Treatment of Water and Leachate by Using Electrocoagulation: An Investigation of Parameters of a Landfill

Sreekutty Sreenivas, Varsha Asokan

Abstract— Solid waste generation is increasing worldwide due to the rampant population and economic growth of its inhabitants. Sanitary landfilling is the most common method and approaches that are used for managing municipal solid wastes (MSWs). Although landfilling is applied as a cheap and effective solution for countries with available space, this application does contain serious environmental risks due to the generation of landfill leachate (LL). The operation of landfill can cause environmental problems due to waste decomposition in the form of leachate production. Leakage of leachate to the environment can damage the water bodies. Leachate is wastewater decomposition of organic waste that can contaminate soil and groundwater if it is not handle properly. Contamination by leachate can be prevented by reducing leachate level before the wastewater reaches the ground. One of the methods used is electrocoagulation. Electrocoagulation is an electrochemical water treatment method where in anode occurred the release of active coagulant as metallic ion, while in cathode occurred the electrolysis reaction in a form of the release of hydrogen gas. This study is objected to investigate the effectiveness of electrocoagulation in removing Biochemical Oxygen Demand (BOD_5) and Chemical Oxygen Demand (COD).

Keywords— Electrocoagulation, Landfill, Leachate, Solid waste, Water contamination, Waste decomposition, Wastewater treatment

1 Introduction

Solid waste management is a widely important issue in all communities worldwide. When contemplated within the scope of the waste hierarchy, the final solid waste disposal method is landfill [10]. Landfill is an engineered method for solid waste disposal and important to conserve the environment. Physical, chemical and biological processes occur in the landfill depending on time, and they result in the generation of gases such as methane, carbon dioxide, etc., and waste water or landfill leachate [4] [5].

Leachate has a complex structure and high pollutant load, and its treatment is relatively hard to supply the discharge standards [4]. Leachate becomes ahead of wastewaters as being the most difficult to treat as it is a wastewater with a complex and widely variable content generated within a landfill [7]. LL contains large numbers of organic or inorganic pollutants such as BOD, COD, ammonia and heavy metals in unreasonable concentrations. Therefore, many pre-treatment and combined treatment methods have been proven to treat leachate such as biological, chemical, physical, wetland and advanced oxidation processes [10]. In addition to the classical treatment methods mentioned above, in recent years, electrochemical methods (electrocoagulation, electro-Fenton, electro-dialysis, etc.) have been used as a pre-treatment stage in the LL treatment process. One of the electrochemical methods is electrocoagulation (EC), and in this process, flotation and precipitation occurs simultaneously [7].

The EC process has many advantages, such as a simple equipment requirement, ease of operation, a larger floc structure, a fast and separable sludge structure, a lower treatment volume requirement and less excessive use of chemicals. In the EC process, sacrificial electrodes such as aluminium, iron, zinc, etc. are used to produces the release of active coagulant precursors into the solution [1]. In an EC process, an electrical current is enacted through a metal electrode; the anode material undergoes oxidation, while the cathode will be subjected to reduction or reductive deposition of elemental metals. Both Al^{3+} and Fe^{3+} react with OH^- to form Al $(OH)_3$ (s) or Fe $(OH)_2$ (s) according to complex precipitation kinetics. The mechanism of EC is exceptionally dependent on the chemistry of the aqueous medium, especially its conductivity. The mechanism of generating ions by EC can be clarified with the examples of iron and aluminium, which were used as the anode and cathode in this study [2] [10].

In recent years, electrochemical treatment having characteristics like relatively more economic and higher treatment efficiency has been a promising method [8] [11] [14]. EC is one of the modest and efficient electrochemical methods for the purification of many types of water and wastewaters [7]. In this technique, which is characterized by its simple equipment, easy operation, and declined amount of sludge, the coagulant is generated by electrolytic oxidation of an appropriate anode material that leads, at an appropriate pH, to the insoluble metal hydroxide which is able to remove a large variety of pollutants. EC has also been functioned to treat the landfill leachate by some researchers. There is no doubt that high COD and toxic matter in the landfill leachate are of the most significant problems in leachate management. In particular, it is well known that the landfill leachate can reach very high COD levels [10].

