Kinetic Study for the Adsorption of Toxic Dyes on Low Cost Modified Agricultural Waste

Saira Syed*, Farozan Umer
Department of Chemistry, Jinnah University for Women, Karachi, Pakistan.
*E-mail: sairasyed450@gmail.com

ABSTRACT

This research emphases on the application of renewable resources and green technologies for absorption of toxic dyes from water resources that are of profound environmental interest. This research discusses the possibilities of bio-char made from agriculture waste using environmentally friendly process. Adsorbent surfaces were prepared by using Potato peel and Rice husk. The characterization of both the prepared adsorbent was performed by Fourier Transformed Infrared spectroscopy for identification of functional group generated after carbonization. Scanning Electron Microscopy and Energy Dispersive Spectroscopy (SEM-EDS) were also applied for the determination of particle size, porosity of surface and elemental composition. Adsorption of two toxic synthetic dyes, Methylene blue (MB) and Congo red (CR) on prepared surfaces were performed. Different parameters such as pH, contact time, adsorbent concentration and temperature were also adjusted to optimize adsorbent performance. The kinetic analysis suggested the reaction had pseudo second order kinetics and the isothermic analysis showed that Langmuir and Freundlich isotherm model was the best model to describe the process. This approach not only helps in mitigating the environmental impact of toxic dyes in water bodies but also provides a sustainable method of recycling agricultural waste materials. The use of these natural adsorbents offers a promising, low-cost, and effective technique for dye removal by supporting both waste management and water purification efforts.

Keywords: Adsorption, Dyes, Agricultural Waste, Kinetics.

INTRODUCTION

All living organisms need water – life on Earth simply cannot exist without it. Water is essential for the farming, domestic, and industrial processes of our everyday lives. Yet we know that less than 1 per cent of Earth's freshwater is easily available, and that its contamination is ecologically disastrous. In recent decades, the high population growth rate and climate change increased the need for water, increasing the pressure on infrastructure for supply and consumption. Purified drinking water and properly managed waste are crucial for growth and development and minimising environmental pollution and disease (Alprol, 2024).

Dyes contaminaed wastewater from industry into water bodies is a major problem these days. Industries such as textile, dye, tanning and paints discharge toxic effluents that contaminates watercourses, influencing not just their appearance but also ecosystems and marine life. This contamination exposes millions of people to water-borne illnesses. This contamination poses a threat to millions of people suffering from waterborne disease. Dye pollution is particularly serious, it is estimated to be as high as 100,000 commercially available dyes are used in textile sector, as a result it contribute about 300,000 tonnes annually to the streams pollution load. Efforts to combat water pollution have heavily emphasized the removal of these colored effluents, drawing attention from academics and researchers alike (Kainth *et al*. 2024).

Generally there are two categories of dyes: natural dyes, which were extracted from plant materials such as seeds, leaves, stems, roots, flowers, and grasses and other category is synthetic dyes, which were extracted in further three groups: (1) water-soluble dyes (direct, basic, acid, reductive, metal complex, solubilised vat dyes);

(2) water-insoluble dyes (vat, disperse, and sulphur dyes) and (3) in-situ color forming dyes, such as azoic dyes (Tsoutsa *et al*. 2024).

Heavy use of dyes in leather, paper, food, cosmetics, textiles and pharmaceuticals is among the leading causes of environmental pollution. By the 1940s, heavy metals and dye contaminants had been accumulating and spread more quickly in the environment as urbanization and industrialisation had increased. These chemicals, accumulated in different organs, can result in a wide variety of disorders. Consequently, a number of techniques for getting rid of dyes and heavy metals have been developed and approved.

Dyes and heavy metals accumulating in water bodies pose threat to humans, animals and plants. These metals and dyes are toxicants because, although they are needed in very small quantities, but they can be harmful at high doses. These toxicants enter the environment through human activities such as mining, transportation, waste, industry, research laboratories, agricultural products and sewage. Because of their toxic nature, they can contaminate our skin, immune system, reproductive system, cardiovascular system, and many other organs (Dutta *et al*. 2024).

Wastewater treatment techniques are categorized on their mode of operational mechanism. Physical separation includes ion exchange, ion flotation, and adsorption; chemical separation includes chemical precipitation, oxidative decomposition, and coagulation/flotation. It is also often degraded through membrane techniques such as dialysis or reverse osmosis, or through instrumental processes such as irradiation or electrochemical decomposition. All these strategies have their own pros and cons (Kallawar and Bhanvase, 2024).

Adsorption is a powerful method for filtering pollutants from contaminated water because of its availability, cost, ease of operation, high efficiency, and recycler ability. Metal oxides, functionalized silica, activated carbon and non-living biomass are typical adsorbents for extracting heavy metal ions and dyes from water. It has increasingly been studied how modified polysaccharides such as chitosan could be used to adsorb toxic compounds. Researcher have also used food scraps like eggshells, banana peels, orange and potato peels, dates, apricots and pumpkin seeds as suitable adsorbents material (Gogoi *et al*. 2024).

OBJECTIVE

Synthesis of low cost adsorbent surfaces by utilizing agricultural waste material for the adsorption of dyes to be used for waste water treatment. Optimization of adsorption condition by adjusting the parameters (pH, contact time, temperature and adsorbent concentration) for the best possible dye removal from aqueous solutions.

METHODOLOGY

Bench-scale adsorption were conducted to investigate the adsorption efficiency and kinetics of dye removal. Agricultural waste were collected form kitchen waste and washed and dried several times at room temperature and ground to obtained powdered form. Powdered PP and RH were then thermally modified by carbonization. Obtained adsorbent surfaces were then used for the adsorption of MB and CR dye solutions. The adsorption efficiency was determined by adjusting important parameters such as pH, contact time, temperature, adsorbent quantity, stirring, and dye concentration in order to maximize the removal of hazardous substances from the water.

RESULT

Rice Husk and Potato Peels were utilized for the preparation of charcoal without any chemical treatment and found best for the adsorption of Congo red and Methylene blue dye form aqueous phase. Optimum results were obtained without adjustment of pH with any chemicals. Therefore this process was found to be eco-friendly as no harsh chemicals were used in synthesis of adsorbent neither in the adsorption process. It was found that the Langmuir model fits best for describing the monolayer adsorption onto prepared surfaces PPC and RHC for CR and MB dye and adsorption reaction follow pseudo second order kinetics.

CONCLUSION

Using agricultural waste as an adsorbent for toxic substances in water treatment could make industrial-scale processes more economical. Bio-adsorbents can be modified to improve their efficiency to adsorb dyes and other contaminant from water bodies. Most bio-adsorbents have very high adsorption rates with minimum reaction time and low dosage. The potential of agricultural waste bio-adsorbents to adsorb toxic dyes from contaminated water, providing a cheap, eco-friendly and easy synthesis method.

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