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RESEARCH ARTICLE

ELECTROCHEMICAL TREATMENT OF COFFEE PULPING WASTEWATER USING ALUMINUM ELECTRODES

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ABSTRACT

Coffee processing involves large volume of water and wastewater. Coffee grown in many regions is processed using the wet method in order to be commercialized as green coffee. The coffee pulping wastewater from source-1 was characterised by low pH which varying between 3.92 to 4.99 and high COD between 8,320 mg/L to 10,400 mg/L, BOD 160 mg/L, total solids concentration was 5,000 mg/L, phosphorus varying between 60 mg/L to 94 mg/L, nitrate nitrogen varying between 32 mg/L to 52 mg/L, and ammonia nitrogen concentration was in the range of 50 mg/L to 84 mg/L. For wastewater to be easily treated in biological reactor the BOD_5 / COD should be 0.5 or greater i.e., the waste is considered to be easily treatable by biological treatment. Since the BOD_5 / COD ratio of coffee pulping wastewater was considerably less than 0.5 electrochemical treatment was tried to improve the BOD_5 / COD ratio using aluminium electrode. The studies done for treating the raw coffee pulping wastewater by electrochemical method resulted in 93 %, 83 % and 90 % removal efficiency of COD, phosphorus and nitrate nitrogen respectively.

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INTRODUCTION

Water is very important for coffee fruit processing - where the pulp portions surrounding the coffee bean is squeezed out and washed thoroughly with copious quantities of water drawn from the nearest tank or streams that feed these tanks. Coffee processing takes place after the monsoon fades away and there is little flow of water in the various streams arising from the western ghats. To overcome this shortage, water from natural and manmade lakes and water bodies are pumped out and the resultant spent water, treated only partially, becomes the main source of water to the next water body (usually another lake /tank) downstream. There are very few coffee plantations that have the capability to remove all undesirable organics and minerals from the coffee effluents before they reach various water bodies downstream. Sometimes the problem is so severe that in many towns downstream, drinking water pumped from natural tanks possess a deep purple shade - characteristic of partly treated coffee effluents reaching these water bodies. Today, coffee cultivation has gradually spread from the wetter hill slopes of the western ghats to the adjoining drier rolling lands where natural and manmade water bodies are important water reservoirs. Coffee processing has now created a great demand for water stored in these reservoirs and is adding a new dimension to this problem.

The BOD_5 / COD ratio of coffee pulping wastewater depend on the nature of the wastewater namely, whether it is municipal or industrial oriented and vary considerably with the degree of treatment the wastewater has undergone. According to Metcalf and Eddy (2003) the BOD_5 / COD ratio should be in the range of 0.3 to 0.8 for biodegradability of wastewater and some industrial raw wastewater it will be less than 0.4 (Krishna *et al*., 2009). Un *et al*. (2002) has found that if the BOD_5 / COD ratio of the effluent is less than it could cause destruction of micro-organisms useful for the degradation. If the BOD_5 / COD ratio for the untreated wastewater is 0.5 or greater, than waste is considered to be easily treatable by biological treatment means.

From the pervious electrochemical treatment have been successfully demonstrated for the removing pollutants in different type of wastewater and also it is the most better method for increasing the BOD_5 / COD ratio by treating the recalcitrant contaminants present in the wastewater (Khoufi *et al*. (2006) Krishna *et al*. (2009) Kobya *et al*. (2003). In the present study the ratio of raw coffee pulping wastewater was found to be 0.125 which is below the range therefore in order

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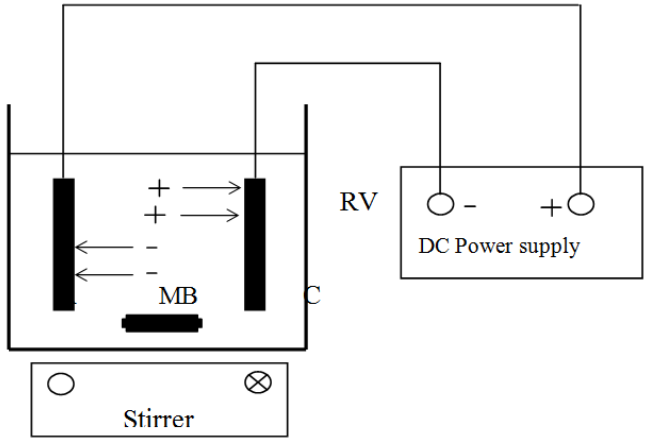
to increase the BOD_5 / COD ratio electrochemical treatment is provided even though the waste is high organic in nature but it is in recalcitrant form. From the earlier research it was found that electrochemical treatment was adapted for the treatment of different types of wastewater. In the present study an attempt has be made for the treatment of coffee pulping wastewater by electrochemical treatment.

