Influence of Physico-Chemical Properties of Different Biochars on Landfill Methane Adsorption

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Presentation Outline

- Introduction & study purpose
- Batch adsorption testing
  - Types of biochars
  - Physico-chemical properties
  - Testing protocol
  - Results
- Effects of physico-chemical properties on adsorption
- Conclusions

Biochar
– A Potential Landfill Cover Material

Biochar can be amended to landfill cover soils to enhance CH_4 adsorption and oxidation (based on preliminary results from a previous study at UIC*)

Biochar is advantageous over current compost biocovers

- Enhanced CH_4 adsorption
- Greater porosity and specific surface area (limits pore clogging due to EPS formation) to conveniently foster methanotrophic communities
- Enhanced gas transport through the pores

Biochars exhibit diverse physical-chemical properties based on feed stocks and production processes;
Thus, careful selection of biochars for landfill cover amendment is critical

*Yaghoubi, P. (2010). "Development of Biochar-Amended Landfill Cover for Landfill Gas Mitigation", Ph.D. Thesis.

Purpose of this Study

To evaluate the influence of physico-chemical properties of different biochars on methane adsorption capacities

Scope:

- Characterize seven different biochars for their physical-chemical properties
- Quantify the maximum methane adsorption capacity for each biochar by conducting batch adsorption tests
- Identify the most predominant property of biochars which control methane adsorption

Batch Adsorption Testing – Biochars Used

Feedstock & Production Processes:

Biochar Type	Feedstock	Treatment Process	Treatment Temperature	Residence Time	Post-treatment
BS	Pine Wood	Slow pyrolysis	350 - 600^{0}C	6 hrs	Screened through 3mm mesh
CK	90% pine & 10% fur wood	Fast pyrolysis	> 500^{0}C	< 1 hr	Activated with oxygen
AW	Aged wood chips	Pyrolysis – conventional kiln	~ 400^{0}C	NA	Inoculated with microbes & screened through 4mm mesh
CE-WP1	Wood Pellets	Gasification	~ 520^{0}C	NA	N/A
CE-WP2	Wood Pellets	Gasification	~ 520^{0}C	NA	Not subjected to fine ash filtration
CE-AWP	Wood Pellets	Gasification	~520^{0}C	NA	Fine ash separated
CE-WC	Wood Chips	Gasification	~520^{0}C	NA	N/A

Batch Adsorption Testing – Biochars Used

BS

CK

AW

CE-WP1

CE-WP2

CE-AWP

CE-WC

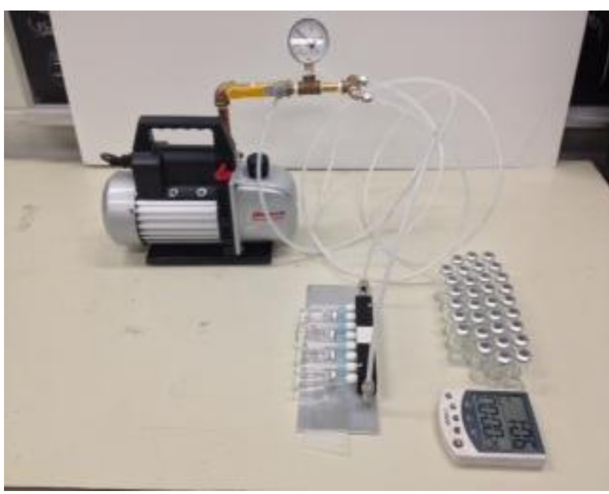
Batch Adsorption Testing – Biochar Characteristics

Property	BS	CK	AW	CE-WP1	CE-WP2	CE-AWP	CE-WC
Porosity (%)	46.25	54.68	29.42	44.37	41.43	39.85	35.62
Effective size (D_{10}, mm)	0.09	0.08	0.33	0.24	1.29	2.68	3.3
Specific gravity	1.36	1.51	1.19	0.77	0.59	0.91	0.87
Dry density (g/cc)	0.73	0.54	0.48	0.56	0.52	0.53	0.38
Water holding capacity	120.58	179.40	113.75	142.41	50.64	80.83	96.35
Moisture content (% dw)	0	0.10	52.4	0.18	0.14	0.47	0.65
Organic matter (% dw) (LOI)	29.16	31.25	75.95	96.88	96.75	82.33	91.53
Volatile matter (% dw)	27.98	28.10	74.11	61.76	62.66	55.40	23.98
Ash content (% dw)	65.71	61.60	25.43	4.62	1.49	4.26	4.59
Fixed carbon (% dw)	4.59	3.69	NA	33.21	35.00	40.33	70.32
Elemental C (% dw)	53.24	23.54	51.88	70.73	74.02	78.13	83.98
pH	8.50	9.00	7.88	6.24	6.78	6.09	7.02

