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Decolourization of Landfill Leachate by Electrochemical Oxidation Techniques

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Abstract
The study aims to treat the landfill Leachate by electrochemical oxidation process in order to render the Leachate reasonable for inland disposal. Electrochemical oxidation of organic compounds from Leachate is a compelling method of breaking down pollutants which are resistant to biological degradation. The electrodes used in the process are graphite which is operated in galvanostatic state with NaCl as electrolyte in batch electrolytic parallel plate reactor. At optimum conditions, the percentage of COD and colour removal by graphite electrode is 84.7% and 95% respectively are procured.
Keywords: Landfill leachate, graphite, electrochemical oxidation, Decolourization, chemical oxygen demand (COD).

1. INTRODUCTION TO LEACHATE
Leachate is complex waste water originating in municipal solid waste landfills as the result of water percolation through wastes which brings with it many pollutant substances dissolved and in suspension. Inadequate leachate management could exert high environmental impact, notably contamination of water resources, at the surface and groundwater, and soils. Because of the variability in the quality and quantity of leachate throughout the life span of the treatment plant, standard treatments become ineffective. It becomes essential to implement technologies that can be adjusted to the in situ needs.

2. ELECTROCHEMICAL OXIDATION
Electrochemical technologies have shown high potential in the elimination of persistent pollutants. The high selectivity of the electrochemical process the production of unwanted by-products. It is operated in room temperature and pressure supplied by a D.C source.

The mechanism of electrochemical oxidation of wastewater is an intricate phenomenon involving Coupling of electron transfer reaction with a dissosiate chemisorption step. Electrochemical oxidation technique substantially reduces organic contaminants and colour in leachate and is highly efficient compared to conventional methods. The process removes high rates of COD and almost all content of ammonia and is economical compared to other leachate treatment methods.

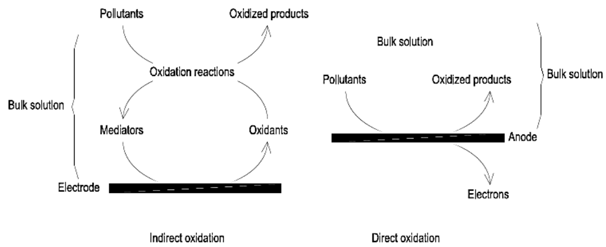

Fig. 1
Pollutant removal pathways in electrochemical oxidation (Indirect and direct oxidation).

2.1 Direct Oxidation Process
In direct anodic oxidation process electron acts as a reagent. The pollutants are absorbed on the anode surface through the generation of physically adsorbed "active oxygen" (adsorbed hydroxyl radical, •OH-) and destroyed by the anodic electron transfer reaction.

2.2 Indirect Oxidation Process
In the process chloride salts of sodium or potassium are added to the wastewater for better conductivity and generation of hypochlorite ions.
During electrolysis regeneration of strong oxidants such as hypochlorite/chlorine or hydrogen peroxide is by the electrochemical reactions.
The reactions of anodic oxidation of chloride ions to form chlorine is given as

$$2Cl^- \longrightarrow Cl_2 + 2e^-$$

The liberated chlorine form hypochlorous acid

$$Cl_2 + H_2o \longrightarrow H^+ + HoCl$$

and further dissociated to give hypochlorite ion

$$HoCl \longrightarrow H^+ + oCl^-$$

The generated hypochlorite ions act as main oxidizing agent in the pollutant degradation.

3.MATERIALS AND METHODS

3.1 Sampling Location
The landfill is situated at survey no.108, at Mavallipura village, Hesaragata zone, Bengaluru North, Karnataka state. This site has been used as processing for the municipal solid waste generated from the Bangalore city.

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Fig 2: Sample Collection Location

4. Electrodes Used In Electrochemical Oxidation

The choice of electrode material is of great importance as it affects the selectivity and the efficiency of the process.

Graphite electrode is usually used as an anode for the electrochemical degradation. the result of color removal using Ni, Ag, Cu, Pd, Pt, stain steel and graphite were 5, 9, 6, 40, 56 ,75 and 80%, respectively [Zainab Haider Mussaa, Mohamed Rozali Othmana, Md Puazi Abdullaha,B And Norazzizi Nordina].Graphite is resistant to chemicals and has a high melting point and is the chosen as the electrode material .

The choice of best electrode was made based on their decolourization ability and also on their stability electrochemically. [Yang Deng, James D. Englehardt].

5. Experimental Set Up

The electrochemical cell consists of an undivided reactor made of borosil glass with two parallel electrodes having an inter-electrode gap of 2cm. The electrochemical cell has a volume of 400ml in a 500ml capacity of beaker. The dimensions of the electrode were 50x50x4mm.Both anode and cathode are placed vertical and parallel to each other with batch operation.

Landfill leachate is prepared by using distilled water to the 1% concentration i.e. 4 ml. Prepared leachate is transferred into electro chemical cell. For every 5 minutes, 5ml of samples were drawn and analysed for colour and pH.

