WASTE WATER TREATMENT USING ELECTRO CHEMICAL COAGULANT

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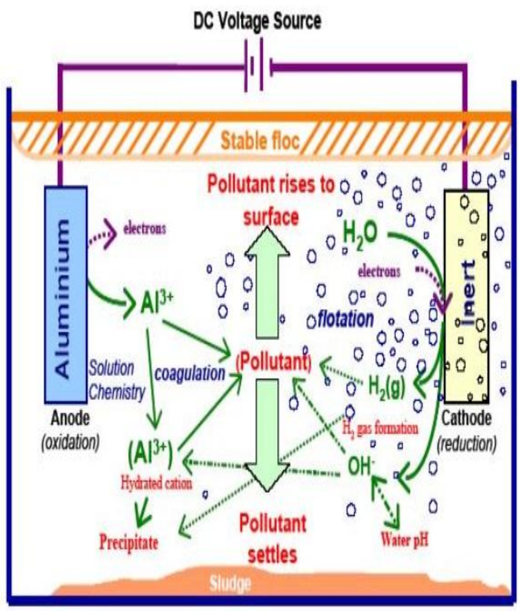
Abstract- *All waters, especially surface waters and sewage water contain both dissolved and suspended particles. Coagulation processes are used to separate the suspended solids portion from the water. The suspended particles vary considerably in source, composition charge, particle size, shape, and density. Chemical and electro coagulation are widely used coagulation methods employed in water and wastewater treatment. Both coagulation processes are effective in removing a wide range of impurities which include dissolved organic matter in form of chemical and biological oxygen demand, pathogens, oils, and colloidal particles as well as heavy metals. The present review has revealed that the mode of action of both coagulation methods is based on charge neutralization and floc formation. The effectiveness of both coagulation techniques depend on factors such as pH, coagulation dose, coagulant type, current density, applied voltage, water and wastewater type, type of electrode, as well as size and number of electrodes. The commonly used chemical coagulants are inorganic coagulants based on aluminum and iron salts. However, there have been considerable successes in the development of pre-hydrolyzed inorganic coagulants which have the added advantage over traditional inorganic coagulants in that they function well over a wide range of pH and water temperatures. Electro coagulation has been proposed as an alternative method to chemical coagulation because it is environmental friendly and cheap to operate.*

***Keywords**: efficiency; electro coagulation; operating parameters; pollutants removal; Industrial waste water.*

1. INTRODUCTION

The major challenges for the 21st century are water and energy. Due to increased pollution from point and non-point sources quality of the water become a crucial problem, particular for the Third-World Countries. The promising methods based on electrochemical technology are electro coagulation, electro flotation, electro decantation, and others. Electro coagulation (EC) consists of number of benefits, compatibility, amenability, cost effectiveness, energy efficiency, safety, and versatility. Though EC has received little scientific attention a decade back, in the last couple of years, this technology has been widely used for the treatment of dilute wastewaters having heavy metals, foodstuff, oil wastes, textile and dyes, fluorine, polymeric wastes, organic matter from landfill leachate, suspended particles, chemical and mechanical polishing wastes, aqueous suspension of ultrafine particles, nitrate, phenolic waste, arsenic, and refractory organic pollutants including lignin and EDTA. Also, electro coagulation is applicable for drinking water treatment. This process has capability to overcome the disadvantages of the other treatment techniques.



