International Journal of Application or Innovation in Engineering & Management (IJAIEM)
Web Site: www.ijaiem.org Email: editor@ijaiem.org
Volume 3, Issue 10, October 2014 ISSN 2319 - 4847

Feasibility Studies on Spent Coffee Grounds Biochar as an Adsorbent for Color Removal

Chinmai K.[1] , Hamsa B. C. [2], Kerwyn Donald D'souza[3], Mahesh Chandra B. R. [4]and Shilpa B. S. [5*]

[1, 2, 3, 4]UG Students, Dept. of Environmental Engg. Vidyavardhaka College of Engg., Gokulam III stage, Mysore- 02

[5] Assoc. Professor, Dept. of Environmental Engg. Vidyavardhaka College of Engg., Gokulam III stage, Mysore- 02

ABSTRACT

The present work objective is to study the feasibility of spent coffee grounds (SCG) biochar as an adsorbent for color removal. SCG were collected from a local cafeteria. The composite SCG sample was prepared for biochar production by washing with distilled water and drying at 100^{o}C for 24 h in a hot air oven. The prepared spent coffee grounds were filled in mud pot fitted with a lid and introduced into the muffle furnace at temperatures 300,400 and 500^{0}C for 4hrs for pyrolysis process. The SCG biochar (BC300, BC400 and BC500) was sieved and the SCG biochar of 0.3mm size was used in the present work. The optimum dosage for BC300 and BC400 was found to be 3.3g, and for BC500 it was found to be 3g. The optimum pH for BC300 was found to be 2, for BC400 and BC500 it was found to be 1. Coffee pulping wastewater was collected and its initial parameters were measured. The initial COD was found to be 19840 mg/L and after treatment under optimum conditions, the final COD was found to be 16480mg/L, 110240mg/L and 11200mg/L for BC300, BC400, and BC500 respectively. The initial BOD was found to be 4134 mg/L and after treatment under optimum conditions, the final BOD was found to be3400mg/L, 2200mg/L and 2400mg/L for BC300, BC400, and BC500 respectively. The initial color concentration of the coffee pulping wastewater was found to be 0.47 mg/L and after treatment under optimum conditions, the final color concentrations were found to be 0.29mg/L, 0.41mg/L and 0.39 mg/L for BC300, BC400, and BC500 respectively. The efficiency of BC300, BC400 and BC500 in color removal was found to be 38.28%, 45% and 17.49% respectively.

Keywords: Biochar, Color, Spent coffee grounds, Coffee pulping wastewater

1. INTRODUCTION

The color of the water is an indication that it contains contaminants of different materials and in varying concentrations. Color of water is aesthetically unacceptable; hence water has to be treated for the removal of color. A very small amount of color in water is highly visible. Wastewater effluents from different industries contain color. Further, discharging even a small amount of color into water can affect aquatic life and food webs due to the carcinogenic and mutagenic effects of synthetic color. Hence, it is imperative that a suitable treatment method should be devised. Many industrial wastewater have color such as textile industry, pulp and paper mill, tannery etc. Coffee effluent contains a high amount of dark brown pigments. When this waste is discharged into the river, it will not allow the sun rays and interfere in the photosynthesis process. In recent years, many methods including coagulation and flocculation, reverse osmosis, chemical oxidation, biological treatments, photo degradation, and adsorption, have been developed for treating color containing wastewater. Among various treatment technologies, adsorption technique is quite popular due to its simplicity and high efficiency, as well as the availability of a wide range of adsorbents. Activated carbon is the most popular adsorbent for removal of dye imparting color from wastewater. However, adsorbent grade carbon is not cost effective and both regeneration and disposal of the used carbon often very difficult. Therefore, there is a growing need to find locally available, low cost and effective materials for the removal of color. Hence, there is a need to search for more effective adsorbents. The quantity of coffee produced in India during the year 2012-2013 is about 318,200MT. The amount of dry coffee waste generated in India is 7.5MT per year. Spent coffee grounds are the main coffee industry residues, obtained during the beans roasting, and the process to prepare "instant coffee". Large quantities of spent coffee grounds are produced during the production and use of coffee. Therefore instead of throwing away the coffee wastes, it can be used for various purposes. Spent coffee grounds can be used as manure for plants, insect repellent, dye, deodorizer etc. But the most common method of disposal of coffee waste is land filling. Thus, the spent coffee grounds are sent to land filling. It is a loss of an intensive source of nutrients and energy. In the process of soluble coffee production, the solid residue that results from coffee extraction is pressed and dried. This residue represents approximately 50% of the input mass of coffee feedstock. Thus, a large amount of residue is annually generated in the production of soluble coffee. This requires from the industries involved the development of a wastes management plan consistent with the existing national regulations. In most of the soluble coffee production industries, the waste is collected by specialized agencies which sell the residues for different purposes (composting, gardening, bioenergy production, mushroom growth, etc.). The spent coffee waste contains large amounts of organic com-pounds like fatty acids, lignin, cellulose, hemicellulose, and other polysaccharides that justify its valorization.