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2 Methods And Methodology

2.1 Study Area

Kerala is grappling with a crisis of plenty: plenty of solid waste. The districts like Thiruvananthapuram, Kochi, Kozhikode, Thrissur and Kottayam have seen rapid urbanization and population growth leads to production of more solid waste than they can deal. When a city generates an overload of solid waste, the only alternative available to the authorities is to make landfills which is located in the outskirts of the city.

Fig. 1 Waste stack in Njeliyanparambu landfill

Calicut City Corporation has a total area of 2345 sq.km and has a total population of 30, 86,293. With the increase in the population and the rising demand for food and other essentials, there has been a growth in the amount of waste being generated by the households. The City Corporation has a waste treatment plant at Njeliyanparambu in Cheruvannur-Nallalam area spread in 7 hectares which are 6 km from Kozhikode.

Kozhikode now generates 300 tonnes of wastes generated by households in the form of organic, plastic covers and papers, recyclable plastics, glasses and lights, e-waste, sanitary napkins, dresses and other wastes. Figure 1 shows the stack of waste in the Njeliyanparambu landfill. The biodegradable wastes collected by the Corporation sanitary workers and Kudumbashree members are transported to Njeliyanparambu dumping yard every day. The collected wastes are dumped in an open surface for drying, and after that, these are converted into manure through a single window system. One of the major defects of the plant is that it does not have a leachate treatment unit and drier for drying. So the collected wastes are openly dumped for more days for drying which permeates stink [6] [9] [10].

Fig. 2 Stagnant leachate in the ground surface in Njeliyanparambu landfill

The people living near the plant argue of health issues like allergy, infection, other diseases etc. Cancer, skin problems and lung ailments are widespread in the area [10]. Around 175 wells and other water sources have over the years become unnecessary due to water contamination and deterioration of water quality. Figure 2 shows the moisture or water content that stagnant at the ground surface. Untreated effluents from this plant pollutes the Chaliyar River, which is the district's main drinking water source.

2.2 Sample Collection

In the experimental study, leachate samples were collected from Njeliyanparambu Landfill, which is located in Kozhikode city, Kerala. Leachate is defined as any contaminated liquid that is produced from water percolating through a solid waste disposal site, accumulating contaminants, and moving into subsurface areas. A second source of leachate arises from high moisture content of certain disposed wastes, it can be a toxic liquid, a chemical or any liquid material otherwise incompatible for use.

Fig. 3 Leachate sample for the experimental study

The leachate sample is strongly odoured brown coloured cloudy liquid. The odour is acidic and offensive. The samples were collected in pre-sterilized bottles and transported to the laboratory and stored at 4°C in order to maintain the leachate characteristics unchanged.

2.3 Experimental Setup

A 0.25L borosil glass reactor was used for the investigation. Batch tests were conducted using 0.25L of leachate sample having different dilutions for each experimental set. LL was taken from Njeliyan Parambu site located on Kozhikode Corporation of Kerala.

The electrochemical cell consisted of a submerged anode and cathode, both of the same material and different materials (i.e., either aluminium or iron) in the form of flat sheets, in the 0.25L borosil glass reactor. Electrocoagulation cell consisted of a DC power supply and submerged anode and cathode [7] [10] [15]. The electrode dimensions were 2.5 cm wide by 10 cm deep, resulting in a dipping area of 25 cm^2. In the study, a digital dc power supply was utilized to power the EC operation. Both anode and cathode were placed parallel and vertical to each other with an inter electrode distance of 1 cm and it positioned into the reactor in a monopolar configuration. In order to maintain an unchanged composition and prevent the association of the flocs in the solution, the stirrer was turned on and set at 200 rpm. All electrodes were rinsed with dilute HCl before every

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experiment conducted. Every experiment was accomplished at the room temperature.

