The Utilization of Sugarcane Bagasse to Remove Cr (VI) Heavy Metal Waste with Adsorption

Narimo[1], Sajidan[2], Maskyuri[3], Maria Theresia Sri Budiastuti[4]

[1]Doctorate Candidate of Environmental Science, Universitas Sebelas Maret, Surakarta, Indonesia, [2]Professor and Senior Lecturer of Environmental Science, Universitas Sebelas Maret, Surakarta, Indonesia, [3]Senior Lecturer of Environmental Science, Universitas Sebelas Maret, Surakarta, Indonesia, [4]Professor and Senior Lecturer of Environmental Science, Universitas Sebelas Maret, Surakarta, Indonesia

Abstract

Sugarcane bagasse obtained from sugar factories is the residue that is usually left behind and considered useless. In fact, sugarcane bagasse can be made nanopore-activated carbon in the form of powder and tablet, which is effective as adsorbent of Cr (VI) in heavy metal waste pollution. The production in this study started from drying using sunlight, crushing sugarcane bagasse into powder, carbonizing the powder at 300^0 C, activating it using HCL5N, sieving with 200 mesh and sonicating in 15 minutes with 40% amplitude. After accomplishing those steps, nanopore powder was obtained and then pressed into a tablet. Absorption capacity testing of Cr (VI) heavy metal was performed with an artificial sample using K2Cr2O7 solution. Sugarcane bagasse nanopore powder was tested for its contact time by adding 0.1 gram of nanopore powder into the sample solution, leaving the sample for a while, and analyzing the sample using spectrophotometry. The results show that the optimum contact time of nanopore powder was six hours to reduce 91.80% of Cr (VI) level and the optimum contact time of the tablet was five hours to remove 56.35% of Cr (VI). Testing on a fixed variable of 105 rpm stirring speed and various contact times produced an optimum result with 90 minutes stirring duration and adsorption capacity of 91.80% for removing Cr (VI). Examination on fixed variable of stirring time and independent variable of stirring speed resulted in an optimum adsorption capacity of 90.07% in Cr (VI) removal, with 105 rpm stirring speed. This study concludes that powder had a greater adsorption capacity than a tablet, while the tablet was more practical for usage.

Keywords: *sugarcane bagasse, nanopore powder and tablet, adsorption, chromium heavy metal.*

Introduction

The environmental order system needs to be preserved and maintained well so as not to be damaged by various pollutions caused by hazardous and toxic waste that is included in the category of Toxic and Hazardous Material, which will disturb the environmental balance, such as heavy metal pollution. Some heavy metals obtained from industrial byproducts that have polluted the environment and are poisonous are lead (Pb), chromium (Cr), cadmium (Cd), mercury (Hg), silver (Ag), nickel (Ni), zinc (Zn), cobalt (Co), lead (Sn), copper (Cu), iron (Fe), molybdate (Mo) and several other metal substances. Heavy metals are metallic elements that have a specific gravity higher than 5 or 6 g/cm^3 . Heavy metal pollution has become a serious problem that will threaten the global environment [(1)].

Chromium (Cr VI) is a heavy metal with an atomic weight of 7.19 g/cm^3, which is potential to contaminate the environment and harmful. In the natural environment, Cr (III) metal is the least active, less soluble and stable, but Cr (VI) is very active, easily dissolved and biologically available (Choppala et al., 2013). The heavy metal pollution of chromium or Cr (VI) has a high toxicity level and it can poison and damage human organs such as the liver, kidneys, and others so that it can interfere with human health [(2)]. Chromium Cr (VI) enters

Corresponding author:
Narimo
sajidan@fkip.uns.ac.id

the environment from various sources, but the common sources that are supposed to be the most influential are industry, mining, household activities, and combustion residue and fuel mobility [3].

Sugarcane bagasse is waste from a sugar factory that has a sucrose content in sugarcane stems of merely about 8-16%, while the remaining 84% is bagasse, water and other solids [4]. Sugarcane bagasse can also be used to reduce heavy metal content, including chromium Cr (VI), in waste pollution by changing it first into an adsorbent due to the large carbon content in it [5]. The function and economic value of sugarcane bagasse are still low nowadays, and these become the reasons to utilize it as the absorbent Cr (VI), which is extremely dangerous.

