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Adsorptive removal of textile dye using carbonaceous material from waste biomass

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Abstract

Dyes are present in the waste waters due to waste mismanagement in industries. Due to its toxicity their removal from water bodiesis necessary. These dyes can be removed by adsorption on activated carbon and this method is an alternative eco-friendly solution of dye removal compared to many other methods. In this study methylene blue (MB) dye was removed by using Tectonagrandis (Sagwan) wood which was activated chemically by using nitric acid (2ml per 100g). Several parameters such as dye concentration (10-60mg/100ml), activated carbon dosage (1-6g), contact time (30-210 minutes), temperature (25-45^oC) and pH (2-10) were examined at 200rpm rotation speed in batch mode experiments. By increasing the initial dye concentration, the percentage dye removal was decreased while by increasing the adsorbent dosage, pH and temperature the percentage dye removal increased. Maximum dye removal was observed at 30min. Maximum percentage of dye removal observed was 99.27%. This was achieved at 60mg of dye concentration, adsorbent dosage of 6g and contact time of 150 minutes. According to the results it was observed that the sagwan wood sawdust has highest capacity for the removal of methylene blue dye.

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Introduction

One of the major global concerns is water pollution due to increasing urbanization, population and industrialization (Huang *et al.*, 2015). Due to increasing population growth, demand for fabrics is also increasing at alarming rate. Theses dyes and pigments are also used by many other industries for products coloration like plastic, rubber, textile, paper, cosmetics, etc. (Raghuvanshi *et al.*, 2005).Consequently, these dyes are regularly discharged in the industrial wastewaters(Malik, 2003). About 3600 different types of dyes are in use of textile industry. In-discharge and drainage water, nearly 20% dyes are lost (Ahmed *et al.*, 2012; Chequer *et al.*, 2013). Dyes are toxic and resistant to degradation (due to molecular complexity), therefore their extraction from effluent and wastewater course is necessary. Dyes also inhibit incoming light and therefore the process of photosynthesis is inhibited which result in damage to aquatic plants (Regti *et al.*, 2017). For dye removal, number of studies is carried out more specifically of methylene blue (MB) (Ardekani *et al.*, 2017). Activated carbon is a carbonaceous material more widely used for treatment purpose because of having a large surface area, high porosity, micro porous structure and higher surface reactivity. It is widely used for different applications. Feed stocks for activated carbon production are peat, coal, wood, lignite, residues of petroleum, but they are non-renewable and expensive (Chen *et al.*, 2011). Therefore, researchers are now focused to synthesize activated carbon by using sustainable and low-cost precursors, such as rice husk, bagasse, sawdust, corn strawn, garden and food waste (Chen *et al.*, 2011; Yahya *et al.*, 2015).

Different Studies have shown that the adsorption capacity is different in many aspects such as type of biomass used, experimental conditions, and the usage of different gases/reagents during activation process. Nevertheless, the adsorbent which shows high adsorption capacity has been prepared by three-stages. Adsorption capacity of methylene blue, in comparison, has recorded to be very low i.e. 0.66 mg/g for lemon peels (sweet) without activation and on egg shell it is found to be 94.9 mg/g (waste) (Abdel-Khalek *et al.*, 2017).

Preparation steps also havehigh significance on the performance of adsorbents. Lanasyngray (2.60×10^3) and Lanasyn orange (2.60×10^3) (mg/g) are usually used in carpet wool dyes. It is recorded to have extremely high adsorption, on nano-porous ACs extracted from bamboo cane which has been chemically activated (Pradhananga *et al.*, 2017). Due to increased surface area, adsorption is also high (2130 m^2/g) with pore volume of 2.69cc/g.Golden shower extracted activated carbons is also observed and for methylene green 5 it shows high adsorption capacity (Tran *et al.*, 2017), and this activation process is also carried out in three steps. However, experimental studies shows that ACs derived from different sources do no depend on their surface area but it is because of their biggest effect of π-π interaction between the two adsorbents and adsorbates.

