azotun giderilmesine göre daha kolay gerçekleşir. Bunun sebebi fosforun çözünemeyen kompleksler oluşturmasıdır.

Fosfor biyolojik olarak sudan yeteri kadar uzaklaştırılmazken, kimyasal olarak giderilmesi kimyasal çöktürme şeklinde gerçekleşir.

Kimyasal çöktürme; koagülasyon, flokülasyon ve çöktürme kademelerinden oluşur.

Bu çalışmanın ikinci bölümünde ele alınan kimyasal çöktürmenin incelenmesi şu kısımlardan oluşur :

1) Kimyasal çöktürmenin tarihi: Bu kısımda kimyasal çöktürmenin ne zaman ve ne şekilde kullanılmaya başlandığını anlatır. Kimyasal çöktürmenin önceleri tercih edilen bir yöntem olmasına karşın neden terkedildiğini ve daha sonra neden tekrar kullanılmaya başlandığını kronolojik olarak inceler.

2) Kimyasal çöktürmenin teorik yaklaşımı: Bu kısım üç ana başlık altında toplanmıştır; koagülasyon, flokülasyon ve

çöktürme.

Koagülasyon kısmında; koagülasyonun tarifi, oluşum esasları incelenir.

Flokülasyon konusunda flokların oluşumuna etki eden durumların incelenmesi ve flokülasyon türlerinin kısaca tanıtılması ve koagülasyon-flokülasyon arasındaki ilişkinin açıklanması yapılmıştır.

Çöktürme bahsinde ise çöktürmenin nasıl gerçekleştiği, çöktürme hızının çöktürme performansına etkisi incelenmiştir.

3) Kimyasal çöktürmenin uygulama esasları: Bu alt başlıkta ise uygulama yönelik konulara ağırlık verilmiştir. Hız gradyanının uygulamada alabileceği değerler, koagülant seçimi nelere göre yapılmalıdır, en çok kullanılan koagülantların fosfor gideriminde oluşturdıkları reaksiyonlar, polielektrotların flok oluşumundaki rolleri, flokülasyon prosesinde uygulanan tipik yavaş karıştırma değerleri ve çöktürme prosesinin sağlanması gereken koşulların belirtilmesi ele alınmıştır.

4) Kimyasal çöktürmenin evsel atıksulara uygulanmasında, genel evsel atıksu karakteriğinin bilinmesinde fayda vardır. Bu nedenle evsel atıksuların genel özellikleri bu bölümde hem parametre olarak hem de kirletici partikül maddelerin toplam atıksuda içinde gösterdikleri dağılım olarak ele alınmıştır. Bu dağılımın yapılması kimyasal artımanın veriminin baştan tayin edilmesine yardımcı olur, zira kolloidal maddelerin oranı ve büyüklükleri hem koagülasyon flokülasyon hem de çöktürme verimine etki eder.

5) Kimyasal çöktürmenin çeşitli parametreler bazında giderme verimlerinin incelenmesi ve kısaca diğer sistemlerle karşılaştırılması bu bölümün son alt başlığını oluşturur.

Çalışmanın üçüncü bölümünde azot ve fosfor parametrelerinin su yaşamı için önemi ve giderme metodları iki genel alt başlık altında toplanmıştır; azot ve fosfor.

AZOT :

Bu bölüm, azotun su yaşamındaki ve kontrol edilmesindeki önemini ve azotun kimyasal olarak nasıl, hangi mertebelerde giderilebileceğini inceler. Kullanılan kimyasal metodları kısaca açıkladıktan sonra kimyasal çöktürme ile giderilebilen organik ve toplam azot giderme verimlerini açıklar. Bu değerler organik azot için % 50 ile 90 arasında değişir. Toplam azot olarak ifade edilen kjeldahl azotu (organik azot + amonyak azotu) ise % 30 ile 50 arasında giderilebilir. Amonyak azotunun sudan uzaklaştırılmasında kullanılan hava ile püskürtme yönteminde amonyum iyonu yüksek pH değerlerinde, 10.5 ile 11 değerlerinde % 95 mertebesinde serbest amonyaga dönüşerek sudan uzaklaştırılır ve atmosfere verilir.

FOSFOR :

Fosforun tanıtılması da aynı azotta olduğu gibi önce su yaşamındaki önemi kontrol edilebilirliği ve kimyasal olarak giderme yöntemlerinin incelenmesinden meydana gelir. Fosfor, azotun aksine çökelebilen kompleksler oluşturur ve kireç, alum veya demir tuzlarının koagülant olarak kullanılmasıyla sudan yüksek mertebelerde giderilir.

Kireç kullanılması halinde, fosfor kalsiyumhidroksiapatit oluşturur ve düşük kireç dozajlarında bile % 80 mertebesinde giderme sağlar. Kireç dozajının arttırılması ve dolayısıyla pH değerinin yükseltilmesi neticesinde hidroksiapatitlerin

cözünürlük çarpımları azalır ve daha iyi bir giderme verimi sağlarlarken arıtma sonrası 1.0 mg P /L altında fosfor elde edilir.

Demir tuzlarının ve alumun kullanılması halinde de giderme verimi oldukça yüksek ve arta kalan fosfor miktarı da 1.0 mg/L altındadır. Demir tuzları ya direkt olarak kullanılırlar ya da kireçle birlikte kullanılırlar. Özellikle demir sülfatın kireçle kullanılması yalnız olarak uygulanmasından daha iyi sonuç verir.

Dördüncü bölümde, bu çalışmaya baz teşkil eden ve çalışmanın gereksinimini sağlayan İstanbul'un arıtma ihtiyacına global olarak bakılmıştır.

Durumun incelenmesi, Marmara Denizi'nin oşinografik yapısına ve Karadeniz'den gelen hem organik hem de nütrient akışlarının İstanbul'dan gelen akışlarla karşılaştırılmasına ve İstanbul açısından nütrient kontrolünün yapılması gerektiğine dayandırılmaktadır.

Beşinci bölümde ise bu çalışmanın amacının sayısal olarak değerlendirilmesini sağlayacak olan deneysel çalışma bulunmaktadır.

Deneysel çalışmada kullanılan procedür, analiz yöntemleri, kullanılan koagülanlar ve sonuçlar bu bölümü oluşturur.

Değerlendirme bölümü ise bu çalışmanın altıncı ve son bölümünü oluşturur. Değerlendirme sistemin genel performansı, diğer sistemlerle karşılaştırma ve genel bir ifadeyle kimyasal köktürmenin faydalarını ve nütrient kontrolündeki önemini ve başarısını belirtir.

1 INTRODUCTION

1.1 INTRODUCING THE STUDY

Istanbul metropolitan city is one of the most crowded cities in the world. Its population is growing day by day, and on the other side industrial progression is becoming more important.

There are many industries in Istanbul. The wastewater flows of these industries are in the large quantities and the characteristic are different from each other. So that it is difficult to decide on which treatment systems are used to treat these wastewaters.

Also, domestic wastewaters have the importance of containing nitrogen and phosphorus compounds that are needed special care to remove from the wastewater before discharging.

Treatment of combined domestic and industrial wastewaters needs special care because of nutrients that are available in domestic wastewaters, and toxic substances that are present in industrial wastewaters.

While the biological treatment systems achieve a good removal efficiency in the organic constituents, they cannot obtain a moderate removal efficiency in nutrient removal.

The importance of chemical precipitation is noticed here. Chemical precipitation achieves a high removal efficiency in nutrient removal, especially in phosphorus.

For toxic substances such as heavy metals, phenol chemical precipitation accomplishes a very high removal rates.

The problem shows itself in discharging the wastewaters into a receiving water. Marmara Sea is the receiving water for the wastewaters of Istanbul. But at present Marmara Sea is an eutrophic sea and cannot dilute the discharges.

In that reason nutrient control is necessary. Chemical precipitation can be used either alone or with the conjunction of biological treatment systems in order to control the nutrients.

1.2 SCOPE AND OBJECT

In this study, nutrients and toxic substances which are not well treated by biological treatment processes from water, are tried to treat by chemical precipitation.

As mentioned above the receiving water for discharging the wastewater of Istanbul is Marmara Sea, and it is an eutrophic sea at the moment, thus, nutrient control is essential. This control can be supplied by chemical precipitation because of having a good removal efficiency in nutrient removal especially in phosphorus.

In the removal of nutrients, chemical precipitation has achieved a removal efficiency over 90 % in phosphorus removal, and a residual phosphorus concentration is less than 1.0 mg/L as P. In the nitrogen removal the efficiency rate varies from 50 to 75 % as total nitrogen depends on the mixing type used. In this study mechanical string and air mixing have been used.

This study contains the following steps in the treating of Istanbul Yenikapi discharge wastewater :

- 1) Chemical precipitation theory and applications; coagulation, flocculation, and sedimentation.

- 2) Nitrogen and phosphorus; their roles in the aquatic life and the treatment processes for their removal from the water.

- 3) Treatment requirement for Istanbul: nutrient control.

- 4) Experimental study; treatability results for organic constituents, nutrients, toxic substances, and sludge characterization.

- 5) Evaluation; comparing with the other treatment systems in terms of removal efficiencies for organic constituents, nutrients, and for toxic substances.

2 TREATMENT OF DOMESTIC WASTEWATERS BY CHEMICAL PRECIPITATION

2.1 CHEMICAL PRECIPITATION

Chemical precipitation in wastewater involves the addition of chemicals to alter the physical state of dissolved and suspended solids and facilitate their removal by sedimentation. In such cases the alternation is slight, and removal is effected by entrapment within a voluminous precipitate consisting primarily of the coagulant itself. Another result of chemical addition is a net increase in the dissolved constituents in the wastewater (Metcalf & Eddy).

Treatment of wastewaters is related to the wastewater type. There is not a general treatment process that is applied to all wastewaters. The process is chosen according to the wastewater type.

In the treatment of industrial wastewaters, generally chemical precipitation is not used alone, it used in the combination with the other treatment systems. But for some industries such as metal finishing industries it can be directly applied. For textile wastewaters chemical precipitation can be applied before or after the biological treatment to balance the organics or

toxins or both, to remove excess toxicity or organics for the optimization of the size of biological treatment, to polish the effluent in terms of degradable and nondegradable organics and suspended solids and mostly to remove color (Germirli F., Tunay O., Orhon D.).

