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EFFECT OF DIFFERENT CHEMICALS ON THE CARBONIZATION BEHAVIORS AND POLLUTION REMOVAL PERFORMANCE OF BIOCHAR ADSORBENTS DERIVED FROM TEXTILE WASTE

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Highlight

Waste textile remnants were converted into functional carbon-rich adsorbents. Chemical type, amounts, and carbonization conditions were seen as dominant in material properties. The recycling of waste materials had double outcomes: environmental preserving and production of fine chemicals by controlled chemical activation of waste textile materials.

Abstract

One of the smart methods of controlling the increasing demand for raw materials and environmental pollution is the recycling of waste. In this study, optimum conditions were determined for the conversion of wastes that will not be reused in the textile industry into functional activated carbon. For this, raw and Fe, H_2SO_4, H_3PO_4 impregnated textile wastes were carbonized at different temperatures for varying times. The molecular structure and crystal lattice of the prepared activated carbons were investigated by FT-IR and XRD analyzes, respectively. SEM and BET analyzes were used to examine the morphology and surface properties of the samples. The existence of C=C, C=O, and C–O–C functional groups was recognized by the vibrations at around 1300-1700 cm-1. A well-crystalline and porous structure was formed as a result of the carbonization of the Fe and H_3PO_4 pretreated samples, while the process was conducted at a lower temperature due to the catalytic effect. 25–85 mg/g methyl orange (MO) and industrial textile water (ITW) removal capacity were recorded for all samples. Efficient biochars were obtained by carbonization of waste materials while protecting the environment. Such a specific approach could be developed for each waste material for environmental and economic production.

Keywords: *Biochar, carbonization, waste recycling, environmental protection.*

doi

Introduction

Most of the methods for obtaining efficient carbon materials are based on general well-known techniques of pyrolysis, hydrothermal carbonization, gasification, and torrefaction [1]. Various raw materials could be used for activated carbon preparation. Different pyrolysis temperature was investigated for rice straw and canola stalk and, 450^0C was found the best condition for obtaining activated carbon which has the highest porosity and largest pore size among the applied temperatures 250, 350, 550, and 650^0C [2]. Mangrove pile samples were exposed to different amount of H_3PO_4 and it was heated at 300, 400 and 500^0C [3]. Highest yield was obtained when the impregnation ratio of H_3PO_4:sample ratio was 3. The AC3004 performed the best methylene blue removal performance (it was 72.3 mg/g at the 150 mg/L solution concentrations). The activated carbons which have 976 and 1496 m^2/g surface area were prepared from bamboo and its solid by CO_2 activation [4], KOH and $ZnCl_2$ pretreated waste truck tire and spent tea leaf carbonization at 800^0C [5], polyvinylidene chloride resin that of activated by ZnO at 950^0C [6], phosphoric acid and iron III chloride exposed carbonized coffee residue for bisphenol A removal are examples of different biochar obtained with different activation agents of various sources [7]. Rice husk, wheat straw, sugar cane, cotton stalk, hemp stem, coconut leaf, and bamboo are also some of the other biomaterials that are used for the preparation of activated carbon at different conditions such as activating agent, heating temperature, heating time, etc. [8–10].

Functionalization of an active carbon could be conducted by the modification of the sample with different methods. Thus, more effective absorption, energy storage, and other applications could be achieved with modified active carbon. Spent malt rootlets were simply dried and heated to 850^0C under limited air conditions to obtain biomass-based activated carbon. Then, it was exposed to sodium persulphate (SPS) at different concentrations to obtain a modified activated carbon catalyst [11]. SPS modification was reported to dissolve inorganic and organic parts of the activated carbon and it changed the surface properties by changing acidity and basicity. It was understood that modification of spent malt rootlets requires a specific SDS treatment to prepare sulfamethoxazole (SMX) oxidation catalyst. A functional activated carbon was prepared by steam activation of commercial beech wood charcoal with K_2CO_3 steam activation [8] for deoxynivalenol (DON) removal. The particles of 8 μm sized with different pore volumes and pore sizes were found effective on DON adsorption. With this study in which 95% adsorption yield was recorded with 0.2 mg/ml adsorbent dosage at 37^0C and 1 hour contact time, the importance of tuned pore sizes was emphasized. 23.48 mg/g xylene removal was achieved by palm kernel-based activated charcoal [9].

However, these two-step preparation methods include disadvantages of time, energy, and chemical consumption. Instead of that, the one-step preparation route could be more yielded. As it is known activated carbon quality depends on parameters such as method, temperature, biomass content, heating time, and pretreatment mainly. The chemical agent, amount, and pretreatment applications are highly important to obtain activated carbon with desired properties. Pretreatment of biomass could be done for separating natural organic/inorganic matters by acid or base washing especially. Many different methods and their results for activated carbon preparation were reported for various biomass because of its importance [11].