Biowaste derived methylene blue adsorption and other adsorbents onto activated carbons has been studied widely. The range of MB for adsorption capacities onto ACs from various bio-waste is a 17.44-476.2mg/g. Methylene blue adsorption is highest (476.2mg/g) when AC is prepared from cotton. But it is less than that produced by using oven heating of H_3PO_4 (487.4 mg/g) (Hao *et al.*, 2014). Those prepared from micro oven heating of bio waste shows high adsorption of methylene blue (Foo el al. 2012; Hao *et al.*, 2014), and it can further be increased by using H_3PO_4.

The purpose of the present study was to prepare activated carbon from *Tectonagrandis* (Sagwan) and the use of this activated carbon as an adsorbent for the removal of methylene blue dye.

Materials and methods

Adsorbent preparation

Sagwan sawdust collected from a local timber market. To remove dust particles and dirt the sawdust was washed it thoroughly with distilled water. It was dried in oven at 100°C for 24hrs, grinded, crushed and weighed. Sawdust was segregated in 2 parts. One part was kept as raw form and the other part is chemically processed to form chemically activated carbon (Garg *et al.*, 2004). Sawdust was treated with nitric acid to make it chemically activated. 2ml of Nitric acid was added in sawdust and mixed it properly.

The sawdust was kept in oven for 24hrs. The carbonized material was then kept in furnace at 300°C for 2hrs for its physical activation. The sample was then washed to take out excess acid if present and dehydrated it in oven at 100°C. Then the material was crushed in a mortar and pestle to obtain a fine particle size (Garg *et al.*, 2004).

Selection of dye

Methylene blue (MB) (analytical grade) was used in the experiment as an adsorbate. It is a cationic dye with molecular formula is $C_{16}H_{18}CIN_{36}$and 373.9g/mol is molecular weight. Distilled water was used for making all the regents and dye solution. Methylene blue is widely used dye in many textile and dyeing industries(Hameed *et al.*, 2009).

Batch experiment

Dye removal experiment was conducted by batch method at different variables by taking different factors such as amount of AC dosage, different concentration of dye, different temperature, and variable time intervals and at different pH by changing the amount of parameter under examination while keeping the other parameters constant. By using 100ml of volume we performed the experiments in 250ml of flasks at 200rpm speed and at variable temperature.

By using ultraviolet spectrophotometer, we determined the dye concentrations at 665nm wavelength. Also, the pH effect was studied by taking range of 2 to 10. Adjustment of pH was done by using 0.1N NaOH and 0.1N H_2SO_4.

The percentage dye removal was determined by using the formula:

$$\%\ \text{Dye removal} = \frac{C_i - C_f}{C_f} \times 100$$

Where,

C_i is the Dye Concentration (Initial)

$C_f$is the Dye Concentration (Final).

Results and discussion

Effect of different initial concentration of dye

The influence of initial dye concentration on the adsorption of methylene blue was studied using a dosage of 2g/100ml of activated carbon. In the current study 10-60 mg/100ml of methylene blue was tested. With the increase in initial dye concentration, it is observed that the percentage adsorption of methylene blue decrease (Table 1 and Fig.1).

Table 1. Variable dye concentration effects on adsorption of MB.

Parameters	Concentration	Absorbance	Remaining Dye Conc. After 150min
Initial Dye Conc.	10 (mg/100ml)	0.654	1.8713
	20 (mg/100ml)	0.551	1.4770
	30 (mg/100ml)	0.911	2.8549
	40 (mg/100ml)	1.752	6.0738
	50 (mg/100ml)	1.927	6.7436
	60 (mg/100ml)	1.954	6.8469
Amount of Activated Carbon	1 (g/100ml)	0.491	1.2474
	2 (g/100ml)	0.486	1.2283
	3 (g/100ml)	0.412	0.9450
	4 (g/100ml)	0.39	0.8608
	5 (g/100ml)	0.296	0.5011
	6 (g/100ml)	0.278	0.4322
Temperature	25 (°C)	2.757	9.9203
	30 (°C)	2.756	9.9165
	35 (°C)	2.652	9.5184
	40 (°C)	2.412	8.5998
	45 (°C)	2.173	7.6851
pH	2	3.768	13.7898

