Production and characterization of H\textsubscript{2}S and PO\textsubscript{4}\textsuperscript{3−} carbonaceous adsorbents from anaerobic digested fibers

Ayiania, M.\textsuperscript{a} Carabajal-Gamarra, F.M.\textsuperscript{a,b} Garcia-Perez, T.\textsuperscript{c} Frear, C.\textsuperscript{d} Suliman, W.\textsuperscript{a} Garcia-Perez, M.\textsuperscript{a} \textsuperscript{a}Department of Biological Systems Engineering, Washington State University, L.J. Smith Hall, 1935 E. Grimes Way, Pullman, WA 99164-6120, United States
\textsuperscript{b}Instituto de Química, Universidade de Brasília, Faculty Gama, Brasilia, DF, St. Leste Projeção A - Gama Leste, Brasília - DF, 72444-240, Brazil
\textsuperscript{c}Faculty of Chemical Sciences, Universidad de Cuenca, Ecuador

Abstract

Anaerobic digestion (AD) is an important technology to produce biogas from dairy manure. Although the AD of dairy manure results in the harnessing of the energy contained in manure, most of the nutrients (phosphorous and nitrogen) remain in the liquid effluent, representing an important source of pollution. Additionally, the biogas produced contains H\textsubscript{2}S and CO\textsubscript{2}, limiting its practical use as fuel. In this paper, we report the production and use of a carbonaceous adsorbent from AD fibers for the removal of hydrogen sulfide (H\textsubscript{2}S) from biogas and phosphate (PO\textsubscript{4}\textsuperscript{3−}) from aqueous liquid effluents. The adsorbents studied were produced via slow pyrolysis between 350 and 800 °C followed by CO\textsubscript{2} activation. The elemental and proximate analyses, surface area and pore size distribution of each of the adsorbents studied are reported. Their adsorption capacities were assessed using H\textsubscript{2}S breakthrough and PO\textsubscript{4}\textsuperscript{3−} batch equilibrium tests. The sorption capacity varied between 21.9 and 51.2 mg g\textsuperscript{−1} for H\textsubscript{2}S and between 4.9 mg g\textsuperscript{−1} and 37.4 mg g\textsuperscript{−1} for PO\textsubscript{4}\textsuperscript{3−}. Commercially available activated carbon studied adsorbed 23.1 mg g\textsuperscript{−1} H\textsubscript{2}S and 15.7 mg g\textsuperscript{−1} PO\textsubscript{4}\textsuperscript{3−}. The results show that the retention of H\textsubscript{2}S and PO\textsubscript{4}\textsuperscript{3−} compounds were governed by the ash content, surface area and pH. Adsorption mechanisms for H\textsubscript{2}S and PO\textsubscript{4}\textsuperscript{3−} sorption are proposed. © 2018

Author keywords

Anaerobically digested fiber, Biochar, Hydrogen sulfide, Phosphate, Pyrolysis

Indexed keywords

Activated carbon, Biogas, Carbon dioxide, Desulfurization, Fertilizers, Hydrogen sulfide, Manures, Phosphates, Pore size, Pyrolysis, Sulfur compounds, Sulfur determination
Dr. Garcia-Perez is very thankful for the financial support provided by the US National Science Foundation (CBET-1703052). This activity was funded, in part, with an Applied BioEnergy Research Program Internal Competitive Grant from the Agricultural Research Center at Washington State University, College of Agricultural, Human, and Natural Resources. The financial contribution of the Washington State department of Ecology Waste to Fuel program is greatly appreciated. This project was also partially funded by the USDA/NIFA through Hatch Projects # 1014753.

References (65)

1. Uludag-Demirer, S., Demirer, G.N., Frear, C., Chen, S.
   Anaerobic digestion of dairy manure with enhanced ammonia removal

2. Wilkie, A.C.
   Anaerobic digestion: biology and benefits

3. Speece, R.E.
   Anaerobic Biotechnology for Industrial Wastewaters
   Anaerobic biotechnology for industrial wastewaters
4. Holm-Nielsen, J.B., Al Seadi, T., Oleskowicz-Popiel, P.
The future of anaerobic digestion and biogas utilization
View at Publisher

5. Guo, J., Luo, Y., Lua, A.C., Chi, R.-a., Chen, Y.-l., Bao, X.-t., Xiang, S.-x.
Adsorption of hydrogen sulphide (H$_2$S) by activated carbons derived from oil-palm shell
View at Publisher

6. Kaparaju, P., Rintala, J.
Mitigation of greenhouse gas emissions by adopting anaerobic digestion technology on dairy, sow and pig farms in Finland
doi: 10.1016/j.renene.2010.05.016
View at Publisher

7. Hobson, P.N., Feilden, N.E.H.
Production and use of biogas in agriculture
doi: 10.1016/0360-1285(82)90017-X
View at Publisher

Characterisation of solid and liquid fractions of dairy manure with regard to their component distribution and methane production
doi: 10.1016/j.biortech.2006.04.032
View at Publisher

