ADSORPTION CHARACTERISTICS OF BIOCHAR AND APPLICATIONS

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What is biochar ?

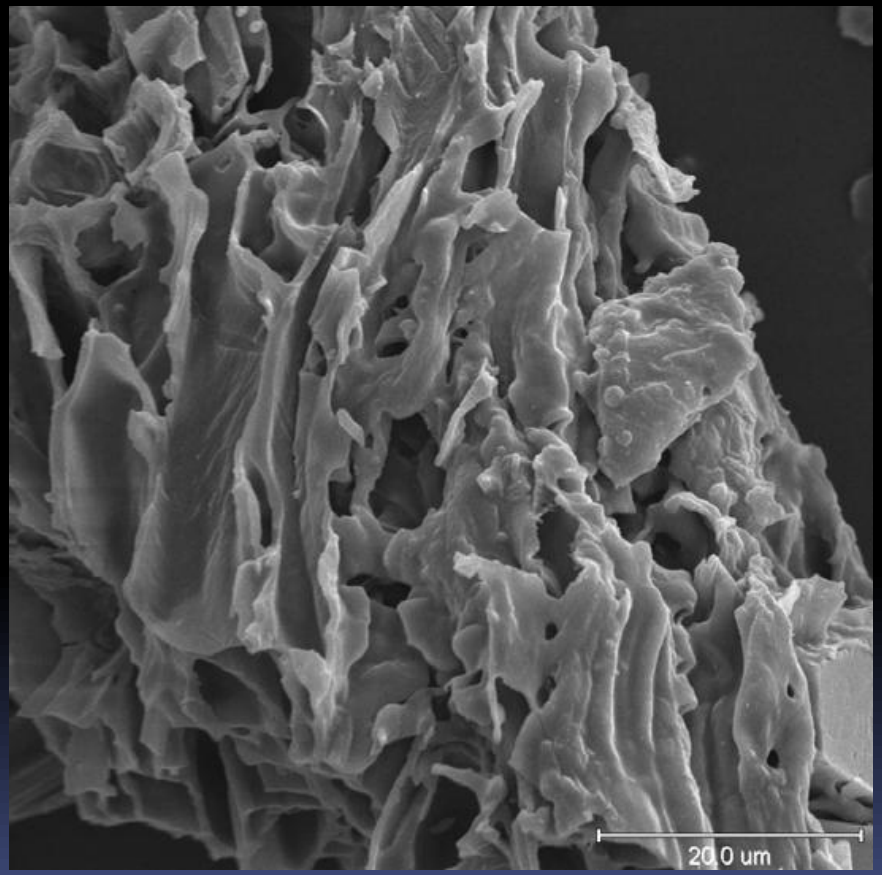
What is biochar?

•The definition of biochar is more about its creation and intended application rather than what it is composed of. Both charcoal and biochar are produced through an energy conversion process called *pyrolysis*, which is essentially the heating of biomass in the complete or near absence of oxygen.

Biochar can be produced from a variety of biomass feedstocks, but is generally designated as *biochar* only if it produces a useable co-product for soil improvement. Biochars are not created equal. The efficiency and effectiveness of the process of its creation and use can vary and the specific biomass sources used can affect the characterization and usability of the biochar (McLaughlin et al., 2009).

Biochar - Structure

- The structure of biochar is largely amorphous but contains some local crystalline structure of highly conjugated aromatic compounds(Downie et al., 2009).
- In addition biochar also contains aromatic-aliphatic organic compounds of complex structure (including residual volatiles), and mineral compounds (inorganic ash)
- Very high surface area
- In soil, biochar is extremely recalcitrant to decomposition
- Soil microorganisms and H_2O inhabit micropores
- Nutrient leaching and volatilization are inhibited, but nutrients are bioavailable to plants



