HEAVY METAL REMOVAL FROM STEEL INDUSTRY WASTEWATER BY ELECTROCOAGULATION

A Thesis

Submitted in partial fulfillment of the requirement for the award of the degree
Of

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IN
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By

SMRITI AZAD

(162757)

Under the supervision of

Prof.Veeresh Gali

JAYPEE UNIVERSITY OF INFORMATION TECHNOLOGY

WAKNAGHAT, SOLAN 173234

HIMACHAL PRADESH, INDIA

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CERTIFICATE

This is to certify that the work being presented in the thesis titled **"HEAVY METAL REMOVAL FROM STEEL INDUSTRY WASTEWATER BY ELECTROCOAGULATION"** in partial fulfilment for the award of the degree of Master of Technology in **"ENVIRONMENTAL ENGINEERING"** and submitted to the Civil Engineering Department, Jaypee University of Information Technology, Wakanghat, Solan, Himachal Pradesh is an authentic record of work carried out by **SMRITI AZAD** (Enrolment No 162757) during a period from July 2016 - May 2018 under the supervision of **Dr. VEERESH GALI**.

The above statement made is correct to be the best for our knowledge.

Date –

Dr.Ashok Kumar Gupta	Dr.Veeresh Gali	External Examiner
Head of the Department	Professor	
Department of Civil Engg.		

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ABSTRACT

Electrocogulation (EC) is the chemical process used for the removal of heavy metals present in wastewater .This process is mainly applied for the industrial wastewater. This is an emerging technique in water and wastewater treatment, because of its versatility, environmental compatibility and ability to offer significant process efficiency at low capital and operation cost.

The setup consists of 8 rods made up of aluminum and iron respectively. In addition to this main reaction, several side reactions, such as hydrogen bubble formation and the reduction of the metals on cathodes, also take place in the cell. According to results of this study, aluminum is more suitable electrode material for electrocoagulation applications because it produces Al(III) species. Metal ions and hydroxides produced by iron electrodes are less effective in the destabilization of pollutants because iron electrodes produce more soluble and less charged Fe(II) species.

The aim of this study was to remove the heavy metals from the steel industry waste water. Various parameters are mentioned such as temperature, current density and pH of the wastewater which are essential for the electrocoagulation. The electrodes are connected in parallel modes. To check the effect of electrode spacing, three electrode positions were selected i.e., 0.5 cm, 1 cm and 1.5 cm. The voltage applied was 0.20 Volt and current passed 4.98 Ampere. Time interval is 30 minutes throughout the process. The temperature value was found to be 30°C. Electrocogulation is the technique used to remove the heavy metals from the contaminated industrial wastewater. There are mainly heavy metals present in steel and iron industry. The most common heavy metal present in these industries is lead.

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ABBREVIATIONS

Al – Aluminum

Fe- Iron

Pb- Lead

BOD- Biological Oxygen Demand

COD- Chemical Oxygen Demand

CHAPTER -1 INTRODUCTION

1.1 HEAVY METALS

Heavy metals are rather like weeds - in the wrong place at the wrong time and in the wrong concentrations, they can be extremely noxious. They are found in elemental form and in a variety of other chemical compounds. Those that are volatile and those that become attached to fine particles can be widely transported on very large scales. Each form or compound has different properties which also affect what happens to it in food web, and how toxic it is.

The most commonly encountered toxic heavy metals in wastewater: • Arsenic, Lead, Mercury, Cadmium

• Less common: Chromium, Copper, Nickel, Zinc

Sources

• Industrial sources: e.g. Printed board manufacturing, metal finishing and plating, semiconductor manufacturing, textile dyes • Street runoffs • Landfills

PROBLEMS CAUSED BY HEAVY METALS

• Many heavy metals are essential trace elements for humans, animals and plants in small amounts

• In larger amounts cause acute and chronic toxicity.

• Linked to learning disabilities, cancers and even death

• Heavy metals have inhibitory effects on the biological treatment process at the wastewater treatment plants.

1.2 TOXIC METALS AND HUMAN HEALTH

- **Effects of lead –**The lead directly affected the central nervous system and rental system. It causes cognitive problems which is maximum in children. Minimum level of lead leads to neuropsychological deficiency with low IQ level.

- **Effects of arsenic –** Inorganic arsenic is hazardous for human beings. Arsenic directly affects the skin, lung, liver, central nervous system as well as blood poisoning.