	4	2.657	9.5376
	6	2.412	8.5998
	8	1.954	6.8469
	10	1.752	6.0738
Time	30 (min)	0.498	1.2742
	60 (min)	0.491	1.2474
	90 (min)	0.412	0.9450
	120 (min)	0.401	0.9029
	150 (min)	0.378	0.8149
	180 (min)	0.352	0.7154
	210 (min)	0.354	0.7231

This decrease can be because of lesser number of adsorption sites of activated carbon available or it may be due to decrease in the driving force required for the adsorption of MB. With increase in MB concentration the sites will not be available for adsorption as when compared with low dye concentration where all active sites were fixed. Methylene orange has been removed using activated carbon and its efficiency has been studied (Danish *et al.,* 2014).

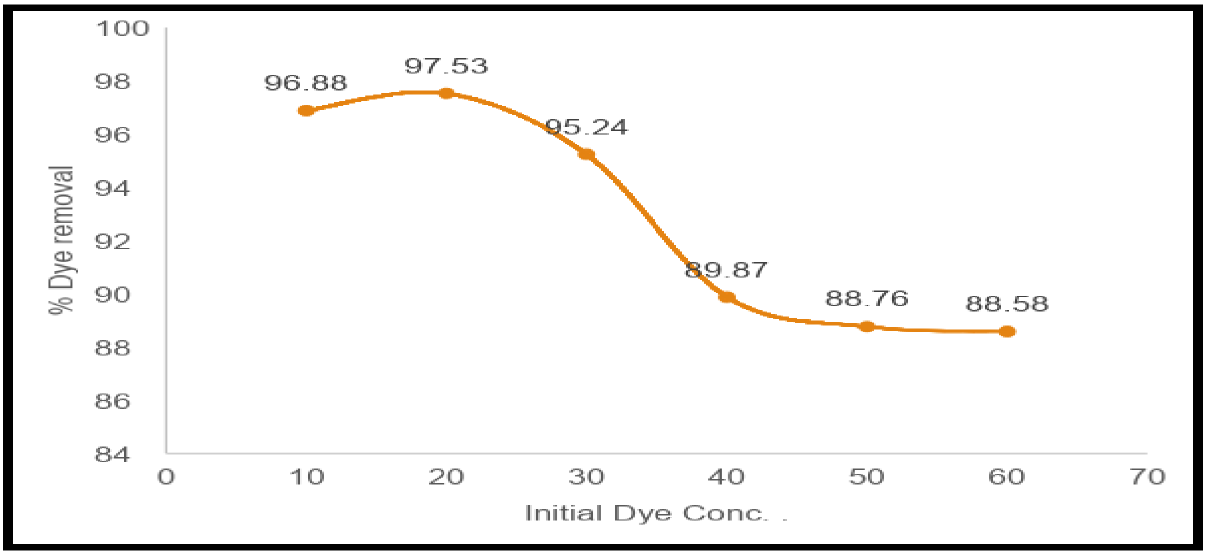

Fig. 1. Effect of various dye concentration on MB removal.

Three synthetic dyes telon blue, astrazon blue, and methylene blue were removed by using activated carbon extracted from pinewood (Tseng *et al.,* 2003).

Results showed that time was the main factor in activation because of pore size and surface area. Textile effluent dye is removed by using activated carbon obtained by Mahogany sawdust (Malik *et al.,* 2004).

Different dosage effects of activated carbon

By changing the amount of activated carbon 1-6g/100ml and keeping the concentration of dye constant (60mg), adsorption of methylene blue was studied at constant time i.e. 150min and the results in the Table1 and Fig. 2. It shows that at 150min maximum dye absorption (99.27%) was attained and by increasing the amount of dose the percentage adsorption of methylene blue significantly increase from 97.92% to 99.27%.

