

Treatment of Distillery Spent Wash Using Electrochemical Coagulation (ECC) Process

Shreedevi.V¹, Dr Istalingamurthy.D², Mr. Chandrashekar.B³

^{1,2,3} Dept of Environmental Engineering

^{1,2,3} JSS Science and Technology University, Mysuru, Karnataka, India.

Abstract- Distillery industry is one of oldest industries which is highly complex and characterized by high BOD, COD, suspended solids, dissolved solids, total solids, and color and low pH. The aim of the present study was carried out to assess the feasibility of Electro-chemical coagulation (ECC) process for the treatment of Bio-digester effluent (BDE) using Aluminium and Stainless steel in a monopolar configuration. The effects of various operating parameters such as voltage and electrolysis duration for the removal Color and COD were investigated. At the current density of 52.85 A/m² and electrode gap 1 cm and pH 9.66 the chemical oxygen demand (COD) and color removal efficiencies were 75.9% COD reduction and 72% color reduction for Al-Al electrode. At the current density of 132.85 A/m² and electrode gap 1 cm and pH 11.54 the chemical oxygen demand (COD) and color removal efficiency were maximum with 63.2% COD reduction and 66% color reduction for SS-SS electrode.

Keywords- Aluminum and Stainless steel electrodes, Bio digester effluent, Chemical oxygen demand, Color reduction, Electro-chemical coagulation.

I. INTRODUCTION

India is the fourth largest producer of ethyl alcohol in the world and conjointly the second largest in Asia (V. Khandegar et al., 2014). Distillery and Sugar industries is recognized together of the foremost polluting industries and waste within the variety of “spent wash” is among the worst pollutants created by distilleries each in magnitude and strength (Krishna.B.M et al., 2009). The characteristics of distillery spent wash depend on the quality of the feed stock and the various aspects of the ethanol production process. During the wastewater is generated in various manufacturing processes fermentation, distillation column and rectification column etc. The by-product of sugar cane molasses like potable liquor and industrial alcohol are deriving fractional distillation of residual part of sugarcane juice after extraction of crystalline juice and hence it contains the major polluting parameter like Chemical oxygen demand, Biological oxygen demand, total solids, Chlorides and Sulphate (Anil.K.Saroha et al., 2012). An even small concentration of these compounds present in effluent causes toxicity and foul odors to water. If

these effluents are improperly treated, they will pose a serious threat to all aquatic species because hydrolysis of the pollutants in wastewater can produce a lot of toxic products. If disposed untreated on land, it reduces alkalinity of the soil and crops may be destroyed (Jyoti Mehta et al., 2014). The conventional wastewater treatment systems have inherent limitations as they employ chemicals, emit foul odours, require technical skills to operate and expensive involving a lot of investment in construction, maintenance and moreover they are not environmentally friendly (S. Venkata Mohan et al., 2010).

To overcome the limitation and disadvantage of the conventional treatment unit treatment can be used to achieve maximum removal efficiency. Nowadays a new sustainable technology is replacing the conventional treatment unit which is based on the electrochemistry and hence the process is known as Electrocoagulation. The major advantage of this technology is that; it generates approximately 83% less sludge volume as compared to classical chemical coagulation (Kaustubh S Sasane et al., 2015).

The aim of this study was carried out to assess the feasibility of Electrochemical coagulation (ECC) process for the treatment of distillery spent wash using Aluminum and Stainless steel electrode in a monopolar configuration. The effects of various operating parameters such as voltage and electrolysis duration for the removal COD and Color were investigated.

II. MATERIALS AND METHODS

In the present study, bio – digester effluent (BDE) collected from a distillery was characterized for various parameters and the results are shown in table 1. The effluent was characterised for various parameters namely COD, Color, total solids, total dissolved solids, nitrate, phosphate, sulphate and chloride, etc., as per the standard method of analysis. Dilution of the waste has been tested for treatment: high abatement levels could be obtained with shorter time of treatment, lower current densities and best energy efficiency. (i.e 1:10 dilute the sample by tap water).

III. EXPERIMENTAL SETUP

The schematic diagram of the experimental set up is shown in fig. 1. Electro-chemical reactor was fabricated using Perspex glass having thickness 0.8 mm. The volume of the reactor is found to be 1500 ml and effective volume is 1200 ml. The reactor is a rectangular shape having dimensions of 150 mm × 100 mm × 100 mm. Lead wires were used to supply DC current to the electrodes. The DC power supply unit had a controlled cell voltage range between 0 – 33 V and a current supply of 0 - 22 A. A digital magnetic stirrer and a magnetic bead were used in the reactor for continuous inductive mixing during the treatment process. The aluminum and stainless steel electrode materials were cut to trapezoidal shape with an effective rectangular dimension of 70 mm × 50 mm × 10 mm (length × width × thickness) were used as electrodes. The experiments were conducted using Al – Al and SS – SS electrodes. The electrodes were connected in a monopolar connection mode.

Each experimental run was performed by charging 1200 ml of the bio – digester effluent in the reactor. Continuous stirring of the solution at 300 fixed agitation speeds was carried out using the magnetic stirrer. The power supply was started at time $t = 0$ and the corresponding time taken as the starting time of the EC process. The electrode gaps were maintained at 10 mm. Cell voltage was kept constant and current across the electrodes were noted down for each batch electrolysis time. All the experiments were conducted for different voltages like 5V, 10V, 15V, 20V with stirring speeds maintained at 300 rpm. Wastewater samples were drawn at 10 min intervals and analysed for pH, color and COD following standard methods (APHA, 2005). The supernatant obtained from the final treated wastewater samples after each discrete electrolytic time interval of 10, 20, 30, 40, 50, 60, 70, 80 and 90 min were analysed for water quality parameters - TDS, TS, chloride, sulphate, nitrate and phosphate. For each experiment, after decanting supernatant, the scum along with the settled sludge were separated.



Plate 1: Experimental setup of Electro chemical coagulation treatment for distillery spent wash

IV. RESULTS AND DISCUSSION

Experiments were performed to study the Electrocoagulation process in batch mode of operation for the treatment of distillery spent wash. The effect of various parameters on the Electrocoagulation process was investigated and the results are discussed below.

Table 1 Characteristics of Distillery spent wash

Sl.No	Parameter	Units	Raw w/w	Dilution 1:10
1	pH	-	7.44	7.76
2	Color	-	Brown	Light brown
3	Conductivity	mS/cm	45.9	33.5
4	Total solids	mg/L	44640	6000
5	TDS	mg/L	22800	5000
6	TSS	mg/L	67440	11000
7	BOD @ 27 °C	mg/L	30260.5	3125
8	COD	mg/L	65553	6400
9	Nitrate	mg/L	1799.4	1519.3
10	Phosphate	mg/L	12379.5	2702.5
11	Sulphate	mg/L	7098.6	4883.8
12	Chloride	mg/L	10996.5	14495.5

4.1 Effect of pH during ECT

A key factor which governs the overall performance of the ECC process is the initial pH of the electrolyte. The variation in the pH values alters the solubility of the aluminum metal into gelatinous form of aluminum hydroxide. Figure 3 shows variation in pH during ECT at different cell voltages of 5, 10, 15 and 20V. The initial pH of the wastewater increased using aluminum electrode from 7.76 to 8.66 at 5V, 9.11 at 10V, 9.31 at 5V and 9.66 at 20V after ECT of 90 min ET. As the voltage increases, the final pH also increases, because during electrolysis process OH^- ions are released into the bulk solution (Jahed et al., 2014).