Interactions Occurring Within an Electrocoagulation Reactor

2. ADVANTAGES AND DISADVANTAGES

- Advantages

(i) EC requires simple equipment and is easy to operate. (ii) EC requires low initial investment with low operating cost. (iii) The electrolytic processes in the EC cell are controlled electrically and with no moving thus requiring less maintenance. (iv) EC does not require any chemicals. So there is no problem of neutralizing excess chemicals and no possibility of secondary pollution caused by chemical substances..(v) EC composed of mainly metallic oxides/hydroxides. Sludge formed by EC tends to be readily settable and easy to dewater, so low sludge generation can be done. (vi) EC flock tends to be much larger, contains less bound water, is acid-resistant and more stable, and therefore, can be separated faster by filtration. (vii) EC produces effluent with less total dissolved solids (TDS) content as compared with chemical treatments. If this water is reused, the low TDS level contributes to a lower water recovery cost. (viii) The EC process has the advantage of removing the smallest colloidal particles, because the applied electric field sets them in faster motion, thereby facilitating the coagulation. (ix) The gas bubbles produced during electrolysis can carry the pollutant to the top of the solution where it can be more easily concentrated, collected and removed. (x) After treatment EC gives palatable, clear, colorless odorless water with zero discharge. (xi) EC handles large variation in the waste streams with multiple contaminants.(xii) The EC technique can be easily used in rural areas where electricity is not available, since a solar panel attached which may be sufficient top carry out the process.

- Disadvantages

1) In some EC systems, an impermeable formation of oxides film form on the cathode, so efficiency of electro coagulation cell. 2) High conductivity of the waste water suspension is required. 3) Gelatinous hydroxide may tend to soluble in some cases. 4) Due to oxidation, sacrificial anode dissolved in the waste water, so need to be regularly replaced. 5) The use of electricity may be expensive in some cases.

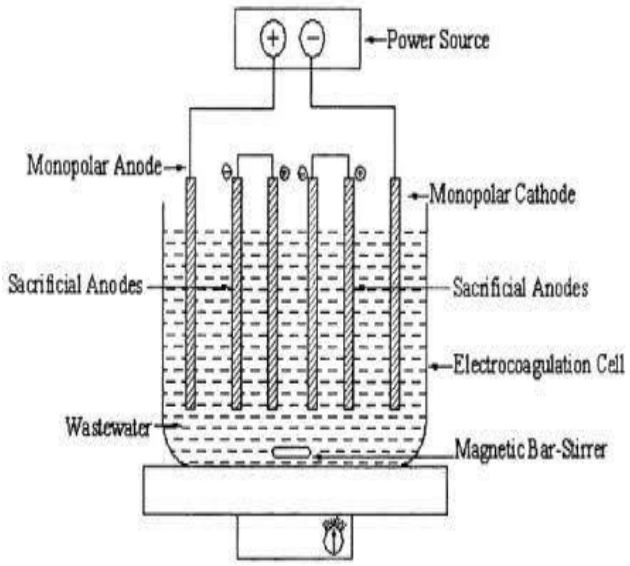
3. MATERIALS AND METHODS

1. Physical-chemical characterization of Industrial waste water, The Industrial waste water was collected from the waste water treatment plant located nearby the industries and the essential physicochemical characteristics were evaluated using standard method. The powdered form of the natural biomass was used as a natural coagulant. The powdered coagulant was characterized for surface functional groups. Experiments the electro coagulation process was carried out in a single compartment reactor equipped with a magnetic stirrer operated at 200 rpm throughout the experiments. The reactor was made of glass with a total volume of 5.0 L and working volume of 2.0 L. The reactor was equipped with a DC power supply and two monopolar plate type electrodes, one cathode and the other anode. The dimensions of both the electrodes were identical (12 cm × 10 cm × 2 mm). The total effective electrode area was 120 cm^2 per electrode and the distance between electrodes was 2 cm. The electro coagulation experiments were conducted under batch conditions at room temperature of 298 K. In the first set of experiments, the effect of type of electrode on electro coagulation performance was studied by choosing three different materials namely copper, steel and aluminum and the operating variables such as initial pH, coagulant dose, current and voltage were fixed. All the experiments were conducted with the actual undiluted effluent for an equilibrium time of 90 min at optimal pH unless or otherwise specified. The EC phenomenon has been known as an electrochemical technique for the last century. It has been used with varying degrees of success for treatment of water and wastewater obtained from various sources. In the treatment of wastewater by a hybrid electro coagulation–flotation technique by Al electrodes, different EC reactors to evaluate their water treatment performance and found out the best configurations to maximize the treatment efficiency. The EC reactors were configured with water up-flow or cross-flow arrangements. The bipolar electrodes were connected in series via the water, and the monopolar electrodes connected in parallel via copper connectors.

