A Review on Removal of Ammonical Nitrogen & COD of Industrial wastewater by Electrocoagulation

[1]Mr. Manoj Kumar, [2]Divyang Gajera, [3]Roshani Pal, [4]Priya Patel, [5]VirbhadrasinhYadav
Assistant Professor, Student, Student, Student, Student
Department of Environmental Science & Technology
Shroff S.R. Rotary Institute of Chemical Technology, Vataria, India

Abstract : Electrocoagulation is one of the process that has a great ability to remove wastes from water because of its high decolourization efficiency, economically attractive and relatively less sludge formation compared with different tradition techniques such as biological, physical, chemical, adsorption and advanced oxidation processes. Electrocoagulation process, which is effective in removing different types of impurities like color, COD, BOD, turbidity, and metal ions removal from wastewater. This review is focuses on number of studies on treatment of industrial wastewater by Electrocoagulation method depending on the mechanisms and many affected factors such as pH, current density, voltage, agitation speed, type, size and number of electrodes, inter electrode distance, initial concentration and electrolysis time which have been published in different journals. The main aim of the review is to explain the basics and up to date advancement of electrocoagulation method for the improvements in the pollutant removal efficiency. In this review paper, a basic overview of electrocoagulation process with effect of key operational parameters on it is provided. Limitations of the electrocoagulation are also represented for the better understanding of the mechanism of pollutant removal and its optimization.

Keywords: COD, Aluminium electrodes, Electrocoagulation process, Effluent treatment, Ammonical Nitrogen

1. INTRODUCTION

Electrocoagulation is an electrochemical process. This process is using electricity for the treatment of wastewater. Electrocoagulation is being used for the treatment of effluent coming from industries such as textile industries, food industries, Pulp and paper industries, mechanical workshops, tanneries, dairy, distillery, heavy oil refineries. The effluent of such industries contains heavy metals, emulsified organic, suspended solids (SS), and some other impurities it may have. By adopting this method we can reduce the generation of sludge. Electrocoagulation is having long history for treatment of water containing impurities. The first patent of electrocoagulation was proposed by A. E. Dietrich in 1906. He has used electrocoagulation process for the treatment of bilge water which was coming from ships.

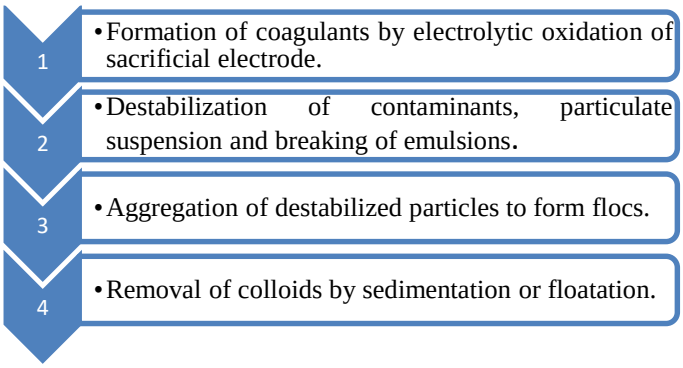
Electrocoagulation process is applied for the treatment of leachate. It is also applied for de fluoridation of ground water successfully. The important modification were in reduction of electrical power consumption and throughout the rates of wastewater. Hence recent studies focuses on the mechanism of electrocoagulation process and other operational factors such as voltage, current density, inter electrode distance, pH of the effluent, treatment time etc. These parameters affects the removal efficiency of the process. The advantages of this process is removal of small colloidal particles. While in the conventional method coagulation and flocculation process would be take place for the removal of colloidal particles, which is time consuming process. Comparatively electrocoagulation process is a better process than the conventional process. This process requires long retention time, pH and conductivity adjustment which makes the process costly.