This may be because more active sites are available for adsorption, which results in more removal of methylene blue and as the surface area of the activated carbon (adsorbent) increases there is more methylene blue adsorption.

The factor which play an significant part are surface area, pore size/volume. As a result different woods have different adsorption ability (Zuo *et al.,* 2010).

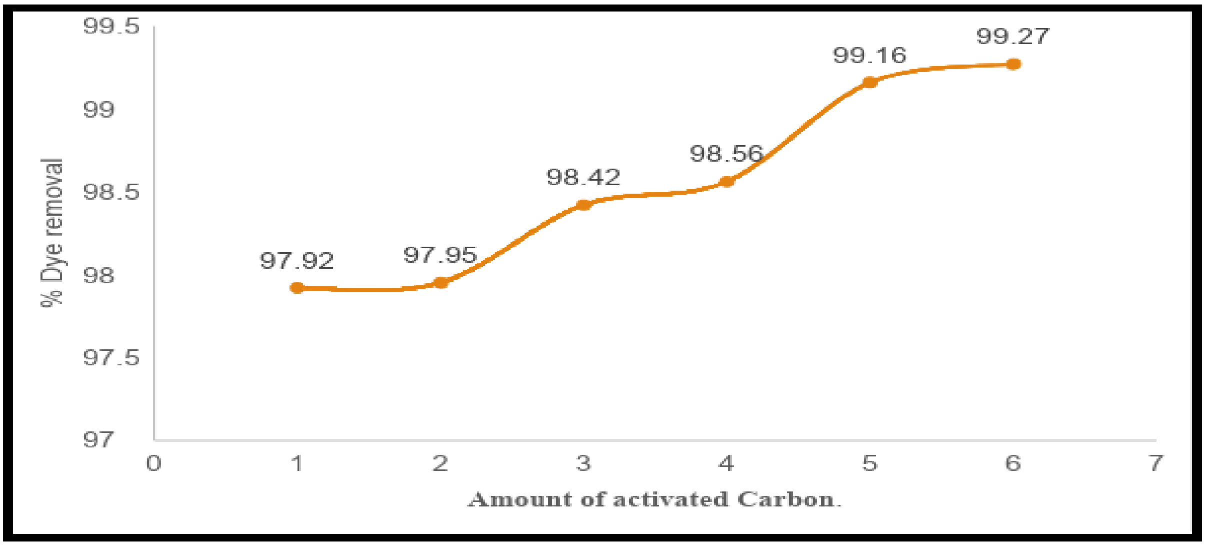

Fig. 2. Different dosage effects of AC on MB removal.

Temperature effects on methylene blue adsorption

Temperature effect was studied at different temperature from (25°C to 45°C) to observe the adsorption efficiency of MB. It was observed from the results that by increasing the temperature the adsorption efficiency of the dye solution also increasedTable 1 and Fig.3. This is due to the fact that the bond strength between dye molecules and activated carbon increases at high temperature. The increased dye adsorption (at increased temperature) indicated that the process is endothermic in nature. Heidari *et al.*, (2014) used H_3PO_4, KOH and $ZnCl_2$ during chemical activation for the formation of activated carbon from *Eucalyptuscamaldulensis* wood. It was notice that the concentration and type of dehydrating agent in wood control the pore size and surface capacity in the AC.

