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Electro coagulation process for the treatment of industrial waste water.

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ABSTRACT

Water is essential to sustain life on the biosphere. However; with the increasing population and industrial growth, its resources are becoming limited and/or contaminated .The main aim of this was the assessments of reduction of COD, BOD ,TDS from various industrial effluent using Electro-coagulation method.Electro-coagulation is an alternative technology for wastewater treatment in addition to its other conventional applications. In this paper we are study the effectiveness of Electro coagulation trying for optimization of the process with respective the effectiveness and cost.EC is considered as a low sludge producing technology. The flocs formed by EC are relatively large, contain less bound water, are more stable and, therefore, amenable to filtration. Chemical aids are not required in EC, which can be easily integrated with conventional waste water control system.

Keywords

COD-Chemical Oxygen Demand, BOD-Biological Oxygen Demand, TDS-Total Dissolved Solid EC-Electro coagulation.

1. INTRODUCTION

Electro Coagulation is the process of destabilizing suspended, emulsified, or dissolved contaminants in an aqueous medium by introducing an electrical current into the medium. The electrical current provides the electromotive force to drive the chemical reactions. When reactions are driven or forced, the elements or compound will approach the most stable state. Generally, this stable state is a solid that is either, less colloidal, less emulsifiable, or less soluble than the element or compound at equilibrium values. As this occurs the contaminants form hydrophobic entities such as precipitates or phase separations, which can easily be removed by a number of secondary separation techniques.

The electrical current is introduced into the water via parallel electrodes constructed of various metals generally selected to optimize the removal process. The two most common electrode materials are Iron (Fe) and Aluminum (Al). In accordance with Faraday's Law, metal ions will be split off or sacrificed into the liquid medium. This will form a nucleus, which will attract the contaminants into a precipitate that will be removed from treated fluid. These metal ions tend to form metal oxide or hydroxide nuclei that are an Electro coagulation attractant to the contaminants, which have been destabilized. The quantity of electrical current required varies with the liquid to be treated. It is necessary to provide sufficient, but not excess electrical current to remove the unwanted contaminants. Excess current only consumes excess electrical power and accelerates the process of Module electrode consumption resulting in increased treatment operating costs.

Electrochemistry and Electro coagulation are the electrochemical means of removing contaminants from aqueous streams. It can be used effectively on both influent and effluent streams. Electro coagulation is generally used on industrial water streams to allow the use or discharge of an industrial waste stream. The Process uses electricity, rather than expensive, dangerous, and sometimes toxic chemicals to remove contaminants. Electro coagulation can also be a pretreatment for other processes such as Reverse Osmosis, or a polish treatment for traditional treatment processes.

2. BASIC CONCEPTS

Treatment of textile wastewaters by electro coagulation uses iron and aluminum electrodes Wastewater from dyeing and finishing processes, with a chemical oxygen demand (COD) concentration exceeding 1600 mg/l and a strong dark color, is categorized as high strength wastewater. It is a significant source of environmental pollution.

The combination of strong color and highly suspended solid content results in high turbidity of the waste effluent. Due to the characteristics of textile wastewater, COD and turbidity removals exhibit similar trends. The total volume of wastewater originating from textile dyeing and finishing factories is around 150 million metric tons per year, two-third of which is waste in dye and rinse baths.

Conventional methods for dealing with textile wastewater consist of various combinations of biological, chemical and physical methods. Because of the large variability of the composition of textile wastewaters, most of these conventional methods are becoming inadequate and insufficient. Furthermore, treatment cost of textile waste effluents has been escalating fairly rapidly in recent years. On the other hand, due to the scarcity of space, extremely high land cost and the complexity of handling chemicals in some countries, a simple and efficient treatment process for the textile wastewater is essentially necessary. It should require minimum chemical consumption and space.

One of promising methods for treating hard-to-treat wastewater streams is the electro- chemically based. Electrochemical processes (electrolysis and electro coagulation) have been successfully demonstrated for removing pollutants in various industrial wastewaters Removal mechanisms reported in the electrolysis process generally include oxidation, reduction, decomposition, whereas the mechanisms in the electro coagulation process include coagulation, adsorption, precipitation and flotation Electro coagulation utilizes aluminum or iron anodes to produce aluminum or iron hydroxide flocs by reaction at the anodes followed by hydrolysis.

