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SYNTHESIS OF ACTIVATED CARBON FROM TREE SAWDUST AND ITS USAGE FOR DIMINUTION OF COLOR AND COD OF PAPER-MILL EFFLUENTS

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Abstract

In present work, activated carbons were prepared from saw dust of *Dalbergia sissoo, Cedrus deodara and Eucalyptus* spp., using H_3PO_4, H_2SO_4 and $BaCl_2$ as activating agents. The activated carbons were evaluated for reduction in color and chemical oxygen demand (COD) of a real paper industry effluents using batch-mode method to explore the effect of operating parameters (contact time, amount of activated carbon, wastewater concentration, solution pH etc). Statistical analysis revealed that all the activated carbons were significantly different in their efficacy for wastewater treatment. *Cedrus deodara* based activated carbon was most efficient; showed 93% COD reduction with 100% color removal and brought other physico-chemical parameters of wastewater within the permissible limits of WHO and NEQS. The maximum percent reduction of COD and color with *Dalbergia sissoo* activated carbon was 80% and 91%, respectively while with *Eucalyptus* spp., activated carbon; it was 74% and 85%, respectively. The effectiveness of activated carbon synthesized from sawdust of different plants for wastewater treatment was in the following order: *Cedrus deodara* > *Dalbergia sissoo* > *Eucalyptus* spp. The quality of wastewaters after treatment was found to be appropriate for direct discharge into streams and irrigation purpose. This study proved highly successful in addressing the local problem of paper industry effluents using locally available wood processing byproducts.

Introduction

Due to population explosion, rapid industrialization and lack of proper planning, water pollution is increasing at an alarming rate (Richardson, 2007). Industries in Pakistan have increased hap hazardously, having no wastewater treatment plants. They emit pollutants directly in environment without treatment (Qadir *et al.,* 2008). Not even a single step of 3R's (Reduce, Reuse and Recycle) is being followed. Degh Nala, Pakistan receives effluents from two major industrial areas. There, the contamination level is very high. The concentration of mercury (Hg) was 72mg/l in water and 887µg/g in sediments. DDT (1, 1, 1-Trichloro-2, 2-Bis (p-chlorophenyl) ethane) and its metabolites were greater than 1.0µg/g in sediment samples (Tehseen *et al*., 2004). Similarly, there is a significant variation in the spatio-temporal quality of water at Nullah Aik, tributary of the Chenab River of Pakistan (Qadir *et al*., 2008).

The pulp and paper mill industry is a very water-intensive and sixth largest polluter (Anon., 1998). It generates as low as $1.5m^3$ of effluent/tone of paper produced (Szolosi, 2003). About 500 different chlorinated organic compounds have been identified in paper mill effluent (Savant *et al*., 2006). The high chemical diversity of these pollutants causes a variety of carcinogenic, endocrinic and mutagenic effects on aquatic communities (Ali & Sreekrishnan, 2001). The brownish color is mainly attributed to the complex compounds derived from polymerization between lignin-degraded products and tannin during various pulping and bleaching operations. Lignin and its derivatives are difficult to degrade naturally because of the strong linkages within their molecular structure, especially biphenyl-type carbon to carbon linkages (Karrasch *et al.,* 2006).

Due to shortage in canal water (due to seasonal variation) and poor quality of ground water, farmers are using the contaminated water (domestic and industrial) to fulfill irrigation needs (Kakar *et al.,* 2011). Soil and vegetables which were grown in the close vicinity of industrial drains are highly contaminated with Cd, Pb, Cr and Co (Ahmad *et al*., 2011; Butt *et al*., 2005). There is a need to develop a wastewater treatment technology for each industry. Various physical, chemical and biological process are used for wastewater treatment like, sedimentation, chemical precipitation, chemical coagulation/flocculation process (Amuda *et al*., 2006), membrane filtration, flotation, adsorption (Galambos *et al*., 2004), chemical oxidation process, ion exchange, reverse osmosis (Martinez *et al*., 2003) and biosorption (Hussein *et al*., 2004; Iram *et al*., 2012). Such treatment technologies are quite expensive to build, operate, maintain and require skilled personnel (Mazumder & Roy, 2000).

Adsorption by using activated carbon had a long and productive history (Faust & Aly, 1986). Activated carbon is considered very effective for removal of dyes (Malik, 2004) chemical oxygen demand (COD) (Hami *et al*., 2007), biological oxygen demand (BOD) (Devi & Dahiya, 2008) and heavy metals (Hamadi *et al.,* 2001) from wastewater. Research efforts are going on to develop activated carbon–based innovative technology with low cost carbonaceous materials.