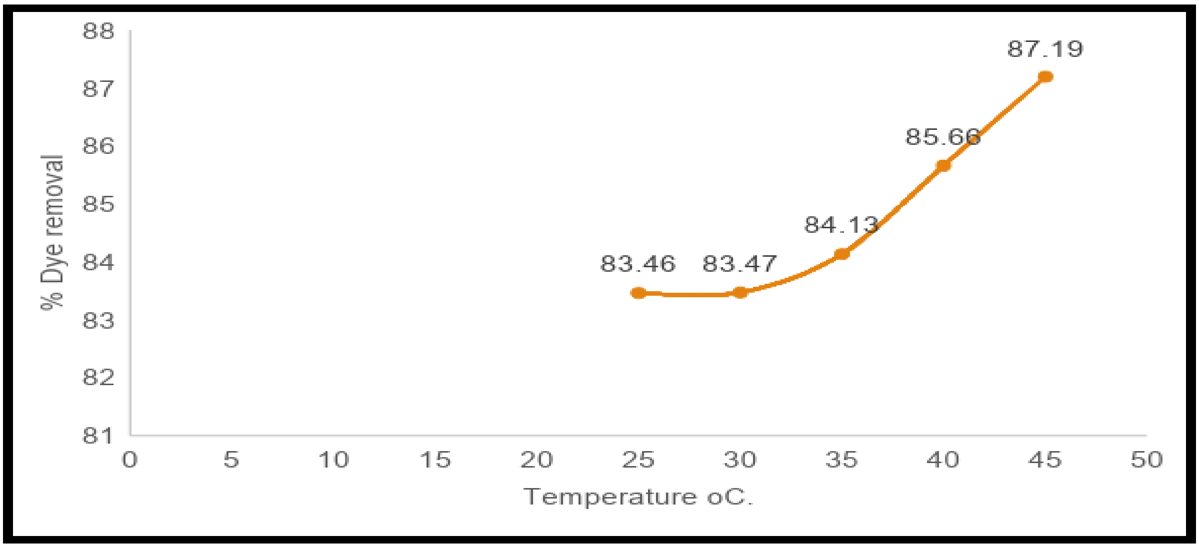

Fig. 3. Temperature effects on adsorption of MB.

Effect of pH

Results for the effect of pH on the dye removal was observed and is given in the Fig.4 and Table 1.Results depicts that when the pH of the dye solution increases the efficiency of removal of dye increases with increase of initial pH of dye solution. But for cationic dyes such as methylene green and methylene blue, the efficiency of dye removal is lower at lower pH which shows that this is because of high hydrogen ions concentration that offers competition with cationic groups. Different concentration of dehydrating agent is added in wood biomass for activation. CaO. $ZnCl_2$, KOH, NaOH, H_2SO_4, H_3PO_4, etc. are usually used dehydrating agents during chemical activation.

The ideal dehydrating agent is phosphoric acid (H_3PO_4), because it is effectively, economic, efficient and above all it is environmentally safe (Bhatnagar *et al.*, 2015). Woodof Paulownia (*Paulownia* elongata) treated with H_3PO_4 (as activating agent) produce activated carbon having high surfacearea (Yorgun *et al.*, 2015).

