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OPTIMIZATION OF CHROMIUM ADSORPTION PROCESS BY SAW DUSTS OF *TECTONA GRANDIS* (TEAK) AND *SHOREA ROBUSTA* (SAKHU)

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Abstract – Chromium is highly toxic and recalcitrant compound it is used in variety of industries such as leather, electroplating, textile dying and steel industries. Its removal is immensely required. Various physico-chemical methods such as chemical precipitation, reduction, solvent extraction, membrane separation and reverse osmosis are in use to remove chromium, but adsorption is more cost effective, efficient and ecofriendly method for the removal of chromium. Present investigation was an attempt to find the optimum conditions for the adsorption of chromium by Teak (*Tectonagrandis*) and Sakhu (*Shorearobusta*) saw dusts, the results indicated maximum adsorption at pH 6, temperature 27 ^oC, adsorbent dose 50 g, adsorbate concentration 50 ppm and contact time 20 minutes**.**

INTRODUCTION

The effluent of tannery includes chromium, sulphide, volatile organics, large quantities of solid waste, suspended solids like animal hair and trimmings. For every kilogram of hides processed, 30 litres of effluent are generated and the total quantity of effluent discharged by Indian industries is about 50,000 m^3 /day (Dhakad and Kushwaha, 2017). The different components present in the effluent affect human beings, agriculture and livestock besides causing severe ailments to the tannery workers such as eye diseases, skin irritations, kidney failure and gastrointestinal problems (Midha and Dey, 2008).

Tannery industry effluents are the major source of the Chromium (VI) in wastewater streams, which are highly toxic and carcinogenic (Gupta and Babu, 2006; Shukla and Mishra, 2021). The hexavalent chromium considered as one of the undesirable heavy metals because it affects human physiology, gets accumulated in the food chain and cause several diseases (Verma *et al.*, 2006). Though various physico chemical methods are on track but they are not at par with biosorption, because it is cost effective, efficient and ecofriendly (Md. Juned and Ahmaruzzaman, 2016).

Wood saw dust, A solid waste product obtained from mechanical wood processing can be used as a low costs adsorbent of heavy metal largely due to its Ligno-cellulosic composition. It is mainly composed of cellulose (40 – 50%) and lignin (23-30 %). Both the capacity for binding metal cations due to hydroxyl, carboxylic and phenolic group present in their structure (Sciban *et al.*, 2007). Variety of works have been done by various workers to remove chromium by different saw dusts (Mohan *et al.*, 2005; Cordero *et al.*, 2002; Hamidi *et al.*, 2001; Kartikeyan *et al.*, 2005).

The present research work deals with comparative study of chemically treated sawdust of Sakhu and Teak, which are used to study the adsorption of hexavalent chromium. The effect of temperature, pH, adsorbent concentration, adsorbate concentration and retention time have also been studied.

MATERIALS AND METHODS

Collection of saw dusts: Saw dusts of Teak and Sakhu were procured from local saw mills.

Preparation of adsorbents: 250 g saw dusts of each

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were sun dried, grinded and sieved to fine powder (218 μ Size). Further saw dusts were treated with 1% formaldehyde in the ratio of 1:4 (w/v) and 50 ml 0.2 NH_2SO_4 followed by washing with distilled water and drying on hot plate at 50 ^{0}C for 4 hours with continuous stirring. The final weights of activated saw dusts were between 180–200 gm indicating 72% – 80% moisture removal.

Percent moisture loss (ML) = W/S X 100

W= weight of dried sample (g)

S= Sample weight (g)

Preparation of adsorbate stock solution: A stock solution of 500 mg/l Cr (VI) concentration was prepared by dissolving 1.41g of 99.9% potassium dichromate ($K_2Cr_2O_7$) in 1 litre distilled water. Further, 5 litres of 100 mg/l Cr (VI) concentration working solution was prepared by diluting the stock solution.

Column preparation for adsorption: Laboratory scale chromium adsorption column was fabricated by two columns of 4.0 cm, 6.0 cm diameter and 24.0cm, 36.0 cm length respectively. The small column was perforated and filled saw dusts, then it was fitted in large column. The flow was regulated by flow regulator. 100 mg/l working solution was passed through the column with retention time of 40, 30, 20 and 10 minutes and flow rates of 0.13, 0.17, 0.25 & 0.5 ml/sec.

