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Review

An update on synthetic dyes adsorption onto clay based minerals: A state-of-art review

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ABSTRACT

Dyes are growing to be a problematic class of pollutants to the environment. The disposal of dyes in water resources has bad aesthetic and health effects, hence the need to remove them from the environment. The need for treatment methods that are effective and low in price is rising hence a lot of research interest is being diverted towards adsorbents that are cheap, preferable naturally occurring materials like clays. In most reported dye adsorption studies, limited information on the relationship between characterization results with adsorbent performance on dye removal has been given. This review article seeks to report on the link between the adsorption characteristics of the clays and their adsorption capacities and to gather information on the modifications done on clays to improve their adsorption capacities. A critical analysis of the different mechanisms involved during the decolouration process and their application for dye removal has been discussed in detail in this up-to-date review. From a wide range of consulted literature review, it is evident that some clays have appreciable adsorption capacities on top of being widely available. It was also noted that several parameters like contact time, dosage, concentration, temperature and pH affect the removal of dyes. Furthermore, the application of clay minerals for decolourising water represents economic viable and locally available materials that can be used substantially for pollution control and management. Conclusions were also drawn and suggestions for future research perspectives are proposed.

Contents

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1. Introduction

Different classes of dyes are used in numerous industries including rubber, textiles, cosmetics, plastics, leather, food and paper making. The variability of these dyes is seen in wastewaters discharged from these industries. “Generally dyes are stable to light, heat and oxidizing agents and are usually non-biodegradable” (Kono, 2015). Because these dyes give colour to the receiving water bodies hence degrading their aesthetic values, it is of paramount importance that their presence in a water body be managed (Kant, 2012).

The presence of colour in an aquatic ecosystem reduces the penetration of sunlight to benthic organisms thus limiting the process of photosynthesis. Dyes also affect the aesthetic value of an aquatic ecosystem due to colouration of water resources (Yagub et al., 2014). The key concern in the treatment of wastewater is the release of dyes and their metabolites into the environment, as some may be mutagens and carcinogens. Some of these dyes are xenobiotic in nature and aerobically recalcitrant to biodegradation (Gupta et al., 2013) and thus pose a threat when wastewater is disposed off to the adjacent environment without being treated. In that regard, there is a need to find treatment technologies that can decolourise the water and at the same time reduce the toxic effects of the dyes to within the recommended water quality guidelines.

Being among the most demanding environmental tasks of the modern day, the increasing amount of toxic industrial waste has led to the development of various methods for its eradication and removal from wastewaters (Chollom, 2014). Usually industrial effluents are treated by several methods including chemical degradation, advanced oxidation processes, adsorption, precipitation, biodegradation and chemical coagulation (Pajootan et al., 2012). These methods have been extensively applied, however they have some shortcomings (Kobya et al., 2007; Mohan et al., 2007). For instance, a lot of time is needed for the biological methods and more often than not, the biological methods are less effective when it comes to highly structured polymer dyes. Buthelezi et al. (2012) reported that dyes are non-biodegradable by nature, as such, biological methods will be inapplicable and their applicability is limited to few dyes because many dyes in the market are toxic to the organisms used hence the biological methods cannot be applied to treat those dyed wastewaters.

Chemical coagulation processes produce huge amounts of sludge thereby causing a lot of pollution as a result of the different chemical reactions that would have taken place during the wastewater treatment processes (Balik and Aydin, 2016). Merzouk et al. (2011) reported that the most effective and important treatment method is chemical degradation using oxidative agents like chlorine, however the disadvantage of this method is the production of highly toxic products like organochlorine compounds. Amongst other oxidation processes, there are more advanced processes not limited to some of the following: fenton reactive and ultrasonic oxidation, UV and ozone–UV combined oxidation and photocatalysis. These oxidation processes are said to be not economically feasible (Daneshvar et al., 2006). The great variability of the wastewater composition often leads to inefficiencies or inadequate treatment of the dye effluents (Drouiche et al., 2011). Having pointed out the above, adsorptions seems to be among the most favoured wastewater treatment technique because of its environmental and economic sustainability.

2. Dyes

Dyes can be defined as organic compounds that have colour and are used to give colour to different substrates like cosmetics, paper, drugs, leather, fur, greases hair, waxes, plastics and textile materials. “Dyes are basically chemical compounds that can connect themselves to surfaces or fabrics to impart colour” (Yagub et al., 2014). Dyes can be classified according to where they are derived. They can be from natural or synthetic sources. Natural dyes are extracted from sources including plants, animals and minerals. Natural dyes were used mostly during early textile industry and these include Jackfruit, Onion, eucalyptus, Turmeric, Weld and henna (Dawood and Sen, 2014). However, because of population increase and industrial activities, people are moving away from natural dyes because they are failing to meet the industrial demand hence their application nowadays is mostly found in the food industry. Synthetic dyes have replaced natural dyes almost completely particularly in the fabrics and textile industry. Several types of dyes are used in numerous industries and these include basic, acid, reactive, direct, vat and disperse dyes (Chen et al., 2016). All these dyes are soluble in water except for disperse and vat dyes. Dyes also contain traces of metals like chromium, copper, lead, zinc,