2. PRINCIPLE OF ELECTROCOAGULATION

Electrocoagulation is the process of destabilization of contaminants (suspended, emulsified, or dissolved) happens by oxidation and reduction because of application of electric current to the electrolytic solution. Electrocoagulation is an alternative electrochemical treatment method which has gained increasing attention in recent years due to its simple operation, high removal efficiency, little sludge production and requiring less chemicals. It is considered as an effective method for treating many different types of wastewater with high color removal efficiency and relatively less sludge formation[3]. This technique is an indirect electrochemical method which produces coagulant agents ions such as (Fe^{+3}or Al^{+3}) from the electrode material (Fe or Al) in aqueous medium. These species, that is $Fe(OH)_3$ can remove dissolved contaminants by precipitation or by floatation. In an electrocoagulation method the coagulating ions are produced "in situ"[11].

3. MECHANISM OF ELECTROCOAGULATION

The mechanism of electrocoagulation is as follows:-



Destabilization mechanism in electrocoagulation process plays a major role, it contains the following major steps.

1. Cationic hydrolysis process neutralizes the negatively charged colloids.

2. Flocs formation, the flocs formed as a result of coagulation creates a sludge blanket that entraps and contaminants are removed in the form of hydroxide precipitate.[9]

3.1 Process Reactions

The main plate electrodes that are most commonly used for electrocoagulation process are iron and aluminum. and the main reactions takes place at the surface of metal electrodes.[8]

Iron Electrode (Anodic reactions)

Anode: $Fe \rightarrow Fe^{2+} + 2e^-$ ——(1)
Cathode: $2H_2O + 2e^- \rightarrow H_2 + 2OH^-$ ——(2) OR
Overall: $Fe^{2+} + 2H_2O \rightarrow H_2 + Fe(OH)_2$ ——(3)

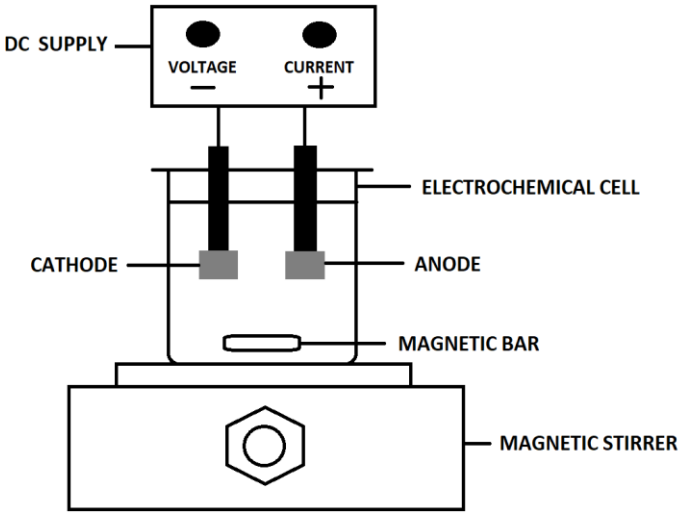
Anode: $Fe \rightarrow Fe^{3+} + 3e^-$ ——(4)
Cathode: $3H_2O + 3e^- \rightarrow 3/2H_2 + 3OH^-$ ——(5)
Overall: $Fe^{3+} + 3H_2O \rightarrow 3/2H_2 + Fe(OH)_3$ ——(6)

OR

Aluminum Electrode

Anode: $Al \rightarrow Al^{3+} + 3e^-$ ——(7)
Cathode: $3H_2O + 3e^- \rightarrow 3/2H_2 + 3OH^-$ —— (8)
Overall: $Al^{3+} + 3H_2O \rightarrow 3/2H_2 + Al(OH)_3$ —— (9)

In general:
Anode: $M \rightarrow Mn^+ + ne$ —— (10)
Cathode : $2H_2O + 2e^- \rightarrow H_2 + 2OH^-$ —— (11)
Overall : $Mn^+ + n\,H_2O \rightarrow nH^+ + M(OH)_n$ —— (12)



3.2 Parameters affecting Electrocoagulation

There are several parameters which affects electrocoagulation. These parameters includes the following: materials of electrode, electrodes arrangement, pH effect. current density, time of treatment, temperature effect, interelectrode distance, and types of power supply.

