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A Study on wastewater treatment of chemical industry using electro-coagulation: A Review

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Abstract : Chemicals are a part of every aspect of human life, right from the food we eat to the clothes we wear to the cars we drive.The chemical industry is critical for the economic development of any country, providing products and enabling technical solutions in virtually all sectors of the economyThe chemical industry produced around 8 million metric tonnes each of basic chemicals and basic petrochemicals and around 10 million metric tonnes of petrochemical intermediariesThe aim of this study is to treat the wastewater coming from chemical industries using a Electro-coagulation Technology. (EC) process is an electrochemical means of introducing coagulants and removing suspended solids, colloidal material, and metals, as well as other dissolved solids from water and wastewaters. The EC process has been successfully employed in removing pollutants, pesticides, and radionuclides. This process also removes harmful microorganisms. More often during EC operation, direct current is applied and electrode plates are sacrificed (dissolved into solution). The dissolution causes an increased metal concentration in the solution that finally precipitates as oxide precipitates. Due to improved process design and material of construction, the EC process is being widely accepted over other physicochemical processes. Presently, this process has gained attention due to its ability to treat large volume and for its low cost. The aim of this study is to review the mechanism, affecting factors, process, and application of the electrocoagulation process

I. Introduction

Electrolysis is a method in which oxidation and reduction occur due to application of electric current to the electrolytic solution. Electrochemical technology has shown to be a hopeful technique for the destruction of organic pollutants in the wide collection of wastewater and there is no need for adding additional chemicals. In addition, the high property of the electrochemical process prevents the assembly of unwanted by-products. And it can also be used for the metal recovery from the different wastewater.

In the 19th century (1889) in London, the electrochemical method was proposed with a well-established plant for the sewage treatment. In this process, wastewater was electrolyzed by mixing with sea water. The prime interest of primary stage development of the EC process was to generate chlorine for the removal of odor and disinfection of sewage wastewater. Electrochemical processes include: electro-coagulation, electro flotation,

electro oxidation, electro-flocculation, electro-disinfection, electro reduction, electro-deposition, etc. Electrocoagulation (EC) is the most established electrochemical process. EC process was developed and patented by A. E. Dietrich in 1906 for the treatment of blige water from ships. Later in 1909 in the US, wastewater treatment by the electrocoagulation using aluminum and iron electrodes was proprietary by J.T.

Harries. In 1984 in the US for the first time, a large scale drinking water treatment by electrocoagulation method was implemented.

Electrocoagulation (EC) finds its application in treating different types of process wastewater, for
example electroplating wastewater, Heavy oil refinery, textile wastewater, Dairy wastewater,
Distillery wastewater, Leachate wastewater. In recent years EC process has successfully applied
for the de-fluoridation of groundwater. In the 20th century electrochemical process had narrow success and acceptance in spite of being a competitive and effective treatment technique for most of the wastewater. The initial improvements were in minimization of electrical power consumption and throughput rates of effluent. Therefore present study focuses on the mechanism of EC process and operational factors (voltage, current density, temperature, time of treatment, electrode arrangement, inter electrode distance and pH) effecting its efficiency for the improvement of the EC process.

II. Mechanism of Electrocoagulation

The EC reactor configuration varies with the number of electrodes and arrangement of electrodes (monopolar or bipolar).

The reaction mechanism of the electrochemical method using aluminum and iron electrodes is shown in Figure 1. On an applied electric current, oxidation of anodic material and reduction of cathodic material takes place.

Anodic reactions:

$Al - 3e \rightarrow Al^{3+}$

Alkaline condition:

$Al^{3+} + 3OH^{-} \rightarrow Al(OH)_3$

Acidic condition:

$Al^{3+} + 3H_2O \rightarrow Al(OH)_3 + 3H^{+} +$

$2H_2O - 4e \rightarrow O_2 + 4H^{+}$

Cathode:

$2H_2O + 2e \rightarrow H_2 + 2OH^{-}$

(i) Cationic hydrolysis products neutralize negatively charged colloids.

(ii) Sweep flocculation: Entrapment and removal of contaminants in the form amorphous hydroxide precipitate.

Gas bubbles H_2 and O_2 adhere to agglomerates which are released at the electrode surfaces during electrolysis and carry them to the water surface

III. Optimization

By considering the Box-Behnken design of surface response analysis for color removal within distillery spent wash, Krisna Prasad et al. found that 95% color removal was obtained with 31 mA/cm2, dilution of 17.5%, and 4 hour electrolysis design. At optimum conditions, the treatment efficiency was at 93.5% [2]. Chavalparit and Ongwandee concluded that removal of 55.43% COD, 98.4% oil and grease, and 96.59% suspended solids was obtained using a pH of 6.06, applied voltage of 18.2 V, and reaction time of 23.5 minutes when using the Box-Behnken design for biodiesel wastewater [3]. Kaparal et al. was able to determine the dye removal by the Taguchi method, by using an initial dye concentration of 100 mg/L, pH of 3, current density of 0.5 mA/cm2, $CaCl_2$ concentration of 2.5 mM for the treatment of Bompalex Red CR-L dye. Experimental design involved an orthogonal array using 5 simultaneous parameters [4]. Tchamango et al. used electrocoagulation for artificial wastewater with milk powder to simulate dairy effluents, COD was reduced by 61%, phosphours by 89%, nitrogen 81%, and 100% turbidity. In addition with low conductivity and neutral pH, treated water would be possible reused, as reagent required was lowered for the aluminum anode for treatment [5]. Körbahti and Tanyolaç concluded that 100% pollution load, 61.6% COD, 99.6% color removal, and 66.4% turbidity were accomplished by an electrochemical reactor, where optimum conditions for conducting the experiment were at temperature of 30 degrees Celsius, 25 g/L electrolyte concentration, 8 V electrical potential, with a 35.5 mA/cm2 current density. This was accomplished to treat simulated textile dye wastewater with NaCl electrolyte based on response surface methodology [6]. Hammami et al. concluded that electrochemical oxidation of chromium(III) from chromium(VI) was accomplished with titanium-platinum anodes for the purpose of treating tanning bath effluent. The Water 2011, 3497 Doehlert design optimized Cl ions, temperature in degrees Celsius, pH, intensity of current, time of electrolysis. From the results, the authors observed that current intensity, COD (chemical oxygen demand), TOC (total organic carbon), and electrochemical oxidation were major parameters [7]. Olmez studied hexavalent chromium removal with stainless steel electrodes with electrocoagulation by response surface methodology and concluded that complete treatment could be accomplished by the elctrocoagulator with 7.4 A current and 33.6 mM electrolyte concentration (NaCl), a 70 minute application time and $FeSO_4 \times 7H_2O$ as a coagulant. The authors considered the use of a Central Composite Design for the optimization [8]. Arslen-Alton et al. concluded that the central composite design was used to optimize CI Acid Blue 193 treatment by electrocoagulation. The central composite design is capable of achieving maximum color, COD, TOC, by manipulating the COD, pH, electrical current density, and treatment time by means of a response surface quadratic model [9]. Cora and

