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Utilization of Bottom Ash Coal and Agarwood in Waste Water Treatment in Palembang Jumputan Fabric

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Abstract

Liquid waste is easily recognized because of the presence of dyes. Waste containing dyes can cause visual pollution and increase the risk of environmental and health damage. The aim of this study was to determine the operating conditions of the best jumputan liquid waste treatment using *bottom ash* batubara and agarwood with variations in feed flow rate (1, 2, and 3 l/minutes), filtration time (30, 60, 90, and 120 minutes), and treatment. The results of jumputan liquid waste treatment are compared with the parameters of Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Suspended Solids (TSS), and pH of clean water quality standards for jumputan industry businesses and/or activities regulated in the Governor's of Sumatera Selatan Regulation Number 16 of 2005 concerning Wastewater Quality Standards. The initials analysis of jumputan liquid waste before processing showed that jumputan liquid waste did not meet these quality standards, except pH and turbidity levels. In this study, jumputan liquid waste was pre-treated using coal bottom ash and activated carbon, then filtered. Biodegradation of jumputan liquid waste by konvensional method. The best of BOD, COD, TSS, pH, and the percentage of color rejection in the study were obtained in the treatment of jumputan liquid waste using *bottom ash* batubara and activated carbon at a 120 minutes filtration time and a 1 l/minutes feed flow rate namely BOD 5.98 mg/l, COD 15 mg/l, TSS 22.3 mg/l, pH 7.32, color 5 Pt-Co, and 0 NTU turbidity. The filtration with bottom ash coal and agarwood can removed the coloring from dyes.

Keywords: jumputan liquid waste, bottom ash, agarwood

Abstrak

Limbah yang mengandung zat warna dapat menyebabkan polusi secara visual dan dapat meningkatkan resiko kerusakan lingkungan dan kesehatan. Tujuan penelitian ini adalah untuk mengetahui kondisi operasi pengolahan limbah cair jumputan terbaik dengan menggunakan *bottom ash* batubara dan kayu gaharu dengan variasi laju alir umpan (1, 2, dan 3 liter/menit), waktu filtrasi (30, 60, 90, dan 120 menit), dan perlakuan. Hasil pengolahan limbah cair jumputan dibandingkan dengan parameter warna, kekeruhan, *Biochemical Oxygen Demand* (BOD), *Chemical Oxygen Demand* (COD), *Total Suspended Solids* (TSS), dan pH baku mutu air limbah bagi usaha dan/atau kegiatan industri tekstil yang diatur dalam Peraturan Gubernur Sumatera Selatan Nomor 16 Tahun 20054 tentang Baku Mutu Air Bersih. Analisa awal limbah cair jumputan sebelum diolah menunjukkan bahwa limbah cair jumputan belum memenuhi baku mutu air bersih tersebut, kecuali pH dan kadar kekeruhan. Penelitian ini, limbah cair jumputan diolah dengan menggunakan *pre-treatment bottom ash* batubara dan karbon aktif, kemudian difiltrasi. Perlakuan limbah cair jumputan dilakukan dengan menggunakan metode konvensional dan persentase penurunan warna terbaik dalam penelitian diperoleh pada pengolahan limbah cair jumputan dengan menggunakan karbon aktif kayu gaharu pada waktu filtrasi 120 menit dan laju alir umpan 1 liter/menit yaitu BOD 5,98 mg/l, COD 15 mg/l, TSS 22,3 mg/l, pH 7,32, warna 5 Pt-Co, dan kekeruhan 0 NTU. Filtrasi dengan *bottom ash* batubara dan kayu gaharu dapat menghilangkan pewarnaan dari zat pewarna.

