

MIDWESTBIOCHAR CONFERENCE

June 14, 2013 - Champaign, Illinois



ILLINOIS SUSTAINABLE
TECHNOLOGY CENTER
PRAIRIE RESEARCH INSTITUTE



2013 Midwest Biochar Conference
June 14, 2013

Chancellor Ballroom and Alma Mater and Lincoln Rooms
I Hotel and Conference Center
Champaign, Illinois

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**ILLINOIS SUSTAINABLE
TECHNOLOGY CENTER**
PRAIRIE RESEARCH INSTITUTE



AGENDA

Friday, June 14

- 8:30 a.m. Registration – outside the Chancellor Ballroom
8:30 a.m. Tour of ISTC Laboratories – meet at the Registration Table
8:30 - 9:30 a.m. Continental Breakfast – Chancellor Ballroom
- 9:30 a.m. Welcome – Chancellor Ballroom
9:45 a.m. Keynote Speaker
10:30 a.m. Oral Presentations
- 11:30 a.m. Lunch and Networking
12:30 p.m. Tour of ISTC Laboratories – meet at the Registration Table
- 1:15 p.m. Oral Presentations resume with two sessions
Session A – Alma Mater Room
Session B – Lincoln Room
- 2:35 p.m. Break – Chancellor Ballroom
- 3:00 p.m. Oral Presentations resume with two sessions
Session A – Alma Mater Room
Session B – Lincoln Room
- 4:20 p.m. Closing Remarks

Reception, Poster Session, and Tour

- 4:30 – 6:00 p.m. Reception in the Chancellor Ballroom with a poster session from 4:30 to 5:30 p.m.
5:30 p.m. Tour of ISTC Laboratories – meet at the Registration Table

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AGENDA

Friday, June 14

- 8:30 a.m.** **Registration** – outside the Chancellor Ballroom
8:30 a.m. **Tour of ISTC Laboratories** – meet at the Registration Table
8:30 - 9:30 a.m. **Continental Breakfast** – Chancellor Ballroom

Chancellor Ballroom

- 9:30 a.m.** **Welcome:** Nancy Holm - Assistant Director, ISTC & Coordinator of IBG;
Kurt Spokas - Research Soil Scientist, USDA-ARS, St. Paul, MN; and Steve
Peterson - Research Chemist, USDA-ARS, Peoria, IL
9:45 a.m. **Keynote Speaker:** Thomas Klasson - Research Leader, USDA-ARS, New
Orleans, LA; Title: *Biochar, soil, pyrolysis, carbon, and more*

Morning Session

Moderator: Nancy Holm

- 10:30 a.m.** Steve Peterson Comparison of TLUD and atmospherically-controlled
retort methods of preparing biochar using corn stover
and wheat straw feedstocks
10:50 a.m. Kurt Spokas Biochar: The field experience
11:10 a.m. Steve Vaughn Comparison of pelletized biochar derived from two
source materials as replacements for peat in potting
substrates
11:30 a.m. **Lunch and Networking**
12:30 p.m. **Tour of ISTC Laboratory** – meet at the Registration Table

Afternoon Session A – Alma Mater Room; Moderator: Kurt Spokas

- 1:15 p.m.** M. R. Bayan Biochar effects on soybean growth and nodulation
1:35 p.m. Nick Christians Physical and mineral-nutrition properties of sand-based
turfgrass root zones amended with biochar
1:55 p.m. Rajesh Chintala Nitrate retention and release by biochars produced
from fast pyrolysis
2:15 p.m. Eric Nooker Uptake of PAH compounds by specialty crops grown in
biochar-amended soils

Afternoon Session B – Lincoln Room; Moderator: Steve Peterson

- 1:15 p.m.** Edward Colosky A survey of biochars: Interactions with dissolved
ammonia, nitrate, and phosphate
1:35 p.m. Paul Anderson Affordable biochar production options: Small
cookstoves, medium barrels, and some large devices
1:55 p.m. Junhua Jiang Progress on biochar supercapacitors
2:15 p.m. Hong Jin Carbon materials from DDGS for supercapacitor and
improvement of capacitance with H₂O₂ surface
modification

2:35 p.m. **Break – Chancellor Ballroom**

Afternoon Session A – Alma Mater Room; Moderator: Kurt Spokas

- 3:00 p.m.** Bala Yamini Sadasivam Adsorption kinetics of methane on various types of biochars
- 3:20 p.m.** Duane Friend Biochar application in low organic matter soils
- 3:40 p.m.** M. R. Bayan Long term effects of biochar on select soil enzyme activities
- 4:00 p.m.** Erin Yargicoglu Enhanced microbial methane oxidation in biochar-amended landfill cover soils

Afternoon Session B – Lincoln Room; Moderator: Steve Peterson

- 3:00 p.m.** Thomas Holm Sorption of polycyclic aromatic hydrocarbons (PAHs) to biochar and potential PAH bioavailability
- 3:20 p.m.** Tao Xie Nutrients recovery from artificial urine through struvite crystallization and biochar adsorption
- 3:40 p.m.** Chung-Ho Lin Utilizing biochar for the development of carbon-based biocatalyst
- 4:00 p.m.** Joseph Polin Upgrading biochar into activated carbon materials through physical activation

4:20 p.m. **Closing Remarks**

Reception, Poster Session, and Tour

- 4:30 – 6:00 p.m.** **Reception in the Chancellor Ballroom with a poster session from 4:30 to 5:30 p.m.**
- 5:30 p.m.** **Tour of ISTC Laboratory – meet at the Registration Table**

ABSTRACTS

Keynote Speaker

Thomas Klasson - Research Leader at the USDA-ARS in New Orleans, LA;

thomas.klasson@ars.usda.gov

Biochar, soil, pyrolysis, carbon, and more

In just a few years, the number of scientific journal articles using the biochar term have grown exponentially. In this presentation we explore what type of articles has been published and what we have learned about biochar. And in the end we will discuss what advantages, opportunities, and challenges that lay ahead.

