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ELECTROCOAGULATION TREATMENT OF ELECTROPLATING INDUSTRIAL EFFLUENT

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Abstract *Electrocoagulation is a new versatile technology which is very effective in treating waste water containing Heavy metals. The Industrial effluent from Electroplating industry had heavy metals like Nickel and Zinc, which were above the permissible limit. It needed to be treated for safe disposal. Electrocoagulation treatment was carried out on this effluent at its initial pH level 1.7, using Aluminium electrodes. The treatment was successful in reducing 78.9% of the initial concentration of Zinc when treated for 120min using 4A/m² current density.*

Key Words: **Electrocoagulation, Electroplating industrial effluent, Heavy Metals.**

1. INTRODUCTION

Water is the main source for Industrialization. According to Ministry of Water resources, about 40 billion m3 of water is used in Industrial areas in India, which is about 6% of the total available water. And most of that water is thrown out as industrial waste water. These effluents need to be treated and reused or to be treated and disposed off in safe manner to provide Sustainable Environment. Employment of Sustainable Technology is essential to meet the Sustainable Environment. "Sustainable Technology" is defined as technologies focusing on sustainability principles: resource conservation, reuse and recycle, energy efficiency, minimizing environmental impact and pollution reduction (As defined in 2015 NAL, United States department of Agriculture).

Electrocoagulation is one of the new and efficient technologies used in the treatment of Industrial Waste Water, especially the waste water containing Inorganic pollutants like toxic compounds and heavy metals. This technology can also be implemented to treat waste water to remove Total Solids, Total Nitrogen, Chemical Oxygen Demand and Inorganic pollutants etc. It is mostly used to treat toxic waste water when biological treatment is not feasible. Since the toxicity of waste water do not allow the micro-organisms to carry out the biological activities. Electrocoagulation Process (ECP) is a very versatile, compactable, easy operation, safe, cost effective and energy efficient. This process generates less amount of sludge and it is more effective compared to chemical coagulation. It is cost effective compared to chemical coagulation, Ultraviolet (UV) treatment, Ozonation and Membrane separation process. ECP is a compact and versatile compared to Aerobic and Anaerobic process treatment. Biological treatment needs ambient conditions for microbes to carryout biological process, thus restraining the ability to treat waste waters with high toxicity, low pH and xenobiotic material.

Three main steps involved during electrocoagulation: The electrode surface undergo electrolytic reaction on passing of electric current, formation of coagulants by dissolution of anode in aqueous solution, adsorption of colloidal pollutants or soluble pollutants on metal hydroxide flocs or by flotation of flocs brought to the surface and which is later skimmed off.

1.1 Scope of present study

Electroplating industrial effluent consist of many sorts of heavy metals which are toxic in nature and may also contain varying range of pH, electrical conductivity, colour etc. Such waste water should mandatorily be treated before disposing it off into the natural water bodies or onto ground. Electroplating industrial effluents are currently treated by chemical coagulation process. This chemical coagulation process need large amount of coagulant material, it requires more amount of energy for mixing and aeration and large area for installation. Thus in this study I have conducted the experiments for treating effluent using electrocoagulation technology which can overcome all the above problems such as operational problems, maintenance problems, it is cost effective, it requires less area and provides better treated water quality.

1.2 Objectives

Main objective in this study is to check the feasibility of the electrocoagulation technology in treating the Electroplating industrial effluent.
Specific objectives are:

- To determine the initial characteristics of electroplating industrial effluent. Characteristics like pH, electrical conductivity, turbidity, concentrations of Ni, Zn and Al.
- To construct the electrode arrangements and electrical connections.
- To treat the effluent with specific Current density and for specific time intervals.
- To compare the pollutant removal efficiency when treated at different current densities and when treated for different time intervals.

- To evaluate further chances to improvise the pollutant removal efficiency.

2. MATERIALS AND METHODOLOGY

The Electro-coagulation treatment was carried out on Electro plating industrial effluent, the effluent was collected from a metal plating industry in Peenya Industrial Area. The effluent consists of heavy metals like Zinc and Nickel which are main pollutants and the waste water is acidic with pH of about 1.7. The treatment was carried out on settled waste water

Table - 1: Initial parameters of Effluent

Parameters	Amount
pH	1.7
Turbidity (NTU)	56
Conductivity (mS/cm)	39.3
Aluminium (mg/lt)	5.9
Nickel (mg/lt)	22
Zinc (mg/lt)	1998

To conduct this experiment an electrolytic cell was built. The cell was built to carry out the treatment for industrial effluent of 1liter at a time. The capacity of electrolytic cell is 1liter. Aluminium plates are used as electrode material, Aluminium is a white-silver coloured soft metal with chemical formula Al. It belongs to Boron group. Aluminium is highly used as metal electrodes because Aluminium oxidizes easily on passing electric current to form metal oxide which is responsible for electrochemical oxidation. Here 2 cathodes and 2 anodes are used as electrodes. Each electrode of size 150mmX50mmX2mm is used. But the submerged length is 100mm. The active surface area of each electrode is 120cm2. These electrodes are mounted on wooden rods to hold the electrodes in position.

