Simple Technology to Convert Coconut Shell Waste into Biochar: A Green Leap Towards Achieving Environmental Sustainability

Yudha Gusti Wibowo*, Bimastaji Surya Ramadan, Muhammad Andriansyah

1Department of Environmental Science, Postgraduate Program, Universitas Jambi, Jambi, Indonesia 36122
2Department of Environmental Engineering, Universitas Diponegoro, Semarang, Indonesia 50275
3Islamic University of Sultan Thaha Saifuddin Jambi, Jambi, Indonesia, 36361
*Correspondence author, e-mail: yudhagustiwibowo26@gmail.com

Abstract
Pyrolysis is a technology to convert biomass into high-value product such as biochar. Biochar is a bio-based material as well as char that can maintain soil, water and air quality. Biochar can be produced by all of plant parts and generated directly from pyrolysis for a few hours in a certain temperature. The quality of biochar production is highly dependent on the pyrolysis temperature, heating rate, particle size, type, and composition of feedstock and reactor conditions. Several studies inform that biochar produced by high temperature such as furnace. Application of biochar in soil can solve contaminated soil from pollutants such as toxic metals contamination, low pH issues and degradable soil caused by industrial activities. Therefore, the application of biochar in water ecosystem can solve some problems such as reduce toxic metals content in wastewater. Biochar known can give significant impact to reduce global warming through the reduction of greenhouse gas emissions and the sequestering of atmospheric carbon into soil. This condition is a problem for several areas especially rural area in developing countries. This paper will describe clearly how to produce biochar use simple technology. Thus, this paper will provide useful information for reducing environmental problems especially on rural areas.

Keywords: coconut shell, biochar, environment, environmental sustainability

1. Introduction
Environmental damage is a global issue since recent decades made industrial activity being grow up and generate more waste. These issues made problems such as water pollution by the existence of plastic industry which caused macro- and microplastic in marine environment (Wibowo, et al., 2019). Therefore, air and soil pollution from fly and bottom ash of power plant, added by the increasing of population growth forced more energy consumption and lead to environmental degradation by its industrial activities (Winarno et al., 2019). Population growth was also lead to the increase of food needs that will give an impact for environment caused by waste such as coconut and waste palm mill (Naswir et al., 2019).

Production of coconut shell has been growing steadily in recent decades (Global Cement Magazine, 2012), coconut shell waste will give impact for environmental such as bad smell, air pollution and if this waste burned will give an impact for ozone especially on developing countries. This condition will give negative impacts for human activity. They were work a day full to fulfill their life needs. They
were doing monotone activities, this condition will give impact for their health (Wibowo, 2019; Wibowo & Indrayana, 2019). Coconut shell waste need some treatment to provide sustainable added value. Coconut shell waste could be a biochar, which has various functional groups and contain polycyclic aromatic hydrocarbons (Wibowo & Naswir, 2019; Wibowo et al., 2019). Several study informs that biochar has been creating by pyrolysis (Tareq et al., 2018; You & Wang, 2016) used different time and temperature with advanced technologies (Vithanage et al., 2016). Biochar has been utilized to reducing environmental damage such as toxic metals content on wastewater (Wibowo et al., 2019), soil remediation (Wibowo & Sadikin, 2019), air pollution and solid waste (Sahoo et al., 2019). Biochar is not only environmentally, but also give positive impact for economy and social development (Ji et al., 2018). Figure 1 shows the schematic process of biochar production and application.

**Figure 1.** Schematic process of biochar production and application

Biochar have many benefits to environment, economy and social aspect but still have problems especially on technology to create this biomaterial. Several study that inform used furnace to created biochar (Zhu, Qiao, & Yan, 2019). Advanced technology made this biomaterial could not possibly be created by traditional treatment especially on rural areas. This paper will give clear information to create biochar by simple technology. Thus, this technology is acceptable for everyone as a green leap towards achieving energy and environmental sustainability.
2. Biochar Preparation

Several study informs that biochar created by furnace, this paper will describe how to create biochar use a simple technology. Biochar created by coconut shell waste that dried for two days to remove water content, then coconut shell waste burned with pan using unused firewood during four hours (Figure 2) at 400 °C. Biochar has burned four hours removed and cooled before using to utilize as a biomaterial that could reducing heavy metals content on water, soil remediation and reducing air pollution. Biochar made from physic and chemical properties. Biochar is different with activated carbon, it caused by biochar do not need activators. Biochar have chemical and physical characterization such as BET, pH, FTIR/FTIS, elemental analysis, Boehm titration, bulk density, CEC analysis, C-NMR, gas chromatography, zeta potential of biochar colloids, particle size distribution, x-ray absorption near-edge structure, SEM/TEM, moisture content, ash content, pores volume (Figure 3) (Nartey & Zhao, 2014).