Source: Robert Brown, Iowa State University

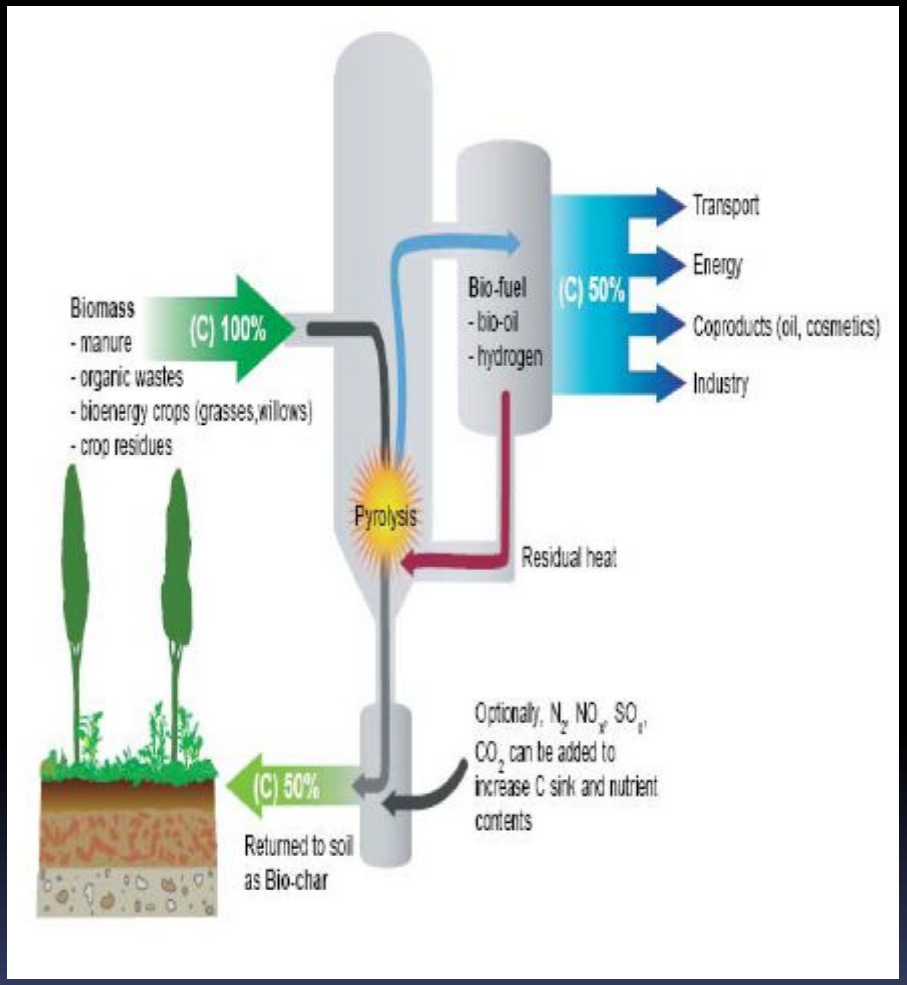
Biochar - Benefits

- May act as a surface sorbent which is similar in some aspects to activated carbon
- Effective in adsorbing organic pollutants from waste water
- Improves soil fertility and increase crop production
- Improves soil tilth, fertility, and water retention
- Reduces soil erosion, vulnerability to degradation
- To some extent reduces need for fertilizer inputs
- Carbon can be sequestered Long-term in soil
- Enhances agricultural adaptation to climate change
- Reduction in N_2O and CH_4 emissions
- Water quality improvements – reduction in NH_4 leaching and run off of P

