



Activated Carbon of Coconut Shell Modified TiO_2 as a Batik Waste Treatment

Fery Eko Pujiono^{1*}, Tri Ana Mulyati¹, Miftakhul Nor Fizakia¹

¹ Departement of Chemistry, Institut Ilmu Kesehatan Bhakti Wiyata Kediri, Indonesia

ARTICLE INFO

Article history:

Received 06 June 2020

Received in revised form 28 July 2020

Accepted 28 July 2020

Available online 19 November 2020

Keywords :

Activated carbon

Coconut shell

TiO_2

Batik waste

ABSTRACT

Research about the modification of activated carbon of coconut shell with TiO_2 as a waste treatment Batik has been done. The purpose of this study was to determine the effect of modified TiO_2 on activated carbon characteristics and the effect of TiO_2 concentration on the adsorption power of activated carbon in batik waste. The method utilized was activated carbon soaked in TiO_2 with 5% and 10% concentrations in a ratio of 1: 5, then stirred with a magnetic stirrer for 2 hours. Next, the mixture was placed in an autoclave bottle and an oven (200°C for 30 minutes). The results were then washed with distilled water and dried (100°C for 5 hours), then the material was characterized by FTIR, XRD, SEM-EDX, and application to batik waste. FTIR results indicated the presence of Ti-O-Ti groups after modification at wave number 682 cm^{-1} , XRD indicated the presence of a combination of amorphous KA and crystalline TiO_2 at $25,2^\circ$; $37,7^\circ$; $48,1^\circ$; $53,8^\circ$; and 55° , and SEM results of TiO_2 agglomeration on the surface of the railroad. Adsorption of batik waste showed $\text{KATiO}_2\text{-10}$ (0,052) lower than KA (0,059) and $\text{KATiO}_2\text{-5}$ (0,057), as well as the presence of COD KA results = $705,6\text{ mg / L}$ (pH = 8), $\text{KATiO}_2\text{-5}$ = $504,0\text{ mg / L}$ (pH = 7) and $\text{KATiO}_2\text{-10}$ = $403,2\text{ mg / L}$ (pH = 7). Based on this research, the activated carbon modified TiO_2 can be used as a material for processing batik waste with the most significant concentration of TiO_2 represent 10%.

1. INTRODUCTION

The development of the batik industry in recent years has been extraordinarily rapid. This is appropriate to an increase in the number of batik enthusiasts both in terms of producers and consumers. However, the problem that arises from this development is the waste generated from batik production process. Batik liquid waste contains dyes, color enhancers, and collections that can cause damage to the aquatic environment (Mukimin et al. 2018). One way to overcome pollution due to batik liquid waste is to use activated carbon as an adsorbent.

Currently, commercial activated carbon has a relatively high selling price According to Global and China Activated Carbon Industry Report 2017-2021 coconut shell-based activated carbon commands the highest price,

above USD 1427,98/t. This causes, it is necessary to synthesize activated carbon from materials containing high carbon sources but at a low price like an agricultural waste (Pujiono, et al. 2017; and Mulyati, 2018). One of the agricultural waste that is used as raw material for making activated carbon is coconut shell. The results of Hidayu, et. al. (2016) research shows that with the same activator, the surface area of activated carbon of coconut shell is greater ($1.011\text{ m}^2 / \text{g}$) than that of oil palm shells ($584\text{ m}^2 / \text{g}$).

The potential of activated carbon from a coconut shell as water treatment has been reported in several studies. Omo-Okoro, et al. (2018) shows that activated carbon from coconut shells can be used as a potent adsorbent for organic wastes and polyfluoroalkyl in aqueous waste. Aljabore, et al. (2017) also reported that activated carbon from coconut shells was effectively used as an adsorbent for toxic textile

*Correspondence author.

E-mail : ferypujiono@gmail.com (F.E. Pujiono)

doi : <https://doi.org/10.21771/jrtppi.2020.v11.no.2.p1-10>

2503-5010/2087-0965© 2020 Jurnal Riset Teknologi Pencegahan Pencemaran Industri-BBTPPI (JRTPI-BBTPPI).

This is an open access article under the CC BY-NC-SA license (<https://creativecommons.org/licenses/by-nc-sa/4.0/>).

Accreditation number : (LIPI) 756/Akred/P2MI-LIPI/08/2016

dyes. A similar thing was reported by Cazetta et al. (2011) which shows that activated carbon has an adsorption power of 916 mg/g for dyes. On the other hand, activated carbon can still be increased its adsorption power through modification of the carbon structure. One compound that is usually used as a modifier for activated carbon is TiO_2 .

