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Adsorption study of chromium(VI) by dried biomass of tea leaves

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Chromium contamination has increased in the last few years in industrial effluents. Environmental Protection Act has set an enforceable Criteria Maximum Concentration (CMC) level of total chromium in freshwater as 16 μg/L. The aim of this study was to investigate the Cr^{VI} adsorption on used and dried tea leaves (*Camellia sinensis*). The parameters used to study the adsorption behaviour of chromium on tea leaves were pH of the reaction mixture, initial chromium concentration, dried biomass of tea leaves and agitation speed. The batch kinetic studies showed that adsorption had increased with increase in dried biomass and decrease in pH. No significant variation in the removal efficiency was seen with the increase in agitation speed. Response Surface Methodology was used as a tool of varying multiple experimental parameters simultaneously to get the output. Maximum removal efficiency (84.57%) was obtained after 24 h at pH 5.7; initial chromium concentration of 19.9 mg/L, agitation of 4.2 rpm and dried biomass of 1.5 g. Successful adsorption by tea leaves had been further confirmed by Scanning Electron Microscope, which showed the appearance of smoother surface after adsorption.

Keywords: *Camellia sinensis*, wastewater, chromium, response surface methodology, scanning electron microscope.

1. Introduction

Chromium is one of the most widely used industrial metals. Due to its wide applications, contamination of chromium has increased in the last years in industrial effluents[1]. US Environmental Protection Act has set an enforceable Criteria Maximum Concentration (CMC) level of total chromium in freshwater as 16 μg/L[2]. Chromium exists in several oxidation states, but the most stable and common forms are Cr^0, the trivalent Cr^{III}, and the hexavalent Cr^{VI}. Cr^{VI} is considered the most toxic forms of chromium. It has been reported to cause severe eye irritations, skin ulcers, liver disorder, renal failure, intravascular haemolysis, reproductive and development effects and cardiovascular effects leading to death[3,4]. Cr^{III} is less toxic as it is relatively insoluble in water, presents lower mobility, and is mainly bound to organic matter in soil and aquatic environments. Chemical methods of chromium removal are quite effective in removing it from industrial effluent but are expensive and often cause disposal problem of toxic sludge generated. Biodegradation by microorganisms are cost-effective but thick biofilm may cause diffusion barrier for the chromium. Physical methods such as adsorption offers significant advantages like cost-effective, availability, simple design, ease of operations and efficiency in comparison with other methods[5–9].

The objectives of this study were to investigate the potential of dried mass of used tea leaves (*Camellia sinensis*) as an adsorbent to remove chromium from aqueous solution. *Camellia sinensis* is a species of plant which is used to produce tea. India is a land of tea lovers. India produces approximately 715,000 tonnes of tea every year, thereby making it leading producer of tea after China. But in most cases the tea leaves are disposed off after one time use, thereby generating huge tea leaf wastes. These tea leaves can adsorb a number of heavy metal ions[10]. The parameters used to study the adsorption behaviour of chromium on tea leaves were pH of the reaction mixture, initial chromium concentration, dried biomass of tea leaves and agitation speed.

Conventional methods of adsorption studies consist of only one variable at a time while maintaining others constant. These techniques require many experimental runs making it more time consuming. They also eliminate the interaction effects of other parameters, thereby leading to false optimal conditions. Design of Experts (DOE) is a structured method of varying multiple experimental parameters simultaneously to get effects in the output. It can identify the factors that can cause change in response. It is also used to