The production of nanopore-activated carbon from bagasse is completed through four stages, namely dehydration process, carbonization process, activation process, and sonication process. The quality of bagasse nanopore-activated carbon is largely determined by the type of raw material, processing technology, working method, and accuracy of usage.

The large surface area due to the change to nanomaterial today becomes interesting and has been widely used for adsorption to remove heavy metal content in waste because it produces high adsorption efficiency [6]. The area of nanoparticles is controlled through the material size, chemical composition, surface modification, and control of particle interaction [7].

The adsorbent is produced in the form of powder and tablet, for comparing the effectiveness of Cr (VI) adsorbing activity. Tablet is practical but it needs the addition of other materials such as binders in this case Polyvinyl alcohol (PVA) so that it can be granulated and then compressed or formed. The binder can also improve the fragility and strength of the granules so that the tablet is not easily cracked and broken [8,9].

Methodology

Instruments and Materials

The equipment used in this research includes crusher, analytical balance, furnace, oven, shaker, porcelain cup, desiccator, funnel, clamp, retort stand, 200 mesh sifter, 1-liter glass beaker, pH meter, burette, condenser, water heater, Erlenmeyer, pipette, sonicator, tablet press machine, Atomic Absorption Spectrophotometer, BET.

The materials used consist of sugarcane bagasse from sugar factories, $K_2Cr_2O_7$ solution, HCl, aquades, standard Na2S2O3 solution, standard iodine, standard KIO3, 10% KI, 2N H2SO4, 1% amylum indicator, and lead filter paper.

Figure 1. Dried and crushed sugarcane bagasse

The Production of Sugarcane Bagasse Charcoal begins some following steps. Sugarcane bagasse that had been dried and crushed was put into a furnace for 30 minutes at the temperature of 300^0 C. After charcoal was made, it was frozen in a desiccator. For the chemical activation, the results of carbonization from furnace in the form of charcoal were activated using chemical activation in a 0.5 N HCl solution. This was carried out in reflux for two hours and then filtered and cooled in the form of a slurry. This was, afterward, synthesized using ultrasonic irradiation using a sonication device for making nanopores.The Production of Sugarcane Bagasse Nanopore-Activated Carbon is executed by using this pattern. Activated carbon, obtained from sugarcane bagasse charcoal activation in the form of a slurry, was sonicated for 15 minutes with a 40% amplitude without breaking.

Figure 2. Carbon bagasse after carbonization and irradiation of ultrasonic waves

The results of sonication in the form of activated charcoal were filtered, rinsed with aquades, and dried with an oven to remove the water at a temperature of 105^0C. The produced powder was pressed using a tablet press machine. The cavity in the activated carbon was checked using Brunaeur-Emmet-Teller (BET) to determine the surface area and pore radius of sugarcane bagasse [10].

Figure 3.Sugarcane bagasse nanopore tablets

The adsorption ability of nanopore powder and tablet from Bagasse activated to Cr (VI) heavy metal was tested on artificial samples of $K_2Cr_2O_7$ solution. The test was carried out by weighing 0.1 gram of bagasse nanopore powder, putting it into an Erlenmeyer that contained 25 ml of $K_2Cr_2O_7$ solution with a concentration of 100 mg/L and leaving it for a certain time. The variable of contact time of sugarcane bagasse nanopore-activated carbon and sample included one hour, two hours, three hours, 4 hours, and five hours. The same treatment was also carried out to tablet, weighing 1.32 grams. Other variables, stirring speed and duration, were also examined. The stirring speed was measured using a shaker, by placing the powder into Erlenmeyer and shaking it with various stirring speeds, 55 rpm, 60 rpm, 75 rpm, 90 rpm, and 105 rpm. Meanwhile, the variations of contact time and stirring duration were 15 minutes, 30 minutes, 45 minutes, 60 minutes, 75 minutes and 90 minutes. The filtrates obtained were checked using Atomic Absorption Spectrophotometer.

