

GNE17-154 final report

References

1. New York State Department of Agriculture and Markets. 2017. New York State Dairy Statistics 2017 annual summary. NYS Agricultural Statistics Service, NYS Department of Agriculture and Markets, Division of Milk Control and Dairy Services, Albany, New York, 2.
2. Natural Resource Conservation Service.
https://www.nrcs.usda.gov/wps/portal/nrcs/detailfull/null/?cid=nrcs143_014154 (last accessed Oct 26, 2018)
3. Sustainable Agriculture Research and Education. <https://www.sare.org/Learning-Center/Books/Building-Soils-for-Better-Crops-3rd-Edition/Text-Version/Animal-Manures-for-Increasing-Organic-Matter-and-Supplying-Nutrients/Chemical-Characteristics-of-Manures>(last accessed Oct 26, 2018)
4. S. Department of Agriculture, NASS, 2014. 2014-2015 Agricultural Statistics Annual Bulletin New York. https://www.nass.usda.gov/Statistics_by_State/New_York/ (last accessed Oct 26, 2018)
5. Wightman, J.L., Woodbury P.B., 2016. New York dairy manure management greenhouse gas emissions and mitigation costs (1992–2022). *J. Environ. Qual.* 45, 266-275.
6. Scharf, P.C., Kitchen, N.R., Sudduth, K.A., Davis, J.G., 2006. Spatially variable corn yield is a weak predictor of optimal nitrogen rate. *Soil Sci. Soc. Am. J.* 70, 2154-2160.
7. DuPont Pioneer ‘Cost of Production Calculator’ 2017.
<https://www.pioneer.com/home/site/ca/agronomy/tools/production-cost-calculator/> (last accessed Oct 26, 2018)
8. Chen, D., Suter, H., Islam, A., Edis, R., Freney, J.R., Walker, C.N., 2008. Prospects of improving efficiency of fertiliser nitrogen in Australian agriculture: a review of enhanced efficiency fertilisers. *Soil Res.* 46, 289-301.
9. Van Meter, K.J., Basu, N.B., Van Cappellen, P., 2017. Two Centuries of Nitrogen Dynamics: Legacy Sources and Sinks in the Mississippi and Susquehanna River Basins. *Glob. Biogeochem. Cycles* 31(1), 2-23.
10. Møller, H.B., Lund, I., S.G., Sommer, 2000. Solid–liquid separation of livestock slurry: efficiency and cost. *Bioresource Technol.* 74, 223-229.
11. Burton, C.H., 2007. The potential contribution of separation technologies to the management of livestock manure. *Livest. Sci.* 112, 208-216.
12. Zhang, R.H., Westerman, P.W., 1997. Solid-liquid separation of annual manure for odor control and nutrient management. *Appl. Eng. Agric.* 13, 385-393.
13. Sakadevan, K., Nguyen, M.L., 2017. Chapter Four-Livestock Production and Its Impact on Nutrient Pollution and Greenhouse Gas Emissions. *Adv. Agron.* 141, 147-184.
14. VanderZaag, A., Baldé, H., Crolla, A., Gordon, R.J., Ngwabie, M., Wagner-Riddle, C., Desjardins, R., MacDonald, D., 2017 Potential Methane Emission Reductions for Two Manure Treatment Technologies. *Environ. Technol.* 1-22.
15. Lind, B.B., Ban, Z., Bydén, S., 2000. Nutrient recovery from human urine by struvite crystallization with ammonia adsorption on zeolite and wollastonite. *Bioresource Technol.* 73, 169-174.
16. Lefcourt, A.M., Meisinger, J.J., 2001. Effect of adding alum or zeolite to dairy slurry on ammonia volatilization and chemical composition. *J. Dairy Sci.* 84, 1814-1821.

17. Crini, G., Lichtfouse, E., Wilson, L.D., Morin-Crini, N., 2019. Conventional and non-conventional adsorbents for wastewater treatment. *Environ. Chem. Lett.* 17 (1), 195-213.
18. Subair, S., Fyles, J.W., O'Halloran, I.P., 1999. Ammonia volatilization from liquid hog manure amended with paper products in the laboratory. *Environ. Qual.* 28, 202-207.
19. Kirchmann, H., Witter, E., 1989. Ammonia volatilization during aerobic and anaerobic manure decomposition. *Plant Soil* 115, 35-41.
20. Lehmann, J., Joseph, S. eds., 2015. Biochar for environmental management: science, technology and implementation. Routledge.