Modification of activated carbon using TiO_2 has several advantages, namely relatively inexpensive, excellent potential economic value to remove pollutants, good availability, inert, excellent photocatalytic activity, relatively excellent chemical stability, effective form of remediation and can prevent the formation of undesirable by-products (Schneider et al. 2014 and Skocaj et al. 2011). Research by Simonetti et al. (2018) showed that activated carbon from coconut shells modified with TiO_2 can be used to increase the adsorbent power of activated carbon to 60.53 m^2/g dye waste using the sol-gel method. MiarAlipour, et al. (2018) determined a combination of TiO_2 photocatalysts which were immobilized in activated carbon to increase the adsorption and photocatalytic efficiency using the in situ method. Research by Pujiono, et al. (2019) showed that activated carbon modified with TiO_2 was able to reduce COD levels up to 93,28%.

Based on the background, a study was conducted on the modification of activated carbon from coconut shells

with TiO_2 to adsorb batik liquid waste. Activated carbon synthesized from coconut shell agricultural waste was further modified with TiO_2 at various concentrations and applied to batik waste adsorption.

2. METHODS

2.1. Materials

Materials needed in this study are coconut shell from Bandar Traditional Market, Kediri, East Java; Batik Waste Derived from the batik home industry in Sampang, Madura; Sodium Hydroxide (NaOH) MERCK 99,9%; Titanium Dioxide (TiO_2) Sigma Aldrich 99%; Ferro Ammonium Sulfate ($(\text{NH}_4)_2\text{Fe}(\text{SO}_4)_2 \cdot 6\text{H}_2\text{O}$) Sigma Aldrich 99%; Ferroin indicator solution 0,1 wt.% in H_2O Sigma Aldrich; Potassium dichromate ($\text{K}_2\text{Cr}_2\text{O}_7$) 99% Sigma Aldrich and distilled water.

2.2. Instrumentation

The instrumentation in this study are glassware, oven for dry sample, furnace, for carbonized sample, magnetic stirrer, pH meter, UV-Vis spectrophotometer (Shimadzu), X-Ray Diffraction (JOEL diffractometer), Bruker FT-IR Spectrometer, Scanning Electron Microscopy (Zeiss EVO MA 10). Digestion vessel, Reflux, and Micro Burette

2.3. Procedure

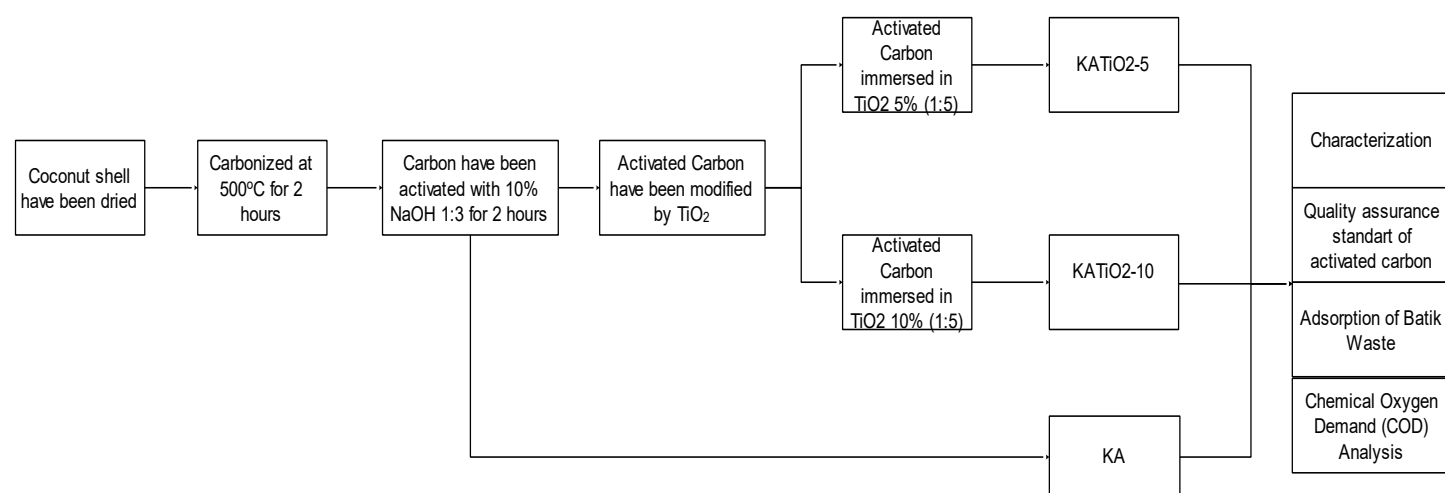


Figure 1. Procedure Synthesis and Characterization of Activated Carbon of Coconut Shell Modified TiO_2 as a Batik Waste Treatment

2.3.1 Sample Preparation

The coconut shell was washed to remove the dirt then dried. The dry coconut shell was then carbonated.