Table 1. HEAVY METALS WITH THEIR EFFECTS

S.NO	Heavy metals	Effects on health	Significant effects
1	Arsenic	Skin cancer	Prolonged exposure causes problems
2	Cadmium	Cancer	50 yrs exposure effects fat persons
3	Lead	ALA-D-EEP	Children affected 10 % prevalence

Table 2. Route of entry of heavy metals in human health

S.NO	Route of entry	Arsenic	Cadmium	Lead	Mercury
1	Through excretion	Urine	Urine	Urine	Foetus
2	Half life	10-30 hrs	>10 yrs	20 yrs	70 days
3	Major route	Keratinous	Kidney,liver	Bone,kidney	Brain, liver

1.3 HEAVY METAL REMOVAL TECHNOLOGIES

CHEMICAL PRECIPITATION

This is the process of removal of heavy metals present in the wastewater by forming a insoluble substance in the form of precipitates. Metals used such as hydroxide, carbonate, sulphide used for the precipitation. The formed precipitates are removed with the help of filteration, flocculation and sedimentation.

ION EXCHANGE

This is the process of exchange of ions present in wastewater .Most widely used ion exchanger is zeolites .These are most widely used in food and beverages industries. ion exchangers are used in nuclear reprocessing and the treatment of radioactive waste .

ADSORPTION

Adsorption is the removal technology in which the various adsorbents are used .Adsorbents such as activated carbon,carbon nanotubes,metal oxides,and bio adsorbents are applied .Most commonly used adsorbant is activated carbon till today

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1.4 STEEL INDUSTRY AND HEAVY METALS

Iron and steel have broad uses in construction and the manufacturing of machinery and equipment, which play an important role in the development of human civilization. The iron and steel industry is highly intensive in both materials and energy, and the world crude steel production amount rose to a total of 1,607.2 million metric tons in 2013.Heavy metals linked with the atmospheric particles may exchange in human body through inhalation and respiration .Heavy metals caused various harmful effect on human

being for example high blood pressure and anaemic symptoms. There are large amount of heavy metals pollutant in the steel industry.

Characterstics of the industrial effluents (Steel Industry)

1. pH- 8.5
2. BOD- 10000mg/L
3. COD- 25000mg/L
4. Total suspended solids – 753 mg/L
5. Total dissolved solids - 275-6400 mg/L
6. Temperature -15-40^{o}C

Treatment of Steel Industry Wastewater

There are various treatment processes applied for the steel industry wastewater such as reverse osmosis, sedimentation,filerartion,electrodialysis .There are basically 3 steps of treatment Primary ,Secondary and Tertiary treatment. Electrocogulation is also the one of the treatment of industrial wastewater. This treatment is beneficial because this process does not need any kind of chemical throughout the experiment.

1.5 Objectives of the study

- To study the appropriateness of electrocoagulation technique in treating industrial wastewaters
- To remove heavy metals from steel industry wastewater using electrocoagulation technique
- To study the cost-effectiveness of electrocoagulation technique in treating steel industry wastewater with other heavy metal removal techniques

1.6 Need of the study – For present days, it is very necessary to improve the Characterstics of water and wastewater. With help of this study of treatment of industrial wastewater, we can make the water contaminant free. Due to the presence of heavy metals in wastewater it becomes harmful for the human beings and environment. Due to excessive use of heavy metals in the industries, methods and processes of heavy metals degradation are of great importance. Presence of heavy metals in water is hazardous to human health. .It leads to the severe health issues such as cancer, liver and kidney damage. This treatment helps us to save our environment and make it a eco friendly.

1.7 Scope of the study

There is considerable scope for the future research with the following objectives;

- To develop and improve electrochemical , methods usign iron anode to achieve permissible limits
- To understand the mechanism and to assess the advantages of oxidant electrocoagulation of dye molecular species.
- To evaluate a simple column electrocoagulation reactor this can be used for electrocoagulation as well as sedimentation.

CHAPTER -2 ELECTROCOAGULATION

2.1 INTRODUCTION

Electrocoagulation is an electrochemical phenomena used for the removal of heavy metals from the industrial waste water. There are basically two sacrificial rods are applied one is anode and other one is cathode. Oxidation process is taken place throughout the mechanism. The rods are made up of mainly iron; aluminum and platinum.Aluminium rod is used mostly because it can easily remove the contaminants from the wastewater. The flocs made as a result of the electrocoagulation is average which are acid resistant and easily removed through filtration.