The electro coagulation is a simple and efficient method for the treatment of many water and wastewaters. It has not been widely accepted because of low initial capital costs as compared to other treatment technologies. In recent years, many investigations have been especially focused on the use of electro coagulation owing to the increase in environmental restrictions on effluent wastewater, Electro coagulation has been applied success- fully to treat potable water, food and protein wastewater, yeast wastewater, urban wastewater, restaurant wastewater tar sand and oil shale wastewater nitrate containing wastewater solutions and arsenic containing smelter wastewater Electro coagulation has been proposed in recent years as an effective method to treat wastewater streams from dyeing factories.

Table 1. Characteristics of Textile Wastewater

Characteristics	Characteristics Value
Chemical oxygen demand (COD) (mg/l)	3422
Total suspended solids (TSS) (mg/l)	1112
Total organic carbon (TOC) (mg/l)	900
Conductivity (J.LS/cm)	3990
Turbidity (NTU)	5700
pH	6.95

2.1 Wastewater treatment by electro coagulation

Applied Electrochemistry includes the use of electrochemical processes in any type of industrial application: synthesis of pharmaceutical products, batteries, effluent treatment, metallic electro deposition, etc. The Department of Physical Chemistry at the University of Alicante is focused since several years on the investigation of new electrochemical processes and the transfer of knowledge and technology to the industry.

Treatment of wastewater by EC has been practiced for most of the 20th century with limited success and popularity. However, in the last decade, this technology has been increasingly used in Europe for treatment of different types of industrial wastewater containing foodstuff waste, oil wastes, dyes, suspended particles, chemical and mechanical polishing waste, organic matter from landfill leachates, defluorination of water, synthetic detergent effluents, mine wastes and heavy metal containing solution.

Coagulation is a phenomenon in which the charged particles in colloidal suspension are neutralized by mutual collision with counter ions and are agglomerated, followed by sedimentation. The coagulant is added in the form of suitable chemical substances. Alum [Al_2 $(SO_4)_3.18H_2O$] is such a chemical substance which has been widely used for ages for wastewater treatment. The mechanism of coagulation has been the subject of continual review. It is generally accepted that coagulation is brought about primarily by the reduction of the net surface charge to a point where the colloidal particles, previously stabilized by electrostatic repulsion, can approach closely enough for Vander Waal's forces to hold them together and allow aggregation. The reduction of the surface charge is a consequence of the decrease of the repulsive potential of the electrical double layer by the presence of an electrolyte having opposite charge.

2.2 Domestic Wastewater Treatment by Electro coagulation with Fe-Fe Electrodes

Municipal wastewater is the mixture of domestic wastewater, (the basic component), small amounts of industrial and storm water, drain water, surface infiltration, and ground water. It usually consists of a number of contaminants, such as suspended solids, biodegradable organics, pathogens, nutrients, refractory organics, and heavy metals and dissolved inorganic. Direct discharge of untreated wastewater into the natural water bodies is not desirable, as the decomposition of the organic waste would seriously deteriorate the water quality. In addition, communicable diseases can be transmitted by the pathogenic microorganisms. Nutrients such as nitrogen and phosphorous, along with organic material when discharged to the aquatic environment can also lead to excessive growth of undesirable aquatic life when discharged in excessive amounts on land can also lead to the pollution of groundwater. It was estimated that nearly half a million organic compounds have been synthesized and some 10,000 new compounds are added each year. As a result, many of these compounds are now found in the wastewater from municipalities and communities. For these reasons, treatment of wastewater has become necessary for the protection of the environment keeping in view public health, economic, social and political concerns.

One of the challenging tasks faced by scientists and engineers today is to provide safe water to support healthy human life. But human activities always generate wastewaters which contain various pollutants that create problems to aquatic life and contaminate water resources. Although wastewaters may come from various sources, it mostly consists of domestic wastewaters (DWWs). Currently, domestic wastewater is mostly is normally treated by aerated biological methods. For example, the activated sludge, being the most famous biological method of wastewater treatment, produces high quality effluent, i.e. 90% biological oxygen demand (BOD) and suspended solids (SS) removal as in. There are some disadvantages of applying the biological method for wastewater treatment, such as requiring continuous air supply, high operating costs (skilled labor, energy, etc), sensitivity against shock toxic loads, longer treatment time and necessary sludge disposal From an environmental point of view, the sewage treatment process is still far from being environmentally sustainable. There is an urgent need for the development of a more sustainable treatment process. Some of the possibilities include electrochemical treatment, improvement of the mitigation of toxic pollutants, high temperature sludge treatment processes, and membrane separation processes. Electrochemical process is a promising treatment method due to its high effectiveness. Its lower maintenance cost, less need for labor and rapid achievement of results other alternative solutions to wastewater treatment problems are still needed.