2.3.2 Synthesis of Activated Carbon

The coconut shell was carbonized in the furnace at 500°C for 2 hours. The carbon that has been produced was then ground to fine and sieved to homogenize at 100 mesh. The carbon from the coconut shell that has been produced was then soaked in 10% NaOH in a ratio of 1: 3 for 2 hours. After the stirring process, it was filtered and neutralized with hot distilled water to pH 6.5-7. The precipitate was dried in an oven at 130°C for 4 hours. The result is namely activated carbon (KA).

2.3.3 Modification of Activated Carbon with TiO₂

The activated carbon (KA) was then immersed in TiO₂ (1: 5) with 5% and 10% concentrations, respectively. Then it was added with 45 ml of distilled water and stirred with a magnetic stirrer for 2 hours. Next, the mixture was put in an autoclave bottle and heated at 200°C for 30 minutes. it was then washed with distilled water and dried at 100°C for 5 hours. Activated carbon modified with 5% TiO₂ is called KATiO₂-5 while those modified with 10% TiO₂ are called KATiO₂-10.

2.3.4 Characterization of Materials

The crystallinity of the material (activated carbon and activated carbon modified with TiO₂) was determined by XRD (X-Ray Diffraction) with CuK α radiation (λ = 1.54056 Å) at 40 kV and 30 mA. The diffractogram pattern is measured at 2 θ between 5–50 °. Material functional groups are determined by FTIR (Fourier Transform Infrared) at wavelengths between 400–4000 cm⁻¹. The surface structure of the material is determined by SEM (Scanning Electron Microscope). In addition, the quality assurance standard of activated carbon material before and after the modification of TiO₂ was carried out, such as moisture content, ash content, iodine numbers, and methylene blue numbers.

2.3.5 Application in Batik Waste

Modified activated carbon TiO₂ (KATiO₂) is applied as batik wastewater material. it is mixed with batik wastewater (1:5) and stirred with a magnetic stirrer for 2 hours. Then the filtrate was measured using a UV-Vis spectrophotometer (at a wavelength of 400 - 800 nm).

2.3.6 Chemical Oxygen Demand (COD) Analysis

The sample is inserted digestion vessel with a digestion solution (K₂Cr₂O₇ 0,1 N) and sulfuric acid reactant. Next, the mixture is shaken until homogeneous. After that, the mixture is refluxed for 2 hours and cooled at room temperature. Then the test solution is titrated with Ferro Ammonium Sulfate (FAS) standard solution and Ferroin indicator until the color changes from bluish-green to reddish-brown. COD results are calculated by the equation :

$$\text{COD (mg/l)} = \frac{((V_b - V_c) \times NFAS \times 8000)}{V_s}$$

With :

V_b = volume of FAS solution needed for blank (ml)

V_c = volume of FAS solution needed for the test sample (ml)

NFAS = normality of FAS solution (N)

V_s = sample volume (ml)

3. RESULT AND DISCUSSION

3.1 Activated Carbon Synthesis

In this research, activated carbon is synthesized from the coconut shell with NaOH activator. At first, the carbon is synthesized by heating it in a furnace at 500 °C. This process aims to release volatile molecules like CO₂ and H₂O (Asrijal, et al. 2014) and describe the components contained in coconut shells, namely cellulose, hemicellulose, and lignin (Hartanto and Ratnawati, 2010). The carbon produced is then activated with a 10% NaOH solution. NaOH activator acts as a dehydrating agent that can break C-O-C and C-O bonds from raw materials, causing a decrease in mass after activation (Bachrun, et al. 2016). The yield of activated carbon produced in this study reached 87.38% (Table 1).

Table 1.Yield of Activated Carbon

Carbon mass (g)	Activated carbon mass (g)	Yield (%)
10,006	8,743	87,38

3.2 Activated Carbon Modified with TiO_2

Activated carbon (KA) was modified with 5% and 10% TiO_2 . The variation of TiO_2 concentration was chosen based on the research of Orha, et al (2017) and Pujiono, et al (2019). It aims to determine the effect of TiO_2 concentration on activated carbon characteristics. Modification of activated carbon is produced by stirring activated carbon with a TiO_2 solution for 2 hours to distribute TiO_2 evenly on the entire surface of activated carbon (Yuliusman, 2014). The precipitate was dried at 100 °C to remove water vapor. Modified activated carbon at 5% TiO_2 hereinafter referred to as $\text{KATiO}_2\text{-5}$ while modification of 10% TiO_2 as $\text{KATiO}_2\text{-10}$.