3.2.1 Electrode material

Material selection depends on the different type of contaminants. And it is also depends on the chemical characteristics of the electrolyte. Generally, aluminum is better than iron in most cases it gives effective results. Aluminum electrodes were most effective in removing the dye of the effluent, whereas iron electrodes removed phenol and from the wastewater more effectively than aluminum electrodes. A combination of aluminum and iron electrodes removed dye, COD, and phenol with high efficiency.[6]

Combination electrodes have been studied for contaminants such as arsenic removal from groundwater. Iron electrodes and a combination of iron and aluminum electrodes gave the highest removal efficiencies for removal of arsenic. Similar results were obtained for copper, chromium and nickel removal from electroplating wastewater. Fe-Al pair has been most effective in removing indium, arsenic from water.[1]

3.2.2 Inter-electrode Distance

Inter-electrode distance plays an important role on electrocoagulation process because the electrostatic field depends on the distance between the anode and the cathode. Minimum inter-electrode distance provides low pollutant removal efficiency. An minimal distance between electrodes provides maximum pollutant removal efficiency. The more the inter electrode distance the decreases the movement of the produced ions.[4]

The larger the inter electrode distance, the greater should be the difference in applied power supply, because the solution presents higher resistivity to the electrical current. According to the characteristics of the effluent, the process efficiency can be improved by varying the distance between the electrodes and power supply will also vary accordingly.[5] In case, the dye wastewater, it was observed that less rapid colour removal with increasing inter-distance between electrodes and it decrease in current density and also interaction rate between metal ions and dye molecules.

3.2.3 Effect of the temperature

The effect of temperature on the removal of pollutants through EC has been studied in a several research paper. The effect of solution temperature on boron removal by EC is studied in the range of 293–333K[1]. When temperature increased by 293 K to 333 K, the boron removal efficiency increased from 83% to 96%. It is reverse in the case when paper mill wastewater which is treated at temperatures between 293 and 333 K. Removal of color, COD, and phenol decreased by 10–20% when temperature increased up to 293 K to 333 K[1]

Results indicating that increasing temperature has a negative effect on removal. However, it is noted that the operation of electrocoagulation process at higher temperature significantly reduced electrical energy consumption. So, the production of hydroxide species increases rapidly then it enhances value of pH. The increase in pH may be affecting on iron and aluminum electrode to be in the oxide form and didn't exist in the hydroxide form which is the coagulant that should remove the color.[2]

3.2.4 Effect of pH

The pH of the solutions is as an important parameter before treatment because it affects the conductivity of the solution, dissolution of the electrodes, speciation of hydroxides, and ζ-potential of colloidal species. pH helps in precipitation of pollutants if the solution achieve desirable pH and it may have better efficiency of contaminants removal. Both low and high pH values from the optimum value decrease the removal efficiency.[3]

In the wastewater treatment process initial pH plays an important role, either in chemical coagulation or EC. However, EC is more appropriate in a wide range of pH, while chemical coagulation is added if pH is high.

pH increases the dissolved iron weight during the electrocoagulation process increases due to the formation of iron hydroxide species which absorb the color molecules and causes the increase of the removal efficiency. The effect of pH on the process performance is explained as follows: the iron species are different according to the solution pH; at alkaline pH, dye removal efficiency is increased as concentration of OH^- ion increases which help in formation of different iron hydroxide complexes.[4]

3.2.5 Current density and time of treatment

Current density is an important factor because it analyzes the coagulant dosage rate, bubble formation rate, size, and development of flocs as they affect the efficiency of the electrocoagulation process. The anode dissolution rate is straightly proportional to the current density. However, an increase in current density beyond the optimum value has no effect on the contaminant removal efficiency.[5]

At high current density, the wastage of electrical energy in heating up of water which results in decrease in current efficiency. The current density must be selected in according to the other operating parameters such as pH, temperature and flow rate. In the electrocoagulation process, current density and the types of the anions define the current efficiency.[5] Example like the dye wastewater containing high colour and COD, it was observed that dye removal increased upon raising current density till 76.5 A/m^2 at 30 minutes.

