SWINE (*Sus scrofa domesticus*) MANURE ACTIVATED CARBON AS A BIOFILTER FOR PIGGERY WASTEWATER

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ABSTRACT

DE JESUS, CHELSEA NICOLE P. and **ECHAVARIA, RAFAEL JAY C.**, Department of Agricultural and Biosystems Engineering, College of Engineering, Central Luzon State University, Science City of Muñoz, Nueva Ecija, Philippines, **July 2023, SWINE (*Sus scrofa domesticus*) MANURE ACTIVATED CARBON AS A BIOFILTER FOR PIGGERY WASTEWATER**

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The disposal of pig manure and the odor associated with their storage facilities are two of the main problems connected to the increasing swine production in terms of surface water, groundwater, and air quality. Converting swine manure into biochar can help mitigate its negative environmental effects while also generating sustainable energy and value-added biochar. This study aims to evaluate swine manure as a precursor for producing activated carbon. Also, this is to assess the potential of the produced activated carbon in adsorbing various contaminants such as biochemical oxygen demand (BOD), total suspended solids (TSS), ammonia, phosphate, and total coliform present in piggery wastewater.

Swine manure was carbonized through an improvised kiln and activated using calcium chloride ($CaCl_2$). The activated carbon was characterized by its physical properties such as percent ash, percent moisture, and bulk density. Scanning Electron Microscopy (SEM) was used to analyze and compare the pore structure of the activated and carbonized swine manure. The study used different amounts of filter media: Treatment 1 with 4-inch

AC thickness, Treatment 2 with 6-inch AC thickness, and Treatment 3 with 8-inch AC thickness.

For the characterization of activated carbon, the ash content of swine manure activated carbon was 18.87%, the moisture content was 9.58%, and the bulk density was 0.26 g/mL, which were within the range of acceptable levels. The operating time for Treatment 1 was 0.45 hr, Treatment 2 was 1.18 hr, and Treatment 3 was 1.40 hr. Their filtering capacities were 2.24, 0.86, and 0.72 liters per hour, respectively. The results showed that among the three treatments, the 8-inch AC thickness (T_3) proved to be the most effective in adsorbing BOD (63.76%), TSS (89.94%), ammonia (97.74%), phosphate (89.97%), and total coliform (63.76%). Statistical analysis showed that there are significant differences among the treatments.

Keywords: Activated carbon; Swine manure; Biofilter; Piggery wastewater

LITERATURE CITED

Abdul, H.A., Anuar, K., Zulkamain, Z., Mohd Zobir, H., Dzulkefly, K., Faujan, A., & Ong, S.W. (2007). Preparation and Characterization of Activated Carbon from Gelan Wood Bark. *Malaysian Journal of Analytical Science.*

Achak, M., Mandi, L., and Ouzzani, N. (2009). Removal of organic pollutants and nutrients from olive mill wastewater by a sand filter. *Journal of Environmental Management,* 90, 2771-2779

Ahmad, M., Lee, S.S., Dou, X., Mohan, D., Sung, J.K., Yang, J.E., & Ok, Y.S. (2012). Effects of pyrolysis temperature on soybean stover and peanut shell-derived biochar properties and TCE adsorption in water. *Bioresour. Technol.* 2012, 118, 536–544

Alam, Md.S. & Alessi, D.S. (2019). Chapter 4 – Modeling the Surface Chemistry of Biochars. Biochar from Biomass and Waste, pp. 59-72. doi 10.1016/B978-0-12-811729-3.00004-2

Almanassra, I.W., Kochkodan, V., Mckay, G., Atieh, M.A., and Al-Ansari, T. (2021). Review of phosphate removal from water by carbonaceous sorbents. *Journal of Environmental Management,* 287. https://doi.org/10.1016/j.jenvman.2021.112245

Cabrera, M.V. (2022). Activated Carbon from Coconut (*Cocos nucifera*) Shells via Chemical Activation using H_2SO_4 (Sulfuric Acid) as Biofilter for Municipal Wastewater. Central Luzon State University.

Chen, T., Zhou, Z., Meng, R., and Wang, H. (2015). Adsorption of Cadmium by Biochar Derives from Municipal Sewage Sludge: Impact Factors and Adsorption Mechanism. *Chemosphere,* 134, 286-293.

Cheng, D., Ngo, H.H., Guo, W.S., Liu, Y.W., Zhou, J.L., Chang, S.W., Nguyen, D.D., Bui, X.T., and Zhang, X.B. (2017). Bioprocessing for elimination antibiotics and hormones from swine wastewater. *Science of the Total Environment* 621, 1664-1682.