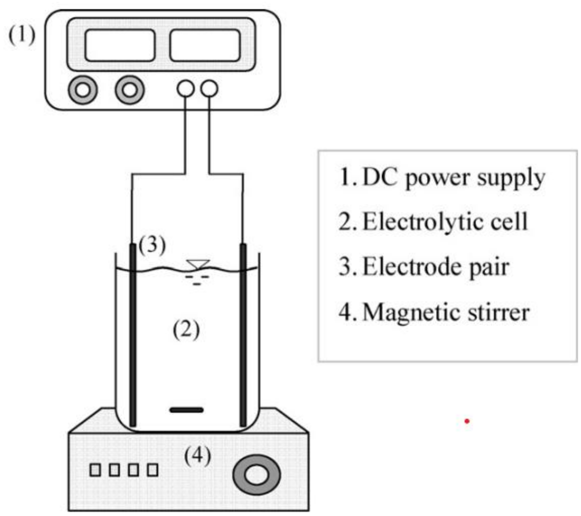


Fig. 4 Experimental Setup

The experimental set-up used in the present study is presented in Fig. 1.

2.4 Experimental Procedure

The procedure started with electrocoagulation cell cleaned with distilled water and dried. The experiments were carried out in a batch mode.For each experiment, a leachate sample of 0.25 L was collected in the electrochemical cell with aluminum electrodes and iron electrodes dipped into the sample.The dipping area of the electrode is 25 cm². Applied current densities have been shown in Table 1. In each current density applied, contact times of 6, 12, 18, 24, 30, 36, 42, 48, 54 and 60 minutes were used. Therefore, the method were tested for metal type, COD removal and sludge formation. The pH, conductivity, TDS and turbidity of the solution after each 6 minutes was taken using pH meter, conductivity or TDS meter and turbidity meter. The electrodes (anode and cathode) were clamped at electrode stand.

Fig. 5 Laboratory Electrocoagulation setup

All connections in the circuit were completed by wire connection to terminal positive and negative to DC power supply. The colour of electrolyte solution was observed before and after the process occurred.After the experiment, the treated sample was then kept undisturbed for 20 min in order to allow the floc to settle.

TABLE 1
THE VARIATION OF ELECTRICAL PARAMETERS APPLIED DURING THE RUNS

	Voltage (V)	Current density (A/m²)	Power consumption(kWh/kgCODremoved)
Run 1	10	242	0.3255
Run 2	15	376	0.08457
Run 3	30	750	0.02450

After settling the sample of supernatant was collected to perform the analysis of pH, hardness, acidity, TDS, conductivity, turbidity BOD_5, COD and most probable number (MPN).

3 Results And Discussions

In this section, results obtained during the study are given and discussed.Leachate treatment performance was detrmined by electrocoagulation process. The EC process was influenced by operating parameters sucha as current density and reaction time on removal of BOD and COD.

3.1 Characterization of leachate

The quality and quantity of leachate is highly variable and is directly related to fluctuations of rainfall amount, composition or characteristics of the waste, age, and landfill operational patterns [5].To this aim sampling was performed and various parameters such as pH, BOD5, COD, TSS etc. were used to assess characteristics o landfill leachate which are presented in Table 2.

TABLE 2
THE PROPERTIES OF LEACHATE FROM NJELIYAN PARAMBU LANDFILL

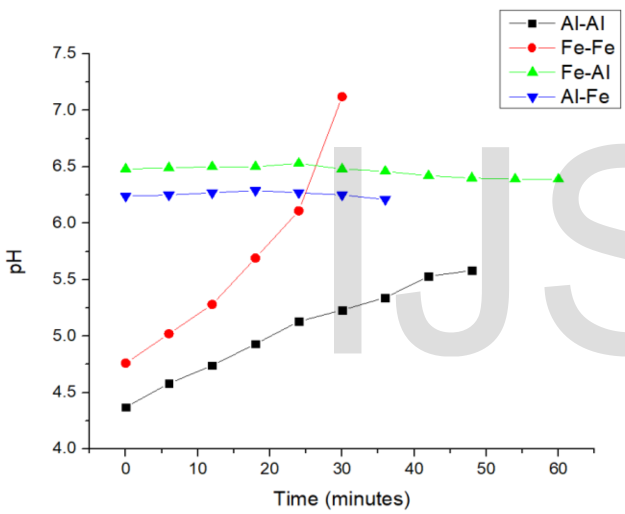
Analysis	Value
pH	4.29
Colour	Dark brown
Odour	Medium
Temparature, °C	31.75
Conductivity	<2000
Turbidity	397
TSS	748
TDS	15900
TN	1356
COD	28220
BOD	9877
DO	< 1.0 mg/l
BOD/COD	0.35
MPN	1100 per 100 ml