Any carbonaceous waste material can be converted into activated carbon, thus its significance is two folds. Firstly, it removes pollutant from wastewater and secondly, converts solid waste into useable activated carbon. Some of the low cost industrial waste/by-products that can be used for activated carbon with varying success include Bagasse (Satyawali & Balakrishnan, 2007), Pecan shell (Bansode *et al*., 2004), Coconut fiber (Mohan *et al*., 2008), Date nut (Anand *et al*., 2009) and peels of Avocado fruits (Devi *et al.,* 2008),

This study was designed to synthesize activated carbon from indigenously available *Dalbergia sissoo, Cedrus deodara* and *Eucalyptus* spp., sawdust, to test their efficiency in paper mill wastewater treatment (with particular emphasis on color/COD reduction) and optimization of conditions for maximum efficiency of activated carbons and maximum treatment.

Material and Methods

Wastewater collection and analysis: Wastewater was collected from the wastewater outlet of Packages (Pvt) Ltd, stored at 2-3^{o}C to prevent any change in physiochemical characteristics. pH, temperature, total solids, dissolved solids, suspended solids, color and COD were determined by the standard method prescribed in APHA (Anon., 1989) handbook, using analytical grade chemicals (Merck).

Activated carbon synthesis: Saw dust of *Dalbergia sissoo, Cedrus deodara and Eucalyptus* spp., was collected free of cost from the local furniture workshops. Sawdust samples were sieved (pore size of 0.25 mm), washed several times to remove dust and dried at 110^{o}C for 24h in drying oven. It was then used for the synthesis of activated carbons. H_3PO_4, H_2SO_4 and $BaCl_2$ were used separately as activating agents for the synthesis of activated carbon.

For activation, 100 g of saw dust (*Dalbergia sissoo, Cedrus deodara* and *Eucalyptus* spp.) was well mixed with 100 ml activating agent (H_3PO_4, H_2SO_4 and $BaCl_2$ separately) having the strength of 2% and placed in the oven at 110^{o}C for 24h. The sample was then soaked in distilled water and was subsequently replaced until the pH of the solution become stable. The sample was then washed with 2% HCl (v/v) or $NaHCO_3$ (w/v), and then with distilled water to remove any activating agent. It was then dried at 110^{o}C. The dried samples were transferred to the muffle furnace at 650^{o}C for 6h, at the expiry of time the activated carbon obtained was used for the wastewater treatment.

Activated carbon analysis: Activated carbon was analyzed for bulk density, moisture content, yield % and ash content, using method described by (Ahmedna *et al*., 1997).

Batch adsorption process: 250ml flask was filled with 100ml of wastewater. The desired pH was adjusted using 0.1N H_2SO_4 / 0.1N NaOH. Then weighed amount of activated carbon was added in the flask and transferred to the orbital shaker for predetermined interval of time. After the expiry of given times the flask was removed from the shaker. The solution was filtered using Watmann filter paper # 44. Filtrate was then examined for the COD and color. The difference in wastewater and filtrate, gives the % removal of COD and color.

Effects of different factors like solution pH, amount of activated carbon, shaking time (contact time) and agitation speed were studied. Contact time was investigated by changing contact time during batch process from 1-6 h, and keeping all the other parameters fixed. Similarly effect of solution pH and amount of activated carbon was examined by changing one parameter and keeping other constant. All the batch experiments were conducted in triplicate.

Statistical analysis: Data of three activated carbons for various parameters were subjected to one-way ANOVA followed by Duncan's Multiple Range Test, in order to reach a certain conclusion about the most efficient activated carbon.

Results and Discussion

Wastewater analysis: The chemical analysis of wastewater from Packages Pvt. (Ltd) is given in Table 1, with Anon., (1995) limits. The effluent pH is about 20.6% higher than the permissible limits. Temperature of the effluent is 50% higher than standard limit. Total solids (TS), total dissolved solid (TDS), total suspended solids (TSS) and COD are 952.3%, 584.4%, 1760% and 446% higher than standard limit, respectively. The reason behind selection of one industrial waste was that activated carbons differ significantly in their surface characteristics (surface charge, pH, surface chemistry, porosity, etc.). Similarly, wastewater from different sources also differs in their characteristic (pH, number of pollutants, amount of pollutants, etc.), this makes activated carbons specific for specific functions.

Table 1. Physical-chemical properties of wastewater of paper mill along with WHO permissible limits (1995), for the release of treated wastewater to irrigation waterway.

