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Effect of Electrocoagulation on Physico-Chemical Characteristics of UASB Reactor Treated Urban Wastewater: A Batch Study

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Abstract: ***Applicability of electrocoagulation (EC) process for post-treatment of UASB reactor-treated municipal wastewater was investigated. Tests were conducted with batch reactor. Effect of current density and electrolysis time on the physico-chemical quality of UASB effluent has been studied. Variation in effluent COD, turbidity, TSS, TKN, NH_3-N, nitrate, phosphate and final pH were studied at varying current and time. Overall observation revealed positive effect of time and applied voltage on the EC process. Faster removal observed at either higher current or for more treatment time. Reduction in electrical conductivity shows removal on dissolved ions from the effluent. Final pH variation was on 0.15 unit for studied range of time and current.***

Keywords: UASB, electrocoagulation, urban wastewater

1. Introduction

High-rate anaerobic processes such as upflow anaerobic sludge blanket (UASB) reactors, anaerobic filters and fluidized bed reactors which attain high organic loading rates with shorter hydraulic detention times have been used for treatment of a variety of wastewaters. In tropical countries like India, UASB process has found widespread application for the treatment of municipal wastewater [1]. Effluents from UASB reactors, however, generally do not meet the disposal standards/guidelines of different countries with respect to organic matter, suspended solids, nutrients and pathogens [1-3]. This necessitates the post-treatment of UASB reactor effluent before it is discharged into water bodies or for its reuse as irrigation water.

Electrocoagulation (EC) process, on the other hand, has attracted great attention as an eco-friendly and cost-effective process [4]. The advantages of EC process include requirement of simple equipment and shorter detention times [5]. EC involves in-situ generation of coagulants by electrolytic oxidation of an appropriate sacrificial anode (generally iron or aluminium) upon application of a direct current [6]. The metal ions (Al^{3+}/Fe^{3+}) flocculate and destabilize the pollutants. Hydrogen bubbles produced at the cathode bring the hydrophobic materials such as fats and oils to the surface of the reactor where they can be removed [4,7]. EC process removes pollutants principally by coagulation, adsorption, precipitation and flotation [4].

Thus the objective of this work was to assess the suitability of electrocoagulation as a post-treatment technique for anaerobically treated urban wastewater.

2. Materials and Method

2.1 UASB reactor effluent

All the tests were performed using real UASB reactor effluent. The effluent was collected from the full scale municipal sewage treatment plant located at Bamroli, Surat, India. The characteristics of the UASB reactor effluent are presented in Table 1.

Table 1: Physico-chemical characteristics of the UASB reactor effluent

Parameters	Values (Mean±SD)*
pH	7.4±0.3
Suspended solids, (mg/L)	175±25
Turbidity (NTU)	225±21
COD (mg/L)	290±65
BOD (mg/L)	120±21
Phosphorus (mg/L) as PO_4^{3-}	3.8±0.4
Total Kjeldahl Nitrogen (TKN) (mg/L)	23.45±2.22
Nitrate (mg/L)	1.315±0.43
Ammonia Nitrogen (NH_3-N) (mg/L)	10.9± 1.48
Electrical conductivity (mS/cm)	3.3±0.2

2.2 Electrocoagulation cell

Batch electrocoagulation was carried out in an electrocoagulator made of Plexiglas with dimensions of 85 mm (width) x 85 mm (length) x 200 mm (height). The unit comprised of one aluminium anode and one aluminium cathode placed in parallel. Each electrode of dimensions 185 mm (height) x 75 mm (width) x 5 mm (thickness) had an effective electric field area of 5100 mm^2. The interelectrode distance was kept at 15 mm (in all other batch mode studies) in the cell. The electrodes were vertically dipped in the cell. A Teflon-coated magnetic stirring bar at the bottom of the cell was used for mixing the contents of the cell. The electrical input to the unit was provided through a digitally regulated DC power supply (TESTRONIX 92C, 0-30 V, 0-5 A).