Batch Adsorption Testing – Protocol

Step 1:

Sterilization of biochars - 121^{0}C (15 psi); 30 min/cycle for 2 consecutive days

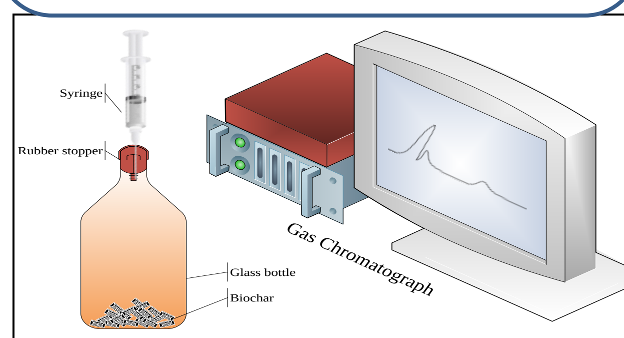


Step 2:

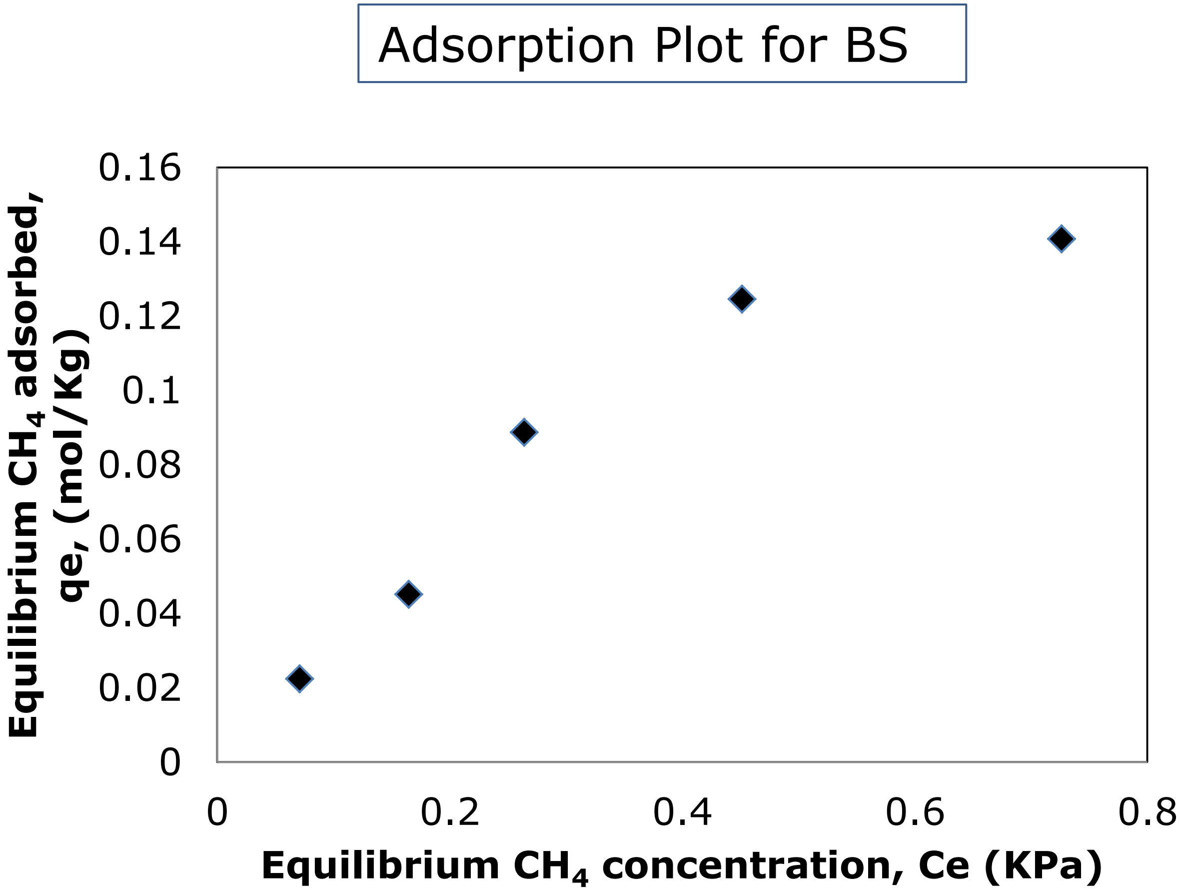
Evacuation of vials – 5 mm glass serum bottles crimped w/ butyl septa & aluminum caps