Kata Kunci : limbah cair jumputan, *bottom ash*, kayu gaharu

INTRODUCTION

Palembang jumputan fabric industry is one of a combination of small and medium businesses that are often found in several regions. Particularly in Palembang, the industry of Palembang jump starting fabric was developed. It is just that the number of Palembang jumputan fabric industry that develops provides negative for environmental pollution resulting from waste. One negative impact is liquid waste that is not treated before discharges to environmental are disposed. Impact in disposal of liquid waste containing synthetic dyes [1]. Synthetic dyes consist of various pollutants, such as metals, phenol, coloring waste), can directly cause ecosystem damage and decreasing in air quality [2]. It also means the jumputan cloth wastewater is difficult to decompose using the provided technology [3]. One technology that can be used as an alternative is filtration using coal ash [4] and activated charcoal [5] from agar wood as an adsorbent.

Conventional wastewater treatment methods are relatively safer than chemical wastewater treatment methods; one of them is the conventional method using natural material filter media. The process is simple because only use absorption of the filter media. This process is also quickly, and is able to reduce concentrated compounds in wastewater [6]. Coal bottom ash and activated charcoal from agar wood are able to bind organic pollutants contained in jumputan cloth wastewater.

Coal bottom ash is solid waste produced from burning coal in power plants. Coal bottom ash could be used as an adsorbent. It is used as adsorbing organic contaminants in liquid waste [7]. In addition, bottom ash is easily obtained in abundant quantities [8], so that this research can be an alternative in the treatment of palm-leaf jumputan fabric waste combined with silica sand, activated carbon.

Agar wood contains resin, can reduce the high level of hardness in water, eliminating the content of lime ($CaCO_3$), adhesives, and so on [9]. In this research, agar wood innovated the adsorption process into activated charcoal [10]. This is also compared to other wood which is the product of forest commodities in Indonesia.

Research using various variations of filter media to treat leachate from cloth wastewater has been carried out such as processing using filter media variation with conventional methods, namely silica sand segments, coal bottom ash, commercial activated carbon, and activated charcoal from agarwood. All variations occur with the same process system which adsorb wastewater. The selection of the best and appropriate method for treating leachate wastewater is the use of a variety of filter media with a variety of silica sand materials, coal bottom ash, commercial activated carbon, and activated charcoal from agarwood to determine the effect of flow rate and filtration time on the reduction in leachate liquid waste using coal bottom ash and activated charcoal from agar wood.

MATERIALS AND METHODS

Materials

Samples were taken directly from the results of wastewater from jumputan fabric in Palembang Kertapati and other materials such as coal bottom ash, agar wood were taken directly from the burning results of the Steam Power Plant (PLTU) Simpang Belimbing, Bangka Tengah Regency and Bangka Belitung Islands.

Methods

The treatment method of jumputan liquid waste is carried out by an adsorption system. The potential of alternative methods for removal of synthetic dyes have been explored, and the adsorption process has been found to be effective compared to other methods [11]. Adsorption process is the humidity gradient between the flowing air and the desiccant material. Due to that, the air releases heat and condenses to become water vapor, which falls on the surface of the desiccant material [12].

Treated cloth liquid waste treatment is carried out using silica sand filter media, coal bottom ash, commercial activated carbon, and activated charcoal from agarwood in a series of conventional filter devices in the form of an adsorption filter column. The flow rate variations of 1-3 liters / minute and the filtration time of 30-120 minutes were used in this study. First, the variation of silica sand with a flow rate of 1 liter/minute was filtered with a filtration time of the 30th minute. Initial waste levels and initial absorbance of BOD, COD, TSS, pH, color, and turbidity were measured. Place the jumputan fabric wastewater, silica sand filter media variations, coal bottom ash, commercial active carbon, and activated charcoal from agarwood in its place in the filter column. Flow rates (1, 2, 3) liters/minute are applied in the filtration process. Filtration time (30, 60, 90, 120) minutes. Then BOD, COD, Then BOD, COD, TSS, pH, color, and turbidity analysis is performed. Repeat the procedure using a different flow rate and filtration time.