Morning Session

Steve Peterson - Research Chemist at the USDA-ARS in Peoria, IL;

Steve.Peterson@ars.usda.gov.

Comparison of TLUD and atmospherically-controlled retort methods for preparing biochar using corn stover and wheat straw feedstocks

Biochar is a very versatile and useful material in many applications beyond carbon sequestration in soils. Rubber composite filler, sorptive media for toxic aqueous components, and peat moss replacement are all examples of biochar applications we have studied at our laboratory. We have two means of producing biochar, the first is by utilizing a top-lit updraft stove, and the second method uses a retort oven under nitrogen to pyrolyze the feedstock into biochar. In this study, we took three different feedstocks (pelletized wheat straw with and without glycerin, and corn stover) and produced biochar using both the TLUD stove (one temperature) and the retort oven (400°, 500°, 600°, and 700°C). These biochar samples were then compared in terms of surface area, density, elemental analysis, and several other physical and chemical characterization methods. Trends in the final biochar properties as a function of the production methods will be discussed in terms of what final properties are desired for each specific end-use application.

Kurt Spokas - Research Soil Scientist at the USDA-ARS in St. Paul, MN;

kurt.spokas@ars.usda.gov.

Biochar: The field experience

Even though the amendment was not called biochar, we have been utilizing the solid residues from biomass pyrolysis as a soil fertilizer agent for at least the 300 years of our modern science record. This presentation will summarize the major historic factors limiting biochar's use in agriculture. In addition, a summary will be given of the USDA-ARS Rosemount, MN biochar research plots, where greenhouse gas fluxes, soil fertility, and crop yield have been monitored for eight different biochar types. Some of these plots have been active for four years under continuous corn to examine the impact of various biochar additions to a productive Upper Midwest soil.

Steve Vaughn - Plant Physiologist at the USDA-ARS in Peoria, IL;

steven.vaughn@ars.usda.gov.

Comparison of pelletized biochar derived from two source materials as replacements for peat in potting substrates

Soiless substrates are primarily used in the production of containerized greenhouse and nursery crops, with sphagnum peat moss being a primary constituent of most substrates. We are examining biochars for several horticultural applications, including as peat moss

replacements. Biochar was prepared from pelletized wheat straw at our laboratory, while biochar produced from recycled wood pallets was obtained from Chip Energy, Goodfield, IL. Increasing levels of biochars (5, 10, and 15% v/v) had variable effects on substrate physical properties (pH, bulk density, air porosity, container capacity, and total porosity). Greenhouse experiments were conducted using tomato (*Solanum lycopersicum* L.) and marigold (*Tagetes erecta* L.) plants grown in 3.0-L pots. No differences were found in tomato dry weights after 4 weeks growth, but plant heights were greater in several biochar treatments. Marigold plants grown in 10% pelletized straw had greater dry weights than controls, and plants heights were greater than the control in all but the 5% wood biochar. These results indicate that both pelletized biochars would be suitable replacements for peat in soilless substrates.

Afternoon Session A

M. R. Bayan - Assistant Professor, Department of Agriculture & Environmental Sciences at Lincoln University in Jefferson City, MO; bayanr@lincolnu.edu.

Biochar effects on soybean growth and nodulation

Soybean (*Glycine max*) was grown in a greenhouse experiment using an Entisol. Pots contained 5 kg of soil and were fertilized with (0-85-90 kg/ha) prior to plantation. Plants were thinned at stage VC to one per pot. Treatments consisted of biochar, 2% and 5% by weight, mixed with soil after passing through 1 cm sieve. Biochar was produced from three feedstocks, a ligneous, pine (*Pinus strobes*), and two herbaceous, switchgrass (*Panicum virgatum*) and miscanthus (*Miscanthus giganteus*). Growth was significantly enhanced by 2% biochar. At 5%, biochar caused stunting that was significant in the case of switchgrass biochar. Biochar increased leaf area more significantly at the 2% rate. Biochar significantly increased pod formation at stage R4, increasing number and total weight of pods. The effect of biochar on nodulation varied; pine biochar increased while herbaceous biochars reduced nodulation. Switchgrass biochar (5%) decreased nodulation by 54% while pine biochar (2%) increased nodule formation by 35% over the control.

Nick Christians – Professor, Department of Horticulture at Iowa State University in Ames, IA; nchris@iastate.edu.

Physical and mineral-nutrition properties of sand-based turfgrass root zones amended with biochar

Sand-based turfgrass root zones have limited nutrient retention and water-holding capacity. Peat moss often is used to offset these deficiencies, but peat moss decomposes. The objective of this research was to evaluate the efficacy of biochar as a sand-based root zone amendment. Water retention, water infiltration, bentgrass rooting depth, and nutrient evaluation experiments were conducted on six sand and biochar root zone mixtures. At field capacity, sand-based media containing 25% biochar retained 260 and 370% more water compared to media containing 5% biochar and a pure sand control, respectively. Saturated hydraulic conductivity (K_{sat}) of the root zones decreased as biochar concentrations increased. The rooting depth of bentgrass was reduced up to 46% at biochar concentrations greater than 10%. Leachate electrical conductivity and dissolved total organic carbon increased as biochar concentrations increased. Nitrogen leaching was reduced as biochar concentrations increased. According to the results, biochar may improve water storage, reduce overall water use, and decrease nitrogen fertilizer applications in sand-based turfgrass ecosystems.