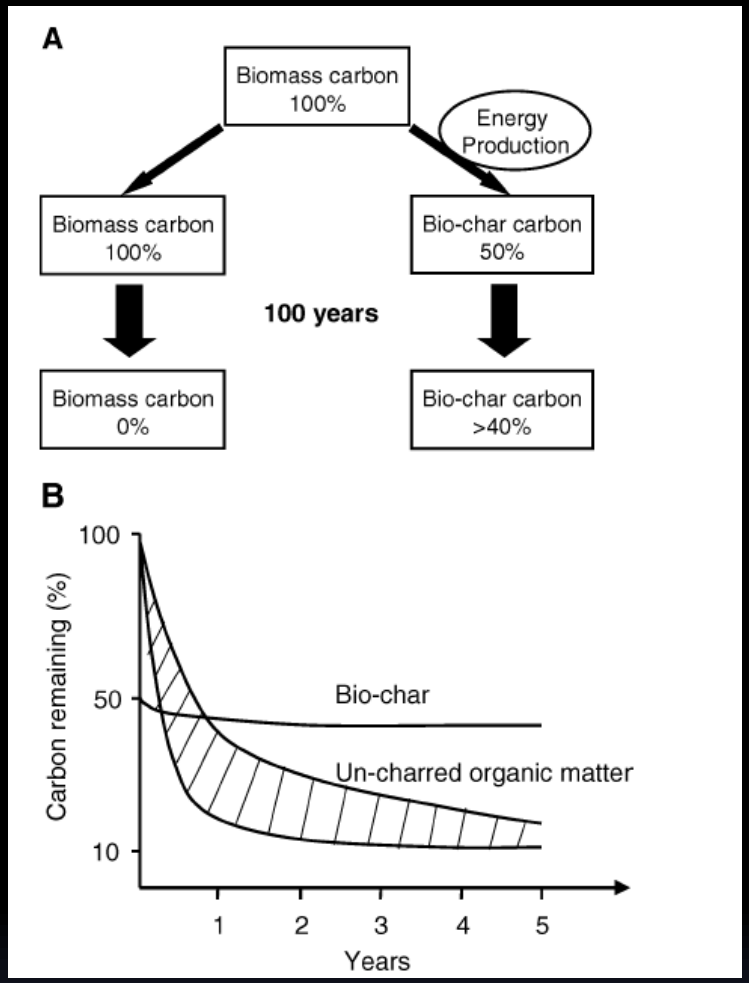
Biochar Hazards

- Air quality
- Dust in transportation and application
- Workers' health

Biochar System – Core Principle



(Lehmann, 2007)



Schematics for biomass or bio-char remaining after charring and decomposition in soil.

(A) C remaining from biomass decomposition after 100 years

(B) Range of biomass C remaining after decomposition of crop residues

(Lehmann et al., 2006)

Biochar - Activation

- Generally obtained at lower temperature and without further activation or processing, but adsorption capacity and surface area of non-activated char are much smaller than activated (e.g., non-activated biochar has about 10 m^2/kg while activated biochar will have 200 – 1000 m^2/kg)
- Biochar can be activated: Steam, NaOH, KOH, CO_2, Acids.

Biochar characterization

Physical Characteristics

- Crush test
- Soap test
- Particle size distribution
- Conductivity
- Ash content
- Moisture
- Bulk density
- Particle density
- Porosity
- Specific surface area
- Volatile matter
- Water holding capacity

Chemical Characteristics

- Total carbon
- P, K, S, Ca, Mg, Na, Bo, Zn, Cu, Fe, Mn
- CEC
- Sorption capacity
- CHNOS

Biological

- Bioassay of C

Biochar Applications

- Improve soil quality
- Increase crop yields ?
- Carbon sequestration
- Animal manure management
- Removal of water and air pollutants

Characterization of Biochar

Sample	Temperature (°C)	pH	Conductivity (ms/cm at 25°C)	Moisture Content (%)		Surface Area (m^2 g^{-1})	
WS 250	250	6.26	235.03	4	±0.1	0.03	±0.04
WS 250 SA	250	10.22	254.13	1.9	±0.1	573	±15
WS 250 PA	250	3.46		3.1	±0.1	851	±7
WS 500	500	7.64	185.59	7.7	±0.0	0	±0
WS 500 SA	500	9.99	331.17	1.6	±0.1	511	±1.4
WS 500 PA	500	3.25		2.4	±0.1	538	±3.9
CL 250	250	7.58	1.5	3.6	±0.0	0.45	±0.64
CL 250 SA	250	11.25	1.67	1.5	±0.0	592	±0.93
CL 250 PA	250						
CL 480	480	9.19	1.31	4.4	±0.3	1.56	±2.20
CL 480 SA	480	11.93	2.86	1.1	±0.2	420	±40
CL 480 PA	480						

Characterization of Biochar

Sample	Carbon	Hydrogen	Nitrogen	Sulfur	Oxygen
WS 250	62.8±0.1	7.41±0.6	0	0.52±0.08	28.1±1.08
WS 250 SA	89.6±0.52	2.07±0.26	2.8±1.78	0.08±0.00	-
WS 250 PA	-	-	-	-	-
WS 500	81.9±0.5	4.03±0.38	0	0.22±0.05	5.5±0.53
WS 500 SA	90±0.1	2.39±0.42	0.19±0.03	0.04±0.04	-
WS 500 PA	-	-	-	-	-
CL 250	46.3±0.2	5.74±0.37	3.18±0.12	0.72±0.07	25.9±0.75
CL 250 SA	46±3.7	0.83±0.16	0.76±0.07	0.56±0.02	-
CL 250 PA	-	-	-	-	-
CL 480	51.2±0.6	3.51±0.5	3.19±0.24	0.55±0.06	9.3±0.15
CL 480 SA	48.4±0.6	0.71±0.13	1.22±0.02	0.34±0.10	-
CL 480 PA	-	-	-	-	-