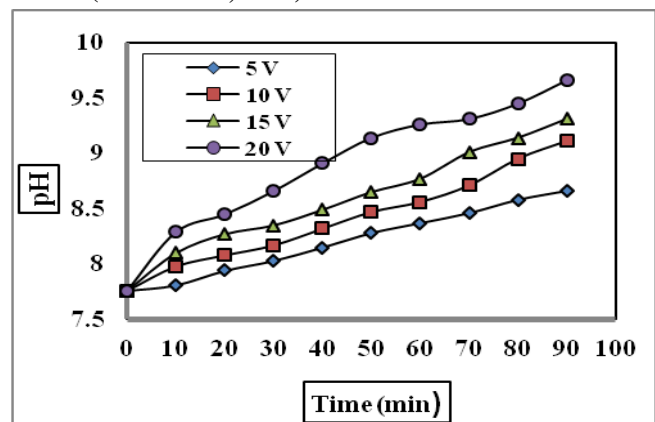


Figure 1: pH variations as a function of ET for Distillery spent wash at different applied cell voltages using Al electrode.

4.2 Effect of voltage on COD removal

As pH increases, the removal efficiency increases during ECC treatment, increase in pH decreases COD removal efficiency. The initial COD were 6400 mg/L. The COD of the wastewater decreased to 2940, 2486, 1910 and 1540 for 5V, 10V, 15V, 20V respectively after ECT. A COD removal of 54%, 61.1%, 71.7% and 75.9% was obtained at 5, 10, 15 and 20V respectively and optimum removal of COD is achieved at 20V for contact time of 90 min respectively at inter-space electrodes distance of 1 cm in monopolar configuration. The COD removal efficiency was found to increase with an increase in the current density. This is due to the fact that with an increase in the current density the anode dissolution increases due to the “Faradays law” (Anil.K.Saroha et al., 2013).

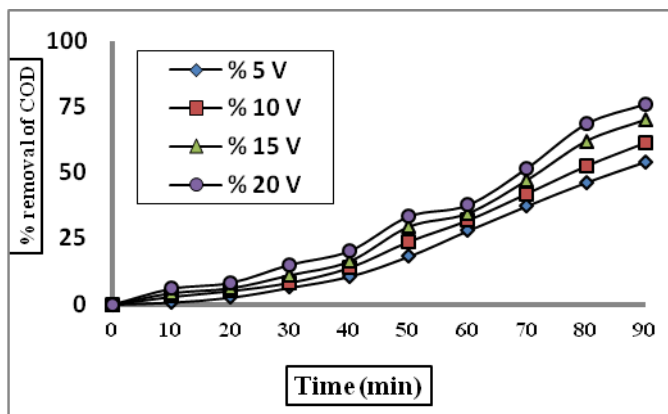


Figure 2: Percentage removal on COD for different voltages using Al electrode

4.3 Effect of voltage on removal Color

Substrate reduction and color removal were observed in dependence on the operational parameters (pH and substrate loading) of the EC because the amount of energy required depends directly on the concentration of pollutants to be removed (Theodoros.Liakos et al., 2016). The initial Color was 500 physical color unit (PCU). The Color of the wastewater decreased from 500 to 360, 280, 210 and 140 PCU for 5, 10, 15 and 20V after ECT. Figure 3 shows Color removal of 30%, 44%, 58% and 72% were obtained at 90 min ET respectively at inter-space electrodes distance of 1 cm in monopolar configuration.

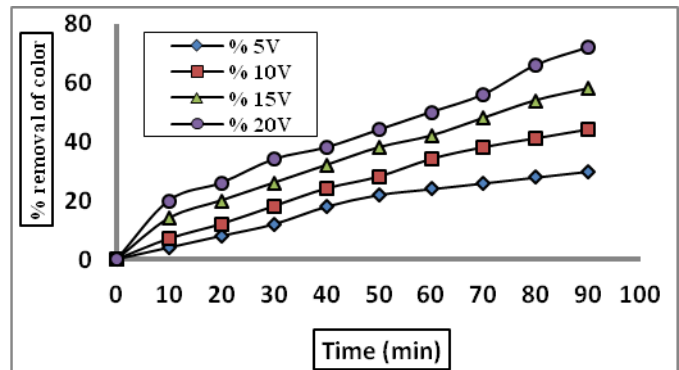


Figure 3: Percentage removal on Color for different voltages using Al electrode

4.4 Effect of Electrolysis time on removal of TDS

The hydraulic retention time (HRT) goes on increasing during Electrolysis time, the poly-nuclear hydroxyl aluminum complexes such as $Al_2(OH)_2^{4+}$, $Al_7(OH)_{17}^{4+}$, $Al_{13}(OH)_{34}^{5+}$, $Al_3(OH)_4^{5+}$, $Al(OH)_6^{3-}$, $Al(OH)_7^{4-}$ and AlO_2^{2-} take place and the phase comes when the charge density of these ions get saturated, at this stage the destabilized element which are suspended, dissolved in the effluent are lose its suspended nature, as the free electron of the aluminum collides the suspended and dissolved particulate matter which is responsible to break the stabilized stage and at same time the hydrogen bubble from cathode lift these impurities in the form of floc.

(Kaustubh S Sasane et al., 2015). The initial TDS was 5000 mg/L. The TDS of the wastewater decreased from 5000 to 3750, 2810, 2300 and 1750 PCU for 5, 10, 15 and 20V after ECT. Figure 6 shows Color removal of 25%, 43.8%, 54% and 65% were obtained at 90 min ET respectively at inter-space electrodes distance of 1 cm in monopolar configuration.

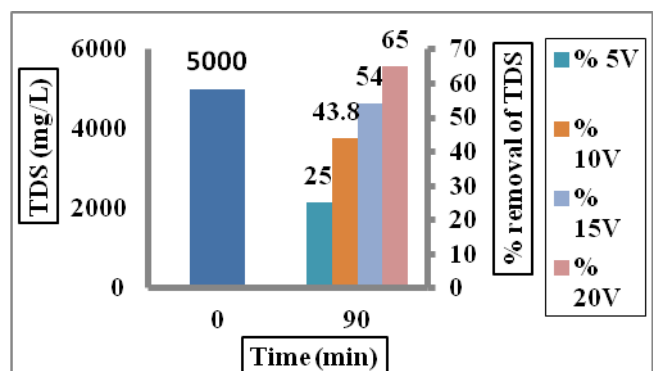


Fig 4: TDS degradation as a function of ET for Distillery spent wash at different applied cell voltages using Al electrode.

4.5 Effect of TS during ECT

During ECC treatment the generation of flocs is more due to dissolution of aluminum electrodes, so generation of solids also more. This could be because at high current densities the amount of oxidized metal increased to form greater amount of precipitate for the removal of pollutants (Kara et al., 2012). The initial TS were 6000 mg/L. The TS of the wastewater increased from 6000 to 7510, 8840, 9400 and 9725 for 5, 10, 15 and 20V after ECT of 90 min at inter-space electrodes distance of 1 cm in monopolar configuration.