Advantages of electrocoagulation-

1. Easy to operate
2. Low sludge production
3. Low toxic content
4. Easy to handle and portable setup

Disadvantages of electrocoagulation-

1. Corrosion of electrodes
2. Electrodes needs to be regularly replaced
3. Decrease in removal efficiency

2.2 MECHANISM OF ELECTROCOAGULATION

There are two mechanism occur during the Electrocogulation

Iron electrodes reactions –

Anode: Fe→Fe2++ 2e

Cathode: 2H2O + 2e-→H2+2OH

Overall: Fe2++ 2H2O→H2 +Fe(OH)2↓

Aluminum electrode reactions –

Anode: Al→Al3++ 3e

Cathode: H2O + 3e-→1.5H2+3OH

Overall: Al+ H2O→H2+Al(OH)2↓

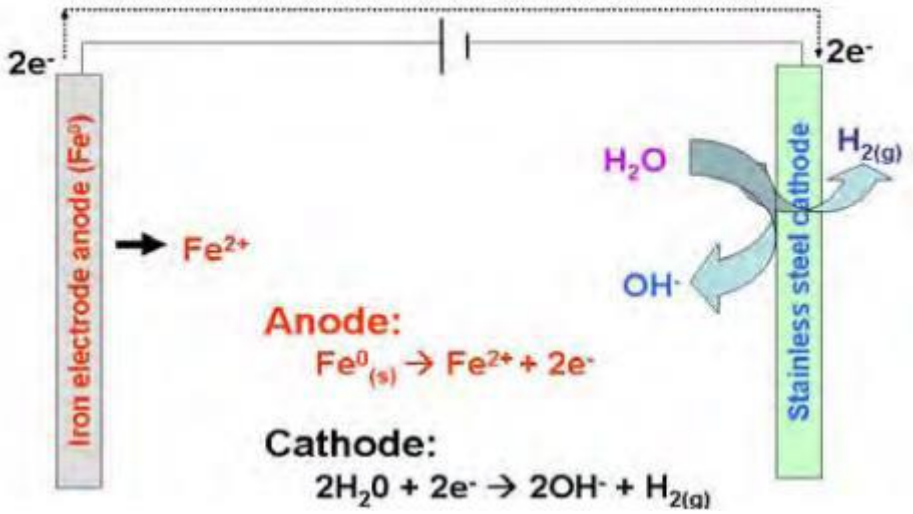

Fig 1 Mechanism of electrocoagulation

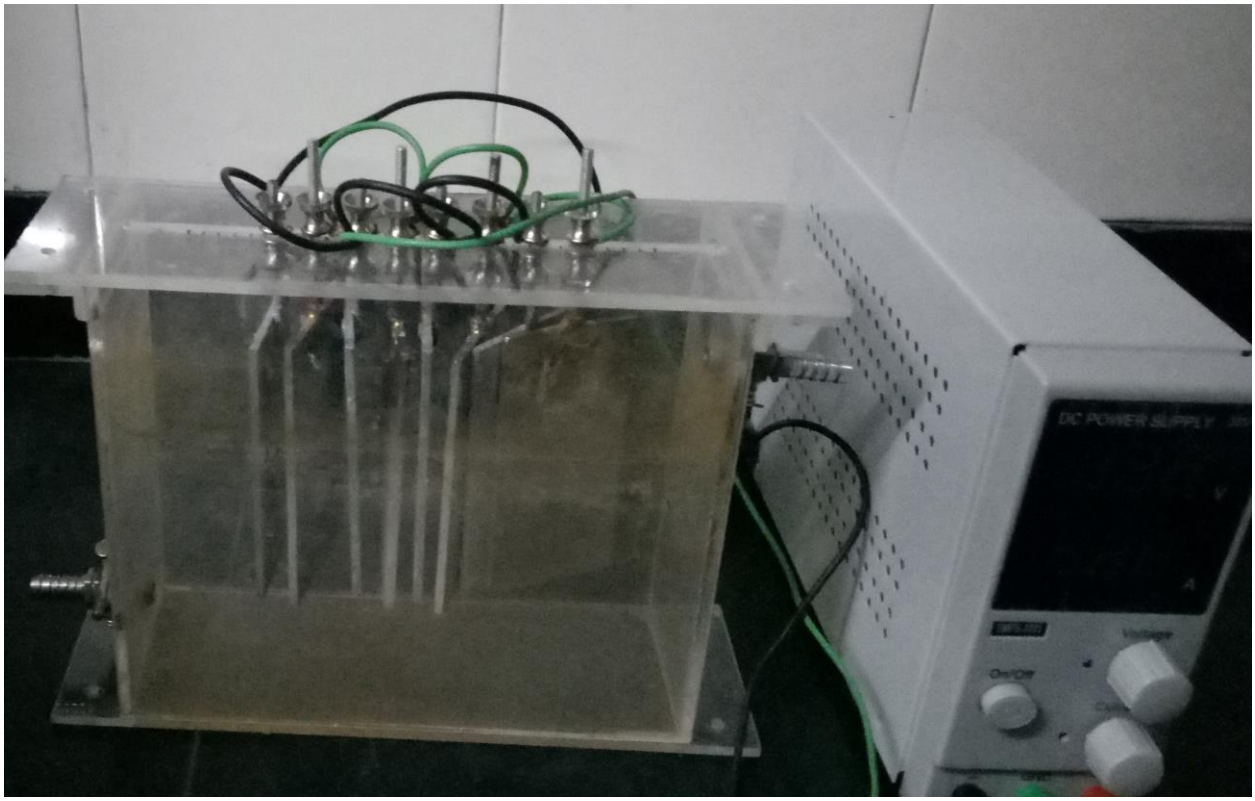

Fig 2 LABORATORY SETUP FOR ELECTROCOAGULATION

This setup in this process is consisted of glass beaker with contaminated industrial wastewater .8 sacrificial rods are applied separated 0.5 cm apart. These rods are connected in parallel which are immersed in the 1l of heavy metal contaminated wastewater. These electrodes are regularly replaced Constant current and voltage is applied with the DC power supply. Current and voltage is check with the help of multimeter.

