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Artificial neural network modelling of amido black dye sorption on iron composite nano material: Kinetics and thermodynamics studies

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ABSTRACT

The sorption of amido black dye in water on iron composite nano material is defined in batch process optimizing starting amido black amount, agitation time, pH, nano martial dose, and temp. The sorption results complied with Langmuir, Freundlich, Temkin and Dubinin-Radushkevich facsimilia. The proposed iron composite nano material were suitable for the sorption of amido black in water with determined 88%. The uptake was impulsive and exothermic. The adjusted batch limits were initial concentration 100 μg/L; agitation time 25 min, pH 7.0, dose 1.0 g/L and 25 °C temperature. The thermodynamic parameters like ΔG°, ΔH° and ΔS° were −8.14, −8.10 and −8.02 kJ/mol at 20, 25 and 30 °C temps; −4.32 kJ/mol and -9.30×10^{-3} kJ/mol K. The pseudo-first-order and liquid-film-diffusion mechanistic of the sorption were projected. The proposed sorption process was quick, ecological responsive and low-priced as may be utilized in normal water conditions. The artificial neural network modelling confirmed the applicability of the developed method. The method was competent to grind at normal water assets pHs with low sorbent amount and agitate time. The sorption process may be practical for the elimination of amido black dye from some water assets at large and low-priced scale.

1. Introduction

The dyed industrialized effluents release from a number of industries is stern matter of concern in water pollution. The majority of dyed industrialized effluents release factories are leather, textile, printing, paper, cosmetics, sugar, food and some drugs manufacturing. The dyed water stops the entry of natural radiations to the base of water bodies (lakes, river and ponds). This results in inhibition of photosynthesis in plants. This also results in the production of anaerobic situation, which is lethal for the flora and fauna [1]. Amido black dye is an amino acid stain diazo dye. It is applied in biochemical studies to dye different proteins in various biological fluids. It is applied in criminal testing to determine blood on fingerprints. It is also used to test handwritings, inks, papers, fibers, hairs, and paints. In industries, this dye is used for coloring natural fibers (wool and cotton) and synthetics polymers. This is also applied in the plastics, ink, paint, and fleece manufacturing [2–5]. This dye is highly toxic as damages respiratory system. Besides, this dye also origin of eye and skin annoyances [2]. The chemical name of amido black dye is 4-amino-5-hydroxy-3-[(4-nitrophenyl)azo]-6-(phenylazo)-2,7-naphthalene disulfonic acid, disodium salt (Fig. 1).

Due to the toxic nature of amido black dye, it is necessary to expand effective, rapid, low-priced and elective removal process for this toxic dye. Some papers describe the removal of this toxic dye using adsorption and degradation methods [6,7]. The microbe degradation of dyes is not recommended due to secondary contamination of water. The described adsorption processes are not effectual as most of them are not competent to take away amido black at normal situation of water, especially pH and temp. Also, the photo-degradation products may be poisonous. The artificial neural network (ANN) is considered as single mainly imperative predicting means for the sorption phenomenon [7]. It has been used by a number of workers to predict the adsorption from [8–11]. Consequently, an ANN based model was built up in this research for relating the sorption. Due to these facts, adsorption is believed as single process for water handling [12–15]. Consequently, the

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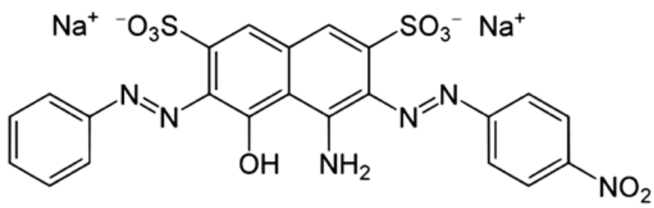

Fig. 1. Chemical structure of amido black dye.

endeavors were made for the elimination of amido black dye in water exploiting iron nano composite material.

2. Experimental

2.1. Chemicals and reagents

A.R. grades chemicals and reagents were used in this research. Amido black dye was gained from Sigma Aldrich (St. Louis, USA). Millipore water was prepared from Millipore-Q, Bedford, MA, USA system. Iron composite nanomaterial was prepared and distinguished as illustrated somewhere else [16,17].

2.2. Instruments

The research was conceded out on thermostatic water bath shaker. The dissimilar concerns. of amido black were ascertained at 620 nm λ_{max} using UV–Visb. Spectrometer (model T 80) PG Instruments Ltd., UK. Additional instruments used were sonicator, centrifuge machine, weighing balance and digital pH meter.