Wheat straw biomass was used to prepare activated carbon by pretreatment and post-treatment with phosphate/magnesium agent. The pretreated sample presented the highest Pb adsorption performance [12], brewers draff-based biochar obtained by heating at 650^0C was activated with 2 M KOH solution [13]. A small amount of increase for Cu removal was recorded in the capacity of BCact10.3 mg/g whereas it was 8.77 for the non-activated sample. The use of biomass as an activated carbon raw material may be regarded as an economic way of obtaining effective carbon-rich materials. Besides, converting carbon-rich waste into functional carbon-rich chemicals could provide a double effect: free of charge raw materials and preserving the environment. Waste cotton textiles were activated by Fe(III) chloride and carbonized, and it was concluded that the carbonization temperature of chemically treated samples was 163^0C whereas it was 300^0C for raw waste [14]. Fe(III) chloride treatment increased the CO_2 and H_2O releasing with decarboxylation. Obtained activated carbon presented 267.12 mg/g Cr(IV) removal performance. Mesoporous activated carbon with 1307 m^2 surface area was obtained by the carbonization of $MgCl_2$ pretreated waste polyester fabric at 900^0C [10]. Potassium salts of carboxymethyl cellulose effective in oil adsorption were synthesized by using purified wood wastes and cellulose-containing wastes of cotton cleaning factory as raw materials [15]. Waste textile materials that could not be reused for weaving were used as unique biomass. Pretreatment, activation, and carbonization parameters are valid for only biomass that was handled.

In this study, we wanted to draw the attention of scientists to the importance of specific treatments of biomass for functional activated carbon preparation. For this, cost-free waste textile materials that could not be reused in the textile industry were pretreated in a controlled manner. The effect of chemical treatment was investigated in terms of characterization techniques of SEM, BET, XRD, and FT-IR with the dye removal performances of samples for methyl orange (MO) and industrial wastewater (IW) solution. Thus, a method has been adjusted for the preparation of useful carbon-rich chemicals from raw materials, while at the same time, an environmental protection method has been developed, which has a guiding quality for other wastes.

Materials and Methods

Materials

Waste textile materials were obtained from UŞAK organized Industrial Zone, Turkey. C_2H_5OH, HCl, H_2SO_4, H_3PO_4, $FeCl_2.4H_2O$ were purchased from Sigma Aldrich and used without any processing. Methyl orange (from Sigma Aldrich) aqueous solution was used as model pollutant. Industrial wastewater obtained from UŞAK, Turkey was used to understand performance of adsorbents again streal polluting agent.

Preparation of Chemically Activated Carbonized Adsorbents

Carbonization of non-recyclable waste textile remnant at the textile industry was conducted as mentioned. Waste textile samples were firstly washed with ethanol and 70–80^{0}C hot water to remove dirt and dye. It was dried at 60^{0}C for 24 h. 5 g sample was wetted by 25 ml activatingH_2SO_4, H_3PO_4 and $FeCl_2.4H_2O$ agents. The mass ratio for activating chemicals:textile waste was adjusted as 0.14/1.4–50. Activation time was applied for 1–1.5 h. The samples that immersed in chemical were dried at 60^{0}C oven for 24 h before carbonization. Those were carbonized in a muffle furnace with the heating rate of 10–15^{0}C/min at the temperature ranges 350-400^{0}C. Static N_2 inert gas was flowed to furnace before heating. Control samples were prepared by carbonization of textile samples at 350 and 400^{0}C without using any chemicals. Carbonized samples were weighted and grounded then they were passed through a 150 μm sieve. Prepared samples were called with explanatory determination according to its activation procedure such as, [01/05/1]-[H2/H3/Fe]-[1/1.5]-[350/400] with H2, H3, Fe-CTW and CTW-350, CTW-400 abbreviations. Where 01/05/1 stand for concentration of chemicals (mol/L) used for activation. H2, H3 and Fe mean chemicals used for pretreatment, 1/1.5 and 350/400 are carbonization time (h) and temperature (C) respectively.

Characterization of Carbonized Textile Waste

Crystalline structure and functional groups of prepared samples were analyzed by XRD (Rigaku 2000) at 2θ=2–80^{0}with 2^0/min scanning speed and Perkin Elmer FT-IR over a range of 4000-400 cm^{-1}. Morphological images were pictured by scanning electron microscopy at 10 kV (Carl Zeiss ULTRA Plus). Surface area of biochars were measured by TriStar II 3020 Version 3.02 BET device. Concentration of initial and final dye solutions were analyzed by UV-visible spectrometer (Shimadzu, 2550) at 660 and 297 nm wavelength for MO and ITW, respectively.

The mass loss (ML%) percentages of carbonized samples were calculated to determine chemical and other effects on the carbonization process according to equation 1

$$ML\% = \frac{W_i - W_F}{W_F} \text{ x } 100 \qquad (1)$$

Where W_i and W_F are initial and final mass (after carbonization) of textile samples, respectively.

Dye Adsorption Experiments

Adsorption performances of biochars were tested in a conical flask by the batch technique. 50 mL MO aqueous solutions (50–150 ppm initial concentrations) and 0.01–0.1 g adsorbent were put into adsorption cup, and it was stirred at 150 rpm for 1-3 h. Adsorption temperature and pH of solutions was adjusted 298–328 K and pH 3.00–9.00 by 0.05 mol/L HCL and NaOH solutions. Similar experimental conditions were adjusted for 1:10 ITW adsorption. After the equilibrium, samples were filtered, and the amount of MO and ITW in the filtrate were analyzed by UV-vis spectrometer at 660 and 297 nm respectively. Adsorption capacity Q_e (mg/g) and adsorption efficiency E_{AD} (%) of adsorbents were calculated by equations 2 and 3 [16]

$$Q_e = \left(\frac{C_0 - C_e}{M}\right) xV \qquad (2)$$

$$E_{AD}(\%) = \left(\frac{C_0 - C_e}{C_0}\right) x100 \qquad (3)$$

C_0 and C_e stand for initial and equilibrium dye concentration in mg/L respectively. M (g) and V (L) represent amount of adsorbent and the volume of dye solution respectively. Reusability studies of adsorbents were conducted after the washing and rinsing of filtrated adsorbents with acid solution (0.5 mol/L HCl, 25 mL). The adsorbents were dried and used for 5 times. Adsorption capacities of all samples were calculated and evaluated according to equation 2 and 3.

