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Efficacy of Newly Developed Activated Carbon from Bark of Butea monosperma For Removal of Hexavalent Chromium

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ABSTRACT

Heavy metals present in the aquatic systems have become a serious problem. Due to this reason, it has been a great concentration on the development of new technologies for the removal of heavy metal ions from contaminated water. The adsorption process is one of the effective technology for the removal of toxic heavy metal ions. Hexavalent chromium is one of the major metal ion pollutants in the environment and is present in wastewater from most of the various industrial sections. Several conventional physical and chemical treatment technologies are reported in the literature for the removal of hexavalent chromium. But, these processes are expensive and energy intensive and lead to the generation of harmful and carcinogenic by-products. In the recent study, the adsorption ability of activated carbon derived from the bark of *Butea monosperma* for removal of Cr(VI) from polluted water has been studied with respect to different parameters like the effect of pH, adsorbent dosage, contact time and initial metal ion concentration. The hexavalent chromium uptake was dependent on equilibrium pH=6.5, being the optimum pH value. Cr(VI) elimination from aqueous solution increases with an increase in contact time, and equilibrium was attained at 150 min. Further, on increasing the adsorbent dose, there was an increase in Cr(VI) removal. The maximum adsorption of Cr(VI) (96%) was examined at 5.0 g/l of adsorbent dose. The upsurge in the initial concentration of Cr(VI) decreases the percent removal of Cr(VI). This examination proved that the newly synthesized activated carbon from the bark of *Butea monosperma* could be used as a cost-effective and less energy-intensive adsorbent to remove hexavalent chromium from aqueous solution and can be successfully applied for the treatment of wastewater.

INTRODUCTION

Water is the most significant resource for all living things throughout the world (Berger, et.al.,2017; Brandes, et.al.,2019; Tran, et.al.,2021; Anush, et.al.,2019). However, water pollution is considered the greatest stimulating issue all over the world, especially in developing countries like India (Anush, et.al., 2019;Jackcina Stobel,et. al.,2019;Tofighy,et.al.,2020). Origin of pollution of water is mainly in urbanization, industrialization and the increase in human population observed during the past one and half-century. Among these, different industries release several toxic contaminants such as heavy metals, organic dyes, pharmaceuticals, petroleum products, and others into water bodies (Hokkanen, et.al.,2016; Mohd., et.al.2020; Qin X., et.al.,2019). Owing to their noxiousness and bioaccumulation, they supply enormous hazards to living things (Md Ariful, et.al., 2020; He C, et.al. 2017; Amanda, et.al.,2020). Some of the metal ions can have toxic effects on many forms of human life and the environment [Shahnaz, et.al.,2020; Tshikovhi, et.al.,2020; Bhanjana, et.al.,2017). Metals that are toxic to human beings and ecological environments include copper, chromium, lead, mercury, cadmium, nickel, iron, and cobalt (Vilardi, et.al.,2018; Yu G, et.al.,2019; Hou S,et.al.,2019). Even the presence of a low concentration of these heavy metal ions in the environment may cause serious environmental and health issues (Alidokht, et.al.2011; Yu X, et.al.,2014). Chromium and its derivative compounds are the most toxic water pollutants out of these toxic metal ions.

Chromium (VI) is present in the effluents of electroplating, metal finishing, magnetic tapes, wood preservation, leather tanning, pigments and chemical manufacturing industries (Gupta, et.al.,2019; Wang, et.al., 2012). Chromium is present in the environment in two oxidation states, viz. trivalent Cr(III) and hexavalent Cr(VI). Cr(III) is referred to as a crucial trace nutrient for humans, while Cr(VI) is highly toxic to human life (Dobrowolski & Otto,2010; Nriagu & Nieboer,1988). Because of the mutagenic and carcinogenic properties of hexavalent chromium affect skin irritation, lung cancer and kidney, liver, and gastric damage (Mansri, et.al.2009). As determined by NTP, IARC and WHO, chromium (VI) is a human carcinogen at a level above its WHO standard value (Ozgunay,et. al.,2007; Hauber & Buljan,2000). According to the WHO, the tolerance limit for Cr(VI) for discharge into inland surface water is 0.1 mg/l and in filtered water is 0.05mg/l. The Ethiopian Environmental Protection Authority (EPA) also set a minimum standard of 0.1 mg/l for hexavalent chrome containing industrial effluent (Belay,2010). Several technologies have been developed for the treatment of water and wastewater. The most common technologies for chromium-carrying wastewater remediation include membrane filtration, ultrafiltration, ion exchange, co-precipitation, electrolytic methods, photocatalysis, and Adsorption (Hegazi, 2013). Most of