In the treatment of domestic wastewaters, biological processes are the most commonly used methods. Conventional biological treatment gives a high removal efficiency in the reduction of organics. When the nitrification-denitrification processes are used nitrogen removal is successfully achieved.

In chemical precipitation, depends upon the coagulant and dosage, chemical oxygen demand (COD), total phosphorus (TP), suspended solids (SS), and turbidity or color are removed with the varying degrees. Nitrogen removal cannot be as high as in nitrification-denitrification process.

According to the purpose, chemical precipitation can be profitable and sometimes has more advantages than that of biological treatment. These advantages are:

a) Chemical precipitation can be applied in a very short period of time;

b) when the appropriate coagulant type and dosage are used the desirable removal efficiency can be obtained;

c) chemical precipitation costs less than biological treatment.

2.2 THE APPLICATION OF CHEMICAL PRECIPITATION TO DOMESTIC WASTEWATERS

2.2.1 HISTORY

There have been many plans, systems and patents for the chemical treatment of sewage since it was first used in Paris in 1740.

The early days of chemical treatment in England are described by Dunbar : The Commission appointed by the Government had all recommended land treatment of sewage, but at an early date, private individuals had urged the advantages of chemical treatment. Government experts had repeatedly emphasized the various chemical methods as insufficient. Austin, the Chief Inspector of the General Board of Health, recommended in 1857, " the preparation of a compost from the solid matters separated from the sewage by the use of precipitants, of which he mentions lime, either alone or in conjunction with sulphate of alumina, sulphate of iron, burnt magnesia, animal charcoal, etc. He regarded the action of chemical precipitants as simply an aid to the separation of suspended matter from sewage, and was opinion that these suspended matters should be removed from the sewage before its application to land."

Dunbar further notes : "With regard to the purification produced, precipitation processes have again and again given rise to disappointment. The splendid

results obtained in laboratory experiments and specially-constructed experimental works led the authorities of English towns to preserve with experiments. About 1888 following the example of England, a few German towns adopted chemical precipitation. In every case, however the opinion of the English commission was confirmed, to the effect that chemical precipitation effected a satisfactory removal of the suspended matters, but yielded a putrescible effluent, which deposited solid matters in the bed of stream; that the process was very expensive, and produced much larger quantities of sludge than were yielded by sedimentation. The sludge was practically unsalable, and thus, owing to the putrescent character, the rapidly growing sludge tips were a menace to the neighbourhood. The sludge question became a bugbear, which was partially overcome by the introduction of sludge presses, which were first used at Aylesbury, then at Merton, and Wimbledon (1884), and at the present day are to be found at almost every sewage works. The presses convert the sludge into solid cakes, which are at least transportable.

Kinnicut, Winslow and Pratt state : " The process was at first greeted on all sides as a method which would solve the sewage problem, and between 1880 and 1890 nearly all the plants installed in England were chemical precipitation plants."

It was claimed that by this method the putrefactive substances in sewage would be removed and that the nitrogenous compounds being precipitated, the sale of this precipitated matter as a fertilizer would pay for the cost of treatment and realize a substantial profit. The hope of financial gain, however, was not realized,

for though the precipitate contained nitrogenous compounds and a certain amount of phosphate, it also contained so much water, that it was found impossible to prepare a markeable product at a cost at all comparable with the price of other chemical fertilizers. Further, it was also slowly recognized that though the process yielded a clear liquid contained a large amount of soluble organic matter and was putrescible.

State of Knowledge in 1893-1894:

Santa Crimp said in 1894 : " The solution of the sewage problem, so far as the employment of the chemicals is concerned, is now placed upon a satisfactory basis, since the vast member of failures or negative results which have been obtained in the use of chemicals have served to reduce the question to one comparative simplicity."

Review of British Processes:

Blew had reviewed the early British processes for chemical treatment of sewage during the period 1860 to 1890. He concluded that the iron salts and lime were most popular, and that very few really new and unique ideas have been developed that can be considered as improvements on early knowledge of the subject.

Kershaw mentions among the principal chemicals in use in Great Britain in 1911 for precipitating sewage; lime, alumino-ferric, ferric sulphate, sulphric acid,

ferrozone, lime and copperas (ferrous sulphate), lime and alumino-ferric, alumino-ferric + blood + charcoal and clay (A.B.C. Process).

The settling of sewage prior to chemical treatment appears in a number of British patents. Manning (1860) proposed to allow the sewage to settle in tanks, draw off the water and add to it as a precipitant and deodorant alum sludge or aluminium sulphate, sulphuric acid and ferric oxide or other material.

Scott (1874) proposed to remove suspended matter by settling tanks, or by filtration, or by combined settling and filtration and to treat the effluent with milk of lime, with further treatment.

The reuse of previously precipitated material as a precipitant appears in a number of British patents. Sillar and Wigner (1863) claim that accumulated sediment from precipitation may be used as a precipitant for another portion sewage.

The most important United States patents relating to the chemical treatment of sewage are also found in Great Britain patent list. Among patents not listed in Great Britain patent list is one of Langleir, in which is claimed a method of water or sewage treatment whereby an acid material added to an alkaline liquid, together with a soluble coagulating salt, in suitable proportions to be determined by experiment (Plant Operation, 1935).

2.2.2 RECENT DEVELOPMENTS IN CHEMICAL PRECIPITATION

In the past, chemical precipitation was used to enhance the degree of suspended solids and BOD removal 1) where there were seasonal variations in the concentrations of the wastewater, 2) where an intermediate degree of treatment was required, and 3) as an aid to the sedimentation process.

Since about 1970, the need to provide more complex removal of the organic compounds and nutrients (nitrogen and phosphorus) contained in wastewater has brought about renewed interest in chemical precipitation. Chemical processes, in conjunction with various physical operations, have been developed for the complete secondary treatment of untreated wastewater, including the removal of nitrogen or phosphorus, or both. Other chemical processes have also been developed to remove phosphorus by chemical precipitation and are designed to be used in conjunction with biological treatment (Metcalf & Eddy).

Among these developments lime-seawater processes have been used since the 1970s. The use of seawater makes lime treatment of wastewater more effective by improving suspended solids and phosphate removal.

II

The process consists of a seawater addition system that continuously blends a small percent of seawater into the wastewater, a lime addition system, mixing, flocculation, sedimentation and sludge handling.

The process has considerably advantages for coastal communities and should be considered whenever biological treatment for BOD removal is not required and where discharge is to marine water (Ferguson F. , 1984).

The beneficial effect of the added seawater is generally; a better quality at a residual lime dosage. The addition of seawater is generally 5 % or 10 % (Odegaard H.,1989).

2.2.3 PROCESS THEORY

Treatment processes in which the removal or treatment of contaminates is brought about by the addition of chemicals or by chemical reactions are classified as chemical processes. Chemical precipitation is the most important and well known example (Tchobanoglous G., Water Quality).

Chemical precipitation consists of the following steps; coagulation, flocculation, and sedimentation.

COAGULATION PROCESS :

It is a chemical process. It has been defined as the addition of chemical to a colloidal dispersion which results in the particle destabilization by the

reduction in forces which tend to keep particles apart. Coagulation involves the reduction of surface charges and the formation of complex hydrous oxides (Talinli I., 1990).

In other words, coagulation is defined as below : Impurities in water and wastewater vary in size by about six orders of magnitude, from a few Angstroms for soluble substances to a few hundred microns for suspended materials. The removal of a large proportion of these impurities in water and wastewater treatment is accomplished by sedimentation. However, because many of the impurities are too small for gravitational settling alone to be an effective removal process, the aggregation of these particles into large more readily settleable aggregates is essential for successful separation by sedimentation. This process of aggregation is termed coagulation (Weber Jr., J., W).

The aggregation of colloidal particles can be considered in two separate and distinct steps; 1) particle transport to effect interparticle contact, and 2) particle destabilization to permit attachment when contact occurs. Theories of particle transport are based on fluid and particle mechanisms; theories of particle destabilization are based on colloid and surface chemistry. The design of structures and flocculation equipment for a coagulation process is influenced by a consideration of interparticle contacts; the selection of the type and dosage of coagulant

is based on particle destabilization. The design of the overall coagulation process must provide for both of these steps (Weber).

Destabilization of colloids can be brought about by different chemical coagulants in different ways. The selection of the proper type and dosage of coagulant for a particular application requires an understanding of these materials function. Four distinct methods are present : 1) Compression of the diffuse layer (double layer compression); 2) adsorption to produce charge neutralization; 3) enmeshment in precipitate; and 4) adsorption to permit interparticle bridging.

Double layer compression is brought about by increasing the total ion concentration. By compressing the electrical double layer, the effect of the surface charge is limited to a thin layer around the particle. As a result the attractive body forces become larger than the repelling electrical forces, so particle growth can occur if the particles collide during flocculation (Tchobanoglous G.).

Charge neutralization can be effected through pH control or by providing cations that adsorb on particle surface (Tchobanoglous G.). The ability of a coagulant to destabilize a colloidal dispersion is actually a composite of coagulant-colloid, coagulant-solvent, and colloid-solvent interactions, coagulant causes the destabilization of a colloidal dispersion.

Precipitate enmeshment results when a precipitate forms and traps colloidal particles (Tchobanoglous). The colloidal particles themselves can serve as nuclei for the formation of the precipitate, so the rate of

the precipitation increases with increasing concentration of the colloidal particles to be removed (Weber).

Within last decade there has been a rapid increase in the use of synthetic organic polymers as destabilizing agents in the treatment of water and wastewater.

To be effective in destabilization, a polymer molecule must contain chemical groups which can interact with sites on the surface of the colloidal particles. When a polymer molecule comes into contact with a colloidal particle, some of these groups adsorb at the particle surface, leaving remainder of the molecule extending out into the solution. If a second particle is not available in time the extended segments may eventually adsorb on other sites on the original particle, so that the polymer is no longer capable of serving as a bridge. Dosages of polymer which are sufficiently large to saturate the colloidal surfaces produce a restabilized colloid, since no sites are available for the formation of interparticle bridges. Under certain conditions, a system which has been destabilized and aggregated can be restabilized by extended agitation, due to the breaking of polymer-surface bands and the subsequent of the particle.

