

## Pharmaceutical Industry Wastewater Treatment Using Electro-Coagulation Method

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**Abstract:** Water is a critical resource in the lives of people who both benefit from its use and who are harmed by its misuse. Industry is a huge source of water pollution, it produces pollutants that are extremely harmful to people and the environment. Many industrial facilities use freshwater to carry away waste from the plant and into rivers, lakes and oceans. Nowadays, water is being purified by various methods but research is being conducted to look for more reliable and cheaper methods that can purify water at an affordable cost. The objective of this paper is to find the optimal operating conditions for the removal of various physical and chemical parameters of wastewater from pharmaceutical industries by electro-coagulation techniques. In this process without using any chemicals and the chemicals which are present in the sample can be removed, it does not leave any additional chemicals in the sample. In the Present study the analysis is done by varying voltage for different period of time.

**Keywords:** Parameters pH value, Specific conductance, odour, taste, colour, turbidity, total dissolved solids, alkalinity, total hardness, calcium, magnesium, chloride, sulphate, fluorides, nitrate, iron and etc.

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### I. Introduction

Pharmaceuticals drugs play a vital role in improving life expectancy and quality of life for peoples. Vast amounts of pharmaceutical are used in every year for human as well as a veterinary medicine for the treatment of fever, infections, mental and physical stress, pregnancy prevention and also stimulating the agricultural growth . There are so many pharmaceuticals which are especially using for medical issues and problems and found as a higher concentration of these compounds in wastewater which are now becoming emerging contaminants of concern. It is mentionable to remark that the pharmaceutical manufacturing industry and hospitals are the most significant sources of pharmaceutically polluted wastewater. These pharmaceutical compounds are usually generated in different operation by the pharmaceutical industry, where the abundant volume of waters are needed for washing and extraction of solid cake or equipment used. The highly strength contaminated wastewater produced from the different manufacturing process of pharmaceuticals contain a large variety of toxic compounds leading to water plants and detrimental to seeds, new-borns, children, and the grown person . The possible pharmaceutical compounds existence in humans water consumption has two sources; (a) production process of pharmaceutical manufacturing industry and (b) common usage of pharmaceuticals which results in their presence in urban and agricultural wastewater. These frequently detected toxic compounds in different water bodies and drinking water has got extensive attention for efficient treatment to water reuse because of their non-biodegradable character which may persist and remain contaminated leading to potential health and environmental risks . This may also establish a possible hazard for the aqueous ecosystem as well as affects the life of the animal and human beings exist in the long run. Recently, researchers are noticing high amounts of pharmaceutical compounds in different types of wastewater, i.e., surface and ground waters, and also to drinking water sources . So, the environmental effects and human health risks can be affected by these types of wastewater, and thus, researchers around the world are giving much attention. Generally, pharmaceuticals compounds enter the natural water sources by the overflow of different nonpoint water sources like agronomic action or static water sources like municipal and hospital wastewater treatment plant. Most of the pharmaceuticals are unregulated contaminants which are needed to bring under standard discharge regulations because of their existence in the ecological media and possible health injury. In view of mitigating water resources scarcity around the world, it is essential to comprehend and create advancement in waste management for treating pharmaceutical wastewater. The numerous wastewater sources coming from the active pharmaceutical industry, unpackaged medicines and related pharmaceuticals which are normally using huge amounts of water need to be identified, and the finest technologies need to be evaluated for removing them to improve environmental health and water resources. Wastewater

generated from the pharmaceuticals industry has severe color, pungent odor, high COD, and low BOD. These properties exhibit challenges for anaerobic or aerobic treatment methods as the presence of their stubborn components may greatly inhibit the activity of the microbes. The application of activated sludge and trickling filter method are also done for the treatment of pharmaceutical wastewater which became unsuccessful and resulted in releasing the wastewater in eco-system and continuously contaminated soil, surface, and groundwater. Actually, for pharmaceutical wastewater treatment, the main treatment methods are physio-chemical and biological methods. Comparatively, biological treatment method is cost-effective but is not so operative in stubborn carbon-based wastewater. Then again, the results found from physiochemical treatment are highly effective and is steady with high-strength wastewater, but installation and operating cost are comparatively high. Actually, neither physiochemical nor biological treatment method is suggested alone and the combined treatment system is often the most suitable procedures in this high-strength pharmaceutical contaminants treatment. In fact, it is not so effective because of their complicated properties so the conventional wastewater treatment processes cannot fully remove active pharmaceutical compounds. Actually, electrocoagulation process was more effective in eliminating stubborn pharmaceutically active contaminants. Pharmaceuticals have much organically active compounds and presence of those in the water system causes serious apprehensions because of their antagonistic toxicological properties on active creatures as well as human health. These contaminants can persist and bioaccumulate in the environment. Additionally, typical wastewater treatment by biological methods are so scarce for removing refractory contaminants completely from pharmaceuticals wastewater. In an EC process, the dissolute metal hydroxides ions are capable enough to eliminate solvable inorganic contaminants. The foremost reactions in the EC procedure are iron/aluminum dissolution from anode and hydroxyl ion production at cathode. Several researchers have been studied the application of EC methods for different types of industrial and agricultural wastewaters. In EC process, electrodes are normally made of stainless steel (SS), aluminum (Al) and iron (Fe), and their primary function is as a dynamic coagulant precursor via dissolution in the anode and progressing hydrogen gas production on the cathode with gas bubble. In EC process, mostly three consecutive phases are involved which are coagulant species generation by the oxidized dissolution of the sacrificial metal anode, pollutants inconstancy, particulate deferral, emulsions breaking and lastly destabilized phase accumulation to form flocs. A search on science direct showed a noticeable increase in EC implementations in attempting the removal of pharmaceutical contaminants, representing an increase in research options in the field of pharmaceutical wastewater. The objective of this review was to regulate a systematic literature assessment on the removal of pharmaceutical contaminants in wastewater by the EC process. The maximum typical pharmaceutical contaminants found in a water body are designated, and water contamination problems are reviewed. The efficiency of the EC system is discussed in removing pharmaceuticals contaminants, which are affected by various operating parameters. Also, the techno-economic analysis was analyzed to get a clear view for future industrial application for pharmaceutical wastewater treatment. The necessity of the operational parameters affecting in effective implementation of the process along with the electrolysis techniques, EC treatment background and potentials, emerging challenges, and current developments are summarized. To conclude, the perspectives for future studies and recommendations of EC treatment for pharmaceutical wastewater has been deliberated along with their existing weaknesses in operational parameters and energy proficiency.

## **II. Literature review**

**Authors: Wenli Xua , Rusen Zoue, Biao Jina, Gan Zhanga, Yanyan Sud, Yifeng Zhang**

Pharmaceutical residues in wastewater are a rising environmental concern due to the fact that they could often penetrate conventional water treatment processes, and enter natural water. Among novel water treatment techniques, microbial electrochemical technologies (METs) emerge as an environment-friendly and efficient means for the treatment of pharmaceutical contaminants in wastewaters. In recent years, extensive research has been conducted towards the understanding and optimization of various METs for efficient treatment. However, a timely review to update the progress of METs studies with the specific focus of pharmaceutical removal is still lacking. Thus, this work provides a review of the recent advances in the removal of pharmaceutical contaminants by using METs. Specifically, the performance of the different systems along with the reactor configurations, reaction mechanisms, and different target pharmaceuticals were discussed. To end, the current challenges and future perspectives of METs for pharmaceutical residues removal were also demonstrated.

**Authors: Jia Zhang , Yaoyu Zhou , Bin Yao , Jian Yang, Dan Zhi**

Various pharmaceuticals have been detected in natural water and wastewater bodies, causing threats to water ecosystem and human health. Although electrochemical anodic-oxidation (EAO) has been shown to be efficient for pharmaceuticals degradation from aqueous solution, it still has a distinct need to apply EAO technology for pharmaceuticals removal rationally. This review provides the most recent progress on the mechanisms, influencing factors, and new technique of EAO for pharmaceuticals degradation. The mechanism and superiority of EAO were analyzed. Major influencing factors (e.g., electrode materials, electrochemical

reactor, applied current density, anode-cathode distance, electrolyte type and concentration, initial solution pH value, and initial pharmaceuticals concentration) were discussed on the removal of pharmaceuticals. The latest development of reactive electrochemical membranes (REM) was regarded as an emerging EAO technique, and it was also highlighted. This work revealed that the EAO of pharmaceuticals has extraordinary application prospects in the field of water and wastewater treatment.