Cheng, D., Ngo, H.H., Guo, W., Chang, S.W., Nguyen, D.D., Liu, Y., Wei, Q., Wei, D. (2019). A critical review on antibiotics and hormones in swine wastewater: Water pollution problems and control approaches. *Journal of Hazardous Materials*. https://doi.org/10.1016/j.jhazmat.2019.121682

Cobb, A., Warms, M., Maurer, E.P., Chiesa, S. (2012). Low-Tech Coconut Shell Activated Charcoal Production. *International Journal for Service Learning in Engineering,* Vol. 7, No. 1, pp. 93-104, Spring 2012.

Costales, M.T.R. (2019). Activated Carbon from Corn (*Zea mays*) Cobs as Biofilter for Piggery Wastewater. Central Luzon State University.

Enaime, G., Bacaoui, A., Yaacoubi, A., Lubken, M. (2020). Biochar for Wastewater Treatment—Conversion Technologies and Applications. *Appl. Sci.* 2020, 10(10), 3492; https://doi.org/10.3390/app10103492

Enaime, G.; Ennaciri, K.; Ounas, A.; Baçaoui, A.; Seffen, M.; Selmi, T.; Yaacoubi, A. (2017). Preparation and characterization of activated carbons from olive wastes by physical and chemical activation: Application to indigo carmine adsorption. *J. Mater. Environ. Sci.* 2017, 8, 4125–4137

Fawzy, S., Osman, A.I., Yang, H., Doran, J., and Rooney, D.W. (2021). Industrial biochar systems for atmospheric carbon removal: a review. *Environmental Chemistry Letters* vol. 19, pp 3023–3055. https://doi.org/10. 1007/s10311-020-01059-w

Gendel, Y. and Lahav, O. (2013). A novel approach for ammonia removal from freshwater recirculated aquaculture systems, comprising ion exchange and electrochemical regeneration. *Aquacultural Engineering* 52: 27–38.

Ghasemi, Z., Sourinejad, I., Kazemian, H., and Rohani, S. (2016). Application of zeolites in aquaculture industry: a review. *Reviews in Aquaculture* 0, 1-21. doi: 10.1111/raq.12148

Ghauri, M., Tahir, M., Abbas, T., ShehzadKhurram, M. (2012). Adsorption Studies for the Removal of Ammonia by Thermally Activated Carbon. *Sci.Int.*, 24(4),443-446.

Hameed, B.H., Din, A.T.M., and Ahmad, A.L. (2007). Adsorption of Methylene Blue onto Bamboo-based Activated Carbon: Kinetics and Equilibrium Studies. *Journal of Hazardous Materials*, 141(3), 819-825.

Hu, H. and Xu, K. (2020). Chapter 8—Physicochemical Technologies for HRPs and Risk Control High-risk Pollutants in Wastewater. *High-Risk Pollutants in Wastewater*, pp. 169-207. DOI: 10.1016/B978-0-12-816448-8.00008-3

Ippolito, J.A., Strawn, D.G., Scheckel, K.G., Novak, J.M., Ahmedna, M., Niandou, M.A.S. (2012) Macroscopic and molecular investigations of copper sorption by a steam-activated biochar. *J Environ Qual*, 41:1150–1156

Islam, M.A.; Auta, M.; Kabir, G.; Hameed, B.H. (2016). A thermogravimetric analysis of the combustion kinetics of karanja (Pongamia pinnata) fruit hulls char. *Bioresour. Technol.* 2016, 200, 335–341.

Jabit, N.B. (2007). The production and characterization of activated carbon using local agricultural waste through chemical activation process. M.S. Thesis, Malaysia.

Jiang, B., Lin, Y., and Mbog, J.C. (2018). Biochar derived from swine manure digestate and applied on the removals of heavy metals and antibiotics. *Bioresource Technology*. doi: https://doi.org/10.1016/j.biortech.2018.08.022

Kaghazchi, T., Soleiman, M., and Yeganeh, M.M. (2006). Production of Activated Carbon from Residue Liquorice Chemical Activation. 8th Asia Pacific International Symposium on Combustion and Energy Utilization.

Khiari, Z., Alka, K., Kelloway, S., Mason, B., and Savidov, N. (2019). Integration of Biochar Filtration into Aquaponics: Effects on Particle Size Distribution and Turbidity Removal. Agricultural Water Management. https://doi.org/10.1016/j.agwat.2019.105874

Kołody´nska, D.; Krukowska, J.; Thomas, P. (2017). Comparison of sorption and desorption studies of heavy metal ions from biochar and commercial active carbon. *Chem. Eng. J.* 2017, 307, 353–363

Komiyama, T., Kobayashi, A., and Yahagi, M. (2013). The chemical characteristics of ashes from cattle, swine and poultry manure. *J Mater Cycles Waste Management*, 15:106–110. DOI 10.1007/s10163-012-0089-2