3. Results and Discussion

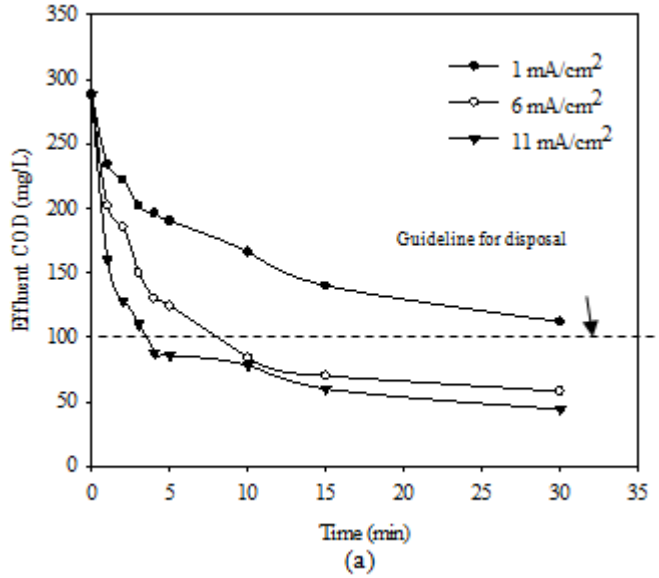
3.1 Effect of current density and electrolysis time

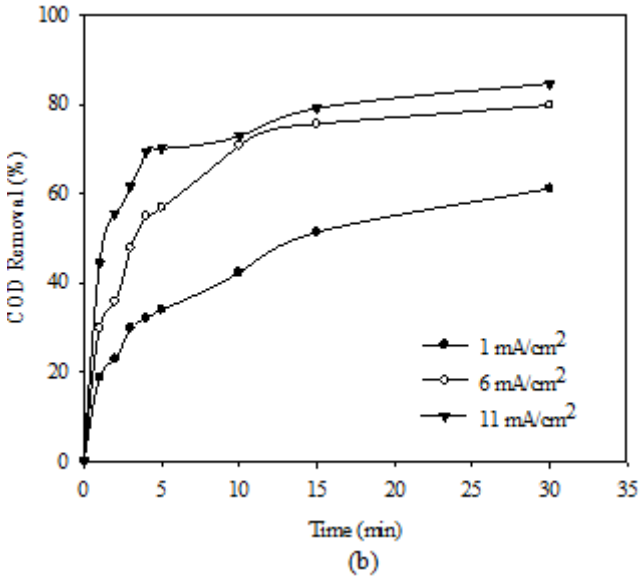
Current density and treatment time have crucial effects on the EC process, because dosing of the coagulant metal into the waste-water is directly dependent on these parameters. [4,8,9]. It is well known that the current density determines the production rate of coagulant (amount of Al^{3+} or Fe^{2+} ions released by the anode), adjusts also bubble production, its size and distribution, and hence affects the growth of flocs [9,21]. The effects of these two parameters were studied on COD, TSS, nutrients, electrical conductivity and pH.

3.2 COD, TSS and turbidity removals

Influence of current density and electrolysis time were evaluated at three current density values of 1, 6 and 11 mA/cm^2 using an electrolysis time up to 30 min. These tests were conducted at the original wastewater pH of 7.51 and interelectrode distance of 15 mm. Fig.1 (a) and (b) present the influence of these two variables on effluent COD and COD removal efficiency. It is seen that for a given current density, COD removal increased with increase in electrolysis time. However, beyond 15 min of electrolysis time, there was little increase in the COD removal at the different current densities tested. At 30 min of electrolysis time, COD removals were 58, 78 and 83% for current densities of 1, 6 and 11 mA/cm^2, respectively. It may be noted that in order to achieve the local COD disposal standard of 100 mg/L, based on the initial COD of the wastewater, removal in excess of 65% was required. This could not be achieved with current density of 1 mA/cm^2 even at 30 min of electrolysis time. Similar removal trends were observed in TSS (Fig. 2) and turbidity (Fig. 3.) also. To achieve 100 mg/L of disposal limit for TSS, 15, 10 and 5 min treatment times were required for 1, 6 and 11 mA/cm^2 respectively.