**Authors; Hugo Olvera-Vargasa, Nissim Gore-Datar, Orlando Garcia-Rodriguez, Srikanth Mutnuri, Olivier Lefebvre**

Even though there is increasing evidence on the benefits of combining electro-Fenton (EF) and anodic oxidation with boron doped diamond anodes (BDD) for the degradation of organic pollutants, the exact contribution of % OH, BDD(% OH) and their synergy in the paired EFBDD process has still not been clearly established, taking into account i) the applied current/potential; ii) the reactivity of the pollutants and their intermediates formed during treatment and; iii) the matrix effect in real wastewater. In this paper, we address the above points by conducting the EF treatment of real pharmaceutical wastewater (COD<sub>0</sub> = 1200 mg L<sup>-1</sup> and BOD<sub>5</sub>/COD = 0.14). In-depth data analysis revealed a synergy between homogeneous and heterogeneous BDD(% OH) that accelerated the mineralization of organics, with homogeneous % OH dominating during the first treatment stages, while BDD prevailed in the last stages through electron transfer reactions. EF-BDD achieved the highest mineralization yield (97.1% of TOC removal at 4.17 mA cm<sup>-2</sup> and 0.2 mM of Fe<sup>2+</sup>), as compared to EF with a dimensionally stable anode (DSA), a material not producing heterogeneous % OH. However, EF-DSA proved equally effective at increasing the biodegradability of the effluent with lower operational costs (BOD<sub>5</sub>/COD = 0.68 at US\$ 1.46 m<sup>-3</sup> in 4 h). Hence, we point out the versatility of EF to reach different targets of water quality depending upon the anode materials: EF-DSA to increase the biodegradability of refractory wastewater vs. more powerful (though costlier) EF-BDD for quasi complete mineralization.

**Authors; B.K. Zaied, Mamunur Rashid, Mohd Nasrullah, A.W. Zularisam, Deepak Pant , Lakhveer Singh**

The pharmaceuticals are emergent contaminants, which can create potential threats for human health and the environment. All the pharmaceutical contaminants are becoming enormous in the environment as conventional wastewater treatment cannot be effectively implemented due to toxic and intractable action of pharmaceuticals. For this reason, the existence of pharmaceutical contaminants has brought great awareness, causing significant concern on their transformation, occurrence, risk, and fate in the environments. Electrocoagulation (EC) treatment process is effectively applied for the removal of contaminants, radionuclides, pesticides, and also harmful microorganisms. During the EC process, an electric current is employed directly, and both electrodes are dissolved partially in the reactor under the special conditions. This electrode dissolution produces the increased concentration of cation, which is finally precipitated as hydroxides and oxides. Different anode materials usage like aluminum, stainless steel, iron, etc. are found more effective in EC operation for efficient removal of pharmaceutical contaminants. Due to the simple procedure and less costly material, EC method is extensively recognized for pharmaceutical wastewater treatment over further conventional treatment methods. The EC process has more usefulness to destabilize the pharmaceutical contaminants with the neutralization of charge and after that coagulating those contaminants to produce flocs. Thus, the review places particular emphasis on the application of EC process to remove pharmaceutical contaminants. First, the operational parameters influencing EC efficiency with the electroanalysis techniques are described. Second, in this review emerging challenges, current developments and techno-economic concerns of EC are highlighted. Finally, future recommendations and prospective on EC are envisioned

### **III. Materials and methodology**

#### **OBJECTIVES**

##### **MAIN OBJECTIVES**

- The main objective of the study is to treat pharmaceutical industry waste water by electrochemical coagulation method

##### **SPECIFIC OBJECTIVES**

- To characterize pharmaceutical waste water for Physio-chemical and biological parameters.
- To carry out electrochemical treatment using Fe, Al, Cu electrodes for selected surface area.
- To study the change in water quality parameters during electrochemical coagulation at different time and cell voltage.

**STUDY AREA**

The raw waste water sample will be obtained from Karnataka Antibiotics and pharmaceuticals limited, 2nd main road, Nalagadderanahalli , Peenya industrial area, Bengaluru , Karnataka 560058 will be analysed as per standard methods. This will be collected and will be treated by the method of electro-coagulation. Karnataka Antibiotics & Pharmaceuticals Limited, (KAPL) Bengaluru is a Government of India

Enterprise.Karnataka Antibiotics and Pharmaceuticals Limited is a Joint Sector Company of Government of India with 59.17% of shareholding and 40.83% from Government of Karnataka through Karnataka State Industrial Infrastructure Development Corporation (KSIIDC).From a modest beginning in 1984, KAPL has grown exponentially in the areas of manufacturing and marketing of various life saving and essential drugs.



Test parameters for ground water analysis





#### Determination of pH of Water

Take the pH standard solution and the water that is to be tested.

Take the colorimetric paper. Dip this paper on the water sample. The obtained color is computed from the standard table and the respective pH value is recorded. This pH Value will conclude whether the sample of water is acidic or alkaline.

#### Hardness

Hard water is generally considered to be one which requires considerable amount of soap to produce foam or leather. Hard water cause scale formation in boilers heaters and hot water pipes. The rain water catches  $\text{CO}_2$  from the atmosphere when the water pass through  $\text{CaCO}_3$  rock in the Soil, these compounds make the water hard. Calcium and magnesium chlorides and sulphates also cause hardness.

#### Alkalinity

Alkalinity is significant in many uses and treatments of natural waters and wastewaters. As alkalinity of many surface waters constitute of carbonates, bicarbonate and hydroxide contents, it is assumed to be an indicator of these constituents as well. Alkalinity in excess of alkaline earth metal concentrations is significant in determining the suitability of water for irrigation. Alkalinity measurements are used in the interpretation and control of water and wastewater treatment processes. Raw domestic wastewater has an alkalinity less than or only slightly greater than that of the water supply.

#### Turbidity

Water is said to turbid when it is seen containing materials of suspension inside it. While turbidity may be defined as the measure of visible material in suspension in water, turbidity may be caused by algae or other organisms. It is generally caused by silt or clay. Total dissolved solids

TDS in water is due to the dissolved salts and minerals in water which are usually present in the form of ions; ex- sodium, potassium, carbonates, sulphates etc. Sometimes these dissolved solids can be toxic and also causes formation of scales in pipes and hence determination of the same is essential.

#### Colour

Colour Is A Useful Index Of Dissolved Humid Substances In Water. Dissolved And Particulate Material In Water Can Cause Discolouration.

#### Odour

Related to taste, a strong odour from a water for consumption will obviously causerevulsion or rejection on the part of the consumer. Its cause is normally dissolved volatileorganic compounds small concentrations of which may have great



organoleptic effects.

### Sulphate

It is one of the major dissolved components of rain. High concentrations of sulphate in water we drink can have laxative effect when combined with calcium and magnesium, the two most common constituents of

hardness. Natural water contains sulphate ions and most of these ions are also soluble in water. Many sulphate ions are produced by oxidation process of their ores, they also present in industrial wastes.

### Nitrate

Relatively little of the nitrate found in natural waters is of mineral origin, most coming from organic and inorganic sources, the former including waste discharges and the latter comprising chiefly artificial fertilisers. Bacterial oxidation and fixing of nitrogen by plants can both produce nitrate. Interest is centred on nitrate concentrations for various reasons. Most importantly, high nitrate levels in waters to be used for drinking will render them hazardous to infants as they induce the "blue baby" syndrome (methaemoglobinemia). The nitrate itself is not a direct toxicant but is a health hazard because of its conversion to nitrite [see also below] which reacts with blood haemoglobin to cause methaemoglobinemia. Of increasing importance is the degree to which fertiliser run-off can contribute to eutrophication problems in lakes. Sewage is rich in nitrogenous matter which through bacterial action may ultimately appear in the aquatic environment as nitrate. Hence, the presence of nitrate in ground waters, for example, is cause for suspicion of past sewage pollution or of excess levels of fertilisers or manure slurries spread on land. (High nitrite levels would indicate more recent pollution as nitrite is an intermediate stage in the ammonia-to-nitrate oxidation).

### Fluoride

Occurs naturally in quite rare instances; arises almost exclusively from fluoridation of public water supplies and from industrial discharges. At levels markedly over 1.5 mg/l an inverse effect occurs and mottling of teeth (or severe damage at gross levels) will arise. For this reason there is a constraint on fluoride levels, the effects of which vary with temperature.

### Iron

Iron is the second most abundant metal in the earth's crust. Dissolved iron in water causes the water to taste metallic. The water may also be discolored due to suspended solids containing minerals of iron that appear brownish in color. Iron will leave red or orange rust stains in the sink, toilet and bathtub. It can build up in your dishwasher and discolor ceramic dishes. It can also enter into the laundry equipment and cause stains on clothing. "Even though the EPA says that the iron in the drinking water is safe to drink, the iron sediments, other trace impurities may support bacteria that are harmful, and these bacteria are mostly found in wells where the water has not been chlorinated".

### Calcium

This element is the most important and abundant in the human body and an adequate intake is essential for normal growth and health. The maximum daily requirement is of the order of 1-2 grams and comes especially from dairy products. There is some evidence to show that the incidence of heart disease is reduced in areas served by a public water supply with a high degree of hardness, the primary constituent of which is calcium, so that the presence of the element in a water supply is beneficial to health.

### Magnesium

magnesium is abundant and a major dietary requirement for humans (0.3-0.5 g/day). It is the second major constituent of hardness (see above) and it generally comprises 15-20 per cent of the total hardness expressed as CaCO<sub>3</sub>. Its concentration is very significant when considered in conjunction with that of sulphate.

### Chloride

Chloride in the form of chloride (Cl<sup>-</sup>) ion is one of the major inorganic anions in water and wastewater. The chloride concentration is higher in wastewater than in raw water because sodium chloride is a common article of diet and passes unchanged through the digestive system (Average estimate of excretion: 6 g of chlorides/person/day; additional chloride burden due to human consumption on wastewater).