3.3 Characterization

In this study, the quality assurance standard of activated carbon before and after TiO_2 modification was carried out by comparing data on moisture content, ash content, iodine numbers, and methylene blue numbers with SNI 06-37-30-1995 requirements. Table 2 shows that activated carbon and TiO_2 modified activated carbon have met the permitted activated carbon quality standard (SNI 06-37-30-1995).

Table 2. The quality assurance standard of activated carbon before and after TiO_2 modification

Type of Test	Materials			SNI 06-37-30-1995
	KA	$\text{KATiO}_2\text{-5}$	$\text{KATiO}_2\text{-10}$	
Moisture content (%)	15,5	15,3	15,2	Max 25%
Ash content (%)	5,2	13,2	13,9	Max 15%
Iodine numbers (mg/g)	856,78	951,97	983,71	Min 750 mg/g
Methylene blue numbers (mg/g)	120,82	123,14	124,03	Min 120 mg/g

Table 2 shows that the modification of TiO_2 on activated carbon did not significantly change the moisture content. This is following the research of Anisuzzaman, et al (2015) which shows that there wasn't a significant correlation between moisture content and the ratio of impregnation to activated carbon modification. On the other hand, ash content increases after modification of TiO_2 . This is due to TiO_2 is a metal oxide that has a bond between titanium tetravalent ions and oxygen ions so that it is stable at high temperatures (Nasution and Fitri, 2018). Table 2 also shows that activated carbon modified with TiO_2 has greater absorption of iodine and methylene blue when compared to activated carbon without modification of TiO_2 . These results indicate the existence of modification of activated carbon with TiO_2 able to increase the ability of adsorption ability of activated carbon in adsorbing adsorbate. This is consistent with the research of Dey, et al., (2011) who reported that modification of carbon fiber with TiO_2 was able to increase the ability of adsorption of methylene blue.

Sample characterization was carried out to show that the activated carbon modified TiO_2 was successfully synthesized. Modification of activated carbon with TiO_2 based on Orha et al. (2017) showed that activated carbon modified with TiO_2 has two adsorption properties, that is physically by activated carbon and chemically by TiO_2 through photocatalytic reactions. It is expected that the activated carbon modification process can increase its adsorption capability. Characterization of the samples conducted in this study was FTIR, XRD, and SEM-EDX. The results of the characterization by FTIR are shown in Figure 2. The peak at wave number 3390 cm^{-1} indicates the hydroxyl group (-OH). The peak is increased in intensity on activated carbon. Because of the reaction of water vapor with free compounds on the activated carbon surface (Wibowo, et al. 2011; Pujiono, et al. 2017). However, the peak decrease occurs in carbon which has been modified with TiO_2 . This is appropriate to the role of TiO_2 modifiers that can reduce hydrogen bonds between the surface of activated carbon and water vapor (Orha, et al. 2016).

