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Removal of methylene blue from wastewater using fly ash as an adsorbent by hydrocyclone

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Abstract

The excessive release of color into the environment is a major concern worldwide. Adsorption process is among the most effective techniques for color removal from wastewater and fly ash has been widely used as an adsorbent. Therefore, this study was carried out to understand the adsorption behavior of methylene blue from aqueous systems onto fly ash using the continuous mode. Continuous mode sorption experiments were carried out to remove methylene blue from its aqueous solutions in hydrocyclone equipment. The experiments were performed at constant temperature and dimensions of hydrocyclone with variation of flows through the equipment, concentrations of methylene blue solutions and fly ash concentration, respectively. A maximum removal of 58.24% was observed at adsorbent dosage of 900 mg/l at pH 6.75 for an initial methylene blue concentration of 65 mg/l.

Keywords: Color removal; Methylene blue; Fly ash; Hydrocyclone; Wastewater treatment

1. Introduction

Most industries use dyes and pigments to color their products. Today more than 9000 types of dyes have been incorporated in the color index and the biggest consumers of these dyes are textile, tannery, paper and pulp industry, cosmetic, plastics, coffee pulping, pharmaceuticals, food processing, electroplating and distilleries spew, perhaps these are the serious polluters of our environment as far as color pollution is concerned. Among these industries, the textile industry ranks first in usage of dyes for coloration of fiber [1]. The textile industry in India is one of the oldest and largest industries in the country. The textile mills required volumes of water of high purity and generate equally large volumes of wastewater, which is highly colored and complex in character. The total dye consumption of the textile industry worldwide is in excess of 10^7 kg/year, and an estimated 90% of this ends up on fabrics. Consequently, 1000 tonnes/year or more of dyes are discharged into waste streams by the textile industry worldwide [2].

Color can cause hazards to the environment due to the presence of a large number of contaminants like toxic organic residues, acids, bases and inorganic contaminants. Some of the dyes are carcinogenic and mutagenic because they were formerly made by hazardous chemicals such as benzidine, metals, etc. [3]. The discharge of colored wastes into the receiving water bodies not only affects their aesthetic nature but also interferes with the transmission of sunlight and therefore reduces the photosynthetic activity [4]. It may present an eco-toxic hazard and introduce the potential danger of bioaccumulation, which may eventually affect man through the food chain. Methylene blue is selected as a model compound in order to evaluate its capacity for the removal of methylene blue from its aqueous solutions. Methylene blue has wider applications, which include coloring paper, temporary hair colorant, dyeing cottons, wools, coating for paper stock, medical purpose, etc. Though methylene blue is not strongly hazardous, it can cause some harmful effects. Acute exposure to methylene blue will cause increased heart rate, vomiting, shock, Heinz body formation, cyanosis, jaundice, quadriplegia, and tissue necrosis in humans [5].

A range of conventional treatment technologies for dye removal have been investigated extensively, such as activated sludge, chemical coagulation, carbon adsorption, electrochemical treatment, reverse osmosis and hydrogen peroxide catalysis.

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However, most of the above methods suffer from one or more limitations and none of them were successful in completely removing the color from wastewater. The removal of dyes and organics in an economic way remains an important problem, although a number of systems have been developed with adsorption techniques. Adsorption has been found to be superior to other techniques for water re-use in terms of initial cost, simplicity of design, ease of operation and insensitivity to toxic substances [6]. The adsorption onto activated carbon has been found to be superior to other techniques in water re-use methodology because of its capability for adsorbing a broad range of different types of adsorbates efficiently, and simplicity of design. However, commercially available activated carbons are still considered expensive. Thus, many researchers researched for cheaper substitutes, which are relatively inexpensive, and are at the same time endowed with reasonable adsorptive capacity. These studies include the use of fly ash, bottom ash bagasse fly ash, starch, cellulose-based waste, rice husk, etc. [7–9].