FLOCCULATION PROCESS :

Flocculation is the physical treatment operation in which particle collisions are brought about hydrodynamically, typically using rotating paddles. When

coagulated particles in water and wastewater colloids they tend to aggregate, and thus flocculation results in growth of larger particles. Because of viscous drag, larger particles settle faster than small particles, and therefore aggregation is desirable (Tchobanoglous).

Interparticle contacts, like particle destabilization, can be accomplished in several ways. Three separate mechanisms have concerned chemists and engineers : 1) Contacts by thermal motion, often termed Brownian motion or Brownian diffusion; 2) contacts resulting from bulk fluid motion as, for example, from transport induced by stirring; 3) contacts resulting from settling of the particles. Contacts produced by thermal motion are termed perikinetic flocculation and contacts resulting from fluid motion are termed orthokinetic flocculation (Weber).

Perikinetic Flocculation :

The random motion of colloid particles was first observed by the English botanist Brown in 1827 using a microscope to observe an aqueous pollen suspension. Such random motion of the colloidal particles results from the rapid and random bombardment of the colloidal particles by molecules of the fluid.

The equation for perikinetic flocculation is expressed as follows:

$$N^{\circ} = \frac{N_0^{\circ}}{1 + (T/T_{1/2})} \quad (2.1)$$

where N^* is the total concentration of the particles in suspension at the time t , N_0^* is the initial particle concentration and $T_{1/2}$ represents the time necessary to halve the concentration of particles.

For water at 25°C:

$$T_{1/2} = \frac{1.6 \times 10^{11}}{\eta N_0^*} \quad (2.2)$$

where η is a collision efficiency factor

representing the fraction of the total number collisions which are successful in producing aggregates, and it is dimensionless.

For low initial particle concentrations or poor destabilization, $T_{1/2}$ can be quite large.

Orthokinetic Flocculation :

In many cases it is observed that agitation accelerates the aggregation of colloidal particles. In such systems the velocity of the fluid varies both spatially and temporally. The spatial changes in velocity gradient, \bar{G} . Particles which follow the fluid motion will also have different velocities, so that opportunities exist for interparticle contacts. When contacts between particles are caused by fluid motion the process is sometimes termed orthokinetic flocculation (Overbeek, 1952).

Equation for orthokinetic flocculation is described as follows :

$\frac{dN}{dt} = \frac{-2\pi\bar{c}d^3N^2}{3}$ (2.3) where d is the diameter of colloidal particles.

It is useful to consider the ratio of the rate at which contacts occur by orthokinetic flocculation, J_{ok} , to the rate at which contacts occur by perikinetic flocculation, J_{pk} , as in any given system. So the equation is expressed as follows :

$$\frac{J_{ok}}{J_{pk}} = \mu \bar{G} \frac{d^3}{2kT} \quad (2.4) \quad \text{where } \bar{k} \text{ is the Boltzman's constant and}$$

T is the absolute temperature.

Stirring, therefore, will not enhance the aggregation rate of small particles until they grow to a size of about 1μ . Because when the colloidal particles having a diameter of 1μ the ratio of J_{ok}/J_{pk} is unity and the velocity gradient is 10 seconds. The velocity gradient increases as the diameter of colloidal particles decreases. Particle growth to a size larger than 1μ requires fluid motion by agitation or other means.

SEDIMENTATION PROCESS :

Sedimentation is the unit operation in which suspended materials are removed from liquid phase by gravity settling. Historically, sedimentation has been, and continues to be the most common treatment method used in both water and wastewater treatment systems (Tchobanoglous).

Gravitational separation by sedimentation is generally an effective technique for removal of unstable and destabilized suspended solids from water and wastewater. Development and application of sedimentation for clarification of a water or wastewater must be based on an understanding of the process and the of the variables which affect its efficiency.

Particles from suspension in different ways, depending upon the concentration of the suspension and the characteristics of the particles. Fitch (1958) has described four distinct types of sedimentation which reflect the concentration of the suspension and the flocculating properties of the particles. Class-1 clarification is the settling of a dilute suspension of particles which have little or no tendency to flocculate. The removal of a dilute suspension of flocculent particles is referred to as class-2 clarification. When particles are sufficiently close, interparticle forces are able to hold them in fixed positions relative to each other. As a result, the particles subside as a large mass rather than as discrete particles. This type of clarification is called zone settling. When the particles actually contact each other the resulting structure of compacting mass acts to restrict further consolidation, this action is called compression.

Hazen and Camp (1946) have suggested that the terminal velocity of a particle which settles a distance equal to the effective depth of the tank in a detention period can be thought as an overflow rate;

$$v_s = \frac{\text{tank depth}}{\text{detention time}} \quad (2.5)$$

$v_s = \frac{Q}{A}$ (2.5.1) where v_s is the settling velocity m/s, Q is the rate of the flow through the tank, and A is the surface area of the tank.

2.2.4 APPLICATION PRINCIPLES

In coagulant process, the coagulant added to sewage react either with substances normally present in the sewage or with substances added for this purpose (Plant Operation, 1935; Talinli I. 1990).

REACTIONS IN CHEMICAL PRECIPITATIONS :

The most commonly using coagulants in water and wastewater are; lime, ferrous sulphate, ferric sulphate, ferric chloride, alum. The metal salts can be used either alone or with lime.

LIME : When lime is alone added as a precipitant, the principles of clarification are explained by the following reactions :



A sufficient quantity of lime, therefore must be added to combine all the free carbonic acid and with the bicarbonates to produce calcium carbonate, which acts as the coagulant.

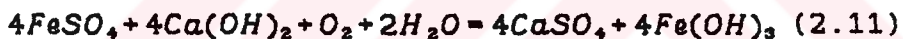
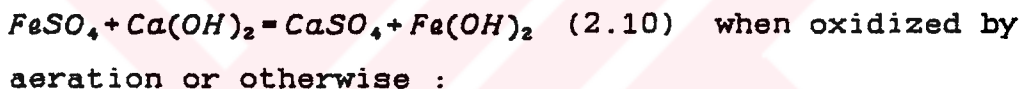
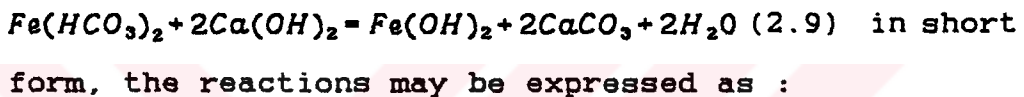
If too much lime is used in the treatment of sewage, some of the suspended organic matter will be dissolved by the caustic calcium hydroxide and the effluent may be worse than the untreated sewage. If insufficient quantities are added, the effluent will not be well clarified.

FERROUS SULPHATE AND LIME : In ordinary sewages, ferrous sulphate (copperas) cannot be employed alone as a

precipitant but lime must also be added, as will appear from the reactions involved (Plant Operation 1935; Germirli, et al.). This process is commonly spoken of as the iron and lime process.



If lime is now added in the form of milk of lime the reaction that takes place is :

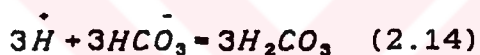
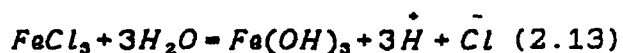


Ferrous bicarbonate, ferrous hydroxide are very slightly soluble materials. In sewage treatment, lime is commonly added in excess of amount required to complete iron and lime reaction, the excess lime acting as an additional clarifying agent. Since the formation of ferric hydroxide is dependent upon the presence of dissolved oxygen, lime and lime cannot well be used with septic sewage or industrial wastes devoid of oxygen (Plant Operation).

FERRIC SULPHATE AND LIME : Ferric sulphate is a good coagulant, even without the addition of lime. The result of adding ferric sulphate and lime also leads to the production of the insoluble ferric hydroxide :



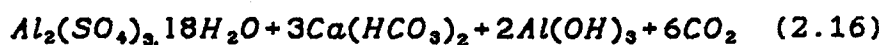
FERRIC CHLORIDE : Hydes points out that when ferric chloride is added to water it hydrolyses to form ferric hydroxide and releases hydrogen and chloride ions. The hydrogen combines with the bicarbonate ion to form slightly ionized carbonic acid. The chloride ion remains in the water. The reactions may be expressed as follows :



FERRIC CHLORIDE AND LIME : The addition of ferric chloride and lime to sewage result in the production of the insoluble ferric hydroxide :



ALUM : When alum is added to sewage containing in solution calcium and magnesium bicarbonate alkalinity, the reaction that occurs may be shown as follows :



The insoluble aluminium hydroxide is formed as a bulky, gelatinous floc which settles slowly through the sewage, sweeping out suspended matter and producing other changes in the liquid.

SELECTION OF COAGULANT : The selection of the optimum type and dosage of coagulant cannot be made for any water and wastewater without experiments. Theories of colloid destabilization are just not sufficiently developed at the present to permit such a selection without some experimentation. The colloid concentration, pH, and alkalinity of a water or wastewater can control the effectiveness of $\text{Al}(+3)$, $\text{Fe}(+3)$, and lime as coagulant (Weber).

Also, the choice of a coagulant depends on various factors other than its basic price. Factors of importance include transportation cost, quantity required and handling, storing and feeding requirements and facilities (Plant operation).

ROLE OF POLYELECTROLYTES IN COAGULATION : Polymeric flocculants or polyelectrolytes can be either synthetic or natural. Many natural compounds are cellulose materials, polysaccharide gums and proteinaceous materials. Synthetic polyelectrolytes have the advantage that they can be tailored to meet specific requirements. They are classified by the type of charge; a negative charge is called an anionic polymer, a positively charged polymer is referred to as cationic, and a nonionic polymer has no charge. The major advantage of the polymer compounds is to increase the floc size of the coagulated particles (Talinli I. 1990).

FLOCCULATION UNITS AND VELOCITY GRADIENT : Flocculation tanks are designed to provide interparticle contacts. Generally these contacts are brought about by orthokinetic flocculation; that is colloidal particles collide with each other due to velocity gradients which are produced within the fluid by hydraulic or mechanical means. Design involves the selection of a velocity gradient, a reactor configuration, and a detention time sufficient to produce aggregates of a size suitable for removal from suspension in a subsequent treatment unit (e.g. a settling tank, vacuum filter).