#### IV. RESULTS

##### 1. SAMPLE PARTICULARS: RAW WATER (WASTEWATER)

##### 2. SAMPLE PARTICULARS: ALUMINIUM 10V, 90 MIN WATER

Sl No	Tests	Results	Protocol
1	Colour, Hazen Units	Greyish	APHA 2120 B
2	Odour	Agreeable	APHA 2150C
3	Turbidity, NTU	<1.0	APHA 2130 B
4	pH Value	6.87	APHA 4500 H <sup>+</sup> B
5	Electrical conductivity $\mu\text{s}/\text{cm}$	901	APHA 2510 B
6	Total Hardness as $\text{CaCO}_3$ , mg/l	232.0	APHA 2340 C
7	Calcium as Ca, mg/l	48.0	APHA 3500 Ca
8	Magnesium as Mg, mg/l	27.0	APHA 3500 MgB
9	Chlorides as Cl, mg/l	130.0	APHA 4500 Cl
10	Total Dissolved Solids, mg/l	570.0	APHA 2540 C
11	Sulphates as $\text{SO}_4$ , mg/l	47.0	APHA 4500 $\text{SO}_4$ E
12	Nitrates as $\text{NO}_3$ , mg/l	18.0	IS 3025 PART 34
13	Fluoride as F, mg/l	0.32	APHA 4500 F-D
14	Iron as Fe, mg/l	0.03	APHA 3500 Fe
15	Total Alkalinity as $\text{CaCO}_3$ , mg/l	298.0	APHA 2320 B
16	Chemical Oxygen Demand	784.0	APHA 5220 B
17	BOD, 3 days @27 <sup>o</sup> C	100.0	IS 3025 PART 44
18	Total Suspended Solids	110.0	APHA 4500 C
19	Dissolved Oxygen	5.9	APHA 4500 - B O

Sl No	Tests	Results	Protocol
1	Colour, Hazen Units	Greyish	APHA 2120 B
2	Odour	Agreeable	APHA 2150C
3	Turbidity, NTU	1.8	APHA 2130 B
4	pH Value	6.9	APHA 4500 H <sup>+</sup> B
5	Electrical conductivity $\mu\text{s}/\text{cm}$	735	APHA 2510 B
6	Total Hardness as $\text{CaCO}_3$ , mg/l	148.0	APHA 2340 C
7	Calcium as Ca, mg/l	29.0	APHA 3500 Ca
8	Magnesium as Mg, mg/l	18.5	APHA 3500 Mg-B
9	Chlorides as Cl, mg/l	160.0	APHA 4500 Cl
10	Total Dissolved Solids, mg/l	470.0	APHA 2540 C
11	Sulphates as $\text{SO}_4$ , mg/l	31.0	APHA 4500 $\text{SO}_4$ -E
12	Nitrates as $\text{NO}_3$ , mg/l	12.0	IS 3025 PART 34
13	Fluoride as F, mg/l	0.11	APHA 4500 F-D
14	Iron as Fe, mg/l	0.09	APHA 3500 Fe
15	Total Alkalinity as $\text{CaCO}_3$ , mg/l	192.0	APHA 2320 B
16	Chemical Oxygen Demand	470.0	APHA 5220 B
17	BOD, 3 days @27 <sup>o</sup> C	60.0	IS 3025 PART 44
18	Total Suspended Solids	66.0	APHA 4500 C
19	Dissolved Oxygen	5.2	APHA 4500 -B O

**3.SAMPLE PARTICULARS: ALUMINIUM 20V, 90 MIN WATER  
ALUMINIUM 30V,90MIN WATER**

**4.SAMPLE PARTICULARS:**

Sl No	Tests	Results	Protocol
1	Colour, Hazen Units	Greyish	APHA 2120 B
2	Odour	Agreeable	APHA 2150C
3	Turbidity, NTU	2.8	APHA 2130 B
4	pH Value	6.85	APHA 4500 H <sup>+</sup> B
5	Electrical conductivity $\mu\text{s}/\text{cm}$	586	APHA 2510 B
6	Total Hardness as $\text{CaCO}_3, \text{mg}/\text{l}$	64.0	APHA 2340 C
7	Calcium as Ca, $\text{mg}/\text{l}$	12.8	APHA 3500 Ca
8	Magnesium as Mg, $\text{mg}/\text{l}$	7.8	APHA 3500 MgB
9	Chlorides as Cl, $\text{mg}/\text{l}$	170.0	APHA 4500 Cl
10	Total Dissolved Solids, $\text{mg}/\text{l}$	370.0	APHA 2540 C
11	Sulphates as $\text{SO}_4, \text{mg}/\text{l}$	13.3	APHA 4500 $\text{SO}_4\text{E}$
12	Nitrates as $\text{NO}_3, \text{mg}/\text{l}$	8.0	IS 3025 PART 34
13	Fluoride as F, $\text{mg}/\text{l}$	0.06	APHA 4500 F-D
14	Iron as Fe, $\text{mg}/\text{l}$	0.15	APHA 3500 Fe
15	Total Alkalinity as $\text{CaCO}_3, \text{mg}/\text{l}$	122.0	APHA 2320 B
16	Chemical Oxygen Demand	548.0	APHA 5220 B
17	BOD, 3 days @27 <sup>o</sup> C	70.0	IS 3025 PART 44
18	Total Suspended Solids	80.0	APHA 4500 C
19	Dissolved Oxygen	5.2	APHA 4500 - B O

Sl No	Tests	Results	Protocol
1	Colour, Hazen Units	Greyish	APHA 2120 B
2	Odour	Agreeable	APHA 2150C
3	Turbidity, NTU	1.6	APHA 2130 B
4	pH Value	7.5	APHA 4500 H <sup>+</sup> B
5	Electrical conductivity $\mu\text{s}/\text{cm}$	552	APHA 2510 B
6	Total Hardness as $\text{CaCO}_3, \text{mg}/\text{l}$	48.0	APHA 2340 C
7	Calcium as Ca, $\text{mg}/\text{l}$	11.2	APHA 3500 Ca
8	Magnesium as Mg, $\text{mg}/\text{l}$	4.9	APHA 3500 Mg- B
9	Chlorides as Cl, $\text{mg}/\text{l}$	155.0	APHA 4500 Cl
10	Total Dissolved Solids, $\text{mg}/\text{l}$	350.0	APHA 2540 C
11	Sulphates as $\text{SO}_4, \text{mg}/\text{l}$	10.5	APHA 4500 $\text{SO}_4\text{- E}$
12	Nitrates as $\text{NO}_3, \text{mg}/\text{l}$	6.8	IS 3025 PART 34
13	Fluoride as F, $\text{mg}/\text{l}$	0.04	APHA 4500 F-D
14	Iron as Fe, $\text{mg}/\text{l}$	0.07	APHA 3500 Fe
15	Total Alkalinity as $\text{CaCO}_3, \text{mg}/\text{l}$	106.0	APHA 2320 B
16	Chemical Oxygen Demand	157.0	APHA 5220 B
17	BOD, 3 days @27 <sup>o</sup> C	28.0	IS 3025 PART 44
18	Total Suspended Solids	32.0	APHA 4500 C
19	Dissolved Oxygen	4.9	APHA 4500 -B O



**5.SAMPLE PARTICULARS: ALUMINIUM 10V, 120MIN WATER  
ALUMINIUM 20V, 120MIN WATER**

**6..SAMPLE PARTICULARS:**

Sl No	Tests	Results	Protocol
1	Colour, Hazen Units	Greyish	APHA 2120 B
2	Odour	Agreeable	APHA 2150C
3	Turbidity, NTU	1.6	APHA 2130 B
4	pH Value	6.96	APHA 4500 H <sup>+</sup> B
5	Electrical conductivity $\mu\text{s/cm}$	670	APHA 2510 B
6	Total Hardness as $\text{CaCO}_3, \text{mg/l}$	96.0	APHA 2340 C
7	Calcium as Ca, $\text{mg/l}$	17.6	APHA 3500 Ca
8	Magnesium as Mg, $\text{mg/l}$	12.0	APHA 3500 MgB
9	Chlorides as Cl, $\text{mg/l}$	150.0	APHA 4500 Cl
10	Total Dissolved Solids, $\text{mg/l}$	430.0	APHA 2540 C
11	Sulphates as $\text{SO}_4, \text{mg/l}$	27.1	APHA 4500 $\text{SO}_4\text{E}$
12	Nitrates as $\text{NO}_3, \text{mg/l}$	6.8	IS 3025 PART 34
13	Fluoride as F, $\text{mg/l}$	0.09	APHA 4500 F-D
14	Iron as Fe, $\text{mg/l}$	0.07	APHA 3500 Fe
15	Total Alkalinity as $\text{CaCO}_3, \text{mg/l}$	175.0	APHA 2320 B
16	Chemical Oxygen Demand	314.0	APHA 5220 B
17	BOD, 3 days @27 <sup>o</sup> C	40.0	IS 3025 PART 44
18	Total Suspended Solids	48.0	APHA 4500 C
19	Dissolved Oxygen	4.9	APHA 4500 - B O