Chromium analysis: The concentration of free Cr(VI) ions in the effluent is determined spectrophotometrically by developing a purple - violet colour with 1, 5- diphenyl carbazide in acidic solution as a complexing agent. The absorbance of the purple – violet coloured solution is read at 540 nm after 20 min (APHA, 1985). The percent reduction in the amount of metal ion was calculated using following formula.

$$\text{Percent reduction} = \frac{(C_o - C_f)}{C_o} \times 100$$

C_o and C_f are the initial and final concentrations (mg/l)

RESULTS AND DISCUSSION

Effect of adsorbate concentration: The experiment was conducted at varying concentrations of adsorbate (10, 20, 30, 40 and 50 ppm) using 50 g of adsorbents (Teak and Sakhusaw dusts), to observe maximum adsorption of chromium. Figure 1, clearly indicates maximum absorption of chromium by saw dusts at 50 ppm adsorbate concentration. It is also observed that percent reduction of chromium by Teak saw dust is more (94.64%) at 50 ppm adsorbate concentration, but at lower concentration Sakhu shows better results.

The grain size of Teak saw dust was smooth, i.e.

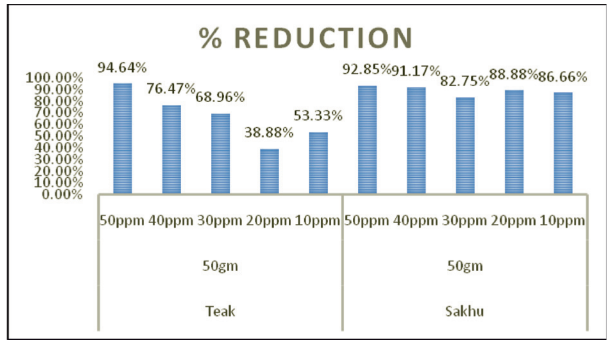

Fig. 1. Effect of adsorbate concentration on chromium adsorption

fine and the grain size of Sakhuwas coarse, this may be the reason for both, maximum adsorption by Teak and consistent good adsorption by Sakhu saw dusts. Due to coarse size, the Sakhusaw dust was more porous leading to consistent good adsorption, whereas in case of Teak due to fine grain size the surface area was more, which resulted more adsorption. At low initial concentration of Chromium, the ratio for surface area of saw dusts to the initial concentrations of chromium is large, therefore increasing the possibility of interactions between positively-charged groups on saw dusts with chromium. However, the ratio is lower when initial Chromium concentrations increases, hence increasing the competition amongst chromium species for positively charged groups on surface area of saw dusts. This results in reduced chromium removal by saw dusts (Zakaria *et al.*, 2009; Shukla and Mishra, 2021).

Effect of adsorbent concentration: Chromium adsorption results indicated maximum adsorption of chromium at 50 ppm adsorbate concentration, so in this set of experiment the adsorbate concentration was fixed at 50 ppm and adsorbent concentration was changed (25, 50 and 75 g) to assess maximum adsorption of the metal. Maximum 94.64% & 92.85% of chromium was adsorbed by Teak and Sakhu saw dusts respectively at 50 gm adsorbent concentration Figure 2. it is also observed that adsorption initially increases by the increase of adsorbent dose, but after reaching an optimum level it decreases by further increase of adsorbent dose.

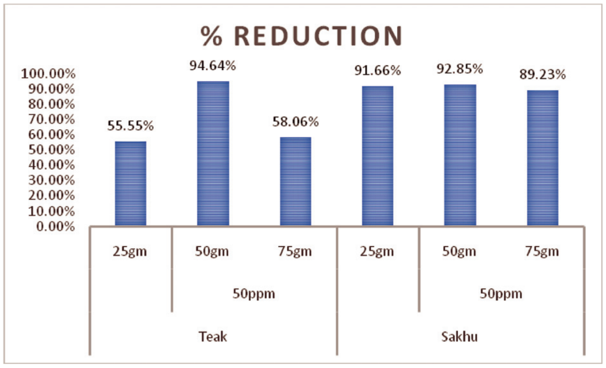

Fig. 2. Effect of adsorbent concentration on chromium adsorption

The adsorption increases by the increase of adsorbent dose up to 50 g from 25 g. It may be due to availability of exchangeable sites or surface area (Thakur and Parmar, 2013). But further increase of adsorbent dose limits the rate of adsorption. It may be due to excessive adsorbent dose in small column, which reduces the pore size and thereby reducing the active surface sites.

Effect of adsorbate pH: The study was conducted at three different pH (viz. 4, 5 and 6) of adsorbate. The percent reduction in chromium content after adsorption by different saw dusts are given in Figure 3. A general trend of increase in chromium adsorption was observed at increasing pH value. This may be due de-protonation of binding sites which makes different functional group available for chromium binding and vice-versa (Nur-E-Alam *et al.*, 2020).