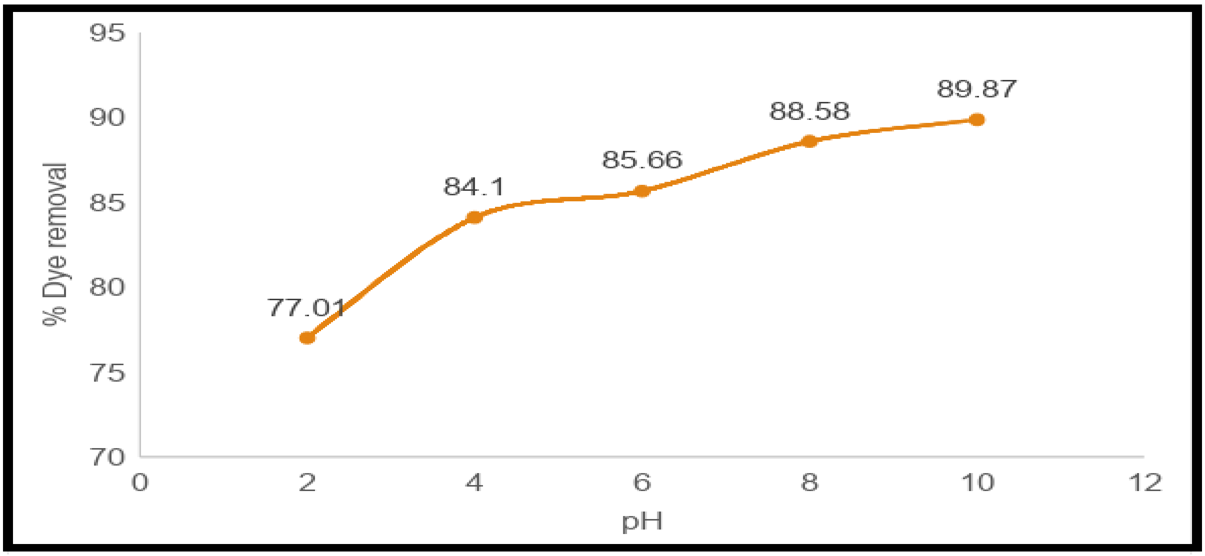

Fig. 4. pH effects on adsorption of MB.

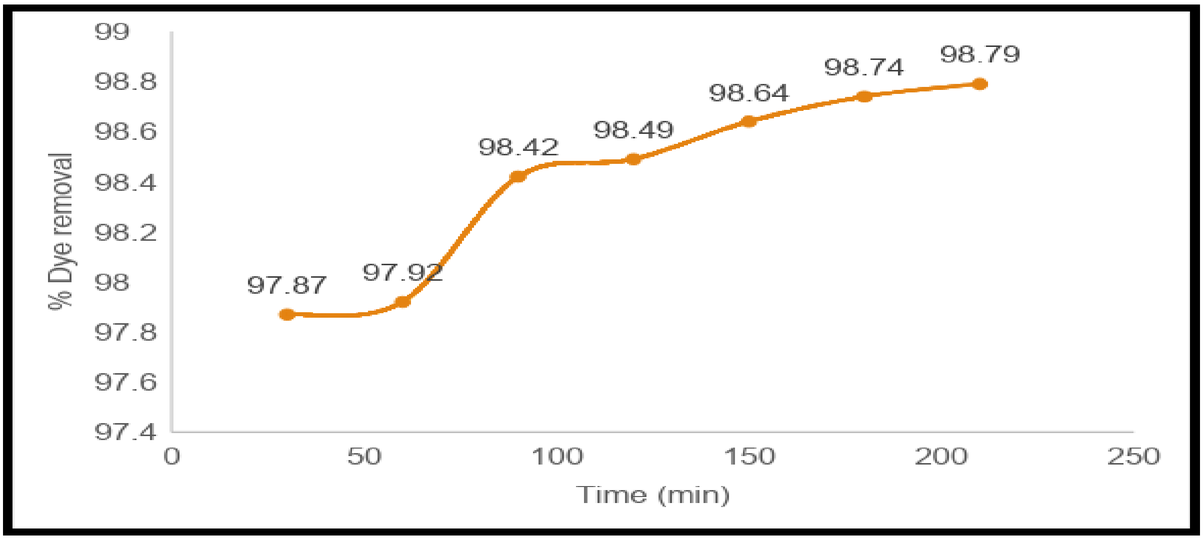

Fig. 5. Contact time effects on adsorption of MB.

Contact time effect on dye adsorption

The influence of time on the adsorption of methylene blue was studied at different contact time (30 to210min).

The amount of dye adsorbed at various intervals of time is shown in Fig.5 and Table 1. Initial dye removal increases as time increase but then it reaches to an equilibrium state within 150–180 min. It is found that adsorption process was initially very rapid, and therefore a large portion of the total dye concentration is removed but after sometime it becomes almost constant.

The maximum adsorption of dye was observed to be 99.27% at optimum conditions of temperature, pH, contact time of 150min, 200 rpm speed, adsorbent dose of 6g/100ml. Zhang *et al.*, (2004) reported that different temperature and time affect the size of pore and area of surface. Study illustrated that loosely bounded substances can be eliminate considerably to open the pore by variations of activation time (Konicki *et al.,* 2015).