Biochar can produced by microalgae, wood, solid waste and all of organic matter. Recent study showed that biochar production by microalgae use slow and fast pyrolysis (between 200-750 °C), another study reported that yield of biochar has decreased from 48% to 24% when pyrolysis temperature increased from 300 to 700 °C. Low temperature range (200-750 °C) of biochar pyrolized from microalgae produced high carbon (J.-S. Chang et al., 2017) and optimum production of biochar is at 500 °C (Y. Chang et al., 2014).

Figure 1. Simple technology to create biochar

| Chemical       | Physical                  |
|----------------|---------------------------|
| 1. pH          | 1. X-ray diffraction      |
| 2. BET         | 2. particle size distribution |
| 3. elemental analysis | 3. bulk density         |
| 4. FTIR/FTIS   | 4. SEM/TEM                |
| 5. Boehm titration | 5. ash content          |
| 6. Beta potential of biochar colloids, | 6. moisture content |
| 7. Gas chromatography | 7. pores volume   |
| 8. CEC analysis |                          |
| 9. C-NMR       |                          |

Figure 2. Biochar Characterization
3. How can Biochar Support Environmental Sustainability?

Biochar material is a good material for environmental sustainability for environmental remediation such as climate change mitigations, reduce organic pollutant, high metal reduction and immobilization, high complexation and soil amelioration include slow nutrient release, microbial abundance (efficient nutrient transfer), better O2 and moisture level. The physical properties of biochar include physical and chemical properties, physical properties of biochar are high surface area and porosity, high surface charge and high holding water capacity and chemical properties include high pH, high carbon sequestration high nutrient exchange and high $–\text{COO;OH;}–\text{CO,–R-OH}$ group (Figure 4), biochar is a potential sorptive media for removal of hazardous benzene in air (Khan et al., 2018), soil nutrients (Gaskin et al., 2010) and reducing wastewater pollution (S. Wang & Wang, 2019). Biochar has been developing as a green energy as catalyst in energy recovery technologies and fuel. Green energy from biochar has created by agriculture waste and showed high porosity, a wide range of mineralogical composition and pH and biochar has found suitable for improvement of waste to energy technologies (Bhowmick et al., 2019). Several study about biochar affected for environmental could see in Table 1. Biochar can decreased heavy metals in soil and water, several study showed that biochar can neutralize pH values of soil. Application biochar in environment can reduce the global warning effect include acidification, euphotrophication, ozon layers and else. Table 1 informs that biochar can support the sustainability of environment.

| Statement                                      | Descriptions                                                                                                                                 |
|------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------|
| Biochar effect of organic pollutants and heavy metals on soil | Biochar decreased the concentration of Cu, As and Cd in maize shoots, which depended upon amount of biochar addition, pH values of soils, and ability of metal to adsorb on biochar (Nartey & Zhao, 2014) |
| Biochar can reduce environmental damage and climate change | Applied biochar for environment that give reducing global warming effect, acidification, euphotrophication, ozone layer depletion, summer smog, winter smog, pesticides, airborne heavy metals, waterborne heavy metals, and carcinogenic substance (Ning et al., 2013). |
| Desorption of atrazine in biochar-amended soils | Biochar can significantly decrease the desorption of atrazine from soil, root exudates and the aging interactions between biochar and soil can enhance the desorption of atrazine (Ren, Wang, Cao, Guo, & Sun, 2018) |
| Biochar role in microbial proliferation and pollutant biodegradation | Biological attributes of biochar related to pollutants removal however develops later phase of the soil application (Oliveira et al., 2017) |
| Effects of biochar materials on arsenic and heavy metals under water and soils | Biomaterial-biochar (using softwood) could reducing arsenic and heavy metals content underwater, status of nitrogen species and elements of potential toxicity in soils (Heaney, Tahir, Al-gharib, & Lin, 2018) |
| Site energy distribution consideration by tetracycline adsorption of biochar | Biochar can reduce tetracycline, biochar can sorption 86% from a solution at initial concentration 200 mg/L. Freundlich-Langmuir was used as an isotherm adsorption. |
4. Conclusion