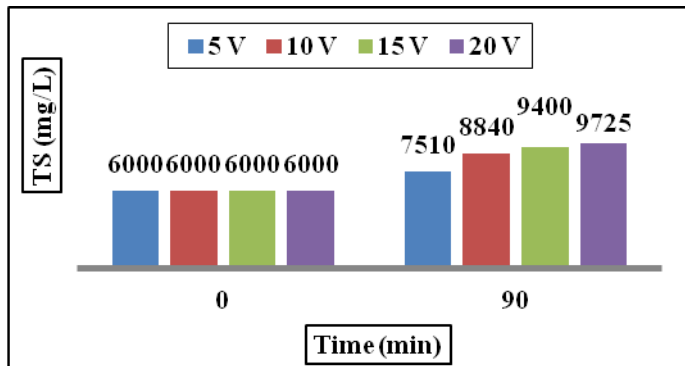


Fig 5: TS increases as a function of ET for Distillery spent wash at different applied cell voltages using Al electrode.

4.6 Effect of Voltage on removal of Nitrate

The nitrate removal efficiency increases with increase in the concentration of TDS. It's referred to this fact that with increase of the TDS (electrical conductivity), the electrical current and floc production increases and subsequent nitrate removal efficiency increases (Malakootian M et al., 2011). The initial nitrate was 1553.5 mg/L. The nitrate of the wastewater decreased from 1553.5 to 1012, 850.3, 683, and 490.5 for 5, 10, 15 and 20V after ECT. Nitrate removal of 34.8%, 45.2%, 56% and 68.4% were obtained at 90 min ET respectively at inter-space electrodes distance of 1 cm in monopolar configuration.

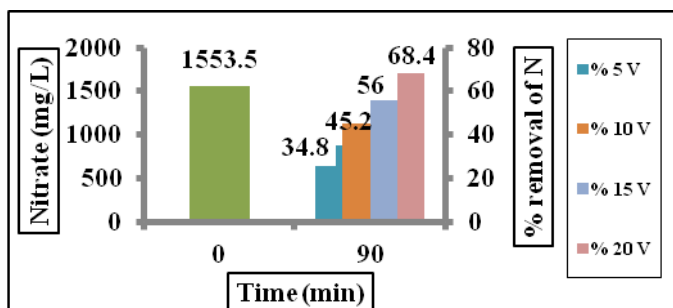


Figure 6: Nitrate degradation as a function of ET for Distillery spent wash at different applied cell voltages using Al electrode.

4.7 Effect of ET on Phosphate removal

The initial Phosphate was 2702.5 mg/L. The phosphate of the wastewater decreased from 2702.5 to 2180, 1695, 1287 and 935 for 5, 10, 15 and 20V after ECT. Phosphate removal of 34.8%, 45.2%, 56% and 68.4% were obtained at 90 min ET respectively at inter-space electrodes distance of 1 cm in monopolar configuration. The phosphate removal efficiency was increases due to the amount of anodic dissolution of Al electrode increased by high current densities resulting in a greater amount of precipitate for the removal of pollutants (Kobyia et al., 2012).

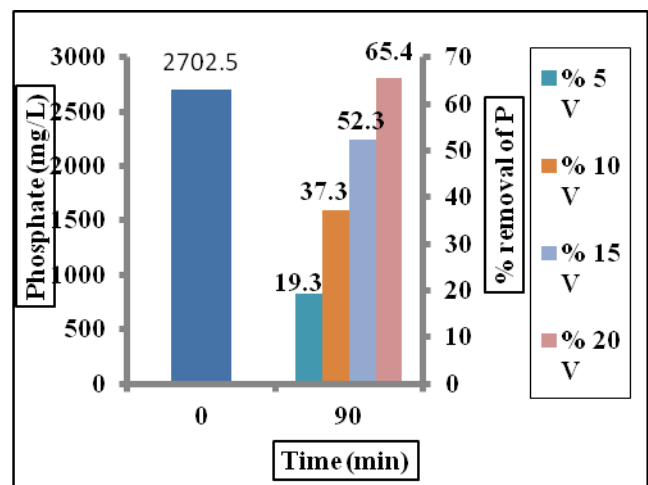


Figure 7: Phosphate degradation as a function of ET for Distillery spent wash at different applied cell voltages using Al electrode.

4.8 Effect of ET on Sulphate removal

The sulphate of the wastewater decreased from 4883.8 to 4095.3, 3010.2, 2392 and 1790 for 5, 10, 15 and 20V after ECT. Sulphate removal of 16.1%, 38.3%, 51% and 63.3% were obtained at 90 min ET respectively at inter-space electrodes distance of 1 cm in monopolar configuration. This was due to the fact that as the current increased more Al (OH)₃ was produced, which contributed to greater removal of sulphate by precipitation and flotation. Thus, the higher values of current electrolysed the higher mass of Al during EC; thereby indicating that applied current density to the EC was directly related to the Electrocoagulation (Arun kumar sharma et al., 2017).

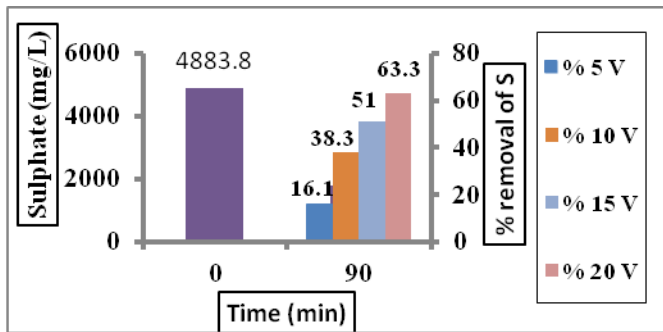


Fig 8: Sulphate degradation as a function of ET for Distillery spent wash at different applied cell voltages using Al electrode.

4.9 Effect of ET on Chloride removal

The initial chloride was 14495.5 mg/L. The chloride of the wastewater decreased from 14495.5 to 11786.2, 8610.7, 6752 and 5150 for 5, 10, 15 and 20V after ECT. The Chloride removal of 18.6%, 40.5%, 53.4% and 64.4% were obtained at 90 min ET respectively at inter-space electrodes distance of 1 cm in monopolar configuration. The increase in electrolysis time with increases chloride removal efficiency due to the oxychloride (OCl⁻) and chlorine gas production during ECC treatment (Shridhar et al., 2011).

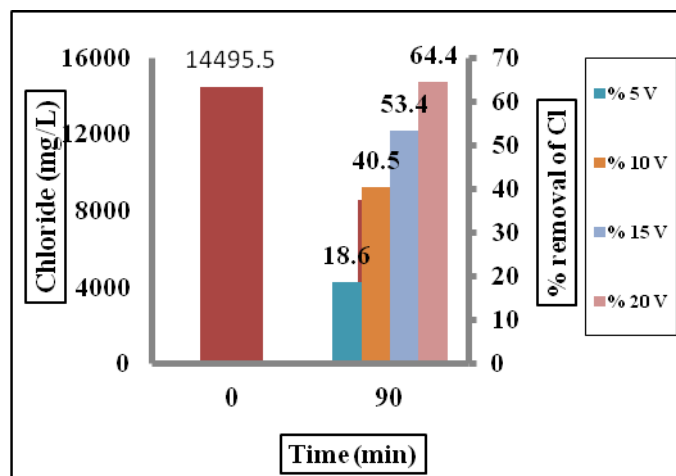


Figure 9: Chloride degradation as a function of ET for Distillery spent wash at different applied cell voltages using Al electrode.