Some researchers have investigated spent coffee waste as a bioresource for various valuable compounds. Thereby, coffee residue has been investigated for biodiesel production, as source of sugars, as precursor for production of activated carbon, and as sorbent for metal ions removal. In developing countries like India, industries cannot afford to use conventional wastewater treatment chemicals like alum, ferric chloride, polymer flocculants and coal based activated carbon because they are not cost-effective. An inexpensive and more easily available adsorbent would make the removal of pollutants an economically viable alternative. Use of spent coffee grounds to remove the color is one of the best alternative methods which is an cost effective and more easily available adsorbent. Biochar is a carbon-rich solid material produced during pyrolysis, which is the thermal degradation of biomass under oxygen limited conditions. Biochar is a porous black carbon made from waste biomass. Biochar can immobilize organic contaminants by adsorption. Biochar that is stable, fixed and recalcitrant carbon can store large amounts of greenhouse gases in the ground for centuries, potentially reducing or stalling the growth in atmosphere greenhouse gas levels; at the same time its presence in the earth can increase soil fertility, raise agricultural productivity, and reduce pressure on forests.

1.1 Objective

The main objective of the present work is to study the feasibility of spent coffee grounds (SCG) biochar for color removal.

Specific Objectives

- Pyrolysis of SCG under varied temperature to produce biochar
- To determine the optimum dosage of SCG biochar
- To determine the optimum pH of SCG biochar for the removal of color from synthetic water
- To find the efficacy of SCG biochar in color removal of coffee pulping wastewater.

2. MATERIALS AND METHODOLOGY

2.1 Preparation of Spent Coffee Grounds (SCG) Biochar

The spent coffee grounds used in the present work is procured from the local cafeteria. The composite SCG sample was prepared for biochar production by washing with distilled water. Plate 1 shows washed SCG and it is dried at 100ºC for 24 hours in a hot air oven as shown in the Plate 2.

Plate 1: Washed Spent Coffee grounds Plate 2: Drying of Washed Spent Coffee Grounds in Hot Air Oven

The washed and dried spent coffee grounds were filled in a mud pot fitted with a lid and introduced into the muffle furnace. The material in the crucibles was slightly pressed in order to provide as much as possible oxygen–limited conditions. The target temperatures for the production of biochars were 300,400 and 500^{0}C. The biochars found at these three temperatures are named as BC300, BC400 and BC400. The mud pots filled with the spent coffee grounds was kept in the muffle furnace for 4hrs at different temperatures for pyrolysis process. The resulting material is washed with distilled water to remove the excess ash and dried in an oven. Finally, three types of biochar were obtained, which are referred to as BC300, BC400 and BC500, where 300, 400 and 500represent the pyrolysis temperatures. The SCG biochar was sieved and the SCG biochars of 0.3mm was used for the conducting the experiments. Figure 2.1 shows the flow diagram of biochar preparation.

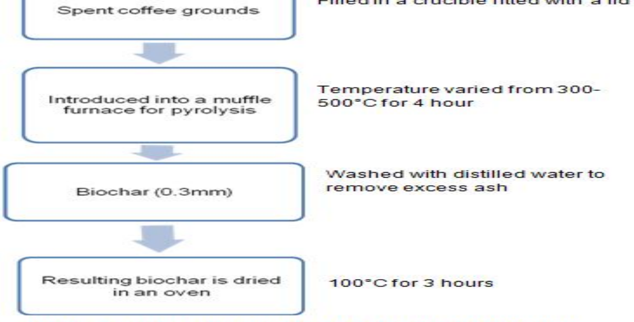


Figure 2.1: Flow Diagram of SCG Biochar Preparation

2.2 Optimum Dosage of SCG biochar

The synthetic water was prepared using Rhodamine B dye by diluting 2.33 g of Rhodamine B in 1000mL of distilled water (1mL= 1g). Standard solution is prepared by adding 5mL of Stock solution of Rhodamine B dye and diluting it to 1L by using distilled water (1mL= 0.005g). To prepare the calibration curve 2,4,6,8 and 10 mL of standard Rhodamine B solution was pipetted into Nesslers tube and diluted to 50 mL using distilled water. The absorbance of diluted solution is measured at 555nm using distilled water as a blank solution. Calibration curve is plotted for absorbance vs concentration. 100mL of the synthetic water is taken in different conical flasks and introduced in the water bath shaker. The spent coffee grounds biochar is added to the conical flasks. The water bath shaker is switched on and the biochars were mixed with coffee pulping wastewater for 30 minutes. After this the water is filtered using filter paper and the absorbance in noted down at 555nm. The dosage, at which efficiency of biochar color removal is high, is taken as optimum dosage. This is procedure is repeated for all the three biochars.