Conclusion

Dyes present in waste water are necessary to remove. Activated Carbon prepared from different biomass and agricultural by-products has great potential to treat waste water from dyes. These bio adsorbents are low in cost, are locally available and eco-friendly.

In this work removal of methylene blue dye has been successfully achieved by using activated carbon prepared from Sagwan wood sawdust. Different parameters such as effect of different dye concentration, contact time, dosage of adsorbents, pH and temperature were optimized to get maximum efficiency. Activated carbon may also used for the removal of trace metals from waste water.

There are several challenges in the use of activated carbon on large scale for dye removal. These challenges need to be overcome for use of activated carbon on large scale.

References

Abdel-Khalek MA, Rahman MA, Francis AA. 2017. Exploring the adsorption behavior of cationic and anionic dyes on industrial waste shells of egg. Journal of Environmental and Chemical Engineering **5(1),** 319-327.
http://dx.doi.org/10.1016/j.jece.2016.11.043

Ahmed TF, Sushil M, Krishna M. 2012. Impact of dye industrial effluent on physicochemical characteristics of KshipraRiver, Ujjain City, India. International Research Journal Environmental Science **1(2),** 41-45.
http://dx.doi.org/ISCA-IRJEvsS-2012-041.pd

Ardekani PS, Karimi H, Ghaedi M, Asfaram A, Purkait MK. 2017. Ultrasonic assisted removal of methylene blue on ultrasonically synthesized zinc hydroxide nanoparticles on activated carbon prepared from wood of cherry tree: experimental design methodology and artificial neural network. Journal of Molecular Liquid **229,** 114-124.
http://dx.doi.org/10.1016/j.molliq.2016.12.028

Bhatnagar A, Sillanpää M, Witek-Krowiak A. 2015. Agricultural waste peels as versatile biomass for water purification. Chemical Engineering Journal **270**, 244–71.
https://doi.org/10.1016/j.cej.2015.01.135

Chen Y, Zhu Y, Wang Z, Li Y, Wang L, Ding L,Guo Y. 2011. Application studies of activated carbon derived from rice husks produced by chemical-thermal process - A review. Advanced colloidal interface science **163(1),** 39-52.
http://dx.doi.org/10.1016/j.cis.2011.01.006

Chequer MD, Oliveira GA, Ferraz A, Cardoso JC, Zanoni MVB, Oliveira DP. 2013. Textile dyes: dyeing process and environmental impact. In Eco-friendly textile dyeing and finishing. InTech.
http://dx.doi.org/10.5772/53659

Danish M, Hashim R, Ibrahim MNM, Othman O. 2014. Response surface methodology approach for methyl orange dye removal using optimized Acacia mangium wood activated carbon. Wood Science Technology **48,** 1085–105.
https://link.springer.com/article/10.1007/s00226-014-0659-7

Foo KY, Hameed BH. 2012. Microwave-assisted preparation and adsorption performance of activated carbon from biodiesel industry solid reside: influence of operational parameters. Bioresource technology **103(1),** 398-404.
http://dx.doi.org/10.1016/j.biortech.2011.09.116

Garg VK, Amita M, Kumar R, Gupta R. 2004. Basic dye (methylene blue) removal from simulated

wastewater by adsorption using Indian Rosewood sawdust: a timber industry waste. Dyes and pigments **63(3)**, 243-250.
http://dx.doi.org/10.1016/j.dyepig.2004.03.005

Hameed BH. 2009. Spent tea leaves: a new non-conventional and low-cost adsorbent for removal of basic dye from aqueous solutions. Journal of Hazardous Material **161(2-3)**, 753-759.
http://dx.doi.org/10.1016/j.jhazmat.2008.04.019

Hao W, Björkman E, Lilliestrale M, Hedin N. 2014. Activated carbons for water treatment prepared by phosphoric acid activation of hydrothermally treated beer waste. Indian Engineering of Chemical Research **53(40),** 15389-15397.
http://dx.doi.org/10.1021/ie5004569

