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Feasibility Study of Electro-Coagulation as a Treatment Method for Textile Industry Wastewater

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Abstract

Electro-coagulation (EC) is becoming a popular process to be used for industrial wastewater treatment. In the present study, a laboratory scale electro-coagulation (EC) process was utilized to treat the textile wastewater in order to bring the quality up to the wastewater reuse standards and also to compare the electro-coagulation process with the conventional coagulation treatment. Effect of various operating parameters such as operating time and voltage on COD removal efficiency was evaluated to achieve the maximum possible treatment efficiency.

Keywords: Electro-coagulation, textile Industry wastewaters, removal efficiency

Introduction

One of the major challenges facing mankind today is to provide clean water to a vast majority of the population around the world. The need for clean water is particularly critical in Third-World Countries. Rivers, canals, estuaries and other water-bodies are being constantly polluted due to indiscriminate discharge of industrial effluents as well as other anthropogenic activities and natural processes. In the latter, unknown geochemical processes have contaminated ground water with arsenic in many countries. Highly developed countries, such as the US, are also experiencing a critical need for wastewater cleaning because of an ever increasing population, urbanization and climatic changes. The reuse of wastewater has become an absolute necessity. There is, therefore, an urgent need to develop innovative, more effective and inexpensive techniques for treatment of wastewater. A wide range of wastewater treatment techniques are known which includes biological processes for nitrification, denitrification and phosphorous removal; as well as a range of physico-chemical processes that require chemical addition. A host of very promising techniques based on electrochemical technology are being developed but are not yet to the commercial stage. One more process has been developed to the commercial stage and is being used in city wastewater treatment plants all over Europe and a few UScities have adopted parts of this technology. This process is known as the Electro-coagulation [Abe Beagles].

Electro coagulation (EC) is the process where an electrical current is introduced into an aqueous medium in an electrochemical cell, usually with an Al or Fe anode. In this process, the anode material undergoes oxidation and hence, various monomeric and polymeric metal hydrolyzed species are formed. These metal hydroxides remove organics from waste water by sweep coagulation and/or by aggregating with colloidal particles present in the waste water to form bigger size flocs and ultimately get removed by settling. Organics contained in wastewater are oxidized directly at the surface of the electrode or oxidizing agent is electro-chemically generated to carry out oxidation in electro-oxidation process of wastewater treatment

Electrochemical methods for the treatment of wastewater have recently attracted attention due to their safe and environmentally friendly nature. They are effective in treating waste-waters containing several organic and inorganic compounds, including phenol, dyes, metal ions, cyanide, etc., because various degradation and removal mechanisms may exist simultaneously in an electrochemical reactor [M.A.Abd El-Khalek, 2001]. Also electro-coagulation has been reported to successfully treat different kinds of wastewater, containing oil, fluoride, arsenic, dyes and suspended particles and a

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variety of pollutants discharged from metal plating, electroplating and all kinds of metal finishing operations.

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. On the other hand, due to the scarcity of space, extremely high land cost and the complexity of handling chemical, 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-coagulation.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. On the other hand, due to the scarcity of space, extremely high land cost and the complexity of handling chemical, 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-coagulation.

Experimental

Characteristics of wastewater

Physical characteristics of wastewater include solids content, color, odor and temperature. The total solids in a wastewater consist of the insoluble or suspended solids and the soluble compounds dissolved in the water. The organic matter consists mainly of proteins, carbohydrates and fats. Between 40 and 65 % of the solids in an average wastewater are suspended. Color is a qualitative characteristic that can be used to assess the general condition of waste-water. Wastewater that is light brown in color is less than 6 h old, while if the color is dark grey or black; the wastewater is typically septic, having undergone extensive bacterial decomposition under anaerobic conditions. The blackening of wastewater is often due to the formation of various sulfides. This results when hydrogen sulfide produced under anaerobic conditions combines with divalent metal. The odor of fresh wastewater is usually not offensive, but a variety of odorous compounds are released when wastewater is decomposed biologically under anaerobic condition.