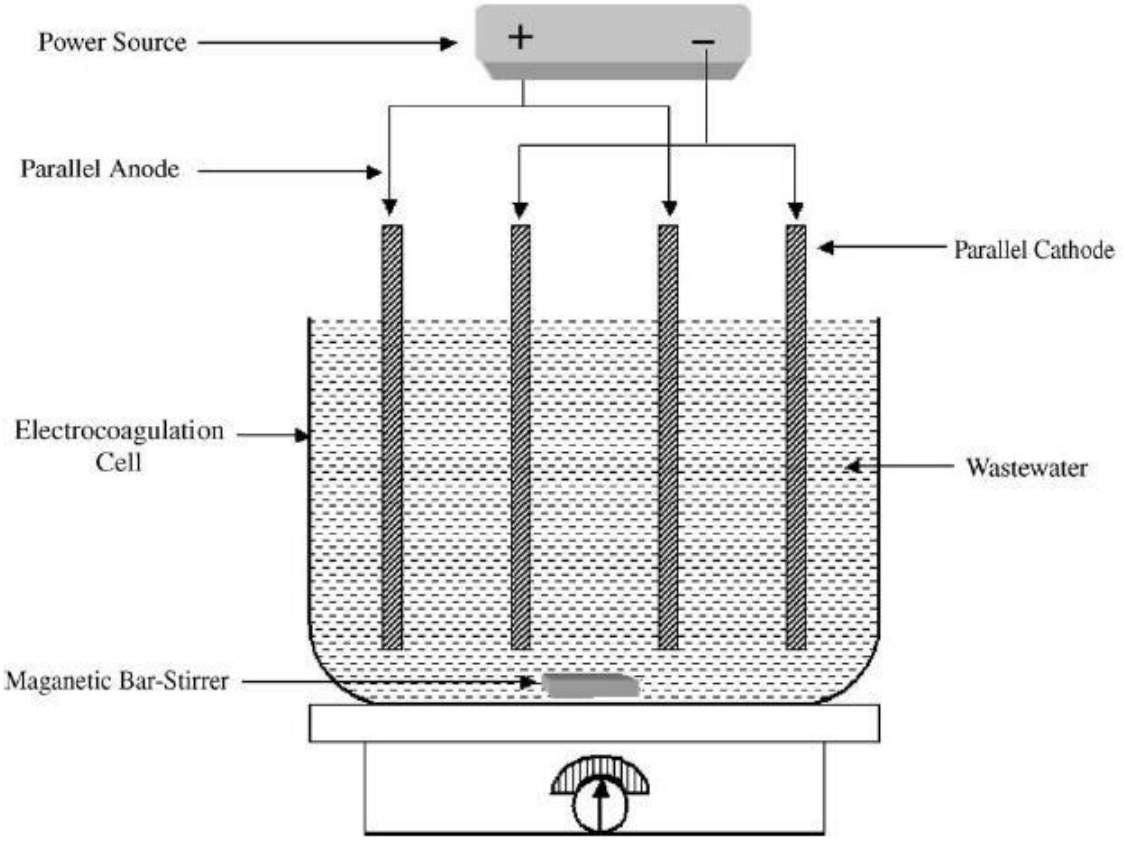

Fig 3 .SCHEMATIC DIAGRAM OF ELECTROCOAGULATION

2.3 TREATMENT PARAMETERS

There are different parameters which have an reverse impact on the efficiency of the electrocoagulation in the ejection of the fouling particles from industrial wastewater .

I. Materials of the electrodes –Electrodes are basically made up of aluminium,iron and platinum.
II. Ph of the solution – Ph should be between 5-9 .It is difficult to determine the Ph of the wastewater .
III. Current Density – It is proportional to the amount of electrochemical reactions taking place in the surface of the electrodes.
IV. Treatment Time-This shold be between 15-30 minutes.This si also called as interval time.
V. Concentration of the pollutant
VI. Temprature

2.4 EFFECTS OF THE PARAMETERS ON THE TREATMENT

- Effect of reaction time – One of the major fundamental components responsible for the removal efficacy of the treatment technique. It is also called as electrolysis time. This time investigate the coagulant concentration created during electrolysis. Reaction time is directly equivalent to the current supplied .The production of current is calculated with the help of Faraday's Law if the current and treatment time is known .
- Effect of applied current – The coagulant produced and flocs formed is dependent of the electric current .It is the prime factor responsible for the separation mechanisn.The amount of metal dispersed depends directly on the electric current supplied. Current density is directly equivalent to the increased removal of color .It is important to maintain the current density to avoid extra amount of oxygen as well as to remove the effect of heat generation.
- Effect of Ph – Ph plays an important role in this treatment . It has direct impact on the conductivity of the solution.It does not change with the reaction time .Electrode consumption is independent of this factor.It has been analyses that when Ph was les than 3 , the rate of production of aluminium during electrolysis was lower than at Ph greater than 3.
- Effect of inter electrode interval – Electrode interval plays a vital job in the decolorisation efficiency .The width between the two electrodes had both positive and negative impacts on the efficiency. If the distance between the electrodes increases, the decolorisation productivity also increases. The gap between the electrodes is filled with the gas during electrolysis and therefore increases the electrical resistance.