Result and Discussion

Characterization of biochars

The biochars prepared by [05]-[H2/H3/Fe]-[1]-[350] conditions with the samples obtained by heating at 350 and 400^{0}C without any chemicals were identified as the samples to investigate. The samples were determined in terms of the carbonization temperature, characterization results, and adsorption performances. The samples of CTW-350 and CTW-400 were prepared without using any chemical and those were analyzed to comparison with the other samples. Carbonization yield decreased with increasing temperature and 14% CTW-400 was obtained Table 1. The carbonization of waste textile did not complete at 350^{0}C. The high amount of the chemical treated samples depend on the amount of activation chemical adheres to the biochar structure by forming a new structure. As could be understood from the color of samples, iron added biochar contains iron oxide species. Also, iron treatment induced the carbonization even at lower temperatures. Thus, well carbonized biochar was formed. Acid treatment has not provided a clear increase at the mass ratio of the carbonized product. Rigid structure of H2-CTW and H3-CTW could be partially seen from the images. Due to prevention effect of PO_4^{3-}, highly hardened H3-CTW was obtained. So that, the structure of H3-CTW prepared at 05-H3-1-400 conditions was almost similar to H3-CTW obtained at 350^{0}C due to fire retardant effect of phosphate groups [17].

The yields of acid treated waste consists of semi-carbonized samples with fragmentary structure. Due to solvent effect of H_2SO_4 on the waste textile, sticky and insufficiently carbonized materials was formed.

Table 1. Proximate analysis of CTW adsorbents

					
Waste textile (TW)	CTW-350	CTW-400	Fe-CTW	H2-CTW	H3-CTW
Yield (%)	30	14	48	33	46
Acidity (in aqueous solution)	neutral	neutral	acidic +	neutral-acidic	acidic
Appearance and grinding	fragmentary, in complete carbonization	well carbonized	well carbonized, iron oxide colored	sticky structure due to acidic dissolution	hardened structure, fragmentary

Before the dye adsorption experiments, biochars were added to deionized water to understand acidity of them. An interesting result was observed from water-Fe-CTW mixture, due to more acidic solution of Fe-CTW while the others acidity was approximately neutral (pH 6.8–7.1). That may be reduction of the small amount of iron oxide releasing acidic species at the presence of carbon [18]. The content, activity, and yield % of carbonized samples could be adjusted as desired by scientific methods to obtain efficient adsorbents or catalyst.

The crystal structure patterns which pointed out formation of biochar were presented in Figure 1 for CTW-350, CTW-400, H2-CTW, H3-CTW and Fe-CTW. Clear evidence for carbonization was observed for biochars obtained from both activated and non-activated waste. A broad peak among the $2\theta=15–30$ could be attributed to characteristic crystalline structure of activated carbon [19]. Especially the peak at around $2\theta=25$ became sharp for CTW-400 and H2-CTW with a small shift to lower angles implied to increasing crystallinity and increasing interspaces respectively [20]. Some of the peaks such as 29.18, 36.12 and 58 observed at Fe-CTW diffraction patterns are due to iron (II) oxide crystals formed because of Fe (II) cation impregnation [21].

According to XRD diffraction patterns, activation methods in this study could be classified as temperature, acidic and cationic induced. The crystallinity of biochars obtained by temperature induction challenging with that obtained by chemical modification due to high temperature and chemical requisition. H3-CTW showed broad peak pointed out disordered structure and low crystallinity probably presence of large phosphate groups disrupting the crystal structure.

The changes of chemical structure and functional groups were analyzed by spectroscopic analysis of FT-IR Figure 2.