There are several treatments for this jumputan liquid waste, namely the carbonization process, the activation process, and the adsorption process. The process of carbonization is the process of heat treatment in very limited oxygen conditions (pyrolysis) of the base material (organic matter). The heating process causes the decomposition of the material and the release of volatile components and carbon begins to form the pore structure. Thus, the base material has a surface area but its absorption is still relatively small because there are still tar residues and other compounds that cover the pores. The carbonized base material is called carbon or carbon [13]. The carbonization process is carried out at temperatures of less than 800 ^{o}C. In his research carried out carbonization at temperatures of 800-950^{o}C[14].

Activation Process

The activation process causes the release of hydrocarbons, tar and organic compounds that are still attached to carbonization of carbon. In the order activation process, the pores are still closed as well as an increase in the size and number of small pores that have been formed. Thus, the activated carbon has a larger internal surface area. Activated carbon is also called activated carbon. The activation process is the most important process because it determines the quality of activated carbon produced both on the surface and its adsorption power. The activation process can be carried out by two ways of chemical activation and physical activation [11].

Analysis Data

The samples for the initial analysis of BOD, COD, TSS, pH, color and turbidity. Decreasing levels of BOD, COD, TSS, pH, color and turbidity are determined using special methods such as COD levels determined by the titrimetry method at the Institute of Environmental Health Engineering-Disease Control (BTKL-PP).

RESULT AND DISCUSSION

Results of Jumputan Liquid Waste Treatment Analysis Using the Manual Conventional Method

The effect of filter media variations on decreasing levels of BOD, COD, TSS, pH, color, turbidity is to determine the ability of each filter material in treating leachate wastewater. The process is carried out by the adsorption method. The adsorption is an exothermic process [12]. The adsorption method is conventional manual method is to flow the leachate liquid waste through the silica sand filter, coal bottom ash, commercial activated carbon, and agar wood activated charcoal. Comparison of the results of jumputan liquid waste treatment with conventional manual methods based on parameters BOD, COD, TSS, pH, color, and turbidity can be seen in Figure 1 below :

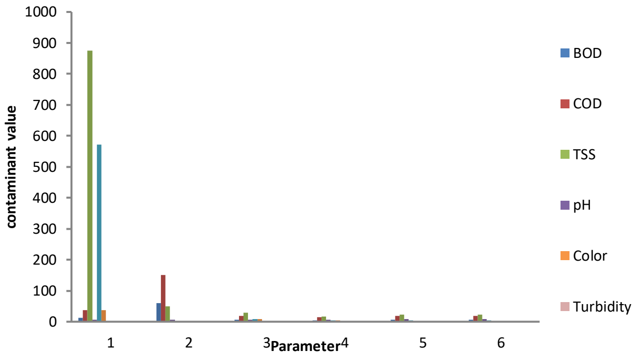

Figure 1. Parameter Comparison of the Processed Waste Liquid Treatment Results with Conventional Manual Method

Figure 1 shows that activated charcoal from agarwood has the effectiveness of reducing levels of BOD, COD, TSS, pH, color, turbidity in the treatment of leachate wastewater, namely 9.20 mg /l, 28.16 mg/l, 508.05 mg/l, 7.21, 376.26 Pt-Co, 15.35 NTU compared to commercial activated carbon commercial the difference in percentage decreased by 21.65%. Activated carbon has the ability to adsorb dyes which are the main pollutants in jumputan liquid waste. The main advantage of activated carbon is its extensive specific surface area, price and availability [17]. Coal bottom ash has the advantage of silica sand in reducing levels of TSS, color with a value of 673.75 mg/l, 440.44 Pt-Co; 860.12 mg/l, 562.28 Pt-Co because coal bottom ash can filter out large particles contained in the leachate liquid waste without being taken out. Very fine sized silica sand comes out along with the results of the jumputan filter, so that it has a high TSS value, which is> 500 mg/l.

Results of Analysis of Jumputan Liquid Waste Treatment using Conventional Methods (Variation 1 Column: Silica Sand)

Fiqure 2 to Fiqure 7 presents the effect of 1 column variation : silica sand on decreasing BOD, COD, TSS, pH, color, and turbidity levels.

