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Research paper

Experimental design via NaOH activation process and statistical analysis for activated sugarcane bagasse hydrochar for removal of dye and antibiotic

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ABSTRACT

In this study, hydrochar derived from SB was activated with sodium hydroxide (NaOH) by the cold alkali activation method, to increase the number of oxygenated functional groups, as well as enhance its porosity by clearing pore blockages. Response surface methodology by central composite design (RSM-CCD) was employed to investigate the effects of NaOH activation process parameters (NaOH concentration (A), hydrochar mass ratio (B) and activation time (C)) on prepared hydrochar towards three responses; activated hydrochar (AHC) yield, tetracycline (TC) antibiotic removal and crystal violet (CV) dye removal. Through the analysis of variance (ANOVA) tests, the significance sequences of single factor affecting were B > C > A for AHC yield, A > B > C for both TC removal and CV removal. However, the significant interaction effect for both AHC yield and TC removal was observed with BC only. Meanwhile, CV removal was noticed with different result whereby two significant interaction effects (AB and AC) were observed. Through optimisation study, optimised AHC (AHC_{op}) was generated by maximising all three responses and it was predicted to generate 54.23% yield with TC and CV adsorption capacity of 22.60 mg g^{-1} and 47.97 mg g^{-1}. A relative standard deviation (R.S.D) of 1.32%, 0.97% and 2.14% ($n = 3$) were obtained for AHC yield, TC and CV removal, respectively. Following optimisation, AHC_{op} was characterised by N_2 adsorption-desorption isotherm analysis, Field Emission Scanning Electron Microscopy, Fourier Transform Infrared Spectroscopy, and Thermogravimetric analysis. In brief, the physiochemical characteristics of AHC_{op} were observed with meso and macro pore structures, numerous microsphere-like particles with crack surfaces, abundance functional groups, strong π-π reaction and high thermal stability. The optimisation study was succeeded to develop AHCop at a higher yield and remove both TC and CV at higher adsorption capacity compared to before activation.

1. Introduction

Antibiotics and dyes are examples of organic pollutants available in wastewater, difficult to degrade and caused potential risk of bioaccumulation [1]. TC is a common antibiotic used in poultry, livestock and fishery industries for diseases treatment and animal growth additives [1,2]. Unabsorbed TC enters environment through the excretion by animals. Moreover, TC residues found in water can increase microbial resistance [3] and cause damage to the human digestive system [4]. Meanwhile, CV which is classified under the class of triphenylmethane dye is widely used in the fishery industry for disease prevention [5]. However, CV is highly toxic, carcinogenic, and mutagenic, thus, threatens the environment and human health [6].

Among various wastewater treatment processes, adsorption is well-known as a cost-effective treatment process because of its high removal efficiency [2]. An adsorbent with good porosity is known to have a remarkable ability to adsorb various types of pollutants from the environment including TC and CV pollutants. The carbonaceous adsorbent (i.e: activated carbon) is an example of adsorbent with good porosity and well-developed surface area [3]. It is highly efficient in removing pollutants due to its textural characteristics and functional groups available on its surface [4].

Currently, hydrochar is considered as the new emerging renewable carbonaceous adsorbent that can be produced by HTC for any types of feedstocks, compared to the traditional activated carbon used previously [5–7]. Hydrochar produced from HTC process has a high carbon content, low ash content, low degree of aromatisation and is also rich in

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