The principal chemical tests include free ammonia, organic nitrogen, nitrites, nitrates, organic phosphorus and inorganic phosphorus. Nitrogen and phosphorus are important because these two nutrients are responsible for the growth of aquatic plants. Other tests, such as chloride, sulfate, pH and alkalinity, are performed to assess the suitability of reusing treated wastewater and in controlling the various treatment processes. Heavy metals can also produce toxic effects; therefore, determination of the amounts of heavy metals is especially important where the further use of treated effluent or sludge is to be evaluated. Many of metals are also classified as priority pollutants such as arsenic, cadmium, chromium, mercury, etc. The hydrogen sulfide content is important not only because its toxicity but also it can affect the maintenance of long sewers on flat slopes, since it can cause corrosion. Wastewater includes biochemical oxygen demand (BOD), chemical oxygen demand (COD) and total organic carbon (TOC) [M.A.Abd El-Khalek, 2001].

Materials

The wastewater of textile industry was collected over seven days of a week. Iron and aluminium rods were used as electrodes. The direct current supply (0-30V, 0-2 A, TESTRONIX 92B) was used.

Lab-Scale Electro-Coagulation Set-Up

EC reactor with mono-polar electrodes connected in parallel was used in the experiments. The reactor having a volume of 2 litres (131 mm diameter and185mm height) was used. Iron rod of 29.8 cm length and 6mm diameter was used as the cathode and aluminium rod of 29.8cm length and 5mm diameter was used as the anode. A regulated direct current supply (0-30V, 0-2 A, TESTRONIX 92B) was used for the experiments. The experimental setup is shown in Fig 1

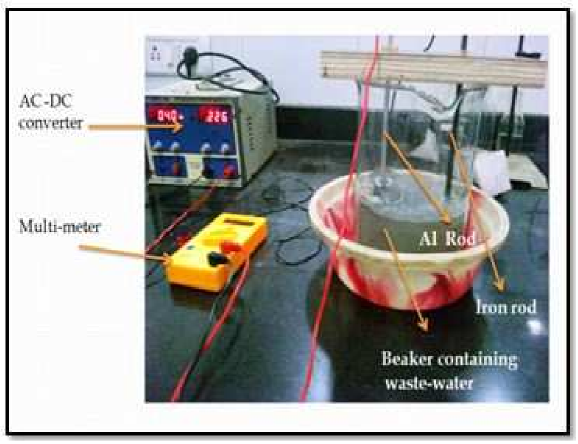

Fig 1. Experimental Setup

A. *Experimental Procedure*

Take 1 litre sample (textile industry and

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molasses) in a 2 litre beaker. Current is passed with the help of DC power supply at varying voltages. Note the varying voltage at a given voltage. The inter-electrode spacing is kept at 7cm for all experiments. Allow the electro-coagulation to occur for 1 hour. After every hour, withdraw 25ml sample from the beaker for residual COD analysis.

B. *Pre And Post Treatment*

Pre-treatment usually includes pre-screening of larger solids and removal of gross oil (if present) upstream of the EC unit. After electro-coagulation has taken place the aggregated contaminants will normally partially settle out and partially float. These need to be removed through a further stage of treatment, filtration and sedimentation. The electro-coagulated flock tends to contain less bound water, is more shear resistant and is more readily filterable than flocks produced in chemically treated systems. The lack of mechanistic understanding of electro-coagulation is reflected in the design of reactors. No single empirical or systematic approach has emerged over the years in the design of electro-coagulation reactors. It is therefore difficult to compare the performance of reactors. This literature review aims to highlight commonalties (or lack of such) between reactors. In this analysis, the discussion is separated in to two main sections; physical and chemical design issues. Obviously, chemical and physical design aspects interact and the division is simply to highlight key features of the system.

Observation

The electrolysis of water induces the formation of small bubbles of oxygen and hydrogen (whose average size is less than 100 micrometers) respectively to the anode and cathode. These bubbles consist mainly of hydrogen because oxygen is the formation of a secondary reaction, often of minor importance to the anode. These micro bubbles are absorbed by the flocculated material and lead them to rise. The impurities can then be treated by flotation. The foam can be formed of poor stability and oxidizable materials fall to the bottom of the decanter. Despite this, many light and heavy particles remain suspended and we must resort to their separation by settling or filtration [Inoussa*et al.*]

One of the greatest operational issues with electro-coagulation is electrode passivation. The passivation of electrodes is concern for the longevity of the process. Passivation of aluminum electrodes has been widely observed in the literature (Nikolaev*et al.* (1982), Novikova*et al.* (1982), Osipenko and Pogorelyi (1977)). The latter also observed that during electrocoagulation with iron electrodes, deposits of calcium carbonate and magnesium hydroxide were formed at the cathode and an oxide layer was formed at the anode.

