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Dye sequestration using agricultural wastes as adsorbents

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ABSTRACT

Color is a visible pollutant and the presence of even minute amounts of coloring substance makes it undesirable due to its appearance. The removal of color from dye-bearing effluents is a major problem due to the difficulty in treating such wastewaters by conventional treatment methods. The most commonly used methods for color removal are biological oxidation and chemical precipitation. However, these processes are effective and economic only in the case where the solute concentrations are relatively high. Most industries use dyes and pigments to color their products. The presence of dyes in effluents is a major concern due to its adverse effect on various forms of life. The discharge of dyes in the environment is a matter of concern for both toxicological and esthetical reasons. It is evident from a literature survey of about 283 recently published papers that low-cost adsorbents have demonstrated outstanding removal capabilities for dye removal and the optimal equilibrium time of various dyes with different charcoal adsorbents from agricultural residues is between 4 and 5 h. Maximum adsorptions of acidic dyes were obtained from the solutions with pH 8–10. The challenges and future prospects are discussed to provide a better framework for a safer and cleaner environment.

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1. Introduction

Industrial developments in recent years have left their impression on the environmental society. Many industries like the textile industry used dyes to color their products and thus produce wastewater containing organics with a strong color, where in the dyeing processes the percentage of dye lost wastewater is 50% of the dye because of the low levels of dye-fiber fixation [1]. Discharge of these dyes in to effluents affects the people who may use these effluents for living purposes such as washing, bathing and drinking [2]. Therefore it is very important to verify the water quality, especially when even just 1.0 mg/L of dye concentration in drinking water could impart a significant color, making it unfit for human consumption [3]. Furthermore dyes can affect aquatic plants because they reduce sunlight transmission through water. Also dyes may impart toxicity to aquatic life and may be mutagenic, carcinogenic and may cause severe damage to human beings, such as dysfunction of the kidneys, reproductive system, liver, brain and central nervous system [4–6]. The removal of color from waste effluents becomes environmentally important because even a small quantity of dye in water can be toxic and highly visible [7]. Since the removal of dyes from wastewater is considered an environmental challenge and government legislation requires textile wastewater to be treated, therefore there is a constant need to have an effective process that can efficiently remove these dyes [8].

Therefore adsorption by agricultural by-products used recently as an economical and realistic method for removal of different pollutants has proved to be an efficient at removing many types of pollutants such as heavy metals [9,10], COD [11,12], phenol [13,14], gasses [15] and dyes [16–18]. In order to increase the adsorption capacity of the adsorbent, Researchers have followed different activation methods and they usually used the Langmuir isotherm to indicate the effectiveness of the activation process. Activation methods involve physical activation such as carbonization of material and chemical activation such as using chemical activating agents. Real textile wastewater is a mixture of dyes, organic compounds, heavy metals, total dissolved solids, surfactants, salts, chlorinated compounds, chemical oxygen demand and biological oxygen demand [19,36]. Therefore some studies tested the agricultural wastes as adsorbents for these pollutants. Ahmad and Hameed [12] studied the reduction of color and COD using bamboo activated carbon, and they found that the maximum reduction of color and COD were 91.84% and 75.21%, respectively.

Many industries, such as dyestuffs, textile, paper, plastics, tannery, and paint use dyes to color their products and also consume substantial volumes of water. As a result, they generate a considerable amount of colored wastewater [20]. The presence of very small amounts of dyes in water (less than 1 ppm for some dyes) is highly visible and undesirable [21,22]. According to Chakrabarti et al. [23], nearly 40,000 dyes and pigments are listed, which consist of more than 7000 different chemical structures. Most of them are completely resistant to biodegradation processes [24]. Over 100,000 commercially available dyes exist and more than 7×10^5 t are produced worldwide annually [25,26]. Recent studies indicate that approximately 12% of produced synthetic dyes are lost during manufacturing and processing operations. Approximately 20% of these lost dyes enter the industrial wastewaters [27,28]. An indication of the scale of the problem is given by the fact that 10–15% of the dye is lost in the effluent during the dyeing process [29,30]. Dye molecules consists of two key components: the chromophores, which are largely responsible for producing the color, and the auxochromes, which not only supplement the chromophore but also render the molecule soluble in water and enhance its affinity (to attach) toward the fibers [31]. Dyes may be classified in several ways, according to chemical constitution, application class, and end use. Dyes are here classified according to how they are used in the dyeing process. Main dyes are grouped as acid dyes, basic dyes, direct dyes, mordant dyes, vat dyes, reactive dyes, disperse dyes, azo dyes, and sulfur dyes. Typical dyes used in textile dyeing operations are given in Table 1 [32]. As a result of increasingly stringent restrictions on the organic content of industrial effluents, it is necessary to eliminate dyes from wastewater before it is discharged.

Many of these dyes are also toxic and even carcinogenic [19,33]. Besides this, they also interfere with the transmission of light and upset the biological metabolism processes, which causes the destruction of aquatic communities present in various ecosystems [34,35]. Furthermore, the dyes have a tendency to sequester metal and may cause microtoxicity to fish and other organisms [36]. However, wastewater containing dyes is very difficult to treat because the dyes are recalcitrant organic molecules, which are resistant to aerobic digestion, and are stable to light, heat, and oxidizing agents [37–41]. So color is the first contaminant to be recognized in the wastewater [22].

In this article, the feasibility of agricultural wastes adsorbents for dye removal from contaminated water has been reviewed. The main goal of this review is to (i) presents a critical analysis of these materials; (ii) describes their characteristics, advantages and limitations; and (iii) discusses various mechanisms involved. Reported adsorption capacities are presented to give some idea of their effectiveness. However, the reported adsorption capacities must be taken as an example of values that can be achieved under specific conditions since adsorption capacities of the adsorbents presented vary, depending on the characteristics of the material, the experimental conditions, and also the extent of chemical modifications.

2. Available technologies for dye removal

Methods of dye wastewater treatment have been reviewed recently [21,22,41–44]. There are several reported treatment methods for the removal of dyes from effluents and these technologies can be divided into three categories: biological methods, chemical methods, and physical methods [21]. However, all of them have advantages and drawbacks. Because of the high cost and disposal problems, many of these conventional methods for treating dye wastewater have not been widely applied at large scale in the textile and paper industries [45]. At the present time, there is no single process capable of adequate treatment, mainly because of the complex nature of the effluents [46,47].

In spite of the availability of many techniques to remove these pollutants from wastewaters as legal requirements, such as coagulation, chemical oxidation, membrane separation process, electrochemical and aerobic and anaerobic microbial degradation, these methods are not