21. Hollister, C.C., Bisogni, J.J., Lehmann, J., 2013. Ammonium, nitrate, and phosphate sorption to and solute leaching from biochars prepared from corn stover (*Zea mays* L.) and oak wood (*Quercus* spp.). *J. Environ. Qual.* 42 (1), 137-144.
22. Sarkhot, D.V., Ghezzehei, T.A., Berhe, A.A., 2013. Effectiveness of biochar for sorption of ammonium and phosphate from dairy effluent. *J. Environ. Qual.* 42 (5), 1545-1554.
23. Takaya, C.A., Fletcher, L.A., Singh, S., Anyikude, K.U., Ross, A.B., 2016. Phosphate and ammonium sorption capacity of biochar and hydrochar from different wastes. *Chemosphere* 145, 518-527.
24. Chen, B., Zhou, D., Zhu, L., 2008. Transitional adsorption and partition of nonpolar and polar aromatic contaminants by biochars of pine needles with different pyrolytic temperatures. *Environ. Sci. Technol.* 42 (14), 5137-5143
25. Lew, B., 2012. High surface area biochar negatively impacts herbicide efficacy. *Plant Soil* 353(1-2), 95-106.
26. , C.S., Lima, E.C., 2018. Removal of emerging contaminants from the environment by adsorption. *Ecotox. Environ. Saf.* 150, 1-17.
27. Enders, A., Hanley, K., Whitman, T., Joseph, S., Lehmann, J., 2012. Characterization of biochars to evaluate recalcitrance and agronomic performance. *Bioresource Technol.* 114, 644-653.
28. Zhao, L., Cao, X., Mašek, O., Zimmerman, A., 2013. Heterogeneity of biochar properties as a function of feedstock sources and production temperatures. *J. Hazard. Mat.* 256, 1-9.
29. Wang, B., Lehmann, J., Hanley, K., Hestrin, R., Enders, A., 2016. Ammonium retention by oxidized biochars produced at different pyrolysis temperatures and residence times. *RSC Adv.* 6 (48), 41907-41913.
30. Vikrant, K., Kim, K.H., Ok, Y.S., Tsang, D.C., Tsang, Y.F., Giri, B.S., Singh, R.S., 2018. Engineered/designer biochar for the removal of phosphate in water and wastewater. *Sci. Tot. Environ.* 616, 1242-1260.
31. Tan, X., Liu, Y., Zeng, G., Wang, X., Hu, X., Gu, Y., Yang, Z., 2015. Application of biochar for the removal of pollutants from aqueous solutions. *Chemosphere*, 125, 70-85.
32. Hestrin, R., Torres-Rojas, D., Dynes, J.J., Hook, J.M., Regier, T.Z., Gillespie, A.W., Smernik, R.J., Lehmann, J., 2019. Fire-derived organic matter retains ammonia through covalent bond formation. *Nat. Comm.* 10.
33. Taghizadeh-Toosi A., T.J. Clough, R.R. Sherlock, Condron, L.M., 2012a. Biochar adsorbed ammonia is bioavailable. *Plant Soil* 350, 57-69.
34. Taghizadeh-Toosi A., T.J. Clough, R.R. Sherlock, Condron, L.M., 2012b. A wood based low-temperature biochar captures NH₃-N generated from ruminant urine-N, retaining its bioavailability. *Plant Soil* 353, 73-84.

35. Mandal, S., Thangarajan, R., Bolan, N.S., Sarkar, B., Khan, N., Ok, Y.S., Naidu, R., 2016. Biochar-induced concomitant decrease in ammonia volatilization and increase in nitrogen use efficiency by wheat. *Chemosphere* 142, 120-127.
36. Mohan, D., Sarswat, A., Ok, Y.S., Pittman Jr, C.U., 2014. Organic and inorganic contaminants removal from water with biochar, a renewable, low cost and sustainable adsorbent—a critical review. *Bioresource Technol.* 160, 191-202.
37. Shaaban, M., Van Zwieten, L., Bashir, S., Younas, A., Nunez-Delgado, A., Chhajro, M.A., Kubar, K.A., Ali, U., Rana, M.S., Mehmood, M.A., Hu, R., 2018. A concise review of biochar application to agricultural soils to improve soil conditions and fight pollution. *J. Environ. Manag.* 228, 429-440.
38. Novak, J.M., Johnson, M.G. eds., 2019. Elemental and spectroscopic characterization of low-temperature (350°C) lignocellulosic-and manure-based designer biochars and their use as soil amendments. In *Biochar from Biomass and Waste* Elsevier (37-58).