2.3 Optimum pH of SCG biochar

The same procedure is repeated to prepare the standard Rhodamine B solution as mentioned above. The pH of the synthetic water was varied to the acidic range by adding diluted HCL and varied to the alkaline range by using diluted NaOH. The optimum dosages of the biochars are added at varied pH. The efficiency of all types of biochar for color removal is found. The pH at which the color removal efficiency is greatest is considered as optimum pH.

2.4 Treatment of coffee pulping wastewater using biochar at optimum condition

The physicochemical characteristics of raw coffee pulping wastewater are measured. Coffee pulping wastewater is taken in conical flasks in a quantity of 100mL and kept it in water bath shaker. The biochars were added to the flasks. It is kept for 2 hours in the water bath shaker and final physicochemical characteristics are found out. The efficiency of reduction in concentration is measured. The color of the coffee pulping effluent was measured at 400nm using UV-Vis spectrophotometer.

2. RESULTS

3.1 Optimum Dosage

The Figure 3.1 shows the efficiency of biochar in color removal at varied dosages of BC 300, BC 400 and BC 500. The optimum dosage for BC 300 and BC 400 was found to be 3.3gm. For BC 500 the optimum dosage was found to be 3 gm.

3.2 Optimum pH

The Figure 3.2 shows the efficiency of biochar in color removal by varying the pH. It was found that optimum pH for BC 300 was 2. For BC 400 and BC 500 the optimum pH was found to be 1.

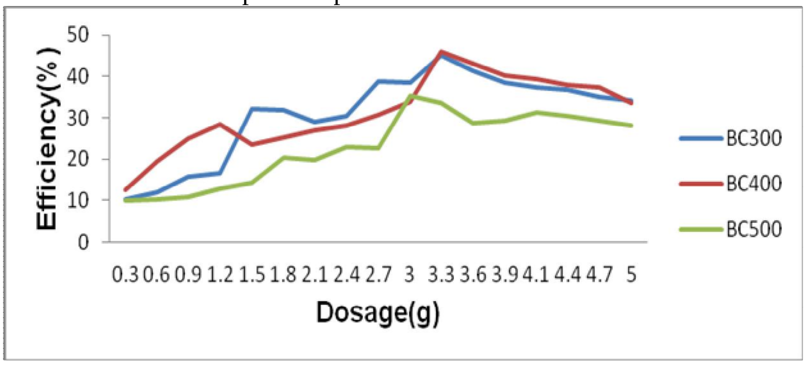


Figure 3.1 Optimum dosage of Biochars

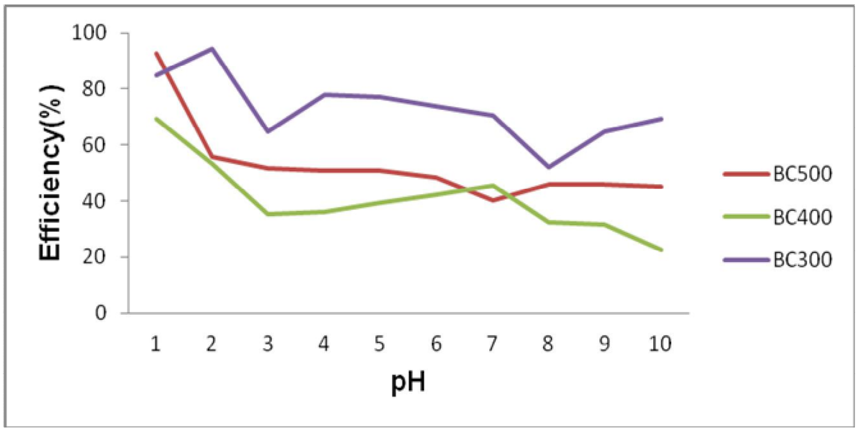


Figure 3.2 Optimum pH of Biochars

3.3 Characterization of Coffee Pulping Wastewater

The raw coffee pulping wastewater was analyzed for its physicochemical characteristics. Table 3.1 shows the physicochemical characteristics of the raw coffee pulping wastewater.