Step 3:

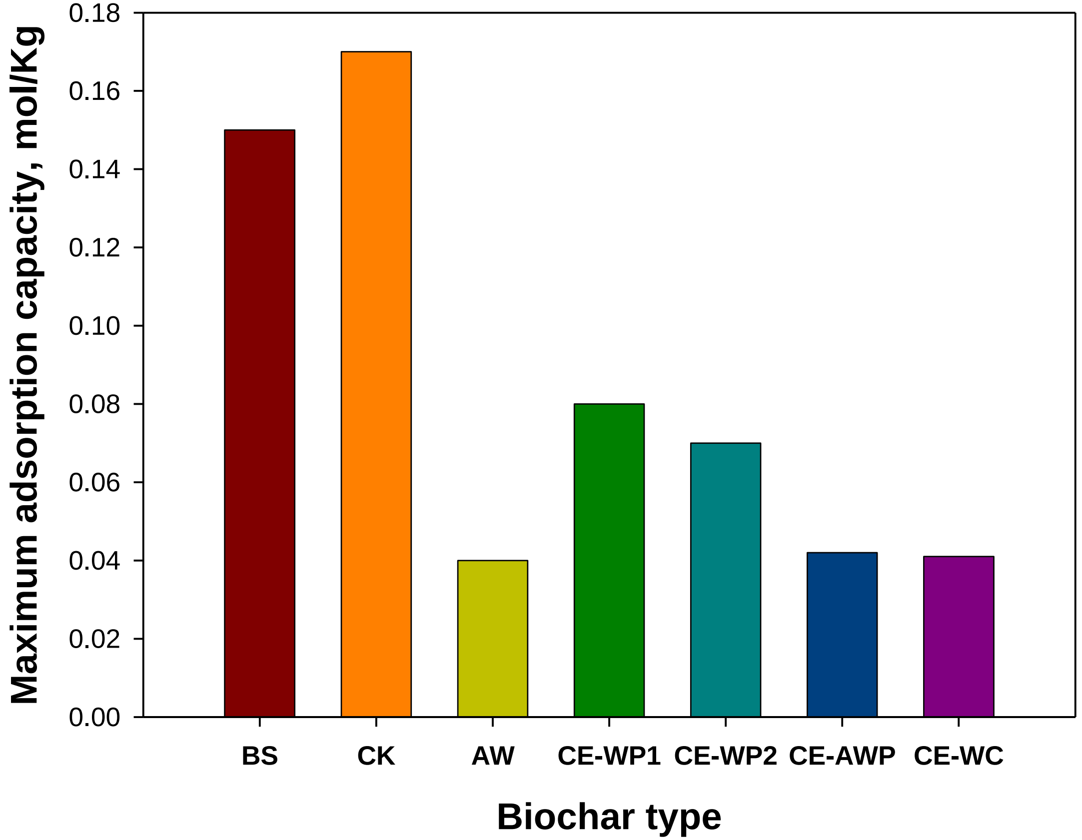
5g material used; controls (no biochar); gas samples stored in 5 ml vials & analyzed within 4 hr using HP 6890 GC w/ FID and GS Carbon plot column