39. Pelaez-Samaniego, M.R., Hummel, R.L., Liao, W., Ma, J., Jensen, J., Kruger, C., Frear, C., 2017. Approaches for adding value to anaerobically digested dairy fiber. *Renew. Sustain. Energy Rev.* 72, 254-268.
40. Jassal, R.S., Johnson, M.S., Molodovskaya, M., Black, T.A., Jollymore, A., Sveinson, K., 2015. Nitrogen enrichment potential of biochar in relation to pyrolysis temperature and feedstock quality. *J. Environ. Qual.* 152, 140-144.
41. Streubel, J.D., Collins, H.P., Tarara, J.M., Cochran, R.L., 2012. Biochar produced from anaerobically digested fiber reduces phosphorus in dairy lagoons. *J. Environ. Qual.* 41 (4), 1166-1174.
42. Xu, X., Cao, X., Zhao, L., 2013. Comparison of rice husk-and dairy manure-derived biochars for simultaneously removing heavy metals from aqueous solutions: role of mineral components in biochars. *Chemosphere* 92 (8), 955-961.
43. Hale, S.E., Alling, V., Martinsen, V., Mulder, J., Breedveld, G.D., Cornelissen, G., 2013. The sorption and desorption of phosphate-P, ammonium-N and nitrate-N in cacao shell and corn cob biochars. *Chemosphere* 91, 1612-1619.
44. Petit, C., Seredysh, M., Bandosz, T.J., 2009. Revisiting the chemistry of graphite oxides and its effect on ammonia adsorption. *Mat. Chem.* 19, 9176-9185.
45. Esfandbod, M., Phillips, I.R., Miller, B., Rashti, M.R., Lan, Z.M., Srivastava, P., Singh, B., Chen, C.R., 2017. Aged acidic biochar increases nitrogen retention and decreases ammonia volatilization in alkaline bauxite residue sand. *Eng.* 98, 157-165.
46. Van Humbeck, J.F., McDonald, T.M., Jing, X., Wiers, B.M., Zhu, G., Long, J.R., 2014. Ammonia capture in porous organic polymers densely functionalized with Brønsted acid groups. *Am. Chem. Soc.* 136, 2432-2440.
47. Shen, W., Fan, W., 2013. Nitrogen-containing porous carbons: synthesis and application. *Mat. Chem. A*, 1, 999-1013.
48. Shafeeyan, M.S., Daud, W.M.A.W., Houshmand, A., Arami-Niya, A., 2011. Ammonia modification of activated carbon to enhance carbon dioxide adsorption: effect of pre-oxidation. *Surf. Sci.* 257, 3936-3942.
49. Yeh, J.T., Resnik, K.P., Rygle, K., Pennline, H.W., 2005. Semi-batch absorption and regeneration studies for CO₂ capture by aqueous ammonia. *Fuel Process. Technol.* 86, 1533-1546.

50. Dutcher, B., Fan, M., Russell, A.G., 2015. Amine-Based CO₂ Capture Technology Development from the Beginning of 2013: A Review. *ACS Appl. Mat. Interfaces* 7, 2137-2148.
51. McLeod, A., Jefferson, B., McAdam, E.J., 2014. Biogas upgrading by chemical absorption using ammonia rich absorbents derived from wastewater. *Water Res.* 67, 175-186.
52. Thornton, T., Hajj, L., Massengill, K., Koch, S., Armstrong, L., 2015. Y Zeolite Reference Material Booklet, 004-16844-02., Micromeritics, Norcross, GA.
53. Serna-Guerrero, R., Sayari, A., 2010. Modeling adsorption of CO₂ on amine-functionalized mesoporous silica. 2: Kinetics and breakthrough curves. *Chem. Eng. J.* 161 (1-2), 182-190.
54. Shafeeyan, M. S.. Daud, W. M. A. W.. Shamiri, A., Aghamohammadi, N., 2015. Modeling of carbon dioxide adsorption onto ammonia-modified activated carbon: kinetic analysis and breakthrough behavior. *Energy Fuels* 29 (10), 6565-6577.
55. R Core Team, 2017. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL <https://www.R-project.org/> (accessed January 2016).
56. Coates, J, 2000. Interpretation of infrared spectra, a practical approach. *Encycl. Anal. Chem.*
57. Biesinger, M. C., 2018. XPS fitting. xpsfitting.com
58. Cheng, C. H., Lehmann, J., Thies, J. E., Burton, S. D., Engelhard, M. H., 2006. Oxidation of black carbon by biotic and abiotic processes. *Org. Geochem.* 37 (11), 1477-1488.