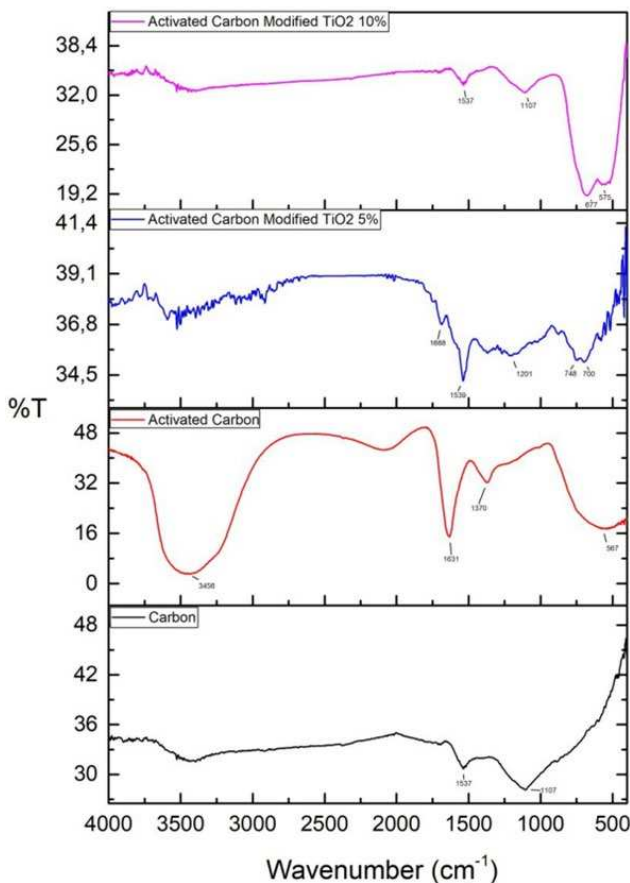


Figure 2. Spectra FTIR of the Materials

The difference between activated carbon before and after activation represents a peak in the wavenumber 1695 cm^{-1} . This peak indicates the stretching of titanium carboxylate (Ti-O-C). Besides that, it shows a peak at wavenumber 1572 cm^{-1} which indicates the presence of Ti-O-C groups. The wavenumbers 1695 cm^{-1} and 1572 cm^{-1} on modified carbon with the between activated carbon and TiO_2 (Irwan et al. 2016). $\text{KATiO}_2\text{-10}$ peaks at these wavelengths express a more extraordinary intensity than $\text{KATiO}_2\text{-5}$ which assumed there are more TiO_2 particles attached to activated carbon (Pujiono et al., 2019). The peak at wave number 682 cm^{-1} indicates the presence of Ti-O-Ti stretching bonds indicating that TiO_2 has covered the activated carbon site.

The difference in a chemical structure on the surface of activated carbon modified TiO_2 equally affects its crystallinity as shown in Figure 3. The diffractogram pattern

of activated carbon indicates the presence of widening peaks at $5\text{-}10^\circ$ and $20\text{-}30^\circ$. This is the characteristic peak of activated carbon which indicates an amorphous form (Le, et al. 2012; Pujiono, et al., 2017; Mulyati, et al. 2017). Besides, the XRD patterns between $\text{KATiO}_2\text{-5}$ and $\text{KATiO}_2\text{-10}$ indicate a combination of widening peaks in the $5\text{-}10^\circ$ and $20\text{-}30^\circ$ indicate the presence of activated carbon characteristics and a sharp peak at $25,2^\circ$; $37,7^\circ$; $48,1^\circ$; $53,8^\circ$; and 55° which represent the characteristic peak of TiO_2 anatase (Theivasanthi and Alagar, 2013, Pujiono, et al. 2019). The decrease in the intensity of activated carbon modified TiO_2 compared to Anatase because there is an interaction between carbon which is amorphous, thereby reducing the crystallinity of TiO_2 . The predominant anatase in this material provides the advantage of being able to increase its photocatalytic ability when compared to rutile (He et al. 2013). This indicates that there is a combination of amorphous activated carbon forms and TiO_2 crystals which the modification of activated carbon with TiO_2 has been successfully synthesized.