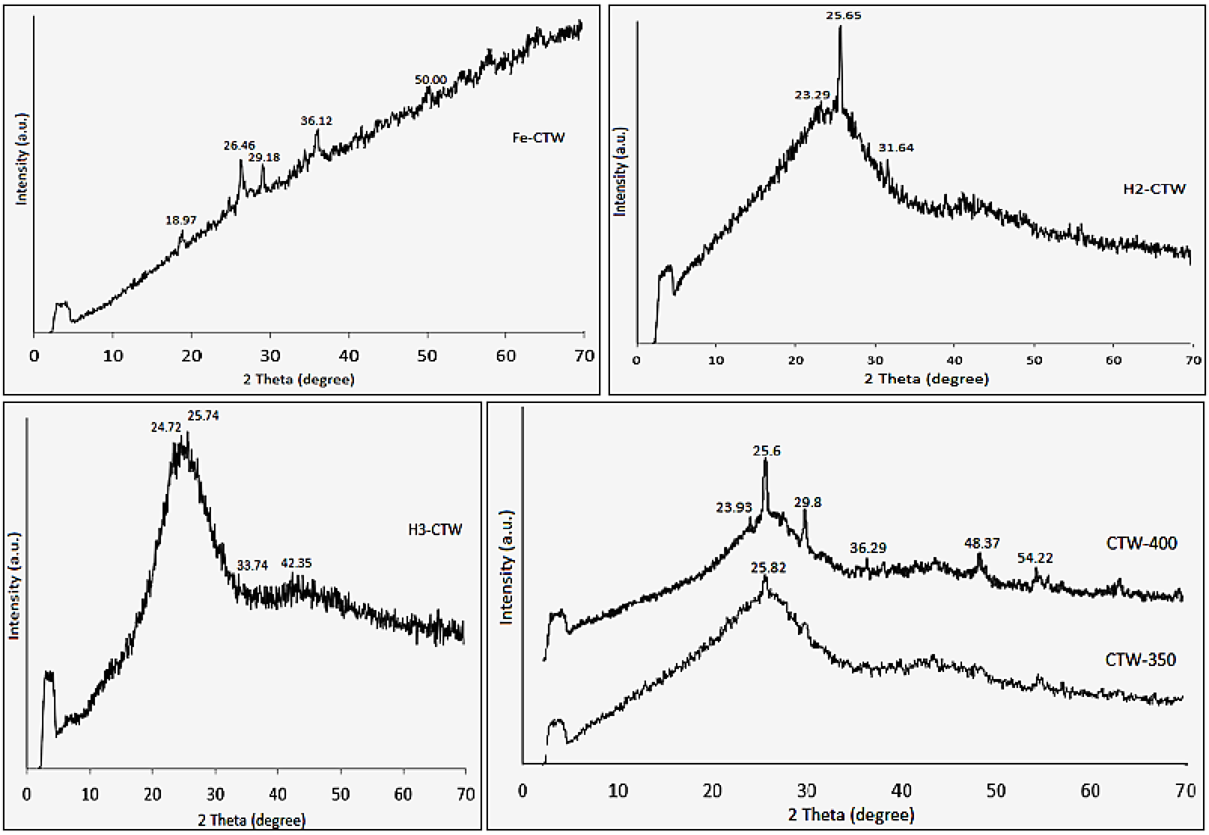

Fig. 1. XRD patterns of CTW samples.

From the spectrums of Fe, H2 and H3-CTW samples, characteristic carbonization peaks pointed out carbonization of cellulosic waste materials had been observed with the bands at around 3400, 1700 and 1090 cm^{-1} OH, C=O and C–O–C vibrations respectively. The spectrum of non activated CTW-350 and CTW-400 samples could be found in our other study [22]. The band at around 1610 cm^{-1} was assigned to C=C bond stretching of aromatic ring, and it was observed for all samples [23]. The Fe activation resulted in different FeO formations on the Fe-CTW structure. That was inferred from the band at around 500–850 cm^{-1} with the 1083 cm^{-1} band that corresponds C–O–C vibration. The presence of different phosphate form could be understood from the clear 998 cm^{-1} bands of H3-CTW as far as the absence of 1700 cm^{-1} C=C band [24].

Surface morphology of obtained biochars are shown in Figure 3. The spongy-like surface of CTW-350 structure became a denser structure with the effect of temperature as could be understood from the CTW-400 surface. Although increased temperature, the volatile matter of CTW-400 was not removed sufficiently due to melting of components in the waste. That covered the carbonized material surface and indicated how important of the temperatures with other parameters for sufficient carbonization. The crystal formations those attributed to iron oxide species with sponge-like structure were observed on the Fe-CTW image. Partially well-ordered pores and voids appeared although lower carbonization temperature at 350^0C. Catalytic effect of iron species is considered a dominant effect for easy transformation.

H2 and H3-CTW exhibited very dense structure compared with iron activated and non-activated samples due to solvent effect of acidic solutions on the waste materials. Thus, pores were covered with particles and chemicals dissolved during the pretreatment and those penetrated to voids or depressed the pore formation. This effect could be understood from the surface area results of samples Table 2. Largest surface was recorded for CTW-400 as 354 m^2/g while it was only 67 for H3-CTW. Activated carbon that is well-ordered and large pores was obtained with 4 ratio H_3PO_4treated mangrove pile sample among 3-5 ratio and 300–500^0C temperature range [3]. It is concluded that, sufficient parameters should be determined for efficient carbonized yield by taking consideration waste material.

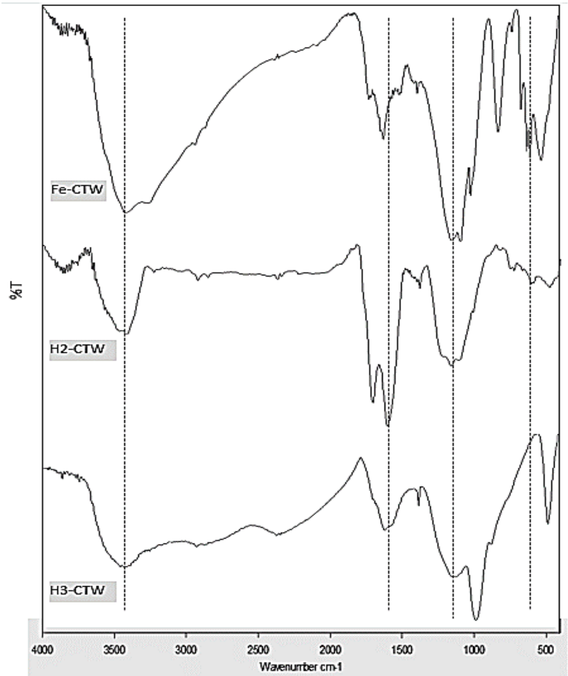

Fig. 2. FT-IR spectra of CTW samples.