Rajesh Chintala - Research Associate, Department of Plant Science at South Dakota State University, Brookings, SD; Rajesh.chintala@sdsstate.edu.

Nitrate retention and release by biochars produced from fast pyrolysis

Agricultural activities have been implicated as a major source of nutrient ions such as nitrate to surface and ground water resources. There is a need to control the nitrate movement in soil to sustain soil and water quality. Batch experiments were conducted to evaluate the nitrate sorption potential and release by non-activated and activated biochars produced from microwave pyrolysis using selected biomass feedstocks of corn stover (*Zea mays* L.), Ponderosa pine wood residue (*Pinus ponderosa* Lawson and C. Lawson), and switchgrass (*Panicum virgatum* L.). Surface characteristics including surface area and net surface charge have shown significant effects on nitrate sorption in biochars. Freundlich isotherms performed well to fit the nitrate sorption data of biochars. The first order model fit the nitrate desorption kinetics of biochars with a high coefficient of determination.

Eric Nooker - Graduate Research Assistant, Department of Soil, Water, and Climate at the University of Minnesota-Twin Cities; Nooke001@umn.edu.

Uptake of PAH compounds by specialty crops grown in biochar amended soils

Previous studies illustrated that biochars have sorbed polycyclic aromatic hydrocarbon (PAH) compounds as well as other organic compounds that could be of potential health concern. The PAH contents of biochars have been highly variable, with no clear understanding of ways to reduce their presence. Sorption of PAH compounds by biochar has been assumed to be strong, and due to limited water solubility, the potential of uptake by specialty crops grown in biochar amended soils were thought to be low. However, in this study, while sorption is still low, the potential exists for uptake and bioaccumulation of the PAH compounds by specialty crops. The uptake of PAH compounds from biochar appears to be controlled by (1) the plant species; (2) the PAH content of the biochar and the original soil; and (3) the native soil organic content.

Bala Yamini Sadasivam - Graduate Student, Geotechnical & Geoenvironmental Engineering Laboratory at the University of Illinois at Chicago; bsadas2@uic.edu.

Adsorption kinetics of methane on various types of biochars

Cover soil system can partially remove landfill methane by the oxidation properties of methanotrophic bacteria. Amendment of the cover soils with biochar has great potential to enhance the methane oxidation. The physical-chemical properties of biochars are highly dependent on some important variables such as feedstock and production process. This study aims to investigate adsorption kinetics of methane of biochars as a function of their respective feedstock and production process. Physical-chemical characterization tests were conducted on six different biochars and batch adsorption kinetic tests were conducted in order to determine the rate of adsorption and maximum adsorption capacity of the biochars. Results from this study demonstrated that the methane adsorption mechanisms varied with biochar characteristics.

Duane Friend - Extension Educator, Environmental Stewardship and Energy at the University of Illinois at Urbana-Champaign; friend@illinois.edu.

Biochar application in low organic matter soils

A biochar field study on three low organic matter soils was initiated in Illinois in 2012. Sites in Mason, Cass, and Calhoun counties were used. Soil organic matter at all sites ranged from approximately 0.5 to 2%. Rates of 0, 10, and 20 tons per acre of biochar were

examined with corn in replicated plots. Normal fertilizer and herbicide applications were employed. Biochar from wood pellets were used. Soil tests were conducted before biochar application and at the end of crop season. Due to extreme weather experienced during the 2012 growing season, yields were dramatically reduced in all plots. While there may have been a slight average increase in corn yield in biochar plots, there was too much variation to be statistically significant. Soil organic matter levels were increased but cation exchange capacity measurements were not greatly changed. The study is continuing in 2013.

M. R. Bayan - Assistant Professor, Department of Agriculture & Environmental Sciences at Lincoln University in Jefferson City, MO; bayanr@lincolnu.edu.

Long term effects of biochar on select soil enzyme activities

A greenhouse experiment was carried out to test the effect of biochar on select soil enzyme activities, acid- and alkaline-phosphatase, arylamidase, and β -glucosidase. Biochar was produced through slow pyrolysis from a ligneous, pine (*Pinus strobus*) and an herbaceous, switchgrass (*Panicum virgatum*) feedstock. Soybean (*Glycine max*) was grown in pots with 5 kg Entisol, fertilized at 0-85-90 kg/ha prior to plantation. Seeds were thinned at stage VC to one per pot. Treatments were: No Biochar/No Plants, No Biochar, and 2 and 5% Biochar of pine and miscanthus. Soil samples were taken after 1-day, 3-days, 10-days, 30-days, and 60-days. Enzyme activities increased during the course of study. Acid phosphatase activities were not affected by the present of biochar. The 5% Miscanthus biochar, however, had an inhibitory but insignificant effect on acid phosphatase activity. Biochar did not have any effect on the activity of alkaline phosphatase or β -glucosidase. The Miscanthus biochar initially increased the arylamidase activities but subsided after ten days.

Erin Yargicoglu - Graduate Research Assistant, Department of Earth and Environmental Sciences at the University of Illinois at Chicago; eyargi2@uic.edu.