Sample of waste water to be treated by using electro coagulation process

4. THEORY OF ELECTRO COAGULATION

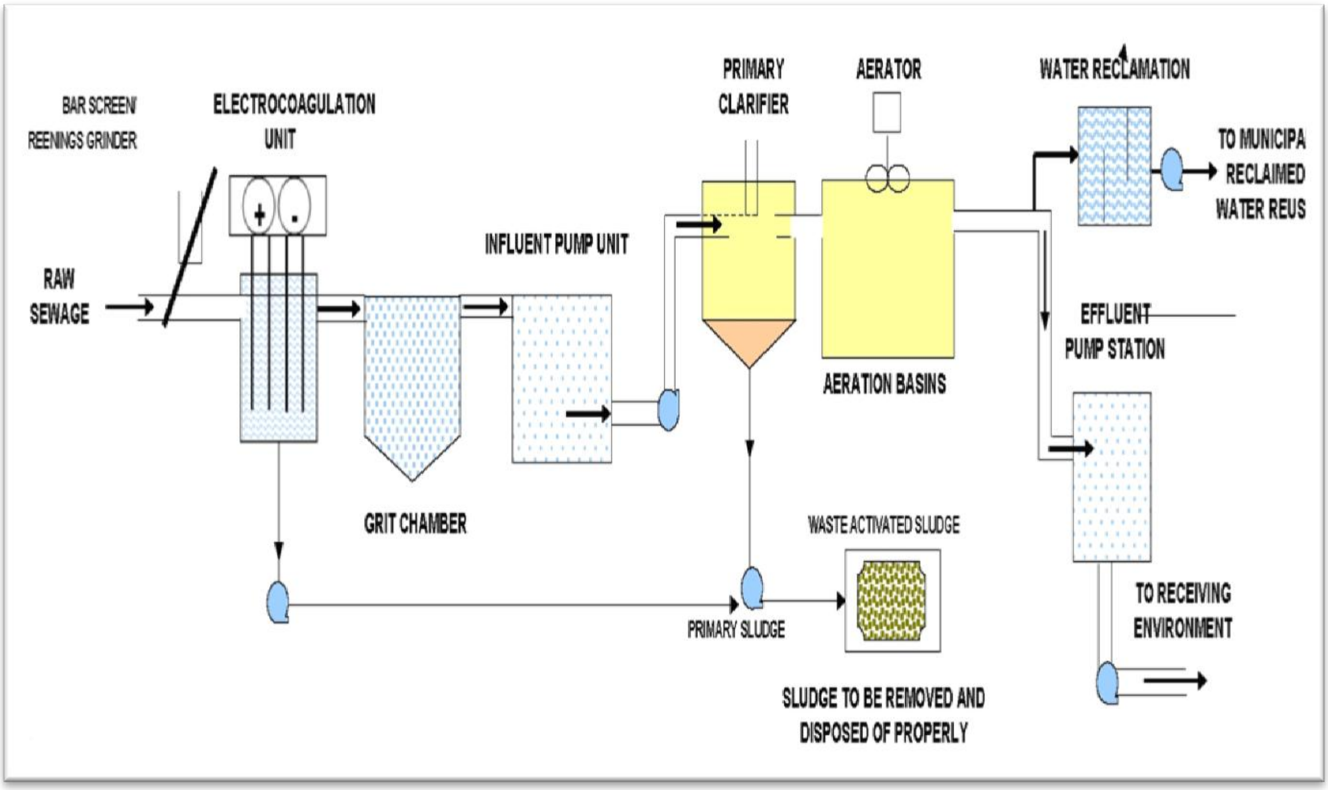
The electro coagulation process operates on the base of the principle that the cations produced electrolytically from iron and/or aluminum anodes, which is responsible for the increasing of the coagulation of contaminants from an aqueous medium. Electrophoretic motion tends to concentrate negatively charged particles in the region of the anode and positively charged particles in the region of the cathode. The consumable metal anodes are used to continuously produce polyvalent metal cations in the region of the anode. These cations neutralize the negative charge of the particles moved towards the anodes by production of polyvalent cations from the oxidation of the sacrificial anodes (Fe and Al) and the electrolysis gases like Hydrogen evolved at the anode and oxygen evolved at the cathode. Electro coagulation is an enigmatic technology. One possible conceptual framework, each foundation area brings to ascertain perspective to electro coagulation, as represented by each lobe of this Venn diagram. The main aim is to shoe how electro coagulation complexity can be simplified by using reductionist approach. Relevant phenomena, characterization methods and tools are mentioning each lobe. Above fig. represents the two removal paths with the relative importance of each being set by a combination of reactor design and operating parameters. Current density represented by a doubled-headed arrow at the base between the flotation and coagulation lobes as it determines both the coagulant dosage and bubble production rates as well as influencing the extent of mixing within a reactor.