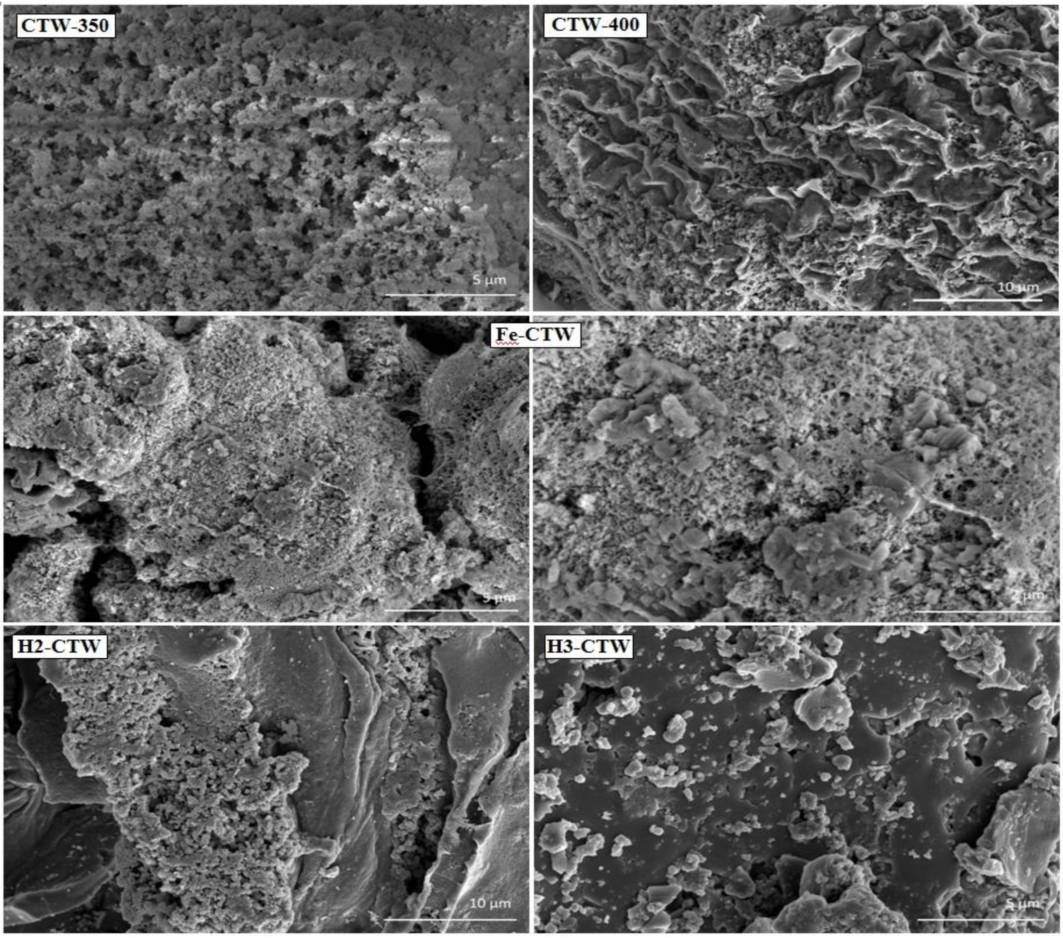

Fig. 3. SEM images of CTW samples.

Table 2. BET surface area of (S_{BET}) CTW adsorbents

Sample	S_{BET} (m^2/g
CTW-350	59
CTW-400	354
Fe-CTW	215
H2-CTW	189
H3-CTW	67

The EDX analysis results revealed that, carbon content reduced with increasing temperature and chemical treatment Table 3. The evidence of catalytic effect for Fe species could be predicted as compatible with explanations given section 3.1. At the other hand, reducing at carbon amount of H3-CTW could be attributed to phosphate penetration in to voids and interaction with volatile matters and carbon structure thus evaporate easily during the carbonization [3]. Sulfuric acid was concluded as the minimal carbon reducing agent with 85.95 % carbon contents for pretreatment of this waste material probably dissolution of samples. The highest carbon content was obtained in CTW-350 and CTW-400, respectively.

Table 3. EDX analysis resuls of CTW adsorbents

Atomic %	CTW-350	CTW-400	Fe-CTW	H2-CTW	H3-CTW
C K	82.98	70.49	53.39	85.95	52.11
N K	0.10	18.59	5.95	9.73	2.35
O K	11.40	2.70	29.28	3.18	23.64
MgK	3.14	7.64	0.60	1.14	0.07
AlK	1.56	0.36	10.77	85.95	17.47
SiK	0.26	0.22	–	–	0.86
TiK	0.54	–	–	–	3.50

Dye adsorption studies onto biochars

Dye adsorption studies were conducted with aqueous MO model chemical with industrial wastewater (ITW). Optimum pH, time, adsorbent dosage, and temperature of MO adsorption on the CTW adsorbents were determined. Temperature effect was studied at 308, 318, and 328 K, however any remarkable increase was not observed. So, 298 K was decided as adsorption temperature for this study. Neutral acidity (pH:7–7.5) and 100 mg/L dye concentration were adjusted as conditions for dye adsorption. 50 mg adsorbent was contacted MO solution for 1 h. These parameters were kept constant to evaluate adsorption performance of biochars prepared by different pretreatments.

dye adsorption performances of biochars from aqueous solutions by means of MO and ITWwere presented in Figure 4. Except for a small difference, it is seen that the change in MO adsorption performances of the samples is proportional to the change in ITW performances. Dye adsorption capacity of CTW-350 was 27.6 while it was 36.2 mg/g for CTW-400. A reasonable increase at adsorption performance with increased carbonization temperature of samples was observed.