4.10 Effect of pH during ECT

Stainless steel electrode is used in the ECC treatment. The EC process is considerably dependent on the initial pH of the solution because pH of the wastewater can affect the stability of various hydroxide species formed and a change in pH can modify the surface charge of particles and greatly

influence the removal of colloidal dispersed organics (kara et al., 2012).

Figure 10 shows variation in pH during ECT at different cell voltages of 5, 10, 15 and 20V. The initial pH of the wastewater increased using aluminum electrode from 7.76 to 8.63 at 5V, 10.2 at 10V, 11.01 at 15V and 11.54 at 20V after ECT of 90 min ET.

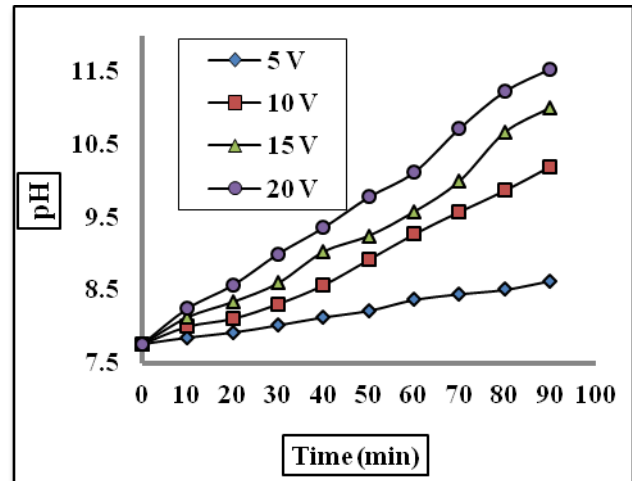


Figure 10: pH variations as a function of ET for Distillery spent wash at different applied cell voltages using SS electrode.

4.11 Effect of voltage on COD removal

Figure 11 depicts the COD removal efficiency at different voltages, time intervals. COD removal efficiency increases as the electrical potential and electrolysis time increases. The initial COD were 6400 mg/L. The COD of the wastewater decreased to 3280, 2890 and 2610 and 2350 for 5V, 10V, 15V and 20V respectively after ECT. A COD removal of 48.7%, 54.8%, 59.2% and 63.2% was obtained at 5, 10, 15 and 20V respectively and optimum removal of COD is achieved at 20V for contact time of 90 min respectively at inter-space electrodes distance of 1 cm in monopolar configuration. This was due to the release of metal ions increases with increase in electrical potential. Therefore, there was an increase in floc formation and hence an enhancement in the COD removal efficiency (Kamath et al., 2017).

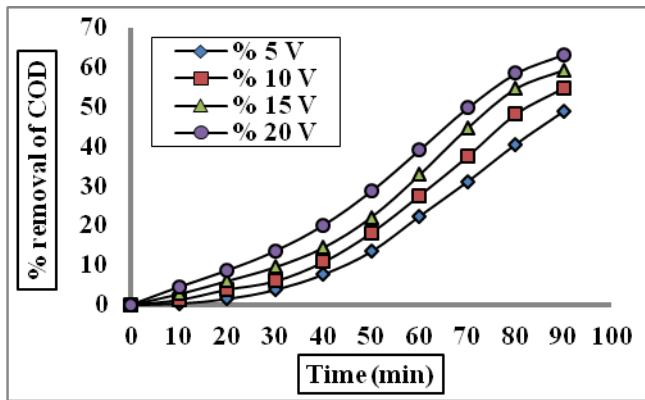


Figure 11: Percentage removal on COD for different voltages using SS electrode

4.12 Effect of voltage on removal Color

Degradation of the acid donor is only possible under the reducing environment of electro-coagulation with SS electrodes where ferric iron is reduced to ferrous iron there by oxidizing the acid ester. During electro-coagulation with SS electrodes, the reducing environment is easily brought about within the first period of electro-coagulation due to oxygen depletion during oxidation of ferrous iron to ferric iron

The initial Color was 500 physical color unit (PCU). The Color of the wastewater decreased from 500 to 410, 330, 250 and 170 PCU for 5, 10, 15 and 20V after ECT. Figure 12 shows Color removal of 18%, 34%, 50% and 66% were obtained at 90 min ET respectively at inter-space electrodes distance of 1 cm in monopolar configuration.

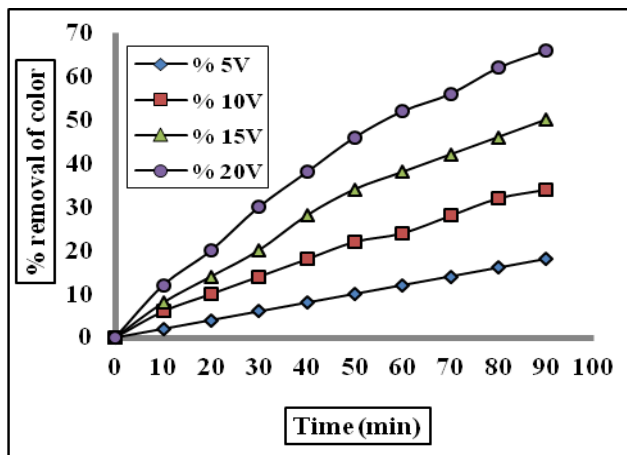


Figure 12: Percentage removal on Color for different voltages using SS electrode

4.13 Effect of Electrolysis time on removal of TDS

The hydrogen gas liberated at the cathode helps to float the contaminants this influences the removal of TDS. The TDS removal efficiency increases with increase in

electrical potential and electrolysis time (Kamath et al., 2017). The initial TDS was 5000 mg/L. The TDS of the wastewater decreased from 5000 to 4050, 3250, 2450 and 1820 PCU for 5, 10, 15 and 20V after ECT. Figure 13 shows Color removal of 19%, 35%, 51% and 63.6% were obtained at 90 min ET respectively at inter-space electrodes distance of 1 cm in monopolar configuration.

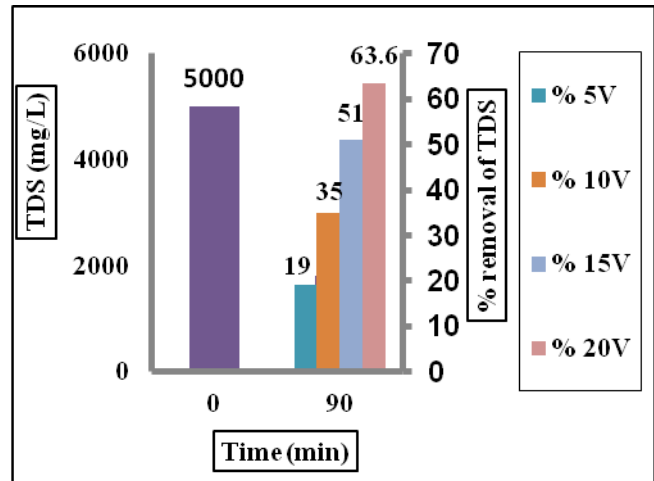


Figure 13: TDS degradation as a function of ET for Distillery spent wash at different applied cell voltages using SS electrode.