This process involves three successive stages: (i) Formation of coagulants by electrolytic oxidation of the “sacrificial electrode” (ii) Destabilization of the contaminants, particulate suspension and breaking of emulsions (iii) Aggregation of the destabilized phase to form flocks

Main function of sacrificial anode is to generating polymeric hydroxides nearby the anode. These polymeric hydroxides are act as a excellent coagulating agents. Due to electrophoretic action negative ions which are produce from the cathode moves towards the anode. Due to combination of the metal cations with these negative particles which turns into the coagulation. Due to electrolysis is continuously carried out, water is electrolyzed. At anode small bubble of oxygen and at the cathode small bubbles of hydrogen are generated which are responsible of electrolysis of water. The flocculated particles attract by these bubbles and these flocculated particles float due to the natural buoyancy towards the surface Physiochemical reaction also occurs in the electro coagulation cell as follows. (i) At the cathode metal ions reduction take place. (ii) In the waste water impurities are responsible for catholic reduction. (iii) Colloidal particles being generated by electrode erosion. (iii) Coagulation and discharge of colloidal particles by electro flotation or sedimentation and filtration. (iv) Ions migration done due to electrophoretic in the solution. (v) Oxygen and hydrogen bubbles which are produced at anode and cathode, (vi) Responsible of electro flotation of coagulated particles. (vii) Other chemical and electrochemical process occurs. (viii) Electro coagulation process carried out by an external power supply.

Electro coagulation operating conditions are mostly dependent on the chemistry of the aqueous medium, mainly conductivity and pHs Also other important characteristics are particle size, type of electrodes, retention time between plate, plate spacing and chemical constituent concentrations. The mainly operating principal is that the cations produced electrolytic from iron and/ or aluminum anodes enhance the coagulation of contaminants from an aqueous medium. Electrophoretic motion tends to concentrate positively charged ions in the regions of the cathode and negatively charged particles in the region of the anode. The sacrificial metal, anode are used to continuously produced polyvalent metal cations in the in the vicinity of the anode. These cations neutralize the negative charge of the particles carried to the anode by electrophoretic motion, which facilitating coagulation. Generally, oxidation of organic matter by electrochemical treatment can be classified as direct oxidation at the surface of anode and indirect oxidation from the anode surface which are influenced by the anode material. Oxidation of organic matter depends upon the anode material, concentration of NaCl and current and voltage applied. In addition, electrocoagulation also occurs during electrochemical treatment of waste water. The electro coagulation mechanism has been proposed for the production of Fe (OH) 3 or Fe (OH) 2.



5. FACTORSAFFECTING ELECTROCOAGULATION

There are various parameters which have an effect on the efficiency of the EC in removing the pollutants from water. The factors which are known to have an effect are:

• **Material of the electrodes** can be iron, aluminum and/or inert material (typically cathodes). Iron and aluminum ions and hydroxides have different chemistries and applications.