Typical Adsorption Results



Results – Maximum Adsorption Capacity

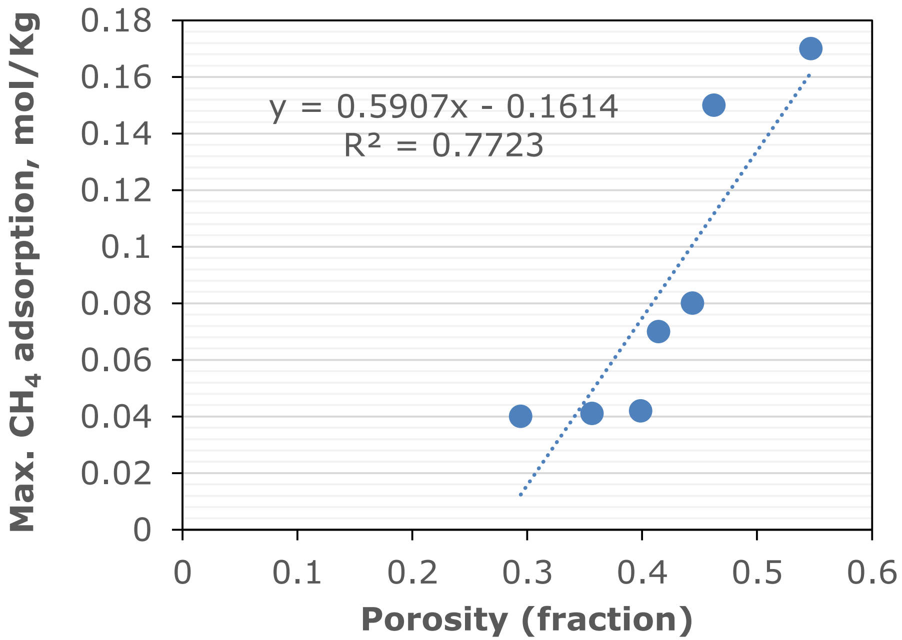


Max. adsorption ranged from 0.04 – 0.17 mol/Kg

AW – lowest adsorption capacity; CK – highest adsorption capacity

AW had highest moisture content; CK – activated biochar with smallest particle size;

Effect of Porosity on Methane Adsorption



SEM images for biochars were processed using Pores (Particles) and Cracks Analysis System (PCAS) software to quantify porosity

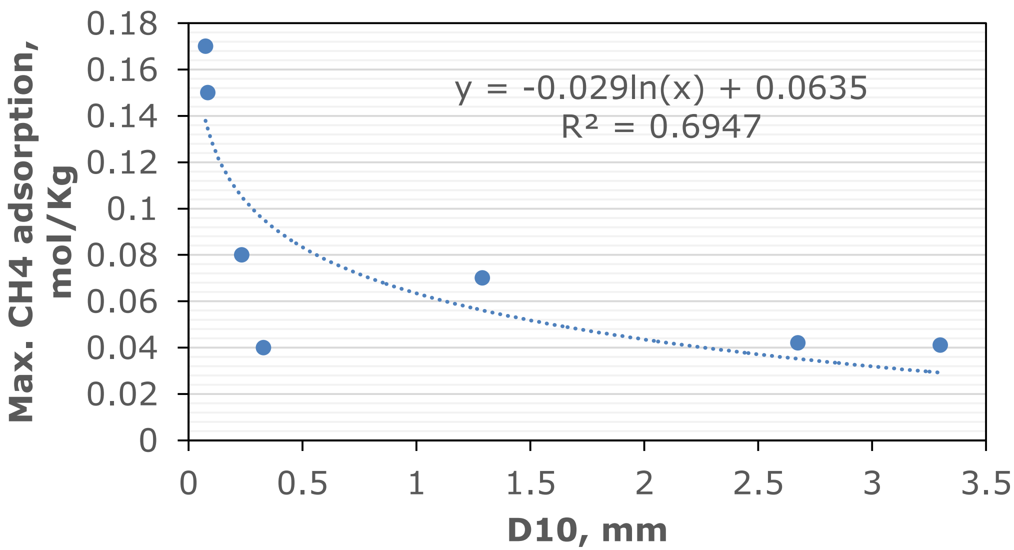
Porosity values ranged from 30% - 55% for all biochars

As porosity increases, CH_4 adsorption increased due to greater availability of pore space within the physical structure of biochars

Several studies have reported an increase in CH_4 adsorption with increasing microporosity*

*Billemont et al. 2013, Perera et al. 2012, Zhou et al. 2001.