Finding and Discussion

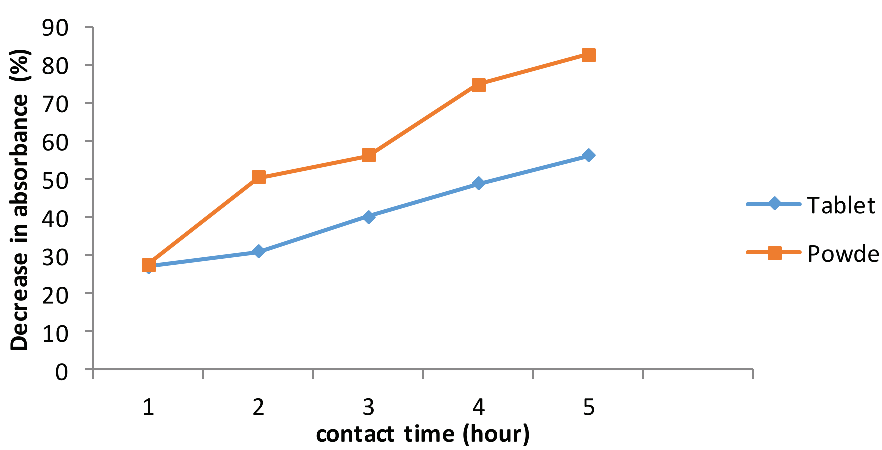

Figure 4. Adsorption of nanopore-activated carbon powder and tablet made of sugarcane bagasse with various contact times

This research was carried out at the Industrial Chemistry Laboratory and the Pharmacy Technology Laboratory of Universitas Setia Budi, Surakarta. The material used in this research, sugarcane bagasse, was obtained from the Sugar Factory in Sragen, and the artificial sample in the form of a $K_2Cr_2O_7$ solution was obtained from the Industrial Chemistry Laboratory. The results of bagasse nanopore carbon powder analysis using Brunaeur-Emmet-Teller (BET) indicate that the pore diameter of bagasse nanopore-activated carbon was 4.10264+01A^{O} [14].

The results of the analysis on the adsorption capacity of nanopore-activated carbon powder and tablet 1,32 grams made of sugarcane bagasse for removing Cr (VI) using $K_2Cr_2O_7$ solution with contact time variations are as follows. Adsorbent dissolved in sample solution without stirring had optimum adsorption capacity 56.35% in a contact time of five hours. The optimum adsorption capacity of powder 82.90% was also achieved in time contact variation of five hours [11].

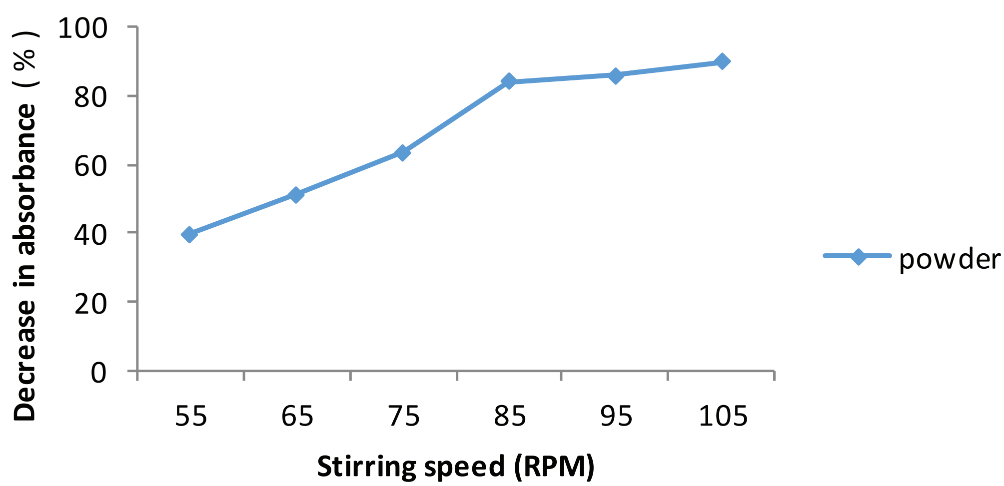

Figure 5. Graph of adsorption capacity of sugarcane bagasse nanopore-activated carbon powder with various stirring speeds.