Njeliyanparambu Landfill has been operating since 2000's and is classified as a mature landfill. The raw leachate was characterized as temperature of around 31.75°C, TSS of 748 mg/L, pH of 4.29, BOD of 9877 mg/L, COD of 28220 mg/L, TN of 1356 mg/L and BOD/COD ratio of 0.35 resemble an intermediate landfill.This deviation is due to the mixing of young leachate and old leachate since the solid waste dumping system in the Njeliyanparambu. Landfill does not follow a cell system as a result the produced leachate is with an intermediate character. The leachate of Njeliyanparambu landfill tends to be acidic.So the conventional biological methods are ineffective to the treatment of leachate because of it has high conductivity and turbidity.According to literatures to treat a wastewater with mentioned characteristic, electrocoagulation method is an effective method.

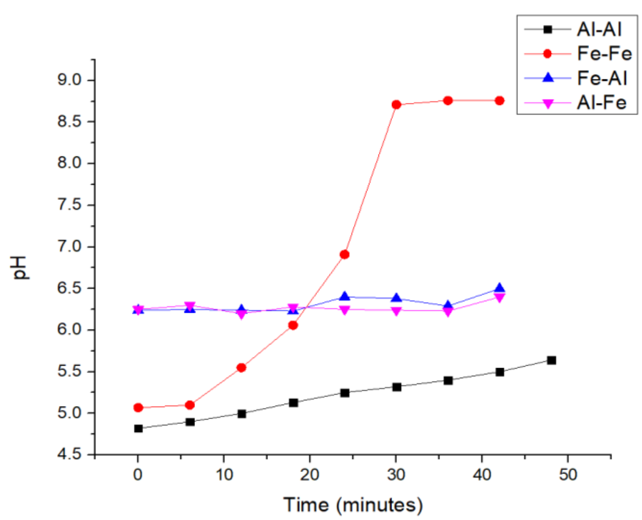
It can be seen from the analysis that the parameters need to improve in order to meet the disposal standards of leachate include COD, TSS, and TN.

3.2 Effect of current density to processing time for pH

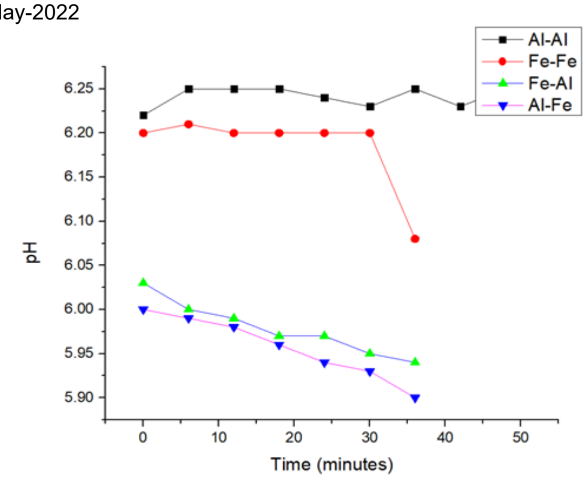
The experiment work used ranges current density of 242 A/m², 376 A/m² and 750 A/m². These ranges will give the data about how current density will affect the electrocoagulation efficiency in the removal of pollutants that contain in the leachate samples.



(a)



(b)



(c)

Fig. 6 The effecet of pH in different current densities
(a) 750 A/m² **(b)** 376 A/m² **(c)** 242 A/m²

The pH is continuously observed during the study. As shown in Fig. 6, the results showed that, depending on the activities of the anode and cathode, pH gradually increased due to dominant activities of the cathode.