Enhanced microbial methane oxidation in biochar-amended landfill cover soils

Landfill gas is the third largest worldwide source of anthropogenic methane, an important greenhouse gas. Biochar amendments to landfill cover soils are proposed as an economic solution to reduce methane emissions from landfills without gas recovery systems, or in conjunction with gas recovery for near-complete methane removal in new landfills. Biochar's high porosity, surface area, and organic content allow it to readily adsorb methane, while providing pore spaces and nutrients for microorganisms, promoting methanotrophic growth. Column and batch incubation experiments were used to simulate the effects of biochar amendments to landfill cover soils and determine kinetic parameters of methane oxidation, respectively. The qPCR of DNA extracted from the column soil targeting the pmoA (particulate methane monooxygenase) gene indicates higher abundance of methanotrophs in the biochar-amended column, supporting the observed higher rates of methane oxidation compared to soil alone. Initial results indicate that biochar is effective in increasing methanotroph populations and promoting methane oxidation.

Afternoon Session B

Edward Colosky - Research Assistant, Department of Soil, Water, and Climate at the University of Minnesota-Twin Cities; Colos009@umn.edu.

A survey of biochars: Interactions with dissolved ammonia, nitrate, and phosphate

Previous biochar (BC) studies indicate that BC-amended soils increases crop production through an interaction with in-soil nutrients such as nitrogen (N) and phosphorus (P). Observed affects include decreasing N leachate and removing P from liquid solution. No

study as of yet has systematically surveyed BCs from various production and parent materials. Results of a BC assessment study may lead to a better understanding of the mechanism by which BC enhances soil quality and how BC can be used in engineered systems. Our study examined the ammonia (NH_3), nitrate (NO_3) and phosphate (PO_4) sorption potentials of 30+ BCs produced from different production processes and parent materials. We performed batch equilibrium sorption experiments, where BCs were submerged in NH_3 , NO_3 , and PO_4 solutions. Results indicate that each BC is different in chemical interactions with in-solution NH_3 , NO_3 , and/or PO_4 .

Paul Anderson – Vice President of Chip Energy, Inc. in Goodfield, IL; psanders@ilstu.edu.
Affordable biochar production options: Small cookstoves, medium barrels, and some large devices

A wide range of low-cost devices and methods for producing biochar are presented, along with the pros and cons of each device. Several devices will be shown (but not ignited). Attention is given to the costs of the devices and the costs of operation. For some devices, construction plan sources are provided.

Junhua Jiang - Senior Research Engineer at the Illinois Sustainable Technology Center, a division of the Prairie Research Institute at the University of Illinois at Urbana-Champaign; junhua@illinois.edu.

Progress on biochar supercapacitors

Ultracapacitors (also known as supercapacitors or electric double-layer capacitors) store electricity physically by polarizing an electrolytic solution to store energy electro-statically. This mechanism is highly reversible, and allows them to be charged and discharged hundreds of thousands of times. They are very efficient in capturing electricity from regenerative braking and deliver power that enables rapid acceleration in vehicles. Supercapacitors are therefore experiencing rapid annual growth for electric vehicles and energy storage station applications. Decreasing the cost and further improving the capacity of supercapacitors will boost their large-scale deployment. Researchers at the Illinois Sustainable Technology Center have systematically investigated a wide range of biochar as supercapacitor electrodes using surface characterizations and electrochemical techniques. They have successfully demonstrated their high performance and high durability at both half-cell and single-cell levels. Their progress suggests that biochar supercapacitors could be a promising technology.

Hong Jin - Graduate Student, Department of Agricultural & Biosystems Engineering at South Dakota State University in Brookings, SD; hong.jin@sdsu.edu.

Carbon materials from DDGS for supercapacitor and improvement of capacitance with H_2O_2 Surface modification

Biochar from DDGS, a co-product, which was produced by thermochemically processing designed for maximum bio-energy production, was collected. Different chemicals would be used to activate the biochar. The pore structure and specific surface area of the carbon samples would be characterized using N_2 adsorption/desorption method. The carbon samples would be used to assemble super-capacitors, and the properties would be evaluated by electrochemical techniques including cyclic voltammetry (CV), galvanostatic charge-discharge, and electrochemical impedance spectrum (EIS). The relationship between specific capacitance and pore structure and surface area will be discussed. All in all, we will get a pathway for developing sustainable electrode materials from bio-resources, and the

previous data indicate that the activated carbon progressively treated by H₂O₂ presents excellent charge/discharge properties (specific capacitance above 200 F g⁻¹) at the high current density of 1.0 A g⁻¹, and excellent rectangular shape of CV curve.

Thomas Holm - Groundwater Geochemist at the Illinois State Water Survey, a division of the Prairie Research Institute at the University of Illinois at Urbana-Champaign; trholm@illinois.edu.

Sorption of polycyclic aromatic hydrocarbons (PAHs) to biochar and potential PAH bioavailability

Char was produced from corn stover by slow pyrolysis under nitrogen at 450°, 550°, and 750°C. Sub-samples of char were subjected to artificial aging for 30 days. The total PAH concentrations in all fresh and aged chars were below 1.5 mg/kg. Sorption and bioavailability of pyrene, a polycyclic aromatic hydrocarbon, were characterized for fresh and aged chars. Pyrene sorbed strongly to all chars. The minimum distribution coefficient for 1 µg/L (1 nM) dissolved pyrene was 106. Freundlich isotherms fit the sorption data very well. The effect of corn stover char on pyrene bioavailability was characterized by extraction with 2-hydroxypropyl-β-cyclodextrin (HPCD). For all chars tested, less than 10% of added pyrene was extractable with HPCD. In some cases, less than 1% was extractable. This result is consistent with the strong sorption of pyrene to corn stover char.

Tao Xie - Visiting Doctoral Student, Department of Civil and Materials Engineering at the University of Illinois at Chicago; xietao@uic.edu.