Parameters	Characteristics of wastewater	Characteristics after treatment	WHO permissible limits
pH	6.39	6.9	6.8 - 8.5
Color	Dark brown	Colorless	
Temperature (^{o}C)	30	Ambient temperature	20
Total solids (mg/l)	6810	> 100	655
Total dissolved solids (mg/l)	3080	> 70	450
Total suspended solids (mg/l)	3720	> 32	200
Chemical oxygen demand (mg/l)	1640	> 147.6	300

Activated carbon analysis: In general, activated carbons can be prepared from any carbonaceous material. But now the researchers are exclusively using waste material/by products for its preparation. The benefits of using waste materials are 2 folds. Firstly, the raw material is available at relatively free of cost. Secondly, the waste materials get used and do not create environmental pollution. In this research work, these two benefits were given prime importance. *Dalbergia sissoo, Cedrus deodara* and *Eucalyptus* spp., sawdust were selected because it is a byproduct of furniture industry and is available at very low cost. Other waste materials used by different researchers are, used tires (Hamadi *et al*., 2001), Bagasse (Satyawali & Balakrishnan., 2007), Coconut fiber (Mohan *et al*., 2008) and Date nut (Anand *et al*., 2009). Activated carbons analysis/comparison is given in Table 2. These activated carbons differed significantly in bulk density, yield, moisture content and ash content. *Cedrus deodara* based carbon shows best characteristics. Table 7 gives a comparative view of some of the activated carbons and their efficiency in removing/reducing COD and color.

Effect of activated carbon amount on COD and color reduction: The equilibrium point by activated carbon amount for COD reduction by *Cedrus deodara* is 5g/l and for *Dalbergia sissoo* is 7g/l (Table. 3). Maximum COD reduction by *Cedrus deodara* and *Dalbergia sissoo* is 94% and 82%, respectively. Further increase in the amount of activated carbon beyond the equilibrium point will no more increase the COD reduction. However the *Eucalyptus* spp., did not show any equilibrium, its COD reduction capacity keeps on increasing with the increase in activated carbon amount. The three activated carbons differ significantly in their COD capacity. This decrease in COD uptake capacity with increase in dose of activated carbon may be due to the formation of clusters of carbon particles resulting in decreased surface area (Nagda, 2006). At low concentration, the interaction between solute and solvent increase, so the solute has low tendency towards activated carbon and high affinity towards solvent (Nadeem *et al*., 2006).

Amount of activated carbon effects color reduction significantly (Fig. 1). Minimum color reduction by *Cedrus deodara* is 40% and maximum is 100%. The rate of color reduction increase sharply from 1-5g/l. *Dalbergia sissoo* shows maximum growth at 10g/l with 100% color reduction. Fig. 1 shows that at lower concentration the color reduction is rapid but as the concentration increases from 7g/l the rate of color reduction decreases slowly. At the concentration of 10g/l the *Cedrus deodara* and *Dalbergia sissoo* shows no significant difference but they are still significantly better, compared to *Eucalyptus* spp. *Eucalyptus* spp., did not show better result, compared to other activated carbons.

Effect of contact time on COD and color reduction: Table 4 reveals the data for COD reduction. All the three activated carbons differ significantly in COD reduction at different time duration. The equilibrium time (91.3% reduction) for *Cedrus deodara* is 4 hours, further increase in time (5 and 6hrs) do not significantly increase COD reduction (92.5%). the COD reduction increase sharply in lower time durations (1-4hrs). for *Dalbergia sissoo* the maximum of 82.6% COD reduction was achieved at 6hrs time. Statistical analysis revealed that all the activated carbons different significantly in their COD reduction at all the time treatments given (1-6hrs).

Table 2. Comparison of activated carbons.

	Characteristic			
Activated carbons	**Bulk density (g/ml)**	**Yield (%)**	**Moisture content (%)**	**Ash content (%)**
Cedrus deodara	0.45 a ± 0.014	44 a ± 0.561	4.1 c ± 0.164	5.2 c ± 0.451
Dalbergia sissoo	0.40 b ± 0.016	41b ± 0.652	5.6 b ± 0.471	5.8 b ± 0.406
Eucalyptus spp.	0.38 c ± 0.12	39 c ± 0.343	5.9 a ± 0.354	6.8 a ± 0.521

Treatments means followed by different letters in each column are significantly different at p=0.05 according to Duncan's Multiple Range Test

Table 3. Percentage COD reduction at different activated carbons types and amounts.

	Activated carbon amount (g/l)									
Activated arbons	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Cedrus deodara	24.3a ± 0.34	43.5 a ± 0.64	64.2 a ± 0.52	81.8 a ± 0.67	90.7a ± 0.38	92.1a ± 0.81	92.4a ± 0.65	93.3a ± 0.44	93.7a ± 0.30	94a ± 0.34
Dalbergia sissoo	6.4 b ± 0.54	15 b ± 0.52	30 b ± 0.32	51.1b ± 0.45	67.7b ± 0.87	76b ± 0.31	80b ± 0.55	81.2b ± 0.84	81.8b ± 0.61	82.1b ± 0.22
Eucalyptus spp.	1.9 c ± 0.11	5.8 c ± 0.21	16.9 c ± 0.97	28.4 c ± 0.21	44.1c ± 0.12	59.1c ± 0.88	68.1c ± 0.91	71.6c ± 0.49	75.7c ± 0.52	76.4c ± 0.71

Other operating conditions are time: 4hrs, pH 5, agitation speed: 800 rpm. Treatments means followed by different letters in each column are significantly different at p=0.05 according to Duncan's Multiple Range Test.