That was due to sufficient carbonization of raw materials at 400^0C compared with CTW-350 without any chemical treatment. But the dye removal performances of Fe-CTW and H3-CTWare more than CTW-400, although these were carbonized at 350^0C.

This is a strong indicator how important the proper chemical treatment. Same raw material was converted to more efficient form by small differences at application. Especially the proper voids and pores that formed on the adsorbent surface after the chemical treatment provided higher adsorption. It is understood from the results that the large surface area alone is not sufficient to achieve high adsorption.

The functional groups on the adsorbent surface are of undeniable importance and, Fe-CTW and H3-CTW were concluded to present these functional groups from the characterization results (section 3.1). At the other hand, adsorption performance of H2-CTW was less than the expected correlation with others.

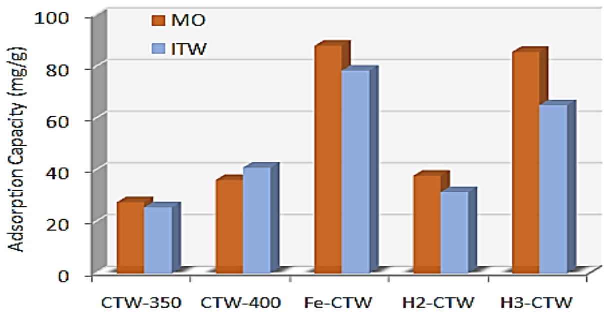

Fig. 4. MO and ITW adsorption performance of CTW samples.

The solubility of raw waste textile particularly with a high percentage of cotton in H_2SO_4resulted in prevented the appropriate carbonization. Acid treated samples covered with sticky slush and that increased during the carbonization. This structure prevented the efficient carbonization and formation of functional groups and pores. It is important to note that, a procedure for carbonization is specific for a raw material that handled even if the similar content. In this study, it was concluded that, Fe and H_3PO_4treatment at determined conditions was favorable for carbonization of waste textile materials used in this study. Application of this procedure provided efficient adsorbent with less energy compared with CTW-400 preparation conditions. Reusability studies of 0.5 mol/L acid washed samples were conducted and dye removal% performance was changed only ± 0–5% only after 5 times usage. The other benefit of converting the waste textile materials to valuable product is contribution to environmental protection. By this, fine chemicals are prepared from cost free raw materials while controlling the environmental pollution caused by disposal or burning of waste materials.

Conclusions

Processing of waste materials provides free of charge raw material besides environmental protection. In this study carbon-rich waste textile materials was investigated in terms of active carbon preparation process. Already waste textile materials was converted to active carbon when they were carbonized simply at 400^0C. Fe, H_2SO_4 and H_3PO_4 pretreatment methods were applied to get more functional and energy saving carbonization. Samples those pretreated with activating agents were carbonized at 350^0C, while it was necessary 400^0C heating to get well carbonized sample from non-treated waste. The structure of carbonized samples was analyzed with FT-IR, SEM XRD and BET investigations. Some functional groups, mainly C=O, porous structure and large surface area were observed for chemical treated samples. An efficient adsorbent was prepared with chemical treatment. Fe-CTW and H3-CTW were concluded as convenient adsorbents that could be achieved with 05-Fe-H3-1-350 carbonization conditions. MO and ITW dye removal performances of samples were recorded as between 25–85 mg/g. These results were highly acceptable when taking account, the dye removal performances of commercial or lab scale biochars. All carbon-rich materials could be converted to fine chemicals that could be used for adsorbent, biosensor or charging. However, the most accurate conditions should be determined scientifically. Waste textile materials were converted to activated carbon with cationic and acidic pretreatment and functional Fe-CTW, H2 and H3-CTW were prepared with lower energy compared with CTW-400 obtaining conditions. These findings contain promising result for waste management for environmental protection and production of fine chemicals with economically and it could be applied to other kind of waste materials.