Nutrients recovery from artificial urine through struvite crystallization and biochar adsorption

Collection of wastewater in segregated streams is one of the new concepts in domestic wastewater management. One such stream is human urine, which contains nutrients including N, P and K. Nutrients from urine can be collected after struvite precipitation and adsorption/ion exchange onto adsorbents such as zeolite and subsequently can be applied for soil fertilization. However, this process usually consisted of two stages: first the removal of nutrients from human urine by an adsorbent, and secondly desorption of the nutrients from the adsorbent, which is not an effective process. The use of biochar as an adsorbent is an alternative option because it can be used to adsorb nutrients from urine and then can be directly mixed in soil in the field, avoiding the need for desorbing the nutrients if other adsorbent is used. This research presents a comprehensive investigation on nutrient recovery from human urine by struvite crystallization and biochar adsorption through a series of laboratory experiments under various initial conditions. The purpose of the study is to optimize the recovery of P and N from urine through struvite precipitation (by MgO addition) and NH⁴⁺ and K⁺ adsorption (by biochar).

Chung-Ho Lin - Research Assistant Professor, School of Natural Resources at the University of Missouri in Columbia MO; linchu@missouri.edu.

Utilizing biochar for the development of carbon-based biocatalyst

Biochar is a solid material obtained from the carbonisation of biomass. The specific surface area of biochar provides access to chemical modification. Our team has developed a technique to utilize the functionalized carbon including biochar as a vehicle to deliver enzymes for industrial applications. This invention utilizes chemical conjugation techniques for the tethering of enzymes to the surface of the functionalized biochar. This approach allows the tethered enzymes to persist over time. The delivery mechanism has a wide range

of commercial applications ranging from development of biocatalysts, biofilters, and drug delivery systems and biosensors. This research provides the opportunity to turn the biochar into value-added products.

Joseph Polin - Graduate Research Assistant, Department of Agricultural & Biosystems Engineering at South Dakota State University in Brookings, SD; Joseph.polin@sdsu.edu.

Upgrading biochar into activated carbon materials through physical activation

Fast pyrolysis involves the thermochemical conversion of biomass at 400° – 600°C that results in three main products: bio-oil, syngas, and biochar. Flue gas and fast pyrolysis syngas atmospheres are investigated as physical activating agents to further upgrade the biochar into activated carbon. Activated carbon, as a value-added product, significantly increases the overall economic potential of thermochemical conversion pathways for producing renewable transportation fuels. Upgraded biochar materials have similar porosity characteristics and BET specific surface area comparable to conventional activated carbon currently used for potable water purification. Because flue gas and syngas are readily available, they represent low cost alternatives compared to traditional chemical activating agents: NaOH, KOH, or ZnCl₂. Furthermore, upgrading of biochar with syngas or flue gas simultaneously improves the efficiency of pyrolysis biorefinery platform by utilizing multiple process streams.

POSTERS

1. Audrey Sweet - Graduate Research Assistant, Department of Forestry at Southern Illinois University - Carbondale; a.sweet@siu.edu.

Biochar application in agricultural buffering systems to facilitate nutrient retention

Riparian buffers have been successful in retaining excess nutrients from agricultural runoff. We hypothesize the addition of biochar to these buffering systems can further enhance nutrient attenuation. This study will test the effectiveness of multiple riparian buffer species and soils amended with non-activated or compost-activated biochar in retaining nitrogen, phosphorus, and sediment. Overland flow was sampled from thirty flumes, consisting of ten treatments replicated three times, during precipitation events large enough to generate runoff. Treatments included: (1) giant cane (*Arundinaria gigantea* (Walt.) Muhl); (2) Kentucky bluegrass (*Poa pratensis* L.); (3) orchardgrass (*Dactylis glomerata* L.); (4) biochar; (5) biochar and giant cane; (6) biochar, giant cane, and compost; (7) giant cane and compost; (8) corn; (9) volunteer species; and (10) control. Preliminary results are variable due to the initial establishment of treatments. Data from this study will provide evidence toward the applicability of biochar in future riparian buffer designs.

2. John Scott - Senior Analytical Chemist at the Illinois Sustainable Technology Center, a division of the Prairie Research Institute at the University of Illinois at Urbana-Champaign; zhewang@illinois.edu.

PAH content of corn stover biochar produced by slow pyrolysis at three different temperatures

Polynuclear aromatic hydrocarbons (PAHs) are compounds that form during the combustion of fossil fuels and biomass. Many of these PAHs are known for their carcinogenic properties. Because biochar is produced by pyrolysis of biomass and often the end use of this product is intended for agriculture, the potential exists to introduce PAHs into soils and food webs. This study investigated the presence of PAHs contained in biochar produced from a corn stover feedstock by slow pyrolysis at three different temperatures. Sixteen U.S. Environmental Protection Agency (EPA) priority PAHs were extracted and analyzed in the biochars generated in this study. The corn stover biochar created at 450°C contained 1.4 mg/kg total target PAH and the biochar created at 550°C contained 0.20 mg/kg total target PAH. Quality control parameters associated with the experiment indicated that the standard methods for extraction of PAHs from biochar generated at 750°C are insufficient.

3. Wei Wang - Graduate Student, School of Technology at Eastern Illinois University - Charleston; wwang@eiu.edu.

*An energy conversion efficiency comparison of *Arundo donax* and woodchips gasification as renewable energy*

Identifying regional alternative biomass fuels for gasification process is significant in terms of energy and cost efficiency. *Arundo donax* is one type of promising energy crop that has superior yield while needing low energy input for its growth. This research compares the thermal conversion efficiency for *Arundo donax* and woodchips, seeking alternative biomass fuel for the region. The higher heating value of biomass fuels was tested by a bomb calorimeter as energy input. The biomass fuels were also burned in a laboratory scale downdraft gasification system to produce combustible syngas. The syngas samples were collected and analyzed through gas chromatography. The gas composition results were used to calculate syngas heating value as energy output. The thermal conversion efficiency is identified by the ratio of energy input and output.