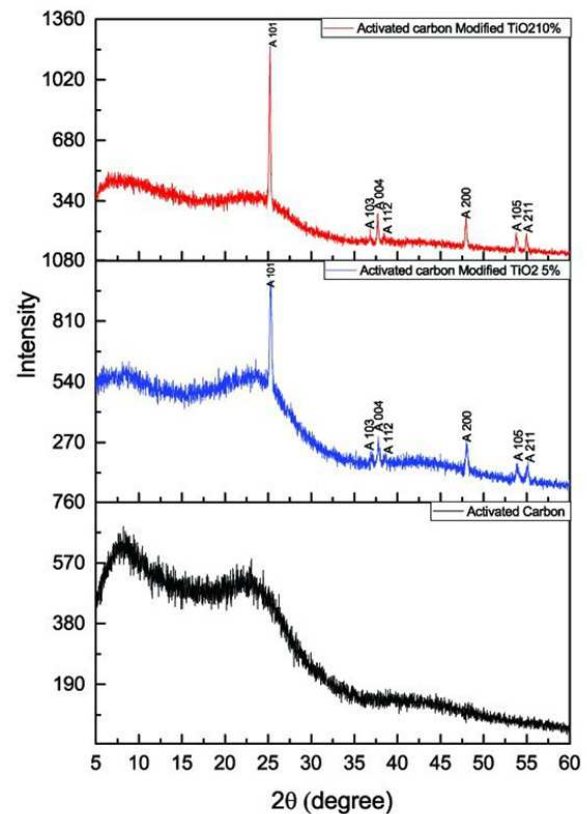


Figure 3. Diffractogram Patterns of The Materials

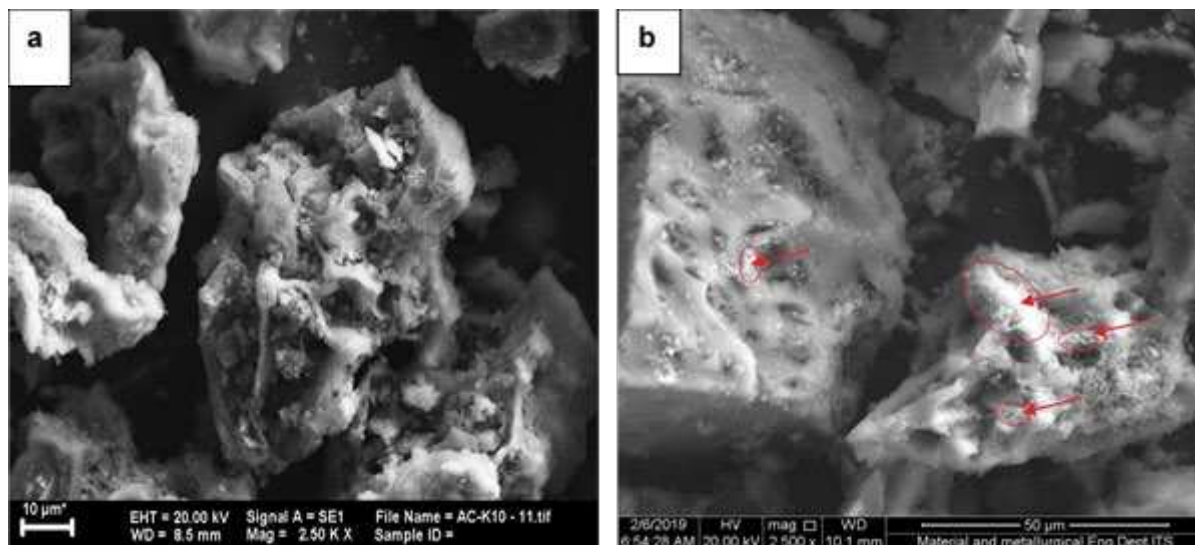


Figure 4. SEM Images of The Materials : (a) Activated Carbon (KA) (b) Activated Carbon Modified by TiO_2 10% ($\text{KATiO}_2\text{-10}$)

The morphology of activated carbon and activated carbon modified with TiO_2 observed using SEM are shown in Figure 4. Figure 4 (a) shows the surface morphology of the activated carbon, while Figure 4 (b) shows the surface morphology of $\text{KATiO}_2\text{-10}$. Based on Figure 4 (a) it can be seen that pores have formed on the surface of activated carbon, this shows that activated carbon has been successfully synthesized. Figure 4 (b) shows that the modified carbon obtains a structure like activated carbon. However, the agglomeration of TiO_2 on the surface of activated carbon indicates the presence of TiO_2 on the surface of activated carbon (Pujiono, et al., 2019). This further proves it has been successfully synthesized.

3.4 Adsorption Batik Waste use Modified Activated Carbon

This modified TiO_2 activated carbon was applied to adsorb batik waste. Batik waste used in this study is Madura batik waste which is yellow and turbid. The waste has a pH = 8 and COD = 1500 mg / L. The results of batik waste adsorption are shown in Table 3. The measurement of batik liquid waste showed a peak at a wavelength of 400 nm with adsorption of 0,536. This is due to the color of the compounds in the batik liquid waste (Rahmawati, et al. 2009). The maximum wavelength of the batik waste solution obtained will be used to measure the absorbance of the waste solution using KA, $\text{KATiO}_2\text{-5}$, and $\text{KATiO}_2\text{-10}$ materials.

Table 3. Batik Waste Adsorption on Activated Carbon and Activated Carbon Modified with TiO_2

Materials	Absorbance
Batik Waste	0,536
KA	0,059
$\text{KATiO}_2\text{-5}$	0,057
$\text{KATiO}_2\text{-10}$	0,052

Table 3 shows that there are differences between KA, $\text{KATiO}_2\text{-5}$, and $\text{KATiO}_2\text{-10}$. $\text{KATiO}_2\text{-10}$ obtained lower adsorption that is equal to 0,052 when compared with KA and $\text{KATiO}_2\text{-5}$ respectively of 0,059 and 0,057. These results indicate that the adsorption ability obtained. This is because the amount of absorbance indicates the concentration of a dye, if the dye has been adsorbed then the concentration will decrease. This means that the smaller the absorbance, the smaller the concentration of the dye due to adsorbent which shows high adsorption ability (Nsami, et al., 2013). The absorbances obtained prove that TiO_2 not only causes photocatalytic reactions but also increases the adsorption power of activated carbon (Lubis et al. 2016). This modified TiO_2 activated carbon is then applied to adsorb batik. Increasing the number of dyes molecules adsorbed will increase the number of dyes undergoing an oxidation reaction with the formation of OH radicals on the catalyst surface of KATiO_2 , then $\bullet\text{OH}$ will react with the

dye waste by attacking aromatic rings and the formation of open rings which contribute to the formation of intermediate compounds, which subsequently oxidized to CO_2 and H_2O (Lubis, et al. 2016). The reaction mechanism can be written as follows (Subramani, et al. 2007):