Effect of Particle Size on Methane Adsorption

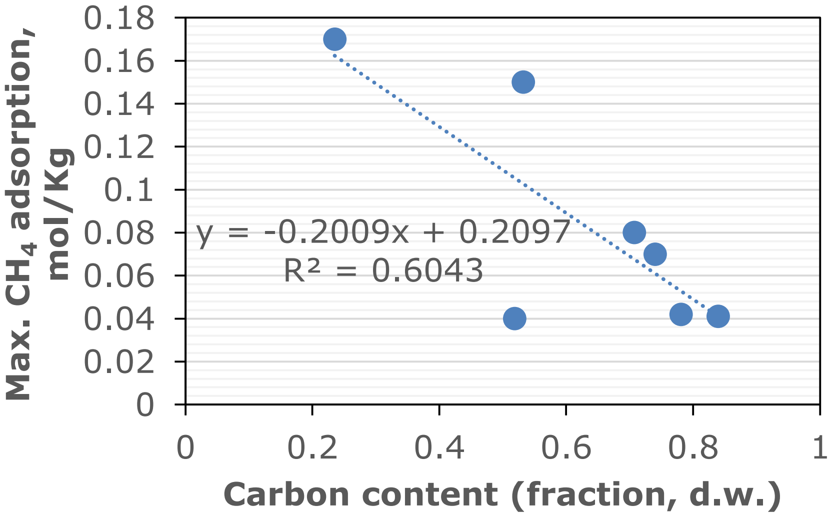


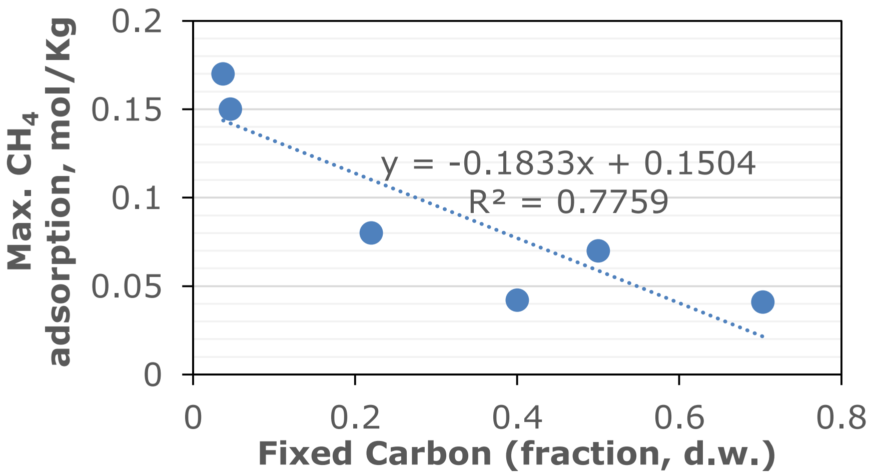
Decreasing trend in adsorption capacity is observed with increase in particle size

CK w/ smallest particle size has highest adsorption capacity; whereas, other biochars w/ larger particle sizes have comparatively lower adsorption capacities

Finer particles generally have greater specific surface area thus providing more number of adsorption sites which increases adsorption capacity

Effect of Carbon Content on Methane Adsorption





Decreasing trend in adsorption capacity observed for the range of carbon content (20 – 80% d.w.) in biochars

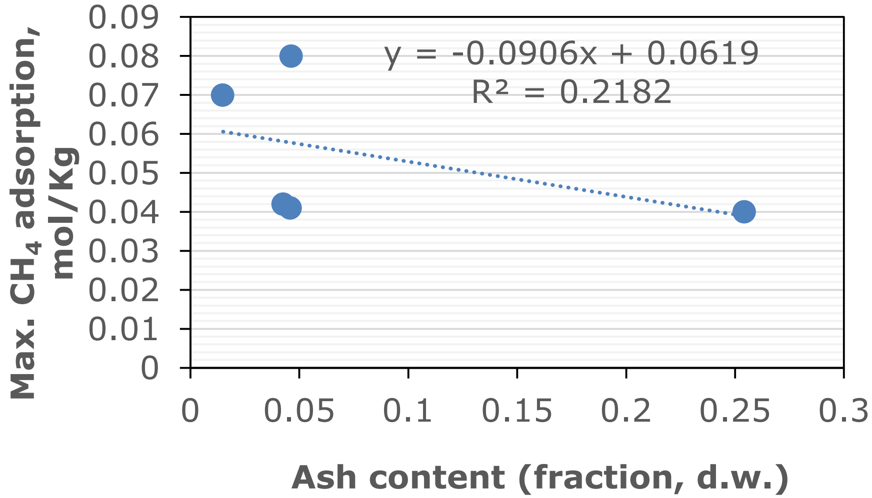
Similar trend for the range of fixed carbon content (4 – 70% d.w.) in biochars