Electrochemical Reactor Setup

During the study the electrochemical setup is as in the Fig. 1. electrochemical reactor employed in the study consists of anode and cathode material as aluminium (5cm × 5cm). These electrodes are positioned in vertically and parallel to each other with an inter electrode gap of 1 cm. The experiments were done using 1 litre of coffee pulping wastewater with constant stirring using magnetic stirrer to maintain uniformity throughout the system. The analysis of sample was done after filtering it using filter paper. 16 V power supply was maintained using direct current power supply unit (Textronix 35D).



A-Anode, C-Cathode, MB-Magnetic Bit, RV-Reactor Vessel

Figure 1. Electrochemical batch reactor setup

Electrochemical Treatment of Coffee Pulping Wastewater

Coffee pulping wastewater for the experiment was collected from pulping units of coffee estates located in Chickmangalore and Mercara districts. For treating the coffee pulping wastewater aluminum was used as electrodes since it is more economical when compared to other electrodes such as copper, iron, titanium etc. Previous researchers have tried electrochemical treatment of different high strength industrial wastewater with different type of electrodes with varying degree of pollutant removal. The implementation of electrochemical processes in treatment of wastewater can result in the destruction of organic contaminant and led to efficient removal of the BOD_5 and COD. A typical electrochemical treatment led to color removal from the wastewater and formation of foam laden with suspended solids. The visible color removal of coffee pulping wastewater in electrochemical treatment was found to be good. Prasad and Srivastava (2009) have found that at higher pH the hypochlorous acid converts itself into chlorate or hypochlorate. Thereby in reduced availability of hypochlorite at higher pH which causes reduction in decolorization. Another reason may be at acidic pH, the chlorine is present in the solution in the form of hypochlorous acid, which is having higher oxidation potential (1.49 V) than that of hypochlorite (0.94 V) where hypochlorite is prevalent in the alkaline condition. In this study electro flotation of the pollutants was observed with scum floating on the surface of water by tiny bubbles of hydrogen and oxygen gases generated from water electrolysis. Probably, the electrochemical reactions at the cathode and anode are hydrogen evolution and oxygen evolution reactions respectively. Initially more foam was formed at high current density due more rapid gas evolution. Furthermore the foam found to be suppressed substantially towards the end of the treatment time. During this study the electrodes distance maintained was 1cm to 2 cm and the volume of wastewater used was 1 L. The voltage maintained was 16 V and during the treatment period the wastewater was continuously stirred using magnetic stirrer. For the removal of 3,232 mg of COD, 27.75 mg of Aluminum electrode is required in electrochemical treatment. The performance of electrochemical reactor is shown in Table 1.

Table 1. Characteristic of Raw coffee pulping wastewater

Parameter	Concentration
pH	3.92-4.99
COD mg/L	8,320-10,400
BOD mg/L	160
Total Solids mg/L	5000
Total Dissolved Solids mg/L	4500
Ammonia nitrogen mg/L	53-84
Nitrate-Nitrogen mg/L	32-52
Phosphorous mg/L	60-94
Chlorides mg/L	63-72
Alkalinity mg/L	85-95
Total Hardness mg/L	560-750
Aluminum mg/L	1.2-1.3
Iron mg/L	6.2-6.86

Table 2. Performance of Electrochemical Treatment Reactor for Coffee Pulping Wastewater

Days	COD, mg/L		Nitrate nitrogen, mg/L		Phosphorus, mg/L		Voltage (V)
	Raw	Treated	Raw	Treated	Raw	Treated	
1	8534	756	40	BDL	40	BDL	16
2	8340	790	42	BDL	46	BDL	16
3	9349	753	43.6	1.6	47	BDL	16
4	8584	726	41.3	1.3	46	BDL	16

The raw coffee pulping wastewater COD was in the range of 8,340 mg/L to 9,349 mg/L, nitrate nitrogen concentration in the range of 41 mg/L to 44 mg/L and phosphorus concentration was in the range of 40 mg/L to 47 mg/L. The duration of electrochemical treatment was 96 minutes and aluminum was used as electrode. The results of this study are shown in Table 1. The performance of the reactor was found to be good. After electrochemical treatment COD was in the range of 726 mg/L to 790 mg/L with the removal percentage of 78 % to 85 %. While the nitrate nitrogen concentration was less than 2.6 mg/L and phosphorus concentration was Below Detection Level (BDL). The percentage removal of nitrate nitrogen was varying in the range of 87 % to nearly 100 % and phosphorus was nearly 100 %.