In the process of coagulation-flocculation the ability of particles to catch up and make contacts one another can be evaluated by the velocity gradient (Oldshue and Mady, 1979).

Camp and Stein (1943) demonstrated that the absolute velocity gradient at a point in a fluid in motion is equal to the square root of the ratio of the power loss by shear per unit volume of fluid to the viscosity of fluid (Mhaisalkar, 1986).

$$\bar{G} = \sqrt{\left(\frac{P/V}{\mu}\right)} \quad (2.17) \quad \text{where } \bar{G} \text{ is the absolute velocity}$$

gradient, P is the power input, V is the volume of fluid, and μ is the absolute viscosity of the fluid. In water and wastewater treatment, mean velocity gradient of 10 to 100/sec are common.

The effectiveness of flocculation facilities has been considered by designers to be proportional to the product of the velocity gradient and the detention time, $\bar{G}.t$. Values for the dimensionless product $\bar{G}.t$ in water treatment practice are reported to vary by about one order magnitude, from 10^4 to 10^5 .

MIXING UNITS : Mixing is an important unit operation in many phases of wastewater treatment where one substance must be completely intermingled with another. Chemicals are also mixed with sludge improve its dewatering characteristics before vacuum filtration.

The production of a floc usually requires a detention time of 15 to 30 minutes. On the other hand, a detention time of 2 to 5 minutes is more than adequate for the flash mixing of chemicals in tanks equipped with turbine or propeller mixers.

Turbine mixers are used in sludge blending tanks. Large blenders are designed to rotate at moderate speeds (about 25 to 100 r/min). Propeller type impellers have also been used for high speed mixing with rotational speeds up to 2000 r/min.

CLARIFIER UNITS : A clarifier usually has at least two and perhaps three main function to perform : 1) The settling must provide for effective removal of suspended solids from its effluent; 2) the sludge removal capacity must be adequate; 3) thickening of the sludge may be important. Any failure in one these functions will impair the performance of the tank and, if serious, destroying the effectiveness of the process almost completely.

Expect for wastes of known characteristics or for suspensions composed of discretely settling particles of known density and size distribution, it is recommended that tank design be based on the results of settling velocity experiments.

The detention time of sedimentation basins may vary from one hour to more than a day. Mechanically cleaned basins are usually designed for a holding time of 1.5 to 3 hours (Weber). Surface loading rate is another important factor affect the settling performance. It is expressed as cubic meters per day per square meter of surface area. Surface loading rate increases as the detention time decreases. For example, while the detention time is 1.5 hours the appropriate surface loading rate is $48 \frac{\text{m}^3}{\text{m}^2 \text{d}}$ for a 3 meter tank depth.

2.2.5 THE CHARACTERISTICS OF DOMESTIC WASTEWATERS

Depending on the concentrations of the constituents, wastewater is classified as strong, medium, or weak. Both of the constituents and the concentrations vary with place, time, and other local conditions. Table 2.1 gives the typical data.

Rates of sedimentation, mass transfer, adsorption, diffusion and biochemical reaction are all influenced by particle size. Therefore classification by size in

wastewater is important for developing a more fundamental understanding of the complex interactions that occur in the unit operations and treatment processes (Levine D. A., 1985).

As Levine et al. pointed out the importance of size distribution in the characterization of wastewater, they also mentioned that the effectiveness of coagulation-flocculation process depended on the nature of the chemical that are used, the effectiveness of the initial mixing operations and the number of collisions between particle brought by differential internal fluid shear and by differential settling velocities. All of these mechanisms are related to the particle size. Chemical coagulation/flocculation processes can be used to aggregate wastewater constituents in the size range from less than 0.1 to about 10 μm .

Classification of particle size is expressed in four groups; soluble, colloidal, supracolloidal, and settleable. Table 2.2 shows the classification of the organic contaminates in wastewater (Odegaard, 1989).

Table 2.3 shows a more recent study on this subject (Munck et al. 1980).

TABLE 2.1. TYPICAL CHARACTERISTICS OF DOMESTIC WASTEWATERS

PARAMETER	STRONG	MEDIUM	WEAK
BOI ₅ (mg/L)	400	220	110
COD (mg/L)	1000	500	250
TP (mg/L)	15	8	4
TKN (mg/L)	85	40	20
NH ₃ -N (mg/L)	50	25	12
ALKALINITY (mg/L)	200	100	50
SS (mg/L)	350	220	100
VSS %	78.6	75	80
GREASE (mg/L)	150	100	50

TABLE 2.2 Classification of organic constituents in wastewater
(Balmat 1957, Heukelekian and Balmat 1959,
Richert and Hunter 1971)

	SOLUBLE	COLLOIDAL	SUPRACOLLOIDAL	SETTLEABLE
SIZE RANGE	<0.08 μm	0.08–1.0 μm	1–100 μm	>100 μm
COD % of tot.	25	15	26	34
TOC % of tot.	31	14	24	31
BOD oxid.rate (k, d ⁻¹)	0.39	0.22	0.09	0.08

TABLE 2.3. Classification of contaminants in wastewater
(Munck et al. 1980)

	SOLUBLE	COLLOIDAL	SUPRAOLLOIDAL	SETTLEABLE
SIZE RANGE	<0.025	0.025–3 μm	3–106 μm	>106 μm
BOD ₅ % of tot	17	16	46	21
COD % of tot	22	15	30	43
TOC % of tot	22	6	36	36
TP % of tot	63	3	12	22
Org.N % of tot	27	15	38	20

2.2.6 THE DEGREE OF TREATMENT ACCOMPLISHED BY CHEMICAL PRECIPITATION

The removal efficiency is affected by the coagulant type and dosage. It is found that the removal rate increases as the dosage increases.

FOR ORGANIC CONSTITUENTS : Organic constituents in wastewater such as BOD, COD can be removed from the wastewater by chemical precipitation. The degree for BOD removal is not as high as in biological treatment systems, but for COD, the removal is moderately. In the reduction of suspended solids the effluent is clear and the rate is up to 95 % .

In BOD reduction, chemical precipitation achieves a removal rate between 20 % to 65 % (Mosey, 1991). To obtain a BOD reduction exceeding 65 % requires excessively large amounts of chemicals (Plant Operation). The COD removal is as high as 80 % (Plant Operation, Mosey).

In fact, it is generally considered to be impossible to remove all of the colloidal matter by chemical precipitation. Thus, effluents from such treatment usually are not sparkling clear but contain fine turbidity or a slight opacity caused by the most highly

dispersed insoluble matter (Plant Operation). The removal rate of suspended solids is in the range of 90 % .

FOR NUTRIENTS : Nutrient removal from wastewater is very important in order to prevent eutrophication in receiving waters. Nitrogen and phosphorus are the main nutrients and chemical precipitation achieves a high removal efficiency in phosphorus.

Phosphorus can be easily removed from the wastewater. With the addition of alum or ferric chloride, the removal rate increases to 80 95 % . The use of ferrous chloride in a two stage phosphorus removal process reduced total phosphorus to less than 0.2 mg / L and lowered operating costs (Philp, D.). When lime is used as coagulant the removal efficiency is about 90 % . Nitrogen removal is in the range of 30 to 50 % as total nitrogen and 50 to 90 % as organic nitrogen.

FOR TOXIC SUBSTANCES : For toxic substances, chemical treatment gives a very high removal efficiency. The removal of heavy metals such as cadmium, zinc by chemical precipitation is high enough to meet the discharge criteria.

When ferric chloride is used as coagulant cadmium removal can be as high as 100 % dependent upon pH. With the increasing pH the removal rate also increases. By adding magnetite the removal efficiency is affected positively (Terashima A.).

2.2.7 THE COMPARISON OF CHEMICAL PRECIPITATION AND OTHER TREATMENT SYSTEMS IN TERMS OF REMOVAL EFFICIENCIES

Chemical precipitation is now considered as a secondary treatment system. As mentioned above it gives more than adequate removal efficiencies and thus, it can be accepted as a proper treatment system.

As it is seen in the comparison table in the evaluation chapter, chemical treatment gives better reduction rates for some constituents.

In BOD removal, while chemical precipitation achieves a maximum removal efficiency of 65 % , conventional biological treatment system gives a removal efficiency of up to 90 % , trickling filter process achieves a removal rate of BOD of 85 to 90 % , rotating biological contactor has a removal efficiency rate of over 95 % .

For COD removal, chemical precipitation achieves good enough removal efficiency for the discharging criteria. The rate is up to 80 % , in the conventional biological treatment system this rate is about 80 to

85 % , in the trickling filter the removal rate is around 80 % , and in the rotating biological contactor this ratio is over 85 % .

In the reduction of suspended solids, chemical precipitation accomplishes over 90 % removal efficiency. Conventional treatment system has a removal efficiency of 90 % , the trickling filter and rotating biological contactor systems have a removal rate of 90 % .

In the removal of phosphorus, chemical precipitation has the greatest removal efficiency in the whole treatment systems. The removal rate is up to 95 % resulting in the value of less than 1 mg / L when the appropriate coagulant and dosage are used. In the conventional treatment system phosphorus removal is about 30 % , for trickling filter process and rotating biological contactor phosphorus removal rate are similar to conventional system's.

Nitrogen removal is sufficiently achieved in nitrification denitrification process. The removal rate of nitrogen as total nitrogen in chemical precipitation is up to 50 % , in conventional system this ratio is about 10 to 20 % , trickling filter has the same removal rate as conventional treatment system, and in the rotating biological contactor this ratio is about 50 % (Metcalf, Weber).

3 NITROGEN AND PHOSPHORUS REMOVAL BY CHEMICAL TREATMENT

3.1 NITROGEN

3.1.1 THE ROLE OF NITROGEN

Nitrogen is an essential nutrient for the growth of plants and microorganisms. However excess nitrogen in wastewater treatment effluents, like excess phosphorus, has been shown to be associated with undesirable algae and plant growth in receiving waters. The ammonia form nitrogen is toxic to fish (Nutrient Control, 1983).

The adverse effects of nitrogen can be counted as follows : Deplete oxygen levels in receiving waters, stimulate aquatic growth, exhibit toxicity toward aquatic life, affect chlorine disinfection efficiency, present a health hazard, affect the suitability of wastewaters for reuse (Eroglu, V.,1990).