High production of coconut shell is not be a solid waste again, coconut shell could though to be a biochar. Biochar is a biomaterial that give positive impact for environment sustainability. Biochar will be give positive impact on soil remediation, reducing wastewater and air pollution. Simple technology on this paper could implemented on everywhere especially rural areas have many coconut resources.
References
Bhowmick, G. De, Sarmah, A. K., & Sen, R. (2019). Science of the Total Environment Zero-waste algal biorefinery for bioenergy and biochar: A green leap towards achieving energy and environmental sustainability☆. Science of the Total Environment, 650, 2467–2482. https://doi.org/10.1016/j.scitotenv.2018.10.002
Brassard, P., Godbout, S., Pelletier, F., Raghavan, V., & Palacios, J. H. (2018). Biomass and Bioenergy Pyrolysis of switchgrass in an auger reactor for biochar production: A greenhouse gas and energy impacts assessment. Biomass and Bioenergy, 116(May), 99–105. https://doi.org/10.1016/j.biombioe.2018.06.007
Chang, J.-S., Chi-Wei Lan, J., Ong, H. C., Chen, W.-H., Ling, T. C., Yu, K. L., & Show, P. L. (2017). Microalgae from wastewater treatment to biochar—Feedstock preparation and conversion technologies. Energy Conversion and Management, 150 (April), 1–13. https://doi.org/10.1016/j.enconman.2017.07.060
Chang, Y., Tsai, W., & Li, M. (2014). Chemical characterization of char derived from slow pyrolysis of microalgal residue. Journal of Analytical and Applied Pyrolysis, 111, 99–93. https://doi.org/10.1016/j.jaap.2014.12.004
Gaskin, J. W., Speir, R. A., Harris, K., Das, K. C., Lee, R. D., Morris, L. A., & Fisher, D. S. (2010). Effect of peanut hull and pine chip biochar on soil nutrients, corn nutrient status, and yield. Agronomy Journal, 102(2), 623–633. https://doi.org/10.2134/agronj2009.0083
Global Cement Magazine. (2012). Coconut shells as an alternative fuel. WwW.Wcponline.Com, (October), 12–13.
Heaney, N., Tahir, H., Algharib, A., & Lin, C. (2018). Ecotoxicology and Environmental Safety Effects of softwood biochar on the status of nitrogen species and elements of potential toxicity in soils. Ecotoxicology and Environmental Safety, 166 (June), 383–389. https://doi.org/10.1016/j.ecoenv.2018.09.112
Ji, C., Cheng, K., Nayak, D., & Pan, G. (2018). Environmental and economic assessment of crop residue competitive utilization for biochar, briquette fuel and combined heat and power generation. Journal of Cleaner Production, 192 (November 2014), 916–923. https://doi.org/10.1016/j.jclepro.2018.05.026
Khan, A., Szulejko, J. E., Samadder, P., Kim, K., Liu, B., Mainto, H. A., ... Ok, Y. S. (2018). Department of Civil Engineering, Balochistan University of Information Technology Engineering Korea Biochar Research Center, O-Jeong Eco-Resilience Institute (OJERI) & Division of Chemical Engineering Journal, 1–40. https://doi.org/10.1016/j.cej.2018.10.193
Naray, O. D., & Zhao, B. (2014). Biochar Preparation, Characterization and Adsorptive Capacity and and Its Effect on Bioavailability of Contaminants: An Overview. Advances in Materials Science and Engineering, 2014, 1–13.
Naswir, M., Arita, S., Hartati, W., Septiarini, L., & Wibowo, Y. G. (2019). Activated Bentonite: Low Cost Adsorbent to Reduce Phosphor in Waste Palm Oil. International Journal of Chemistry, 11(2), 67–76. https://doi.org/10.5539/ijc.v11n2p67
Ning, S., Hung, M., Chang, Y., Wan, H., Lee, H., & Shih, R. (2013). Benefit assessment of cost, energy, and environment for biomass pyrolysis oil. Journal of Cleaner Production, 59, 141–149. https://doi.org/10.1016/j.jclepro.2013.06.042
Oliveira, F. R., Patel, A. K., Jaisi, D. P., Adhikari, S., Lu, H., & Khanal, K. (2017). Environmental application of biochar: Current status and perspectives. Bioresource Technology, 246, 110–122. https://doi.org/10.1016/j.biortech.2017.08.122
Ren, X., Wang, F., Cao, F., Guo, J., & Sun, H. (2018). Desorption of atrazine in biochar-amended soils: Effects of root exudates and the aging interactions between biochar and soil. Chemosphere, 212, 687–693. https://doi.org/10.1016/j.chemosphere.2018.08.124
Sahoo, K., Bilek, E., Bergman, R., & Mani, S. (2019). Techno-economic analysis of producing solid biofuels and biochar from forest residues using portable systems. Applied Energy, 235(July 2018), 578–590. https://doi.org/10.1016/j.apenergy.2018.10.076