4.14 Effect of TS during ECT

The increase of TS with increase in the voltage and current time is shown in the Fig. 3. From 6000 to 7320 at 5V, 6000 to 8950 at 10V, 6000 to 9157 at 15V, 6000 to 9456 at 20V were obtained at 90 min ET respectively at inter-space electrodes distance of 1 cm in monopolar configuration. Electrical potential affected the efficiency of total solids removal significantly. This is due to the influence of the increased hydroxides with the increase in the voltage and electrolysis time (Kamath et al., 2017).

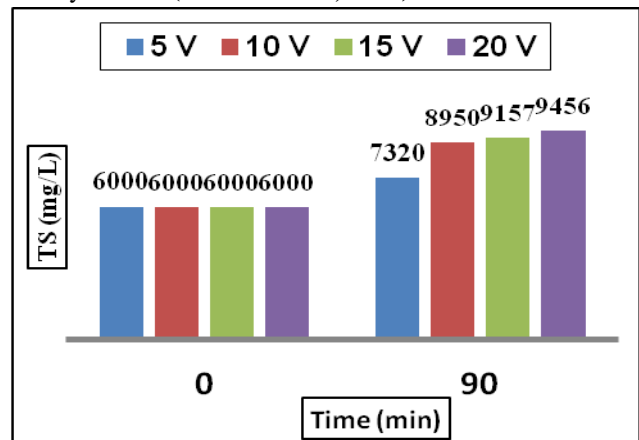


Figure 14: TS increases as a function of ET for Distillery spent wash at different applied cell voltages using SS electrode.

4.15 Effect of Voltage on removal of Nitrate

The nitrate removal efficiency increases with increase of pH. This can be attributed to the reaction between metal and hydroxides ions. As figure represents, with increase of the electrical potential difference, the nitrate removal efficiency increases. This is due to more flocs production in high voltage (Malakootian et al., 2011). The initial nitrate was 1553.5 mg/L. The nitrate of the wastewater decreased from 1553.5 to 1210, 960.3, 750, and 580.5 for 5, 10, 15 and 20V after ECT. Nitrate removal of 22.1%, 38.1%, 51.7% and 62.6% were obtained at 90 min ET respectively at inter-space electrodes distance of 1 cm in monopolar configuration.

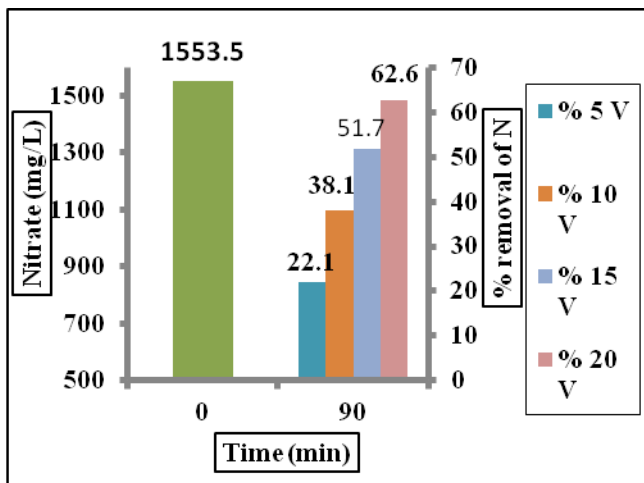


Figure 15: Nitrate degradation as a function of ET for Distillery spent wash at different applied cell voltages using SS electrode.

4.16 Effect of ET on Phosphate removal

The phosphate removal efficiency depends directly on the concentration of ions produced by the electrodes which in-turn depends upon time. When the value of time increases, an increase occurs in concentration of iron ions and their hydroxide flocs. Consequently, an increase in the time increases the phosphate removal efficiency. Figure shows phosphate removal efficiency gets enhanced at higher time value. At higher time, formation of metal hydroxides is more results in higher phosphate removal efficiency via co-precipitation and sweep coagulation (Jaymatjha 2010). The phosphate of the wastewater decreased from 2702.5 to 2310, 1992, 1385 and 1098 for 5, 10, 15 and 20V after ECT. Phosphate removal of 14.5%, 26.2%, 48.7% and 59.3% were obtained at 90 min ET respectively at inter-space electrodes distance of 1 cm in monopolar configuration.

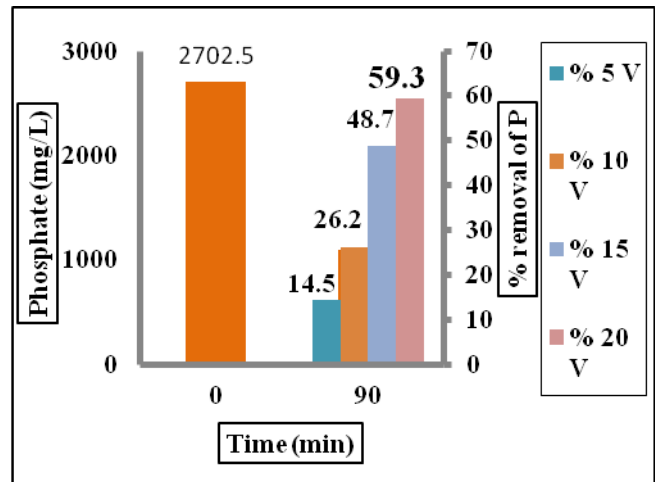


Figure 16: Phosphate degradation as a function of ET for Distillery spent wash at different applied cell voltages using SS electrode.

4.17 Effect of ET on Sulphate removal

The sulphate of the wastewater decreased from 4883.8 to 4325, 3750, 2670 and 2100 for 5, 10, 15 and 20V after ECT. Sulphate removal of 11.4%, 23.2%, 45.3% and 57% were obtained at 90 min ET respectively at inter-space electrodes distance of 1 cm in monopolar configuration. In this case, bulky iron hydroxide precipitate formation was observed clearly, and hence, the results have to be explained in terms of entrapping of the sulphate ions into the iron hydroxide growing precipitates, either by adsorption or by ion exchange (Gina Marie Densmore 2015).

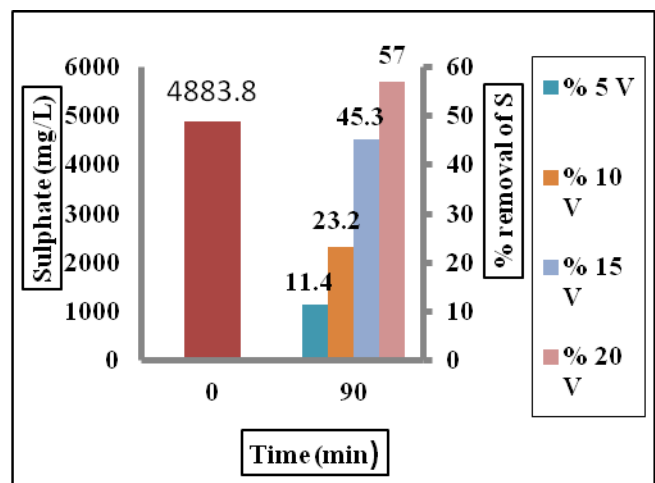


Figure 17: Sulphate degradation as a function of ET for Distillery spent wash at different applied cell voltages using SS electrode.