Numerous study have shown that nitrogen can become limiting in the control of algal growths during the summer season at a limiting level of 0.05 mg / L of inorganic forms (NH_3-N+NO_3-N). On this basis,

nitrogen removal wastewaters may become necessary when receiving waters are insufficient in quantity to dilute inorganic forms to the limiting level.

The principal compounds of nitrogen are; ammonia nitrogen, nitrite nitrogen, nitrate nitrogen, organic nitrogen and nitrogen gas.

Ammonia nitrogen may serve as a prime nutrient to support phytoplankton and rooted aquatic growths. Some will be lost to the atmosphere as gaseous NH_3 when its partial pressure in the water is greater than that of in the atmosphere (Nutrient Control, 1983).

The degree of loss is a function of pH and temperature, which controls the concentration of ammonia (ammonium ion) by this effect on the equilibrium :



At a pH level of 7, only ammonium ions (NH_4^+) in true solution are present.

3.1.2 CHEMICAL NITROGEN REMOVAL

In chemical precipitation, insoluble complexes are brought about by the coagulants and the colloidal particles. These complexes precipitate in the sedimentation process.

For nitrogen there are not much complexes that are insoluble and precipitable. But by the addition of adequate coagulants organic nitrogen can be removed from the water in the ratio of 50 to 90 % (Metcalf).

As previously mentioned, ammonium ions (NH_4^+) converts to ammonia (NH_3) at high pH levels. By raising the pH to 11 ammonium / ammonia ($\text{NH}_4^+/\text{NH}_3$) ratio can be as high as 95 % .

Nitrogen removal can be accomplished by either air stripping of ammonia or breakpoint chlorination or selective ion exchange.

AIR STRIPPING :

The air stripping of ammonia from the wastewater is a modification of the process used for the removal of gases dissolved in water. As previously mentioned above, ammonium ions converts to ammonia which may be removed as a gas by agitating the wastewater in the presence of air.

There are three basic types of stripping units now being used in full-scale application ; 1)countercurrent towers, 2)crossflow towers, and 3)stripping ponds.

The advantages of ammonia stripping are ; low cost, simplicity, and reliability. In cold weather this process has poor efficiency in removing ammonia (Nitrogen Control, EPA).

Generally lime is used to rise the pH to 11. It also serves as a coagulant for phosphorus removal.

BREAKPOINT CHLORINATION :

Breakpoint chlorination, in which a sufficient amount of chlorine is added to oxidize ammonia nitrogen in solution to nitrogen gas and other stable compounds, is an alternative method of achieving nitrogen control. Perhaps the most important advantage of this process is that, with proper control and flow equalization, all ammonia nitrogen in the wastewater can be reduced to zero. An added advantage is that disinfection of the wastewater is achieved at the same time (Metcalf).

ION EXCHANGE :

Ion exchange is a unit process by which ions of a given species are displaced from an insoluble exchange material by ions of a different species in solution. It may be operated in either a batch or a continuous mode. In a batch process, the resin is simply stirred with the water to be treated in a reactor until the resin is complete. The spent resin is removed by settling and subsequently is regenerated and reused. Although both natural and synthetic resins are available, synthetic resins are used more widely because of their durability. Nevertheless, some natural resins (zeolites) have found application in the removal of ammonia from water (Metcalf).

3 . 2 P H O S P H O R U S

3 . 2 . 1 T H E R O L E O F P H O S P H O R U S

Phosphorus is another essential nutrient for the growth of plants and microorganisms. However, excess phosphorus, and nitrogen in treated wastewater has been shown to be associated with undesirable algae and plant growth in receiving waters.

The phosphorus is described as total phosphorus, organically bound phosphorus, and inorganic phosphorus all expressed as P. The inorganic phosphorus includes simple orthophosphates and polyphosphates. The inorganic form of phosphorus comprise approximately 70 % of total phosphorus in domestic wastewater (Nutrient Control).

The soluble orthophosphates are the simplest forms of phosphorus and are the end product of the breakdown of inorganic polyphosphates and organically bound phosphorus. Soluble orthophosphates typically comprise 15 to 30 % of the total phosphorus in fresh domestic wastewater (Nutrient Control).

3.2.2 CHEMICAL PHOSPHORUS REMOVAL

In instance where nutrient control is deemed desirable, control of phosphorus is considered to be absolutely essential because, when nitrogen becomes limiting, any excess of phosphorus can support growth of nitrogen-fixing blue-green algae. In such cases, the nitrogen budget of a body of water will be increased, thereby materially off-setting any benefits from nitrogen removal.

Phosphorus in the form of phosphates and organic compounds can be easily removed by precipitation with lime or with multivalent cations as relatively inexpensive salts of aluminium or iron (Nutrient Control).

3.2.2.1 PHOSPHORUS REMOVAL WITH IRON AND ALUMINIUM SALTS

It is now generally recognized that a metal phosphate is formed when ferrous or ferric of iron or aluminium is added to a solution containing phosphate.

Phosphate removed with aluminium or iron often settles poorly, requiring the use of excess salts or organic polymers, or both, for attaining good settling and hence, good removal of the phosphate precipitate.

The reactions for aluminium and iron are expressed as follows :



where $K = 10^{-23}$



where $K = 10^{-21}$

Although these values indicate that a low residual is possible, in practice the mole ratios for substantial level of removal (greater than 95 %) are generally near 1.5 and 2.0. This is probably the result of the necessity to operate at pH values somewhat removed from optimum.

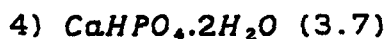
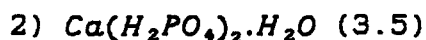
Optimum pH values for Fe(+3) and for Al(+3) are 5.3 and 6.3 respectively. But generally these values cannot be used in actual practise as explained above. The pH is generally higher than the optimum values.

The dosage of aluminium and iron salts are generally expressed as the molar ratio of the metal ion to total phosphorus present in the wastewater. These ratios vary in the range of 1.5 to 2 as metal ion molar concentration to total phosphorus molar concentration.

As a result, phosphorus removal in excess of 90 % and residual phosphorus values of less than 0.5 mg / L are easily attainable with iron and aluminium salts (Nutrient Control, Metcalf).

3.2.2.2 PHOSPHORUS REMOVAL WITH LIME

There are five calcium phosphate compounds that can be precipitated from aqueous solutions, as reported by Van Wazer. There are:



Clark reports the K_{25}° as follows :

$$K_{25}^{\circ} = [\text{Ca}]^{10} [\text{PO}_4]^{6} [\text{OH}]^2 = 10^{-118} \quad (3.9)$$

Mener and Jenkins confirm that the significant form is hydroxiapatite $\text{Ca}_5(\text{OH})(\text{PO}_3)_3$ at all encountered sewage process pH values.

Low lime treatment can be used to precipitate a portion of phosphorus usually about 65 to 80 % at pH values 9.5 or below (Nutrient Control, Metcalf). In the high lime system, sufficient lime is added to raise the pH to about 11. Sawyer found that a pH of 11 was required to reduce phosphate to residual values of less than 0.5 mg / L phosphorus.

The quantity of lime required for phosphorus precipitation is proportional to the buffering capacity of the system and is not related to the quantity of phosphate present in most wastewaters. Wuhrman has stated that the lime requirement for reaching a pH of 10.5 to 11 will be 1.5 times the alkalinity available in wastewater.

Lime requirement is also related to the pH, turbidity, and magnesium concentration (Nutrient Control).

3.2.3 OTHER PHOSPHORUS REMOVAL PROCESSES

Phosphorus removal is also achieved by biological-chemical treatment processes and land treatment.

Chemicals can be added at a variety of different points in the biological chemical treatment process. These points can be summarized as; a) before primary sedimentation, b) before and/or following biological treatment system, c) following secondary treatment, d) several locations.

In the last years biological phosphorus removal is used especially in U.S. (Syed R. Qasim, Ramodori R.).

4 TREATMENT REQUIREMENT IN ISTANBUL

Istanbul metropolitan area is divided into fourteen (14) main wastewater discharge regions. These can be gathered in three groups according to the oceanographic characteristics of receiving waters that they are used for wastewater discharging :

1. REGION : Discharging to Istanbul Bosphorus (Baltalimani, Uskudar, Kucuksu, Tarabya, and Pasabahce).

2. REGION : Discharging to the mixing area of Istanbul Bosphorus and Marmara Sea (Kadikoy and Yenikapi).

3. REGION : Discharging to Marmara Sea, out of the mixing area of Istanbul Bosphorus and Marmara Sea (Atakoy, Tuzla, Kucukcekmece, Buyukcekmece, Tuzla leather industry, islands, and Western Buyukcekmece).

Because of having the maximum the maximum values in the meaning of wastewater flow, BOD loading, suspended solids loading, total nitrogen loading, and total phosphorus loading the second region Istanbul Bosphorus and Marmara Sea mixing area comes first. The reason is related to the rapid population augmentation and industrial progression.

According to the calculations of wastewater flow and contaminates loadings for the year of 2020, there will be an increment three or four times as much as for the year of 1990.

The most important environmental deterioration observed in Marmara Sea is the lack of dissolved oxygen.

Marmara Sea is an eutrophic sea according to the parameters of nitrogen and phosphorus. While the upper limit values of an eutrophic sea for phosphate (PO_4-P) and nitrogen (NO_3-N+NO_2-N) are approximately $0.3 \mu\text{mol} / \text{L}$ and $1.0 \mu\text{mol} / \text{L}$ respectively, in Marmara Sea mean concentration values of phosphate (PO_4-P) and nitrogen (NO_3-N+NO_2-N) are $0.24 \mu\text{mol P} / \text{L}$ and $1.6 \mu\text{mol N} / \text{L}$ respectively. So when the values of Marmara Sea are compared with these limits, it is accepted that Marmara Sea is an eutrophic sea (Meric S.).

When the calculated values of phosphorus loading coming from Istanbul for 1990 is compared with the value of phosphorus loading coming from Blacksea, it is seen that Istanbul gives phosphorus loading 1.03 times as much as Blacksea's. For nitrogen loading, Istanbul gives approximately 1.6 time as much as Blacksea's (Meric S.).

