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Effect of Electrode Connections on Cost Governing Parameters of Electrocoagulation Process Treating Leachate

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Abstract: ***This study reports effect of electrode connections on cost governing parameters of electrocoagulation process treating leachate in a batch mode. Real leachate samples were collected from Nandesari Environment Control Ltd., GIDC Nandesari, Vadodara, Gujarat. Batch electrocoagulation was performed using aluminium and stainless steel as electrode material to understand effect of current density (10 and 30 mA/cm^2), electrolysis time (o-120 min) using different connection modes like monopolar parallel, monopolar series, and bipolar series. Leachate contained 91-95% of soluble COD. It is reported that either increase in current density or electrolysis time resulted increase in COD removal. At both the CD of 10 and 30 mA/cm^2, minimum electrode was sacrificed by MPS mode using Al electrodes, while for SS electrode MPS was found better at lower CD of 10 mA/cm^2, and at higher CD of 30 mA/cm^2, MPP sacrified lesser electrode. At 10 mA/cm^2, Al-MPS showed lowest energy consumption while at 30 mA/cm^2 Al-MPP performed better. While SS-MPS consumed lowest energy at both the studied current densities. It is noted that to achieve optimized removal, EC alone cannot work due to soluble COD and hence aided treatment should be given to leachate along with EC.***

Keywords: Leachate, electrocoagulation, connection modes

1. Introduction

Basic problem with leachate is its complex structure with high pollution which makes it difficult waste with respect to sustainable disposal. Wide variety of content generated in landfill site which is origin of leachate, which makes leachate more complex than wastewater. Conventional biological treatment, membrane process, coagulation flocculation process lagoon or advanced oxidation process are proven treatments [1], but faster urbanization changes types of solid waste generated hence, suggested treatment may fail.

Looking to this scenario, trial for new treatment is better. Electrochemical treatment technique can produce similar ions and effect by means of electrocoagulation method. [2-6]. EC uses current to dissolve Fe, steel or Al sacrificial electrode submerged in polluted water. Current gives rise to different metal ion species (Fe^{+2}, Fe^{+3} or Al^{+3}) along with the release of hydroxide ion (OH^-) [5,7]. These species are coagulants or destabilizing agents that bring about charge neutralization for pollutant separation from the wastewater. The coagulated particles can also be separated by electroflotation when they are attached to the bubbles of H_2 gas evolved at the cathode and transported to the top of the solution where they can be separated [4,5].

Literature reports process variables such as current density, operating time, initial pH, influent concentration as commonly explored variables at laboratory scale study based on various pollutant removal efficiencies. Electrode connection mode though being an important design variable not yet fully investigated, which actually needs to be judged based on complete techno-economical evaluation before actual process design[8]. Hence the objective of this study was to evaluate EC process cost effective parameter like electrode consumption and energy consumption using Al and SS electrode with respect to different connection modes.

2. Materials and Method

2.1 Electrocoagulation Cell

The experimental setup is shown in Fig. 01. The reactor is made of acrylic with the dimensions of 115mm×100mm×100 mm. There are four electrodes used in each configuration. Both aluminium or stainless steel cathodes and anodes were made from plates with dimensions of 100mm×50mm×5 mm. The spacing between electrodes was 10 mm. The electrodes were connected to a digital DC power supply operated at galvanostatic mode. The following electrode connection modes have been considered. Table 01 shows characteristics of leachate used in the study, with 91-95 % soluble COD. All three connection modes were analysed at 10 and 30 mA/cm^2 current density for 120 min electrolysis time considering energy and electrode consumption as their evaluation parameters.

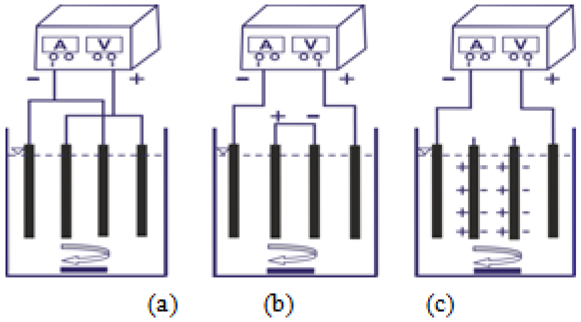


Figure 1: Different connection modes used (a) Monopolar parallel (MPP) mode (b) Monopolar series (MPS) mode (c) Bipolar series (BPS) mode (Adopted from Kobya et al., 2007)

Table 1: Characteristics of leachate

Parameters	Average Value
pH	8.2-8.4
COD (mg/L)	1500-12000
sCOD (mg/L)	1365-11400
Turbidity (NTU)	150-410
Chloride (mg/L)	13000-13200
Alkalinity (mg $CaCO_3$/L)	730-750