59. Graf, N., Yegen, E., Gross, T., Lippitz, A., Weigel, W., Krakert, S., Terfort, A., Unger, W. E., 2009. XPS and NEXAFS studies of aliphatic and aromatic amine species on functionalized surfaces. *Surf. Sci.* 603 (18), 2849-2860.
60. Rouxhet, P. G., 2011. Genet, M. J. XPS analysis of bio-organic systems. *Surf. Interface Anal.* 43 (12), 1453-1470.
61. Mulch & Soil Council, 2018. http://mulchandsoilcouncil.org/pdf/Standards/MSC_Grow_Tests.pdf (last accessed January, 2019)
62. Wickham, H., 2009. ggplot2: Elegant graphics for data analysis. Springer-Verlag New York. <http://ggplot2.org>
63. Lenth R.V., 2016. Least-squares means: the R Package lsmeans. *J. Stat. Soft.* 69, 1-33.
64. Graves, S., Piepho, H.P., Selzer, L., Dorai-Raj, S., 2012. multcompView: visualizations of paired comparisons. R package version 0.1-5, URL <http://CRAN.R-project.org/package=multcompView>.
65. Fujiki, J., Yogo, K., 2016. The increased CO₂ adsorption performance of chitosan-derived activated carbons with nitrogen-doping. *Chem. Commun.* 52 (1), 186-189.
66. Giles, C. H., MacEwan, T. H., Nakhwa, S. N., Smith, D., 1960. Studies in adsorption. Part XI. A system of classification of solution adsorption isotherms, and its use in diagnosis of adsorption mechanisms and in measurement of specific surface areas of solids. *J. Chem. Soc. (resumed)* 786, 3973-3993.
67. Merlin, N., Nogueira, B. A., Lima, V. A. D., Santos, L. M. D., 2014. Application of fourier transform infrared spectroscopy, chemical and chemometrics analyses to the characterization of agro-industrial waste. *Química Nova* 37 (10), 1584-1588.

68. Carballo, T., Gil, M. V., Gómez, X., González-Andrés, F., Morán, A., 2008. Characterization of different compost extracts using Fourier-transform infrared spectroscopy (FTIR) and thermal analysis. *Biodegradation* 19 (6), 815-830.
69. Chen, B., Zhou, D., Zhu, L., 2008. Transitional adsorption and partition of nonpolar and polar aromatic contaminants by biochars of pine needles with different pyrolytic temperatures. *Environ. Sci. Technol.* 42 (14), 5137-5143.
70. Chakraborty, A. K., Bischoff, K. B., Astarita, G., Damewood, J. R., 1988. Molecular orbital approach to substituent effects in amine-CO₂. *J. Am. Chem. Soc.* 110 (21), 6947-6954.
71. Lim, G., Lee, K. B., Ham, H. C., 2007. Effect of N-containing functional groups on CO₂ adsorption of carbonaceous materials: A density functional theory approach. *J. Phys. Chem C* 120 (15), 8087-8095.
72. Barin, G., Peterson, G. W., Crocella, V., Xu, J., Colwell, K. A., Nandy, A., Reimer, J. A., Bordiga, S., Long, J. R., 2017. Highly effective ammonia removal in a series of Brønsted acidic porous polymers: investigation of chemical and structural variations. *Chem. Sci.* 8 (6), 4399-4409.
73. Lee, J. W., Barin, G., Peterson, G. W., Xu, J., Colwell, K. A., Long, J. R.. 2017. A microporous amic acid polymer for enhanced ammonia capture. *ACS Appl. Mat. Interfaces* 9 (39), 33504-33510.
74. Kortunov, P. V., Siskin, M., Baugh, L. S., Calabro, D. C., 2015a. In situ nuclear magnetic resonance mechanistic studies of carbon dioxide reactions with liquid amines in aqueous systems: New insights on carbon capture reaction pathways. *Energy Fuels* 29 (9), 5919-5939.
75. Kortunov, P. V., Baugh, L. S., Siskin, M., Calabro, D. C., 2015b. In situ nuclear magnetic resonance mechanistic studies of carbon dioxide reactions with liquid amines in mixed base systems: The interplay of Lewis and Brønsted basicities. *Energy Fuels* 29 (9), 5967-5989.