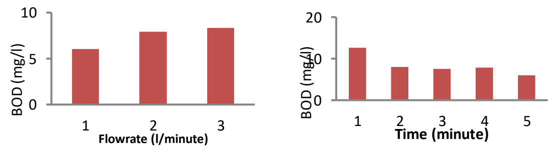

Figure 2. Testing of BOD level (Variation I)

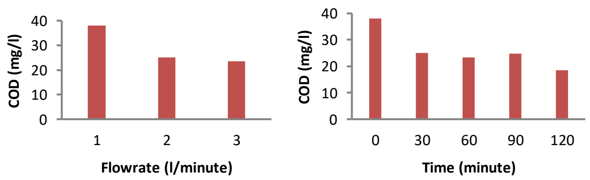

Figure 3. Testing of COD level Variation I)

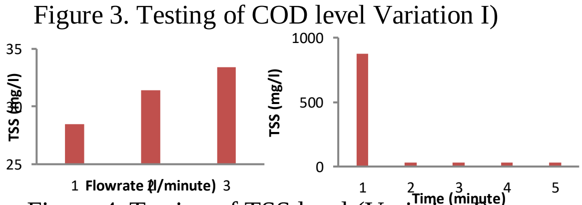

Figure 4. Testing of TSS level (Variation I)

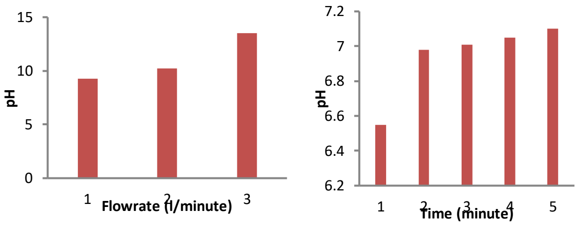

Figure 5. Testing the pH level (Variation I)

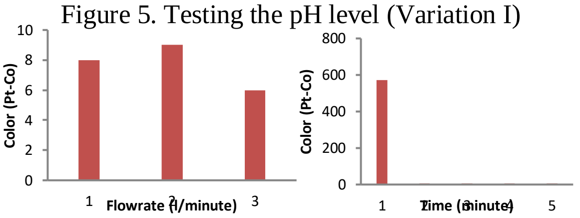

Figure 6. Testing of color level (variation I)

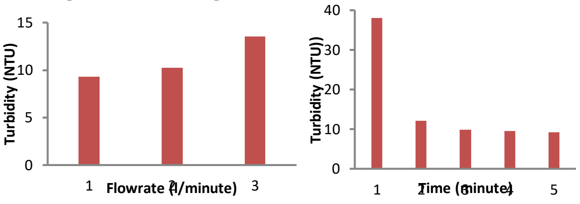

Figure 7. Testing turbidity levels (variation I)

Treated wastewater treatment using conventional methods with a variation of 1 column (silica sand), obtained as shown in Figure 1 - 5 decreased levels of BOD, COD, TSS, pH, color, and turbidity. The maximum level is reached at a reaction time of 120 minutes that occurs at a flow rate of 1 liter / minute with a turbidity reduction reaching 100%, but the percentage reduction in BOD, COD, TSS, pH, color, and turbidity levels in various treatments occurs from the reaction time of 30-120 minutes later experienced a significant decrease in wastewater content at 120 minutes. So the longer the reaction time, the greater the decrease in wastewater content produced, the lower the flow rate, the greater the reduction in wastewater content produced. This happens because the lower the flow rate of the process, the more hydroxyl (OH) radicals formed, because with the lower flow rate increasing time, slow contact provides more opportunity for a decrease in organic compounds or pollutants in wastewater [2].

Decrease in levels of BOD, COD, TSS, PH, color, turbidity in each treatment due to the silica content found in silica sand. The higher the content of silica sand, the greater the adsorption power is absorbed. Besides the water content is also influenced by the high nature of silica sand filtrate which has a very open pore structure and has a large internal surface area so that it is able to adsorb large numbers of particles other than water [2].