5 EXPERIMENTAL STUDY

5.1 PLANNING OF EXPERIMENTAL STUDY

The experimental study of chemical precipitation of Istanbul Yenikapi discharge wastewater contains the following steps :

1) Characterization of wastewater, 2) classification by size distribution, 3) settling performance, 4) coagulation with lime, 5) coagulation with iron salts, 6) sludge characterization, 7) results.

5.2 SYSTEMS USED IN THIS STUDY

Both in coagulation with lime and iron salts, jar test apparatus is used in order to obtain optimum pH and dosages for the removal of various parameters.

Jar test apparatus consists of mixing paddles which its speed is adjustable for rapid mixing or slow mixing. Beakers are used as tanks that provide coagulation, flocculation and sedimentation processes. To obtain the

optimum pH and dosages five or six beakers are used with a volume of 500 ml. Different dosages are applied to each one.

For rapid mixing, over 100 rpm is chosen for 45 seconds. In the slow mixing where flocculation occurs, 15 to 20 rpm is chosen for 15 minutes.

Flocculation by air mixing is also used in this study. The air requirement is calculated from the following equations :

$$\frac{P_o}{P_i} = \frac{101000 + (A \cdot 9.81)}{101000} \quad (5.1)$$

where P_o and P_i are outlet and inlet pressures respectively (Pa), since atmospheric pressure is 101 kPa, h is the height of tank (mm)

So the ratio of $\frac{P_o}{P_i} = 1.0038$ when h is taken as 40 mm (for beaker).

By using the expression of;

$$\frac{\Delta T}{T} = \left(\frac{P_o}{P_i} \right)^{\frac{1-(1/\gamma)}{\gamma}} - 1 \quad (5.2)$$

where ΔT is the change in temperature (K) between inlet and outlet gas temperatures, γ for air 20°C (293.2 K) is 1.40, thus ΔT is calculated as $\Delta T = 0.325$ K.

The power dissipated in mixing a body of water by mean of air diffusers can be calculated from the expression;

$$P = 1236 Q_a \Delta T \quad (5.3)$$

where P is the power in watt, and Q_a is the free air flowrate in m^3/s

by using the velocity gradient expression the power is found;

$$G = \sqrt{\left(\frac{P/V}{\mu}\right)} \quad (5.4)$$

G is chosen 70 s^{-1} , V is 500 ml. and $P = 2.695.10^{-3}$ is found. From the equation of (5.3) $Q_a = 402.5 \text{ ml} / \text{min}$ is found.

In this study this flowrate is used between the ranges of 300 to 400 ml / min.

One and half (1.5) hours is chosen for the detention time of sedimentation.

5.3 SAMPLING

Samples are supplied from Istanbul Yenikapi physical treatment plant, after screening and grit chamber as composite samples for 1/2 hour in a 6 hour period.

5.4 THE PROCEDURE

In characterization of wastewater the following parameters are examined: BOD_5 , COD, TKN, TP, NH_3-N , NO_3-N , Cl^- , detergent, phenol, oil and grease, pH, alkalinity, SS, VSS, turbidity, TCr, Zn, and Cd.

Classification by size distribution is achieved in three groups; total, soluble and settleable.

Soluble part of wastewater is supplied by filtering the sample through a $0.045\ \mu m$ glass fibre. Settleable part of the wastewater is supplied by leaving the sample in Imhoff funnel for one hour.

Settling performance, is achieved by settling the sample without addition of coagulant.

In the coagulation with lime $Ca(OH)_2$ is used as coagulant. The lime dosages vary from 100 mg/L to 350 mg/L to find out the optimum pH and dosages for the removal efficiencies of various parameters.

In the coagulation with iron salts, $FeSO_4$ and $FeCl_3$ are used either alone or with the conjunction of lime. The dosages are obtained for phosphorus removal. The calculation is determined according to the molar concentration of total phosphorus present in wastewater. This ratio is accepted as 2.5 as metal molar concentration to total phosphorus molar concentration present wastewater.

A nonionic synthetic polymer N-207 is used in the coagulation with lime and cationic polymer separan is used in the coagulation with iron salts processes. The application value is 2 mg/L.

In the examination of parameters " Standard Methods for the Examination of Water and Wastewater APHA AWWA WPCF 1989 17. Edition " is used as reference. Only for COD parameter " International Organization for Standardization " is used as reference.

Table 5.1 shows the methods that are used in the examination of parameters :

5.5 RESULTS

The results of the experimental study are expressed with the Tables. There are three wastewater characterization and jar test results in the study. In the third wastewater, total phosphorus concentration is raised to 15 mg/L, TCr is raised to 2 mg/L, Zn is raised to 5 mg/L, and Cd is raised to 1.0 mg/L by synthetically in order to understand the chemical precipitation performance, when the heavy metal concentrations and phosphorus are high.

TABLE 5.1. Methods used in the examination of parameters
(APHA, 17. Edition, 1989)

PARAMETER	METHOD
BOD ₅	General
COD	Open reflux / ISO
TKN	Macro Kjeldahl + titrimetric
NH ₃ -N	Distillation + titrimetric
NO ₃ -N	Cadmium reduction
TP	Nitric acid+sulphuric acid dig./col
Cl ⁻	Mercuric nitrate method
DETERGENT	Anionic MBAS
PHENOL	Clen up / direct colorimetric
OIL & GREASE	Soxlet procedue
SS	General
VSS	General
ALKALINITY	General
METALS	Nitric acid dig./ atomic absorp.

TABLE 5.2. YENIKAPI WASTEWATER CHARACTERIZATION I

PARAMETER	TOTAL	SOLUBLE	SETTLEABLE
BOI ₅ (mg/L)	320	140	200
COD (mg/L)	650	197	293
TP (mg/L)	6.3	2.6	3.1
TKN (mg/L)	64	41	44
NH ₃ -N (mg/L)	35	30	–
Cl [–] (mg/L)	910	–	–
DETERGENT (mg/L)	1.64	–	–
PHENOL (mg/L)	0.60	–	–
pH (pH unit)	7.25	–	–
ALKALINITY (mg/L)	190	–	–
SS (mg/L)	360	–	–
VSS %	65.6	–	–
TURBIDITY (NTU)	77	–	–
TCr (mg/L)	0.5	<0.1	<0.1
Zn (mg/L)	1.7	0.14	0.22

TABLE 5.3. YENIKAPI WASTEWATER CHARACTERIZATION II

PARAMETER	TOTAL	SOLUBLE	SETTLEABLE
BOI ₅ (mg/L)	290	100	198
COD (mg/L)	650	175	380
TP (mg/L)	6.7	2.9	5.1
TKN (mg/L)	56	43	50
NH ₃ -N (mg/L)	32	28	-
Cl ⁻ (mg/L)	700	-	-
DETERGENT (mg/L)	1.4	-	-
PHENOL (mg/L)	1.0	-	-
pH (pH unit)	7.25	-	-
ALKALINITY (mg/L)	230	-	-
SS (mg/L)	450	-	178
VSS %	69	-	-
TURBIDITY (NTU)	115	-	-
TCr (mg/L)	1.0	<0.5	0.5
Zn (mg/L)	0.44	<0.1	0.23
Cd (mg/L)	<0.1	<0.1	<0.1

TABLE 5.4. YENIKAPI WASTEWATER CHARACTERIZATION III

PARAMETER	TOTAL	SOLUBLE	SETTLEABLE
BOI ₅ (mg/L)	310	175	245
COD (mg/L)	625	215	392
TP (mg/L)	12.5	7.6	11.2
TKN (mg/L)	64.4	56	62
NH ₃ -N (mg/L)	37	32.5	35.8
NO ₃ -N (mg/L)	0	0	0
Cl ⁻ (mg/L)	650	-	-
DETERGENT (mg/L)	1.3	-	-
PHENOL (mg/L)	0.7	-	-
OIL & GREASE (mg/L)	137	-	115
pH (pH unit)	7.3	-	-
ALKALINITY (mg/L)	220	-	-
SS (mg/L)	350	-	150
VSS %	66	-	-
TURBIDITY (NTU)	74	-	-
TCr (mg/L)	1.75	<0.5	0.75
Zn (mg/L)	0.3	<0.1	0.15
Cd (mg/L)	0	0	0

TABLE 5.5. PARTICLE DISTRIBUTION I

PARAMETER	SOLUBLE % of total	SETTLEABLE % of total
BOD ₅	43.75	62.5
COD	30	45
TP	41	49
TKN	64	68.75
NH ₃ -N	85.7	-

TABLE 5.6. PARTICLE DISTRIBUTION II

PARAMETER	SOLUBLE % of total	SETTLEABLE % of total
BOD ₅	34	68
COD	27	58
TP	43	76
TKN	77	89
NH ₃ -N	87.5	-

TABLE 5.7. PARTICLE DISTRIBUTION III

PARAMETER	SOLUBLE % of total	SETTLEABLE % of total
BOD ₅	56	79
COD	34.4	62.7
TP	60.8	89.6
TKN	87	96
NH ₃ -N	87.8	96.7

TABLE 5.8.1. JAR TEST RESULTS I

Ca(OH) ₂ mg/L	pH	IN TKN mg/L	OUT TKN mg/L	REMOVAL TKN %	IN NH ₃ -N mg/L	OUT NH ₃ -N mg/L	REMOVAL NH ₃ -N %	IN COD mg/L	OUT COD mg/L	REMOVAL COD %	IN TP mg/L	OUT TP mg/L	REMOVAL TP %	IN SS mg/L	OUT SS mg/L	REMOVAL SS %
100	9.2	64	43.3	32	35	32.8	6	650	169	74	6.3	1.1	82.5	360	16	95.5
150	9.4	64	42.0	34	35	34.4	2	650	173	73	6.3	0.7	88.8	360	13	96.4
200	10.0	64	37.8	41	35	21.8	38	650	130	80	6.3	0.5	92.0	360	8	97.7
250	10.4	64	39.8	38	35	19.0	46	650	140	78	6.3	0.8	87.3	360	6	98.3
300	11.3	64	36.9	42	35	21.0	40	650	128	80	6.3	0.9	85.0	360	4	98.8