The analysis of the adsorption process of sugarcane bagasse nanopore powder with various stirring speeds on a heavy metal sample of $K_2Cr_2O_7$ solution reveals that the maximum result was obtained at stirring speed of 105 rpm with an adsorption capacity of 90.07%.

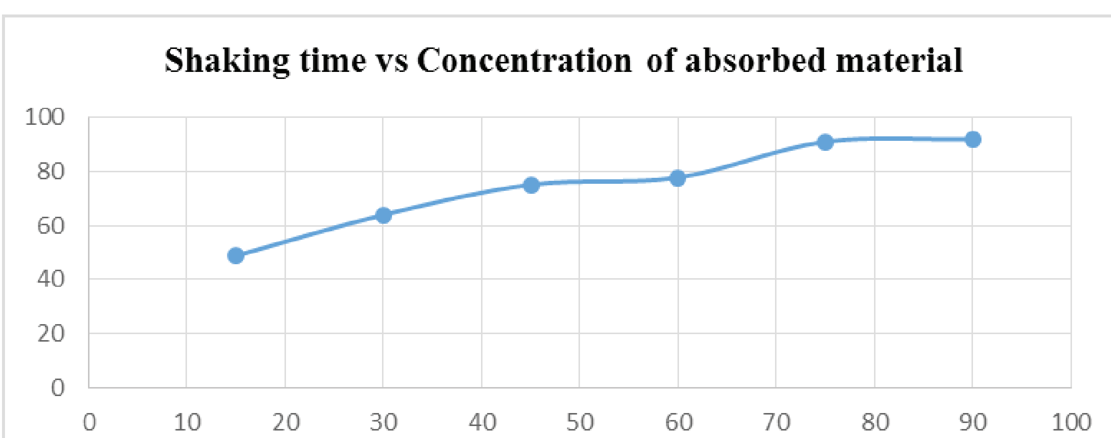

Figure 6. The adsorption capacity of sugarcane bagasse nanopore-activated carbon powder in various stirring time duration

The analysis on the adsorption process of sugarcane bagasse nanopore powder with variations of stirring time duration and fixed stirring speed of 105 rpm on a heavy metal sample of $K_2Cr_2O_7$ solution shows that the maximum result was obtained when the stirring duration of 90 minutes, the adsorption capacity of 91.80%, although the addition of time duration would cause an increase in adsorption capacity, the increase was not significant [12,13].

Conclusion

In conclusion, analysis using Brunaeur-Emmet-Teller (BET) results in the pore diameter of bagasse nanopore-activated carbon of 4.10264 + 01 A^{O}. The highest adsorption capacity of sugarcane bagasse nanopore tablet on Cr (VI) heavy metal removal 56.35% with the sample of $K_2Cr_2O_7$ solution was in a five-hour stirring duration. The highest adsorption capacity of powder 82.90% also occurred in a five-hour stirring duration. The powder had a greater adsorption capacity, while the tablet was more practical to be used. The adsorption capacity of sugarcane bagasse nanopore powder in removing Cr (VI) was optimum, reaching 90.07%, with a 105-rpm stirring speed. The adsorption of sugarcane bagasse nanopore powder was optimized with a stirring duration of 90 minutes, which resulted in an adsorption capacity of 91.80% [15].

Ethical Clearance: This study has been conducted under ethical clearance number: 0712/KEPK/UNS/V/2020.

Source of Fundings: The authors received no specific funding for this work. Hence, the authors provide self-funded to cover this publication.

Conflict of Interest: The authors declare that there is no conflict of interest.

References

[1] Dave, P. N. & Choda, L. V. Application of iron oxide nanomaterials for the removal of heavy metals. *Journal of Nanotechnology*; 2014. 398-412.