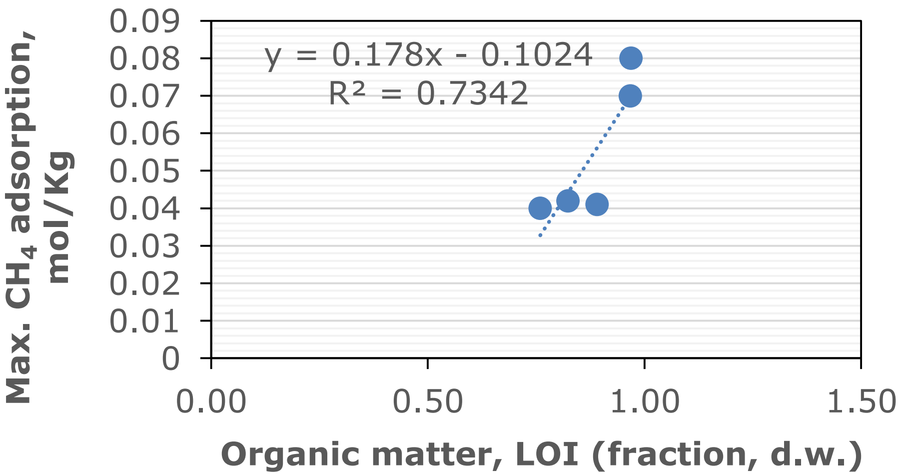
Similar phenomenon was observed in some studies for different types of coals within this range of carbon content*

Within this range, minimal open porosities for gas adsorption were observed; 'U' shape curve for gas sorption is proposed with the bottom point of the curve at 83.5 % fixed C*

*Perera et al. 2012, Faiz et al. 2007, White et al. 2005, Gurdal and Yaclin, 2000

Effect of Ash Content on Methane Adsorption





Decreasing trend in adsorption capacity observed with increasing ash content for biochars with carbon content >50% d.w.

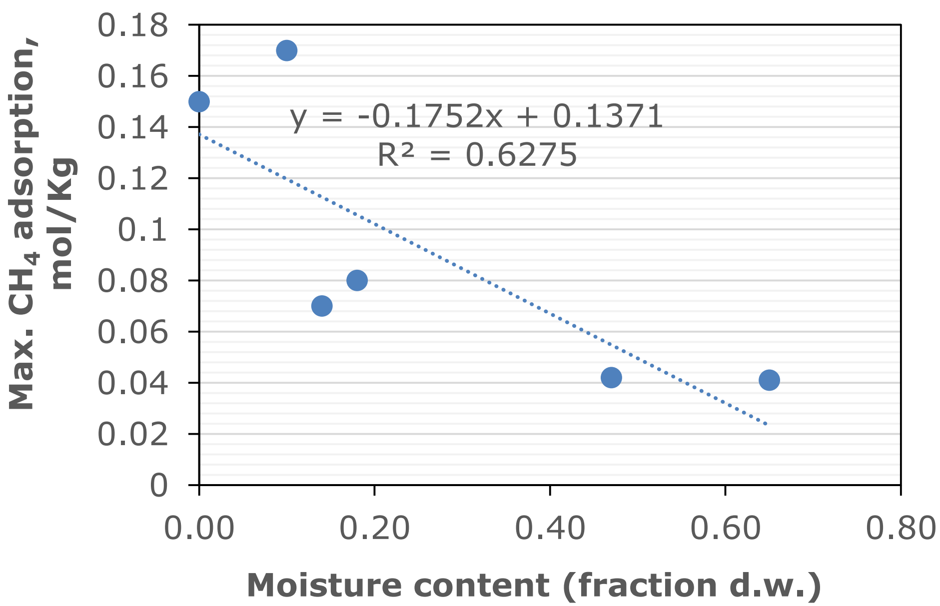
Similar trend was reported in literature for coals having carbon content > 50% d.w.*

Methane adsorption is positively correlated to increasing organic content in biochars

Higher organic matter results in a more amorphous & porous structure which increases the available surface area for adsorption

*Perera et al. 2012, Gurdal and Yaclin, 2000

Effect of Moisture Content on Methane Adsorption



Moisture content negatively influences the methane adsorption capacity of biochars

Presence of moisture hinders the entry of methane molecules into biochar pores*

Diameter of water molecule (0.306 nm) < methane molecule (0.38 nm) hence competes with each other for adsorption sites*

*Zhou et al. 2001

Conclusions

1. Porosity, particle size, moisture content, carbon content (total and fixed), ash content and organic content appear to influence methane adsorption onto biochars
2. No visible trend was observed in the effect of all other properties (pH, specific gravity, volatile matter content, dry density and water holding capacity) on methane adsorption capacity of biochars
3. Methane adsorption increases with increasing porosity and organic content and decreases with increasing particle size and carbon content (total & fixed)
4. Methane adsorption decreased with increasing ash content for biochars used in this study with carbon content > 50% d.w.
5. However, the conclusions derived are limited to biochars with elemental carbon content ranging from 20 – 83% d.w.

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Thank you!

National Science Foundation
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