CHAPTER -3 LITERATURE REVIEW

Sachin K.Patil , Kiran K.Patil (2016)

The objective of this study was to treat the textile industrial wastewater. Wastewater water discharged through is the most polluted wastewater due to its quality and quantity. The pollution in the textile mill is due to the presence of high amount of dyes, dispersing agents and salts. This study concluded that the electrocoagulation is the most efficient method for the treatment of the industrial wastewater. This method provides complete color decreasing in all treatment conditions.

International Journal of Research and Reviews in Applied Sciences (2014)

Researchers find out that there has been small amount of effort was dedicated to the electrocoagulation phenomena. They realized that the no distribution is made for the optimal parameters and design parameters. They introduce the chemical and electrocoagulation techniques in coagulation, flocculation in water and wastewater treatment.

Merzouk et.al (2010)

This study detected the effects of operating parameters like Ph, initial concentration, current density, inter electrode distance and conductivity in the treatment of wastewater with the help of electrocoagulation and electroflocculation.Firstly an Electrocoagulation and Electro flocculation reactor was managed at different current densities ,between 11.55-9.15 Ma/cm² and different electrodes division (1,2 and 3cm) .For the solution 300 mg/l of silica gel , turbidity removal 89.6% was concluded deprived of any coagulant with the initial Ph of 7.6 and conductivity of 2.1 Ms/cm² .Textile wastewater removal efficiency was 85.5% .

Khataee et.al (2009)

Researchers made a comparison study between UV/Nano -TiO2, Fenton, Fenton like, electro-Fenton (EF) and electrocoagulation treatments for the removal of C.I.Acid Blue 9 Results investigated that the decolorization efficiency was in order of Fenton>EC>UV/Nano>Fenton like>EF.The effect of optimal parameters including current density ,initial Ph ,and the electrolysis time were studied in electrocoagulation process.