[2] Agustina, T. *Kontaminasi logam berat pada makanan dan dampaknya pada kesehatan* [Contamination of heavy metals on food and its effect on health]. *Jurnal Teknobuga*; 2014. 1(1), 53 – 65.

[3] Bugis, H., Daud, A., & Birawida, A. Studi kandungan logam berat kromium VI (Cr VI) pada air dan sedimen disungai Pangkajene Kabupaten Pangkep. *Fakultas Kesehatan Masyarakat. Universitas Hasanuddin. Makassar*; 2013.

[4] Harsanto, U. PSMI Training Modul 2011 of PT Pemuka Sakti Manis Indah Plantation Departemen, Pakuan Ratu-Way Kanan, Bandar Lampung; 2011.

[5] Yasril, H., Kasjono, S. & Ganefati, S. P. *Penurunan kadar krom dengan menggunakan biomassa ampas tebu secara bio-adsorpsi* [The reduction of chromium content with bio-adsorption using sugarcane bagasse biomass]. *Jurnal Teknologi Lingkungan*; 2009. 10(2), 145 – 151

[6] Pang, F.M., et al., Removal of lead, zinc and iron by coagulation–flocculation. *Journal of the Taiwan Institute of Chemical Engineers*; 2011. 42(5), 809-815.

[7] Abdulah, M., Virgus, Y., Nirmin, & Khairurrijal. *Reviev: Sintesis nanomaterial* [Review: Nanomaterial synthesis]. *Jurnal Nanosains & Nanoteknologi*; 2008. 1(2), 33-57.

[8] Anief, M. *Farmasetika*. Gajah Mada University Press. Yogyakarta;1994.

[9] Sugiyono, S., Afrilianana, H. S., & Windriati, Y. N. *Pengaruh penggunaan amilum biji durian (durio zibethinus l.) sebagai bahan penghancur yang ditambahkan secara internal-ekternal terhadap sifat fisik dan kimia terhadap tablet ibuprofen* [The effect of the use of durian seed starch (Durio zibethinus l.) as a crushing material added internally-externally to the physical and chemical properties of ibuprofen tablets]. *E-publikasi ilmiah Fakultas Farmasi Uwahas Semarang*; 2013. 10(1), 31-5.

[10] Delmifiana, B. & Astuti. *Pengaruh sonikasi terhadap struktur dan morfologi nanopartikel magnetik yang disintesis dengan metode kopresipitasi* [The effects of sonication on the structure and morphology of magnetic nanoparticles synthesized using coprecipitation method]. *Jurnal Fisika Unand*; 2013. 2(3), 186 – 189.

[11] Gultom, E.M. & Lubis, M. T. *Aplikasi karbon aktif dari cangkang kelapa sawit dengan aktivator H3PO4 untuk penyerapan logam berat Cd dan Pb* [Application of activated carbon from palm kernel shells with H3PO4 activator for removing Cd and Pb heavy metals]. *Jurnal Teknik Kimia USU*; 2014.

3(1), 5 - 10.

[12] Hanif, S. & Shahzad, A. Removal of chromium (VI) and dye Alizarin Red S (ARS) using polymer-coated iron oxide (Fe3O4) magnetic nanoparticles by co-precipitation method. *Journal of Nanoparticle Research;* 2014. 16(6).

[13] Purnawan, C., Hilmiyana, D. & Fatmawati, E. *Pemanfaatan limbah ampas tebu untuk pembuatan kertas dekorasi dengan metode Organosolv* [The utilization of waste cane waste for making decorative paper with Organosolv method]. *Jurnal Ekosains*; 2012. 4(2), 1 - 6.

[14] Salihi, I. U., Kutty, S. R. M., & Isa, M. H. *Adsorption of lead ions onto actived carbon derived from sugarance bagasse.* Paper presented in the 7th International Conference on Key Engineering Materials, Malaysia; 2017.

[15] Choppala, G., N. Bolan, & J.H. Park,. Chapter two - Chromium contamination and its risk management in complex environmental settings in L.S. Donald (Ed), Advances in agronomy, *Academic Press;* 2013. p. 129-172.