9. Güngör, K., Karthikeyan, K.G.
Phosphorus forms and extractability in dairy manure: A case study for Wisconsin on-farm anaerobic digesters
doi: 10.1016/j.biortech.2006.11.049
View at Publisher

10. MacConnell, C., Collins, H.
Utilization of re-processed anaerobically digested fiber from dairy manure as a container media substrate
2007

Approaches for adding value to anaerobically digested dairy fiber
doi: 10.1016/j.rser.2017.01.054
View at Publisher
12 Streube, J.D., Collins, H.P., Tarara, J.M., Cochran, R.L.
Biochar Produced from Anaerobically Digested Fiber Reduces Phosphorus in Dairy Lagoons
https://www.agronomy.org/publications/jeq/pdfs/41/4/1166
doi: 10.2134/jeq2011.0131
View at Publisher

13 Yao, Y., Gao, B., Inyang, M., Zimmerman, A.R., Cao, X., Pullamanappallil, P., Yang, L.
Biochar derived from anaerobically digested sugar beet tailings: Characterization and phosphate removal potential
doi: 10.1016/j.biortech.2011.03.006
View at Publisher

14 Soreanu, G., Béland, M., Falletta, P., Edmonson, K., Seto, P.
Laboratory pilot scale study for H₂S removal from biogas in an anoxic biotrickling filter
doi: 10.2166/wst.2008.023
View at Publisher

15 Kleerebezem, R., Mendez, R.
Autotrophic denitrification for combined hydrogen sulfide removal from biogas and post-denitrification.
View at Publisher

16 Nishimura, S., Yoda, M.
Removal of hydrogen sulfide from an anaerobic biogas using a big-scrubber
doi: 10.1016/S0273-1223(97)00542-8
View at Publisher

17 Zhao, Q., Leonhardt, E., MacConnell, C., Frear, C., Chen, S.
Purification Technologies for Biogas Generated by Anaerobic Digestion
Compressed Biomethane, CSANR

Efficacy of carbonaceous nanocomposites for sorbing ionizable antibiotic sulfamethazine from aqueous solution
www.elsevier.com/locate/watres
doi: 10.1016/j.watres.2016.03.014
View at Publisher
19 Sun, Y., Zhang, J.P., Wen, C., Zhang, L.  
An enhanced approach for biochar preparation using fluidized bed and its application for H_2S removal  
doi: 10.1016/j.cep.2016.02.006  
View at Publisher

20 Yao, Y., Gao, B., Inyang, M., Zimmerman, A.R., Cao, X., Pullammanappallil, P., Yang, L.  
Removal of phosphate from aqueous solution by biochar derived from anaerobically digested sugar beet tailings  
doi: 10.1016/j.jhazmat.2011.03.083  
View at Publisher

21 Sethupathi, S., Zhang, M., Rajapaksha, A.U., Lee, S.R., Nor, N.M., Mohamed, A.R., Al-Wabel, M., (...), Ok, Y.S.  
Biochars as potential adsorbers of CH_4, CO_2 and H_2S  
(Open Access)  
(2017) Sustainability (Switzerland), 9 (1), art. no. 121. Cited 16 times.  
http://www.mdpi.com/2071-1050/9/1/121/pdf  
doi: 10.3390/su9010121  
View at Publisher

22 Bagreev, A., Bandosz, T.J.  
A role of sodium hydroxide in the process of hydrogen sulfide adsorption/oxidation on caustic-impregnated activated carbons  
http://pubs.acs.org/journal/iecred  
doi: 10.1021/ie010599r  
View at Publisher

23 Yan, R., Liang, D.T., Tsen, L., Tay, J.H.  
Kinetics and mechanisms of H_2S adsorption by alkaline activated carbon  
doi: 10.1021/es0205840  
View at Publisher

24 Bagreev, A., Bashkova, S., Locke, D.G., Bandosz, T.J.  
Sewage sludge-derived materials as efficient adsorbents for removal of hydrogen sulfide  
doi: 10.1021/es001678h  
View at Publisher

25 Bagreev, A., Bandosz, T.J.  
On the mechanism of hydrogen sulfide removal from moist air on catalytic carbonaceous adsorbents  
View at Publisher

View at Publisher


View at Publisher


View at Publisher


View at Publisher


View at Publisher


View at Publisher


View at Publisher
Teater, C., Yue, Z., MacLellan, J., Liu, Y., Liao, W.  
Assessing solid digestate from anaerobic digestion as feedstock for ethanol production  
doi: 10.1016/j.biortech.2010.09.099  
View at Publisher

Streubel, J.D.  
Biochar: its Characterization and Utility for Recovering Phosphorus from Anaerobic Digested Dairy Effluent  
Washington State University

Shang, G., Shen, G., Liu, L., Chen, Q., Xu, Z.  
Kinetics and mechanisms of hydrogen sulfide adsorption by biochars  
www.elsevier.com/locate/biortech  
doi: 10.1016/j.biortech.2013.01.114  
View at Publisher