Hung were able to remove metallic ions between 90 and 99% after 30 minutes of treatment using an electrocoagulation/electrofiltration with a pH of 9.5 and cadmium chloride for the metallic ions [10].

Aleboyeh et al. concluded that Acid Red 14 had a 91% removal rate when current density reach 102 A/m2, electrolysis time of 4.47 minutes, and a pH of 7.27. This treatment was obtained within an electrocoagulation batch reaction under a 23 full factorial central composite face center design, where a second-order regression model was used [11]. Zodi et al. derived a statistic analysis using a Box-Behkey design for surface response analysis using electrochemical sedimentation. Having considered current density, pH, and electrolysis design, the authors were capable of studying the effects of COD, turbidity, TS removal, and sludge settling with aluminum electrodes [12]. Vasudevan et al. considered using mild steel as anode and cathode, removing 98.6% arsenate at a current density of 0.2 A/dm2, and a pH of 7. Kinetics determined that the removal was within 15 minutes, following a second order rate absorption. Finally, Langmuir adsorption isotherm describes appropriately this condition [13].

IV. Conclusion

This study confirmed that the Electrocoagulation is highly effective on removing COD up to 78.21% from wastewater of ‘PASUPATI INDUSTRIES” manufacturing industry.

15mA/cm2 is the optimum current density & 20min time interval is the optimum condition for the process using Mild Steel and Aluminium electrodes as a cathode & anode.

25mA/cm2 is the optimum current density & 25min time interval is the optimum condition for the process using Mild Steel and Aluminium electrodes as an anode & Graphite electrode as a cathode

Initially the pH of chemical wastewater sample was more acidic but due to the techniques implemented the pH was brought up much near to the neutral.

Experiments shows that by using Iron electrode as anode & cathode the COD removal is higher than using Aluminium electrode as a anode & cathode. So the treated waste can be discharged to the CETP for the further treatment. Hence, the electrocoagulation treatment may prove to be a effective solution for the chemical industry of manufacturing of ‘PASUPATI INDUSTRIES’.

The COD reduction is maximum at pH 6.1.

Experiments shows that by increasing the distance between the electrodes the COD removal efficiency is decreased.

4.1 advantages of electrocoagulation

It can lead to better quality effluent

Electrocoagulation treats water without the need for chemicals. This means there is no danger of residual chemicals making their way into the effluent, leaving behind toxins and odors. There is also no thickener required as there would be in chemical coagulation, which reduces the cost of the operation up front.

Research from 2009 found that electrocoagulation reduces the total number of suspended solids in the solution by as much as 95 to 99 percent.

Metals can be recovered from the solution

The metals that are found suspended in untreated water may not be useless. In fact, they may be very useful indeed; it is just that they pose a hazard when they are suspended in water.

Some water treatment methods are unable to extract metals in a meaningful way, and instead destroy or remove them in other ways. Electrocoagulation is a little different.

As the process uses a form of electrolysis to separate and coagulate liquids, it can collect metals in a purer form. These metals can then be used in various applications.

It only requires a low level of electrical current

It actually does not take much current, in most cases, to run the coagulation equipment. This low level of current can easily be produced using green energy sources.

4.2 disadvantages

Electrodes are impermanent

Electrocoagulation requires electrodes to feed the current into the solution. Unfortunately, the process of coagulation is an intensive one, and places a lot of strain on the electrodes themselves, resulting in wear and tear.

This means, regular cleaning and maintenance for the electrodes are involved in the process. This can be labor-intensive work, not to mention expensive.

This also means a short life span for the electrodes, which need to be replaced often.

Many different factors can affect results

All of the following factors can affect the results of the process:

Material and design of the electrode

The gap between the two electrodes

The electrodes’ polarity

The density of the current

The conductivity of the wastewater

The pH of the wastewater

The size of the particles

And other elements

This makes it very difficult to predict the results of each wastewater treatment. This is a process in which consistency is very important, and this consistency is difficult to achieve, particularly over longer durations of treatment.

Active fine-tuning is required

As it is difficult to be consistent, the process ceases to be a passive one. You cannot just set up the equipment, let it run, and collect the effluent. Instead, you need a team who can actively fine-tune the equipment in order to get the right outcome.

This can be seriously time-consuming and expensive. Sure, the results can be highly beneficial for your firm, but the hard work and expense required to get there are significant.

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