This investigation developed a pilot-scale electro coagulation process combined with direct flotation by hydrogen gas evolution in the cathodes for reclaiming domestic grey water that followed the general guidelines for water reuse for human noncontact usage. This work thus attempted to determine the total cost of the reclaimed water and the consequent payoff period. Furthermore, the proposed process was compared with other processes for grey water reuse in buildings described in the literature, with regard to both the serving area required by the treatment facility and the cost of the reclaimed water.

Textile dyeing processes are among the most environmentally unfriendly industrial processes, because they produce colored wastewaters that are heavily polluted with dyes, textile auxiliaries and chemicals. Besides textile finishing's wastewaters, especially dye-house effluents, contain different classes of organic dyes, chemicals and auxiliaries. Thus they are colored and have extreme pH, COD and BOD values, and they contain different salts, surfactants, heavy metals, mineral oils and others. Therefore, dye bath effluents have to be treated before being discharged into the environment or municipal treatment plant.

Textile dyes are structurally different molecules themselves with low or no biodegradability. The removal of color is associated with breakup of the conjugated unsaturated bonds in molecules. For this reason, many chemical treatment processes have been used extensively to treat textile wastewaters. Most of the studies, such as chemical precipitation, adsorption by activated carbon photo catalytic oxidation, ozonation and Fenton' oxidation focusing on color removal although effective, are expensive or can cause further secondary pollution In most water treatment plants, the minimal coagulant concentration and the residual turbidity of the water are determined by the Jar-Test technique. Besides, physical-chemical treatment allows reducing dissolved, suspended, colloidal and non-settable matter as well as coloring from dyes. Depending on the wastewater characteristics, COD of a textile effluent can be reduced between 50% and 70% after optimizing the operating conditions such as pH, coagulant and flocculants concentrations.

Coagulation or flocculation process was conducted for the treatment of industrial wastewater to achieve maximum removal of COD, BOD and TDS. The effect of coagulant dose, polyelectrolyte dose, pH of solution and addition of polyelectrolyte as coagulant aid and found to be important parameters for effective treatment of industrial wastewater. Colloid particles are removed from water via coagulation and flocculation processes.

Chromium is released into aquatic environment from electroplating, metal finishing, chromate preparation, tannery, and fertilizer industries, and from industries that employ Cr^{6+} compounds as corrosion inhibitors. It is a potential carcinogen and its deleterious effects are well documented .The permissible limit of Cr (VI) for industrial wastewater to be discharged to surface water is 0.1 mg l^{-1}.Hence it becomes imperative to remove Cr(VI) from wastewaters before discharging them into aquatic systems or on to land. Different methods, such as reduction and precipitation, ion exchange, electro dialysis, reverse osmosis, solvent extraction, electrochemical precipitation, and activated carbon adsorption have been suggested for the removal of the Valeant chromium. Most of them, however, are not efficient or cost elective. Electro coagulation method using aluminum electrode has attracted significant attention for chromium removal process due to its operational simplicity. Electro coagulation is a simple and efficient method where the flocculating agent is generated by electro-oxidation of a sacrificial anode, generally made of iron or aluminum. In this process, the treatment is performed without adding any chemical coagulant or flocculants, thus reducing the amount of sludge that must be disposed .On the other hand, electro coagulation is based on the in situ formation of the coagulant as the sacrificial anode corrodes due to an applied current, while the simultaneous evolution of hydrogen at the cathode allows for pollutant removal by floatation. This technique combines 3 main interdependent processes, operating synergistically to remove pollutants: electrochemistry, coagulation, and hydrodynamics. An examination of the chemical re- actions occurring in the electro coagulation process shows that the main reactions occurring at the electrodes (aluminum electrodes) are:

$$Al \leftrightarrow Al^{3+} + 3e^- \text{ (anode)} \quad (1)$$

$$3H_2O + 3e^- \leftrightarrow 3/2H_2 + 3OH^- \text{ (cathode)} \quad (2)$$

In addition, Al^{3+} and OH^- ions generated at electrode surfaces react in the bulk wastewater to form aluminum hydroxide:

$$Al^{3+} + 3OH^- \leftrightarrow Al\,(OH)_3 \quad (3)$$

If the anode potential is sufficiently high, secondary reactions may occur at the anode, such as direct oxidation of organic compounds and of H_2 O or Cl− present in wastewater:

$$2Cl^- \leftrightarrow Cl_2 + 2e^- \quad (4)$$

$$2H_2O \leftrightarrow O_2 + 4H^+ + 4e^- \quad (5)$$

The produced chlorine undergoes a dismutation reaction at pH higher than 3–4:

$$Cl_2 + H_2O \leftrightarrow HClO + H^+ + Cl^- \quad (6)$$

$$HClO \leftrightarrow ClO^- + H^+ \quad (7)$$

The aluminum hydroxide flocs act as adsorbents and/or traps for metal ions and so eliminate them from the solution. Furthermore, a direct electrochemical reduction of Cr (VI) in Cr (III) may occur at the cathode surface the hydroxyl ions, which are produced at the cathode. This acts synergistically to remove pollutants from water. Also, in the electro coagulation (EC) cell, iron an- odes dissolve and produce Fe^{2+}. This newly produced Fe^{2+} directly reduces Cr^{6+} to Cr^{3+} leading to the precipitation of Cr(OH)3 and Fe(OH)3 . Followings are the major reactions taking place in the EC cell

Anode (oxidation):

$$Fe \leftrightarrow Fe^{2+} + 2e^- \quad (8)$$

$$Cr^{6+} + 3Fe^{2+} \leftrightarrow Cr^{3+} + 3F \leftrightarrow e^{3+} \quad (9)$$

Cathode (reduction):

$$2H_2O + 2e^- \leftrightarrow H_2 + 2OH^- \quad (10)$$

Co − precipitation:

$$Cr^{3+} + 3OH^- \leftrightarrow Cr(OH)_3 \quad (11)$$

$$Fe^{3+} + 3OH^- \leftrightarrow Fe(OH)_3 \quad (12)$$

$$Fe^{2+} + 2OH^- \leftrightarrow Fe(OH)_2 \quad (13)$$

Electro coagulation (EC) has been suggested as an advanced alternative to chemical coagulation in pollutant removal from raw waters and wastewaters. In this technology, metal cations are released into water through dissolving metal electrodes. Simultaneously, beneficial side reactions can remove flocculated material from the water. However, there are also adverse side reactions, such as deposition of salts on the electrode surface, which may cause deterioration of removal efficiency after long operation. As in the case of chemical coagulation with metal salts, aluminum or iron cations and hydroxides are the active compounds in EC. Chemical coagulation and EC have fundamentally similar destabilization mechanisms and it is therefore important to go through the theory of colloid destabilization with metal salt coagulants, because chemical coagulation has been studied more extensively than EC.

The Alkali-catalyzed trans esterification is widely an electro coagulation (EC) process has been attracted a great attention on treatment of industrial wastewaters because of the versatility and environmental compatibility. This technique has several advantages as compared to conventional methods in terms of use of simple equipment, ease of operation, less treatment time, reduction or absence of chemicals addition. Moreover, an EC process provides rapid sedimentation of electro- generated flocs and a less amount of sludge production. It has been used to effectively treat numerous wastewaters including leachate from solid wastes, municipal wastewater, industrial wastewaters such as dying wastewater, olive oil wastewater and wastewater containing organic species such as phenol. The electrochemical react ions with electrode metals (M) can be summarized as follows:

At Anode $M_{(s)} \rightarrow M_{(aq)}^{3+} + 3e^-$

At cathode: $3H_2O + 3e^- \rightarrow 3/2\ H_2\ (g) + 3OH^-$

In Solution: $M_{(aq)}^{3+} + 3H_2O \rightarrow M(OH)_3 + 3H^+$

Electro coagulation- electro flotation (ECF) technology is a treatment process of applying electrical current to treat and flocculate contaminants without having to add coagulations. Coagulation occurs with the current being applied, capable of removing small particles since direct current applied, setting them into motion. Also electro coagulation could reduce residue for waste production.

Electro coagulation consists of pairs of metal sheets called electrodes that are arranged in pairs of two anodes and cathodes. Using the principles of electrochemistry, the cathode is oxidized (loses electrons), while the water is reduced (gains electrons), thereby making the wastewater better treated. When the cathode electrode makes contact with the wastewater, the metal is emitted into the apparatus.

