International Journal of ChemTech Research
CODEN(USA): IJCRGG ISSN : 0974-4290
Vol.6, No.1, pp 339-346, Jan-March 2014

Performance Evaluation of two Batch Operations using Electrochemical Coagulation followed by Sequential Batch Reactor in treating Coffee wastewater

S Mahesh[1], Srikantha H[1*], Aashith Loren Lobo[2]

[1]Department of Environmental Engineering, Sri Jayachamarajendra College of Engineering, Mysore-570006, Karnataka State, India

[1*, 2]Department of Environmental Engineering, Adichunchanagiri Institute of Technology, Chikamgaluru-577102, Karnataka State, India.

*Corres.author: sriki.env@gmail.com

Abstract: In this paper, we present color, solids and organic matter removal from Electrochemical coagulation (ECC) followed by Sequential batch reactor (SBR) of coffee wastewater. Sacrificial electrode (Aluminium) dissolutions controlled by the cell voltage was found as key factor. Electrocoagulation is used as a pretreatment which is then followed by sequential batch reactor. Electrochemical coagulation is conducted in wide range of voltages from 5 to 40 volts to find optimum voltage for a time period of 60 minutes. Samples were collected at a time interval of 15 minutes each and were analyzed. Efficiency obtained were ~97 % for removal of color, ~60 % of solids and ~64 % for removal of organic matter in electrochemical coagulation. After electrochemical coagulation wastewater is passed to sequential batch reactor for further treatment. Sequential batch reactor is a biological treatment process, where wastewater was treated in a batch by adding cow dung slurry as seeding innoculum. Whole process is divided into five phases with total time period of eight hours. Overall efficiency obtained after both the processes was ~93 % in the removal of color, ~62 % removal in solids and ~84 % in removal of organic matter
Key words: Electrochemical coagulation (ECC), Sequential batch reactor (SBR), Coffee wastewater.

INTRODUCTION

India is one of the leading producers of good quality coffee since from decades, which is grown in southern states of India like Karnataka, Tamil Nadu and Kerala[1]. The coffee industry uses large quantities of water during the various stages of the production process[2]. The wet processing of coffee cherries is an alternative, however generates a large amount of wastewater, rich in suspended organic matter, organic and inorganic compounds in solution, with high polluting potential which must be necessarily treated before its release into receiver water bodies[3]. The macromolecules contain mainly lignins, tannins, humic acid, which are all highly structured compounds. Such macromolecules are difficult to degrade using conventional biological treatment processes and are responsible for the color of the wastewater[2]. In Karnataka state the coffee pulping wastewater is disposed into unlined kutcha pits and major disadvantages associated with it are odour problems, mosquito breeding and low loading rates, unsatisfactory treatment and loss of cultivable area[4].

Electrocoagulation is an electrochemical method of treating industrial wastewaters whereby sacrificial anodes dissolve to produce active coagulant precursors into solution[5]**.** Electrochemical oxidation is one of the advanced oxidation processes, potentially a powerful method of pollution control[6, 7]. [8] have reported the effectiveness of electrochemical technology using iron electrodes for treating paper and pulp mill wastewater removing ~91 % COD and 100 % .colour. [9] studied the removal of color and organic compounds from biologically treated coffee curing wastewater by an electrochemical oxidation method.