Treated turbidity of ~10 NTU could be achieved at higher current densities and longer treatment time (Fig. 3). These trends can be explained by increased Al dissolution rate at higher current density. Increase in Al dissolution rate fastens $Al(OH)_3$ formation and H_2 gas release and thus reduces H_2 bubble diameter. Smaller H_2 bubbles are known to fasten electroflotation rate [10]. Increased electroflotation separates pollutants from the medium, thus increases the pollutant removal. Electrolysis time also influences the efficiency of EC. Longer electrolysis time produces higher removal. The electrocoagulation process involves successive





stages of coagulant formation by electrolytic oxidation of electrode, destabilization of the particulate pollutants, followed aggregation of the destabilized particles to form flocs [11]. Both insufficient and excess reaction times are undesirable as the former would result in reduced efficiency while the latter might increase the treatment costs associated with excess electrode dissolution, energy and sludge disposal [5].

3.3 Removal of Nutrients

Nearly 82.0, 92.0 and 94.0% phosphorus reduction were achieved after 30 min at 1, 6 and 11 mA/cm^2 respectively (Fig.4.). Mores et al. (2016) studied total phosphorus removal from swine wastewater using aluminium electrode with initial concentration of 73.41 ± 3.30 mg/L and observed 74–94% removal at applied current densities from 27.78 to 38.89 mA/cm^2. Kuokkanen et al. (2015a) employed EC in the removal of phosphorus from synthetic wastewater (SWW) at varying current density from 25–150 A/m^2 and observed satisfactory removal at 30 min time at all current densities except for 25 A/m^2. Current density of 100 A/m^2 and treatment time of 15 min was observed to be optimal with a phosphorus removal of 94% [9].

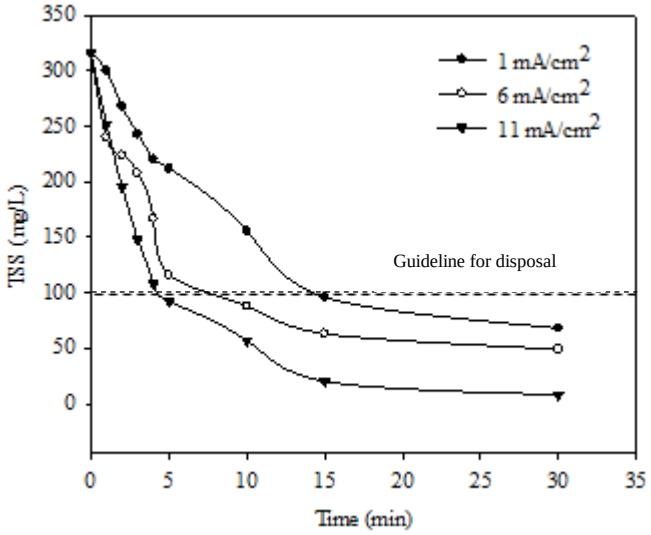


Figure 2: Effect of current density and electrolysis time on TSS removal (pH = 7.51, interelectrode distance = 1.5 cm)

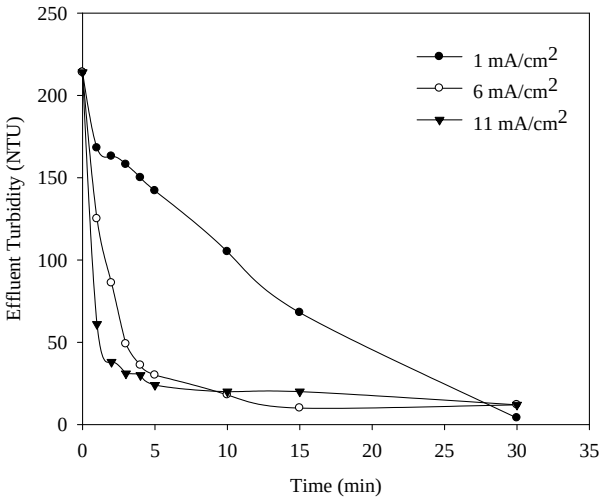


Figure 3: Effect of current density and electrolysis time on turbidity removal (pH = 7.51, interelectrode distance = 1.5 cm)