Heidari A, Younesi H, Rashidi A, Ghoreyshi AA. 2014. Adsorptive removal of CO_2 on highly microporous activated carbons prepared from Eucalyptuscamaldulensis wood: effect of chemical activation. Journal of Taiwan Internationa lChemical Engineering **45,** 579–88.
https://doi.org/10.1016/j.jtice.2013.06.007

Huang H, Zhang G. 2015. Adsorption of Rhodamine B onto a yellow–brown soil: Kinetics, thermodynamics, and role of soil organic matter. Environmental Programme Sustainable Energy **34(5),** 1396-1403.
http://dx.doi.org/10.1002/ep.12135

Konicki W, Cendrowski K, Bazarko G, Mijowska E. 2015. Study on efficient removal of anionic, cationic and nonionic dyes from aqueous solutions by means of mesoporous carbon nanospheres with empty cavity. Chemical Engineering Research Design **94,** 242-253.
https://doi.org/10.1016/j.cherd.2014.08.006

Malik P. 2004. Dye removal from wastewater using activated carbon developed from sawdust: adsorption equilibrium and kinetics. Journal of Hazardous Material **113(3),** 81-88.
https://doi.org/10.1016/j.jhazmat.2004.05.022

Malik PK. 2003. Use of activated carbons prepared from sawdust and rice-husk for adsorption of acid dyes: a case study of Acid Yellow 36. Dyes and pigments **56(3),** 239-249.
http://dx.doi.org/10.1016/S0143-7208(02)00159-6

Pradhananga RR, Adhikari L, Shrestha RG, Adhikari MP, Rajbhandari R, Ariga K, Shrestha LK. 2017. Wool carpet dye adsorption on nanoporous carbon materials derived from agro-product. Carbon **3(2)**, 12-16.
http://dx.doi.org/10.3390/c3020012

Raghuvanshi SP, Singh R, Kaushik CP, Raghav AK. 2005. Removal of textile basic dye from aqueous solutions using sawdust as bio-adsorbent. International Journal of Environmental Studies **62(3),** 329-339.
http://dx.doi.org/10.1080/00207230420000275150

Regti A, Laamari MR, Stiriba SE, El-Haddad M. 2017. Use of response factorial design for process optimization of basic dye adsorption onto activated carbon derived from Persea species. Microchemical Journal **130**, 129-136.
http://dx.doi.org/10.1016/j.microc.2016.08.012

Tran VT, Nguyen DT, Ho VT, Hoang PQH, Bui PQ, Bach LG. 2017. Efficient removal of Ni^{+2} ions from aqueous solution using activated carbons fabricated from rice straw and tea waste. Journal of Material **8(2),** 426-437.
Document/vol8/vol8_N2/46-JMES-2634-Tran.pdf

Tseng RL, Wu FC, Juang RS. 2003. Liquid-phase adsorption of dyes and phenols using pinewood-based activated carbons. Carbon **41(3),** 487-495.
https://doi.org/10.1016/S0008-6223(02)00367-6

Yahya MA, Al-Qodah Z, Ngah CZ. 2015. Agricultural bio-waste materials as potential sustainable precursors used for activated carbon production: a review. Renewable Sustainable Energy

Reviews **46,** 218-235.
http://dx.doi.org/10.1016/j.rser.2015.02.051

Yorgun S, Yıldız D. 2015. Preparation and characterization of activated carbons from Paulownia wood by chemical activation with H_3PO_4. Journal of Taiwan International Chemical Engineering **53,** 122–31.
https://doi.org/10.1016/j.jtice.2015.02.032

Zhang T, Walawender WP, Fan LT, Fan M, Daugaard D, Brown RC. 2004. Preparation of activated carbon from forest and agricultural residues through CO_2 activation. Chemical Engineering Journal **105(1),** 53–9.

Zuo S, Yang J, Liu J. 2010. Effects of the heating history of impregnated lignocellulosic material on pore development during phosphoric acid activation. Carbon **48(11),** 3293–5.
https://doi.org/10.1016/j.carbon.2010.04.042