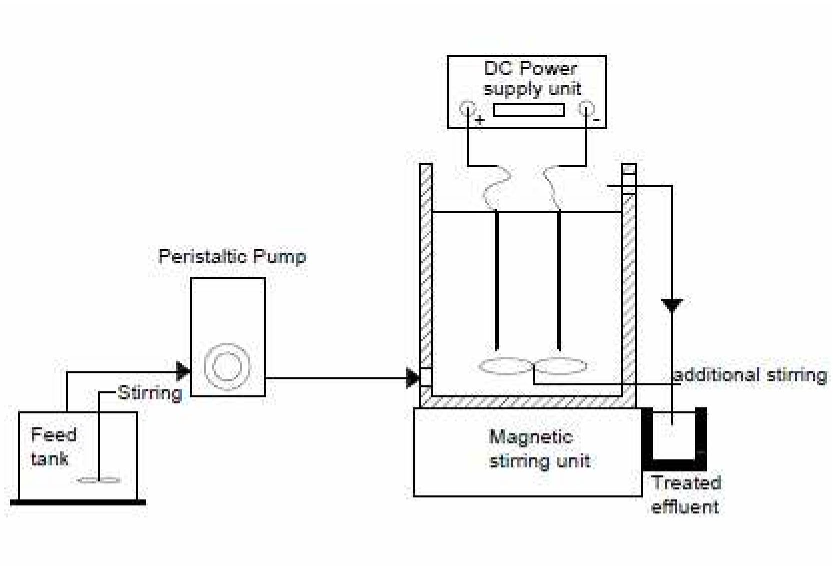
Sequencing batch reactors (SBR) have become a popular means of providing activated sludge treatment. With proper design and configuration, SBRs will provide very low effluent nutrient levels[10]. The cycle for each tank in a typical SBR is divided into five discrete time periods: Fill, React, Settle, Draw and Idle[11].Nitrogen and phosphorus are not toxic chemicals; however, they are limiting nutrients for algal growth. As a result, since the input of these elements to aquatic environments accelerates eutrophication, nitrogen and phosphorus must be removed from discharged wastewater effluents[12]. SBRs are often operated under high total solids concentration conditions, compared with operating conditions associated with conventional wastewater treatment plants. This enables a reduction in SBR reactor volumes, thus decreasing investment costs for the treatment plant[13].

MATERIALS AND METHODS

The coffee wastewater used for both Sequential Batch Reactor (SBR) and Electrocoagulation (ECC) experiments was collected from Ballupet Estate, Chikamagalur, India. Raw wastewater samples were collected in polymer containers, characterized and used as is in the laboratory batch scale experiments. Characterization for physico-chemical parameters were carried out as per standard methods[14].

As treatment of coffee wastewater using SBR alone showed less efficiency due to higher organic loading, electrocoagulation is used as pretreatment. The electrocoagulation was carried out using aluminium electrodes and for different voltages from 5 to 40 volts and time duration of 60 minutes and samples was collected at every 15 minutes interval. Aluminium plates were used as electrodes (anode and cathode) and were arranged in bipolar configuration. Reactor for both SBR and ECC were made up of plexi glass and of cubical shape. Total volume of reactor is 3.3 L with a SA/V ratio of 4.34 m^2/m^3. A tap is fixed on a side wall of the reactor at a height of 3 cm from the bottom to withdraw the treated effluent. Three liters of wastewater was treated at a time and top 0.3 L of volume is left as sludge margin (Figure 1).

Figure 1: Laboratory bench scale ECC experimental set-up



In sequential batch reactor also the volume of 3.3 L was used, wastewater is added to a single batch reactor, treated to remove undesirable components, and then discharged. Each operating cycle of SBR comprises of five distinct phases. The total run for the SBR system was kept for eight hours. Out of these, three hours each for fill and react phase, one hour each to settle and draw the wastewater after treatment. Finally idle stage is used to remove the settled sludge and to clean the reactor. Addition of seeding increases the efficiency of SBR, so cow dung slurry is used for the purpose. Slurry is prepared using cow dung and domestic wastewater sludge mixed together in equal amount. The slurry is kept for a period of 10 days with periodic stirring before it could be used as seeding Innoculum. The wastewater was allowed to flow into the reactor with the help of a peristaltic pump. An aerating pump of capacity 2.5 L/min was used for uniform aeration.

RESULTS AND DISCUSSIONS

Untreated raw coffee wastewater used in the studies had the characteristics of pH 3.92; BOD 3600 mg/L: COD 9000 mg/L; color 3900 Pt-Co: Total dissolved solids 780 mg/L: Nitrate 120 mg/L: Phosphorous 118 mg/L. pH change was observed and a slight increase in bulk solution temperature during ECC. pH was seen to change from 3.92 before ECC to 4.25 just after ECC.