Latos, M., Karageorgos, P., Kalogerakis, N., Lazaridis, M.  
Dispersion of odorous gaseous compounds emitted from wastewater treatment plants  
doi: 10.1007/s11270-010-0508-8  
View at Publisher

Lee, E.Y., Lee, N.Y., Cho, K.-S., Ryu, H.W.  
Removal of hydrogen sulfide by sulfate-resistant Acidithiobacillus thiooxidans AZ11  
doi: 10.1263/jbb.101.309  
View at Publisher

Ferraz, G.P., Frear, C., Pelaez-Samaniego, M.R., Englund, K., Garcia-Perez, M.  
Hot water extraction of anaerobic digested dairy fiber for wood plastic composite manufacturing  

Soil interaction and fractionation of added cadmium in some Galician soils  
doi: 10.1016/j.microc.2013.08.003  
View at Publisher

Dubinin, M.M., Zaverina, E., Radushkevich, L.  
Sorption and structure of active carbons. I. Adsorption of organic vapors  

Dubinin, M.M., Radushkevich, L.  
Equation of the characteristic curve of activated charcoal  
Impact of combined acid washing and acid impregnation on the pyrolysis of Douglas fir wood

doi: 10.1016/j.jaap.2015.05.014

Hach, C.
(2014) *Molybdovanadate with Acid Persulfate Digestion Method* 1 Method 10127 1.0 to 100.0 mg/L PO43– (HR), 9.

Dada, A., Olalekan, A., Olatunya, A., Dada, O.
Langmuir, Freundlich, Temkin and Dubinin–Radushkevich isotherms studies of equilibrium sorption of Zn2+ unto phosphoric acid modified rice husk

Sheets, J.P., Yang, L., Ge, X., Wang, Z., Li, Y.
Beyond land application: Emerging technologies for the treatment and reuse of anaerobically digested agricultural and food waste (Open Access)
www.elsevier.com/locate/wasman
doi: 10.1016/j.wasman.2015.07.037

Smith, M.W., Pecha, B., Helms, G., Scudiero, L., Garcia-Perez, M.
Chemical and morphological evaluation of chars produced from primary biomass constituents: Cellulose, xylan, and lignin
http://www.journals.elsevier.com/biomass-and-bioenergy/
doi: 10.1016/j.biombioe.2017.05.015

Suliman, W., Harsh, J.B., Abu-Lail, N.I., Fortuna, A.-M., Dallmeyer, I., Garcia-Perez, M.
Influence of feedstock source and pyrolysis temperature on biochar bulk and surface properties
http://www.journals.elsevier.com/biomass-and-bioenergy/
doi: 10.1016/j.biombioe.2015.11.010

Shang, G., Li, Q., Liu, L., Chen, P., Huang, X.
Adsorption of hydrogen sulfide by biochars derived from pyrolysis of different agricultural/forestry wastes (Open Access)
http://www.tandfonline.com/loi/uawm20?
doi: 10.1080/10962247.2015.1094429

View at Publisher
49. Sadhwani, N., Adhikari, S., Eden, M.R.  
Biomass Gasification Using Carbon Dioxide: Effect of Temperature, CO₂/C Ratio, and the Study of Reactions Influencing the Process  
doi: 10.1021/ac504000 
View at Publisher

High graphite N content in nitrogen-doped graphene as an efficient metal-free catalyst for reduction of nitroarenes in water  
doi: 10.1039/c6gc00222f 
View at Publisher

51. Rivera-Utrilla, J., Sánchez-Polo, M.  
Ozonation of naphthalenesulphonic acid in the aqueous phase in the presence of basic activated carbons  
doi: 10.1021/la0487234 
View at Publisher

52. Sánchez-Polo, M., Von Gunten, U., Rivera-Utrilla, J.  
Efficiency of activated carbon to transform ozone into ·OH radicals: Influence of operational parameters  
doi: 10.1016/j.watres.2005.05.026 
View at Publisher

Transitional adsorption and partition of nonpolar and polar aromatic contaminants by biochars of pine needles with different pyrolytic temperatures  
doi: 10.1021/es8002684 
View at Publisher

54. Keiluweit, M., Nico, P.S., Johnson, M., Kleber, M.  
Dynamic molecular structure of plant biomass-derived black carbon (biochar)  
doi: 10.1021/es9031419 
View at Publisher

Characterization and influence of biochars on nitrous oxide emission from agricultural soil  
View at Publisher
<table>
<thead>
<tr>
<th></th>
<th>Authors</th>
<th>Title</th>
<th>Source</th>
<th>Cited Times</th>
<th>View at Publisher</th>
</tr>
</thead>
</table>
Engineered biochar reclaiming phosphate from aqueous solutions: Mechanisms and potential application as a slow-release fertilizer


Removal of arsenic, methylene blue, and phosphate by biochar/AIOOH nanocomposite