4. Xiaomin Wang - Research Assistant, Department of Agricultural & Biosystems Engineering at South Dakota State University in Brookings, SD; zhengrong.gu@sdstate.edu.

Activated carbon from biochar of Big bluestem as electrode in supercapacitor

Activated carbon based on biomass is an attractive material for energy storage in terms of the high specific capacitance and low cost. The activated carbon samples based on big bluestem bio-char, which was a waste from a thermochemical process optimized for bio-oil production, were obtained by chemical activation using different reagents. The relationship between pore structure and activation parameters was studied by N₂ adsorption/desorption method. The highest specific surface area (2490 m² g⁻¹) of activated carbon was obtained by the activation of 0.05 mol g⁻¹ KOH/Biochar at 820°C. Electrochemical properties study indicates that the specific capacitances are closely related with pore structure and micropore ratio. The highest area specific capacitance (26 μF cm⁻²) was obtained at the micropore volume ratio of 0.34, and the transportation control would be the main factor after the micropore ratio was greater than 0.34.

5. Hongmei Gu - Forest Products Technologist at USDA Forest Service - Forest Products Laboratory in Madison, Wisconsin; hongmeigu@fs.fed.us.

Life cycle assessment of bio-products from advanced modular biomass pyrolysis system

Using a biomass pyrolysis system for producing syngas or biofuel has drawn world-wide attentions for its environmental benefits and sustainability. Biochar as a by-product from the system has also increased the interests of forest product and paper industries and forest management researchers because of its applications and environmental impacts. Expanding biofuels and bio-products production has the potential to reduce net greenhouse gas emissions and improve energy security. Science-based assessments of new energy technologies and new products are essential tools for policy makers working to expand renewable energy production, including production of biofuels from biomass.

The overall project is to integrate biofuel and bio-products production into the forest products supply chain using modular biomass thermal conversion systems (gasifier/pyrolysis) and activating biochar for value-added applications. This part of the project will compare the environmental impacts of fossil fuel-derived products of activated carbon and electricity to the equivalent products from the advanced modular biomass pyrolysis system (Tucker unit) using life cycle assessment (LCA) methodology. The 200 kWe modular pyrolysis system consumes about five dry tonnes per day of residue from primary wood products manufacturing and forest residues. Primary product outputs are synthesis gas (75% by weight) and biochar (25% by weight). Secondary products include electricity from synthesis gas (syngas) and soil amendment or activated carbon from biochar. Syngas can also be a feedstock to produce liquid biofuels.

Specific objectives include: (1) develop environmental profiles for the syngas and biochar produced by the system using LCA methods following ISO 14040 standards; (2) conduct a mass balance of the system studied; (3) determine the net energy balance for each product using LCA methods; and (4) use secondary data of equivalent commercially-available products for comparison.

Questions to be addressed include the following: (1) energy to maintain the endothermic thermo-conversion reaction of the Tucker unit from either external (i.e. propane) or internal energy sources (i.e. syngas); (2) energy to chipping and drying the wood chips used as feedstock to the desired specifications; and (3) relating the environmental impacts on mass, energy, and economic allocation bases.

6. Omar Al-Qudah - Postdoctoral Research Associate, Department of Agriculture and Environmental Sciences at Lincoln University of Missouri in Jefferson City, MO; al-qudah@lincolnu.edu.

Potential applications of biochar in environmental bioremediation: A critical review

Biochar is a by-product of biomass pyrolysis. Although biochar has been applied as a soil amendment for a long time, there are many other applications that need to be explored. The objective of this research was to review and evaluate existing published studies that assess the application of biochar as a medium for soil and environmental remediation and pollution mitigation. Utilization of biochar in nanotechnology applications was also explored. During the last three decades, many studies have been conducted mainly on small-scale models that are currently limited to specific biochar type and site locations. The results of this research: (1) summarize the main keystones of biochar applications and (2) define the research gaps and the major research needs to design and evaluate innovative materials and environmental systems that utilize biochar.

7. Hamed El-Mashad - Assistant Professor, Department of Biomass and Bioenergy Engineering at Lincoln University in Jefferson City, Missouri; el-mashadh@lincolnu.edu.

Biochar production from anaerobically digested switchgrass

Lignocellulosic materials (e.g., switchgrass) contain a recalcitrant fraction that cannot be converted by anaerobic microorganisms to biogas. The undigested materials end up in the effluent of anaerobic digesters. Pyrolysis was proposed as a post treatment for the solid fraction of the digestion effluent to produce biochar, biooil, and syngas. Switchgrass was anaerobically digested at 50°C for 21 days. Undigested and the solid fraction of the digested switchgrass were pyrolyzed at 500°C for two and half hours. Preliminary results showed that biogas yield from switchgrass was 155 mL/g volatile solids. Biochar yield (based on total solids) was 28.8% and 31.5% for the digested switchgrass and undigested switchgrass, respectively. The ash content was 21.1% and 12.6% of the biochar produced from the digested and undigested switchgrass, respectively. The C/N ratio, nutrients and micro-elements in the biochar will be presented.

8. Brajendra Kumar Sharma - Senior Research Scientist at Illinois Sustainable Technology Center, a division of the Prairie Research Institute at the University of Illinois at Urbana-Champaign; bksharma@illinois.edu.