Table 3.1: Physicochemical Characteristics of Raw Coffee Pulping Wastewater

Parameter	Value
pH	4
BOD	4134 mg/L
COD	19840 mg/L
Color	0.47 mg/L

2.1 Treatment of Coffee Pulping Wastewater Using Biochar

3.4.1 Chemical Oxygen Demand (COD)

The Figure 3.3 shows COD removal efficiency of Biochars in treating coffee pulping wastewater.

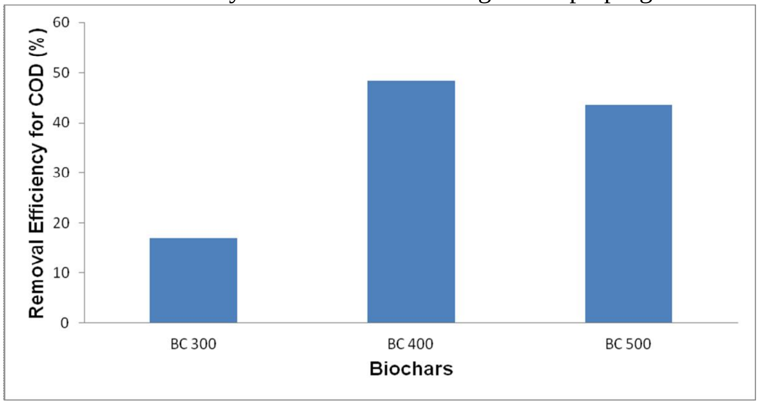
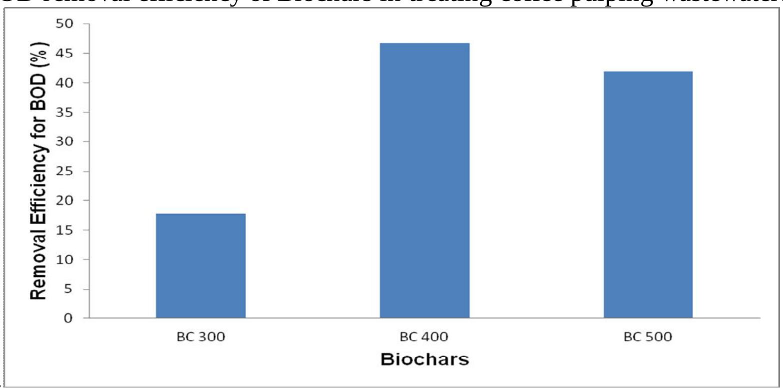


Figure 3.3: COD Removal Efficiency of Biochars

3.4.2 Biological Oxygen Demand (BOD)

The Figure 3.4 shows BOD removal efficiency of Biochars in treating coffee pulping wastewater.



.

Figure 3.4: BOD Removal Efficiency of Biochars

3.4.3 Color Removal

The absorbance was found using a spectrophotometer at 400 nm. The initial concentration of the coffee pulping wastewater was found to be 0.47 mg/L. Figure 3.5 shows color removal efficiency of Biochars.

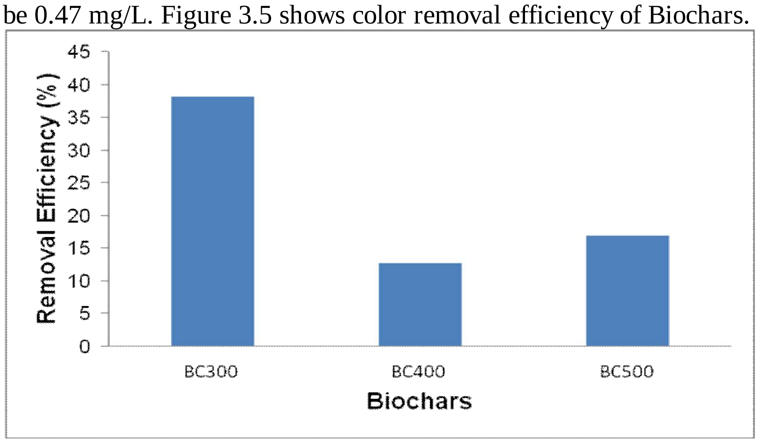


Figure 3.5: Color removal efficiency of Biochars

4. CONCLUSION

The conclusions drawn from the present work are as follows,

- The optimum dosage for the biochar BC300 and BC400 was 3.3gm and for BC500 it was 3gm
- All three biochar showed highest removal efficiency at pH 1 to 2
- The efficiency of color removal for BC300 was 38%, for BC400 it was 45% and for BC500 it was 18%
- In recent days, since sustainable development is prioritized, Biochar production is a viable waste management option in handling the spent coffee waste.

