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ORIGINAL ARTICLE

Sorption of malachite green from aqueous solution by potato peel: Kinetics and equilibrium modeling using non-linear analysis method

El-Khamsa Guechi, Oualid Hamdaoui *

Laboratory of Environmental Engineering, Department of Process Engineering, Faculty of Engineering, University of Annaba, P.O. Box 12, 23000 Annaba, Algeria

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Abstract Potato peel (PP) was used as a biosorbent to remove malachite green (MG) from aqueous solution under various operating conditions. The effect of the experimental parameters such as initial dye concentration, biosorbent dose, initial pH, stirring speed, temperature, ionic strength and biosorbent particle size was investigated through a number of batch sorption experiments. The sorption kinetic uptake for MG by PP at various initial dye concentrations was analyzed by non-linear method using pseudo-first, pseudo-second and pseudo-*n*th order models. It was found that the pseudo-*n*th order kinetic model was the best applicable model to describe the sorption kinetic data and the order *n* of sorption reaction was calculated in the range from 0.71 to 2.71. Three sorption isotherms namely the Langmuir, Freundlich and Redlich–Peterson isotherms in their non-linear forms were applied to the biosorption equilibrium data. Both the Langmuir and Redlich–Peterson models were found to fit the sorption isotherm data well, but the Redlich–Peterson model was better. Thermodynamic parameters show that the sorption process of MG is endothermic and more effective process at high temperatures. The results revealed that PP is very effective for the biosorption of MG from aqueous solutions.

* Corresponding author. Tel./fax: +21338876560.
E-mail addresses: oualid.hamdaoui@univ-annaba.org, ohamdaoui@yahoo.fr (O. Hamdaoui).

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1. Introduction

Synthetic dyes are an important class of recalcitrant organic compounds and are often found in the environment as a result of their wide industrial use. Dyes are used in many industries such as food, paper, plastics, cosmetics, papermaking and textile in order to color their products. These colored effluents can be mixed in surface water and ground water systems, and then they may also be transferred to drinking water. Color is the first contaminant to be recognized in wastewater. The presence of very small amounts of dyes in water (less than

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1 ppm for some dyes) is highly visible and aesthetically unpleasant. Due to intense color they reduce sunlight transmission into water hence affecting aquatic plants, which ultimately disturb aquatic ecosystem. Dye bearing effluents are characterized by high chemical oxygen demand, low biodegradability and high salt content. In addition, it has been stressed recently that color compounds such as dyes discharged from several industries are very harmful to aquatic life in rivers and lakes. Therefore, it is necessary to reduce dye concentration in the wastewater before it is released into the environment.

Malachite green (MG), a basic dye, is most widely used for coloring purpose, amongst all other dyes of its category (Crini et al., 2007). This triarylmethane dye is widely used in the aquaculture industry worldwide as a biocide as well as in the silk, wool, cotton, leather, paper and acrylic industries as a dye. However there are several reports describing its hazardous and carcinogenic effects (Srivastava et al., 2004). It is known to be highly cytotoxic and carcinogenic to mammalian cells and acts as a liver tumor promoter. In humans, it may cause irritation to the respiratory tract if inhaled and causes irritation to the gastrointestinal tract upon ingestion. Contact of malachite green with the skin causes irritation with redness and pain; upon contact with eye will lead to permanent injury of human eyes. It also affects the aquatic life and causes detrimental effects in liver, gill, kidney, intestine, gonads and pituitary gonadotrophic cells (Hameed and El-Khaiary, 2008a). Therefore, the treatment of effluent containing such dye is of interest due to its harmful impact on receiving waters.