Spent coffee grounds or its biochar: Which is better

Energy production from renewable or waste biomass/material is a more attractive alternative compared to conventional feedstocks, such as corn and soybean. In this study, we explored the potential of spent coffee grounds, a waste organic carbon material, to produce renewable energy. After preparing the spent coffee grounds two ways, drying and defatting, the grounds were converted into bio-oil and biochar using a thermochemical process. It was found that the spent coffee grounds produced more bio-oil and less biochar compared to defatted coffee grounds. The biochars produced have the potential to be used as fuel and also as soil amendment material. These biochars were characterized for their BET surface area, energy content, and ultimate and proximate analysis. Both biochars displayed similar surface area and elemental makeup. In a greenhouse experiment, it was found that the application of biochar with fertilizer enhanced the yields of sorghum-sudangrass by two-times, highlighting biochar's potential as a soil amendment.

9. Brajendra Kumar Sharma - Senior Research Engineer at the Illinois Sustainable Technology Center, a division of the Prairie Research Institute at the University of Illinois at Urbana-Champaign; bksharma@illinois.edu.

Effect of biochar addition on nutrient leaching from soil planted with giant cane

Biochar, a charcoal-like substance produced from the pyrolysis of biomass, has a high surface area that may make it useful in increasing the adsorption of fertilizer in soil. In this study, giant cane rhizomes were planted into soil amended with two different commercial biochars (at a rate of 20 t/ha). After several months, the plants were watered with a fertilizer solution containing nitrate and phosphate ions, and the water runoff was analyzed for fertilizer concentrations. Biochar effect on nutrient retention and leaching will be discussed.*

*Studies are currently ongoing and further results will be presented during the symposium.

10. Karen Mitchell - Graduate Research Assistant, Department of Botany and Plant Pathology at Purdue University in West Lafayette, IN; karen.mtchll@gmail.com.

The effect of biochar on three common agricultural weeds

Biochar has been proposed as a soil amendment to improve soil quality and increase crop yields. The beneficial effect of biochar on crops may extend to weeds, which could increase weed pressure on crops. Barnyardgrass (*Echinochloa crus-galli*), large crabgrass (*Digitaria sanguinalis*), and redroot pigweed (*Amaranthus retroflexus*) were grown to maturity under greenhouse conditions using a factorial design with biochar and nitrogen treatments. Weeds responded to nitrogen as expected, but each species responded differently with the addition of biochar. Biochar increased barnyardgrass height and total dry weight but did not affect root-shoot partitioning. Biochar increased large crabgrass shoot weight but reduced root weight. Finally, biochar reduced redroot pigweed height but increased branch weight. The variable responses of the weed species suggest that the addition of biochar to agricultural soils may complicate current weed management practices and emphasizes the need for further research on the intricate interactions between biochar and weed species.

11. Ling Zhao - Visiting Scholar from Shanghai Jiao Tong University in Minhang District, China, at the Illinois Sustainable Technology Center, a division of the Prairie Research Institute at the University of Illinois at Urbana-Champaign; wszhaoling@gmail.com.

Heterogeneity of biochar properties as a function of feedstock and production temperatures

Feedstock and temperature influence specific biochar properties to different extent and the heterogeneity depended on them were compared quantitatively. The quantitative evaluation was based on statistical analysis of coefficients of variation, and thus, they derived indices representing the extent of influence of the two factors – i.e., a feedstock-dependent heterogeneity (HF) and a temperature-dependent heterogeneity (HT). The results showed that the biochar parameters most affected by feedstock properties were total organic carbon, fixed carbon, and mineral elements of biochar. On the other hand, biochar surface area and pH was mainly influenced by production temperature. Biochar recalcitrance was mainly determined by production temperature, while the potential total C sequestration (product of recalcitrance and pyrolysis carbon yield) depended a little more on feedstock. The work sheds some light on the relative importance of different biochar production process parameters on the final biochar product, which is an important step towards designed “custom” biochar.

12. Wei Zheng - Senior Research Scientist at the Illinois Sustainable Technology Center, a division of the Prairie Research Institute at the University of Illinois at Urbana-Champaign; weizheng@illinois.edu.

Synergistic effect of combined application of biochar and nitrogen fertilizer

Biochar is a carbon-rich byproduct generated from biomass through pyrolysis. The use of biochar as a soil amendment has been suggested as a means to sequester carbon and improve soil quality. This study evaluated the effect of combined application of biochar and nitrogen fertilizer on crop yields. A sorption experiment showed that biochar can adsorb ammonium ions and retain nitrogen nutrients in soils. Accordingly, a greenhouse experiment was conducted to investigate the effect of the combined use of biochar and nitrogen fertilizer on radish yields. The addition of biochar into the soil did not increase crop yields in the absence of fertilizer. However, a significant yield increase was observed when biochar was used as a soil amendment in the presence of nitrogen fertilizer, even greater than fertilizer application alone. Similarly, a synergistic effect was observed in a corn field trial when the use of biochar was combined with nitrogen fertilizer.

13. Rena Weis - Pathways Intern at USDA-ARS in St. Paul, Minnesota; collydog7@gmail.com.

Impacts of biochar on soil greenhouse gas emissions, soil moisture, and crop PAH concentrations

The purpose of this study was to examine the impacts of biochar additions on soil greenhouse gas emissions and soil moisture, as well as quantify polyaromatic hydrocarbon (PAH) uptake in specialty crops. Triplicate plots were amended with 0.763 kg/m² of pine chip biochar (650°C) and three were untreated as the control plots. There were no significant differences observed between the control and biochar plots for nitrous oxide or carbon dioxide emissions. However, the biochar plots emitted significantly lower amounts of methane, suggesting higher rates of methane oxidation or lower rates of methane production were occurring in the biochar treated plots. Biochar plots possessed significantly higher soil moisture contents than the control plots. There were no statistically significant differences in the PAH concentration noted between the treatments. In conclusion, amending biochar to soil reduced soil methane emissions, increased soil moisture content, and had no effect on the PAH concentration of the harvested crops.