Sl No	Tests	Results	Protocol
1	Colour, Hazen Units	Greyish	APHA 2120 B
2	Odour	Agreeable	APHA 2150C
3	Turbidity, NTU	<1.0	APHA 2130 B
4	pH Value	7.1	APHA 4500 H <sup>+</sup> B
5	Electrical conductivity $\mu\text{s/cm}$	556	APHA 2510 B
6	Total Hardness as $\text{CaCO}_3, \text{mg/l}$	48.0	APHA 2340 C
7	Calcium as Ca, $\text{mg/l}$	9.6	APHA 3500 Ca
8	Magnesium as Mg, $\text{mg/l}$	5.8	APHA 3500 Mg-B
9	Chlorides as Cl, $\text{mg/l}$	150.0	APHA 4500 Cl
10	Total Dissolved Solids, $\text{mg/l}$	350.0	APHA 2540 C
11	Sulphates as $\text{SO}_4, \text{mg/l}$	13.4	APHA 4500 $\text{SO}_4\text{-E}$
12	Nitrates as $\text{NO}_3, \text{mg/l}$	8.4	IS 3025 PART 34
13	Fluoride as F, $\text{mg/l}$	0.07	APHA 4500 F-D
14	Iron as Fe, $\text{mg/l}$	0.03	APHA 3500 Fe
15	Total Alkalinity as $\text{CaCO}_3, \text{mg/l}$	139.0	APHA 2320 B
16	Chemical Oxygen Demand	157.0	APHA 5220 B
17	BOD, 3 days @27 <sup>o</sup> C	20.0	IS 3025 PART 44
18	Total Suspended Solids	26.0	APHA 4500 C
19	Dissolved Oxygen	4.5	APHA 4500 -B O

**7.SAMPLE PARTICULARS: ALUMINIUM 30V, 120MIN WATER 90MIN WATER**

1	Colour, Hazen Units	Greyish	APHA 2120 B
2	Odour	Agreeable	APHA 2150C
3	Turbidity, NTU	3.2	APHA 2130 B
4	pH Value	7.5	APHA 4500 H <sup>+</sup> B
5	Electrical conductivity $\mu\text{s}/\text{cm}$	528	APHA 2510 B
6	Total Hardness as $\text{CaCO}_3, \text{mg}/\text{l}$	32.0	APHA 2340 C
7	Calcium as Ca, $\text{mg}/\text{l}$	6.4	APHA 3500 Ca
8	Magnesium as Mg, $\text{mg}/\text{l}$	4.0	APHA 3500 MgB
9	Chlorides as Cl, $\text{mg}/\text{l}$	150.0	APHA 4500 Cl
10	Total Dissolved Solids, $\text{mg}/\text{l}$	340.0	APHA 2540 C
11	Sulphates as $\text{SO}_4, \text{mg}/\text{l}$	11.1	APHA 4500 $\text{SO}_4\text{E}$
12	Nitrates as $\text{NO}_3, \text{mg}/\text{l}$	6.0	IS 3025 PART 34
13	Fluoride as F, $\text{mg}/\text{l}$	0.04	APHA 4500 F-D
14	Iron as Fe, $\text{mg}/\text{l}$	0.35	APHA 3500 Fe
15	Total Alkalinity as $\text{CaCO}_3, \text{mg}/\text{l}$	126.0	APHA 2320 B
16	Chemical Oxygen Demand	235.0	APHA 5220 B
17	BOD, 3 days @27 <sup>o</sup> C	30.0	IS 3025 PART 44
18	Total Suspended Solids	38.0	APHA 4500 C
19	Dissolved Oxygen	4.1	APHA 4500 -B O

**8. SAMPLE PARTICULARS: IRON 10V, 90MIN WATER**

Sl No	Tests	Results	Protocol
1	Colour, Hazen Units	Greyish	APHA 2120 B
2	Odour	Agreeable	APHA 2150C
3	Turbidity, NTU	6.8	APHA 2130 B
4	pH Value	6.95	APHA 4500 H <sup>+</sup> B
5	Electrical conductivity $\mu\text{s}/\text{cm}$	702	APHA 2510 B
6	Total Hardness as $\text{CaCO}_3, \text{mg}/\text{l}$	152.0	APHA 2340 C
7	Calcium as Ca, $\text{mg}/\text{l}$	32.0	APHA 3500 Ca
8	Magnesium as Mg, $\text{mg}/\text{l}$	17.5	APHA 3500 Mg- B
9	Chlorides as Cl, $\text{mg}/\text{l}$	160.0	APHA 4500 Cl
10	Total Dissolved Solids, $\text{mg}/\text{l}$	450.0	APHA 2540 C
11	Sulphates as $\text{SO}_4, \text{mg}/\text{l}$	61.0	APHA 4500 $\text{SO}_4\text{- E}$
12	Nitrates as $\text{NO}_3, \text{mg}/\text{l}$	32.0	IS 3025 PART 34
13	Fluoride as F, $\text{mg}/\text{l}$	0.39	APHA 4500 F-D
14	Iron as Fe, $\text{mg}/\text{l}$	10.4	APHA 3500 Fe
15	Total Alkalinity as $\text{CaCO}_3, \text{mg}/\text{l}$	196.0	APHA 2320 B
16	Chemical Oxygen Demand	392.0	APHA 5220 B
17	BOD, 3 days @27 <sup>o</sup> C	50.0	IS 3025 PART 44
18	Total Suspended Solids	56.0	APHA 4500 C
19	Dissolved Oxygen	5.1	APHA 4500 -B O

\*Corresponding author:

**9. 20V, 90MIN**

**10. SAMPLE PARTICULARS: IRON 30V, 90MIN WATER**

1	Colour, Hazen Units	Greyish	APHA 2120 B
2	Odour	Agreeable	APHA 2150C
3	Turbidity, NTU	5.6	APHA 2130 B
4	pH Value	6.9	APHA 4500 H <sup>+</sup> B
5	Electrical conductivity $\mu\text{s}/\text{cm}$	588	APHA 2510 B
6	Total Hardness as $\text{CaCO}_3, \text{mg}/\text{l}$	76.0	APHA 2340 C
7	Calcium as Ca, $\text{mg}/\text{l}$	16.0	APHA 3500 Ca
8	Magnesium as Mg, $\text{mg}/\text{l}$	8.7	APHA 3500 MgB
9	Chlorides as Cl, $\text{mg}/\text{l}$	165.0	APHA 4500 Cl
10	Total Dissolved Solids, $\text{mg}/\text{l}$	370.0	APHA 2540 C
11	Sulphates as $\text{SO}_4, \text{mg}/\text{l}$	54.6	APHA 4500 $\text{SO}_4\text{E}$
12	Nitrates as $\text{NO}_3, \text{mg}/\text{l}$	22.0	IS 3025 PART 34
13	Fluoride as F, $\text{mg}/\text{l}$	0.23	APHA 4500 F-D
14	Iron as Fe, $\text{mg}/\text{l}$	9.34	APHA 3500 Fe
15	Total Alkalinity as $\text{CaCO}_3, \text{mg}/\text{l}$	131.0	APHA 2320 B
16	Chemical Oxygen Demand	120.0	APHA 5220 B
17	BOD, 3 days @27 <sup>o</sup> C	16.0	IS 3025 PART 44
18	Total Suspended Solids	20.0	APHA 4500 C
19	Dissolved Oxygen	5.9	APHA 4500 -B O

Sl No	Tests	Results	Protocol
1	Colour, Hazen Units	Greyish	APHA 2120 B
2	Odour	Agreeable	APHA 2150C
3	Turbidity, NTU	4.2	APHA 2130 B
4	pH Value	7.6	APHA 4500 H <sup>+</sup> B
5	Electrical conductivity $\mu\text{s}/\text{cm}$	534	APHA 2510 B
6	Total Hardness as $\text{CaCO}_3, \text{mg}/\text{l}$	44.0	APHA 2340 C
7	Calcium as Ca, $\text{mg}/\text{l}$	9.6	APHA 3500 Ca
8	Magnesium as Mg, $\text{mg}/\text{l}$	4.9	APHA 3500 Mg- B
9	Chlorides as Cl, $\text{mg}/\text{l}$	165.0	APHA 4500 Cl
10	Total Dissolved Solids, $\text{mg}/\text{l}$	340.0	APHA 2540 C
11	Sulphates as $\text{SO}_4, \text{mg}/\text{l}$	58.0	APHA 4500 $\text{SO}_4\text{- E}$
12	Nitrates as $\text{NO}_3, \text{mg}/\text{l}$	23.0	IS 3025 PART 34
13	Fluoride as F, $\text{mg}/\text{l}$	0.31	APHA 4500 F-D
14	Iron as Fe, $\text{mg}/\text{l}$	2.87	APHA 3500 Fe
15	Total Alkalinity as $\text{CaCO}_3, \text{mg}/\text{l}$	86.0	APHA 2320 B
16	Chemical Oxygen Demand	80.0	APHA 5220 B
17	BOD, 3 days @27 <sup>o</sup> C	6.0	IS 3025 PART 44
18	Total Suspended Solids	7.0	APHA 4500 C
19	Dissolved Oxygen	6.1	APHA 4500 -B O

\*Corresponding author:

**11. 10V, 120MIN**

**12. SAMPLE PARTICULARS: IRON 20V, 120MIN WATER**

1	Colour, Hazen Units	Greyish	APHA 2120 B
2	Odour	Agreeable	APHA 2150C
3	Turbidity, NTU	5.6	APHA 2130 B
4	pH Value	8.5	APHA 4500 H <sup>+</sup> B
5	Electrical conductivity $\mu\text{s}/\text{cm}$	503	APHA 2510 B
6	Total Hardness as $\text{CaCO}_3, \text{mg}/\text{l}$	40.0	APHA 2340 C
7	Calcium as Ca, $\text{mg}/\text{l}$	8.0	APHA 3500 Ca
8	Magnesium as Mg, $\text{mg}/\text{l}$	5.0	APHA 3500 MgB
9	Chlorides as Cl, $\text{mg}/\text{l}$	165.0	APHA 4500 Cl
10	Total Dissolved Solids, $\text{mg}/\text{l}$	320.0	APHA 2540 C
11	Sulphates as $\text{SO}_4, \text{mg}/\text{l}$	29.2	APHA 4500 $\text{SO}_4\text{E}$
12	Nitrates as $\text{NO}_3, \text{mg}/\text{l}$	6.8	IS 3025 PART 34
13	Fluoride as F, $\text{mg}/\text{l}$	0.38	APHA 4500 F-D
14	Iron as Fe, $\text{mg}/\text{l}$	1.33	APHA 3500 Fe
15	Total Alkalinity as $\text{CaCO}_3, \text{mg}/\text{l}$	77.5	APHA 2320 B
16	Chemical Oxygen Demand	40.0	APHA 5220 B
17	BOD, 3 days @27 <sup>o</sup> C	6.0	IS 3025 PART 44
18	Total Suspended Solids	7.0	APHA 4500 C
19	Dissolved Oxygen	6.9	APHA 4500 -B O

SI No	Tests	Results	Protocol
1	Colour, Hazen Units	Greyish	APHA 2120 B
2	Odour	Agreeable	APHA 2150C
3	Turbidity, NTU	3.8	APHA 2130 B
4	pH Value	8.7	APHA 4500 H <sup>+</sup> B
5	Electrical conductivity $\mu\text{s}/\text{cm}$	475	APHA 2510 B
6	Total Hardness as $\text{CaCO}_3, \text{mg}/\text{l}$	32.0	APHA 2340 C
7	Calcium as Ca, $\text{mg}/\text{l}$	6.4	APHA 3500 Ca
8	Magnesium as Mg, $\text{mg}/\text{l}$	4.0	APHA 3500 Mg- B
9	Chlorides as Cl, $\text{mg}/\text{l}$	150.0	APHA 4500 Cl
10	Total Dissolved Solids, $\text{mg}/\text{l}$	300.0	APHA 2540 C
11	Sulphates as $\text{SO}_4, \text{mg}/\text{l}$	27.0	APHA 4500 $\text{SO}_4\text{- E}$
12	Nitrates as $\text{NO}_3, \text{mg}/\text{l}$	8.0	IS 3025 PART 34
13	Fluoride as F, $\text{mg}/\text{l}$	0.35	APHA 4500 F-D
14	Iron as Fe, $\text{mg}/\text{l}$	1.24	APHA 3500 Fe
15	Total Alkalinity as $\text{CaCO}_3, \text{mg}/\text{l}$	61.0	APHA 2320 B
16	Chemical Oxygen Demand	32.0	APHA 5220 B
17	BOD, 3 days @27 <sup>o</sup> C	5.0	IS 3025 PART 44
18	Total Suspended Solids	6.0	APHA 4500 C
19	Dissolved Oxygen	7.0	APHA 4500 -B O



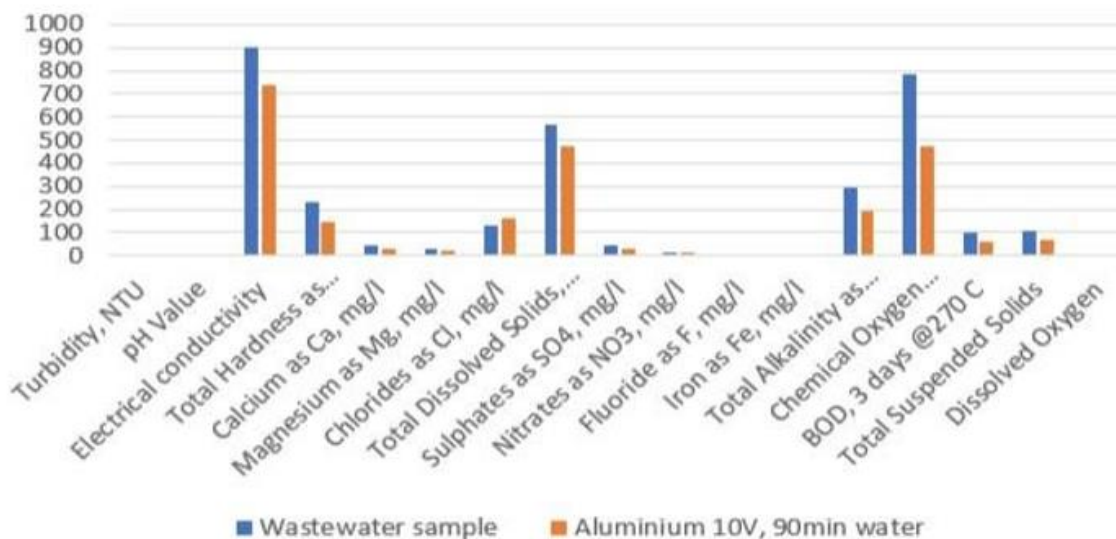
13. 30V, 120MIN

1	Colour, Hazen Units	Greyish	APHA 2120 B
2	Odour	Agreeable	APHA 2150C
3	Turbidity, NTU	9.4	APHA 2130 B
4	pH Value	6.9	APHA 4500 H <sup>+</sup> B
5	Electrical conductivity $\mu\text{s}/\text{cm}$	639	APHA 2510 B
6	Total Hardness as $\text{CaCO}_3$ , mg/l	112.0	APHA 2340 C
7	Calcium as Ca, mg/l	24.0	APHA 3500 Ca
8	Magnesium as Mg, mg/l	12.6	APHA 3500 MgB
9	Chlorides as Cl, mg/l	160.0	APHA 4500 Cl
10	Total Dissolved Solids, mg/l	408.0	APHA 2540 C
11	Sulphates as $\text{SO}_4$ , mg/l	64.5	APHA 4500 $\text{SO}_4$ E
12	Nitrates as $\text{NO}_3$ , mg/l	24.0	IS 3025 PART 34
13	Fluoride as F, mg/l	0.40	APHA 4500 F-D
14	Iron as Fe, mg/l	11.24	APHA 3500 Fe
15	Total Alkalinity as $\text{CaCO}_3$ , mg/l	168.0	APHA 2320 B
16	Chemical Oxygen Demand	80.0	APHA 5220 B
17	BOD, 3 days @27 <sup>o</sup> C	6.0	IS 3025 PART 44
18	Total Suspended Solids	7.0	APHA 4500 C
19	Dissolved Oxygen	6.4	APHA 4500 -B O

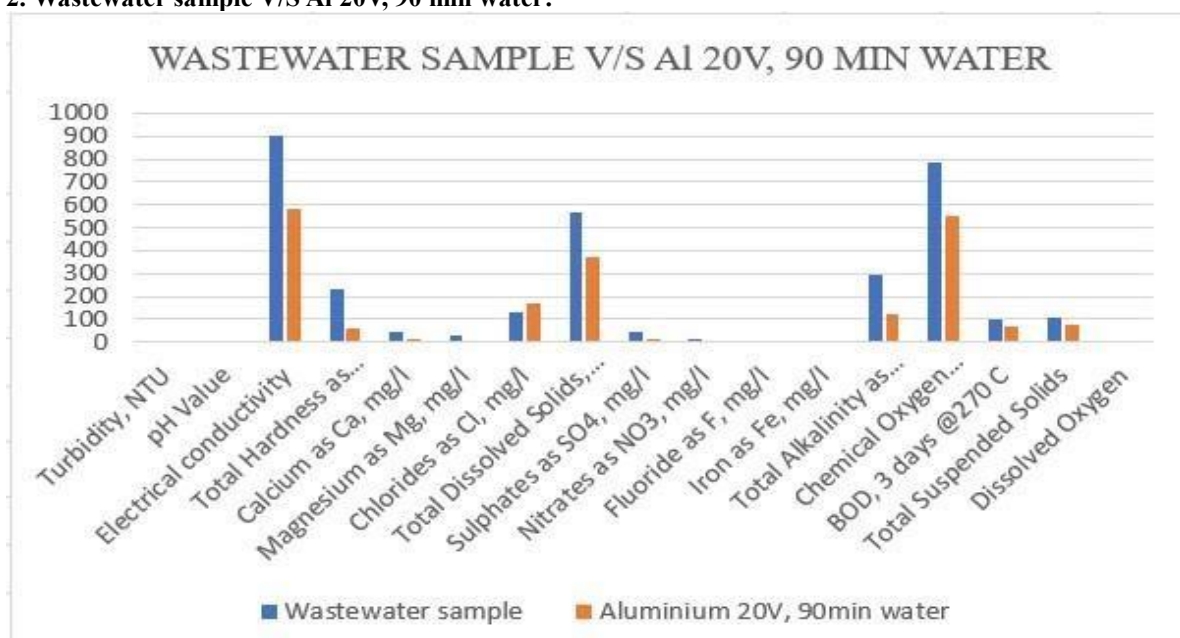
GRAPHS

1.Wastewater sample V/SAI 10V, 90 min water:

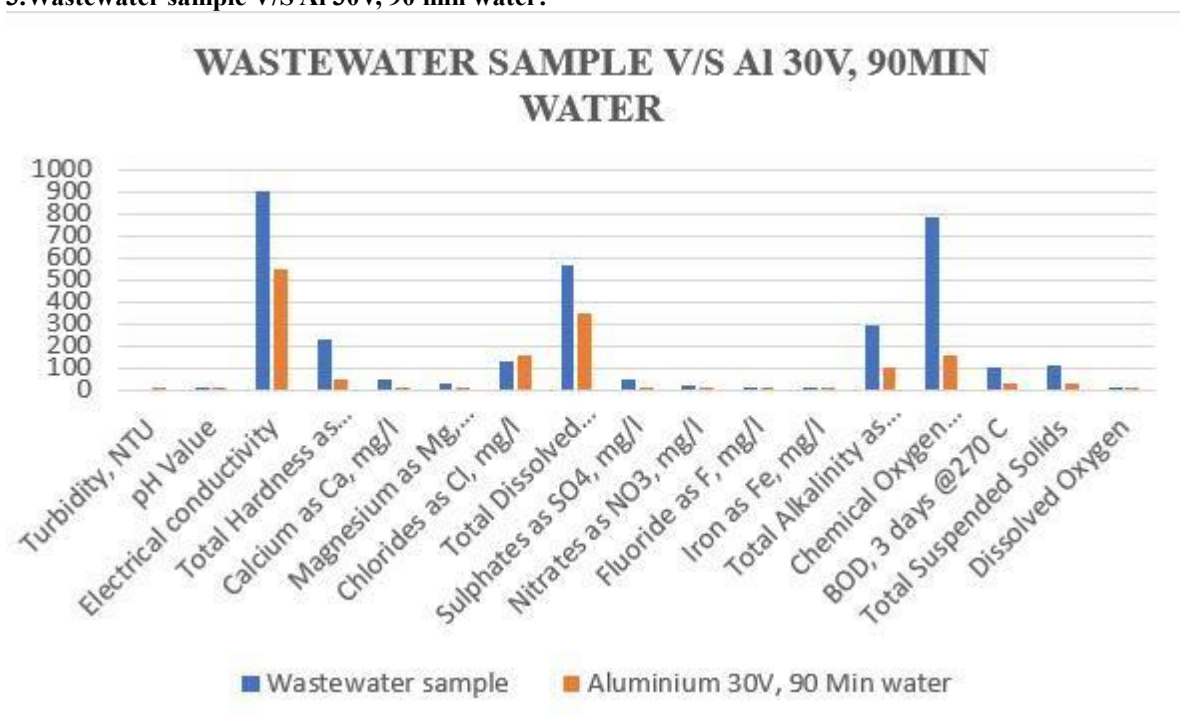
WASTEWATER SAMPLE V/S AI 10V, 90MIN WATER



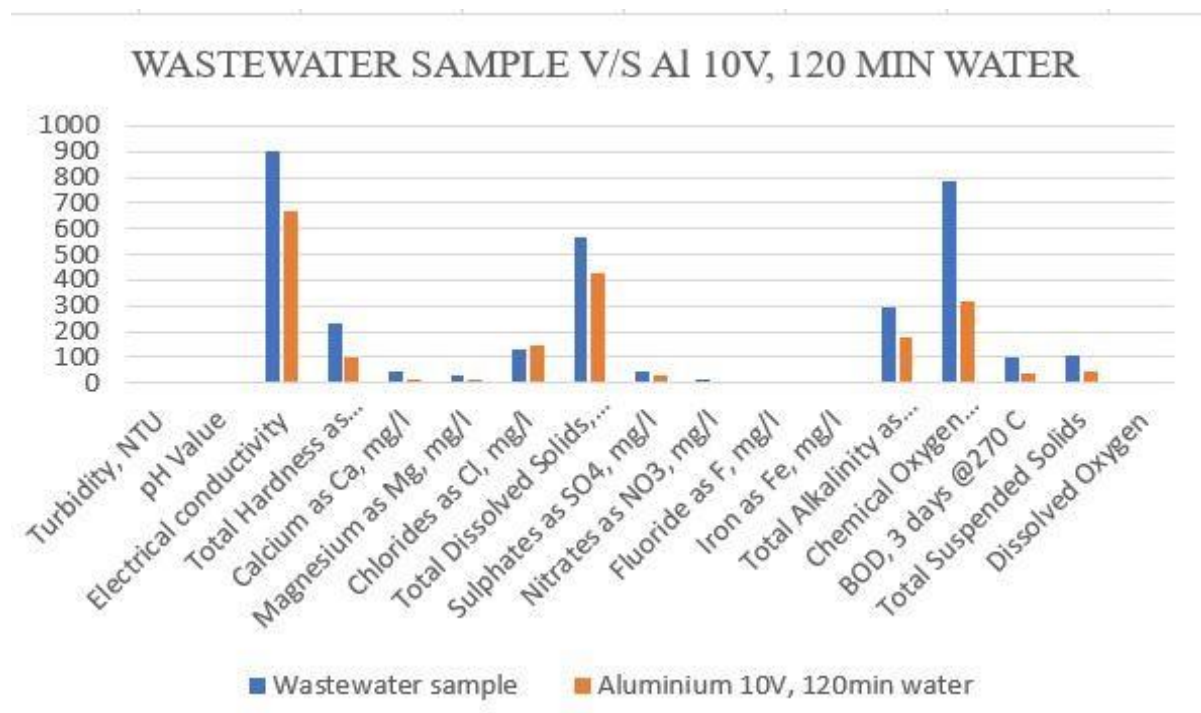
2. Wastewater sample V/S Al 20V, 90 min water:



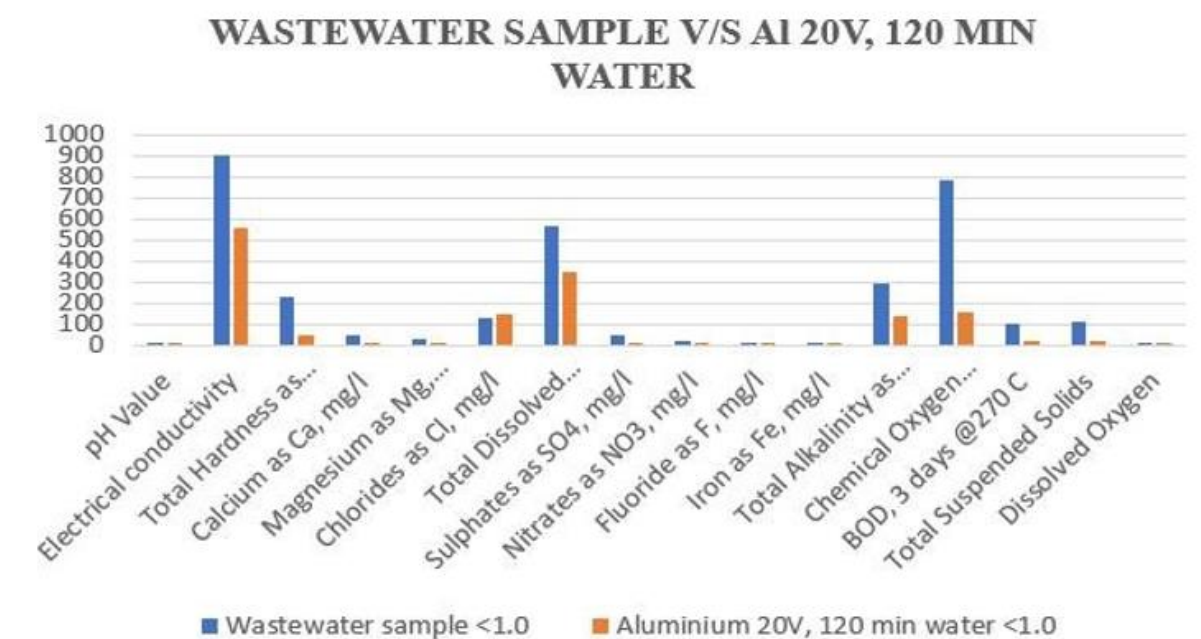
3. Wastewater sample V/S Al 30V, 90 min water:



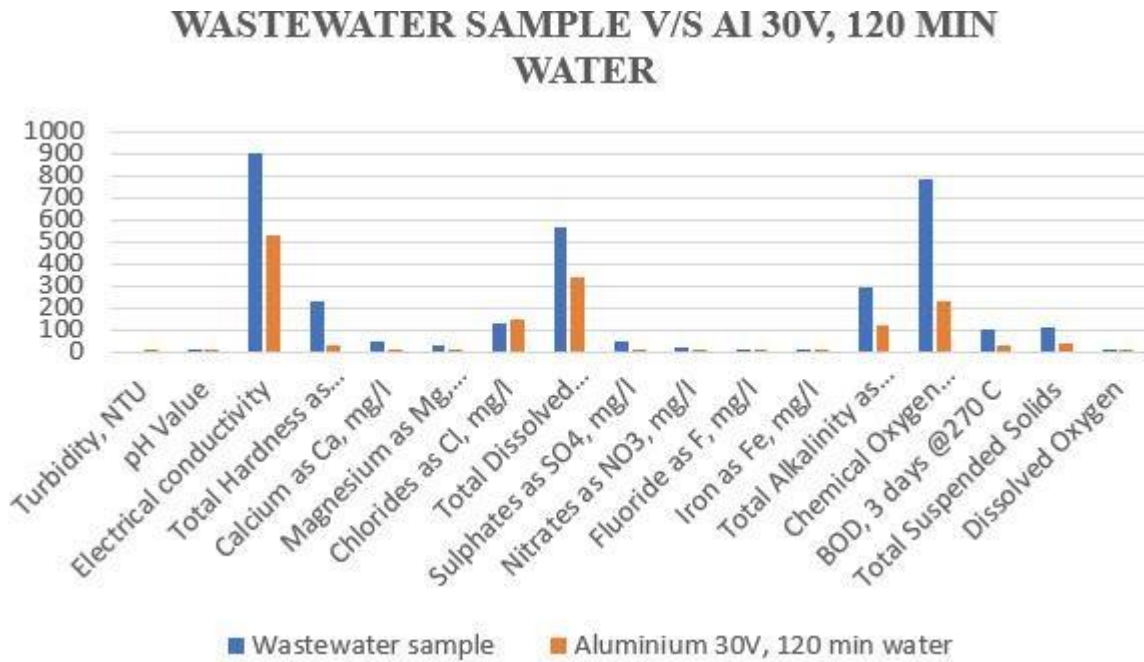
4. Wastewater sample V/S Al 10V, 120 min water:



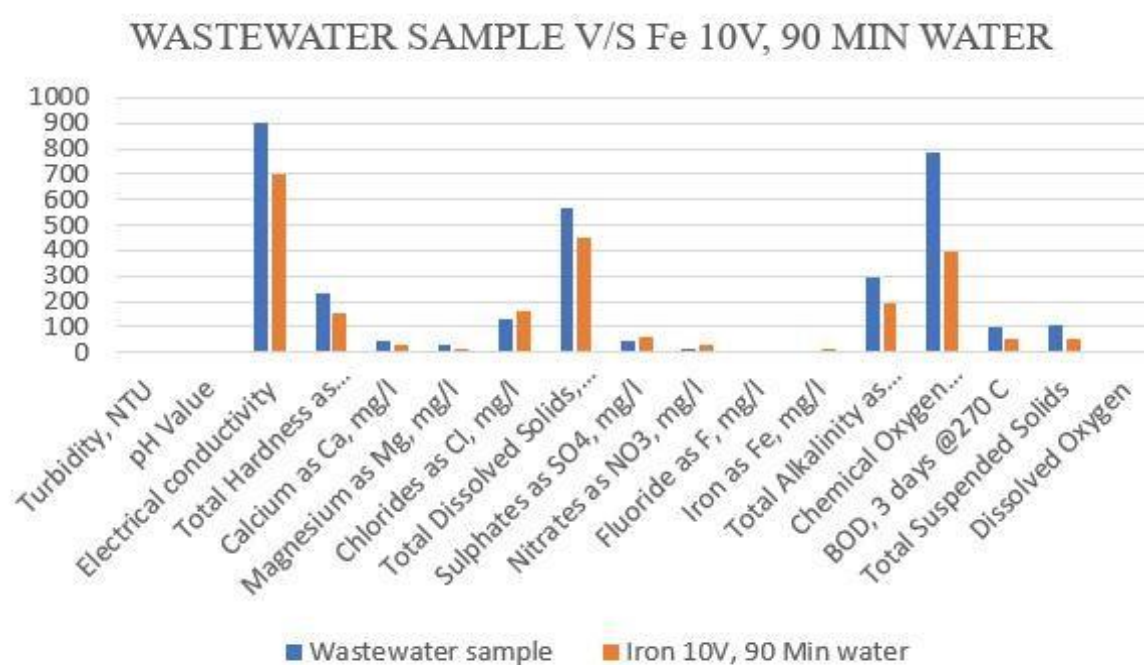
5. Wastewater sample V/S Al 20V, 120 min water:



6. Wastewater sample V/Al 30V, 120 min water:

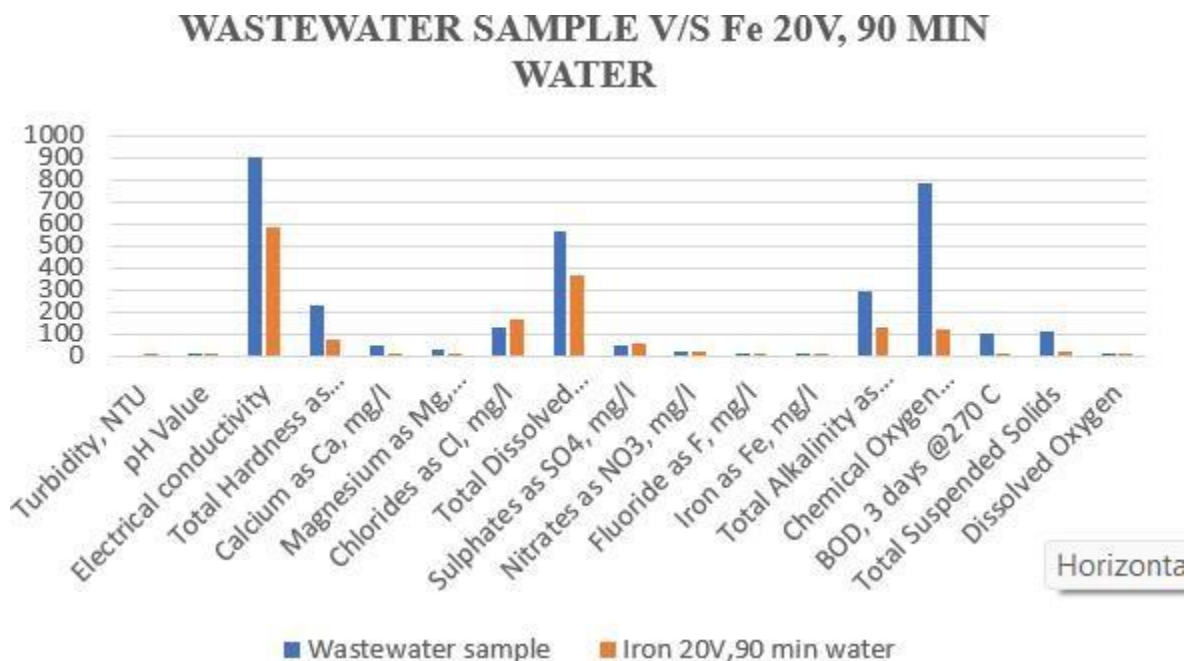


7. Wastewater sample V/S Fe 10V, 90 min water:

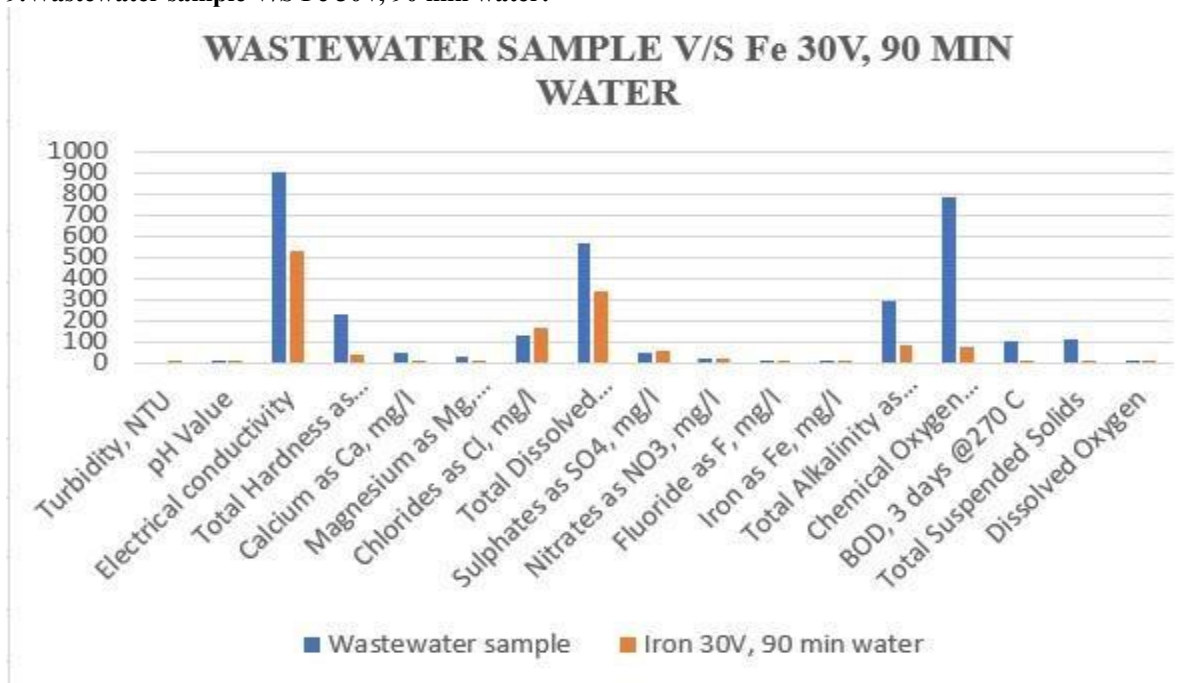




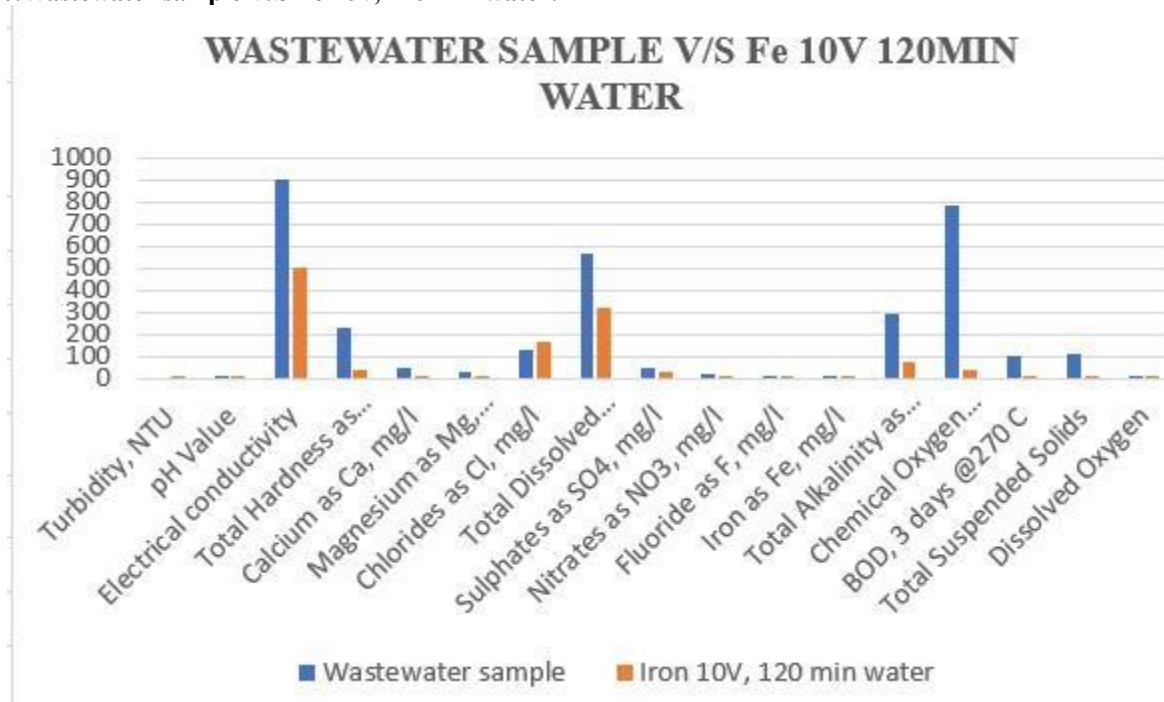
8. Wastewater sample V/S Fe 20V, 90 min water:



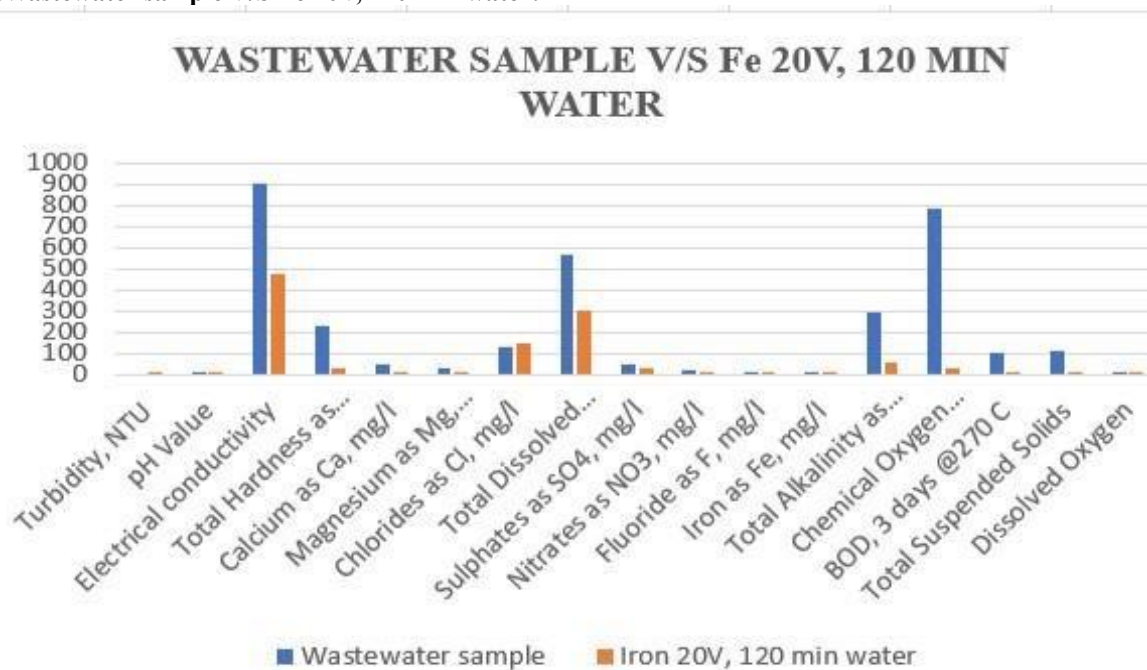
9. Wastewater sample V/S Fe 30V, 90 min water:



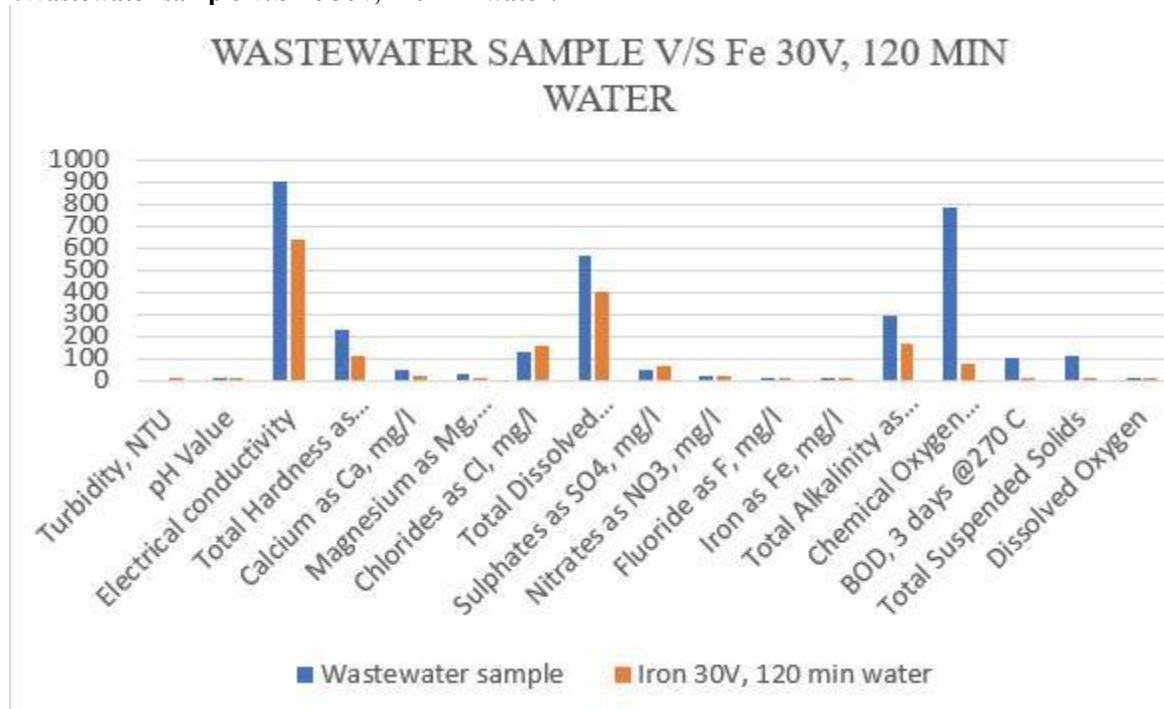
10. Wastewater sample V/S Fe 10V, 120 min water:



11. Wastewater sample V/S Fe 20V, 120 min water:



12. Wastewater sample V/S Fe 30V, 120 min water:



V. CONCLUSION

Both the technologies have same efficiency in the removal of suspended solids and COD. The percentage reduction of TDS and chloride is very high with electrocoagulation when compared to the conventional chemical coagulation. The major disadvantage of chemical coagulation is an increase in the sludge volume due to high TDS and also a reduction in the self purification capacity of the streams when discharged without treatment. In electro coagulation method using Fe-Al electrode combination, the parameters COD, TDS, Chloride and Suspended solids are reduced almost above 90 % with a lower consumption of current (0.04Amp). Hence Fe-Al electrode assembly is considered more efficient assembly compared to Fe-Fe and Al-Al. In Electro coagulation, electrode consumption is only 0.02 g of Iron and 0.17 g of Aluminium for treating 500 ml of effluent using Fe-Al electrode assembly whereas in case of chemical coagulation 3 g of ferric chloride and 7gms of alum are required for treating 500 ml of the effluent. Therefore, the coagulant consumption is also less in electro coagulation which makes it a cost effective technique. Electrocoagulation treatment gives clearer water than chemical coagulation. Hence it is reiterated that electrocoagulation is an efficient and reliable technique for a number of applications in the future, which in turn will give hope for purified water for coming generations.

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