Among the numerous treatment technologies developed for the removal of dyes from industrial effluents, biosorption is receiving increasing attention in becoming an attractive and promising technology. The study of biosorption is of great importance from an environmental point of view, as it can be considered as an alternative technique for removing toxic pollutants from wastewaters (Vieira and Volesky, 2000; Nouri and Hamdaoui, 2007). A number of low cost biosorbent have been studied in the literature for their capacity to remove MG from aqueous solutions (Baek et al., 2010; Bekçi et al., 2009; Hamdaoui et al., 2008; Hameed and El-Khaiary, 2008a; Khattri and Singh, 2009; Mittal, 2006; Pradeep Sekhar et al., 2009; Sonawane and Shrivastava, 2009). Undoubtedly, agricultural waste biomass is presently one of the most challenging topics, which is gaining stern considerations during the past several decades. In perspective, potato peel has emerged to be an invaluable source.

Potato peel (PP), agricultural and easily available waste, could be an alternative for more costly wastewater treatment processes. Losses caused by potato peeling range from 15% to 40% their amount depending on the procedure applied, i.e. steam, abrasion or lye peeling (Scieber et al., 2001). Plants peel the potatoes as part of the production of French fries, crisps, puree, instant potatoes and similar products. The produced waste is 90 kg per Mg of influent potatoes and is apportioned to 50 kg of potato skins, 30 kg starch and 10 kg inert material. The problem of the management of PP causes considerable concern to the potato industries, thus implying the need to identify an integrated, environmentally-friendly solution. PP is a zero value waste from potato processing plants. In the interest of the environment, we propose this agricultural waste as a low-cost sorbent to remove malachite green from aqueous solution.

The objective of this work was to investigate the potential of PP as a novel sorbent in the removal of the basic dye, malachite green, from aqueous solutions. Batch sorption studies were conducted to investigate the effects of various parameters such initial dye concentration, biosorbent dose, pH, temperature, stirring speed, ionic strength and particle size on MG biosorption. Equilibrium isotherm and kinetic data are analyzed and modeled using different models by non-linear regression technique.

2. Materials and methods

2.1. Biosorbent

The PP used in the present study was obtained from the university canteen. It was washed, dried, crushed and sieved to desired mesh size (0.5–1.25 mm). Finally, the obtained material was then dried in an air circulating oven at 50 °C for 7 days and stored in a desiccator until use.

2.2. Sorbate

The cationic basic dye (C.I. 42000; Basic Green 4), malachite green oxalate salt, (molecular formula $C_{52}H_{56}N_4O_{12}$, FW 929), was obtained from Merck and used without further purification. The structure of this dye is displayed in Fig. 1. Five hundred milligram per liter stock solution was prepared by dissolving the required amount of dye in distilled water. Working solutions of the desired concentrations were obtained by successive dilutions.

2.3. Analytical method

A well-known procedure for determining MG concentrations, based on Beer's law calibration plots, was applied using a UV–visible spectrophotometer (Jenway 6405). The wavelength resolution and the bandwidth were, respectively, 1 and 0.5 nm. The length of the optical path in glass cell was 1 cm. The maximum absorption wavelength was determined as equal to 618 nm. Then, the calibration plot was constructed. The calibration was repeated five times during the period of measurements. The linearization of this plot usually provided

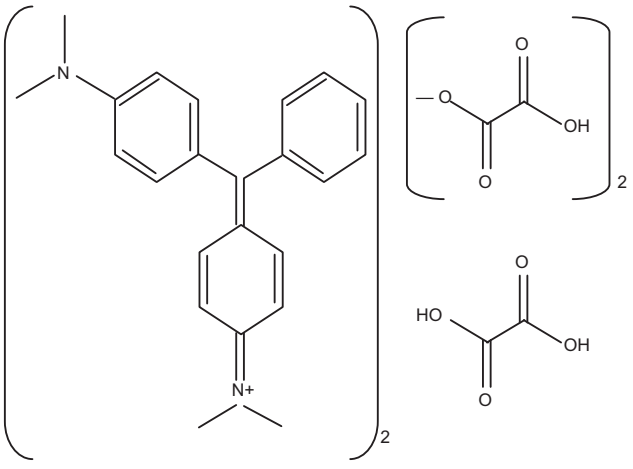

Figure 1 Chemical structure of malachite green (oxalate salt).

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