TABLE 5.8.2. JAR TEST RESULTS I

Ca(OH) ₂ mg/L	pH	IN PHENOL mg/L	OUT PHENOL mg/L	REMOVAL PHENOL %	IN DETERGENT mg/L	OUT DETERGENT mg/L	REMOVAL DETERGENT %	IN TCr mg/L	OUT TCr mg/L	REMOVAL TCr %	IN Zn mg/L	OUT Zn mg/L	REMOVAL Zn %	IN TURB. NTU	OUT TURB. NTU
100	9.2	0.6	0.07	88.3	1.64	0.44	73.2	0.5	0.1	80	1.7	0.1	94	77	19
150	9.4	0.6	0.05	91.6	1.64	0.29	82.3	0.5	0.1	80	1.7	<0.1	>94	77	14
200	10.0	0.6	0.05	91.6	1.64	0.44	73.2	0.5	0.1	80	1.7	<0.1	>94	77	3.2
250	10.4	0.6	<0.01	>98.3	1.64	0.32	80.5	0.5	0.1	80	1.7	<0.1	>94	77	2.4
300	11.3	0.6	0.05	91.6	1.64	0.44	73.2	0.5	0.1	80	1.7	<0.1	>94	77	2.1

TABLE 5.9.1 JAR TEST RESULTS II

Ca(OH) ₂ mg/L	pH	IN TKN mg/L	OUT TKN mg/L	REMOVAL TKN %	IN NH ₃ -N mg/L	OUT NH ₃ -N mg/L	REMOVAL NH ₃ -N %	IN COD mg/L	OUT COD mg/L	REMOVAL COD %	IN TP mg/L	OUT TP mg/L	REMOVAL TP %	IN SS mg/L	OUT SS mg/L	REMOVAL SS %
100	9.15	56	43	23	32	26.3	18	650	243	63	6.7	2.5	63	450	96	78.6
150	9.25	56	37	34	32	26	18.7	650	226	65	6.7	2.6	62	450	80	82.2
200	9.7	56	29.6	47	32	25.2	21.2	650	186	71.4	6.7	1.5	78	450	62	86.2
250	10.1	56	29	48	32	24	25	650	177	73	6.7	1.0	85	450	53	88.2
300	10.5	56	27	52	32	22.9	28.4	650	181	72	6.7	0.9	86.5	450	44	90.2
350	11.0	56	24	57	32	22.4	30	650	128	80	6.7	0.6	91	450	35	92.2

TABLE 5.9.2. JAR TEST RESULTS II

Ca(OH) ₂ mg/L	pH	IN PHENOL mg/L	OUT PHENOL mg/L	REMOVAL PHENOL %	IN DETERGENT mg/L	OUT DETERGENT mg/L	REMOVAL DETERGENT %	IN TCr mg/L	OUT TCr mg/L	REMOVAL TCr %	IN Zn mg/L	OUT Zn mg/L	REMOVAL Zn %	IN Cd mg/L	OUT Cd mg/L	REMOVAL Cd %
100	9.15	1.0	<0.1	>90	1.4	0.35	75.4	1.0	<0.5	>50	0.44	<0.1	>77	<0.1	<0.1	100
150	9.25	1.0	<0.1	>90	1.4	0.25	82	1.0	<0.5	>50	0.44	<0.1	>77	<0.1	<0.1	100
200	9.7	1.0	<0.1	>90	1.4	0.20	85.7	1.0	<0.5	>50	0.44	<0.1	>77	<0.1	<0.1	100
250	10.1	1.0	<0.1	>90	1.4	0.25	82	1.0	<0.5	>50	0.44	<0.1	>77	<0.1	<0.1	100
300	10.5	1.0	<0.1	>90	1.4	0.15	89.3	1.0	<0.5	>50	0.44	<0.1	>77	<0.1	<0.1	100
350	11.0	1.0	<0.1	>90	1.4	0.20	85.7	1.0	<0.5	>50	0.44	<0.1	>77	<0.1	<0.1	100

TABLE 5.10.1 JAR TEST RESULTS II-BY AIR MIXING

Ca(OH) ₂ mg/L	pH	IN TKN mg/L	OUT TKN mg/L	REMOVAL TKN %	IN NH ₃ -N mg/L	OUT NH ₃ -N mg/L	REMOVAL NH ₃ -N %	IN COD mg/L	OUT COD mg/L	REMOVAL COD %	IN TP mg/L	OUT TP mg/L	REMOVAL TP %	IN SS mg/L	OUT SS mg/L	REMOVAL SS %
100	9.15	56	35.8	36	32	25.7	19.7	650	194	70	6.7	2.1	68.7	450	87	80.6
150	9.25	56	32.5	42	32	25.2	21.2	650	164	74.7	6.7	1.8	73	450	68	84.8
200	9.6	56	24	57	32	19.3	39.7	650	156	76	6.7	1.7	74.6	450	45	90
250	10.1	56	15.7	72	32	19	40.6	650	145	77.7	6.7	1.35	79.8	450	36	92
300	10.6	56	13.7	75.5	32	12.3	61.6	650	134	79.4	6.7	1.35	79.8	450	30	93.3
350	11.1	56	13.4	76	32	11.2	65	650	107	83.5	6.7	0.6	91	450	26	94.2

TABLE 5.10.2 JAR TEST RESULTS II-BY AIR MIXING

Ca(OH) ₂ mg/L	pH	IN PHENOL mg/L	OUT PHENOL mg/L	REMOVAL PHENOL %	IN DETERGENT mg/L	OUT DETERGENT mg/L	REMOVAL DETERGENT %	IN TCr mg/L	OUT TCr mg/L	REMOVAL TCr %	IN Zn mg/L	OUT Zn mg/L	REMOVAL Zn %	IN Cd mg/L	OUT Cd mg/L	REMOVAL Cd %
100	9.15	1.0	<0.1	>90	1.4	0.2	85.7	1.0	<0.5	>50	0.44	<0.1	>77	<0.1	<0.1	100
150	9.25	1.0	<0.1	>90	1.4	0.12	91.4	1.0	<0.5	>50	0.44	<0.1	>77	<0.1	<0.1	100
200	9.6	1.0	<0.1	>90	1.4	0.13	90.7	1.0	<0.5	>50	0.44	<0.1	>77	<0.1	<0.1	100
250	10.1	1.0	<0.1	>90	1.4	0.12	91.4	1.0	<0.5	>50	0.44	<0.1	>77	<0.1	<0.1	100
300	10.6	1.0	<0.1	>90	1.4	0.12	91.4	1.0	<0.5	>50	0.44	<0.1	>77	<0.1	<0.1	100
350	11.1	1.0	<0.1	>90	1.4	0.12	91.4	1.0	<0.5	>50	0.44	<0.1	>77	<0.1	<0.1	100

TABLE 5.11.1 JAR TEST RESULTS III

Ca(OH) ₂ mg/L	pH	IN TKN mg/L	OUT TKN mg/L	REMOVAL TKN %	IN NH ₃ -N mg/L	OUT NH ₃ -N mg/L	REMOVAL NH ₃ -N %	IN COD mg/L	OUT COD mg/L	REMOVAL COD %	IN TP mg/L	OUT TP mg/L	REMOVAL TP %	IN SS mg/L	OUT SS mg/L	REMOVAL SS %	IN OIL mg/L	OUT OIL mg/L	REMOVAL OIL %
0	7.3	64.4	62	4	37	35.8	3	625	392	37.3	12.5	11.2	10	350	150	57	137	115	16
100	9.25	64.4	48.4	25	37	31.4	15	625	252	59.7	12.5	4.2	66.4	350	101	71	137	86	37.2
150	9.55	64.4	42.3	34	37	29	21.6	625	234	62.6	12.5	3.9	68.8	350	79	77.4	137	68	50.4
200	9.8	64.4	38.9	39	37	26.8	27.6	625	191	69.4	12.5	2.3	81.6	350	58	83.4	137	54	60.6
250	10.1	64.4	36.7	43	37	25.2	31.9	625	183	70.7	12.5	1.1	91.2	350	51	85.4	137	41	70
300	10.4	64.4	33.5	48	37	22.4	35.4	625	160	74.4	12.5	0.9	92.8	350	42	88	137	37	73
350	11.1	64.4	30.8	52	37	20.2	45.4	625	135	78.4	12.5	0.7	94.4	350	33	90.6	137	29	78.8

TABLE 5.12.1 JAR TEST AIR MIXING RESULTS III

Ca(OH) ₂ mg/L	pH	IN TKN mg/L	OUT TKN mg/L	REMOVAL TKN %	IN NH ₃ -N mg/L	OUT NH ₃ -N mg/L	REMOVAL NH ₃ -N %	IN COD mg/L	OUT COD mg/L	REMOVAL COD %	IN TP mg/L	OUT TP mg/L	REMOVAL TP %	IN SS mg/L	OUT SS mg/L	REMOVAL SS %
0	7.3	64.4	62	4	37	35.8	3	625	392	37.3	12.5	11.2	10	350	150	57
100	9.2	64.4	43.2	33	37	29.6	20	625	221	64.6	12.5	4.1	67.2	350	96	72.6
150	9.6	64.4	39.5	38.6	37	27.4	26	625	187	70	12.5	3.9	68.8	350	74	78.8
200	9.8	64.4	32.4	49.7	37	23.1	37.6	625	173	72.3	12.5	1.9	84.8	350	53	84.8
250	10.0	64.4	28.1	56.4	37	19.7	46.7	625	155	75.2	12.5	1.0	92	350	44	87.4
300	10.4	64.4	21.6	66.5	37	14.2	61.6	625	142	77.3	12.5	0.8	93.6	350	37	89.4
350	11.0	64.4	16.3	74.6	37	12.2	67	625	126	79.8	12.5	0.75	94	350	31	91.1

TABLE 5.12.2. JAR TEST RESULTS FOR SPECIAL CASE

Ca(OH) ₂ mg/L	pH	IN TP mg/L	OUT TP mg/L	REMOVAL TP %	IN TCr mg/L	OUT TCr mg/L	REMOVAL TCr %	IN Zn mg/L	OUT Zn mg/L	REMOVAL Zn %	IN Cd mg/L	OUT Cd mg/L	REMOVAL Cd %
250	10.1	15	1.2	92	2.0	<0.5	>75	5.0	<0.1	>98	1.0	0	100
350	11.2	15	0.65	95	2.0	<0.5	>75	5.0	<0.1	>98	1.0	0	100