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these techniques are not capable of efficient removal of chromium metal ion concentration up to the tolerable limit (Zare,et.al.,2018). They also have some technical drawbacks such as intensive operation, high energy-expensive, high cost, a lot of chemical consumption and the generation of secondary products which are toxic and harmful (Maitlo,et.al.,2019). Therefore most conventional techniques are not profitable as an industrial-scale method for removal of hexavalent chromium from an aqueous solution (Jin L,et.al.,2019). Amongst these methods, adsorption is a very effective and economical process. Adsorbents are prepared from various kinds of biomass, agricultural by-products, clay, corncob and fly ash (Selvi, et.al., 2001; Rao, et.al., 2007; Ait Bentaleb, et.al., 2016) which are used for the removal of contaminants from the water. A large number of low-cost biosorbents are developed from different by-products, such as green coconut shell (Kumar & Meikap,2014), sugarcane bagasse (Singh,2017), coffee husk (Berihun,2017), rice husk (Dai, et.al.,2015), mango kernel (Rai,et.al., 2016), maize cob (Ibrahim, 2013), sawdust (Ibrahim & Jimoh, 2012), hazelnut shell (Kobya, 2004), groundnut hull (Owalude & Tella, 2016), sugarcane bagasse (Kumari, 2017), pea pod peel (Sharma, et.al.,2016), avocado seed kernel (Mekonnen, et.al.,2015), tea waste (Malkoc & Nuhoglu, 2007) and olive bagasse (Demiral, et.al.,2008) had been used for Cr(VI) adsorption. In the recent work, the studies are carried out for the removal of Cr(VI) from an aqueous solution using activated carbon generated from the bark of *Butea Monosperma*. *Butea monosperma* is a flowering plant belonging to Fabaceae family, locally known as dhak or palas. *Butea monosperma* is mostly used in Ayurveda, Unani and Homeopathic medicine (*The Ayurveda Pharmacopeia of India,1999*) and has become a cynosure of modern medicine (Sindhia & Bairwa, 2010). The characterization of newly prepared activated carbon from the bark of Butea monosperma was done by XRD, FTIR and scanning electron microscopy (SEM) studies. The batch equilibrium method was conducted at 308K to evaluate the efficacy of the newly developed adsorbent for the abatement of hexavalent chromium from the aqueous solution. Experiments were conducted to evaluate the effect of pH, adsorbent dosage, contact time and initial metal ion concentration. Thus, recently activated carbon has been confirmed a very excellent adsorbent and successfully utilized the abatement of hexavalent chromium from an aqueous solution.

MATERIALS AND METHOD

Chemicals:

The chemicals of AR grade are used and purchased from Global Marketing, Nagpur (India).

Activated Carbon preparation from the bark of *Butea Monosperma* (ACBBM):

The bark of *Butea monosperma* tree is collected in a native forest area. The bark of the tree was divided into small pieces and washed with tap water to get rid of sand particles. The washed material was then immersed in formaldehyde to prevent the formation of pigment in the aqueous solution. It is also washed with water. Once drying, the bark is subjected to the pyrolysis process for carbonization at 7500C for 5 to 6 hr. So that volatile matter was removed and converted into a char. The char is placed in a microwave oven for microwave activation for 30 min. Activated carbon particles were grounded and sieved in 120-200 mm size. The newly generated activated carbon was then washed with double distilled water and dried at 105oC for 4 to 5 hr.

Characterization of ACBBM

Characterization of ACBBM was done by SEM (Fig.1), FTIR (Fig.2), XRD (Fig.3)

Adsorption Studies

Standard operating solutions were developed from the Cr(VI) stock solution. The batch equilibrium method is performed for Cr(VI) removal using ACBBM. The different parameters such as pH effect, contact time, adsorbent dosage and initial metal ion concentration have been examined. The pH impact and contact time were investigated at 350C with an initial metal ion concentration of 25 mg/l and 5g/lit of adsorbent, i.e., ACBBM. The impact adsorbent dose turned into studied with varying quantities of adsorbent from 1g to 9g with Cr(VI) concentration of 25mg/l, while the effect of initial metal ion concentration was investigated with concentrations ranging from 5mg/l to 50mg/l with an adsorbent dose of

Figure A: Bark of *Butea Monosperma*

Figure B: Activated Carbon Derived from Bark of BM

5g/l at 350C and the residual concentration is measured the usage atomic absorption spectrophotometer.

RESULT AND DISCUSSION

Characterization of ACBBM

FTIR Analysis: FTIR analysis (fig.1) was performed to identify the various functional group present in ACBBM. The spectrum of ACBBM implies that different absorption peaks are present that indicate the complex nature of ACBBM. A band at 3420 cm-1 represents –OH and –NH group stretching. The absorption peak at 2960 cm-1 can be proven withinside the aliphatic C-H group. The peak at 1740cm-1 was displayed in the -C=O group, similar to the carboxylic or ester group. A band around at 1620cm-1 displaying in –C=O group (the amide band is usually a stretching band). The peak at 1520 cm-1 implies that –C=O group corresponds to the carbonyl stretching band.