4.18 Effect of ET on Chloride removal

The chloride of the wastewater decreased from 14495.5 to 10756.2, 8770, 7220 and 5550 for 5, 10, 15 and 20 V after ECT. The Chloride removal of 25.7%, 39.4%, 50.1% and 61.7% were obtained at 90 min ET respectively at inter-space electrodes distance of 1 cm in monopolar configuration.

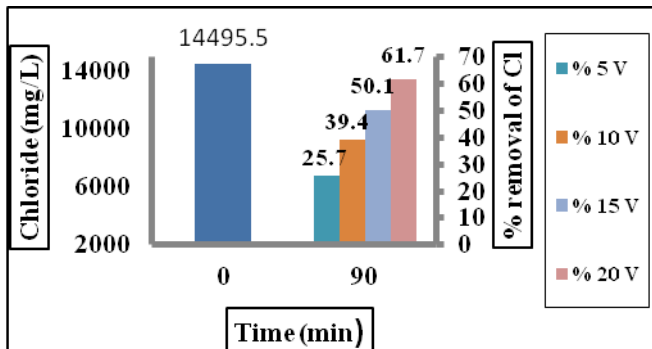


Figure 18: Chloride degradation as a function of ET for Distillery spent wash at different applied cell voltages using SS electrode.

V. KINETIC MODEL

Kinetics studies of treatment process have important role in determining the reaction time in any reactor system to achieve desired removal. So, rate constant is very significant in the design of wastewater treatment units. It is very essential to know the type of reaction rate for design a wastewater treatment unit in order to determine the pollutant removal to be modelled using the adsorption kinetics (Z.V.P. Murthy et al., 2011)

(a) Pseudo first order kinetics model

A simple kinetic model suggested for adsorption process in solid/liquid systems is Lagergren’s pseudo first order expression, which is given as 1

$$\frac{dq_t}{dt} = k_1(q_s - q_t) \tag{1}$$

Where, k1 is the pseudo–first–order rate constant (min⁻¹), and q_t are concentration of reaction (mg/L) at equilibrium and at time t (min), respectively. After integration of this kinetic expression for the initial condition of qt equal to 0, when time (t) approaches 0, its linear form are obtained:

$$\ln(q_s - q_t) = \ln q_s - k_1t \tag{2}$$

The plot of ln(q_s - q_t) vs t gives a straight line and pseudo first order rate constant k1 can be calculated from the slope of that line.

(b) Pseudo second order kinetics model

The kinetic data also can be analyzed by Ho’s (Y.S. Ho et al., 1999) pseudo second order kinetics model, which can be represented in the linear expression as 3

$$\frac{t}{q_t} = \frac{1}{k_2 q_s^2} + \frac{t}{q_s} \tag{3}$$

Where, k₂ (g/mg/min) is the rate constant of the pseudo second order.

The plots of time versus COD concentration for determining the reaction order are shown in below Figure 19 and 20. Result shows that the removal of COD exhibited pseudo first order kinetics with good correlation coefficient of (> 0.65) according to equation ln(q_e - q_t). The rate constant was found to be 0.067 and 0.069 for Aluminum and Stainless steel electrode at 20 V respectively.

Figures 19 (a) and 20 (a) shows that pseudo second order kinetic with no correlation coefficient because the correlation value less than zero.

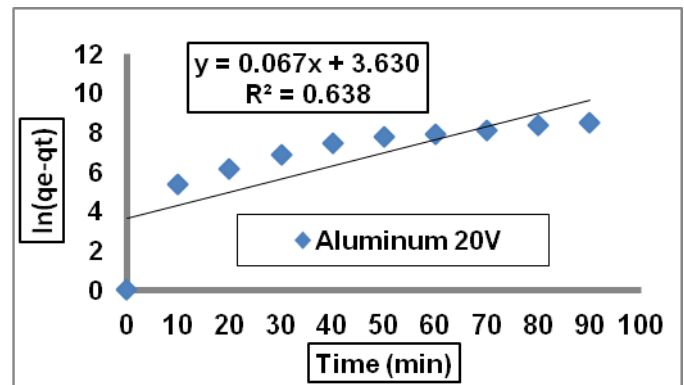


Figure 19: plot of time versus concentration – pseudo first order reaction for aluminum electrode

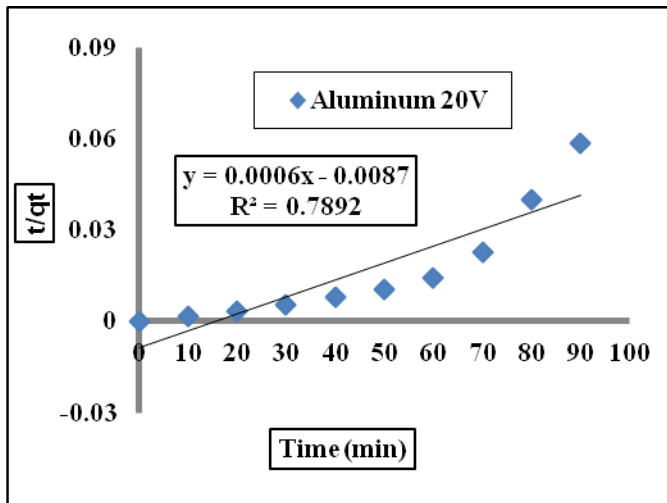


Figure 19 (a): plot of time versus concentration pseudo second order reaction for Aluminum electrode

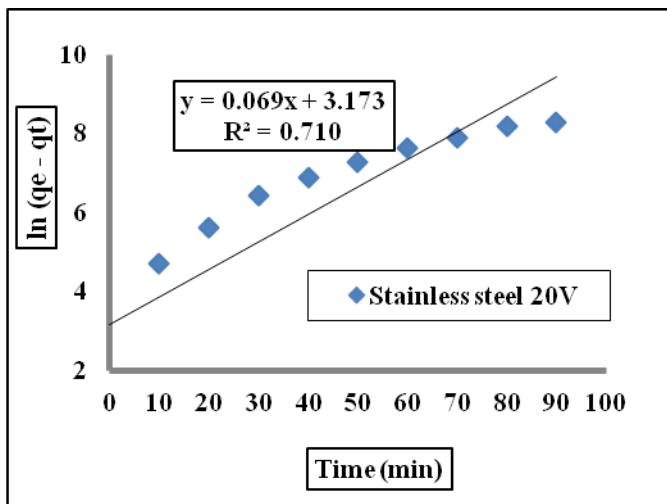


Figure 20: plot of time versus concentration – pseudo first order reaction for Stainless steel electrode

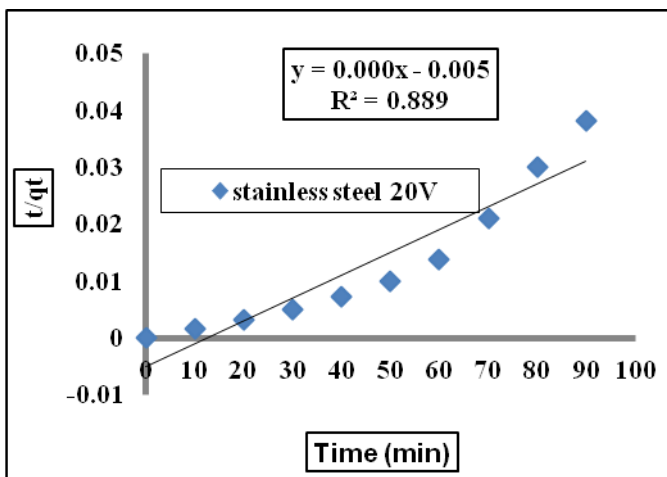


Figure 20 (a): plot of time versus concentration – pseudo second order reaction for Stainless steel electrodes

• **Current Density (CD):**

Current density was found to be one of the most important parameter of electrolytic process. It was determinate with the help of following equation.