TABLE 5.12.3. JAR TEST RESULTS

COAGULANT	DOSAGE mol Fe/mol P	pH	IN COD mg/L	OUT COD mg/L	REMOVAL COD %	IN TP mg/L	OUT TP mg/L	REMOVAL TP %	IN TKN mg/L	OUT TKN mg/L	REMOVAL TKN %	SLUDGE VOL. ml/L	SLUDGE QUANT. mg/L
FeSO ₄ + Ca(OH) ₂	2.5	8.1	625	174	72	12.5	1.4	88.8	64.4	43.1	33	32	539
FeSO ₄ + Ca(OH) ₂	2.5	9.1	625	145	77	12.5	1.1	91.2	64.4	39.7	38	38	615
FeCl ₃ + Ca(OH) ₂	2.5	9.1	625	147	77	12.5	0.9	92.8	64.4	39.7	38	44	623

TABLE 5.13.1. SLUDGE VOLUME, SS, AND VSS I

Ca(OH) ₂ mg/L	pH	SLUDGE VOLUME ml/L	SS mg/L	VSS %
100	9.2	9.0	498	50
200	10.0	18.0	635	38
300	11.3	52.0	760	29

TABLE 5.13.2 SLUDGE VOLUME, SS, AND VSS II AIR

Ca(OH) ₂ mg/L	pH	SLUDGE VOLUME ml/L	SS mg/L	VSS %
100	9.15	12	592	50
200	9.6	26	729	46
300	10.6	61	870	33
350	11.1	65	920	32

TABLE 5.13.3. SLUDGE VOLUME, SS, AND VSS II

Ca(OH) ₂ mg/L	pH	SLUDGE VOLUME ml/L	SS mg/L	VSS %
100	9.15	11	592	50
200	9.7	24	729	46
300	10.5	58	870	33
350	11.0	64	920	32

6 EVALUATION

6.1 SYSTEM PERFORMANCE

6.1.1 REMOVAL EFFICIENCIES

The samples used in this study are supplied from Yenikapi Physical Treatment Plant, after screening and grit chamber. In chapter 5, the characterization of wastewaters are given by size distribution. The typical characteristics of domestic wastewaters are given in chapter 2. If characteristics of typical domestic wastewater and Yenikapi samples are compared with each other, it is seen that for BOD and COD parameters, the sample can be classified between medium and strong domestic wastewater type, for suspended solids it is a strong type, for total phosphorus it is between weak and medium type, for total nitrogen and ammonia nitrogen it is between medium and strong type. But Yenikapi Treatment Plant accepts not only domestic wastewaters but also accepts some industrial wastewaters. So the samples contain heavy metals, phenol and another types of toxic e.g. detergent. In that reason these samples can be called as a mixture of medium strength domestic wastewaters and industrial wastewaters.

To understand the suitability for chemical precipitation of a wastewater sample, it is helpful to look at the size distribution. When the colloidal and settleable part of the wastewater are higher than the

is suitable for chemical precipitation. Chemical precipitation removes not only the colloidal and settleable part of wastewater, but also adsorbs some of the soluble part of wastewater. In this study for total nitrogen colloidal and settleable part of wastewater is about 25 % , for total phosphorus this ratio is about 55 % , and for COD this is about 70 % . These values are higher than literature values so that the results are better than the literature results.

As it is known volatile suspended solids shows the quantity of organic matter and inorganic matter in the sample. In the typical characteristics of domestic wastewater the VSS is about 80 % of suspended solids and in Yenikapi sample this value is about 67 % of suspended solids. It means that it contains more inorganic matter than the typical domestic wastewater does.

Chemical precipitation has the advantage of removing heavy metals and toxic substances according to other treatment systems. Heavy metals such as TCr, Zn, Cd can be removed from wastewater 100 % from the wastewater by chemical precipitation. For toxic substances such as phenol and detergent, chemical precipitation removes them about 90 % from the wastewater.

When the jar test results are compared with the literature it is seen that the removal rates are most of the time better than the literature. For COD and SS removal rates, the experimental study results are as good as literature values and for COD this study

gives better removal rates than literature. For total nitrogen removal this study gives better results than literature because of difference of colloidal and settleable parts of typical and Yenikapi wastewaters. For total phosphorus removal chemical precipitation gives over 90 % removal rate. So for nutrient control chemical precipitation achieves adequate removals.

6.1.2 SLUDGE QUANTITIES :

In this experimental study the sludge volume, SS and VSS are examined and the SS values vary from 500 to 900 kg / 1000 m^3 according to dosage. As the dosage increases the removal efficiencies increase and sludge quantity increases. Though lime is an inorganic matter, as the dosage increases the VSS percentage decreases. Unthickened sludge concentrations vary for different sludge types. For primary sludge this value varies from 4 to 12 % and for primary and activated sludge this value varies from 3 to 10 % (Metcalf). In this study sludge volumes vary from 9 to 60 ml / L according to dosage.

6.2 COMPARISON

The comparison of the chemical precipitation with the other treatment systems especially with biological treatment systems in the terms of removal efficiencies, gives a clear idea on the performance of chemical precipitation. For COD removal chemical precipitation gives removal efficiency as good as biological treatment does and sometimes chemical precipitation gives better efficiency. So for COD removal chemical precipitation achieves adequate removal efficiency at least biological

treatment does. In the suspended solids removal chemical precipitation again matches with biological treatment. The removal rates vary from 80 to 92 % . For total phosphorus removal chemical precipitation achieves 80 to 90 % removal rates, but biological treatment gives about 5 to 20 % removal. For total nitrogen removal chemical precipitation gives removal rates similar to biological treatment. So for nutrient control chemical precipitation achieves good removal efficiencies. For heavy metal removal chemical precipitation achieves 100 % removal rates. Biological treatment cannot achieve heavy metal removals. So chemical precipitation has the advantage of removing metals.

To treat and dispose of the sludge produced from wastewater treatment plants in the most effective manner, it is important to know the characteristics and the quantities of the sludge that will be processed.

Sludge characteristics, quantities and disposal methods vary from each different wastewater and treatment systems. Table 6.1 presents the sludge quantities produced from various wastewater processes.

Sludge from chemical precipitation is usually dark in color, and contains so much water. If lime is used as coagulant the sludge is stabilized with lime. Sludge from chemical precipitation is like primary or biological treatment sludge and its quantity changes according to dosage.

TABLE 6.1. SLUDGE QUANTITIES PRODUCED FROM WASTEWATER PROCESSES

TREATMENT PROCESS	DRY SOLIDS kg/1000 m ³
Primary sedimentation	110-170
Activated sludge	70-100
Trickling filtration	55-90
Chemical addition to primary clarifiers Low lime(350-500 mg/L)	250-400
High lime(800-1600mg/L)	600-1280

6.3 GENERAL EVALUATION

Treatment requirement in Istanbul is discussed in chapter 4 and it is mentioned that phosphorus loading from Istanbul is 1.03 times as much as Blacksea's and nitrogen loading from Istanbul is 1.6 times as much as Blacksea's. So nutrient control is necessary for Marmara Sea.

PHOSPHORUS :

For phosphorus removal there are some methods that are applied today. Presedimentation, biological treatment, chemical precipitation, the combination of biological treatment and chemical precipitation. In Table 6.2 the removal efficiencies of phosphorus are given. As it is seen, chemical precipitation alone achieves the adequate removal efficiency. When it is used in the conjunction with biological treatment BOD is removed besides phosphorus removal. This is the advantage of using chemical precipitation in wastewater treatment.

NITROGEN :

Presedimentation, chemical precipitation, nitrification are the most commonly used methods for nitrogen removal according to the treatment requirement.

In this study presedimentation achieves about 4 % removal rate in total nitrogen removal. Chemical precipitation generally achieves 30 to 40 % removal rates, but in this study this rate is over 50 % because of the advantage of size distribution of samples. Nitrification process achieves 80 to 85 % removal rates.

TABLE 6.2. THE COMPARISON OF CHEMICAL PRECIPITATION WITH THE OTHER TREATMENT SYSTEMS

TREATMENT OPERATIONS OR PROCESSES	ORGANIC-N REM. %	TKN REM. %	TP REM. %	BOD ₅ REM. %	COD REM. %	SS REM. %
1)CONVENTIONAL SYSTEM						
PRIMARY	10-20	5-10	5-10	25-40	N/A	40-70
SECONDARY	N/A	10-20	10-20	80-90 ^b	80-85	85-95 ^a
SECONDARY WITH NITR.	N/A	80-85	-	-	-	-
2)CHEMICAL PROCESSES						
CHEMICAL COAGULATION	50-90	30-40	80-95 ^a	40-60 ^c	70-85	80-90
BREAKPOINT CHLORINATION	N/A	80-95	-	-	-	-
ION EXCHANGE	SLIGHT	70-90	-	-	-	-

a:with iron or alum salts
b:trickling filter
c:with low lime(200-400mg/L)
d:activated sludge
N/A:not available

Flocculation by air is used in this study. Total nitrogen is removed in the range of 65 to 75 % .

The ammonia gas given to atmosphere in this study can be calculated as the difference of remaining values of ammonia nitrogen in normal mixing and air mixing. For the second sample the ammonia gas given to atmosphere after mixing is about 3.5 ton / day.

TOXIC SUBSTANCES :

Heavy metals such as TCr, Zn, Cd and other toxic substances such as phenol and detergent can be removed from wastewater by chemical precipitation. The removal rates in heavy metals as high as 100 % and though the synthetic heavy metals are added to the sample, the removal rates has not changed. Phenol and detergent are removed 90 % from wastewater by chemical precipitation.

SUSPENDED SOLIDS :

Chemical precipitation achieves over 90 % removal rates in this study and it matches with biological treatment.

So as a result, chemical precipitation has the advantage of removing phosphorus, nitrogen, COD, suspended solids, heavy metals and toxic substances according to biological treatment systems. The coagulation type and dosage are to be obtained by laboratory experiments and tested in pilot plants. So to understand the performance of chemical precipitation pilot plants are to be operated and the economic feasibility is to be done.

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