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Removal of dyes by *Moringa oleifera* seed extract. Study through response surface methodology

J. Beltrán-Heredia, J. Sánchez-Martín* and A. Delgado-Regalado

Abstract

BACKGROUND: The effect of pH and initial dye concentration (IDC) on dye removal by coagulation/flocculation process with *Moringa oleifera* seed extract has been studied. The study was carried out by using the response surface methodology (RSM) in an orthogonal and rotatable design of experiments. Three types of dye were studied: anthraquinonic (Alizarin Violet 3R); indigoid (Indigo Carmine); and azoic (Palatine Fast Black WAN).

RESULTS: The interaction level of the two variables studied is higher in the case of azo dye, while it is almost null in the case of anthraquinonic dye. Indigoid dye presents an intermediate situation. pH has a negative influence on dye removal, and by raising IDC *q* capacity tends to be higher. Polynomic regression of the surface plot was carried out and the adjusted r^2 found for each case, this being 0.99 in the case of anthraquinonic dye, 0.94 in the case of indigoid dye, and 0.74 in the case of azoic dye.

CONCLUSIONS: *Moringa oleifera* is an interesting natural coagulation agent for use in dye removal. pH should be taken into account in the cases of indigoid and azo dyes, while its influence is rather small in the case of anthraquinonic dye.
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Keywords: *Moringa oleifera*; dye removal; response surface methodology; natural flocculation agents

INTRODUCTION

The removal of dye effluents is a challenge in many industrial wastewater treatment plants. Pigments and dyes are used extensively in many applications, such as textiles, printing, pharmaceuticals and a large variety of other products. The discharge of these chemical pollutants is a dangerous and noxious practice that may affect the aquatic systems[1,2] and therefore may enter the alimentary chain, with corresponding risks owing to their well-known toxic and mutagenic properties for living organisms.[3,4]

Dyes may be classified in many ways, the most common classification being in terms of their industrial usage[5] (direct, reactive, disperse, ... dyes). Other categorizations may be according to their chemical composition: azo, anthraquinonic, indigoid or thiazinic dyes can then be considered. Taking into account previous work on the removal of azo dyes by *Moringa oleifera* seed extract,[6] the current work has considered the anionic dyes: azo, anthraquinonic and indigoid dyes.

Three dyes have been selected to work on:

- ***Alizarin Violet 3R*** is an anthraquinonic dye. It is a synthetic dye, characterized by a high chemical/biological oxygen demand and intense blue color.[7] These aspects make industrial effluents of this dye highly toxic and extremely injurious to both aquatic and land life forms. The difficulty met when attempting to degrade or remove this dye has been thoroughly reported previously,[8] and is caused mainly by the four aromatic rings and the two sulfonated groups that make this dye a persistant and carcinogenic agent.
- ***Indigo Carmine*** is an indigoid dye. Its structure includes two aromatic rings with a double link inside them and two sulfonate negative-charged groups.[9] This gives it an anionic and aromatic character that allows the *Moringa* active principle, which is presumably proteinic,[10] cationic character, to link dye molecules and provoke their destabilization and settlement in a coagulation and flocculation process.
- ***Palatine Fast Black WAN*** is an azo dye. It is an extremely long molecule whose structure includes twelve aromatic rings and three sulfonate groups, apart from many other functional groups (Fig. 1). The presence of chromium atoms associated with the organic chain makes it especially dangerous, because of its mutagenic action.[11]

Moringa oleifera is a well-known source of a coagulant agent,[12,13] and its ability to remove specific water pollutants has been tested and reported previously: heavy metals,[14] surfactants[15] or surface water.[16] It is very interesting because it is a widespread, easily available water treatment method. Using it as coagulant/flocculant agent is ideal for application in developing countries. Its strengths are that it is not technologically difficult to operate by non-qualified personnel, it is easy to maintain and it is not dependent on external

* Correspondence to: J. Sánchez-Martín, Universidad de Extremadura. Department of Chemical Engineering and Physical Chemistry. Avda. de Elvas, s/n. 06071. Badajoz, Spain. E-mail: jsanmar@unex.es

Universidad de Extremadura. Department of Chemical Engineering and Physical Chemistry. Avda. de Elvas, s/n. 06071. Badajoz, Spain

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