14. Thomas Klasson - Research Leader at USDA-ARS in New Orleans, LA; thomas.klasson@ars.usda.gov.

Reduction of fermentation lag phase due to inhibitors using a novel activated biochar material

Lignocellulosic feedstocks can be prepared for ethanol fermentation by treatment with a dilute mineral acid catalyst that hydrolyzes the hemicellulose and possibly cellulose into soluble carbohydrates. The acid catalyzed reaction scheme is sequential whereby released monosaccharides are further degraded to furans and other chemicals that are inhibitory to the subsequent fermentation step. This work evaluates the use of agricultural residues (flax shive) as starting materials for making activated biochars to adsorb these degradation products. Results show that both furfural and hydroxymethylfurfural (HMF) are adsorbed by steam-activated biochar prepared from flax shive. Decontamination of the hydrolyzates significantly improved the fermentation behavior by *Saccharomyces cerevisiae* yeast, including significantly reducing lag phase. No negative effects were noted from addition of activated char to the process.

15. Mark Dietenberger - Research General Engineer at USDA Forest Service - Forest Products Laboratory in Madison, Wisconsin; mdietenberger@fs.fed.us.

Modifying pine residues for removal of pesticides and phosphates from storm water runoff and related biofiltering applications

Pesticide entrainment in storm water runoff can contribute to non-point source pollution of surface waters. Granular activated carbon has been successfully used to remove pesticides from wastewater. However, implementation of granular activated carbon sorption media in storm water filtration systems comes with high initial capital investment and operating costs. Modified pine residues offer attractive alternative sorption media for use in storm water filtration systems. The effectiveness of modified pine residues or barks is evaluated for removal of pesticides and phosphates from water under dynamic conditions by percolating water solutions of pesticides or phosphates through fixed bed columns of the test materials. Certain results indicate that the modified pine is as effective as granular activated carbon in removing hydrophobic pesticides from water. New research will focus on improvement of adsorption capacity and selectivity of biochar-based filtration sorbents for various anions of environmental concern, including phosphates, nitrates, arsenates, and perchlorates.

16. Andre Thomazini - Student, Department of Soil, Water, and Climate at University of Minnesota in Saint Paul, MN; andre.thz@gmail.com.

Variability in biochar's greenhouse gas response as a function of soil type

One potential abatement strategy to increasing atmospheric levels of carbon dioxide (CO₂) is to sequester atmospheric CO₂ in biochar, which is a more stable form of carbon created through the use of pyrolysis. However, different responses have been observed in the impact of biochar additions on greenhouse emissions following incorporation. I evaluated the impacts of the same biochar type (hardwood sawdust) amended at the same rate to 10 different soil types to observe the differences in methane, carbon dioxide, and nitrous oxide dynamics after incorporation. These soils included a Brazilian Terra Preta soil; an Antarctica soil; and agricultural soils from Minnesota, Florida, South Carolina, Illinois, Pennsylvania, Michigan, and California. The poster will discuss the different responses observed in greenhouse gas emissions and N-availability for the same biochar as a function of the soil type.

17. Michael Aide - Department Chair, Department of Agriculture at Southeast Missouri State University in Cape Girardeau, MO; mtaide@semo.edu.

Black carbon in soils

Black carbon (BC), also called biochar or charcoal, has recently been proposed as a soil amendment to create a more favorable soil environment by improving the soil pH in acidic soils; raising the cation exchange capacity in poorly buffered soils; and improving nutrient retention and availability in strongly weathered soils. We conducted a series of greenhouse experiments involving acid soil horizons from an Ultisol amended with various rates of BC. Common bean (*Phaseolus vulgaris* L. var 'contender') was grown in these amended soils using a completely randomized design and harvested when the untreated check had plants attaining two fully developed trifoliolate leaves. Plants grown in BC amended soil showed symptoms indicating boron toxicity. Plant tissue analysis and soil characterization showed elevated levels of boron. Black carbon amendments also showed elevated soil and plant calcium concentrations. We conclude that boron threshold levels should be established for BC amended soils.

ABOUT THE ILLINOIS BIOCHAR GROUP

The Illinois Biochar Group (IBG) has members from throughout the Midwest and encourages research in the production and use of biochar. The group informs and educates others about biochar and its potential for applications in agriculture, site remediation, and carbon sequestration.

The Illinois Biochar Group is hosted by the Illinois Sustainable Technology Center and is affiliated with the International Biochar Initiative.

To learn more, visit www.biochar.illinois.edu.

ABOUT THE ILLINOIS SUSTAINABLE TECHNOLOGY CENTER

The Illinois Sustainable Technology Center (ISTC) is a division of the Prairie Research Institute on the University of Illinois at Urbana-Champaign campus. Its mission is to encourage and assist citizens and businesses to prevent pollution and reduce waste to protect human health and the environment in Illinois and beyond.

To learn more, visit www.istc.illinois.edu.

ABOUT THE UNITED STATES DEPARTMENT OF AGRICULTURE

The United States Department of Agriculture (USDA) was founded in 1862 and signed into law by President Abraham Lincoln. Its mission is to provide leadership on food, agriculture, natural resources, rural development, nutrition, and related issues based on sound public policy, the best available science, and efficient management.

To learn more, visit www.usda.gov.

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