Effect of temperature: At 50 ppm adsorbate concentration, 50 gm adsorbent dose and pH 6 the study for the assessment of maximum adsorption was conducted at different temperatures (25, 27, 30 and 32 °C). the results are presented in Figure 4.

The results indicated maximum adsorption at 27 °C. The extent of adsorption increased with increase in temperature from 25 to 27 °C. this is an

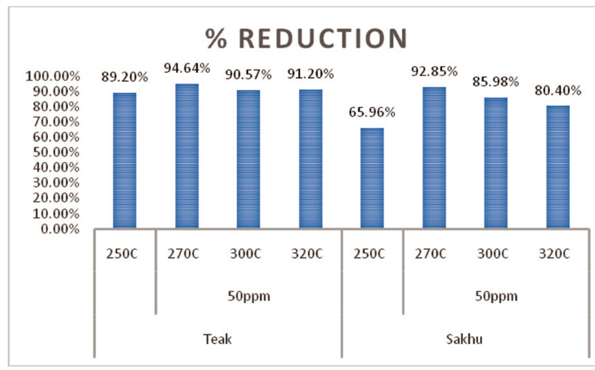

Fig. 4. Effect of temperature on chromium adsorption

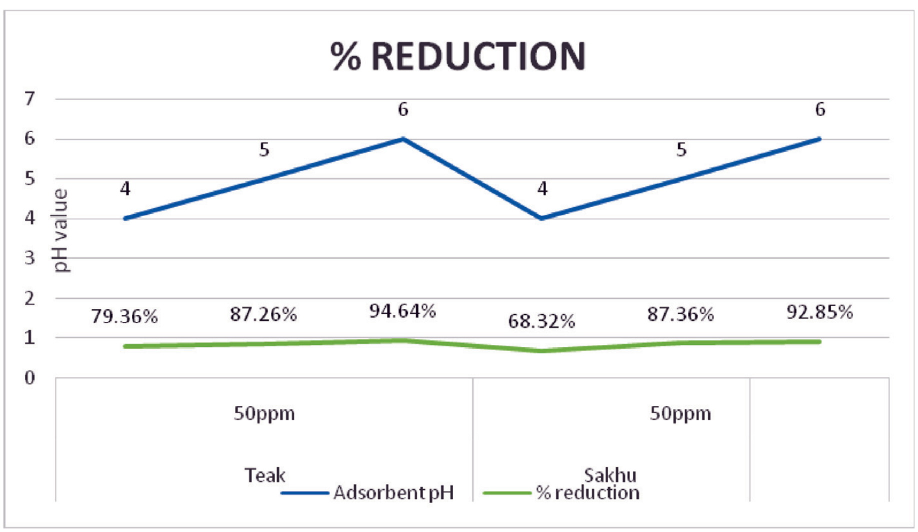

Fig. 3. Effect of adsorbate pH on chromium adsorption

Table 1. Effect of retention time on chromium adsorption

Sr. No.	Adsorbents		Retention time (Minutes) 10	20	30	40
1.	Teak	Percent Removal	72.22%	94.64%	94.43%	94.45%
2.	Sakhu		70.33%	92.23%	90.12%	90.84%

indication that this process of adsorption by saw dusts is endothermic. The enhancement in the adsorption capacity was due to the chemical interaction between adsorbate and adsorbent, creation of some new adsorption site or the increased rate of intraparticle diffusion of chromium ions into the pores of the adsorbents at higher temperature (27 ^{o}C) (Sciban *et al.,* 2007; Argon *et al.,* 2007). Further increase in temperature the percentage removal of chromium decreased. The reason for the fall in the percentage removal at elevated temperatures is that higher temperatures a part of chromium leaves the solid phase and re-enters the liquid phase (Naik and Kumar, 2015).

Effect of retention time: Results indicated, with the initial increase of retention time the adsorption increases up to 20 minutes, but further with the increase of retention time the rate of adsorption almost gets stabilized. It may be due to initial abundant availability of adsorption sites, which is frequently occupied by chromium, resulting reduced availability of adsorption sites at increased retention time (Table 1).

CONCLUSION

The adsorption of hexavalent chromium from solution using Teak and Sakhu saw dusts is ecofriendly, efficient and cost effective. Results of the study indicates, that Teak is more effective adsorbent that removes chromium up to 94.64% within 20 minutes of contact time. The results also indicated that optimum conditions for maximum adsorption of chromium by Teak and Sakhu saw dusts are pH 6, temperature 27 ^{0}C, adsorbent dose 50 g and adsorbate concentration 50 ppm.

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