Canizers (2009)

The objective of this researcher was to study the impact of Ph of the waste in the coagulation with the aluminum by conventional and electrochemical dosing .The Ph has the influence on the coagulant along with the aluminum hydroxides precipitates. The results of this study clear that the considerable change in the capability of the coagulation .By the end of the treatment Ph values was found, the efficiencies of the solution dosing and of the electrochemical dosing were alike .

Eyvaz (2009)

Studied the electrocoagulation treatment of two textile dyes from aqueous solution using several dissimilar supplies .Aluminum electrodes was used as sacrificial electrodes in parallel connection. Current was passed through DC power supply at galvonastic manner while alternating pulse current was obtained by time relay integrated with DC power supply. The comparison was made between Dye and TOC removal with DC and APC.The removal efficiency of TOC and dye was higher with APC system .Electrodes surfaces was cleaned and then used again.

Balasubramanian (2009)

Balasubramanian analyzed the electrocoagulation using adsorption isotherm models and observed that Langmuir isotherm models matches reasonably with the experimental.

CHAPTER-4 PROCEDURE OF ELECTROCOAGULATION

4.1 EXPERMENTAL SETUP

Experiments were performed at the Environmental laboratory of the Civil Department of the Jaypee University of Information Technology .All the samples required in the experiment was carried out from the steel industry. Since the metal compound present in the samples are harmful so we kept the samples stored properly at specific place. All the instruments was used in the experiment are properly washed .The setup consist of glass beaker with the 8 electrodes .The samples should be washed properly with the water .The current and voltage applied throughout the experiment was 0.20 Volt and 4.98 Ampere respectively .There are specific parameters are tested in the laboratory and the values are given below in the table 4.1

Table 3 Characteristics of Steel Industry Wastewater

Parameter	Concentration
pH	6.45
Total Suspended Solids , mg/l	1210
COD, mg/l	2611
BOD_5 (@ 20^oC), mg/l	844
Total Dissolved Solids, mg/l	2720
Total Solids, mg/l	3930
Lead, mg/l	0.5
Iron, mg/l	0.5
Copper, mg/l	0.5

From the above table we find out that the heavy metal detected was Lead ,Iron and Copper. No chemicals are added throughout the experiment.

Procedure of Electrocoagulation

An experiment was carried out regularly and results were observed at the end of 30 minutes .Samples was taken out from the beaker during 30 minutes. The rods were interchanged from iron to aluminum for the different removal of the heavy metals. From the above experiment, it is realized that aluminum rod is the best suited for the removal of heavy metals. After the electrocoagulation process sample was taken out from the beaker and the sample collected was filter with the help of filter paper 0.3 µm. After the filtration of the sample, the collected sample was tested in the laboratory and heavy metals were detected. The heavy metals found was lead , iron and copper,.