Nearly 12.0, 22.0 and 52.0 % reduction of total Kjeldahl nitrogen (TKN) (Fig. 5.) and 52.0, 84.0 and 95.0 % reduction of nitrate-N (Fig. 6) were achieved after 30 min treatment time at 1, 6 and 11 mA/cm^2 respectively. Nearly 32.0, 43.0 and 57.0 % reduction of NH_3-N were achieved after 15 min treatment time at 1, 6 and 11 mA/cm^2 respectively (Fig. 7). [13] studied denitrification of simulated nitrogenous wastewater suing Al with current from 1.5 to 4.5A upto 120 min with initial nitrogen concentration of 55 mg/L and reported that an increase of current results in an acceleration of nitrate removal. This is also consistent with the studies reported by [12] who showed that the removal of nitrate anions depended only on the amount of aluminium released from the anode. Local disposal standards for TKN (as NH_3-N), ammonical nitrogen (as NH_3-N), nitrate nitrogen (as NO_3^--N) and phosphorus (as PO_4^{-3}) are 100.0, 50.0, 10.0 and 5.0 mg/L respectively. Though the UASBR effluent used in the present study meets all these nutrient disposal limits, analysis of nitrate, NH_3-N and TKN variation during EC treatment is necessary since presence of nitrogen species reduce current efficiency of the EC process due to wastage of oxidizing agent in oxidation of nitrogen. It is reported that N-species reduces the efficiency of cathode since a part of the current is consumed in the nitrate reduction [16]. Further, presence of nitrate reduces oxidation reduction potential (ORP), hence provides favorable atmosphere for microbes [16]. Also, little or no nutrient removal may be expected in an anaerobic systems treating domestic wastewater, as reported by several authors [14,15]. The concentration of ammonia nitrogen and phosphorous in anaerobically treated municipal wastewater have been reported to range from 30-50 and 10-17 mg/L respectively [15]. UASB reactor have reported to have less nutrient removal efficiency [2,14,15,17]. Hence post-treatment is recommended to further treat UASB effluent in order to meet the nutrient discharge standards.

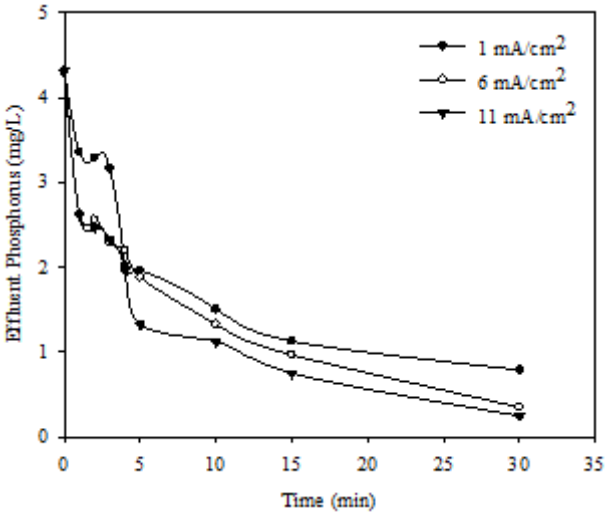


Figure 4: Effect of current density and electrolysis time on phosphorus removal (pH = 7.51, interelectrode distance = 1.5 cm)

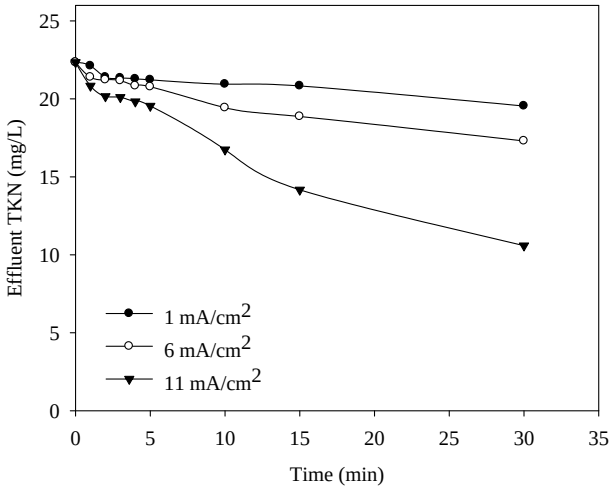


Figure 5: Effect of current density and electrolysis time on Total Kjeldahl Nitrogen removal (pH = 7.51, interelectrode distance = 1.5 cm)