Current density (A/m²)

$$= \frac{I}{\text{Electrode surface area} \times \text{Number of positive electrodes}}$$

Where;

I is the current in ampere (A)

CD for Aluminum at 20V = 52.85 A/m²

CD for Stainless steel at 20V = 132.85 A/m²

• **Energy Consumption:**

For the optimum design of EC treatment, energy consumption has also been evaluated. It was determinate with the help of following equation.

$$\text{Energy consumption (kwh/m}^3\text{)} = \frac{UIT}{V}$$

Where;

U is the cell voltage in volt.

I is the current in ampere (A)

t is the electrolysis time (h).

V is the volume of wastewater taken in the reactor

For Aluminum at 20V = 0.055 kwh/L

For Stainless steel at 20V = 0.1425 kwh/L

• **Operating Cost**

Operating cost can be calculated by following equation

$$\text{Operating cost} = a C_{\text{energy}} + b C_{\text{electrode}}$$

Where; a is the electrical energy price rupees/kwh, b is the electrode material price rupees/kg

$$C_{\text{energy}} (\text{kwh/m}^3) = \frac{UIT}{V}$$

Where; U is the cell voltage in volt, I is the current in ampere (A), t is the electrolysis time in seconds, V is the volume of wastewater taken in the reactor in L.

$$C_{\text{electrode}} (\text{kg of electrode/m}^3) = \frac{ITMw}{zFV}$$

Where; I is the current in ampere (A), t is the electrolysis time in seconds, M_w is the Molecular weight of electrode, z is the no of electron transferred, F is the Faraday's constant (96500 C/mol), V is the volume (m^3).

For Aluminum at 20V = 2081.2 Rs/ m^3

For Stainless steel at 20V = 5231.2 Rs/ m^3

VI. CONCLUSION

Electrochemical coagulation (ECC) is an efficient process to treat distillery spent wash characterized by presence of high COD concentration and colour content. Aluminum and stainless steel electrodes were tested for their efficiencies with regard to colour and COD reduction. This efficiency varies with electrode material. Aluminum electrode was found to be more efficient than Stainless steel electrode in colour and COD removal. On the other hand, the high efficiency of COD and color removal was found at 20V in the presence of aluminum electrode. Energy consumption was less with aluminum when compared to stainless steel electrode for the maximum COD removal. The total aluminum electrode dissolution at optimum voltage of 20V is 1.788 gram and weight of aluminum electrode consumed during ECC treatment is 1.862 gram. The total stainless steel electrode dissolution at optimum voltage of 20V is 15.367 gram and weight of stainless steel electrode consumed during ECC treatment is 14.532 gram. The results conclude that the electrode material play an important role in electrochemical coagulation method for treatment of distillery spent wash. An economic aspect has to be taken care before selection of electrode material characteristics with regard to current efficiency. It was found that the one step treatment by electrochemical process was not sufficient and further treatment by appropriate biological method is required to bring down the pollutant concentration within the statutory limits of effluent disposal.

REFERENCES

- [1] Abhinesh Kumar Prajapati., Bidyut Mazumdar, Parmesh Kumar Chaudhari. (2013) "Electrochemical treatment of rice grain based Distillery effluent using iron electrode", IJCRGG – International journal of chemtech research CODEN., (USA), Vol. 5, No.2, pp 694 – 698.
- [2] Arun Kumar Sharma, Chopra A.K (2017), "Removal of nitrate and sulphate from biologically treated municipal wastewater by Electrocoagulation", Appl Water Science, Vol.7, pp.1239 – 1246.
- [3] American Public Health Association (APHA), American water works Association (AWWA) and Water environment Federation. (2005) Standard methods for estimation of water and wastewater, 19th edition.
- [4] Asaithambi. P., Matheswaran. M. (2016) "Electrochemical treatment of simulated sugar industrial effluent: optimization and modelling using a response surface methodology", Arabian J. Chem, Vol. 9, pp 981-987.
- [5] Baxarafshan, E., Ownagh, K.A and Amir, H.M. (2012) "Application of Electrocoagulation process using iron and Aluminum electrodes for fluoride removal from aqueous environment", Journal of chemistry, Vol. 9, pp 2297 – 2308.
- [6] Bhise B R.M., Patil A.A., Raskar A.R., Patil P.J. and Deshpande D.P. (2012) "Removal of Colour of Spent Wash by Activated Charcoal Adsorption and Electrocoagulation", Research Journal of Recent Sciences, Vol. 1(6), pp 66 -69.
- [7] Benaissa, F., Hadjira, K.S and Mostefa, N.M. (2014) "optimization and kinetic modelling of Electrocoagulation treatment of dairy wastewater", International conference on water, pp 1 – 7.
- [8] Charles David, M., Arivazhagan, N., FazaludeenTuvakara. (2015) "Decolorization of distillery spent wash effluent by electrooxidation(EC and EF) and Fenton processes: A comparative study Eco toxicology and Environmental Safety.
- [9] Chandra, Kumar, R. (2006) "Decolourisation and detoxification of synthetic molasse melanoidins by individual and mixed cultures of Bacillus spp, Bioresource Technology, Vol. 7, pp 2096 – 2102.
- [10] Chaudhari P.K., Mishra, I.M., Chand, S. (2007), "Decolorization and removal of chemical oxygen demand (COD) with energy recovery: Treatment of biodigester effluent of a molasses - based alcohol distillery using inorganic coagulants", Colloids Surf. A: Physicochem. Eng.Aspects Vol. 6, pp 238–247.
- [11] Chaudhari, P.K., Singh, R., Mishra, I.M. Chand. (2010) "Kinetics of catalytic treatment (Catalytic Thermolysis) of distillery wastewater and Biodigester effluent of alcohol production plant at atmospheric pressure", Int. J. Chem. Reactor Eng., Vol. 8, pp 1 – 22.
- [12] Chaudhari, P.K, Chand, S, Mishra, I.M. (2012), "Kinetics of catalytic thermal treatment (catalytic thermolysis) of bio-digester effluent of an alcohol distillery plant", Chem. Engg. Commn. Vol. 199, pp 1–15.
- [13] Chen, X. (2000) "Separation of pollutants from restaurant wastewater by electrocoagulation", Sep. Purf. Technol. Vol. 19, pp 65–76.
- [14] Chompey Den, Lawrence P., Belo, Elaine G., Mission, Hirofu,i Hinode, Leonila C. Abella and Pagasa D. Gaspillo. (2016) "Experimental investigations of the effects of current density during the Electrocoagulation of