2.3. Uptake of amido black dye

The bulk solution of amido black (1.0 mg/L) was arranged in Millipore water. In addition, the required dilutions were done as per the rations (10–200 μg/L). The batch uptake experimentations were finished at fixed stir time. The subsequent experimentation constraints were diversified to get hold of the highest elimination of amido black.

1. Amido black concen.
2. Contact time.
3. Dose.
4. Dye solution pH.
5. Temperature.

Adsorbent (fixed amount) was to solution of amido black dye (10 mL) of changeable concentrations in 250 mL Erlenmeyer flasks. These flasks were stimulated incessantly in water bath shaker at 20, 25 and 30 °C temperature. The solutions were taken out and centrifuged after certain determined time intervals. The concentrations of dye were ascertained spectrometrically. The adsorption was done at fixed dose and dissimilar concerns. and temps. for kinetic purpose. For adsorption isotherms, the experiment were done at 5–35 min contact time, 0.1–1.5 g/L dose, 25–200 μg/L conc., 3–9 pHs and 20.0–30.0 °C temps. The experimentations were done at 5 times ($n = 5$). Amount of the dye up taken per unit mass (q_e, mg/g) was premeditated utilizing the equation given below.

$$q_e = (C_o - C_e)/m \quad (1)$$

where, C_o = original conc. of amido black (μg/L), Ce = equilibrium concentrations of amido black (μg/L) and m = quantity of the adsorbent (g/L).

Percentage adsorption was calculated using equation given below.

$$\%adsorption = 100\,(C_o - C_e)/C_o \quad (2)$$

2.4. Artificial neural network model

Basically, ANN architecture comprises input layers (independent variables), hidden layers and output layers (dependent variables). Each layer has a number of interconnected processing units (neurons). All the neurons are connected to each other in the preceding and following layer by links system. The input layer gets information from outside resources and bypasses to the hidden layer for dealing out. Prior to ingoing the hidden layer, the input values are weighted independently and the all the data processing is done by the hidden layer; resulting into generation of output supported on the total the weighted magnitudes from the input layer adapted by a sigmoid transfer function [18,19]. The contact time, temp., pH, dye concen. and the quantity of nanosorbent were considered as input data for the model. The sorption effectiveness data were place in and considered as output. The data was separated into three classes of training, validation and testing. 60, 20 and 20% data were applied for training, validation and testing. The numbers of neurons were 5, 8 and 1 in the input and hidden and output layers, respectively. The network structure with the three layers is shown in Fig. 2. The network presentation was estimated based to experimental data fitness and the forecast accuracy of the model utilized. Mean Square Error (MSE) was measured using following equation.

$$MSE = \frac{\sum \left| \left(q_{exp} - q_{cal} \right) / q_{exp} \right| \times 100}{N} \quad (3)$$

where, q_{exp}, q_{cal} and N were the experimental amount, calculated amount adsorbed and number of variables.

3. Results and discussion

The adsorption of the reported dye was fixed by the different variables. These variables include concentration of amido black dye, time of contact, adsorbent dose, dye solution pH and temperature. The variation of these parameters is discussed in subsequent headings.

3.1. Amido black concentration

The concentration result of removal of amido black was studied using various concentrations (10 to 200 μg/L) while the other variables were constant *i.e.* contact time 30 min, pH 7.0, dose 0.5 g/L and temperature 25 °C. The uptake of amido black ranged from 88 to 100%. It was 100% (2.0 μg/g), 95% (4.75 μg/g), 92% (9.20 μg/g) and 88% (17.6 μg/g) at 10, 25, 50 and 100 μg/L concentrations (Fig. 3a). It was steady at elevated conc. of amido black. It is obviously exhibited that the uptake was reliant on the starting conc. of amido black. It might be owing to the open obtainable viable surface area on adsorbent at little conc., which reduced as the conc. of the amido black augmented. It is significant to state that quantity at equilibrium (qe) enlarged as the percentage reduced. It was owing to the reality that at elevated conc. huge amount of amido black molecules absorbed the adsorbent surface, leading to uptake of elevated figure of amido black molecules. As a result, the highest molecular adsorption of amido black was achieved at 100 μg/g conc. in the described experimentation circumstances.

3.2. Equilibrium time

The batch adsorption experiments were carried out during 5–35 min by making other parameters constant *i.e.* initial concentration 100 μg/L, pH 7.0, dose 0.5 g/L and temp. 25 °C. This affect is shown in Fig. 3b. It is apparent from this Figure that uptake of the amido black augmented from 5.0 to 30.0 min, that had become steady on additional rising of contact time. The maximum uptake of the amido black at 30 min was 17.6 μg/L (88%). Therefore, 30 min shaking time was preferred as the best one.