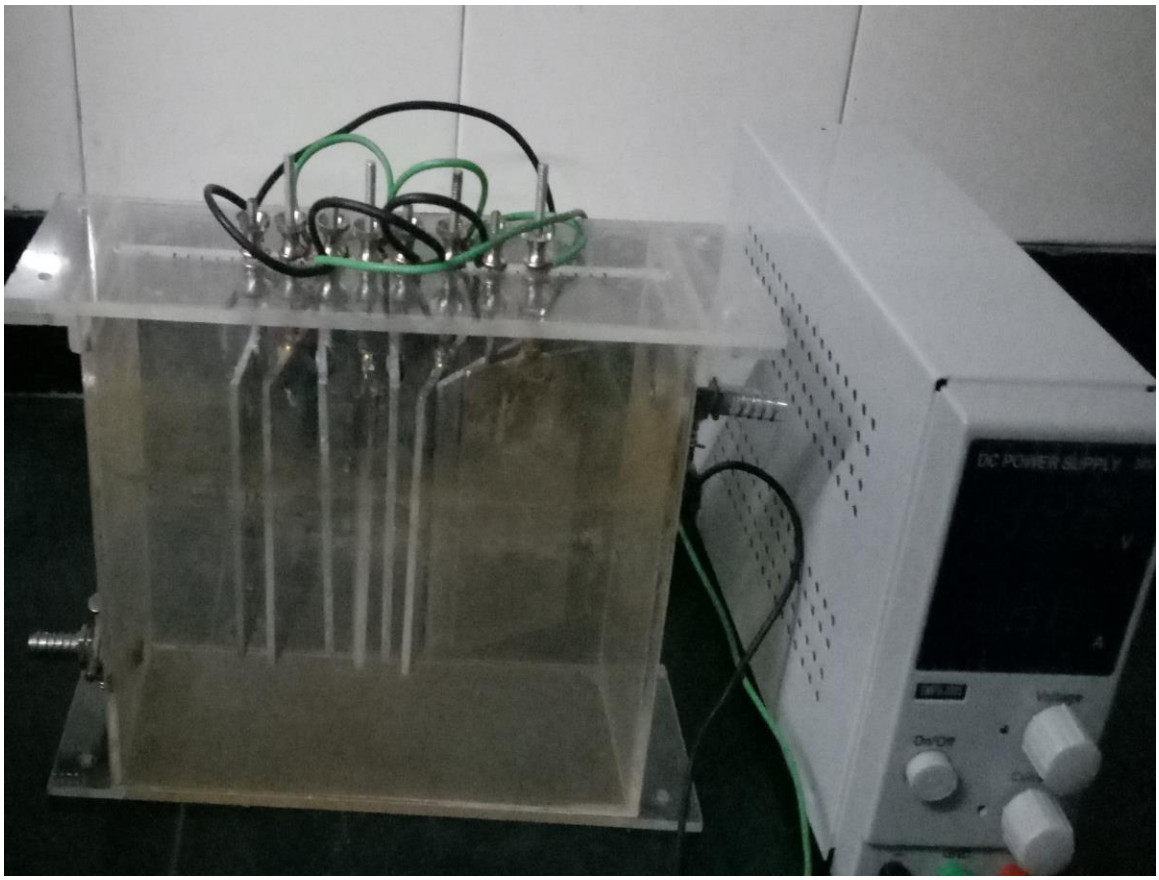

Fig. 4 EXPEPERIMENTAL SETUP

Table 4. METAL POLLUTANTS FROM INDUSTRIAL EFFLUENTS

METAL POLLUTANT	AMOUNT(mg/l)	AVERAGE(mg/l)
Magnesium	0.10	0.01
Cadmium	0.10	0.03
Copper	0.10	0.01
Lead	0.50	0.06

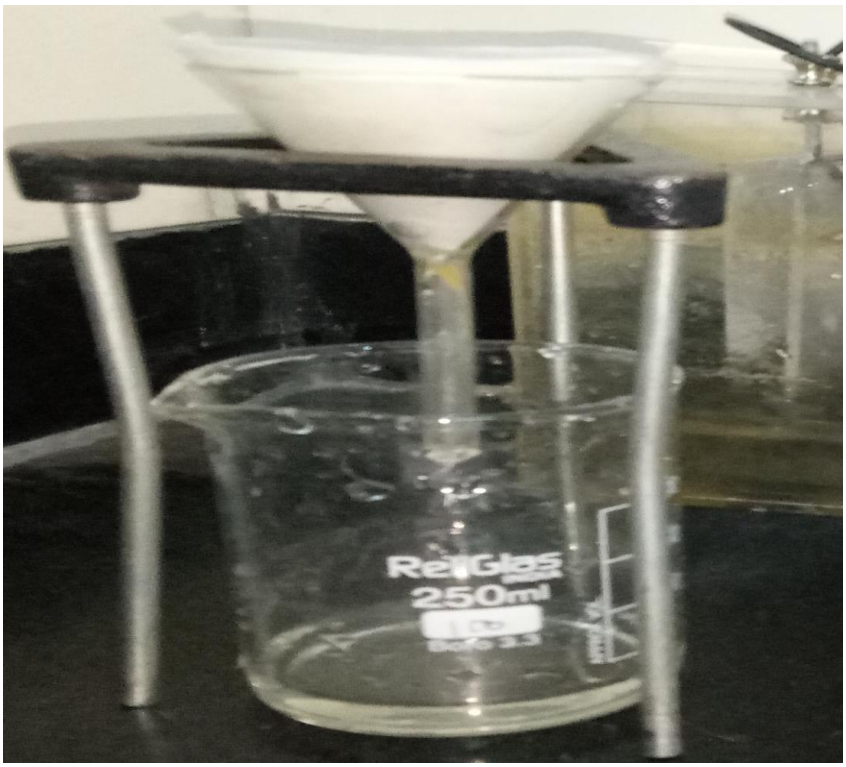

Fig 5 FILTERATION OF THE SAMPLE

4.2 FACTORS AFFECTING THE ELECTROCOAGULATION

Effect of initial Ph – This is the most important factors on which the electrocoagulation depends. For the further experiment the Ph value should be checked. The Ph of the sample provided was 6.5. There was slight increase in the ph after the electrocoagulation.The effect of Ph was tested at a constant current density and concentration.