Results of Jumputan Liquid Waste Treatment Analysis Using Conventional Methods (Variation of 2 Columns : Silica Sand and Bottom Ash Coal)

Fiqure 8 to Fiqure 10 presents the results of the conventional method wastewater treatment with a variation of 2 columns : silica sand and coal bottom ash) and at the best operating conditions, i.e a flow rate of 1 liter/minute.

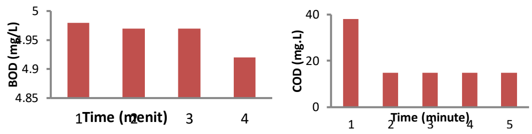

Figure 8. Testing Levels of BOD (mg/l) and COD (mg/l)-Variation II

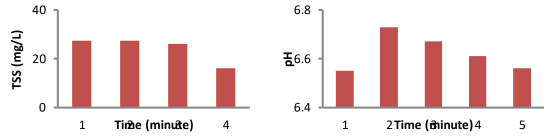

Figure 9. Testing Levels of TSS (mg/l) and pH (Variation II)

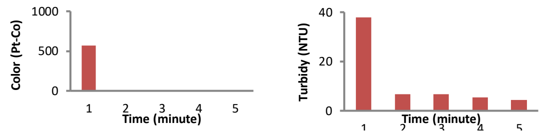

Figure 10. Testing Levels of Color (Pt-Co) and Turbidity (NTU)-Variation II

Figure 8-10 can be seen that at the reaction time of 30 minutes a decrease in levels has not occurred, this is because the hydroxyl radicals (OH •) that are formed are still small, so it has not been able to oxidize all organic compounds present in the wastewater cloth jumputan. However, the reduction in wastewater content begins at the reaction time of 60 minutes and continues to experience a significant increase until the reaction time of 120 minutes. That the percentage decrease in levels increases with increasing reaction time. The longer the greater the percentage of reduction in wastewater content achieved, where the hydroxyl radicals (OH) are formed more and more. With increasing time and low flow rates will provide more opportunities for the reduction of pollutants in this case the levels that are in wastewater [18]. The best condition of decreasing levels in this treatment is achieved during the reaction time of 120 minutes.

This research is about the utilization of coal waste which is more appropriately utilized, namely bottom ash as solid waste generated from coal combustion which can be used as a filter media for the treatment of liquid wastewater cloth. In this study a comparison of the ability of the filter media is variation I (silica sand), variation II (silica sand and bottom ash coal). Rosyida (2011) filtration experiment results show that filtration using coal bottom ash media is better than filtration with active zeolite. Bottom ash filtration can reduce the pollution load in a greater amount, especially in the value of BOD, COD, TSS, and heavy metal content of Cr. Therefore, variation II (combining silica sand filter media and coal bottom ash) is more effective in the filtration process of textile liquid waste compared to variation I (only with one filter media: silica sand).

Results of Analysis of Jump-Up Liquid Waste Treatment with Conventional Methods (Variation of 3 Columns : Silica Sand, Bottom Ash Coal, and Commercial Activated Carbon)

Fiqure 8 to Fiqure 10 presents factors that influence the adsorption process include filter media. In this study filter media was varied into 3 columns of filter media (silica sand, coal bottom ash, and commercial activated carbon). The effect of jumput wastewater treatment using variation III (silica sand, coal bottom ash, and commercial activated carbon with a comparison of feed flow rate and filtration time.

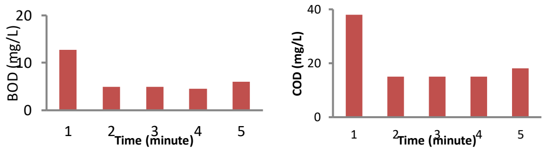

Figure 11. Testing Levels of BOD (mg/L) and COD (mg/l) – Variation III

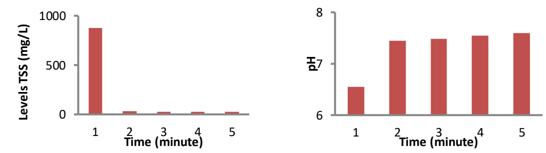

Figure 12. Testing Levels of TSS (mg/l) and pH (Variation III)