The internal space of 20mm is provided between each electrode. These electrodes are connected with parallel electric supply. The cathode supply was split into two cables and was connected to the cathodes and same for the anodes. The power supplied to electrodes will be in the form of Direct current.

Magnetic stirrer is used to keep the effluent in suspension. The speed of the magnetic stirrer is chosen such that good mix of Al^{3+} and OH^- ions are achieved and the flocs are not broken or disturbed. Thus the speed of the stirrer is set to 150RPM.

Fig - 1: Experimental setup

2.1 Treatment Mechanism

Electrocoagulation can be achieved when the electric potential is applied from external power source to electrodes. In case of a simple electrocoagulating cell (Fig - 2), when aluminium metal electrodes are used some chemical reactions and electrochemical reactions occur. They are summarized as follows:

Formation of Al (III) ions at anodes

$2Al \rightarrow 2Al^{3+} + 6\ e^-$

Reduction of water by electrons at cathodes

$6H_2O + 6\ e^- \rightarrow 3H_2 + 6\ OH^-$

Formation of oxygen at the anode and hydrogen at the cathode by electrolysis of water

$2H_2O\ (l) \rightarrow 4H^+\ (aq) + O_2 + 4\ e^-$

$2H_2O\ (l) + 2\ e^- \rightarrow H_2\ (g) + 2OH^-\ (aq)$

When the pH is favorable i.e., alkaline or slightly alkaline, these two species can react to form $Al(OH)_3$ according to the following reaction

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

Attack of the cathode at alkaline pH

$2Al + 6H_2O + 2OH^- \rightarrow 2Al\ (OH)^{4-} + 3H_2(g)$

The removal of pollutants takes place mainly by two mechanisms. Firstly the Cations Al^{3+} released through the EC eliminates pollutants like Suspended and colloidal matters, dyes, heavy metals etc., by various mechanisms like electrostatic destabilization or by adsorption on the metal hydroxide flocs or its polymers. Secondly the gases like Hydrogen and Oxygen released by the Electro-coagulation contribute to the elimination of a part of the suspended matters in the liquid medium by electroflotation (EF). The small size of gas bubbles allows them to join efficiently to the suspended solid material and bring them to the surface causing electroflotation. The size of the gas bubbles varies from 10 to 100 μm. The amount of gas released and size of gas bubbles varies with several factors like pH, Current density etc.

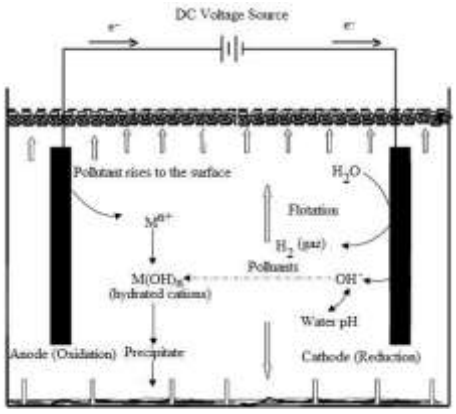

Fig – 2 : Principle of Electrocoagulation

2.2 Methodology

The settled electroplating effluent will be taken and measured in 1 liter measuring jar and transferred into a beaker of 1 liter capacity. Here 4 electrodes are mounted on wooden plank, where the cathodes and anodes are arranged alternatively. The electrodes mounted on wooden plank are submerged into the effluent water. Electricity is supplied to the electrodes to establish potential difference between the electrodes. Here the waste water is treated at two different Current densities i.e., at 2 Amps and 4 Amps. And for each Current density the effluent is treated for different time intervals like at 15min, 30min, 45min, 60min, 75min, 90min, 105min and 120min. these treated water samples are filtered using Whatman filter paper. The experiment is carried out in ambient room temperature of 25^0 C.

Then the analysis is carried out for all the 17 samples to determine parameters like pH, Electrical conductivity, and metal contents like Aluminium, Nickel, and Zinc. It is analyzed to determine the amount of abatement of heavy metals like Nickel and Zinc using Atomic Absorption Spectrometer (AAS), analysis were performed following standard test methods for examination of treated water using APHA 2017-3111B method. Wavelength of Aluminium is 309.3nm, wavelength of Nickel and Zinc are 232.0 nm and 213.9 nm respectively.

3. RESULTS & DISCUSSION

The Electro-coagulation is prejudiced by several Operational parameters like pH, Current density, Pollutants concentration, Period of treatment or Hydraulic Retention Time (HRT). In the present experiment the behavior of the above operational parameters is done in order to assess the technology for the removal of Zinc and Nickel from the metal plating industrial effluent.