SEM Analysis: The scanning electron microscopy (SEM) of ACBBM, as proven in fig. 2, suggests that it has a clean pore shape structure developed on the floor of ACBBM. It was noticed that there had been very small and big cavities on the surface of the ACBBM. Due to the existence of the hollow space like the shape of an adsorbent, ACBBM possessed excessive surface area and high adsorptive properties. The adsorption method of any heavy metal relies upon the dimension of hallow space on the surface of the activated carbon.

XRD Analysis: The XRD is tested to observe the crystalline or amorphous nature of the ACBBM and is shown in Figure 3. The fabric is an amorphous characteristic in the comprehensive XRD pattern structure, indicating an extremely disordered structure. The elevation is found around to 2θ value of around 22°,

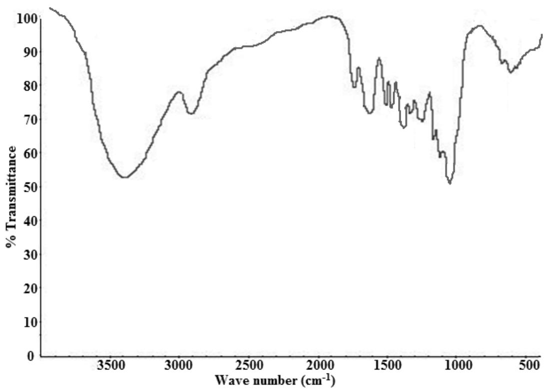

Figure 1: FTIR Spectrum of activated carbon of Bark of Butea Monosperma(ACBBM)

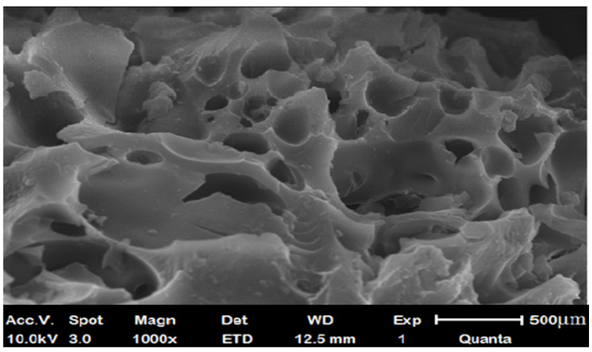

Figure 2. X-ray diffractogram of ACBBM

and small peaks near 16° and 35° and is associated with crystalline cellulose (Barnette, et.al., 2012).

Impact of pH: The impact of pH on Cr(VI) adsorption is shown in fig.4. It is proven that pH of the solution plays an essential role in the elimination of Cr(VI). The elimination percentage of Cr(VI) increases from 55 to 94.5 as the initial pH of the solution rises from 1 to

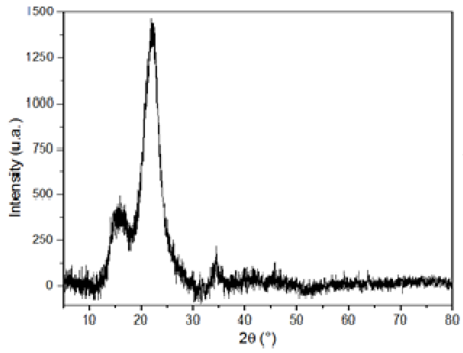

Figure 3. X-ray diffractogram of ACBBM

6.5 and is appreciably better at 6.5 pH . The adsorption percentage gradually decreased to 80% as the pH of the solution increased from 6.5 to 8.0. So the adsorbent, i.e., ACBBM, can be effectively used at 6.5 pH for the Adsorption of Cr(VI).

Effect of Contact Time on Cr(VI) adsorption: Sorption of Cr(VI) ion with contact time was studied and shown in fig.5. The figure indicates the removal of Cr(VI) ability to extend with increasing contact time before reaching equilibrium. Alternative limitations like a dose of ACBBM, solution pH and initial Cr(VI) ion concentration were unbroken optimum. From Fig.4, it is observed that removal potency inflated from 50% to 96% once contact time increased from 60 to 150 min. The optimum contact time for ACBBM was found to be 150 min. However, when equilibrium is achieved, it is nearly constant.