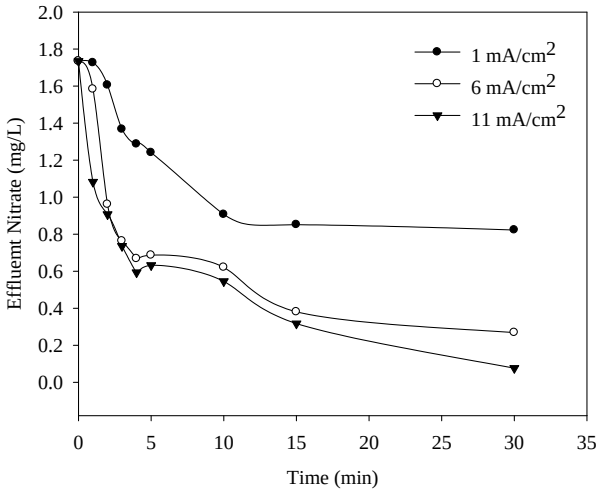


Figure 6: Effect of current density and electrolysis time on Nitrate removal (pH = 7.51, interelectrode distance = 1.5 cm)

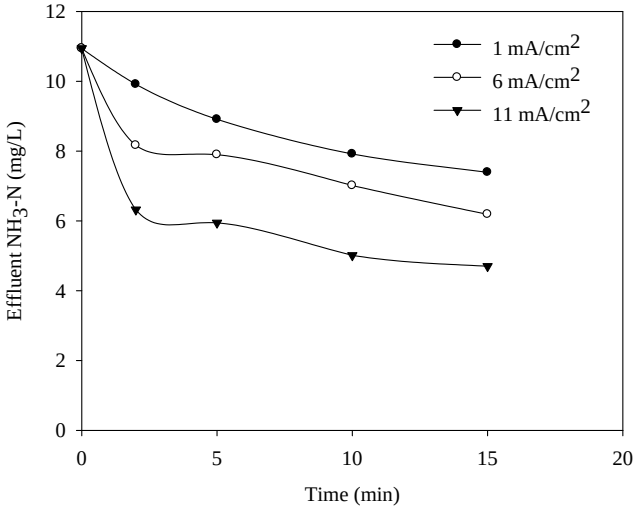


Figure 7: Effect of current density and electrolysis time on NH_3- Nitrogen removal (pH = 7.51, interelectrode distance = 1.5 cm)

3.4 Electrical conductivity

Fig.8. presents the effect of current density and electrolysis time on electrical conductivity of treated wastewater. It can be seen that there is a gradual reduction in electrical conductivity with increase in electrolysis time. Conductivity is directly proportional to the temperature and solids ions present in the solution. In the present study tests were carried at room temperature (25-27°C). This shows that some dissolved ions are also removed during electrocoagulation [18] studied arsenic removal from groundwater using Al electrode and reported decrease in conductivity with time. This slight decrease of conductivity was attributed to the slight increase of groundwater pH during the experimental run due to aluminium hydroxide floc formation [18]. It is known that increasing electrical conductivity cause an increase in the current density at constant cell voltage, or a decrease in the cell voltage at constant current density, thus operating cost decreases with increasing conductivity [19].