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References

1. Yaashikaa P.R., Kumar P.S., Varjani S., Saravanan A. A critical review on the biochar production techniques, characterization, stability and applications for circular bioeconomy, Biotechnology Reports. 28 (2020) e00570. doi:10.1016/j.btre.2020.e00570.
2. Yang C., Liu J., Lu S. Pyrolysis temperature affects pore characteristics of rice straw and canola stalk biochars and biochar-amended soils, Geoderma. 397 (2021) 115097. doi:10.1016/j.geoderma. 2021. 115097.
3. Zakaria R., Jamalluddin N.A., Abu Bakar M.Z. Effect of impregnation ratio and activation temperature on the yield and adsorption performance of mangrove based activated carbon for methylene blue removal, Results in Materials. 10 (2021) 100183. doi:10.1016/j.rinma.2021. 100183.
4. Khuong D.A., Nguyen H.N., Tsubota T. Activated carbon produced from bamboo and solid residue by CO2 activation utilized as CO2 adsorbents, Biomass and Bioenergy. 148 (2021) 106039. doi:10.1016/j.biombioe.2021.106039.
5. Guclu C., Alper K., Erdem M., Tekin K., Karagoz S. Activated carbons from co-carbonization of waste truck tires and spent tea leaves, Sustainable Chemistry and Pharmacy. 21 (2021) 100410. doi:10.1016/j.scp.2021.100410.
6. Hwang B., Yi S.H., Chun S.E. Dual-role of ZnO as a templating and activating agent to derive porous carbon from polyvinylidene chloride (PVDC) resin, Chemical Engineering Journal. 422 (2021) 130047. doi:10.1016/j.cej.2021.130047.
7. Naganathan K.K., Faizal A.N.M., Zaini M.A.A., Ali A. Adsorptive removal of Bisphenol a from aqueous solution using activated carbon from coffee residue, Materials Today: Proceedings. 47 (2021) 1307–1312. doi:10.1016/j.matpr.2021. 02.802.
8. Müller B.R. Preparation and characterization of K2CO3-doped powdered activated carbon for effective in-vitro adsorption of deoxynivalenol, Bioresource Technology Reports. 15 (2021) 100703. doi:10.1016/j.biteb.2021.100703.
9. Pazira R., Lashanizadegan A., Sharififard H., Darvishi P. Xylene removal from dilute solution by palm kernel activated charcoal : Kinetics and equilibrium analysis Advances in Environmental Technology Xylene removal from dilute solution by palm kernel activated charcoal : Kinetics and equilibrium analysis, Advanced in Environmentak Technology. 2 (2018) 83–92. doi:10.22104/AET. 2018.2989.1145.
10. Yuan Z., Xu Z., Zhang D., Chen W., Huang Y., Zhang T., Tian D., Deng H., Zhou Y., Sun Z. Mesoporous activated carbons synthesized by pyrolysis of waste polyester textiles mixed with Mg-containing compounds and their Cr(VI) adsorption, Colloids and Surfaces A: Physicochemical and Engineering Aspects. 549 (2018) 86–93. doi:10.1016/j.colsurfa.2018.04.008.
11. Cuong D.V., Matsagar B.M., Lee M., Hossain M.S.A., Yamauchi Y., Vithanage M., Sarkar B., Ok Y.S., Wu K.C.W., Hou C.H. A critical review on

biochar-based engineered hierarchical porous carbon for capacitive charge storage, Renewable and Sustainable Energy Reviews. 145 (2021) 111029. doi:10.1016/j.rser.2021.111029.

12. Miao Q., Li G. Potassium phosphate/magnesium oxide modified biochars: Interfacial chemical behaviours and Pb binding performance, Science of the Total Environment. 759 (2021) 143452. doi:10.1016/j.scitotenv.2020.143452.
13. Trakal L., Šigut R., Šillerová H., Faturíková D., Komárek M. Copper removal from aqueous solution using biochar: Effect of chemical activation, Arabian Journal of Chemistry. 7 (2014) 43–52. doi:10.1016/j.arabjc.2013.08.001.
14. Xu Z., Sun Z., Zhou Y., Chen W., Zhang T., Huang Y., Zhang D. Insights into the pyrolysis behavior and adsorption properties of activated carbon from waste cotton textiles by FeCl3-activation, Colloids and Surfaces A: Physicochemical and Engineering Aspects. 582 (2019) 1–10. doi:10.1016/j.colsurfa.2019.123934.
15. Y.A.G. Rustamov Ya.I., Mammadova Sh.G., Rustamova G.Ya., Nasirova V.A. The, Synthesis Of Cellulose Derivatives With Special Properties From Cellulose- Containing Natural Materials And Priority Fields Of Their Use, (2019) 39–43.
16. Li Z., Hanafy H., Zhang L., Sellaoui L., Schadeck Netto M., Oliveira M.L.S., Seliem M.K., Luiz Dotto G., Bonilla-Petriciolet A., Li Q. Adsorption of congo red and methylene blue dyes on an ashitaba waste and a walnut shell-based activated carbon from aqueous solutions: Experiments, characterization and physical interpretations, Chemical Engineering Journal. 388 (2020) 124263. doi:10.1016/j.cej.2020.124263.
17. Scharte B. Phosphorus-based flame retardancy mechanisms-old hat or a starting point for future development? Materials. 3 (2010) 4710–4745. doi:10.3390/ma3104710.
18. Wei R., Cang D., Bai Y., Huang D., Liu X. Reduction characteristics and kinetics of iron oxide by carbon in biomass, Ironmaking and Steelmaking. 43 (2016) 144–152. doi:10.1179/1743281215Y.0000000061.
19. Sawant S.Y., Munusamy K., Somani R.S., John M., Newalkar B.L., Bajaj H.C. Precursor suitability and pilot scale production of super activated carbon for greenhouse gas adsorption and fuel gas storage, Chemical Engineering Journal. 315 (2017) 415–425. doi:10.1016/j.cej.2017.01.037.
20. Alagha O., Manzar M.S., Zubair M., Anil I., Mu'azu N.D., Qureshi A. Magnetic Mg-Fe/LDH intercalated activated carbon composites for nitrate and phosphate removal from wastewater: Insight into behavior and mechanisms, Nanomaterials. 10 (2020) 1–22. doi:10.3390/nano10071361.A.
21. Mishra, M. Sardar, Isolation of Genomic DNA by Silane-Modified Iron Oxide Nanoparticles, Nanotechnology: Novel Perspectives and Prospects. McGraw Hill Education, New York. (2015) 309–315.
22. Gumus H., Buyükkidan B., Pollution Removal Performance of Chemically Functionalized Textile Waste Biochar Anchored Poly (vinylidene fluoride) Adsorbent, Journal of the Turkish Chemical Society Section A: Chemistry. 9 (2022) 777–792.
23. Zhang L., Tu L.Y., Liang Y., Chen Q., Li Z.S., Li C.H., Wang Z.H., Li W., Coconut-based activated carbon fibers for efficient adsorption of various organic dyes, RSC Advances. 8 (2018) 42280–42291. doi:10.1039/c8ra08990f.
24. Sartova K., Omurzak E., Kambarova G., Dzhumaev I., Borkoev B., Abdullaeva Z. Activated carbon obtained from the cotton processing wastes, Diamond and Related Materials. 91 (2019) 90–97. doi:10.1016/j.diamond.2018.11.011.