From Fig. 6, when current density was 750 A/m², pH changed from 4.37 to 5.58 with Al-electrode and from 4.76 to 7.12 with Fe electrode. When current density was 376 A/m², pH changed from 4.82 to 5.64 with Al-electrode and from 5.1 to 8.76 with Fe-electrode.When current density was 242 A/m², there is an slight decrease in pH in both Al and Fe electrode in a range of 6 to 5. By using electrodes of different materials also shows a slight increase in pH in all different current densities.

The increase in pH is a desired a result for the treatment of leachate.Fe electrodes showed a better efficiency than Al electrodes did.

3.3 Effect of current density to processing time for BOD_5

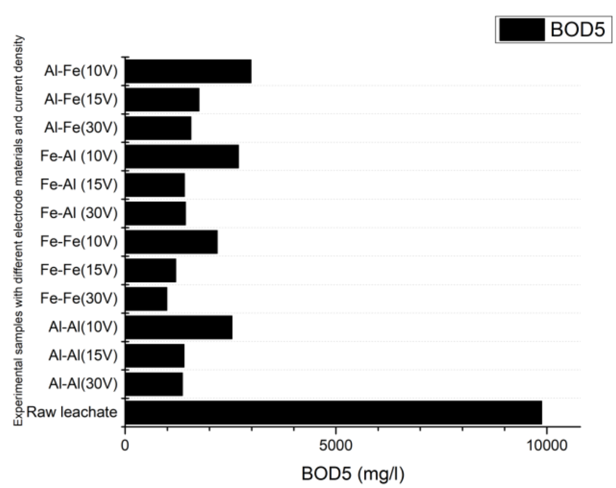


Fig. 7 Effect of current density to processing time for BOD_5

Result of BOD5 analysis determined the quality of water bodies, amount of oxygen necessary by microorganisms to decompose organic matter comprised in water in the aerobic state. BOD_5 high value played an important role in inferring the ability of the water bodies in supporting the better evolution of algae and aquatic organisms. The greater the number of the bacterial population, the higher the level of the water pollution would be [15].

In Fig. 7, the results of electrocoagulation of leachate to the value of BOD_5 is decreased. The best result of BOD_5 impairment was at 42 min and current density of 750 A/m² with a value of BOD5 987 mg/L by using Fe electrode. At this process time, there was significant change in the value of BOD_5 from 9877 mg/L to 987 mg/L, that is of about 90% BOD_5 is removed. The higher the density of current and the greater the time, the electrode process would be more saturated that caused the electrocoagulation process reached its lowest point and increased in the value of BOD_5.

3.4 Effect of current density to processing time for COD

COD was the quantity or amount of oxidant that responded with the sample under certain conditions. The quantity of oxidant was proportional to the oxygen. Organic and inorganic compounds in the sample were oxidized dependent but organic compounds were more dominant [15]. COD was often used for assessing the quantity of pollutants in the water. In Fig. 8, the best result of leachate waste by method of electrocoagulation in decreasing the value of COD was at 60 min with a current density of 750 A/m² . COD value decreased drastically from 28220 mg/L to 2820 mg/L. Basically, the reduction in COD values in electrocoagulation occured by destabilization. Maximum COD removal is seen in Fe electrode at 750 A/m² that is about more than 90% of COD is removed by EC process.By Al electrode about 86%of COD is removed at 750 A/m² current density.

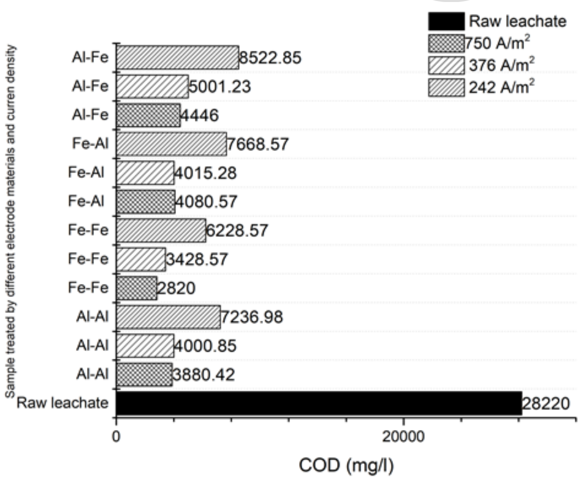


Fig. 8 Effect of current density to processing time for COD

3.5 Operational conditions of EC process

3.5.1 pH

The pH is continuously observed during the study.Detailed explanation of pH is discussed in section 3.2.