- Bio treated Distillery wastewater using Aluminum – Aluminum Electrode pair”, DLSU - De La Salle University Vol. 4, pp 2449 – 3309.
- [15] Gina Marie Donsmore (2015) “Electrocoagulation for sulphate removal”, Chemical Engineering.
- [16] Jaymantjha (2010), “Phosphate removal by Electrocoagulation”, Chemical Engineering.
- [17] Kamath G. M, Dr. Narayana G, Dr. Ramalinga Reddy Y (2017), “Treatment of Dairy Wastewater Using Electrocoagulation Technique”, International Journal of Recent Engineering Research and Development (IJRERD) Vol. 2, pp 93 - 99.
- [18] Khandegar and Anil, K.S. (2012) “Electrochemical Treatment of Distillery Spent Wash using Aluminum and Iron Electrodes”, Chinese Journal of Chemical Engineering Vol. 20, No. 3 pp 439 - 443
- [19] Khandegar and Anil, K.S. (2014) “Treatment of Distillery Spent Wash by Electro Coagulation”, Journal of Clean Energy Technologies Vol. 2, No. 3 pp 244 - 246.
- [20] Khandegar and Anil, K.S. (2013) “Electrocoagulation of Distillery Spentwash for Complete Organic Reduction”, International Journal of Chem Tech Research, Vol. 5, No. 2, pp 712 - 718.
- [21] Kobya, M and Gengec, E. (2012) “Decolourization of melanoidins by a Electrocoagulation process using aluminium electrodes”, Environmental Technology,
- [22] Krishna, B.M, Murthy, UN, Manoj Kumar, B, Lokesh, K.S. (2010) “Electrochemical pre-treatment of distillery wastewater using aluminum electrode”, J. Appl. Electrochem., 40, pp 663 - 667.
- [23] Kumar, M. Infant, F. Ponselvan, A. Malviya, J.R. Srivastava, V.C. Mall, I.D. (2009) “Treatment of bio-digester effluent by electrocoagulation using iron electrodes”, J. Hazard. Mater, Vol. 165, pp 345 – 352.
- [24] Liang, Z, Wang, Y, Zhou, Y, Liu, H and Wu, Z., (2009) “Variables affecting melanoidins removal from molasses wastewater by coagulation/flocculation”, Sep. Purif. Technol, Vol. 68 , pp 382 – 389.
- [25] Manoj, P.W and Nemade, P.D. (2015) “Treatment process and Technology for Decolourisation and COD Removal of Distillery Spent Wash”, International Journal of Innovative Research in Advanced Engineering, Vol. 2, pp 2349 -2163.
- [26] Mehmet Kobya, Orhan Taaner Can, Mahmut Bayramoglu. (2003) “Treatment of Textile wastewaters by electrocoagulation using iron and aluminum electrodes”, Journal of hazardous Materials, Vol. 100, pp163 - 178.
- [27] Malakootian, M and Yousefi, N. (2009) “The efficiency of Electrocoagulation process using aluminum electrodes in removal of hardness from water”, Iran J. Of Environ. Health. Sci. Engg., Vol. 6, pp 131 – 136.
- [28] Monireh Majlesi, Amir Sheikhmohammadi (2016) “improvement of aqueous nitrate removal by using continuous Electrocoagulation/electroflotation unit with vertical monopolar electrodes”, Sustainable Environment Research, Vol. 26, pp. 287 – 290.
- [29] Nandy, T.S, Shastry, S.N. Kaul. (2002) “Wastewater management in a cane molasses distillery involving bio resource recovery, J. Environ. Manage, Vol. 65, pp 25 - 38.
- [30] Nataraj, S.K., Hosamani, K.M., Aminabhavi, T.M. 2006 “Distillery wastewater treatment by the membrane-based nanofiltration and reverse osmosis processes”, Water Res. Vol. 40, pp 2349 - 2356.
- [31] Paramesh Kumar Chaudhari, Indra Mani Mishra, ShriChand. (2010) “Decolourization and removal of chemical oxygen demand (COD) with energy recovery treatment of bio digester effluent of a molasses – based alcohol distillery using inorganic coagulants. Vol. 5, pp 102 – 110.
- [32] Pooja, Shanmuka, N.T, Chandrappa, K.G, Lokeshappa, B. (2016) “Degradation of colour and COD from distillery spent wash by aluminium and zinc-titania composite electrodes”, IRJET – International research Journal of Engineering and Technology Vol. 3, pp 307-313
- [33] Roopa Farshi, Priya, S, Saidutta, M.B. (2013) “Reduction of Color and COD of Anaerobically Treated Distillery Wastewater by Electrochemical Method”, ISSN – International Journal of Current Engineering and Technology, pp 168 – 171.
- [34] Santosh, H.G, Shanmukha, N.T, Dr.Lokeshappa. (2017) “Comparative assessment of iron and aluminium electrode for treatment of distillery spent wash by electro coagulation method”, International Conference on Emerging Trends in Engineering, Technology, Science and Management, pp 317 – 322.
- [35] Seth Apollo Maurice, S. Onyango Aoyi Ochieng. (2005) “An integrated anaerobic digestion and UV photocatalytic treatment of distillery wastewater” Journal of Hazardous Materials, Vol – 3, pp 1 – 36.
- [36] Shi, Y, Liu, H, Zhou, H, Xie, A and Hu, C.Y. (2009) ”Mechanism on impact of internal electrolysis pretreatment on biodegradability of yeast wastewater”, Chinese Sci. Bull. Vol - 54, pp 2124–2130.
- [37] Shruthi, M, Lokesh, K.S, Krishna, B.M and Usha N Murthy. (2013) “Color Removal from Bio-Digester Effluent (BDE) by Electrochemical Treatment with and Without Fenton Reagent”, International Journal of Current Engineering and Technology, pp 2277 - 4106
- [38] Sohail Ayub, Shoebuddin Usmani. (2014) “Treatment of Distilleries and Breweries spent wash wastewater”, IJRET – International Journal of Research in Engineering and Technology, Vol. 3, pp 204 – 214.

- [39] Sridhar, R., Sivakumar, V., Immanuel, V.P., Maran, J.P. (2011) “Treatment of pulp and paper industry bleaching effluent by electrocoagulant process”, *J. Hazard. Mater.* Vol. 186, pp 1495 – 1502.
- [40] Theodoros I. Liakos, Sotiris Sotiropoulos, Nikolaos K. Lazaridis. (2016) “Electrochemical and bio-electrochemical treatment of baker’s yeast effluents”.
- [41] Venkata Mohan S, Mohanakrishna G, Chiranjeevi P, Dinakar Peri, Sarma P.N. (2010) “Ecologically engineered system (EES) designed to integrate floating, emergent and submerged macrophytes for the treatment of domestic sewage and acid rich fermented-distillery wastewater: Evaluation of long term performance”, *Bioresource Technology.* Vol.101, pp.3363 – 3370