• **pH of the solution** has an effect on the speciation of metal hydroxides in the solution and also on the zeta potential of the colloidal particles. It also affects the dissolution of aluminum cathodes.

• **Current density** is proportional to the amount of electrochemical reactions taking place on the electrode surface.

• **Treatment time** or electric charge added per volume is proportional to the amount of coagulants produced in the EC system and other reactions taking place in the system.

• **Electrode potential** defines which reactions occur on the electrode surface.

• **Concentration of the pollutants** affects the removal efficiency because coagulation does not follow zeroth-order reaction kinetics but rather pseudo second or first-order kinetics.

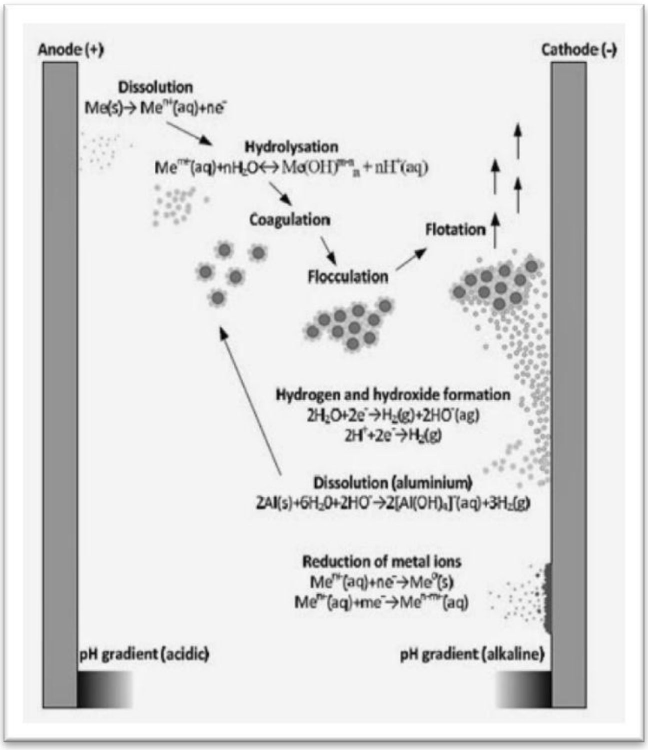
• **Concentration of anions**, such as sulphate or fluoride, affects the composition of hydroxides because they can replace hydroxide ions in the precipitates.

• **Temperature** affects floc formation, reaction rates and conductivity. Depending on the pollutant, increasing temperature can have a negative or a positive effect on removal efficiency.

• **Other parameters,** such as hydrodynamic conditions and inter-electrode distance, may have effect on efficiency of the treatment and electricity consumption.

6. REACTION MECHANISM

Electro coagulation is a complex process occurring via series steps. When current is passed through electrochemical reactor, it must overcome the equilibrium potential difference, anode over potential, cathode over potential and potential drop of the solution. The anode over potential includes the activation over potential and concentration potential, as well as the possible passive over potential resulted from the passive film at the anode surface, while the cathode over potential is principally composed of the activation over potential and concentration over potential. Reactions at electrode surfaces, formation of coagulants in aqueous phase, adsorption of soluble or colloidal pollutants on coagulants. Generally, aluminum and iron are used as an electrode material in the electro coagulation process. In the iron electrode, two mechanisms have been proposed



Mechanism 1:

Anode: 4Fe(s) → 4Fe+2(aq) + 8e, (2)

4Fe+2(aq) + 10H2O(l) + O2(g) → 4Fe(OH)3(s) + 8H+(aq) ,(3)Cathode:

8H+(aq) + 8e → 4H2(g) , (4)

Overall:

4Fe(s) + 10 H2O (l) + O2 (g) → 4Fe (OH) 3(s) + 4H2 (g), (5)

Mechanism 2:

Anode:

Fe(s) → Fe+2(aq) + 2e-, (6)

Fe+2(aq) + 2OH-(aq) → Fe (OH) 2 (s) , (7)