3.5.2 Temperature and conductivity

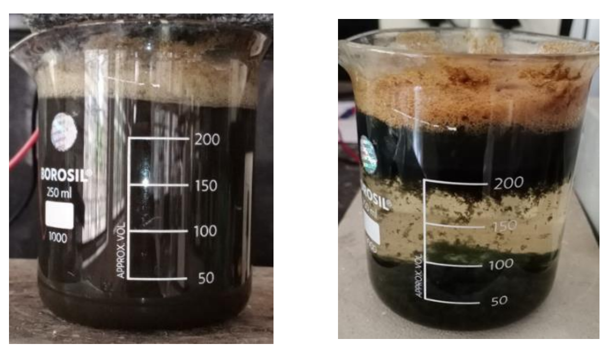
The temperature in the reactor tends to high during the study as a result of reactions takes place. This raise in temperature as a result of electrolytic reactions depending contact time, electrode type and applied electrical power. In addition, depending on contact time and applied electrical power, electrical conductivity also changes [7]. When current density was 750 A/m2, temperature changed from 31.75 to 33.5 ◦C with Al-electrode and from 31.75 to 33.3 ◦C with Fe-electrode. The temperature tends to increase as a result of electrolytic reactions.
But in this experiment the value of electrical conductivity remains high (that is greater than 2000) before and after the electrocoagulation process. According to the experimental results, increasing electrical power has supplied an unremarkable decrease in the conductivity [7].

3.5.3 Electrode type

Fe and Al electrodes were compared under similar operational conditions. Fe electrodes showed a higher treatment efficiency than Al ones on the basis of turbidity and colour removal. The rates of COD removals for Fe and Al electrodes obtained were 90% and 86.25% in 42 min contact time, respectively. Fe electrodes transfer higher numbers of Fe ions into solution and they produce a higher amount of sludge [7]. Due to the fact that the costs of both types of electrodes are almost same, it will be a good choice for higher treatment efficiencies to select Al electrodes.

(a) (b)

Fig. 9 Leachate sample (a) before and (b) after electrocoagulation by using Al electrode



(a) (b)

Fig. 10 Leachate sample (a) before and (b) after electrocoagulation by using Fe electrode

According to a study performed on diluted leachate (%10) by Ilnan et al.[7], COD removal efficiencies with Al-electrode and Fe-electrode were obtained 52% and 42%, respectively (pH:

6.2, current density: 200 A/m², and contact time: 30 min). Al-electrode has a higher treatment efficiency than Fe one for NH_3-N removal. The removals of NH_3-N were determined to be almost 11% and 14% in 30 min contact time for Fe and Al electrodes, respectively.Fig. 9 and Fig. 10 represents the vatiation in leachate sample before and after the performance of electrocoagulation by Al electrode and Fe electrode respectively.

3.5.4 Dilution

The EC process by using raw leachate is stucked or stopped due to high electroconductivity and turbidity of the leachate sample and high production of sludge. So the sample samples are diluted to perform electrocoagulation. Adilution can be used to lower the concentration of the analyte being tested so that it is below the acceptable limits. Here 5% and 10% dilution is selected for the experimental procedure of electocoagulation process.

3.5.5 Current density

For the experimental purpose10, 15and 30 V potentials were applied. The treatment efficiency appeared to be slightly increasing with increasing current density. Here current density was changed from 242 to 750 A/m². When current density was increased, the efficiency of COD removal was also increased in contact time.