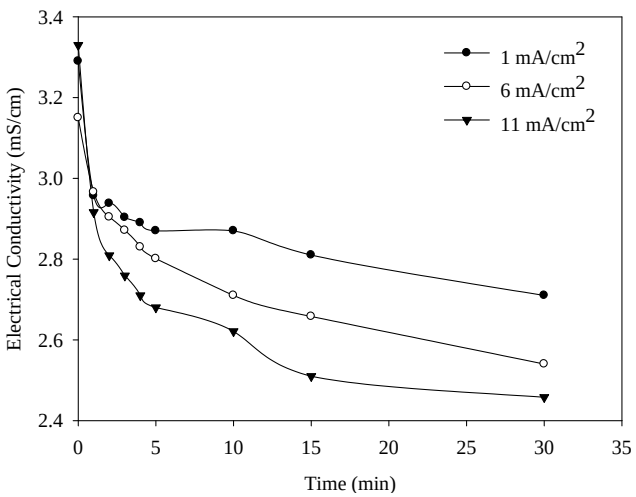
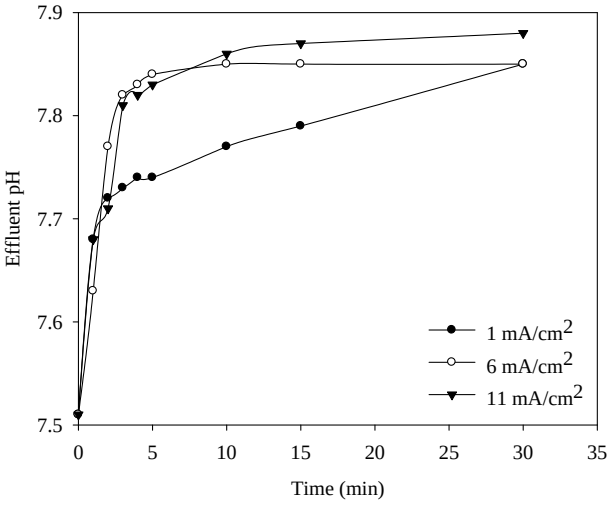


Figure 8: Effect of current density and electrolysis time on electrical conductivity variation (pH = 7.51, interelectrode distance = 1.5 cm)

3.5 Variation in treated wastewater pH

Fig. 9. presents the variation of pH in the electrocoagulator at different current densities and electrolysis time. It is seen that electrocoagulation resulted in an increase in pH. However, the increase was within 0.15 pH units for different current densities tested at 30 min electrolysis time. The effluent pH after electrocoagulation treatment would increase for acidic influent but decrease for alkaline influent. This is one of the advantages of this process. The increase of pH at acidic condition was attributed to hydrogen evolution at cathodes [10]. In fact, besides hydrogen evolution, the formation of $Al(OH)_3$ near the anode would release H^+ leading to decrease of pH [10]. In addition, there is also oxygen evolution reaction leading to pH decrease. Hence, the increase of pH due to hydrogen evolution is more or less compensated by the H^+ release [10].



Figuree 9: Effect of current density and electrolysis time on effluent pH variation (pH = 7.51, interelectrode distance = 1.5 cm)

Further it is evident from the literature that nearly at neutral pH an electrostatic interaction is possible between negatively charged microbe cells and the positively charged alumina nanoparticles formed during EC leading to bacterial adhesion

onto nanoparticles surfaces. This fact is supported by [20] that toxicity of alumina nanoparticles was not only from the dissolved metal ions, but also from their greater tendency to attach to the cell walls than to aggregate together.

4. Conclusion

At 30 min of electrolysis time, COD removals were 58, 78 and 83% for current densities of 1, 6 and 11 mA/cm^2, respectively. It may be noted that in order to chieve the local COD disposal standard of 100 mg/L, based on the initial COD of the wastewater, removal in excess of 65% was required. To achieve 100 mg/L of disposal limit for TSS, 15, 10 and 5 min treatment times were required for 1, 6 and 11 mA/cm^2 respectively. Nearly 82.0, 92.0 and 94.0% phosphorus reduction were achieved after 30 min at 1, 6 and 11 mA/cm^2 respectively. Nearly 12.0, 22.0 and 52.0 % reduction of total Kjeldahl nitrogen (TKN) and 52.0, 84.0 and 95.0 % reduction of nitrate-N were achieved after 30 min treatment time at 1, 6 and 11 mA/cm^2 respectively. Nearly 32.0, 43.0 and 57.0 % reduction of NH_3-N were achieved after 15 min treatment time at 1, 6 and 11 mA/cm^2 respectively. Study showed reduction electrical conductivity that means some dissolved ions are also removed during electrocoagulation. It is seen that electrocoagulation resulted in an increase in pH. However, the increase was within 0.15 pH units for different current densities tested at 30 min electrolysis time.

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