MÜXTƏLİF KİMYƏVİ MADDƏLƏRİN TOXUCULUQ TULLANTILARINDAN ALINAN BİOKÖMÜR ADSORBENTLƏRİNİN KARBONLAŞMA DAVRANIŞLARINA VƏ ÇİRKLƏNMƏNİN TƏMİZLƏMƏ EFFEKTİVLİYİNƏ TƏSİRİ

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Xammala artan tələbata və ətraf mühitin çirklənməsinə nəzarət etməyin ağıllı üsullarından biri tullantıların təkrar emalıdır. Bu araşdırmada tekstil sənayesində təkrar istifadə olunmayacaq tullantıların funksional aktivləşdirilmiş karbona çevrilməsi üçün optimal şərtlər müəyyən edilmişdir. Bunun üçün xam və Fe, H_2SO_4, H_3PO_4 hopdurulmuş toxuculuq tullantıları müxtəlif vaxtlarda müxtəlif temperaturlarda karbonlaşdırılmışdır. Hazırlanmış aktivləşdirilmiş karbonların molekulyar quruluşu və kristal şəbəkəsi müvafiq olaraq FT-IR və XRD analizləri ilə tədqiq edilmişdir. Nümunələrin morfologiyasını və səth xüsusiyyətlərini araşdırmaq üçün SEM və BET analizlərindən istifadə edilmişdir. C=C, C=O və C–O–C funksional qruplarının mövcudluğu 1300–1700 sm^{-1} ətrafında olan titrəyişlərlə tanınıb. Fe və H_3PO_4 ilə əvvəlcədən təmizlənmiş nümunələrin karbonlaşması nəticəsində yaxşı kristal və məsaməli struktur əmələ gəlmiş, proses isə katalitik təsirə görə daha aşağı temperaturda aparılmışdır. Bütün nümunələr üçün 25–85 mq/q metil narıncı (MO) və sənaye toxuculuq suyunu (ITW) çıxarma qabiliyyəti qeydə alınıb. Ətraf mühiti qoruyarkən tullantı materiallarının karbonlaşdırılması yolu ilə səmərəli biokarbonlar əldə edilmişdir. Ekoloji və iqtisadi istehsal üçün hər bir tullantı materialı üçün belə bir xüsusi yanaşma hazırlana bilər.

Açar sözlər: *Biokömür, karbonlaşma, tullantıların təkrar emalı, ətraf mühitin mühafizəsi.*

ВЛИЯНИЕ РАЗЛИЧНЫХ ХИМИЧЕСКИХ ВЕЩЕСТВ НА ПОВЕДЕНИЕ ПРИ КАРБОНИЗАЦИИ И ЭФФЕКТИВНОСТЬ УДАЛЕНИЯ ЗАГРЯЗНЕНИЙ БИОУГОЛЬНЫМИ АДСОРБЕНТАМИ, ПОЛУЧЕННЫМИ ИЗ ТЕКСТИЛЬНЫХ ОТХОДОВ

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Одним из разумных методов контроля растущего спроса на сырье и загрязнения окружающей среды является переработка отходов. В этом исследовании были определены оптимальные условия для преобразования отходов, которые не будут повторно использоваться в текстильной промышленности, в функциональный активированный уголь. Для этого необработанные и пропитанные Fe, H_2SO_4, H_3PO_4 текстильные отходы карбонизировали при разных температурах в течение разного времени. Молекулярную структуру и кристаллическую решетку приготовленных активированных углей исследовали методами FT-IR и XRD соответственно. Анализы SEM и BET использовались для изучения морфологии и свойств поверхности образцов. Существование функциональных групп C=C, C=O и C-O-C было установлено по колебаниям в районе 1300-1700 см$^{-1}$. Хорошо кристаллическая и пористая структура формировалась в результате карбонизации предварительно обработанных образцов Fe и H_3PO_4, при этом процесс проводился при более низкой температуре за счет каталитического эффекта. Для всех образцов была зарегистрирована способность удаления метилового оранжевого (MO) и промышленной текстильной воды (ПТВ) на уровне 25-85 мг/г. Эффективные биоугли были получены путем карбонизации отходов при защите окружающей среды. Такой специфический подход можно было бы разработать для каждого вида отходов для экологического и экономичного производства.

Ключевые слова: *биоуголь, карбонизация, переработка отходов, защита окружающей среды.*