3. Results and Discussion

3.1 Al electrode

Fig. 02 shows effect of connection modes on energy and electrode consumption at 10 and 30 mA/cm^2 current densities. Fig. 02 (a) and (b) shows graph only with total COD because during initial stage of study inefficient COD removal was not predicted hence all analysis were done on total COD, later both total and sCOD were measured to better understand the EC process. At 10 mA/cm^2 electrode consumption after 60 min electrolysis were 0.5 kg / kg COD removed, 0.2 kg / kg COD removed and 0.9 kg / kg COD removed using MPP, MPS and BPS modes respectively. While at 30 mA/cm^2 electrode consumption after 120 min electrolysis were 0.5 kg / kg COD removed, 0.6 kg / kg COD removed and 0.6 kg / kg COD removed using MPP, MPS and BPS modes respectively.

On the other hand at 10 mA/cm^2 energy consumption after 60 min electrolysis were 2.1 kWh / kg COD removed, 1.0 kWh / kg COD removed and 7.3 kWh / kg COD removed using MPP, MPS and BPS modes respectively. While at 30 mA/cm^2 electrode consumption after 120 min electrolysis were 3.8 kWh / kg COD removed, 5.9 kWh / kg COD removed and 7.4 kWh / kg COD removed using MPP, MPS and BPS modes respectively.

Hence for electrode consumption, MPS performed better while for energy consumption MPP performed better at higher CD.

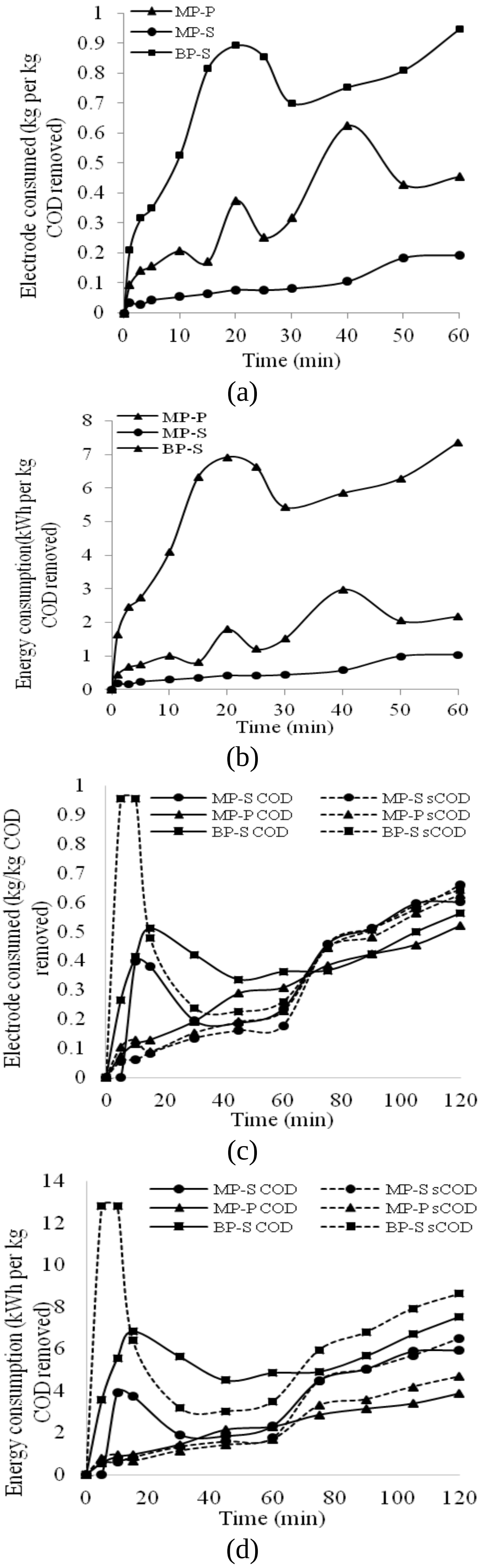
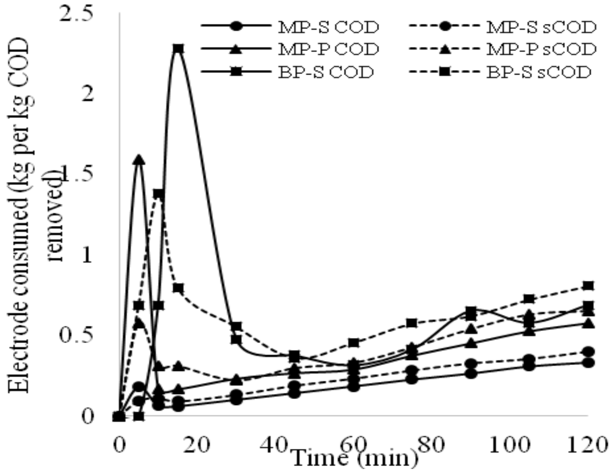
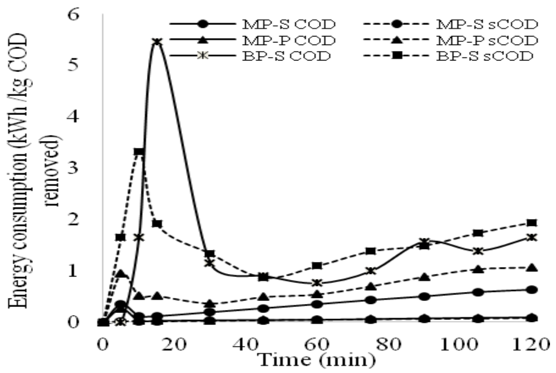