Fly ash is a waste material originating in great amounts in combustion processes. At present, a number of thermal power plants fuelled with coal are in operation in many countries. In modern coal-firing power stations, pulverized coal is used, and fly ash is obtained as a waste product in large quantities. The fly ash collected in precipitators is generally disposed of in lagoons at the plant site or in landfills located in isolated areas. Indian coals have very high ash content. The ash content of coal used by thermal power plants in India varies between 25% and 45%. However, coal with an ash content of around 40% is predominantly used in India for thermal power generation. As a consequence, a huge amount of fly ash is generated in thermal power plants, causing several disposal-related problems. In spite of initiatives taken by the government, several non-governmental organizations and research and development organizations for fly ash utilization, the level of fly ash utilization in the country was estimated to be less than 10%. Globally, less than 25% of the total annual fly ash produced in the world is utilized [10]. Therefore, an inexpensive by-product management technology is needed for fly ash re-use. In India, more than 100 million tonnes/year of fly ash have been generated and disposal or utilization of this large amount of fly ash remains a problem. Although the disposal of fly ash using land filling is routinely practiced, increasing disposal costs and serious environmental concern over the leaching of latent toxic substance from the ash to soil, surface water and groundwater [11] are making the utilization of fly ash a more attractive alternative compared with direct disposal (land filling). Though fly ash is utilized effectively in brick and tile manufacturing, and other construction operations, it is unlikely that this will ever use all the fly ash generated [12]. Research is therefore needed to develop new alternative environmental friendly applications that can further exploit fly ash. In the present study fly ash has been used as adsorbent material for the treatment of dye-bearing wastewaters.

Adsorption of different type of dyes including methylene blue onto fly ash has been previously studied by many researchers [13,14]. Also, the adsorption of various dyes at solid–liquid interfaces has been studied extensively at equilibrium and various thermodynamic behaviors have been investigated. But very few studies were available explaining the actual dynamic and continuous mode during the sorption process.

The separation of dispersed solid particles from a suspension is an essential unit operation in many fields of mechanical separation technology. Typical apparatus used are filters, centrifuges and hydrocyclone. Whereas an enormous energy input is necessary using centrifuges at high rotational speed, hydrocyclones work more economically as the only amount of energy, which has to be supplied, is to overcome the pressure drop. A further advantage of hydrocyclone is their high operational reliability as they are simple in construction without any moving parts. In addition, in case of changing operational conditions, for example with unsteady flow, good separation efficiency can be achieved. Thus, hydrocyclones are widely used to separate particulates from liquid at high throughput because of their advantages like simple structure, low cost, large capacity and small volume, require little way of maintenance and support structure. Hydrocyclones belong to a class of fluid–solid classifying devices that separate dispersed material from a fluid stream [15].

In the present study, the effects of initial methylene blue concentration, fly ash doses on the removal of color in a hydrocyclone have been investigated. On the basis of available literature and from the point of view of advantages in terms of cost, space and power requirement, a hydrocyclone was chosen for the stated purpose. As powder particulate matter adsorbent have higher adsorption capacity compare to granular matter adsorbent, but again separation of adsorbent is a problem, so in our study hydrocyclone chosen to remove both color and adsorbent. Also some industries have particulate and color is a common pollutant, so this study is very useful for them. Commercial activated carbons are usually expensive, so that regeneration is essential, whereas fly ash is inexpensive, so regeneration is not necessary.

2. Experimental methods and technique

2.1. Adsorbate: methylene blue

Methylene blue is a basic dye, with the molecular formula $C_{16}H_{18}N_3ClS$ (molecular weight 373.91) with CAS No. 61-73-4, was chosen as adsorbate. The chemical structure of the dye is shown in Fig. 1. A stock solution of methylene blue was prepared (1000 mg/l) by dissolving required amount of methylene blue in distilled water. The stock solution was diluted with distilled water to obtain desired concentration. The concentration of methylene blue in each aqueous solution was measured on an ET99731 UV–vis spectrophotometer (Tintometer GmbH, Germany) by measuring absorbance at λ_{max} of 665 nm. A cali-

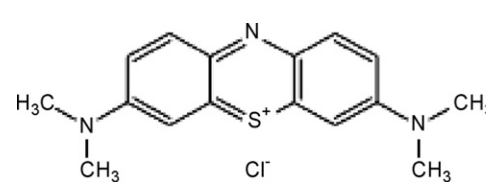

Fig. 1. Chemical structure of methylene blue dye.