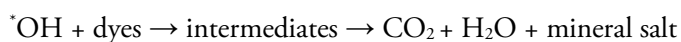
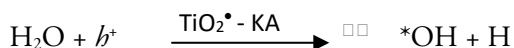
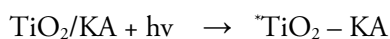


Table 3 also shows that the adsorption of batik waste with activated carbon before and after the modification of TiO_2 did not show a significant difference. These results lead to the need for batik COD tests before and after adsorption to determine the ability of the most optimum activated carbon adsorption. COD test aims to determine the number of pollutants that still exist in batik waste. The result of the COD test on batik waste before and after adsorption was shown in Table 4.

Table 4. Batik Waste pH and COD after adsorbed with activated carbon and Activated Carbon Modified with TiO_2

Materials	pH	COD (mg/L)
Batik Waste		1500
KA	8	705,6
KATiO ₂ -5	7	504,0
KATiO ₂ -10	7	403,2

These results are supported by COD (chemical oxygen demand) analysis of batik waste after treatment with activated carbon. Table 4 shows that batik waste treated by KA was 705,6 mg / L (pH = 8). After being processed with KATiO₂-5 COD levels were obtained 28,57% and KATiO₂-10 increased COD levels by 42,86%. This shows that the presence of TiO_2 is effective in removing dyes from water and TiO_2 is efficient for degrading organic pollutants in liquid waste (Pujiono, et al. 2019). The results of the process of adsorption on batik waste showed that activated carbon modified with TiO_2 can be used as a material for processing batik waste.

4. CONCLUSION

Based on the results of the study showed that the influence of TiO_2 concentration on the adsorption power of activated carbon in batik waste, where KATiO₂-10 had the lowest adsorption i.e 0,052 compared to KA (0,059) and KATiO₂-5 (0,057). The activated carbon modified TiO_2 can be used as a material for processing batik waste with the most significant concentration of TiO_2 represent 10%.

ACKNOWLEDGMENT

Researchers would like thanking the Bhakti Wiyata Foundation and the Institut Ilmu Kesehatan Bhakti Wiyata kediri for the assistance that has been given as well as to students who have assisted in the research process.

REFERENCE

- Aljeboree, A. M., Alshirifi, A. N., & Alkaim, A. F. (2017). Kinetics and equilibrium study for the adsorption of textile dyes on coconut shell activated carbon. *Arabian Journal of Chemistry*, 10, S3381–S3393.
- Anisuzzaman, S. M., Joseph, C. G., Taufiq-Yap, Y. H., Krishnaiah, D., & Tay, V. V. (2015). Modification of commercial activated carbon for the removal of 2, 4-dichlorophenol from simulated wastewater. *Journal of King Saud University-Science*, 27(4), 318–330.
- Cazetta, A. L., Vargas, A. M. M., Nogami, E. M., Kunita, M. H., Guilherme, M. R., Martins, A. C., ... Almeida, V. C. (2011). NaOH-activated carbon of high surface area produced from coconut shell: Kinetics and equilibrium studies from the methylene blue adsorption. *Chemical Engineering Journal*, 174(1), 117–125.
- Dey, N. K., Kim, M. J., Kim, K.-D., Seo, H. O., Kim, D., Kim, Y. D., ... Lee, K. H. (2011). Adsorption and photocatalytic degradation of methylene blue over TiO_2 films on carbon fiber prepared by atomic layer deposition. *Journal of Molecular Catalysis A: Chemical*, 337(1–2), 33–38.
- He, Z., Cai, Q., Fang, H., Situ, G., Qiu, J., Song, S., &