4 Conclusion

The effectiveness of electrocoagulation were investigated in this study. Optimum conditions and the effectiveness of electrocoagulation for each parameter are in the current density 750 A/m² with 60 minutes of time process by Fe electrode. The electrocoagulation method is effectively reduced the value of BOD_5 90%; COD 91%; and for the increased of pH from 5.1 to 8.76 by Al electrode respectively. Electrocoagulation method are succesfully decreased levels of pollutants in accordance with environmental standard.

References

[1] Ahmed Samir Naje, Mohammed A. Ajeel, Isam Mohamad Ali, Hussein A. M. AlZubaidi and Peter Adeniyi Alaba (2019), "Raw landfill leachate treatment using an electrocoagulation process with a novel rotating electrode reactor", *Water Science & Technology*, 80.3 , 2019

[2] Bambang Iswanto, M Lindu and Diana Hendrawan (2013), "Domestic Waste Water Treatment By Electrocoagulation", *International Journal of Engineering Research & Technology (IJERT)*, ISSN: 2278-0181 Vol. 2 Issue 10, October – 2013

[3] Beena K.S., George Meril(2010),"Contaminant Transport from MSW Landfill: A Case Study", *Indian Geotechnical Conference* – 2010, GEO trendz December 16–18, 2010

[4] E Noerfitriyani, D M Hartono, S S Moersidik, I Gusniani (2018), "Leachate characterization and performance evaluation of leachate treatment plant in Cipayung landfill, Indonesia", *IOP Conference Series: Earth and Environmental Science*, doi :10.1088/1755-1315/106/1/012086

[5] Eka Sri Yusmartini , Dedi Setiabudidaya , Ridwan , Marsi and Faizal (2013),"Characteristics of Leachate at Sukawinatan Landfill, Palembang, Indonesia", *Journal of Physics* ,423 (2013) 012048

[6] Fathima Akhila & Sachin Pavithran A (2018)," Municipal Solid Waste Management In Calicut City- A Case Study of Njeliyanparambu", *International Journal of Research and Analytical Reviews (IJRAR)*, July 2018, Volume 5, Issue 3

[7] Fatih Ilhan , Ugur Kurt , Omer Apaydin , M. Talha Gonullu (2007), "Treatment of leachate by electrocoagulation using aluminum and iron electrodes", *Journal of Hazardous Materials* 154 (2008) 381–389

[8] Omer Apaydina, Ebru Ozkan (2019), "Landfill leachate treatment with electrocoagulation: optimization by using Taguchi method",*Desalination and Water Treatment* 10.5004/dwt.2019.24719

[9] Prathibha Ganesan (2017), "Landfill sites, solid waste management and people's resistance: a study of two municipal corporations in Kerala", *International Journal of Environmental Studies*, DOI: 10.1080/00207233.2017.1374076

[10] Rejuna C A & Prof (Dr). K.X. Joseph (2016)," Environmental Health Hazards of Solid Waste Dumping in Calicut City Corporation", *International Journal of Research and Analytical Reviews*, e ISSN 2348 –1269, Print ISSN 2349-5138

[11] Rusdianasari, Ahmad Taqwa , Jaksen and Adi Syakdani (2017), "Treatment of landfill leachate by electrocoagulation using aluminium electrodes", *MATEC Web of Conferences* , 02010 (2017) DOI: 10.1051

[12] S Ispara Xavier et al (2021),"Characteristics Study on Leachate Samples of Laloor, Thrissur", *Journal of Physics*: Conference Series2040 012053

[13] Tahereh Rookesh , Mohammad Reza Samaei , Saeed Yousefinejad , Hassan Hashemi , Zahra Derakhshan , Fariba Abbasi , Mahrokh Jalili , Stefanos Giannakis and Muhammad Bilal (2021)," Investigating the Electrocoagulation Treatment of Landfill Leachate by Iron/Graphite Electrodes: Process Parameters and Efficacy Assessment ", *Water* 2022, 14, 205

[14] Xiangdong Li, Junke Song, Jiandong Guo, Zhichao Wang, Qiyan Feng (2011), "Landfill leachate treatment using electrocoagulation", *Procedia Environmental Sciences* ,10 (2011) 1159 – 1164