When this happens, the particulates are neutralized by the formation of hydroxide complexes for the purpose of forming agglomerates. These agglomerates begin to form at the bottom of the tank and can be siphon out through filtration. However, when one considers an electro coagulation-flotation apparatus, the particulates would instead float to the top of the tank by means of formed hydrogen bubbles that are created from the anode. The floated particulates can be skimmed from the top of the tank.

To consider how effective the ECF reactor can be, one must consider the following inputs or variables wastewater type, pH, current density, type of metal electrodes (aluminum, steel, iron), number of electrodes, size of electrodes, and configuration of metals. These variables would affect the overall treatment time, kinetics, and also the removal efficiency measured.

Electro coagulation flotation is an alternative method to classic chemical coagulation for many reasons. ECF is capable of reducing the need for chemicals due to the fact that the electrodes provide the coagulant. However, many individuals still use chemical coagulants to attempt to enhance treatment. Traditionally, chemical coagulation involves the use of alum (aluminum sulfate), ferric chloride (FeCl3), or ferrous sulfate (Fe2SO4) which can be very expensive depending on the volume of water treated. When applying the coagulant, the coagulant performs a similar function as the electrodes, neutralizing the charge of the particulates, thereby allow them to agglomerate and settle at the bottom of the tank. In addition, electro coagulation-flotation is capable of reducing waste production from wastewater treatment and also reduces the time necessary for treatment.

Coagulants used for water and waste-water treatment are pre-dominantly inorganic salts of iron and aluminum. When dosed into water the iron or aluminum ions hydrolyze rapidly and in an uncontrolled manner, to form a range of metal hydrolysis species. A range of factors such as the nature of the water, the coagulation pH and the dose of coagulant together influence the range of species formed and subsequently, the treatment performance.

3. DESIGN AND IMPLEMENTATION

3.1 Experimental Set up

The experimental setup of a laboratory scale Electro coagulation system is as shown in Figure1. A 1ft x 1 ft x 1 ft water tank that operates at atmospheric pressure was used. The tank capacity of 10 liters .Electrode made of an material such as metal or graphite to exchange ions in water to the sides of tank coming into close contact with each other. This power supply up equilibration and provides for a greater number of mass transfer cycles and ion exchanges cycles.

Tank specification / operating condition of Electro coagulation system

- Tank size - 1 ft x 1 ft x 1 ft.
- Graphite electrode height -400mm
- Aluminum electrode height – 400mm
- Tank capacity -10 lit
- Temperature feed – 303k.

Fig No.1 Experimental Set Up

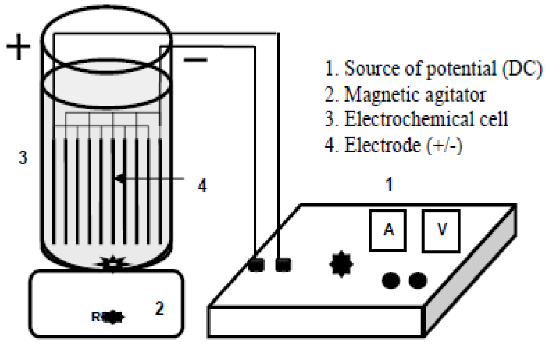

Fig. No 2 Typical Electrocoagulation system

3.2 Procedure

The reactant consisting of solvents and free ions and water was fed (different-different electrolyte weight condition) continuously added to the tank .In the tank, two immiscible phases are formed, an aqueous phase i.e. water and organic phase free ions gas. The feed Electro coagulation agent is before introducing it to the tank. The sample was analyzed by using COD, BOD, TDS analyzer. After experimentation of feed condition we again analyze the sample solution w.r.to reduction of above parameter.

4. RESULTS

4.1 Effect of Electrolyte Added on COD Removal.

Condition:-Temperature: - 30 ^{0}C

By varying the weight added of electrolyte, the % separation of solvents varies. Readings were taken for 2gm, 4 gm, 6gm and 8 gm of weight. The temperature of the feed was kept constant at 30 ^{0}C. Now if we further increase the weight to 8gms. Separation obtained was almost same for 6gm of electrolyte added i.e.66.8%, w.r.to the 8 grams of electrolyte added i.e.67.3%. Thus at same point, % separation is same even after we increases the weight of electrolyte.