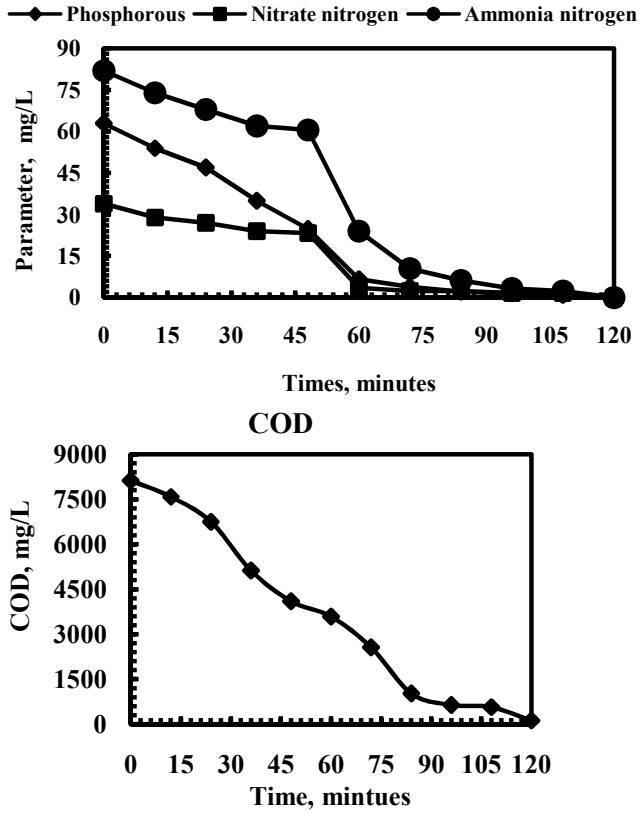


Figure 1. Varitions of parameter (P, NO_3-N, NH_3-N, COD) during Track Study

It is evident from Fig. 1 that maximum of 98 % COD reduction has been achieved in 120 minutes of electrolysis duration. The experiment was continued for two hours and there was slight decline in COD removal. This may be due to the exhaustion of hypocholrite ($HOCl_3^-$) and free chlorine generation in-situ in the reactor (indirect oxidation) and secondly, due to deposition of toxic metal/materials on the anode (direct oxidation) which might have further prevent COD removal. It can be observed that BOD_5 / COD increased form 0.1525 to 0.4 at 120 minutes, suggesting increase in biodegradability with an increase in electrolysis duration. In this experiment the COD reduced from initial concentration of 8,250 mg/L to 120 mg/L while BOD_5 increased from the initial value of 160 mg/L to 250 mg/L at optimum electrolysis duration of 120 minutes. The increase in BOD_5 concentration is attributed to the fact that some of the organics have broken down into smaller fragments, which are more biodegradable than parent compounds (Krishna *et al*., 2009)

Track study was done during electrochemical treatment to know the variations in pollutant parameters. Track study was done with raw coffee pulping wastewater was fed to the reactor and at every 12 minutes time interval the samples were collected. From the Fig. 1 it was observed that COD of the influent sample gradually decreases with increase in time where the initial concentration of COD was 8,124 mg/L and it was gradually decreases to 3,584 mg/L in first 60 minutes, in 84 minutes it was deceased by 87 % of initial concentration. The maximum removal efficiency of COD was 120 mg/L with percentage removal of 98 % which occurred at electrolysis time of 120 minutes.

Fig. 1 shows the removal of nitrate nitrogen, ammonia nitrogen and phosphorus with time. In the first 12 minutes the nitrate nitrogen was reduced from 34 mg/L to 29 mg/L, ammonia nitrogen reduced from 82 mg/L to 74 mg/L and phosphorus was reduce 63 mg/L to 54 mg/L. By 60 minute nitrate nitrogen, ammonia nitrogen and phosphorus was reduced to 3.49 mg/L, 24 mg/L and 6.7 mg/L respectively. Fig.1 specifically gave the best removal percentage of phosphorus as 96 %, while removal of nitrate nitrogen and ammonia nitrogen was achieved 93 % and 96 % respectively. When the reaction time was increased the nitrate nitrogen, ammonia nitrogen and phosphorus was BDL.

Conclusion

Based on the findings of this study, the electrochemical technique can be effectively used for the treatment of coffee pulping wastewater using aluminum electrode. The electrolytic efficiency was primarily based on the efficiency of COD removal and improvement in BOD_5 to COD ratio. The efficiency of aluminum electrode in terms of COD removal was 98 % at 120 minutes of electrolysis duration, at a voltage of 16 V and wastewater pH of 4.56. There was an improvement in biodegradability of wastewater with BOD_5/COD ratio. The COD removal rate for aluminum electrode was found to be 7.16 kg COD h^{-1} A^{-1} m^{-2} and energy consumption was found to be 891.01 W h/ Kg COD. After the electrochemical treatement of coffee pulping wastewater charaterstic was found to be in the dischargable limit ie COD was 120 mg/L, phosphorous and nitrogen below BDL where the water can be discharge in to near by river source and can be used for plantation for the watering purpose.

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