Table 4. Percentage COD reduction at different activated carbons types and contact time.

	Contact time (hrs)					
Activated carbons	**1**	**2**	**3**	**4**	**5**	**6**
Cedrus deodara	37.4a ± 0.54	59.7a ± 0.98	81.9a ± 0.32	91.3a ± 0.54	92a ± 0.81	92.5a ± 0.39
Dalbergia sissoo	18.7b ± 0.34	31.2b ± 0.65	47.6b ± 0.21	75.7b ± 0.38	80.2b ± 0.55	82.4b ± 0.54
Eucalyptus spp.	8.6c ± 0.32	19c ± 0.71	34c ± 0.77	59c ± 0.83	63.9c ± 0.31	66.4c ± 0.67

Other operating conditions are, activated carbon amount: 5g/l, pH 5, agitation speed: 800 rpm. Treatments means followed by different letters in each column are significantly different at p=0.05 according to Duncan's Multiple Range Test

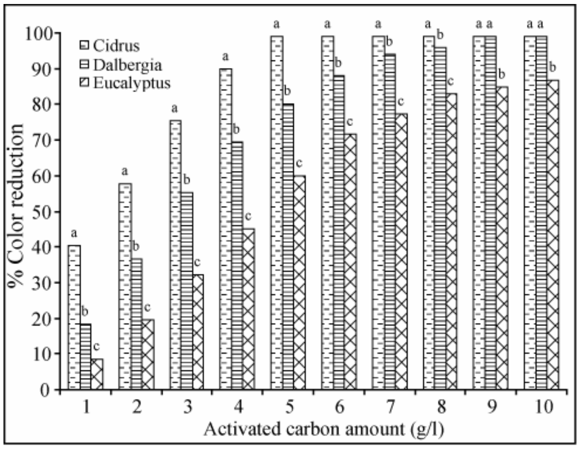

Fig. 1. Effect of activated carbon amount on percentage Color reduction. time: 4hrs, pH 5, agitation speed: 800 rpm. Different letters in each treatment (at X-axis) are significantly different at p=0.05 according to Duncan's Multiple Range Test.

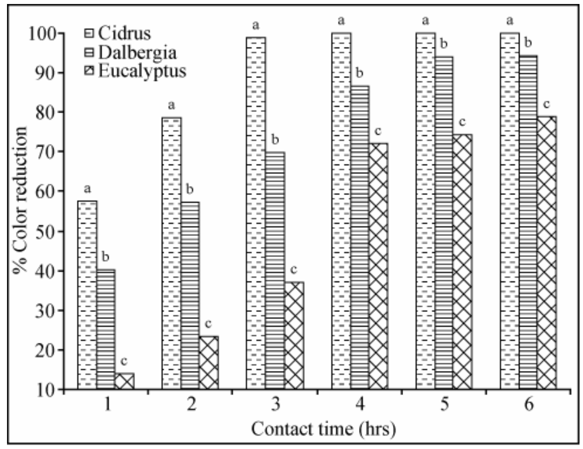

Fig. 2. Effect of contact time on percentage Color reduction. adsorbent dose: 6g/l, pH 5, agitation speed: 800rpm. Different letters in each treatment (at X-axis) are significantly different at p=0.05 according to Duncan's Multiple Range Test.

All the three activated carbons exhibit different behavior regarding color reduction (Fig. 2). At lower time concentrations (1-4hrs), *Cedrus deodara* shows very sharp decrease in color starting from 56% to 100%. *Dalbergia sissoo* has almost constant rate of reaction. Whereas *Eucalyptus* spp., exhibit less reduction from 1-3hrs but reduction shoots up sharply at 4hrs time duration, further increase from 4hrs to 6hrs does not significantly increase color reduction. A similar observation was reported previously by activated carbon using bamboo waste as raw material and phosphoric acid as activating agent (Pala & Tokat, 2002). They evaluated activated carbon for color and COD reduction of a textile mill effluent. A maximum reduction in COD and color of 75.21% and 91.84%, respectively was achieved.