- Chen, J. (2013). Photocatalytic activity of TiO₂ containing anatase nanoparticles and rutile nanoflower structure consisting of nanorods. *Journal of Environmental Sciences*, 25(12), 2460–2468.
- Hidayu, A. R., & Muda, N. (2016). Preparation and characterization of impregnated activated carbon from palm kernel shell and coconut shell for CO₂ capture. *Procedia Engineering*, 148, 106–113.
- Ikawati, I., & Melati, M. (2010). Pembuatan Karbon Aktif dari Limbah Kulit Singkong UKM Tapioka Kabupaten Pati.
- Irwan, I., Lubis, S., Ramli, M., & Sheilatina, S. (2016). Photocatalytic degradation of indigo carmine by TiO₂/activated carbon derived from waste coffee grounds. *Jurnal Natural*, 16(1).
- Le, H. A., Chin, S., & Jurng, J. (2012). Photocatalytic degradation of methylene blue by a combination of TiO₂-anatase and coconut shell activated carbon. *Powder Technology*, 225, 167–175.
- MiarAlipour, S., Friedmann, D., Scott, J., & Amal, R. (2018). TiO₂/porous adsorbents: Recent advances and novel applications. *Journal of Hazardous Materials*, 341, 404–423.
- Mukimin, A., Vistanty, H., Zen, N., Purwanto, A., & Wicaksono, K. A. (2018). Performance of bioequalization-electrocatalytic integrated method for pollutants removal of hand-drawn batik wastewater. *Journal of Water Process Engineering*, 21, 77–83.
- Mulyati, T. A. (2018). PREPARASI DAN KARAKTERISASI KARBON AKTIF DARI LIMBAH AMPAS TEBU MENGGUNAKAN AKTIVATOR KOH. *Indonesian Chemistry and Application Journal*, 1(2), 61–67.
- Nasution, N., & Fitri, A. (n.d.). SINTESIS NANOPARTIKEL TiO₂ FASA RUTILE DENGAN METODE KOPRESIPITASI.
- Ndi Nsami, J., & Ketcha Mbadcam, J. (2013). The adsorption efficiency of chemically prepared activated carbon from cola nut shells by on methylene blue. *Journal of Chemistry*, 2013.
- Omo-Okoro, P. N., Daso, A. P., & Okonkwo, J. O. (2018). A review of the application of agricultural wastes as precursor materials for the adsorption of per-and polyfluoroalkyl substances: a focus on current approaches and methodologies. *Environmental Technology & Innovation*, 9, 100–114.
- Orha, C., Pode, R., Manea, F., Lazau, C., & Bandas, C. (2017). Titanium dioxide-modified activated carbon for advanced drinking water treatment. *Process Safety and Environmental Protection*, 108, 26–33.
- Pujiono, F. E., Mulyati, T. A., & Fizakia, M. N. (2019). Modification of activated carbon with titanium dioxide as a water treatment material. *Journal of Public Health in Africa*, 10.
- Pujiono, F., & Mulyati, T. A. (2017). Potensi Karbon Aktif dari Limbah Pertanian Sebagai Material Pengolahan Air Limbah. *Jurnal Wiyata: Penelitian Sains Dan Kesehatan*, 4(1), 37–44.
- Rahmawati, N. I., Suhartana, S., & Gunawan, G. (2009). Pengolahan Limbah Cair Industri Batik dengan Metoda Elektrokoagulasi Menggunakan Seng Bekas Sebagai Elektroda. *Jurnal Kimia Sains Dan Aplikasi*, 12(2), 40–46.
- Schneider, J., Matsuoka, M., Takeuchi, M., Zhang, J., Horiuchi, Y., Anpo, M., & Bahnemann, D. W. (2014). Understanding TiO₂ photocatalysis: mechanisms and materials. *Chemical Reviews*, 114(19), 9919–9986.
- Simonetti, E. A. N., de Simone Cividanes, L., da Silva Fonseca, B. C., de Freitas, A. P. B. R., dos Reis Coutinho, A., & Thim, G. P. (2018). TiO₂Carbon composite using coconut waste as carbon source: Sonocatalysis and adsorption evaluation. *Surfaces and Interfaces*, 12, 124–134.
- Skocaj, M., Filipic, M., Petkovic, J., & Novak, S. (2011). Titanium dioxide in our everyday life; is it safe? *Radiology and Oncology*, 45(4), 227–247.
- Subramani, A. K., Byrappa, K., Ananda, S., Rai, K. M. L., Ranganathaiah, C., & Yoshimura, M. (2007).

- Photocatalytic degradation of indigo carmine dye using TiO₂ impregnated activated carbon. *Bulletin of Materials Science*, 30(1), 37–41.
- Theivasanthi, T., & Alagar, M. (2013). Titanium dioxide (TiO₂) nanoparticles XRD analyses: an insight. *ArXiv Preprint ArXiv:1307.1091*.
- Wibowo, S., Syafi, W., & Pari, G. P. (2011). Karakterisasi permukaan arang aktif tempurung biji nyamplung. *Makara Journal of Technology*, 15(1).
- Yukselen, Y., & Kaya, A. (2008). Suitability of the methylene blue test for surface area, cation exchange capacity and swell potential determination of clayey soils. *Engineering Geology*, 102(1–2), 38–45.
- Yukselen, Y., Kaya, A., He, Z., Cai, Q., Fang, H., Situ, G., ... Gunawan, G. (2018). Performance of bioequalization-electrocatalytic integrated method for pollutants removal of hand-drawn batik wastewater. *Powder Technology*, 12(1), 167–175.