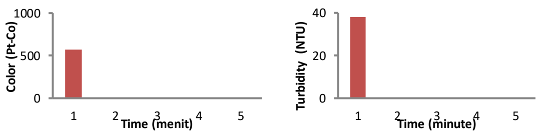

Figure 13. Testing Levels of Color (Pt-Co) and Turbidity (NTU) - Variation III

From Figure 11 to 13 we can figure out the highest percentage reduction in COD level reached 60.52 % by subtract final value from initial value, and then divided by initial by initial value. The result will be converted into percent. shows that the high`est percentage reduction in COD levels reached 60.52% while for each treatment reached 52%. The percentage reduction in COD shows that the smaller the flow rate, the greater the percentage decrease in COD produced. This happens because the smaller the passage of the passing wastewater content. The small amount of coloring agent can be apart by oxidation, so the percentage of COD reduction achieved is greater [19]. Then in the use of a smaller flow rate of 1 liter/minute, the percentage reduction in COD produced is quite high at an average above 60% compared to other filtration flow variations, where the percentage reduction in COD achieved above 50%. This shows that the decrease in COD is getting smaller along with the reduced amount of yarn dyes used. The percentage reduction in COD is greater along with the addition of filtration contact time [20]. In the silica sand filtering method activated carbon with three replications results in an average reduction in BOD levels of 39.97 while the decrease in COD levels was 41.19%.

Results of Analysis of Jumputan Liquid Waste Treatment using Conventional Methods (Variation of 3 Columns: Silica Sand, Bottom Ash Coal, and Activated Carbon of Agar Wood)

Waste water is put into the adsorption column in variation III (silica sand, coal bottom ash, and activated charcoal from agarwood). Basically the higher the filtration time means the higher the absorbed wastewater content, and the lower the processing flow rate means the higher the absorbed wastewater content. Resulting in decreased levels of BOD, COD, TSS, pH, color, and turbidity. As can be seen in Figure 14-16 that the maximum percentage of wastewater content achieved is turbidity level of 100%. In this study increased with increasing filtration time at 120 minutes.

The reduction in BOD was achieved in commercial activated carbon variations, the resulting difference of 7.67% is 4.57 mg/l (Commercial) : 4.95 mg/l (Agarwood), where the difference ratio is not significant. While the best condition of TSS was achieved in the variation of activated charcoal from agarwood, the resulting difference was 9.70% which was 23.7 mg/l (Commercial): 21.4 mg/l (Agarwood), the comparison difference was not significant. This shows that activated agarwood wood can reduce the water content of jumputan cloth in proportion to commercial activated carbon that is marketable. These results have met the clean water quality standard, where BOD, COD levels are almost close to the clean water quality standard.

