



# A spectroscopic study for understanding the speciation of Cr on palm shell based adsorbents and their application for the remediation of chrome plating effluents

Shilpi Kushwaha<sup>a</sup>, B. Sreedhar<sup>b</sup>, Padmaja P. Sudhakar<sup>a,\*</sup>

<sup>a</sup> Department of Chemistry, The M. S. University of Baroda, Vadodara 390002, India

<sup>b</sup> Inorganic and Physical Chemistry Division, Indian Institute of Chemical Technology (Council of Scientific & Industrial Research), Hyderabad 500607, India

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## ABSTRACT

Palm shell based adsorbents prepared under five different thermochemical conditions have been shown to be quite effective for removal of chromium (III and VI) from aqueous solutions. X-ray photoelectron spectroscopy (XPS) and Fourier Transform Infrared Spectroscopy (FT-IR) have been used to determine information about the speciation and binding of chromium on the adsorbents under study. X-ray photoelectron spectroscopy (XPS) studies indicate that oxidation of lignin moieties takes place concurrently to Cr(VI) reduction and leads to the formation of hydroxyl and carboxyl functions. The maximum adsorption capacity for hexavalent chromium was found to be about 313 mg/g in an acidic medium using PAPS. This is comparable to other natural substrates and ordinary adsorbents. The efficacy of the adsorbents under study to remove chromium from plating waste water has been demonstrated.

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## 1. Introduction

Chromium is used in various industries including metallurgy, leather tanning, and electroplating. It is also used as a control agent for corrosion. Among the several oxidation states of chromium, trivalent chromium together with the hexavalent state is mainly present in the aquatic environment (Evangelou, 1998). Although trivalent chromium is less toxic than hexavalent chromium, a long-term exposure to trivalent chromium is known to cause allergic skin reactions and cancer (Eisler, 1986). As a result, there is regulation of total chromium in many countries. Hexavalent chromium species are strong oxidants that act as carcinogens, mutagens, and teratogens in biological systems. Hexavalent chromium exists in water as oxyanions such as chromate ( $\text{HCrO}_4^-$ ) and dichromate ( $\text{Cr}_2\text{O}_7^{2-}$ ). Its speciation is dependent on the pH. It causes diseases such as epigastric pain, nausea, vomiting, severe diarrhea, and hemorrhage by ingestion. The maximum allowed contaminant drinking level for the drinking water is 0.05 mg/L (Faust and Aly, 1987).

Among available conventional processes used to remove chromium, the most commonly used are reduction and precipitation as chromium hydroxide (Argo and Culp, 1972) or ion exchange (Costa et al., 1998). However, these methods suffer from some disadvantages due to relatively high operational costs of ion exchange process and production of significant amounts of sludge when

precipitation technique is used. There is therefore a need for the developments of cheaper alternative technologies that can be used as complement to the usual methods mentioned above.

Adsorption processes were studied and emerged as one of the most promising techniques. This process can be a potential alternative to the usual treatments of waters and wastewaters in order to reduce the metal content to the levels established by the legislation. Nevertheless, the sorbent must also be cheap and have a high bio-disposability to render the cleanup process suitable and competitive. Several inexpensive sorbents have been tested in the removal of hexavalent and trivalent chromium such as condensed tannin gel (Nakano et al., 2001), natural material such as sawdust (Yu et al., 2003; Acar and Malkoc, 2004); plants (Ucun et al., 2002; Garcia-Reyes et al., 2009; Li et al., 2009; Garcia-Reyes and Rangel-Mendez, 2010), chitin/chitosan biopolymer (Justi et al., 2005; Zhou et al., 2009), microorganism and sea weed biomass (Yun et al., 2001; Park et al., 2005, 2007; Elangovan et al., 2008).

Most reports claim that the  $\text{Cr}^{6+}$  was removed from aqueous systems by anionic adsorption (Acar and Malkoc, 2004; Ucun et al., 2002) but Yu et al. argued that these findings were misinterpreted due to errors in measuring chromium species in aqueous phase, insufficient contact time required for equilibrium, and the lack of information about the oxidation state of the chromium bound on the biomaterials (Yu et al., 2003). Some researchers have reported that the removal of  $\text{Cr}^{6+}$  was partly through reduction, as well as anionic adsorption, and that the partial reduction could take place only under strongly acidic conditions (pH <2.5) (Acar and Malkoc, 2004).

\* Corresponding author. Tel./fax: +91 265 2795552.

E-mail address: [p\\_padmaja2001@yahoo.com](mailto:p_padmaja2001@yahoo.com) (P.P. Sudhakar).