Devi *et al*., (2008) reported that as the treatment time progress, the activated carbon sites had the affinity towards saturation. Differences In reduction capacities of different activated carbons might be due to the difference in number of carbonaceous sites. at the start of experimentation, the pollutants are absorbed by the exterior surface of activated carbon, so the rate was high. When the exterior surface reached saturation, the molecules will diffuse through the pores of activated carbon to reach the interior surface. This mechanism takes comparatively longer time (Hami *et al.,* 2007; Hamadi *et al*., 2001). However, Gupta *et al.,* (2011) attained equilibrium of 60 min for Acid Blue 113 dye uptake .The decrease in dye reduction with time might be due to aggregation of dye molecules around the activated carbon. There will be no more reduction in COD, after the equilibrium point has reached. Infect at equilibrium the rate of adsorption of pollutant onto the activated carbon is almost equal to the rate of desorption (Mohan *et al.,* 2008).

Effect of pH on COD and color reduction: It is clear from the results (Table 6) that *Cedrus deodara* and *Dalbergia sissoo* based activated carbons perform best at low pH. For *Cedrus deodara* based activated carbon the equilibrium pH is 5, beyond this point COD reduction do not increase significantly. Whereas, *Eucalyptus* spp., show maximum reduction at relatively neutral pH. Similar finding was relieved by (Devi *et al.,* 2008).

In case of color reduction all the activated carbons differ significantly at different pH (Fig. 3). Maximum color reduction by *Cedrus deodara, Dalbergia sissoo Dalbergia sissoo* and *Eucalyptus* spp., was 100%, 94% and 85%, respectively. There is a Sharpe decrease in color reduction by *Cedrus deodara* from pH 6 to pH 7. These results conclude that all the prepared activated carbons have different surface charges/properties, which are under the direct influence of change in pH. The possible mechanism of the better adsorption at lower pH may be related to the presence of high number of H^+ ions (Nagda, 2006). These H^+ ions combine with the-ve charged adsorbent surface (oxides of aluminum, calcium, silicon, iron, etc.) and neutralize them (Devi *et al.,* 2008), and thereby reduce the hindrance to the diffusion of organic molecules. The lower adsorption at higher pH might be possible due to the presence of OH^- ions. These OH^- ions cause hindrance to the diffusion of organic (contributing to COD) ions (Das & Patnaik, 2001).

The difference in COD and color mechanisms also relates to the heterogeneity (having different types of sites) or homogeneity (having same types of sites) of the activated carbon surface/sites (Satyawali & Balakrishnan, 2007). Activated carbon having heterogeneous sites may be capable in performing well in both acidic and basic pH. While those having homogenous sites will only function either in acidic, basic or neutral pH (Malik, 2004). The negative charge (hydroxyl groups) residing at activated carbon surface, provide active sites, causing strong electrostatic pull for the anionic pollutants in wastewater. This causes the ease in diffusion and adsorption process of pollutant for active sites. whereas, with increase in pH or alkaline conditions, protonation of pollutant is reduced, thus hinder diffusion and adsorption (Pala & Tokat, 2002).

Effect of agitation speed on COD and color reduction: Agitation speed effects the contact duration between pollutant and activated carbon. Agitation speed was evaluated from 200-1000 (rpm). The data for COD reduction is given in Table 5. Statistical analysis reveals that all the activated carbons differ significantly among each other. The highest efficiency was of *Cedrus deodara,* which reduces COD up to 94%. *Dalbergia sissoo* and *Eucalyptus* spp., were inferior having 81% and 74% COD reduction, respectively. *Cedrus deodara* achieved the equilibrium at 800rpm and does not significantly increase COD reduction with further increase in agitation speed (1000rpm). Whereas *Dalbergia sissoo* and *Eucalyptus* spp., attain equilibrium at 1000rpm. Our results are in accordance with the previous finding (Devi & Dahiy, 2008; Satyawali & Balakrishnan, 2007) and Santhy & Selvapathy (2006) investigated BOD and COD reduction with 100-1000rpm agitation speed. Maximum reduction was observed around 600rpm, however at higher agitation speeds, the loosely attached molecules may re-enter into the activated carbon, thus lowering the potential of COD reduction (Nagda, 2006) (Fig. 4).

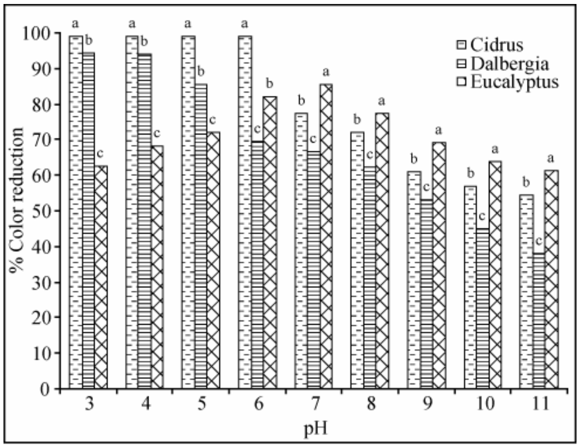

Fig. 3. Effect of pH on percentage Color reduction. time: 4hrs, adsorbent dose: 6g/l, agitation speed: 800rpm. Different letters in each treatment (at X-axis) are significantly different at p=0.05 according to Duncan's Multiple Range Test.