Figure 2: Effect of connection modes using Al electrode (a) on electrode consumption at 10 mA/cm^2 (b) on energy consumption at 10 mA/cm^2 (c) on electrode consumption at 30 mA/cm^2 (d) on electrode consumption at 30 mA/cm^2

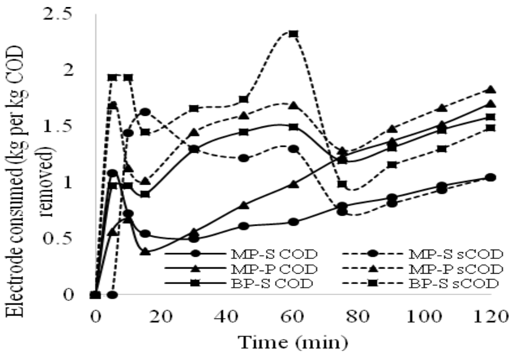
3.2 SS electrode



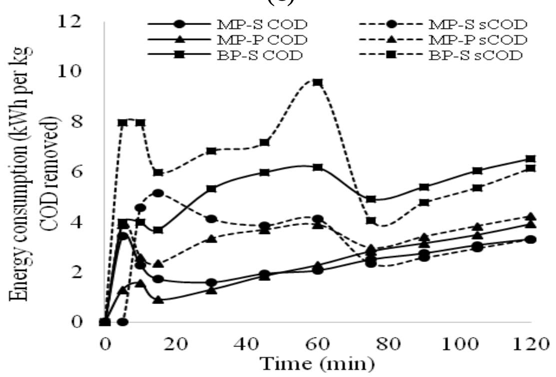
(a)



(b)



(c)



(d)

Fig. 03 Effect of connection modes using SS electrode (a) on electrode consumption at 10 mA/cm^2 (b) on energy consumption at 10 mA/cm^2 (c) on electrode consumption at 30 mA/cm^2 (d) on electrode consumption at 30 mA/cm^2

Fig. 03 shows effect of on energy and electrode consumption at 10 and 30 mA/cm^2 current densities. At 10 mA/cm^2 electrode consumption after 120 min electrolysis were 0.6 kg / kg COD removed, 0.3 kg / kg COD removed and 0.7 kg / kg COD removed using MPP, MPS and BPS modes respectively. While at 30 mA/cm^2 electrode consumption after 120 min electrolysis were 1.7 kg / kg COD removed, 1.0 kg / kg COD removed and 1.5 kg / kg COD removed using MPP, MPS and BPS modes respectively.

On the other hand at 10 mA/cm^2 energy consumption after 60 min electrolysis were 0.1 kWh / kg COD removed, 0.6 kWh / kg COD removed and 1.7 kWh / kg COD removed using MPP, MPS and BPS modes respectively. While at 30 mA/cm^2 energy consumption after 120 min electrolysis were 3.9 kWh / kg COD removed, 3.3 kWh / kg COD removed and 6.5 kWh / kg COD removed using MPP, MPS and BPS modes respectively.

Hence for both electrode and energy consumptions, MPS performed better even at higher CD.

4. Conclusions

Looking to overall effect of connection modes on energy consumption it is observed that at higher current density SS-MPS and Al-MPP connection modes performed better. Hence it is better to configure electrocoagulation cell to MPS mode when SS to be used as electrode material and to MPP mode for Al electrodes.

Effect of connection modes on electrode consumption revealed that SS-MPS and Al-MPS connection modes performed best. As the cost of both the electrode material are nearly similar, and one assembly can be suggested as optimum.

Further overall operating cost should be calculated to better understand the economy of this EC process and based on that finalization of electrode material and connection mode should be done.

It is also revealed that, soluble COD is the main problem parameter which is difficult to remove through EC because; EC process involves coagulation which is nothing but physical separation of particulate pollutant.

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