3.1 Change in pH

The effluent is tested at its original pH level. Initial pH of the effluent is 1.7 which means the water is highly acidic. From Chart – 1 it is observed that the pH level of water gradually increases with the time of treatment. And the pH at 4Amps Current supply increases faster than at 2Amps Current supply. It is observed that the heavy metal removal efficiency increases linearly with the increase in pH. Vik *et al.* (1984) reported that the observed increase of pH at low initial pH is accountable for the evolution of hydrogen gas and OH ions generation at the cathodes. In alkaline medium the pH does not change remarkable because the generated OH ions at the cathode are taken up by the Al^{3+} ions which are generated at the anode, forming $Al(OH)_3$ flocs. Further, OH ions can also partially combine with the Ni^{2+} and Zn^{2+} ions to form insoluble hydroxide precipitate i.e., $Ni(OH)_2$ and $Zn(OH)_2$ respectively. The removal percent of nickel and zinc is very low at pH<2. Remains high and almost constant in the pH range 4 - 9 and slightly decreases at pH>10.

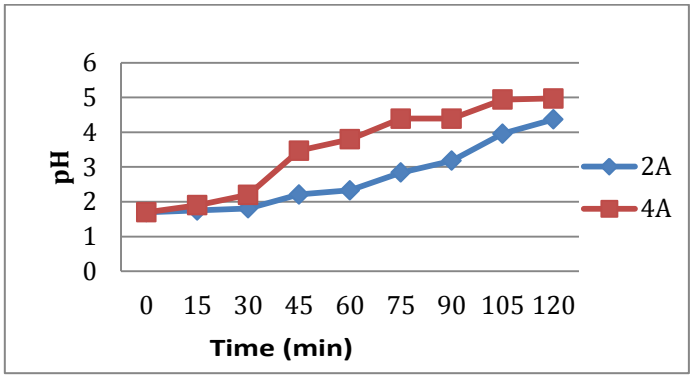

Chart - 1: Evolution of pH with time

3.2 Changes in Conductivity

Chart - 2 shows that the electrical conductivity of the effluent decreases with increase in time of treatment and with increase in current density. Above graph shows that at, 4Amps power supply the initial conductivity was 39.3mS/cm, conductivity dropped drastically to 18.49 mS/cm when treated for 45min. After 45min the conductivity reduced very slowly. It reached 15.59mS/cm for 120min treatment. This profile can be seen because the metal salts which promote electrical conductivity are removed. All though Auminium salts are induced, it doesn't influence on conductivity much because Aluminium is not a very good conductor of electricity like Zinc and Nickel. It also shows that the conductivity reduces with increase in Current density.

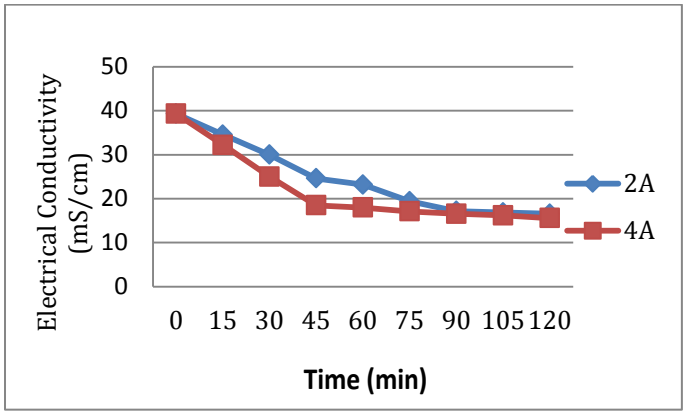

Chart - 2: Reduction in conductivity with time

3.3 Changes in Zinc Concentration

Chart - 3 shows the change in Zinc concentration with time. Zinc is the main heavy metal pollutant in this Wastewater sample. The initial concentration of Zinc is 1998mg/lt. Here the ion concentration decreased gradually with the time of treatment. As the current density increases the rate of zinc removal also increases. At 2Amps power supply the Zinc concentration reduced to 957 mg/liter by the end of 120min treatment i.e, the reduction efficiency is 52% at that point of time pH increased to 3.37. And in the similar way at 4Amps current density the Zinc concentration reduced to 422 mg/liter by the end of 120min treatment i.e, the reduction efficiency is 78.9% at that point of time pH increased to 3.39.