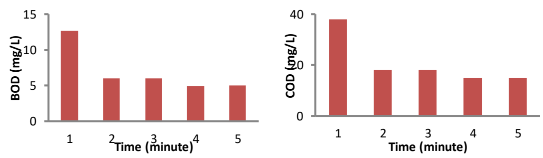

Figure 14. Testing Levels of BOD (mg/l) and COD (mg/l) – Variation IV

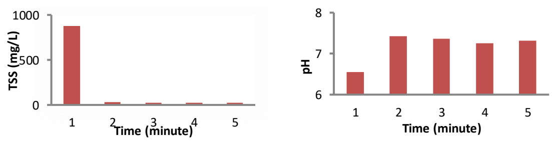

Figure 15.Testing Levels of TSS (mg/l) and pH–Variation IV

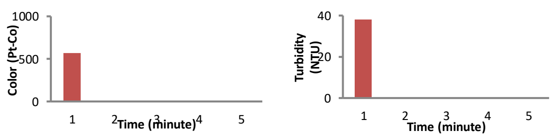

Figure 16. Testing Levels of TSS (mg/l) and pH–Variation IV

CONCLUSION

From the results of the treatment of jumputan liquid waste using conventional methods, it can be concluded that the silica sand filter media, coal bottom ash, commercial activated carbon, and agarwood active charcoal can reduce the levels of BOD, COD, TSS, pH, color, and turbidity. The decrease in BOD, COD, and TSS levels, pH, color, and turbidity is affected by the flowrate and filtration time of the waste treatment process. The lower the process flowrate, the levels of BOD, COD, TSS, pH, color, and turbidity will be lower. The higher feed flowrate causes the filtration power to be lower, so that the decrease in the value of BOD, COD, TSS, pH, color, and turbidity of the leachate wastewater tends to increase. The longer the filtration time of the fabric waste water treatment with jumps, BOD, COD, TSS, color pH, and turbidity levels decreased because the contact time of the liquid waste jumputan with coal bottom ash and activated charcoal from agar wood is longer. The best condition is achieved when the filtration is 120 minutes and the flowrate is 1 liter/minute that has met the quality standards of the Republic of Indonesia Minister of Environment Regulation Number 5 of 2014 [21] and South Sumatra Governor Regulation Number 16 of 2005 [22]. The treatment of jumputan liquid waste was carried out using conventional methods and the best percentage of color reduction in the study was obtained in the treatment of jumputan liquid waste using agar wood activated carbon at a filtration time of 120 minutes and a feed flow rate of 1 liter/minute namely BOD 4.98 mg/l, COD 15 mg/l, TSS 22.3 mg/l, pH 7.32, 5 Pt-Co color, and turbidity 0 NTU.

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REFERENCES

[1] T.E.Agustina, and H.M.Ang, "Decolorization and Mineralization of C.I. Reactive Blue 4 and C.I. Reactive Red 2 by Fenton Oxidation Process", *Int. J. Chem. Environ. Eng.*, 3, 142-147. 2012.

[2] T.E.Agustina, D.Teguh, Y.Wijaya, F.Mermaliandi, A.Bustomi, J.Manalaoon, G.Theodora, and T.Rebecca, "Study Of Synthetic Dye Removal Using Fenton/TiO_2, Fenton/UV, and Fenton/TiO_2/UV Methods and The Application To Jumputan Fabric Wastewater", Universitas Teknis Ceko di Praha Acta Polytechnica 59(6):527–535. 2019.

[3] Rusdianasari., I.Hajar, and I.Ariyanti, "Electrocoagulation Method to Reduce Pollutants in The Wastewater of Jumputan Fabric Industry", Indonesian Journal of Fundamental and Applied Chemistry. 5(3) : 71-77. 2020.

[4] R.Gandhimathi, S.T.Ramesh, V.Sindhu, and P.V.Nidheesh, "Bottom Ash Adsorption of Basic Dyes from Their Binary Aqueous Solutions", J.Songklanakarin, Sci. Technol. 35 (3) : 339-347. 2013.

[5] J. Ethiraj, M. R. Karthikeyan, D. Ramesh, and A. K. Berekute, "Dye Effluent Treatment using Activated Charcoal of Coconut Shell", International Journal for Scientific Research & Development. Arba Minch University, Ethiopia, East Africa. ISSN : 2321-0613.

[6] G. Crini, E. Lichtfouse, L.Wilson, and N. Morin-Crini, "Conventional and Non-conventional Adsorbents for Wastewater Treatment". Environmental Chemistry Letters, Springer Verlag, 17(1) : 195-213. 2019.

[7] A. R. Dincer, A. R, Y. Gunes, and N. Karakaya, "Coal-based bottom ash (CBBA) waste material as adsorbent for removal of textile dyestuffs from aqueous solution", Department of Environmental Engineering, Trakya University, C¸ orlu, Tekirdag, Turkey. Journal of Hazardous Materials 141 : 529–535. 2006.

[8] M. L. D. Jayaranjan, E.D. van Hullebusch, and A.P. Annachhatre, "Reuse Options for Coal Fired Power Plant Bottom Ash and Fly Ash". Rev. Environ. Sci. Biotechnol. 2014.