Tareq, R., Akter, N., & Azam, M. S. (2018). Biochars and Biochar Composites. In Biochar from Biomass and Waste. https://doi.org/10.1016/b978-0-12-81729-3.00010-8

Uchimiya, M., Lima, I. M., Klasson, K. T., & Wartelle, L. H. (2010). Contaminant immobilization and nutrient release by biochar soil amendment: Roles of natural organic matter. Chemosphere, 80(8), 935–940. https://doi.org/10.1016/j.chemosphere.2010.05.020

Vithanage, M., Mayakaduwa, S. S., Herath, I., Ok, Y. S., & Mohan, D. (2016). Kinetics, thermodynamics and mechanistic studies of carbofuran removal using biochars from tea waste and rice husks. Chemosphere, 150, 781–789. https://doi.org/10.1016/j.chemosphere.2015.11.002

Wang, S., & Wang, J. (2019). Activation of peroxymonosulfate by sludge-derived biochar for the degradation of trichloran in water and wastewater. Chemical Engineering Journal, 356, 350–358. https://doi.org/10.1016/j.cej.2018.09.062

Wang, Y. R., Tsang, D. C. W., Olds, W. E., & Weber, P. A. (2013). Utilizing acid mine drainage sludge and coal fly ash for phosphate removal from dairy wastewater. Environmental Technology (United Kingdom), 34(24), 3177–3182. https://doi.org/10.1080/09593330.2013.808243

Wibowo, Y. G. (2019). Managing Sport for Healthy Lifestyle: A Brief Review and Future Research Directions. Indonesian Journal of Sport Science and Coaching, 1(2), 49–57.

Wibowo, Y. G., & Indrayana, B. (2019). Sport: A Review of Healthy Lifestyle in The World. Indonesian Journal of Sport Science and Coaching, 1(1), 30–34.

Wibowo, Y. G., Maryani, A. T., Rosanti, D., Rosarina, D., Program, P., Jambi, U., & Tangerang, U. M. (2019). Microplastic in Marine Environment and Its Impact. Sainmatika: Jurnal Ilmiah Matematika Dan Ilmu Pengetahuan Alam, 16(1), 81–87. https://doi.org/10.31851/sainmatika.v16i1.2884

Wibowo, Y. G., & Naswir, M. (2019). A Review of Biochar as a Low-cost Adsorbent for Acid Mine Drainage Treatment. Prosiding Seminar Nasional Hari Air Dunia 2019, 1–10.

Wibowo, Y. G., Rosarina, D., Fardillah, F., & Gusva, D. W. (2019). An Overview; Wastewater Treatment Using Biochar to Reduce Heavy Metals. Prosiding Seminar Nasional Hari Air Dunia 2019, 11–16.

Wibowo, Y. G., & Sadikin, A. (2019). Biology in 21st Century: Transformation in Biology Science and Education for Supporting Sustainable Development Goals. Jurnal Pendidikan Biologi Indonesia, 5(2).

Winarno, H., Muhammad, D., Ashyar, R., & Wibowo, Y. G. (2019). Pemanfaatan Limbah Fly Ash dan Bottom Ash dari PLT SUMSEL-5 Sebagai Bahan Utama Pembuatan Paving Block. Jurnal Teknika, 11(1), 1067–1070.

You, S., & Wang, X. (2016). Potential and Economic Viability of Biochar Production Systems: Life Cycle Assessment. In Biochar from Biomass and Waste. https://doi.org/10.1016/B978-0-12-81729-3.00020-0

Zhu, N., Qiao, J., & Yan, T. (2019). Science of the Total Environment Arsenic immobilization through regulated ferrolysis in paddy field amendment with bismuth impregnated biochar. Science of the Total Environment, 648, 993–1001. https://doi.org/10.1016/j.scitotenv.2018.08.200