Effect of current density – In the experiment the effect of current density was tested at the initial stage .The current density was remained constant throughout the experiment. Current density helps to calculate the removal efficiency of the metals.

Effect of concentration – Concentration of metal was between 50-150 mg/l

4.3 HEAVY METALS DETECTED AFTER ELECREOCOAGULATION

Copper (Cu)

- Reddish orange in color
- Soft and ductile metal with atomic number 29
- Good electric conductor and mainly used in industries of daily life
- Highly used in electrical appliances and wrings
- Excess exposure of copper leads to hazardous causing vomiting, nausea, cramps and also leads to kidney damage.
- Due to the more use of copper pipes in the distribution networks and household piping leads to get the drinking water harmful and dangerous.
- Concentration of copper in water id leads due to the excessive use of agricultural pesticides ,manufacturing operation and mining.

Lead (Pb)

- Bluish white in color
- Lustrous metal, soft and highly malleable
- Poor conductor of electricity
- Impervious to corrosion but tarnishes upon disclosure to air.
- Naturally occurring radioactive element
- Major patron of the lead acid battery used in car batteries
- One of the crucial application is in the glasses of computer and television screens
- Customary base metal for organ pipes and used as electrodes also in electrolysis

Iron (Fe)

- Silvery white in color
- It has luster and forms positive ions in its chemical reactions
- Good conductor of electricity
- When combines with small quantity of carbon ,it becomes steel
- Used as pigment in paints for bridges and railroad cars.
- Iron cores are used in electromagnets for phones ,motors and other equipments

CHAPTER -5 RESULTS AND DISSCUSSIONS

5.1 RESULTS

The above experiment showed that the eradication of heavy metals from steel industry with the help of electrocoagulation .Electrocoagulation was performed with the help of electrocoagulation reactor which is assembling of 8 electrodes (aluminum and iron). With the help of electrocoagulation three metals was removed are iron, copper and lead. After the experiment the sample was filtered with the help of filter paper and the sludge was produced.

Table 5. Heavy Metals detected after treatment

METALS DETECTED	ANALYTICAL VALUES
Iron	0.5
Copper	0.5
Lead	0.5

Table 6. Variation in Ph with electrocoagulation time

S.NO	Time (minutes)	pH
1	0	6
2	15	6.34
3	30	6.58
4	45	6.84

The effect on sample provided Ph change with electrocoagulation time was determined. The initial current and Ph was 6 and 4.98 m A/cm^2.The distance between the electrodes was 0.5 cm .

Table 7. Removal of Iron by electrocoagulation

Anode/cathode	Mode of reactor	Initial(iron) mg/l	Current density	pH
Al-Al-Al-Al	Parallel	0.05	4.98	6.25
Fe-Fe-Fe-Fe	Parallel	0.10	2.20	7

Table 8 Removal of Lead by Electrocoagulation

Anode/Cathode	Mode of reactor	Initial(Lead) mg/l	Current density	pH
Al-Al-Al-Al	Parallel	0.05	4.98	6.23
Fe-Fe-Fe-Fe	Parallel	0.10	2.36	7

Now calculated removal efficiency of lead and copper is calculated with the help of equation = initial concentration-Final concentration /Initial *100

Therefore the calculated concentration was 50%

CHAPTER-6 CONCLUSION

From the experiment performed showed that electrocoagulation is the beneficial treatment for the elimination of heavy metals from the industrial wastewater. The main aim of this thesis was to understand the mechanism of electrocoagulation for the eradication of heavy metals from the industrial pollutants .This is the most efficient method from the other treatment methods of wastewater. We also find out that aluminum is the most efficient for the removal as compared to the iron rods. Among the chosen parameters for the experiment, the Ph of 6.5 at the duration of 30 minutes was found to be best.

Based on the present work following conclusions were made-

- pH of 6.5 was found to be most accurate for heavy metals removal.
- With electrocoagulation time Ph of the sample was increased.
- The amount of sludge produced was less.
- The calculated removal concentration was 50 %

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