Electrochemical coagulation (ECC)

Coffee wastewater is usually rich in color due to the presence of flavanoids which induces dark green or brown color. Although these are harmless in every sense, they ought to be removed as they are aesthetically unacceptable. Coffee wastewater had initial color of 3900 Pt-Co units**.** Figure 2 shows the variation in color, electrocoagulation proved to be very much effective and the effluent was almost removed at electrolyze time 45 minutes, 35 V with the value of 221 Pt-Co units, achieving the efficiency of ~95 %.

Total dissolved solids are used as an indication of aesthetic characteristics and as an aggregate indicator of the presence of a broad array of chemical contaminants. The initial TDS concentration of coffee wastewater was found to be 780 mg/L and after treating with electrocoagulation (Figure 3), the concentration decreased to 300 mg/L (~61 % removal).

Coffee wastewater is usually rich in organic content and thus BOD was very high. Initial BOD was 3600 mg/L which indicates that dissolved oxygen concentration was almost nil. But as the experiment proceeded, BOD decreased and final concentration obtained was 1256 mg/L (Figure 4).

Figure 5 shows COD removal during ECC of coffee wastewater for aluminium electrode at different receiving applied cell voltages. As can be seen in the figure 5, an applied cell voltage of 35 V provides as much as ~65 % COD removal (3160 mg/L) from its initial value of 9000 mg/L. Electrolyze times of 45 min was found sufficient to remove COD.

All ECC experiments that followed were carried out at 40V, 60 min ET, with a set of aluminium electrodes at an electrode spacing of 1cm. Due to high organic loading, treatment of coffee effluent using only ECC did not yield good results. Electrochemical coagulation alone gave an overall efficiency of more than 65 % in removal of organic matter. Hence electrocoagulation was used as pretreatment for SBR and ECC optimum voltage and time was proved to be 35V and ET 45 min respectively.

Sequential Batch Reactor (SBR)

Color of coffee wastewater considerably decreases after undergoing electrocoagulation (~97%). Figure 6 showed that SBR proved useful in removing color to a small extent. Even though color appears to be increased after adding innoculum, after settling, the color has been found to have decreased by about maximum of ~85 % for the innoculum dosage of 2 %.

Figure 7 shows SBR does not prove to be effective for TDS removal. In fact for some innoculum dosages TDS was found to be increased. Minimum TDS concentration of 300 mg/L was found at 2 % innoculum dosage. So it can be concluded that SBR is not effective for TDS removal.

BOD is the amount of oxygen required by microorganisms to degrade organic matter. Like other biological processes, SBR is efficient in removal of organic content. Overall removal efficiency was around ~85 % with minimum BOD of 525 mg/L at 2 % innoculum dosage. Thus SBR can be effectively used for the removal of BOD. Figure 8 shows BOD concentrations at different innoculum dosages.

As in the case of BOD, COD has also been observed to decrease consistently with the increase in innoculum dosages up to 2 %, which is shown in figure 9. Minimum COD concentration was obtained at 2 % innoculum dosage. Removal efficiency obtained was more than ~85 %.

In the study, as the SBR alone proved to be less efficient, the combination of SBR process with electro coagulation as the pretreatment method has been done. 35 volts and 45th minute was the optimum voltage and time respectively for electrocoagulation and 2 % innoculum dosage as the optimum dosage for SBR. From the Table 1, we can conclude that combining electrocoagulation with SBR has more efficiency in treating coffee wastewater than SBR alone.