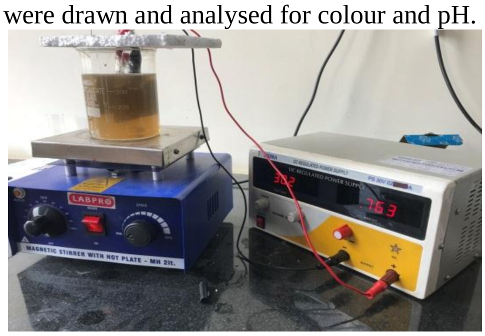


Fig 3: Experimental Set Up of Electrochemical Oxidation Process

5.1 ANALYSIS

The chemical oxidation demand of the effluent sample is determined by open reflux method, using COD digestion apparatus. The absorption of the sample is recorded to measure colour on Spectrophotometer, recording the spectra over 190nm to 1000nm range. The pH is determined by pH meter.

Percentage of Colour Removal Calculation As Follows:

$$\text{Colour removal}(\%) = \frac{(\text{Abs }(234)\ (i) - \text{Abs }(234)\ (t)) \times 100}{\text{Abs }(234)\ (i)}$$

Where,

Abs (234) (i) =Initial absorbance of the sample at a wavelength of 234nm.

Abs (234) (t) = Absorbance of the treated sample at time intervals “t” in min.

Percentage of COD Removal Calculation As Follows:

$$\text{Colour removal }(\%) = \frac{(\text{COD }(i) - \text{COD }(t)) \times 100}{\text{COD }(i)}$$

Where,

COD (i) = Initial COD concentration in mg/L.

COD (t) = Initial COD concentration removal in mg/L at time intervals, “t” in min.

6.EFFETS OF OPERATING FACTORS

6.1 Variation of NaCl Concentrations

Addition of electrolyte increases rate of reaction. The electrolysis is carried out at different NaCl concentrations of 0.1M, 0.5M, and 1M for Graphite electrodes.

Each experiment is of batch operation with duration until the decolourization of landfill leachate. The samples are drawn at a regular interval of 5minutes for Graphite electrode. The drawn sample is tested for colour, pH.

6.2 Variation of Time

The electrolysis is carried out at a maximum current of 2A, until the decolourization is achieved to know the time and maximum current taken by the decolourization of landfill leachate sample. Here the optimum time is chosen for Graphite electrode based on the colour removal.

6.3 Variation of Current Density

When wastewaters are treated by action of direct. Maximum current of 2A in set and varied along the experiment to check for optimum NaCl concentration.For the optimum NaCl concentration Electrolysis is carried out at different Current Density of 56A/m2, 96A/m2, 136 A/m2, 176A /m2 and 216A/m2 for Graphite electrodes. Each experiment is of batch reaction operation. The samples are drawn at regular intervals of 5min. The drawn sample is tested for colour, pH as per the APHA, 1998 and the time taken by each experimental run is recorded.

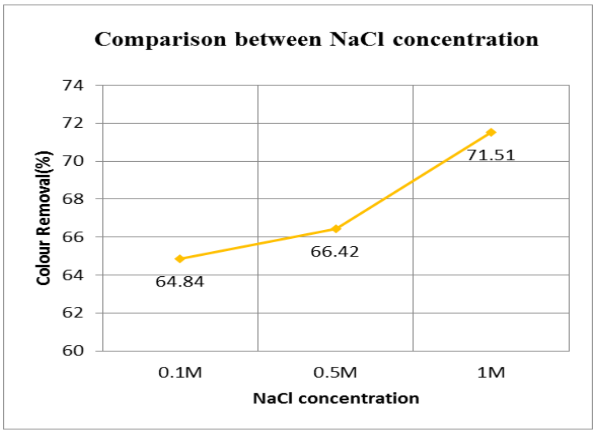
7. RESULTS

The impacts of the operating components in variation such as current density, reaction time, chloride ion concentration, anode material and pH that influence the removal of pollutant

from landfill leachate electrochemically are contemplated. It also investigates the efficiency of COD and colour removal at optimum conditions of landfill leachate by using electrochemical oxidation with a graphite electrode.
176 A/sqm is the optimum current density at 1M NaCl concentrations for 15 minutes to attain at 95% abolishing of leachate colour and 84.7% reduction in COD values.

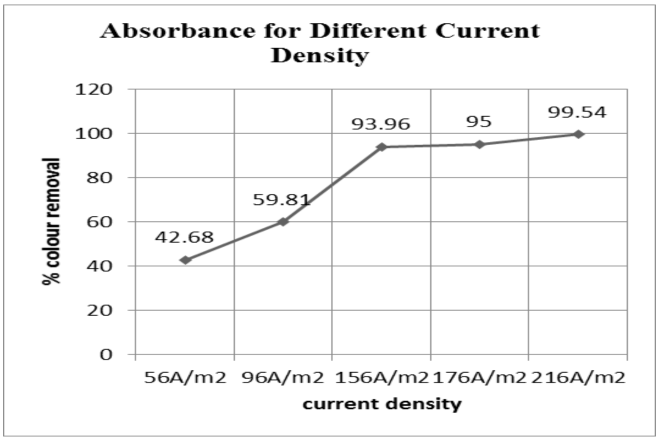
7.1 Preliminary Observation
Wavelength of the Sample
Raw leachate sample wavelength - 820nm
1% diluted leachate sample wavelength -234nm
Electrode Weights
Initial weight of anode -17.795g,
Initial weight of cathode -18.729g

7.2 Direct And Indirect Method
Time taken for decolourization in the direct method is 80 minutes and colour removal is only about 19.58% in 30 minutes whereas in indirect method colour removal is 64.84% in 30 minutes at maximum current of 2A.
Hence indirect method of electrochemical oxidation is carried out for further process.