Cathode:

2H2O (l) + 2e- → H2 (g) + 2OH-(aq), (8)

Overall:

Fe(s) + 2H2O (l) → Fe (OH) 2(s) + H2 (g), (9)

Due to oxidation in an electrolyte system, iron produces form of monomeric ions, Fe (OH)3 and polymeric hydroxy

Complex such as:

Fe(H2O)6(3+),Fe(H20)5(2+),Fe(H2O)4(OH)2+,Fe(H2O) 8(OH)2(4+)and Fe2(H2O)6(OH)4(4+) depending upon the Ph of the aqueous medium.

In the case of Aluminum electrode, reactions are a follows:

Anode: Al(s) → Al3+ (aq) + 3e, (10)

Cathode: 3H2O (l) + 3e- → 3/2 H2 + 3H+,(11) For the aluminum electrodes, Al3+(aq) ions will immediately undergo further spontaneous reaction to generate corresponding hydroxides and polyhydroxides.

Due to hydrolysis of Al3+, Al(H2O)6

3+, Al(H2O)5OH2+, Al(H2O)(OH)2+generated.

This hydrolysis products produced many monomeric and polymeric substance such as,

Al(OH)2+, Al(OH)2+,Al2(OH)2(4+) , Al(OH)4, Al6(OH)1(3+), Al7(OH)17(4+), Al8(OH)2 (4+), Al13O4(OH)24,7+Al13(OH)345+ [38].

Within the electro coagulation reactor, several distinct electrochemical reactions are produced independently. These reactions are as follows: (i) Seeding: This is resulting from the anode reduction of metal anions that becomes very centers for larger, stable, insoluble complexes that precipitate as complex metal ions. (ii) Emulsion breaking: Due to the oxygen and hydrogen ions that bond into the water receptor sites of oil molecules creating a water in soluble complex separating water from oil, mud, dyes inks, etc. (iii) Halogen complexing: As the metal ions bind into a chlorinated hydrocarbon molecules resulting in a large insoluble complexes separating water from pesticides, herbicides, chlorinated PCB" s, etc. (iv) Bleaching: As the oxygen ions produced in the reaction chamber oxidizes dyes, cyanides, bacteria, viruses, biohazards. Electron flooding of the water eliminates the polar effect of the water complex, allowing colloidal materials to precipitates and increase of electrons creates an osmotic pressure that raptures bacteria, cysts and viruses. (v) Oxidation reduction: These reactions are forced to their natural end point within the reaction tank which seeds up the natural process of nature that occurs in wet chemistry. (vi) Electrocoagulation induced pH: This is swings toward the neutral.

7. CONCLUSIONS

Without doubt the provision of an adequate water supply suitable for a diversity of uses by world‟s growing population is one of the 21st century more pressing challenges. Even in the developed countries, the use of large scale, continuous throughput waste treatment plant is not complete solution. Electro coagulation has successfully treated a wide range of polluted waste water. But the full potential of EC techniques as a waste water treatment is not yet to be fully realized due to following deficiencies in a number of following key areas:

- It is still an empirically optimized process that requires more fundamental knowledge for engineering design.
- No dominant reactor design exists, adequate scale-up parameters have not been defined, and materials of construction are varied.
- No widely applicable mechanistically based approach to the mathematical modeling of electrocagulation reactors.
- Failure to fully appreciate that the performance of an electro coagulation reactor is largely determined by the interaction that occur between the three foundations technologies of electrochemistry, coagulation and flotation.
- No generic solution to the problem of electrode passivation

After all electro coagulation has been used successfully to treat a wide range of polluted wastewaters. But the full potential of EC technique as a wastewater treatment is yet to be fully realized. It is still an empirically optimized process that requires more fundamental knowledge for engineering design. No dominant reactor design exists, adequate scale-up parameters have not been defined, and materials of construction are varied. This technology has excellent future because of numerous advantages and the nature of the changing strategic water needs in the world.

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