76. McDonald, T. M., Mason, J. A., Kong, X., Bloch, E. D., Gygi, D., Dani, A., Crocella, V., Giordanino, F., Odoh, S. O., Drisdell, W. S., Vlaisavljevich, B., 2015. Cooperative insertion of CO₂ in diamine-appended metal-organic frameworks. *Nat.* 519 (7543), 303.
77. Flaig, R. W., Osborn Popp, T. M., Fracaroli, A. M., Kapustin, E. A., Kalmutzki, M. J., Altamimi, R. M., Fathieh, F., Reimer, J. A., Yaghi, O. M., 2017. The chemistry of CO₂ capture in an amine-functionalized metal-organic framework under dry and humid conditions. *J. Am. Chem. Soc.* 139 (35), 12125-12128.
78. Hahn, M. W., Jelic, J., Berger, E., Reuter, K., Jentys, A., Lercher, J. A., 2016. Role of amine functionality for CO₂ chemisorption on silica. *J. Phys. Chem. B* 120 (8) 1988-1995.
79. Lee, J. J., Chen, C. H., Shimon, D., Hayes, S. E., Sievers, C., Jones, C. W., 2017. Effect of humidity on the CO₂ adsorption of tertiary amine grafted SBA-15. *J. Phys. Chem. C* 121 (42), 23480-23487.
80. Xiao, M., Liu, H., Idem, R., Tontiwachwuthikul, P., Liang, Z., 2016. A study of structure-activity relationships of commercial tertiary amines for post-combustion CO₂. *Appl. Energy* 184, 219-229.
81. Chen, C. H., Shimon, D., Lee, J. J., Mentink-Vigier, F., Hung, I., Sievers, C., Jones, C. W., Hayes, S. E., 2018. The “missing” bicarbonate in CO₂ chemisorption reactions on solid amine sorbents. *J. Am. Chem. Soc.* 140 (28), 8648-8651.

82. Cormack, A. N., Du, J., Zeitler, T. R. 2002. Alkali ion migration mechanisms in silicate glasses probed by molecular dynamics simulations. *Phys. Chem. Chem. Phys.* 4 (14), 3193-319.
83. Chin, A., Schmidt, S., Buckley, S., Pirie, R., Redding, M., Laycock, B., Luckman, P., Batstone, D.J., Robinson, N., Brackin, R., 2018. Sorbents can tailor nitrogen release from organic wastes to match the uptake capacity of crops. *Sci. Tot. Environ.* 645, 1474-1483.
84. Burns, R.G., Pukite, A.H., McLaren, A.D., 1972. Concerning the Location and Persistence of Soil Urease 1. *Soil Sci. Soc. of Am. J.* 36 (2), 308-311.
85. Cela, S., Ketterings, Q.M., Soberon, M., Rasmussen, C., Czymbek, K.J., 2017. Upper Susquehanna watershed and New York State improvements in nitrogen and phosphorus mass balances of dairy farms. *J. Soil Water Conserv.* 72 (1), 1-11.
86. Wang, B., Lehmann, J., Hanley, K., Hestrin, R., Enders, A., 2015. Adsorption and desorption of ammonium by maple wood biochar as a function of oxidation and pH. *Chemosphere* 138 120-126.
87. Mia, S., Singh, B., Dijkstra, F.A., 2019. Chemically oxidized biochar increases ammonium-15 N recovery and phosphorus uptake in a grassland. *Biol. Fert. Soils* 1-12.
88. Hartz, T.K., Mitchell, J.P., Giannini, C., 2000. Nitrogen and carbon mineralization dynamics of manures and composts. *Hort Sci.* 35 (2), 209-212.
89. Pettygrove, G.S., Doane, T.A., Horwath, W.R., Wu, J.J., Mathews, M.C., Meyer, D.M., 2003, March. Mineralization of nitrogen in dairy manure water. In Western Nutrient Management Conference 5, 34-41.
90. Grunert, O., Reheul, D., Van Labeke, M.C., Perneel, M., Hernandez-Sanabria, E., Vlaeminck, S.E., Boon, N., 2016. Growing media constituents determine the microbial nitrogen conversions in organic growing media for horticulture. *Microb. Biotechnol.* 9 (3), 389-399.
91. org, 2019. Provides information on fertilizers to public and private sector. [http://https://africafertilizer.org/](https://africafertilizer.org/) (accessed July 2019)
92. Krounbi, L., Enders, A., van Es, H., Woolf, D., van Herzen, B., Lehmann, J., 2019. Biological and thermochemical conversion of human solid waste to soil amendments. *Waste Manage.* 89, 366-378.