Table No 2 Effect of Qty of electrolyte Added on COD Removal

Qty of Electrolyte added (gms)	% COD Removal
2	54.2
4	61.4
6	66.8
8	67.3

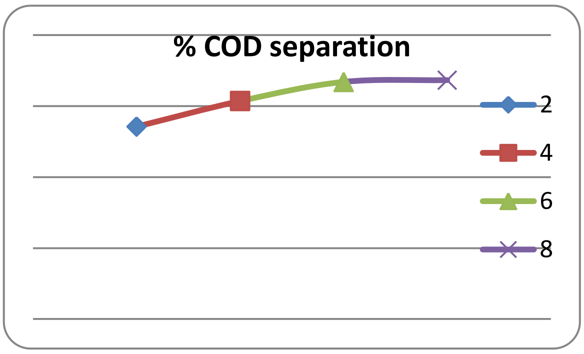

Fig. No 3 Effect of Electrolyte Added on COD Removal

4.2 Effect of Electrolyte Added on BOD Removal

Condition:-Temperature: - 30 ^{0}C

By varying the weight added of electrode, the % separation of solvents varies. Readings were taken for 2gm, 4 gm, 6gm and 8 gm of weight. The temperature of the feed was kept constant at 30 ^{0}C. Now if we further increases the weight to 8gms, separation obtained was almost same i.e.54.8%. Thus at same point, % separation is same even after we increases the weight of electrolyte.

Table No 3 Effect of Qty of electrolyte Added on BOD Removal

Qty of Electrolyte added (gms)	% BOD Removal
2	41.6
4	49.2
6	53.5
8	54.8

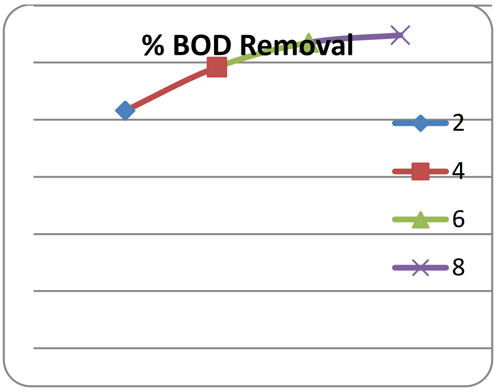

Fig.4 No Effect of Electrolyte Added on BOD Removal

4.3 Effect of Electrolyte Added on TDS Removal

Condition:-Temperature: - 30 ^{0}C
By varying the weight added of electrode, the % separation of solvents varies. Readings were taken for 2gm, 4 gm, 6gm and 8 gm of weight. The temperature of the feed was kept constant at 30 ^{0}C. Now if we further increases the weight to 8gms, separation obtained was almost same i.e.65.7%. Thus at same point, % separation is same even after we increases the weight of electrolyte.

Table No 4 Effect of Qty of electrolyte added on TDS Removal

Qty of Electrolyte added (gms)	% TDS Removal
2	52.3
4	61.7
6	65.7
8	67.7

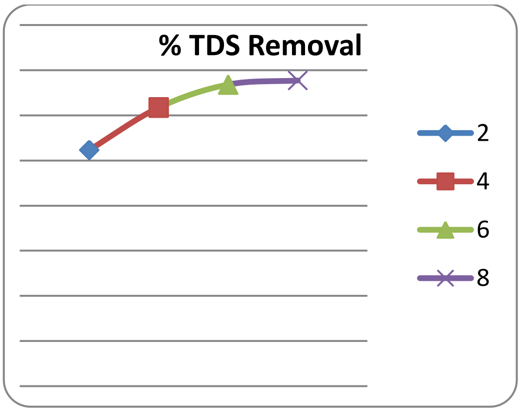

Fig No 5 Effect of Qty of electrolyte Added on TDS Removal

CONCLUSION

The Electro coagulation system is one of an effective separation processes for the wastewater treatment. The optimum parameters of the Electro coagulation system for the design purpose were studied with respective to electrolyte weight and found a conclusion that if the temperature of the feed was kept constant at 30^{0}C and increasing the weight of electrolyte up to 8gms, separation obtained was almost same up to 6gm of electrolyte. Thus on the basis of quantity of effluent to be handled we chose the optimum electrolyte weight for the betterment of the process and with respective the cost reduction and Optimization of the process.

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