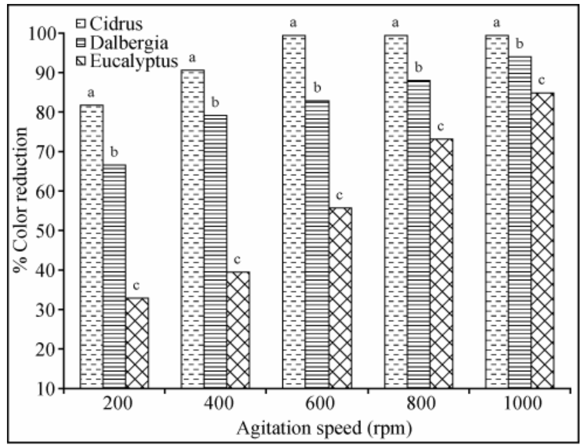

Fig. 4. Effect of agitation speed on percentage Color reduction. time: 4hrs, adsorbent dose: 6g/l, pH 5. Different letters in each treatment (at X-axis) are significantly different at p=0.05 according to Duncan's Multiple Range Test.

Table 5. Percentage COD reduction at different activated carbons types and agitation speed.

	Agitation speed (rpm)				
Activated carbons	**200**	**400**	**600**	**800**	**1000**
Cedrus deodara	59.8a ± 0.43	73.2a ± 0.76	84.1a ± 0.91	93a ±+0.85	94.4a ± 0.71
Dalbergia sissoo	38.9b ± 0.21	44.5b ± 0.87	56.2b± 0.48	76.4b ± 0.55	81b ± 0.54
Eucalyptus spp.	13.4c ± 0.54	18.1c ± 0.45	29.6c ± 0.31	59.6c ± 0.37	74.5c ± 0.27

Other operating conditions are time: 4hrs, activated carbon amount: 5g/l, pH 5. Treatments means followed by different letters in each column are significantly different at p=0.05 according to Duncan's Multiple Range Test

Table 6. Percentage COD reduction at different activated carbons types and pH.

Activated carbons	pH								
	3	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
Cedrus deodara	96.5a ± 0.43	94.6a ± 0.87	92a ± 0.65	78a ± 0.34	62.9b ± 0.85	58.8b ± 0.54	56.2a ± 0.62	55.3a ± 0.56	54.6a ± 0.43
Dalbergia sissoo	81.8b ± 0.23	80.5b ± 0.43	74b ± 0.74	58.8c ± 0.63	47.3c ± 0.25	43.1c ± 0.24	40.6b ± 0.74	36.1c ± 0.15	30.7c ± 0.55
Eucalyptus spp.	32.9c ± 0.76	42.2c ± 0.56	58.5c ± 0.75	71.2b ± 0.76	74a ± 0.26	69.6a ± 0.64	55.6a ± 0.33	47b ± 0.64	43.8b ± 0.56

Other operating conditions are time: 4hrs, activated carbon amount: 5g/l, agitation speed: 800 rpm. Treatments means followed by different letters in each column are significantly different at p=0.05 according to Duncan's Multiple Range Test

Table 7. Comparison of COD and color reduction potential by various activated carbons (Ahmad & Hameed, 2009).

Activated carbon type	Wastewater	COD removal (%)	Color removal (%)	Reference
Cedrus deodara based activated carbon	Paper mill effluent	92	100	This work
Dalbergia sissoo based activated carbon	Paper mill effluent	80	94	This work
*Eucalyptus s*pp based activated carbon	Paper mill effluent	74	86	This work
Bamboo-based activated carbon	Textile wastewater	75	91	Ahmad and Hameed, 2009
Bagasse fly ash	Pulp and paper wastewaters	50	55	Srivastava *et al.,* 2005
Powdered activated carbon	Textile wastewater	78	86	Pala *et al.,* 2002
Coconut fibers carbon	Industrial (mixed)	50–74	–	Mohan *et al.,* 2008
Carbon developed from fertilizer waste	Industrial	>50	–	Srivastava *et al.,* 1993
Mixed adsorbent carbon	Domestic	96	–	Devi *et al.,* 2008
Pecan shell-based activated carbon	Municipal wastewater	>70	–	Bansode *et al.,* 2004

Conclusion

This research study confirmed the usefulness of *Cedrus deodara, Dalbergia sissoo* and *Eucalyptus* spp., saw dust in removing COD and color for the first time in this region. It removed maximum COD up to 92% and 100% color reduction. The effectiveness of activated carbon synthesized from sawdust of different plants for wastewater treatment was in the following order: *Cedrus deodara* > *Dalbergia sissoo* > *Eucalyptus* spp. The final COD of treated wastewater was within the permissible limit of Anon. (1995), so that the treated water can be discharged safely, into streams. This study proved highly successful in addressing the local problem of paper industry effluents using locally available wood processing byproducts.