[9] J. Balfas, "Kandungan Resin Pada Kayu Gaharu. Pusat Litbang Hasil Hutan", Jurnal Penelitian Hasil Hutan Vol. 27 No.3, September 2009 : 235-244, 2008.

[10] X. Zhang, B. Gao, A. E. Creamer, C. Cao, and Y. Li, "Adsorption of VOCs onto Engineered Carbon Material", A Review. *Journal of Hazardous Materials* 338:102–123,2017.doi:10.1016/j.hazmat.2017.05.013.

[11] Firdaus, M. Lutfi., N. Krisnanto, W. Alwi, R.Muhammad, Serunting, M. Alan, "Adsorption of Textile Dye by Activated Carbon Made from Rice Straw and Palm Oil Midrib", Aceh International Journal of Science and Technology. doi:10.13170/aijst.6.1.550.Journalhomepage:http://jurnal.unsyiah.ac.id/aijst.

[12] A. S. Norarazam, H.M.Kamar, N. Kamsah, M. I. Alhamid, "Simulation Of Adsorption Process In A Rotary Solid Desicant Wheel", International Journal of Technology 10(6): 1120-1130.Permalink/DOI:https://dx.doi.org/10.14716/ijtech.v10i6.3590, 2019.

[13] M.H. Dahlan, A. Saleh, F. Asip, A. Makmun, Defi., "Application of Mixed Based Membrane Technology from Component Materials Bintaro, Zeolite and Bentonite to Reduction of Songket Waste Liquid Cloth", Proceedings of the 3rd International Conference on Construction and BuildingEngineering(ICONBUILD)2017.https://do.org/10.1063/1.5011, 2017.

[14] H. Teng, J-A. Ho, Y-F. Hsu, and C-T. Hsieh, Ind. Eng. Chem. Res., 35, 4043-4049, 1996.

[15] J. E. Sontheimer, "*Activated Carbon for Water Treatment*", Elsevier, Netherlands, p.51-105, 1985.

[16] A. C. Lua, and J. Guo, "Preparation and characterization of activated carbons from oil-palms stones for gas-phase adsorption, *Colloids and*

Surfaces", *A : Physicochemical and Engineering Aspects* 179:151–162, doi:10.1016/S0927-7757(00)00651-8, 2001.

[17] E. Wolak, E. Vogt, and J. Szczurowski, "Chemical and Hydrophobic Modification of Activated WD-extra Carbon. *Energy Fuels*", 14:1–8, doi:10.1051/e3sconf/20171402033, 2017.

[18] A. Rosyida, "Bottom Ash Limbah Batubara sebagai Media Filter yang Efektif pada Pengolahan Limbah Cair Tekstil", Jurnal Rekayasa Proses. Vol. 5(2), 2011.

[19] Aliaman, "Pengaruh Absorbsi Karbon Aktif dan Pasir Silika Terhadap Penurunan Kadar Besi (Fe), Fosfat (PO_4) dan Deterjen Dalam Limbah Laundry", Skripsi Jurusan Pendidikan Fisika. Universitas Negeri Yogyakarta, 2017.

[20] Ronny, dan M. S, Dedi, "Aplikasi Teknologi Saringan Pasir Silika dan Karbon Aktif dalam Menurunkan Kadar BOD dan COD Limbah Cair Rumah Sakit Mitra Husada Makassar", Jurnal Penelitian. Politeknik Negeri Makassar, 2018

[21] Menteri Lingkungan Hidup Republik Indonesia, Peraturan Menteri Lingkungan Hidup Republik Indonesia Nomor 5 Tahun 2014 tentang Baku Mutu Air Limbah, Kementerian Lingkungan Hidup Republik Indonesia, Jakarta, 2014.

[22] Gubernur Sumatera Selatan, Peraturan Gubernur Sumatera Selatan Nomor 16 Tahun 2005 tentang Baku Mutu Air Bersih, Palembang, 2005.