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## ORIGINAL PAPER

# Clay and charcoal composites: characterisation and application of factorial design analysis for dye adsorption

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The characterisation of smectite clay, charcoal and prepared clay–charcoal composites was carried out through the X-ray diffractometry, energy dispersive X-ray spectroscopy (EDS), simultaneous thermal analysis (TGA/DTA), infrared spectroscopy (FTIR) and scanning electron microscopy (SEM). The analysis revealed the composites to have different characteristics from the precursor clay and charcoal, and a peak displacement ($d_{001}$) was observed through the X-ray diffraction; this suggests the incorporation of charcoal into the clay lamellas and the formation of a new phase. Tests of adsorption with methylene blue dye were also carried out to evaluate the percentage of dye removal by the adsorbent, in which the composites presented better results than charcoal, indicating great potential for industrial use. A $2^3$ factorial design was employed to evaluate the influence of temperature, ionic strength and pH on the adsorption of methylene blue using the $AV_{50}$ composite that presented the best adsorption efficiency.


**Keywords:** methylene blue dye, adsorption, composites, smectite clay, charcoal

## Introduction

In general, consumption of water is quite high, since industrial processes, for instance, produce huge volumes of effluent, of varied composition, which include acids, alkalis, dissolved solids, toxic compounds that can be highly coloured (Moreira et al., 2001; Rodrigues et al., 2004). The residual water might contain dyes, hundreds of which are reported in the literature, classified according to their chemical nature or in terms of their application. On the other hand, dyes can be applied to a number of substrates (textile materials, paper, leather, etc.) as liquids, in which they are totally or partially soluble (Mckay et al., 1980; Hui et al., 2009; Rosseto et al., 2009).

A number of adsorbents are currently used in the attempt to remove contaminants from residual waters; of these, the adsorption capacity of activated coal in relation to a specific contaminant is dependent on the intrinsic characteristics of the adsorbent, resulting basically from the way in which the material is activated and produced. On the other hand, clays present special chemical and physical characteristics which contribute to their use as adsorbents, rendering them of interest both to scientific research and to the development of new technologies (Longhinotti et al., 1996; Barbosa, 2009).

In the last fifty years, interest in clays as well as clay and carbonaceous materials composites for use in the treatment of industrial effluents has grown significantly, particularly in relation to the composition, structure and properties of the constituents (Albers et al., 2002; Coelho et al., 2007; Bangash et al., 2009).

Composites are materials formed by the combination of two or more materials, thereby affording unique and synergic properties, which differ from those of the individual components. In general, a composite is deemed to be any multi-phase material which exhibits a significant proportion of properties from all its constituent phases so that the best combination

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