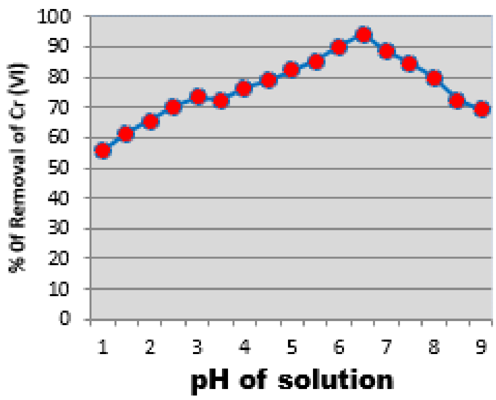

Figure 4: pH effect on Cr(VI) adsorption

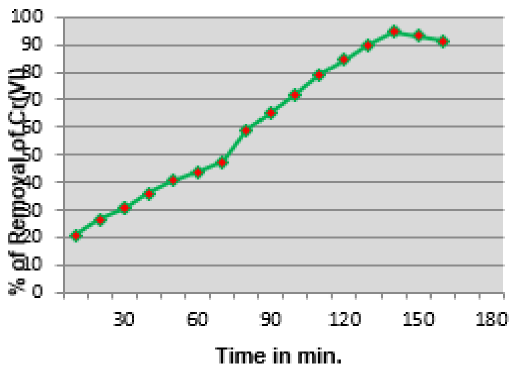

Figure.5: Effect of Contact time

Effect of Adsorbent Dosage: The result of adsorbent dose on Cr(VI) sorption is shown in fig 6. The study was performed by changing the ACBBM value from 1 to 9 g/l while maintaining other limiting parameters like the pH scale of the solution, contact time and initial metal in concentration fixed. The figure shows that the proportion of Cr(VI) removal inflated with the rise in the dose of ACBBM. The highest Cr(VI) removal was found at 94.5% with a dose of adsorbent 6gm. This is often attributed to the fact that more accessibility of cavity and availability of surface area of the adsorbent. Once the

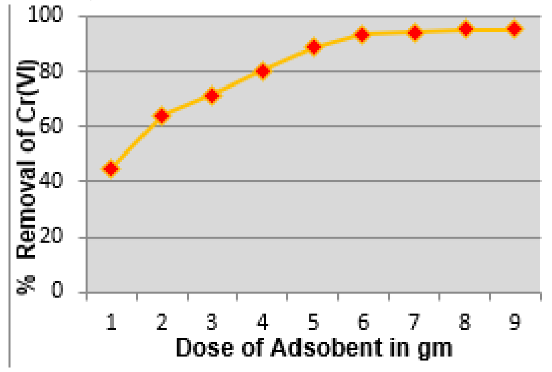

Figure 6: Effect of Adsorbent dose

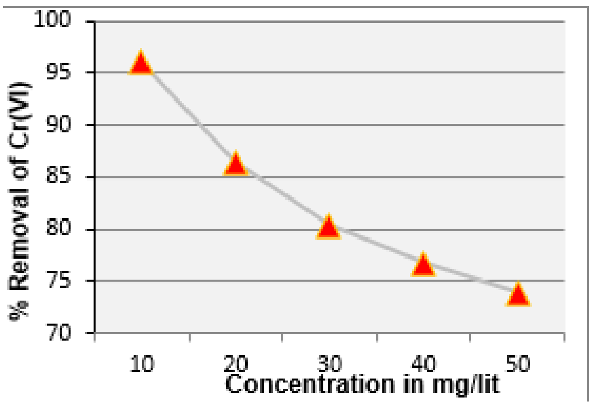

Figure 7: Effect of concentration on Cr(VI) adsorption

bound dose of adsorbent, the potency of the removal remains unchanged as a result of the utmost sorption set and Cr(VI) ion present within the solution are sure to the adsorbent almost unchanged.

Impact of initial metal ion concentration: The result of initial metal ion concentration on hexavalent chromium removal by ACBBM as shown in fig.7. It is ascertained that the percentage of Cr(VI) removal decreases with increasing of Cr(VI) ion concentration. In the current study, the experiments were performed to gauge the effect of initial metal ion concentration at 10mg/l to 50mg/l. A dose of adsorbent was taken at 5g/l.The result shows a decrease in Cr(VI) removal from 96% to 73%.This will be even because the adsorbent has a restricted number of active sites or pores that are saturated beyond.

CONCLUSION

• Powder X-ray confirmed that ACBBM was crystalline with a diffraction pattern, the scanning microscopy (SEM) of adsorbent ACBBM steered that it had clear little cavities developed at the surface, and FTIR showed numerous functional groups is associated with them.

• ACBBM was the foremost effective adsorbent for the removal of Cr(VI), i.e., 95% removal at pH 6.5. After pH 6.5, the removal of Cr(VI) was decreased. Therefore adsorbent is employed most effectively at pH 6.5 for removing Cr(VI).

• Further increase within the adsorbent and exaggerated contact time is found to extent Cr(VI) removal percentage

• As the dose of ACBBM was fixed, surface assimilation of Cr(VI) from aqueous solution decreased with the rise within the initial Cr(VI) ion concentration.

• We can say that the newly developed ACBBM material features a potential application prospect as an economical adsorbent for Cr(VI) removal from waste water through a price effective and environment-friendly method.

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