Electrochemical technologies for leachate Treatment: A review

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Abstract— Sanitary landfill leachate is very complex and toxic wastewater containing different organic and inorganic components and heavy metals. The conventional treatment technologies are not sufficient to reduce the negative impacts due to leachate contamination. Hence many advanced technologies are introduced and studies are going on in this field to nullify the complete toxic effect due to leachate. Studies reveal that among them electrochemical technologies provide more simplicity in process and more efficiency in removal of pollutants. The commonly used electrodes materials are Aluminium (Al), Iron (Fe) and Steel (St). Studies reveal that at optimum conditions a 99% PO4-P, 60% COD, 75% BOD and 92.4% TSS removal can be obtained by electrochemical technology. The main operating parameters which affect the removal of organic, inorganic and heavy metal components in electrochemical process are electrode material distance between electrodes, electrode configuration, current density and electrolysis time.

Index Terms— electrochemical technologies, leachate, operating parameters

1 Introduction

ALL environmental elements are facing a huge problem, which is pollution. Increasing population and changes in lifestyle are leading to increase in production of wastes of all types. The treatment and disposal of wastes and it's by products are the major challenge. In urban areas the waste generated are collected and brought to Municipal Solid Waste (MSW) dumping sites where it is subjected to various treatment methods in which they may undergo many physical, chemical and biological changes. These processes lead to the production of leachates. The composition of the leachates produced varies according to the characteristics of the waste. The disposal of leachates without proper treatment will lead to the contamination of surrounding environment, which in majority of cases is ground water. The removal efficiency of the various physico-chemical parameters mainly depend upon the characteristics and age of leachate [1]. The improper disposal of leachate and associated ground water contamination need to be addressed and has to be treated before discharging.

As the quality of leachate is highly toxic and variable in nature, no single method is efficient in treating leachate of all qualities. The commonly adopted methodologies for leachate treatment include physical, chemical, biological, advanced oxidation techniques and wetland treatment processes. Nowadays, the electrochemical treatment processes (ECP) are drawing more attention in the treatment of wastewater and leachate [2]. The important properties that favour leachate treatment adopting electro chemical processes are its high electrical conductivity and TDS [3].

In most of the studies relating to electrochemical technologies for leachate treatment a large number of studies were found to adopt electro-coagulation, electro-fenton and electrochemical oxidation processes. One of the major advantages of the electrochemical method is the prevention of formation of unwanted by products due to the selective nature of the process.

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2 Materials and Methods

Recent studies have proved that, electrolysis and electro coagulation techniques are efficient in treatment of organic pollutants in wastewater. The removal mechanisms associated with electrolysis process includes oxidation, decomposition and deposition, whereas in electro coagulation process coagulation, absorption, adsorption, precipitation and floatation are bringing about the treatment [1]. These methods can be used as a single treatment method or in combination with other methods as pre-treatment or post treatment.

The influence of different electrode materials, varying current density, pH and conductivity of leachate, electrode configuration and distance between electrodes in the treatment efficiency was studied by various researchers [3].

2.1 Electrode material

In electrochemical method, the most widely used electrode materials are Aluminium (Al) and Iron(Fe). Ready availability, low cost, and better treatment efficiency are the factors making them most popular [4]. These metals produce metal hydroxide on electrolysis and the metal hydroxides so formed get flocculated in the process. pH of the system is the important parameter that influences the formation of bigger metal hydroxide floc [5]. Passivation property of the electrode material is the deciding parameter for electrode selection. Even though Al electrode is efficient for electrochemical process, its passivation is not favourable for this process. This can be prevented by the anions present in electrolyte [6]. Some of the researchers used stainless steel and copper (Cu) as electrodes in their experiment [1] [13]. The treatment efficiency in electrochemical process is not solely depended on electrodes. It is depended on parameters like characteristics of leachate and other operating conditions, which are discussed below.

2.2 Current density

Several studies show the relation between current density and removal efficiency in electrochemical process. M.O. Orkun et.al is of the opinion that energy consumption is related to current density [8]. They obtained maximum removal at a current density of 300A/m^2.

2.3 Mechanical mixing

In some of the studies mechanical mixing is reported to reduce the COD removal efficiency in electrochemical process [5]. Mixing of the electrolyte is found to increase coagulation as the electrolyte become homogeneous. Mechanical mixing may also lead to break up of flocs formed.

2.4 Distance between electrodes

Distance between electrodes influence the electric field between them and thus affect the performance of the system. F. Bouhezila et.al studied the effect of inter electrode distances on removal of COD. Removal efficiency of BOD, Zn, TSS, Mn and turbidity was reported to increase when the distance increased from 1 to 3 cm [2].

2.5 Reactor configuration and arrangement of electrode

Reactors are set up either in batch mode or in continuous mode. The formation of flocs and bubbles are effected by the configuration of reactor[8]. A good reactor must be of low cost material with good flexibility in operation, installation and maintenance. Electrodes can be arranged in monopolar, bipolar, parallel or series (Fig 1).