Nikolaev*et al.* (1982) investigated various methods of preventing and / or controlling electrode passivation including:

- Changing polarity of the electrode;
- Hydro mechanical cleaning;
- Introducing inhibiting agents;
- Mechanical cleaning of the electrodes.

Results and Discussions

The whole analysis performed on the textile wastewater can be tabulated as follows:

Table 1.Textile Wastewater Analysis

Sr. No.	Voltage (volts)	Time (hours)	pH	TDS (ppm)	Current Density (A/m^2)	COD (mg/L)
1.	4	Initial	7.44	3220	-	1312
		1	6.66	3170	228.35	688
		2	6.54	3150	201.42	880
		3	6.52	3170	192.40	832
						Avg = 800
2.	6	Initial	7.53	3790	-	1623
		1	6.67	3980	143.62	1152
		2	6.55	3930	135.90	928
		3	6.43	3890	122.77	752
						Avg = 944
3.	8	Initial	6.90	3202	-	1360
		1	6.27	3090	202.94	960
		2	6.06	2950	202.20	880
		3	6.00	3030	192.64	1280
						Avg =1040

Operating parameters like pH and TDS were found to be almost constant with electro-coagulation time.

Generally, the pH of the medium changes during the process, as observed also by other investigators [X. Chen, G. Chen, P.L. Yue, E.A. Vik, D.A. Carlos, A.S. Eikum, E.T. Gjessing]. This change depends on the type of electrode material and on initial pH. In the case of aluminium, the final pH is higher for initial pH <8, and above this point the final pH is lower. Furthermore, for iron, the final pH is always higher than initial pH. The difference between initial and final pH values diminishes for initial pH >8. These results suggest that electro-coagulation exhibits some pH buffering capacity, especially in an alkaline medium [X. Chen, G. Chen, P.L. Yue]

The varying TDS can be attributed to the presence or absence of anions like chloride and sulphate that reduce the removal efficiency and vary the total dissolved solids (TDS) in the treated waste-water. [M. A. Abd El-Khalek]. Electro-coagulation test was first performed at fixed potential of 4V, 6V, 8V and at different electrolysis times. The variation of COD with electrolysis time is shown in figure. COD decreases with increasing electrolysis time and starts to increase after 1 hour. The same trend of evolution of COD with electrolysis time is reported by Diaz et al. [C.B. Diaz, M.P. Pardave, M.R. Romo, S. Martinez,].

The investigation of the effect of electrolysis potential on treatment efficiency was conducted under a fixed electro-coagulation time of 1hour. Evolution of COD with electrolysis potential is presented in Fig. 5. The COD decreases with increasing potential. This behaviour is similar to those founded in literature [S.H. Lin, C.F. Peng, N. Daneshvar, H.A. Sorkhabi, A. Tizpar].

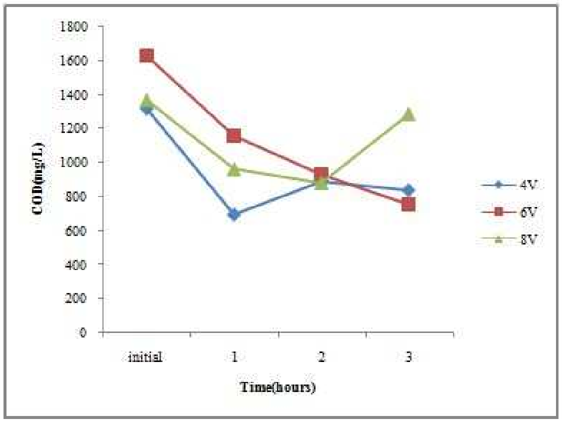

Fig 2: Effect of Electro-Coagulation Time and Voltage on Residual COD

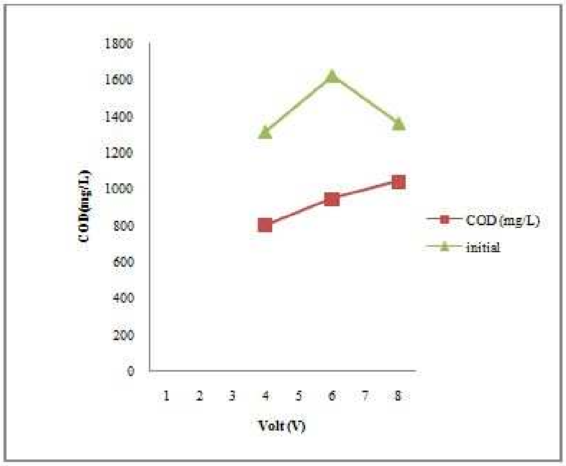

Fig 3: Variation of COD with Voltage

The percentage COD removal efficiency has been tabulated below:

Table 2.COD Removal Efficiency

Sr. No	Voltage (volt)	Time (hours)	% COD Reduction
1.	4	1	47
2.		2	32
3.		3	36
1.	6	1	28
2.		2	42
3.		3	53
1.	8	1	29
2.		2	35
3.		3	5

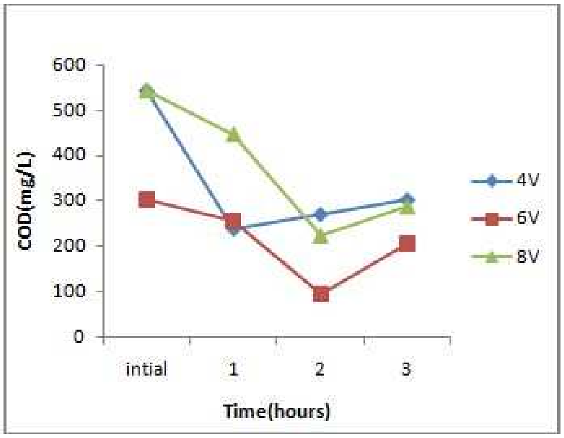

Fig 4: Variation of COD with Time

Two trends are observed in COD at different voltages: partial removal and increased COD:

i. The EC process generates Fe ions that hydrolyze to form $Fe(OH)_2$ and/or $Fe(OH)_3$ together with H^+ ions, since Fe (II) and Fe (III) are more acidic than.
Na^+ then OH^- will preferentially stay with them to from insoluble iron hydroxides and the acetate ion will be only removed in low proportion and thus COD will be partially removed.

ii. Compounds which react with Fe (II) or Fe (III) to form soluble products will remain in solution. The increase in COD can be attributed to the further oxidation of Fe (II) into Fe (III).

Generally, inter-electrode spacing is a vital parameter in EC process for the removal of pollutant from effluent. Increasing the electrodes spacing will

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reduce the capital cost of treatment but may reduce the treatment efficiency. The low efficiency in these experiments may probably be due to the high inter electrode spacing.

Hence, an optimization of this parameter is critical (Bukhari, 2008). The experimental states that a shorter gap would favour the minimization of the potential drop, which lead to a higher current density. However, after an optimum spacing surface charge double layer dominates and suppresses the removal efficiency (Mattenson*et al*., 1995). Furthermore, that the formation of scale on cathode surface may also passivate the electrode (Belmont *et al*., 1998, Virkutyte*et al*., 2010; Reyter*et al*., 2009, 2010) resulting in lower efficiency

Conclusion

Electro-coagulation is an efficient process to treat textile wastewater characterised by high dyes content and high COD content. The time and potential are the most important operation variable for treatment efficiency.

On evaluating the effect of various operating parameters such as operating time and voltage on COD removal efficiency, the maximum possible treatment efficiency was 53% for textile wastewater. On observing the efficiency of electro-coagulation at various parameters it was observed that the first step reduction at 4V is more while the subsequent reductions are more at 6V and 8V. This suggests that future research work could be pursued in using 4V and other volts for a single cycle. In addition, the experimental results also show that the electro-coagulation can neutralize pH of wastewater. On comparing the two processes, it was observed that electro-coagulation process is capable of being an effective treatment process as conventional methods such as chemical coagulation but it is expensive on account of the cost of electricity and electrode consumption. However, these costs can be recovered over an extended period of time.

Having observed trends over the last few years, it has been noted that electro-coagulation is capable of having high removal efficiencies of color, chemical oxygen demand (COD), biochemical oxygen demand (BOD), and achieving a more efficient treatment processes quicker than traditional coagulation and inexpensive than other methods of treatment such as ultraviolet (UV) and ozone. Unlike biological treatment which requires specific conditions, therefore limiting the ability to treat many wastewaters with high toxicity, xenobiotic compounds, and pH, electro-coagulation can be used to treat multifaceted wastewaters, including industrial, agricultural, and domestic. Continual research using this technology will not only improve its efficiency, but new modeling techniques can be used to predict many factors and develop equations that will predict the effectiveness of treatment.

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