Journal of Environmental Chemical Engineering 4 (2016) 1769–1779

Contents lists available at ScienceDirect

Journal of Environmental Chemical Engineering

journal homepage: www.elsevier.com/locate/jece

Rapid adsorption of ternary dye pollutants onto copper (I) oxide nanoparticle loaded on activated carbon: Experimental optimization via response surface methodology

S. Agarwal[a,b], I. Tyagi[a], V.K. Gupta[a,b,**], A.R. Bagheri[c], M. Ghaedi[c,*], A. Asfaram[c], S. Hajati[d], A.A. Bazrafshan[c]

[a] Department of Chemistry, Indian Institute of Technology, Roorkee, 247667, India
[b] Department of Applied Chemistry, University of Johannesburg, Johannesburg, South Africa
[c] Chemistry Department, Yasouj University, Yasouj 75918-74831, Iran
[d] Department of Physics, Yasouj University, Yasouj 75918-74831, Iran

A R T I C L E I N F O

Article history:
Received 2 December 2015
Received in revised form 27 February 2016
Accepted 2 March 2016
Available online 4 March 2016

Keywords:
Adsorption
Copper (I) oxide nanoparticle loaded on activated carbon
Experimental design
Ternary dye

A B S T R A C T

Rapid adsorption of hazardous anionic dyes sunset yellow (SY), eosin B (EB) in the presence of cationic dye i.e. methylene blue (MB) from ternary solutions using copper oxide nanoparticle loaded on activated carbon(Cu_2 O-NP-AC) was well investigated and elucidated. The synthesized adsorbent was well characterized using various analytical techniques such as X-ray diffraction (XRD), and FE-SEM. The impact of effective parameters such as pH, sonication time, adsorbent dosage and initial dye concentration was well studied and optimized using central composite design superimposed with response surface methodology. The numerical optimization revealed that the optimum removal (>96.0%) for all dyes were achieved using of 0.025 g, 25, 15and15 mg L^{-1} of SY, EB and MB after 4 min sonication at pH of 5.0 at above conditions. The adsorption equilibrium and kinetic data was well fitted and found to be in good agreement with Langmuir and pseudo-second order respectively. The maximum adsorption capacities SY, EB and MB were 113, 137 and 110 mg g^{-1}, respectively.

1. Introduction

Metallurgical, chemical, ceramics, electro-galvanization, textile industrial waste effluents and pollutants such as dyes and heavy metals reaches the aqueous sources and subsequently changes the water quality i.e. made inappropriate for drinking as well as commercial usage purpose [1,2]. Organic molecules i.e. dyes due to their surface charge divided in to nonionic, cationic or anionic type [3]. The anionic dyes i.e. sunset yellow and eosin B, which are famous as reactive dyes or acidic dyes [4], even pass through conventional treatment systems and known to be very hazardous for different flora and fauna [5]. Cationic dyes, such as methylene blue (basic dyes) with high color intensity applied for brightening the textile products [6].

Sunset yellow (SY) is a composition of candies, beverages, bakery and dairy products, while Eosin b (EB) (Nitrile dye) has biological applications. Methylene blue (MB) usually used as redox indicator, in bacteria stain and as trace of viable yeast cell and dyestuff for wool, cotton, paper and silk [7–9]. The presence of these substances in natural environment (e.g. water bodies) has great focus and attention in term of toxic and aesthetic reasons [10]. Moreover, the long term exposure of these noxious dyes lead to severe detrimental and toxicological effect on human health and problem concern to these material cause construction of novel method to achieve the safe and clean environment following the elimination of these toxic material to follow their residual lower than threshold [11]. Physical, chemical and biological treatment like photocatalysis, ozonation, chemical oxidation, flotation, coagulation, membrane filtration, enzyme degradation, aerobic and anaerobic microbial degradation and adsorption [12–29] has great contribution in achievement of clean environment.

Each method has its own limitations such as generation of hazardous intermediate products, secondary effluents lower efficiency of photo and/or bio degradation via expensive procedure encounter in other approach cause that adsorption still be popular

* Corresponding author.
** Corresponding author at: Department of Chemistry, Indian Institute of Technology Roorkee 247667, India.
E-mail addresses: vinodfcy@iitr.ac.in, vinodfcy@gmail.com, vinodg@uj.ac.za (V.K. Gupta), m_ghaedi@mail.yu.ac.ir, m_ghaedi@yahoo.com (M. Ghaedi).

http://dx.doi.org/10.1016/j.jece.2016.03.002
2213-3437/

and widely applied method via easy and high efficiency protocol [30,31].

A statistical design of experiment can be preferred to decrease the number of experiments and considered the interaction between variables [32,33]. Designing and optimization of experiments and evaluation of the parameter impact need to employ methods to be able for simultaneous optimization while consider the interaction of parameters.

Recently, intelligent methods such as artificial neural networks (ANN), adaptive Neuro-Fuzzy inference system (ANFIS), support vector machine (SVM) are widely used for computational modeling of adsorption process [34,35]. One of the novel and powerful methods applied used to predict the adsorption process is called random forests (RF) [36–55].

Nano scale material has high specific surface area as well as it possess porous nature which improve the dye adsorption efficiency. Copper oxide nanoparticle possesses diverse nature which is due the double role of copper. Center as boarder line center, and also its synergic interaction with various activated carbon (AC) functional centers provide good reactive centers for the rapid removal and fast adsorption.