Lee, N.H. and Han, K.N. (2012). The effect of dead coral skeletons on the water quality and sessile mollusks in the closed system. *The Korean Journal of Malacology*, volume 28 issue 3. Pp 187-196. https://doi.org/10.9710/kjm.2012.28.3.187

Li, F., Wu, X., Ji, W., Gui, X., Chen, Y., Zhao, J. Zhou, C., and Ren, T. (2020). Effects of pyrolysis temperature on properties of swine manure biochar and its environmental risks of heavy metals. *Journal of Analytical and Applied Pyrolysis*. DOI: https://doi.org/10.1016/j.jaap.2020.104945

Li, K.; Liu, R.; Sun, C. (2015). Comparison of anaerobic digestion characteristics and kinetics of four livestock manures with different substrate concentrations. *Bioresour. Technol*, 198, 133–140

Li, R.; Tan, W.; Zhao, X.; Dang, Q.; Song, Q.; Xi, B.; Zhang, X. (2019). Evaluation on the Methane Production Potential of Wood Waste Pretreated with NaOH and Co-Digested with Pig Manure. *Catalysts*, 9, 539.

Lorimor, J., Powers, W., Sutton, A. (2014). Manure characteristics. Manure Management Systems Series MWPS-18 Section 1 2nd Edition.

Magtibay, B.B. (2006). Biosphere Environment and Health System Series Vol. 2: Philippine Regulations on Sanitation and Wastewater Systems (International Edition). B.B. Magtibay's Publishing House. Imus, Cavite, Philippines.

Meng, J., Liang, S., Tao, M., Liu, X., Brookes, P.C., and Xu, J. (2018). Chemical speciation and risk assessment of Cu and Zn in biochars derived from co-pyrolysis of pig manure with rice straw, *Chemosphere*, 200 (2018) 344-350

Mohan, D., Sarswat, A., Ok, Y.S., and Pittman, C.U. (2014). Organic and inorganic contaminants removal from water with biochar, a renewable, low-cost, and sustainable adsorbent—A critical review. *Bioresource Technology*. 160, 191-202.

Molinuevo, B.; Mahdy, A.; Ballesteros,M.; González, C. (2016). From piggery wastewater nutrients to biogas: Microalgae biomass revalorization through anaerobic digestion. *Renew. Energy*, 96, 1103–1110

Odemis, B. and Evrendilek, F. (2007). Monitoring Water Quality and Quantity of National Watersheds in Turkey. Department of Farm Structures and Irrigation. Mustafa Kemal University, 31034 Antakya-Hatay, Turkey.

Oluyemi, J.A., Longe, B., and Esubi, R. (1979). Replacing Corn with Sun-dried Manure of Laying Pullet, Mature Pig, Sheep, and Cow. *Poultry Science*, 58: 852-857.

Palm HW, Knaus U, Appelbaum S, Goddek S, Strauch SM, Vermeulen T, Jijakli MH, Kotzen B (2018) Towards commercial aquaponics: a review of systems, designs, scales and nomenclature. *Aquac Int* 26(3):813–842

Paul, D. and Hall, S.G. (2021). Biochar and Zeolite as Alternative Biofilter Media for Denitrification of Aquaculture Effluents. Water 2021, 13, 2703. https://doi.org/10.3390/ w13192703

Philippine Agricultural Engineering Standard PAES 413:2001.

Philippine Statistics Authority. Swine Situation Report.

Rakocy J.E. (2012). Aquaponics: integrating fish and plant culture, Aquaculture Production Systems, 1, 344- 386.

Reddy, K.R.; Xie, T.; Dastgheibi, S. (2014). Evaluation of biochar as a potential filter media for the removal of mixed contaminants from urban storm water runoff. *J. Environ. Eng*. 2014, 140, 04014043.

Selmi, T.; Sanchez-Sanchez, A.; Gadonneix, P.; Jagiello, J.; Seffen, M.; Sammouda, H.; Celzard, A.; Fierro, V. (2018). Tetracycline removal with activated carbons produced by hydrothermal carbonisation of Agave americana fibres and mimosa tannin. Ind. *Crops Prod*. 2018, 115, 146–157

Shen, F.; Zhong, B.; Wang, Y.; Xia, X.; Zhai, Z.; Zhang, Q. (2019[a]). Cellulolytic Microflora Pretreatment Increases the Efficiency of Anaerobic Co-digestion of Rice Straw and Pig Manure. *Bioenergy Res*, 12, 703–713

Shen, J.; Zhao, C.; Liu, Y.; Zhang, R.; Liu, G.; Chen, C. (2019[b]). Biogas production from anaerobic co-digestion of durian shell with chicken, dairy, and pig manures. *Energy Convers. Manag*. 2019, 198, 110535