Figure 2; Variation in color with respect to different time and voltages

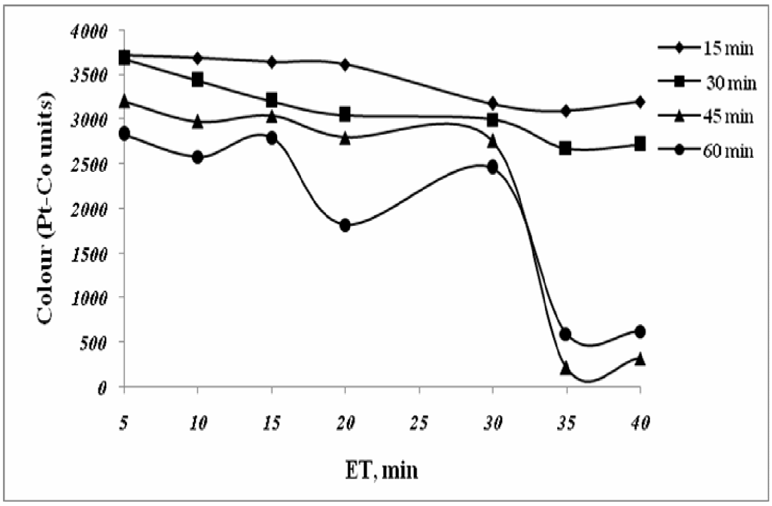


Figure 3: TDS degradation curves as a function of different applied voltages

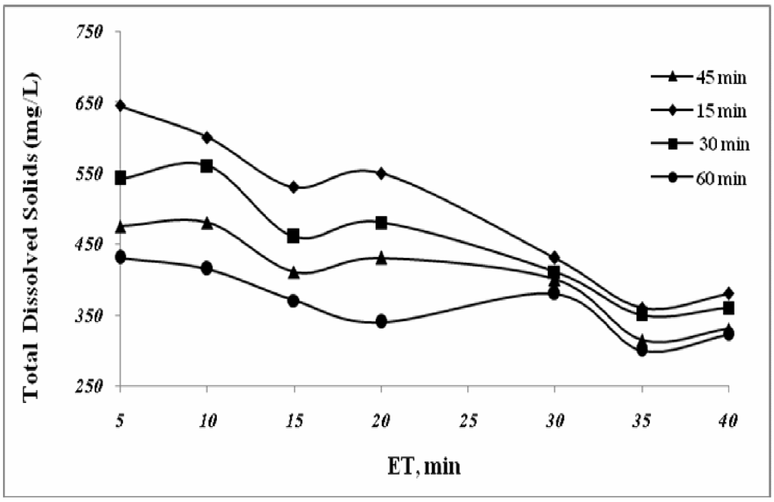


Figure 4: Degradation curves for BOD using aluminium electrodes in operating conditions

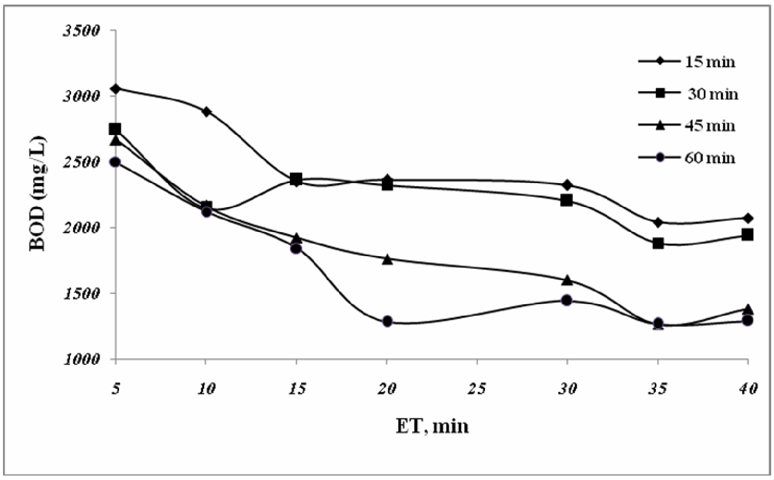


Figure 5: COD degradation curves as a function of electrolyze time for different applied cell voltages