References

Ahmad, A.A. and B.H. Hameed. 2009. Reduction of COD and color of dyeing effluent from a cotton textile mill by adsorption onto bamboo-based activated carbon. *J. Hazard. Mat.,* 172: 1538-1543.

Ahmad, M., A. WAHID, S.S. Ahmad, Z.A. Butt and M. Tariq. 2011. Ecophysiological responses of rice (*Oryza Sativa L.*) to hexavalent chromium. *Pak. J. Bot*., 43(6): 2853-2859.

Ahmedna, M., M.M. Johns, S.J. Clarke, W.E. Marshall and R.M. Rao. 1997. Potential of agricultural by-product based activated carbons for use in raw sugar decolonization. *J. Sci. Food Agri., 7*5: 117-124.

Ali, M. and T.R. Sreekrishnan. 2001. Aquatic toxicity from pulp and paper mill effluent. *Adv. Environ. Res.*, 5: 175-196.

Amuda, O.S., I.A. Amoo and O.O. Ajayi. 2006. Performance optimization of some coagulants / flocculants in the treatment of beverage industrial wastewater. *J. Hazard. Mat.,* 129: 69-72.

Anand, K., A. Parande, A. Sivashanmugam, H. Beulah and N. Palaniswamy. 2009. Performance evaluation of low cost adsorbents in reduction of COD in sugar industrial effluent. *J. Hazard. Mat.,* 168: 800-805.

Anonymous. 1989. APHA, American Public Health Association. Standard Methods for Examination of Water and Wastewater, seventeenth ed., Washington DC, NY, USA.

Anonymous. 1995. WHO, World Health Origination. Guidelines for Discharge of Industrial Effluent Characteristic. Geneva, vol. 3: 231-36.

Anonymous. 1998. Environmental Protection Agency and U.S. Department of Agriculture. Clean water action plan: restarting and protecting America is waters. EPA-840-R-98-001, Washington.

Bansode R.R., J.N. Losso, W.E. Marshall, R.M. Rao and R.J. Portier. 2004. Pecan shell-based granular activated carbon for treatment of chemical oxygen demand (COD) in municipal wastewater. *Biores. Technol.,* 94: 129-135

Butt, M.S., K. Sharif, B.E. Bajwa and A. Aziz. 2005. Hazardous effects of sewage water on the environment: focus on heavy metals and chemical composition of soil and vegetables. *Mgt. Environ. Qty.,* 16: 338-46.

Das, C.P. and L.N. Patnaik. 2001. Use of industrial waste for reduction of COD from paper mill effluents. *Ind. J. Environ. Health.,* 43(12): 21-27.

Devi, R. and R.P. Dahiya. 2008. COD and BOD removal from domestic wastewater generated in decentralized sector. *Biores. Technol*., 99: 344-49.

Devi, R., V. Singh and A. Kumar. 2008. COD and BOD reduction from coffee processing wastewater using Avocado peel carbon. *Biores. Technol.,* 99: 1853-60.

Faust, S.D and O.M. Aly. 1986. Adsorption Process for Water Treatment. Butterwoeths, Stoneham, pp. 14-23.

Galambos, I.I., J.M. Molina, P. Jaray, G. Vatai and E. Bekassy-Molnar. 2004. High organic content industrial wastewater treatment by membrane filtration. *Desalination,* 162: 117-120.

Gupta, V.K., B. Gupta, A. Rastogi, S. Agarwa and A. Nayak. 2011. A comparative investigation on adsorption performances of mesoporous activated carbon prepared from waste rubber tire and activated carbon for a hazardous azo dye-Acid Blue 113. *J. Hazard. Mat.,* 186: 891-901

Hamadi, N.K., X.D. Chen, M.M. Farid and M.G. Lu. 2001. Adsorption kinetics for the removal of chromium (VI) from aqueous solution by adsorbents derived from used tires and sawdust. *J. Chem. Eng*., 84: 95-105.

Hami, M.L., M.A. Al-Hashimi and M.M. Al-Doori. 2007. Effect of activated carbon on BOD and COD removal in a dissolved air flotation unit treating refinery wastewater. *Desalination*, 216: 116-122.