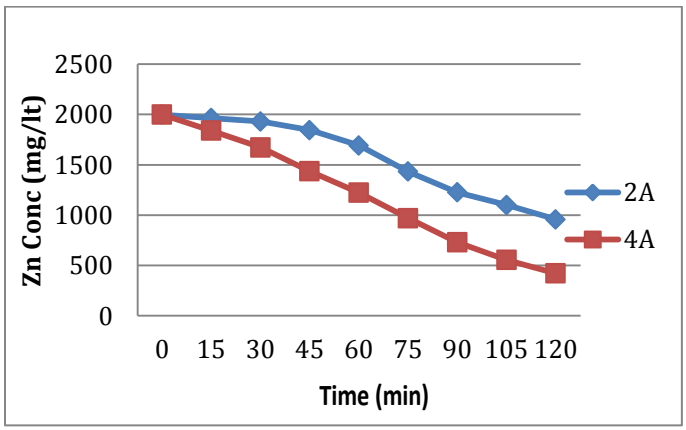

Chart - 3: Change in Zinc concentration with time

3.4 Changes in Nickel Concentration

Chart - 4 shows the change in Nickel concentration with time. Nickel is the second main heavy metal pollutant found in this Wastewater sample. The initial concentration of Nickel is 24.1mg/lt. Here no considerable reduction of Nickel concentration is found. Though the pH reduces with time of treatment, Nickel ion concentration is considerably constant. There may be slight variation due to external factors like inhomogeneous mixture of instrumental errors. It can be depicted that, Nickel concentration is not reduced due to low pH level of the effluent.

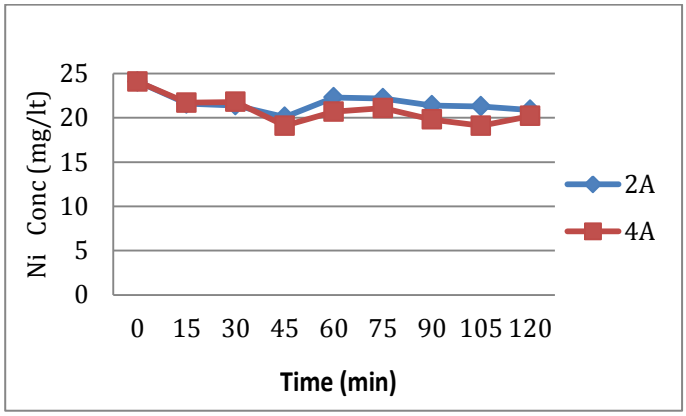

Chart - 4: Change in Nickel concentration with time

3.5 Discussions

The Electrocoagulation treatment of Metal plating industrial effluent gave quite convincing results. The pollutant removal efficiency depends on pH of the medium and the Current density provided to carryout electrocoagulation. Since Aluminium electrodes are used initial release of Al^{3+} ions increased drastically at the beginning and got stabilized later. The Al^{3+} ions generated combines with OH^- ions to form Aluminium hydroxide then they undergo polymerization and stabilization, later precipitates forming flocs on which pollutants get adsorbed. The heavy metal pollutants like Ni and Zn also combines with OH^- ions forming their respective hydroxides and later precipitates by themselves or by adhering on to Aluminium hydroxide flocs. Reduction in Zinc concentration was remarkable since the pH was favorable. About 78.9% of Zinc was abated treating for 120min by using 4Amps current density. But Nickel was not satisfactorily reduced, since the pH was not favorable. As the concentration of Zinc dropped and Aluminium hydroxide concentration increased, the electrical conductivity of the effluent also diminished. Thus Electrocoagulation is an efficient and safe method to remove heavy metal like Zinc when the pH is very low (pH<4). The abatement rate increases with the increase in Current density.

4. CONCLUSION

The Electrocoagulation treatment is a new technology developed in recent days. It uses electrolysis principle. It can be used to treat all sorts of waste water. It can eliminate organic, inorganic and toxic pollutants. The Electrocoagulation treatment of Metal plating industrial effluent is an efficient and cost effective way. But it is not cost effective to treat organic pollutants, since there are technologies which can treat them in lower cost. The electrode material need to be chosen carefully, different type of metal electrodes are compatible for different heavy metals, thus electrodes should be chosen such that the ion forms stable complex with the metal pollutant. Aluminium electrodes form its hydroxide and coagulate with pollutants. Aluminium electrodes are cheaper compared to chemical coagulants. Aeration is not required

since air bubbles are generated by electrolysis process itself. Thus this technology requires less man power, low energy consumption. But the operation cost will be comparatively higher than traditional technologies. Extra addition of chemicals is not necessary though Optimum range of pH and current density need to be maintained for the efficient removal of pollutants. Different factors like electrode dimension, conductivity, type of power supply also affect the process in less magnitude. In this technology the volume of sludge generated is very low. Thus sludge management is quite easy. The experimental results with bench scale, pilot plant scale and full scale varies immensely. Hence care should be taken while scaling up the technology for industrial application. It is best applicable to remove toxicity of water caused by heavy metals and provide clean and Sustainable environment. Thus Electrocoagulation can be considered as Sustainable technology.

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