Shen, X., Zeng, J., Zhang, D., Wang, F., Li, Y., Yi, W. (2020). Effect of pyrolysis temperature on characteristics, chemical speciation and environmental risk of Cr, Mn, Cu, and Zn in biochars derived from pig manure, *Sci. Total Environ*., 704 (2020) 135283

Suliman, W.; Harsh, J.B.; Abu-Lail, N.I.; Fortuna, A.M.; Dallmeyer, I.; Garcia-Perez, M. (2016). Influence of feedstock source and pyrolysis temperature on biochar bulk and surface properties. *Biomass Bioenerg*. 2016, 84, 37–48

Summerfelt, R.C. (2018). Water Quality Considerations for Aquaculture. Department of Animal Ecology Iowa State University Ames, IA 50011-3221

Tareq, R., Akter, N., and Azam, Md.S. (2019). Chapter 10 - Biochars and Biochar Composites: Low-cost Adsorbents for Environmental Remediation Biochar From Biomass and Waste. *Biochar from Biomass and Waste*, pp. 169-209. DOI: 10.1016/B978-0-12-811729-3.00010-8

The American Water Works Association. (2011). Preparation and Characterization of Activated Carbon. Company Brochure. Retrieved on December 29, 2022, from https://www.awwa.org/portals/0/files/publications/documents/toc/activatedcarbon toc.pdf

Trakranrungsie, N., Royer, E., and Durosoy, S. (2012). Heavy Metals in Pig Production: A Concern for Public Health. The 8th Congress of Toxicology in Developing Countries, September 10-13, 2012. Retrieved from https://animine.eu/wp-content/uploads/2020/12/2012-09-CTDC-Bangkokabstract-Heavy-metals-in-pig-production.pdf

Troy, S. M., Nolan, T., Leahy, J. J., Lawlor, P. G., Healy, M. G., & Kwapinski, W. (2013). Effect of sawdust addition and composting of feedstock on renewable energy and biochar production from pyrolysis of anaerobically digested pig manure. *Biomass and Bioenergy*, 49, 1–9.

Troy, S.M., Lawlor, P.G., O'Flynn, C.J., and Healy, M.G. (2014). The Impact of Biochar Addition on Nutrient Leaching and Soil Properties from Tillage Soil Amended with Pig Manure. *Water Air Soil Pollution*, 225:1900. DOI 10.1007/s11270-014-1900-6

Tsai, W.T., Liu, S.C., Chen, H.R., Chang, Y.M., and Tsai, Y.L. (2012). Textural and chemical properties of swine-manure-derived biochar pertinent to its potential use as a soil amendment. *Chemosphere* 89 (198-203).

Wilson, M.L., Niraula, S., and Cortus, E.L. (2019). Nutrient Characteristics of Swine Manure and Wastewater. Animal Manure: Production, Characteristics, Environmental Concerns, and Management, Volume 67. https://doi.org/10.2134/asaspecpub67.c6

Xu, X.Y., Cao, X.D., Zhao, L., Wang, H.L., Yu, H.R., Gao, B. (2013) Removal of Cu, Zn, and Cd from aqueous solutions by the dairy manure-derived biochar. *Environ Sci* Pollut R 20:358–368

Yildiz, H.Y., Robaina, L., Pirhonen, J., Mente, E., Dominguez, D., and Parisi, G. (2017). Fish Welfare in Aquaponic Systems: Its Relation to Water Quality with an Emphasis on Feed and Faeces—A Review. Water 2017, 9, 13; doi:10.3390/w9010013

Zeng, X., Xiao, Z., Zhang, G., Wang, A., Li, Z., Liu, Y., Wang, H., Zeng, Q., Liang, Y., and Zou, D. (2018). Speciation and bioavailability of heavy metals in pyrolytic biochar of swine and goat manures, *Journal of Analytical and Applied Pyrolysis*, 132 (2018) 82-93

Zhang, C.; Li, J.; Liu, C.; Liu, X.; Wang, J.; Li, S.; Fan, G.; Zhang, L. (2013). Alkaline pretreatment for enhancement of biogas production from banana stem and swine manure by anaerobic codigestion. *Bioresour. Technol*, 149, 353–358

Zhang, Y. and He, Y. (2006). Co-composting Solid Swine Manure with Pine Sawdust as Organic Substrate. *Bioresource Technology*, pp. 2024-2031.

Zhou, X., Qiao, M., Su, J.Q., Wang, Y., Cao, Z.H., Cheng, W.D., and Zhu, Y.G. (2019). Turning pig manure into biochar can effectively mitigate antibiotic resistance genes as organic fertilizer, *Sci. Total Environ.*, 649 (2019) 902-908

Zulkania, A., Hanum, G., and Sri Rezki, A. (2018). The potential of activated carbon derived from bio-char waste of bio-oil pyrolysis as adsorbent. MATEC Web of Conferences, 154, 01029. https://doi.org/10.1051/matecconf/201815401029