Hussein, H., S.F. Ibrahim, K. Kandeel and H. Moawad. 2004. Biosorption of heavy metals from waste water using Pseudomonas sp. *J. Electronic Biotechnol.,* 7(1): 24-29.

Iram, S., Ahmad I., Riaz, Y. AND A. Zahra. 2012. Treatment of wastewater by *Lemna minor. Pak. J. Bot*., 44(2): 553-557.

Kakar, S.R., A. Wahid, R.B. Tareen, S.A. Kakar and R. Jabeen. 2011. Impact of municipal wastewater of Quetta city on some oil seeds crops of Pakistan: Effect of biomass, physiology and yield of sunflower (*Helianthus annuus L.*). *Pak. J. Bot*., 43(3): 1477-1484.

Karrasch, B., O. Parra, H. Cid, H. Mehrens, M. Pacheco, P. Urrutia, R. Valdovinos and C. Zaror. 2006. Effects of pulp and paper mill effluents on the micro plankton and microbial self-purification capabilities of the Biobio River, Chile. *Sci. Total Environ.,* 359: 194-208.

Malik, P.K. 2004. Dye removal from wastewater using activated carbon developed from saw dust: adsorption equilibrium and kinetics. *J. Hazard. Mat.,* B 113: 81-88.

Martinez, N.S., J.F. Fernandez, X.F. Segura and A.S. Ferrer. 2003. Pre-oxidation of an extremely polluted industrial wastewater by the Fenton's reagent. *J. Hazard. Mat.,* B 101: 315-322.

Mazumder, D. and B. Roy. 2000. Low cost options for treatment and reuse of municipal waste water. *Ind. J. Environ. Prot.,* 20 (7):529-32.

Mohan, D., P.S. Kunwar and K.S. Vinod. 2008. Wastewater treatment using low cost activated carbons derived from agricultural byproducts-A case study. *J. Hazard. Mat.,* 152: 1045-1053

Nadeem, M., A. Mahmood, S.A. Shahid, S.S. Shah, A.M. Khalid and G. McKay. 2006. Sorption of lead from aqueous solution by chemically modified carbon adsorbents. *J. Hazard. Mat.*, B138: 604-13.

Nagda, G.K., V.S. Ghole and A.M. Diwan. 2006. Tendu leaves refuse as biosorbent for COD removal from Molasses fermentation based bulk drug industry effluent. *J. Appl. Sci. Environ. Mgt.,* 10 (3): 15-20.

Pala, A. and E. Tokat. 2002. Color removal from cotton textile industry wastewater in an activated sludge system with various additives. *Ind J. Environ. Prot.,* 36: 2920-2925.

Qadir, A., R.N. Mailk and S.Z. Husain. 2008. Spatio-Temporal variation in water quality of Nulla Aik-tributary of the river Chenab, Pakistan. *Environ. Monitor. Assessment,* 14: 43-59.

Richardson, S.D. 2007. Water Analysis: Emerging Contaminants and Current Issues. *Annual of Chemistry*, 79: 4295-4324.

Santhy, K. and P. Selvapathy. 2006. Removal of reactive dyes from wastewater by adsorption on coir pith activated carbon. *Biores. Technol*., 97: 1329-1336

Satyawali, Y. and M. Balakrishnan. 2007. Removal of color from biomethanated distillery spent wash by treatment with activated carbons. *Biores. Technol*., 98: 2629-2635

Savant, D.V.R. Abdul-Rahman and D.R. Ranade. 2006. Anaerobic degradation of absorbable organic halides (AOX) from pulp and paper industry wastewater. *Biores. Technol*., 97: 1092-1104.

Srivastava, S.K., V.K. Gupta, D. Mohan and N. Pant. 1993. Removal of COD from reclaimed rubber factory effluents by using the activated carbon (developed from fertilizer waste material) and activated slag (developed from the blast furnace waste material) - a case study. *Fresen. Environ. Bull*., 2: 394-401.

Srivastava, V.C., I.D. Mall and I.M. Mishra. 2005. Treatment of pulp and paper mill wastewaters with poly aluminum chloride and bagasse fly ash. *Colloid. and Surf. A: Physicochem. Eng. Asp.,* 260: 17-28.

Szolosi, O. 2003. Water cycle with zero discharge at Visy Pulp and Paper, Tumut, NSW. *Water*, (Australia) 30: 34-36.

Tehseen, W.M., I.G. Hassen, S.G. Wood and M. Hanif. 2004. Assessment of chemical contaminations in water and sediment samples from Degh Nala in the province of Punjab, *Pak. Arch. Environ. Cont. Toxicol.*, 26(1): 79-89.

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