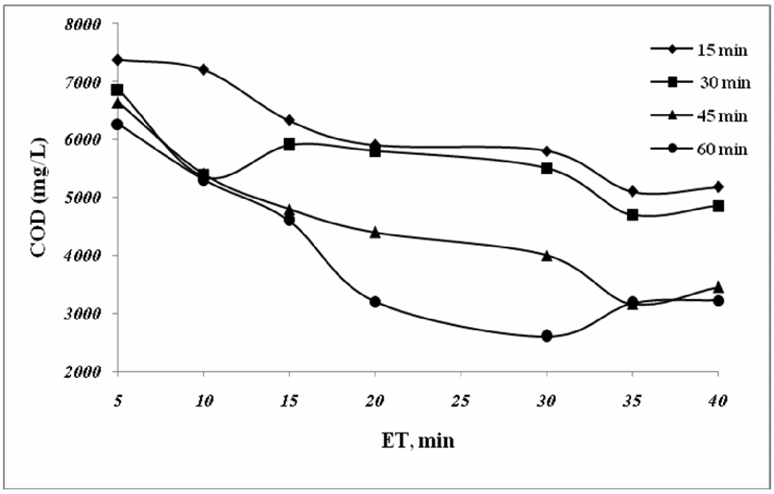


Figure 6: Color variations with respect to innoculum dosages

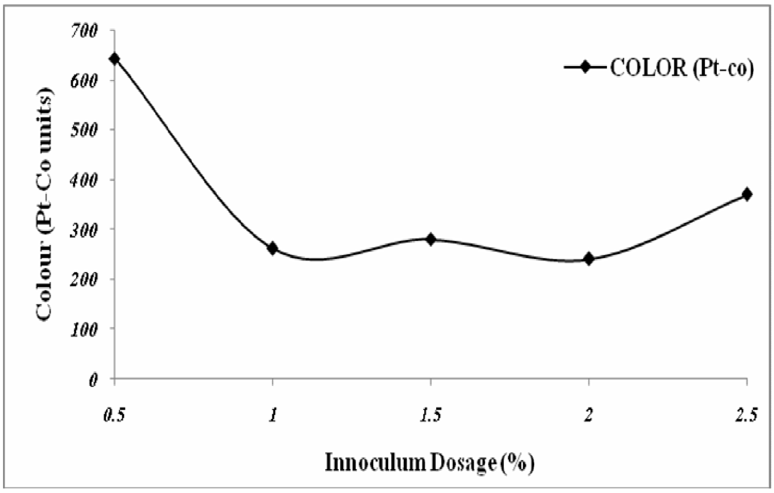


Figure 7: Variation in TDS after adding inoculums

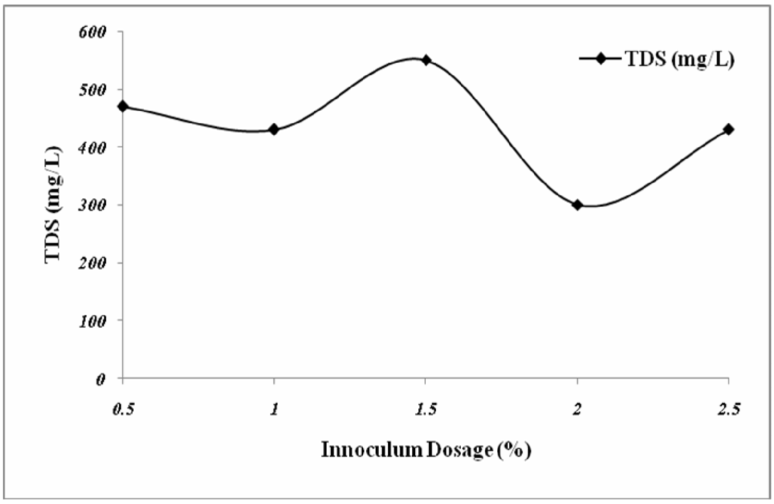


Figure 8: BOD variations after seeding inoculums

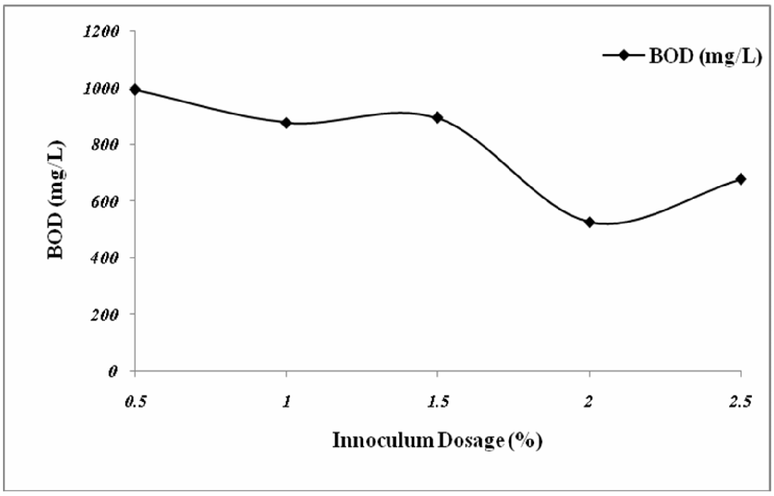


Figure 9: COD dosage variations

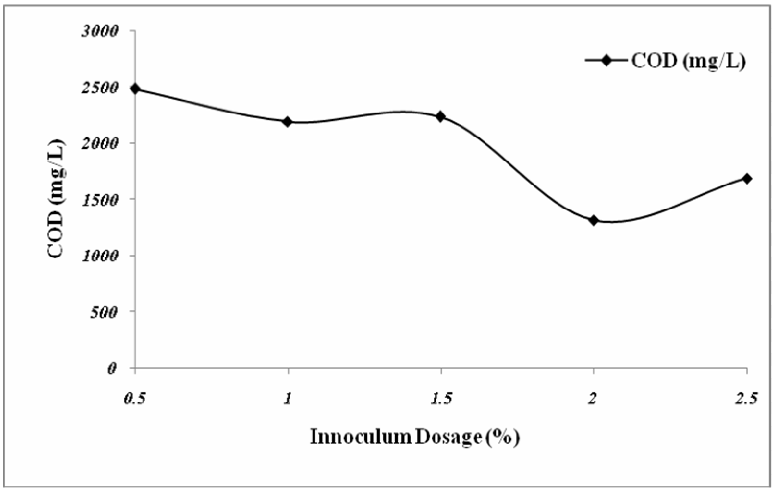


Table 1: Comparison of ECC vs SBR for different operating parameters

Parameter	Initial concentration	ECC (35V and 45 minutes)	SBR after ECC
Color (Pt-Co)	3900	121	240
TDS (mg/L)	780	315	300
BOD (mg/L)	3600	1256	525
COD (mg/L)	9000	3140	1313

CONCLUSIONS

- Due to high organic loading, treatment of coffee effluent using only SBR did not yield good result. Hence electrocoagulation was used as pretreatment and optimum voltage and electrolyze time was found out to be 35 volts and 45 minutes respectively. Similarly, in SBR process 2 % innoculum dosage was found to be optimum.
- Coffee wastewater is rich in color and initial color was 3900 Pt-Co units. After electrocoagulation, the color decreased to 121 Pt-Co units with a removal of ~93 %. After adding innoculum the color again increased to 240 Pt-Co units. Hence it can be concluded that electrocoagulation is very effective in the removal of color and SBR is not an option.
- Initial TDS concentration of coffee wastewater was 780 mg/L. After undergoing electrocoagulation process, the concentration decreased to 300 mg/L and even after SBR the concentration remained same. It can be observed that electrocoagulation and SBR had an efficiency of around ~62 %. Hence both the processes are not the ideal options for removal of TDS in case of coffee wastewater.
- Due to presence of abundant organic content, initial BOD in coffee wastewater was 3600 mg/L. Both electrocoagulation and SBR were effective in decreasing BOD and final concentrations obtained were 1264 mg/L and 525 mg/L respectively. That marks an overall BOD removal of around ~85 %. Hence it could be concluded that both electrocoagulation and SBR are very much useful in removing BOD.
- As in the case of BOD, both the processes were very effective in decreasing COD and the concentration decreased to 3160 mg/L after electrocoagulation from initial concentration of 9000 mg/L. The final concentration obtained after SBR was 1313 mg/L with an overall efficiency of above ~85 %. Hence both the processes could be approved to be useful in COD removal.