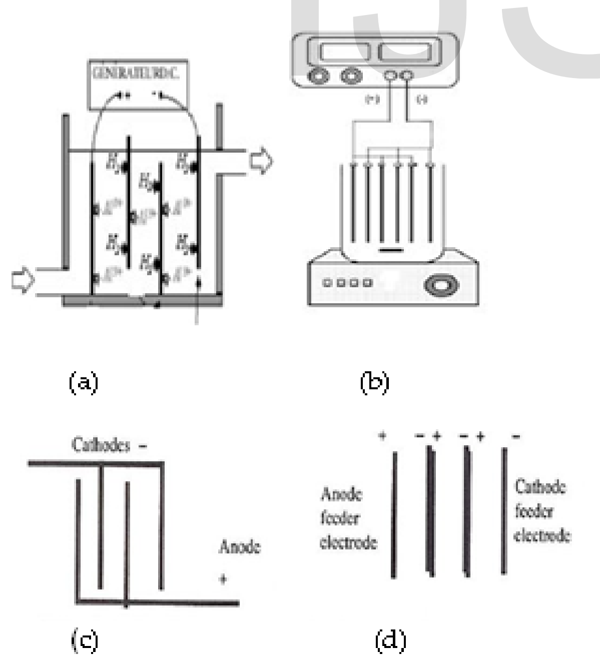

Fig 1. (a)Continuous reactor with bipolar electrodes.
(b)Batch reactor with parallel connection
(c) monopolar electrode connection
(d) bipolar electrode connection [1]

Each configuration has both advantages and disadvantages. In most of the cases batch reactor with monopolar electrode in parallel connection mode is used.

3 Results and Discussion

O. Apaydin et.al found that the important parameter which influences the COD removal efficiency in electrochemical process is current density and the second one is reaction time. They conducted the experiments at 5, 10, 15, 20, 25 minutes interval. The maximum COD removal efficiency of 58% was obtained at 25 minutes [11].

In a study using Fe-Cu and Al-Cu electrode pair, the Fe-Cu electrode combination was found to have higher removal efficiency of organic content in the leachate. Larger as well as smaller molecules and VOC was effectively removed by electrochemical technologies [1]. C.Ramprasad et.al, conducted a study using stainless steel electrode, aluminium electrode and titanium (Ti) electrode coated with platinum (Pt). They studied the removal of TDS, NH3 and Cl- from the leachate. With Al electrode the COD removal efficiency was found to be 68%, whereas NH3 and Cl- could be removed to the extent of almost 100%. Titanium coated with Platinum (Ti/Pt)-Al electrode pair showed higher removal efficiency. From the economical point of view it is very costly and its availability is limited [14].

Amimul Ahsan et.al, studied the removal efficiency at three different current densities and obtained 76% and 57% for BOD and COD removal efficiencies. TSS and TDS removal of 87% and 72% respectively were also observed at higher current density [13]. Retention time is another important factor which influences the removal efficiency and deposition thickness. With increase in current density the production of bubbles and flocs is also reported to be increasing [15]. In this study, a 20 mm deposition thickness in 4 hrs retention time is reported.

M.O. Orkun et.al. found that when current density increased the anode consuming rate increases leading to a better removal of pollutant by increase in flocculation. The amount of electric current passing through leachate leading to an increase in the pH of system is reported as the main drawback of this method [8].

J. Labanowski et.al., conducted a comparative study with Al and Fe electrodes[7]. They found that Al electrode is more efficient than iron in leachate containing higher Cl- concentration. When the current density is high, Al electrode shows higher removal efficiency than Fe [7].

Iqbal K.Erabee et.al., reported that the removal efficiency can be increased by adding additional NaCl[2]. The results showed that at a higher NaCl concentration, removal efficiency has a considerable increase. Instead of NaCl solution, sea water itself can be used for small communities. The efficiency decreased due to increase in pH and increase in NaCl concentration above 5%. When using Al as anode and Fe as cathode, at 120 min hydraulic retention time (HRT) and 60V electrical potential, they obtained 94% and 93% of COD and Manganese removal efficiency. Hence electrochemical technology can be effectively used for treatment of wastewater/leachate from different industries containing large amount of pollutants [2].

TABLE 1
SUMMARY OF POLLUTANT REMOVAL EFFICIENCY

Reactor type	Electrode material (Cathode-Anode)	Paramrter	Removal percentage	Reference
5litre reactor with recircula-tion	SS-Pt/Ti	COD	85%	[12]
		VSS	100%	
		N-NH_4	100%	
		PO_4-P	100%	
500ml reactor at batch mode	SS-Al	COD	68%	[13]
		TDS	80%	
	SS- Pt/Ti	COD	61%	
		TDS	80%	
2 litre reactor	Cu-Fe	COD	35.3%	[1]
	Cu-Al	COD	32.5%	
240ml. circular rector	SS-SS	BOD	76%	[13]
		COD	57%	
		TSS	84%	
		TDS	72%	
250ml.plexi glass reac-tor	Al-Al	COD	58%	[11]

To study the effect of pH on removal of COD and colour, experiments were conducted at three different pH values of 3, 7, and 9, by Zanab H Mussa et.al [16]. The maximum removal efficiency was observed at an acidic pH [15]. When the current density increases the pH value of the wastewater is observed to increase. This is because of the increase in production of OH^- ions through the electrode at the time of electrolysis [16]

4 CONCLUSION

Electrochemical methods are advanced technology used for the effective treatment of landfill leachate. The main advantages include lesser land area requirement and sludge production. In this method the use of chemicals is minimum, which makes the process eco-friendly.

Even though an electrochemical method has many advantages than conventional treatment methods, there are some drawbacks. Among this the most important one is the increase in temperature of the system. The anode gets corroded in the process necessitating periodical replacement of anode. Further study is needed to reduce the production of H2 gas and chloramines in the process.

For the treatment of leachates, electrochemical technology can be used as an effective method considering its removal efficiency. Further studies are needed to optimise the technology and to minimize the present drawbacks.

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