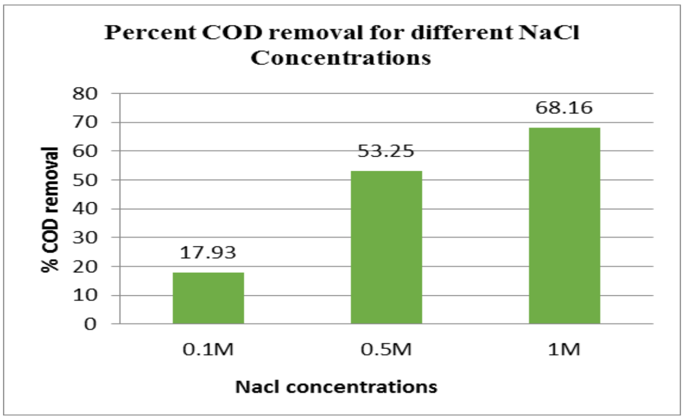
Graph 1: The Effect of different NaCl Concentration on Colour Removal Efficiency.

Graph 1 shows maximum colour removal in 1M NaCl concentration in 20 minutes of electrolysis time with 71.51% of colour removal Whereas 0.1M and 0.5M NaCl concentrations shows 64.84% in 30 minutes and 66.42% in 25 minutes respectively.Hence optimum dosage of 1 M NaCl concentration in kept constant and varied for different minimal current densities.

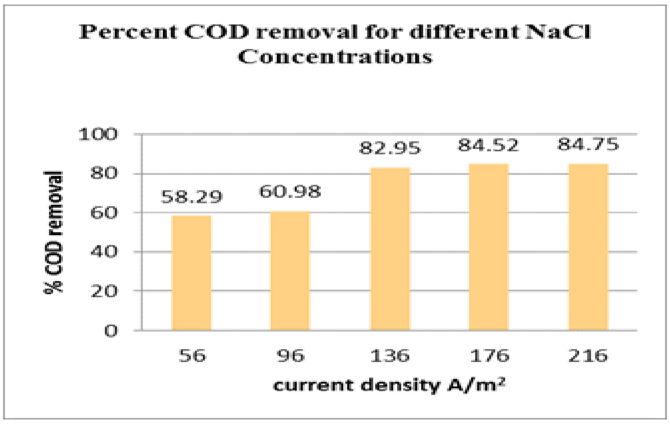


Graph 2: The Effect of different current density on Colour Removal Efficiency.

Graph 2 shows maximum colour removal of 99.54% at 216A/m2 current density in 10 minutes of electrolysis time with 1M NaCl concentration. However, 176 A/sqm is accepted as optimum current density at 1M NaCl concentrations to attain at 95% abolishing of leachate colour in 15 minutes of electrolysis time.



Graph 3: Effects of NaCl concentration



Graph 4: The Effect of current densities

In Graph 3 and 4 the highest COD removal is observed as 84.75% in 1M NaCl concentration and 216A/m2current density.17.93% and 53.25% of COD removal was observed in

0.1M and 0.5M respectively. Therefore, 1M NaCl concentration is considered to be optimum.

In Graph V 216A/m2 shows maximum colour removal efficiency of 84.75% in 10 min. In this case an increase in current density of 56A/m2, 96 A/m2, 136 A/m2, 176A/m2 and 216 A/m2 increase in the colour removal efficiency from 58.26% to 84.75%. Hence, 216A/m2 is considered to be optimum.
As the current supplied increases, the production of ions increases which improves the colour removal efficiency.

Fig 5: Sample Before and After Treatment for various current densities.

8. CONCLUSIONS
The following conclusions are drawn from the results of the present study:
-The direct electrochemical oxidation consumed more time that is 80 minutes than indirect electrochemical oxidation which took 30 minutes.
-The percentage of colour removal for 0.1 M, 0.5 M and 1M NaCl concentrations is found to be 64.84% at an optimum time of 30minutes and 66.42% at an optimum time of 20 minutes and 71.51% at an optimum time of 15 minutes respectively.
-The percentage of colour removal for 176 A/m2 current density is found to be 95% at 15 minutes.
-The COD removal for 1M and 216 A/m2 current density is found to be 68.16%and 84.75% respectively.
-With minimum current i.e 0.44A, colour removal efficiency is 95% and COD removal is 84.52%.

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