REFERENCES

1. Mohana V.S., Nandini N, Pramila C.K and Manu K J, Effect of Treated and Untreated Coffee Wastewater on Growth, Yield and Quality of Palmarosa Grass (Cymbopogon martini L.) var. motia, International Journal of Research in Chemistry and Environment, 2011, Vol. 1 Issue 2, pp 111-117.
2. Zayas P'erez Teresa, Geissler Gunther, Hernandez, and Fernando, Chemical oxygen demand reduction in coffee wastewater through chemical flocculation and advanced oxidation processes, Journal of Environmental Sciences, 2007, 19, pp 300–305.
3. Ronaldo Fia, Antonio Teixeira de Matos and Fátima Resende Luiz Fia, Biological systems combined for the treatment of coffee processing wastewater: II - Removal of nutrients and phenolic compounds, Acta Scientiarum. Technology Maringá, 2013, v 35, pp 451-456,
4. Manoj Kumar B, Savitha Ullavi, Ramesh H. S, Asha G, Pallavi R, Pretreatment of coffee pulping wastewater by Fenton's reagent, Indian journal of Chemical Technology 2012, vol 19, pp 213-217
5. Zaied M, Bellakhal N, Electrocoagulation treatment of black liquor from paper industry, Journal of Hazardous materials, 2009, pp 995-1000,
6. Mahesh S, Prasad B, Mall I D, Mishra I M, Electrochemical degradation of pulp and paper mill wastewater. Part 1. COD and Color removal, Ind Eng. Chem. 2006, Res 45(8), pp 2830-2839.

7. Mahesh S, Thapaswini M R, Anitha S, Electrochemical Coagulation (ECC) of textile wastewaters – COD removal, Settleability & Filterability Aspects. International Journal of Advances in Management, Technology and Engineering, 2012.
8. Mahesh S, Prasad B, Mall I D, Mishra I M, Electrochemical degradation of pulp and paper mill wastewater. Part 2. Characterization and analysis of sludge, Ind Eng. Chem. 2006, Res 45(8), pp 2830-2839,
9. Bejankiwar R S, Lokesh K S, Gowda T P, Colour and organic removal of biologically treated coffee curing wastewater by electrochemical oxidation method [J]. J Environmental Sci, 2003, 15(3): pp 323–327.
10. Alvin C. Firmin , Comparison of SBR and Continuous Flow Activated Sludge for Nutrient Removal
11. Wisaam S. Al-Rekabi, He Qiang and Wei Wu Qiang, Review on Sequencing Batch Reactors, Pakistan Journal of Nutrition, 2007, 6 (1): pp 11-19.
12. Seong-Jin Lim, Ra Kyung Moon, Woo Gi Lee, Sunhoon Kwon, Byung Geon Park, and Ho Nam Chang, Operation and Modeling of Bench-Scale SBR for Simultaneous Removal of Nitrogen and Phosphorus Using Real Wastewater, Biotechnol. Bioprocess Eng. 2000, 5: pp 441-448.
13. Sirianuntapiboon, S., Tondee, T., Application of packed cage RBC system for treating wastewater contaminated with nitrogenous compounds. Thammasat Int. J. Sci. Technology. 2000; 5: pp 28–39.
14. American Public Health Association (APHA), American Water Works Association and Water Pollution Control Federation, Standard Methods for the Examination of Water and Wastewater, 20th ed, Washington DC, USA, 1988.

*****