In the present work, we investigate and optimize a multi-response ultrasonic adsorption process of dyes onto the developed adsorbent i.e. copper (I) oxide nanoparticles loaded on activated carbon using the RSM was well investigated. The adsorption process was followed by UV–vis spectroscopy on proper wavelengths were determined from λ_{max} each dye. The research results showed that the combination of ultrasound and adsorption methods can significantly increase the quality level of wastewater purification. The results obtained also revealed that the developed techniques and method proved to be an excellent adsorbent because it takes very short time for the rapid removal of the noxious impurity and shows maximum adsorption with very low adsorbent dose amount. Kinetics and isotherm of adsorption at different initial concentration and adsorbent dosage was followed and empirical model for well representation of equilibrium and kinetic of model obtained.

2. Materials and methods

2.1. Instruments and reagents

Copper (II) acetate monohydrate ($Cu(CH_3COO)_2{\cdot}H_2O$), Poly (*N*-vinyl-2-pyrrolidone) (PVP), sodium hydroxide (NaOH) and hydrochloric acid (HCl) were purchased from Merck company. The dyes used in this study were sunset yellow (SY), anionic dye eosin B (EB) and cationic dye methylene blue (MB) supplied from Sigma-Aldrich Chemicals (USA). The pH was adjusted and measured using pH/Ion meter model 686 (Metrohm, Switzerland, Swiss). The dyes have stable color during the study in the physiological pH range. The structures and UV–vis spectrum of these dyes are shown in Fig. 1.

Stock solutions of 200 mg L^{-1} of each dye was prepared by dissolving 20 mg of each dye in 100 mL volumetric flask and subsequent dilution. The concentration of the dyes was determined at 412 nm for SY, 500 nm for EB and 664 nm for MB using UV–vis spectrophotometer model V–530 (Jusco, model V–530, Tokyo, Japan). The textural surface morphology was well elucidated and investigated using a ZEISS Ultraplus model field emission scanning electron microscopy (FESEM). X-ray diffraction (XRD, Philips PW 1800) was performed to characterize the phase and structure of the prepared nanoparticles using cu kα radiation (40 KV and 40 mA) at angles ranging from 5 to 120°. An ultrasonic bath with heating system (Tecno-GAZ SPA Ultrasonic System, Italy) at 40 kHz of frequency and 500 W of power was used for the ultrasound assisted adsorption. The chromatographic analyses were carried out via the use of an Agilent Technologies (Wilmington, DE, USA) 1100HPLC system equipped with Micro Vacuum Degasser (model G 1379A), Quaternary Pump (model G 1311A), a ZORBAXSB-C8 (Agilent) column and series Multiple wavelength Detector (model G13658).

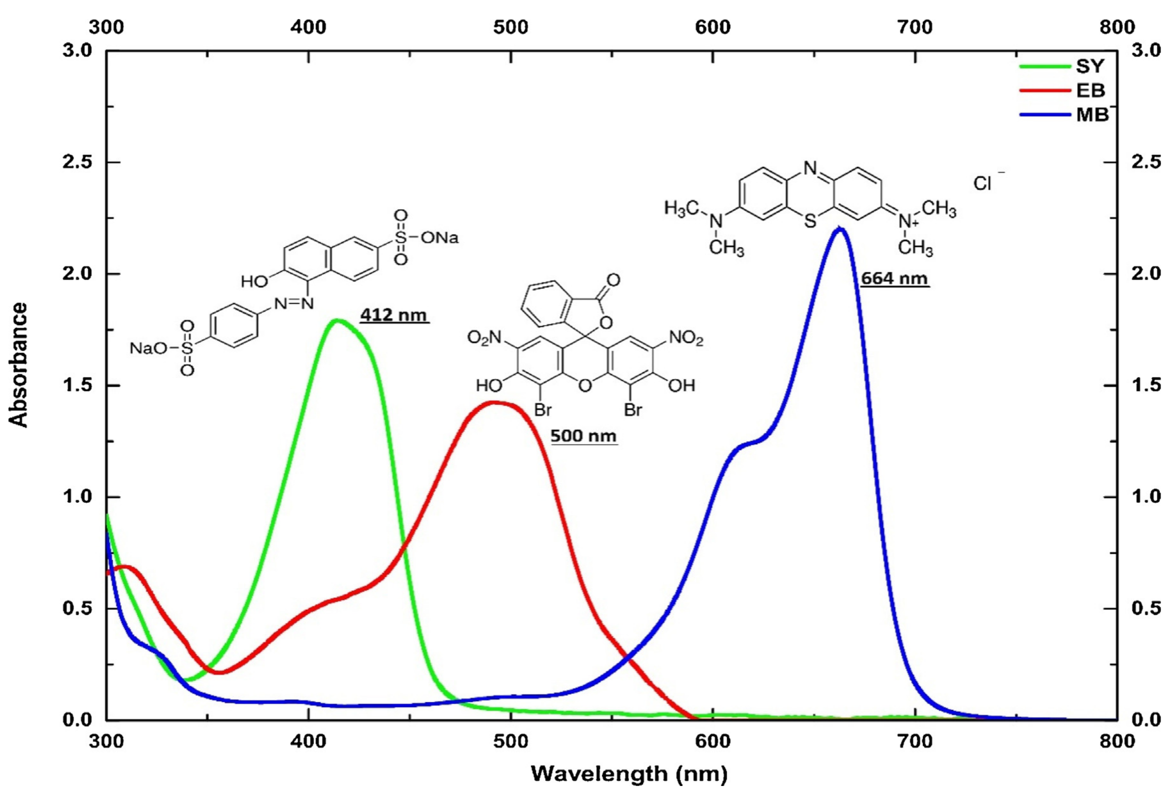

Fig 1. UV–vis spectra with chemical structure of SY, EB and MB in single solution (15 mg L^{-1} for each dye).