4. ADVANTAGES AND DISADVANTAGES

EC process is easy in operate. It needs a simple equipment. It is a low sludge producing process. EC generated Sludge is mainly composed of metallic oxides/hydroxides.There are no additional chemicals required in EC process. It requires less maintenance. EC requires less civil works and other constructions. Flocs formed by EC process tends to be much larger.EC process is used to removes the smallest colloidal particles. It gives clear, colorless and odour less water.

The sacrificial anodes need to be replaced periodically. The usage of electricity may be expensive in some of cases. High conductivity of the wastewater suspension is required. Operational can be increased due to high cost of electricity.

5. CONCLUSION

This review was mainly focused on the electrocoagulation process for to treatment of water and wastewater by analyzing and studying the mechanism, chemical reactions on the electrodes and the effect parameters. It was found that electrocoagulation method is an effective treatment technique for the removal of wastes and other contaminants from water. It has been noted that electrocoagulation process is capable of having better removal efficiencies as compared with other different treatment techniques available in the market. Electrocoagulation is an attractive method for the treatment of various kind of wastewater. It is characterized by simple & reliable equipment, easy operation, less operating time and decreased amount of sludge which sediments rapidly. In this review article, research articles applied electrocoagulation process from a period of 2010 to 2018. As from the results, this technology has excellent future because of numerous advantages was found in this method.

6. REFERENCES

[1].Ahmed Samir Naje*, ShreeshivadasanChelliapan*, ZuriatiZakaria, Mohammad A. Ajeel and Peter AdeniyiAlaba A review of electrocoagulation technology for the treatment of Textile wasterwater;Department of Engineering, UTM Razak School of Engineering and Advanced Technology, UniversitiTeknologi Malaysia

[2].Ajeel MA, ArouaMK,DaudWMAW.p-Benzoquinine anodic degradation by carbon black diamond composite electrodes. ElectrochimActa 2015;169:46-51.

[3].Bharath M*, Krishna B M and Manoj Kumar B, A Review of Electrocoagualation Process for Wastewater Treatment; Department of Environmental Engineering, Sri Jayachamarajendra College of Engineering, Mysuru-570006, Karnataka, India.

[4].Gajjar N. S., Patel M. N. (2013), Treatment of paint (Emulsion) industry wastewater by electrocoagulation, Journal of environmental science, toxicology and food technology, 3(5), 42-45

[5].K. Dermentzis, A. Christoforidis, E. Valsamidou, A. Lazaridou and N. Kokkinos,- Removal of Hexavalent Chromium From Electroplating Wastewater By Electrocoagulation With Iron Electrodes. Glob.NEST J., vol. 13,no.4,pp.412-418,2011

[6].M.F. Ni'am, F.Othman, J.Sohaili, Z.Fauzia "Electrocoagulation technique in enhancing COD and suspended solids removal to improve wastewater quality" Water Science& Technology Vol.56 No.7 2007.

[7].Prof.Shrti A Byadgi, Prof.MAnjunath S Sharanappanavar, Mr.BasavarajDhamoji, Mr.AsifNadaf, Mr.SiddarameshMunennavar "Treatment of Sugar Industry Waste Water using Zinc Electrodes" IJETSR-International Journal of Engineering Technology Science and Research | Volume 4, Issue 6, June 2017.

[8] Rumi Chaudhary, O.P. Sahu "Treatment of Sugar Waste Water by Electrocoagulation" Journal of Atmospheric Pollution, 2013, Vol. 1.

[9].Salman Hussein Abbasl, Wail Hassan Ali- Electrocoagulation Technique Used To Treat Wastewater: A Review, Eng.Technical College, Middle Technical University2MechatronicEng. American Journal of Engineering Research (AJER)e-ISSN:2320-0847 p-ISSN : 2320-0936 Volume-7 , Issue-10,pp-74-88.

[10].Sharma S., Can O. T., Hammed M., Nawarathna D., Simsek H. (2018), Organic pollutant removal from edible oil process wastewater using electrocoagulation, IOP Conf. series: Earth and Environmental Science 142, 012079, 1-13

[11].Vidal J., Espinoza C., Contreras N., Salazar R. (2017), Elimination of industrial textile dye by electrocoagulation using iron electrodes, J.Chil.Chem.Soc., 62(2), 3519-3524