References

[1] Abhishek Sharma, Vishnu Pareek , Shaobin Wang, Zhezi Zhang, Hong Yang, Dongke Zhang (2014), "A phenomenological model of the mechanisms of lignocellulosic biomass pyrolysis processes", Computers and Chemical Engineering, 60, pp 231-241.

[2] Akwasi A. Boateng, Charles A. Mullen, Neil M. Goldberg, Kevin B. Hicks, Thomas E. Devine, Isabel M. Lima and James E. McMurtrey (2010), "Sustainable Production of Bioenergy and Biochar from the Straw of High-Biomass SoybeanLines via Fast Pyrolysis", Environmental Progress and Sustainable Energy, Vol.29, No.2, pp 175-183.

[3] David A. Laird (2008), "The Charcoal Vision: A Win–Win–Win Scenario for Simultaneously Producing Bioenergy, Permanently Sequestering Carbon, while Improving Soil and Water Quality", Agronomy Journal 100 (1), pp178-181.

[4] Didem O¨zcimen, Filiz Karaosmanoglu (2004), "Production and characterization of bio-oil and biochar from rapeseed cake" Renewable Energy 29, pp 779-787.

[5] Kurt A. Spokas, Keri B. Cantrell, Jeff rey M. Novak, David W. Archer, James A. Ippolito, Harold P. Collins, Akwasi A. Boateng, Isabel M. Lima, Marshall C. Lamb, Andrew J. McAloon, Rodrick D. Lentz, and Kristine A. Nichols (2011), "Biochar: A Synthesis of Its Agronomic Impact beyond Carbon Sequestration", Journal of Environmental Quality, 4, pp 973-989.

[6] Leandro S. Oliveira, Adriana S. Franca, Thiago M. Alves, Sonia D.F. Rocha (2008), "Evaluation of untreated coffee husks as potential biosorbents for treatment of dye contaminated water", Journal of Hazardous Materials, 155, pp 507-512.

[7] Li Wang, Junping Zhang, Aiqin Wang (2011), "Fast removal of methylene blue from aqueous solution by adsorption onto chitosan-g-poly (acrylic acid)/attapulgite composite", desalination 266, pp 33- 39.

[8] P. Pappa, F.M. Pellera and E. Gidarakos (2012), "characterization of biochar produced from spent coffee waste",CRETE 2012 – Proceedings of 3rd International Conference on Industrial and Hazardous Waste Management, pp 1-8.

[9] Puja Khare, Uzma Dilshad, P.K. Rout, Vinit Yadav, Shilpi Jain (2013), "Plant refuses driven biochar: Application as metal adsorbent from acidic solutions", Arabian Journal of Chemistry, pp 1-10.

[10] P. Senthil Kumar, S. Ramalingam, C. Senthamarai, M. Niranjanaa, P. Vijayalakshmi, S. Sivanesan P. (2010), "Adsorption of dye from aqueous solution by cashew nut shell: Studies on equilibrium isotherm, kinetics and thermodynamics of interactions", Desalination 261, pp 52-60.

[11] Ryan J. Lopez, Scott R. Higgins, Eulyn Pagaling, Tao Yan, Michael J. Cooney(2014), "High rate anaerobic digestion of wastewater separated from grease trap waste", Renewable Energy 62, pp 234-242.

[12] Rojith G. and Bright Singh I.S. (2012), "Lignin recovery, biochar production and decolourisation of coir pith black liquor", Journal of Environment Research and Development, Vol. 7, Issue 4.

[13] Savitha Ulavi, B. Manoj Kumar (2013), "Electrochemical Coagulation Followed By Sequencing Batch Reactor for Treating Coffee Pulping Wastewater" , International Journal of ChemTech Research, Vol.5, No.3, pp 1387-1389.

[14] Wan Azlina Wan Ab Karim Ghani, Ayaz Mohd, Dalia Khalid Mahmoud, Nur Zalikha Rebitanim, Lamin Sanyang, Ruziah Binti Zainudin (2013), "Adsorption of methylene blue on sawdust-derived biochar and its adsorption isotherms" pp 34-50.

[15] X. Peng, L.L. Ye, C.H. Wang, H. Zhou, B. Sun (2011), "Temperature- and duration-dependent rice straw-derived biochar: Characteristics and its effects on soil properties of an Ultisol in southern China",Soil and Tillage Research, Vol. 112, Issue 2, pp 159–166.