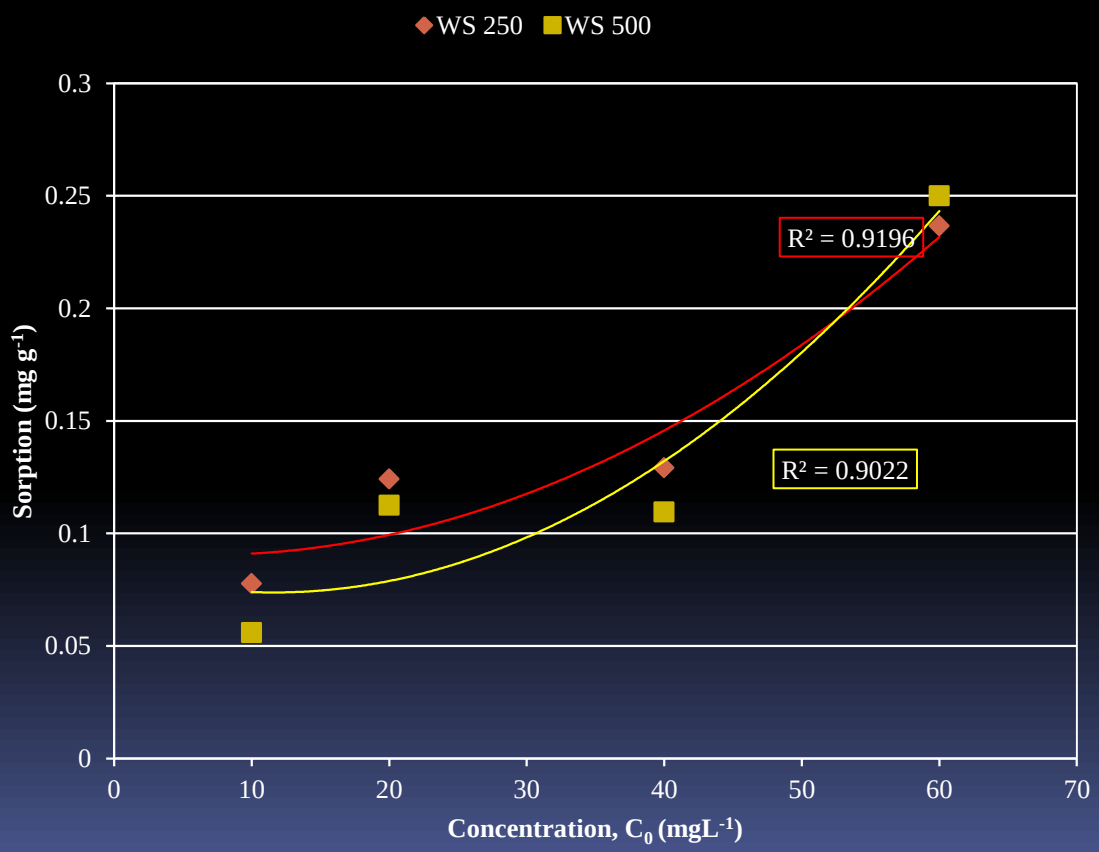
WS250: Wood shavings 250°C biochar
WS250SA: Wood shavings 250°C steam activated char
WS250PA: Wood shavings 250°C phosphoric acid activated char
WS500: Wood shavings 500°C biochar
WS500SA: Wood shavings 500°C steam activated char
WS500PA: Wood shavings 500°C phosphoric acid activated char

CL250BC: Chicken litter 250°C biochar
CL250SA: Chicken litter 250°C steam activated char
CL250PA: Chicken litter 250°C phosphoric acid activated char
CL480BC: Chicken litter 480°C biochar
CL480SA: Chicken litter 480°C steam activated char
CL480PA: Chicken litter 250°C phosphoric acid activated char

Characterization of Biochar

Sample	Volatile Carbon	Fixed Carbon	Ash Content
WS 250	59.1 ±0.7	38.3 ±0.4	2.6 ±0.9
WS 250 SA	6.0 ±0.3	88.4 ±1.2	5.6 ±1.2
WS 250 PA	35.8 ±0.1	57.8 ±2.2	6.4 ±2.2
WS 500	14.2 ±0.6	80.3 ±0.8	5.6 ±0.3
WS 500 SA	6.3 ±0.6	87.1 ±0.4	6.6 ±0.9
WS 500 PA	30.2 ±0.4	62.8 ±7.1	7.1 ±1.9
CL 250	59.5 ±0.2	27 ±0.4	13.5 ±0.2
CL 250 SA	7.3 ±0.5	44.7 ±1.0	48 ±1.4
CL 250 PA	-	-	
CL 480	21.8 ±0.5	38.1 ±3.8	40.1 ±3.5
CL 480 SA	7.0 ±0.6	37.8 ±5.3	55.2 ±5.9
CL 480 PA	-	-	-

Sorption of NH_4-N using Non-activated Wood Shavings Biochar



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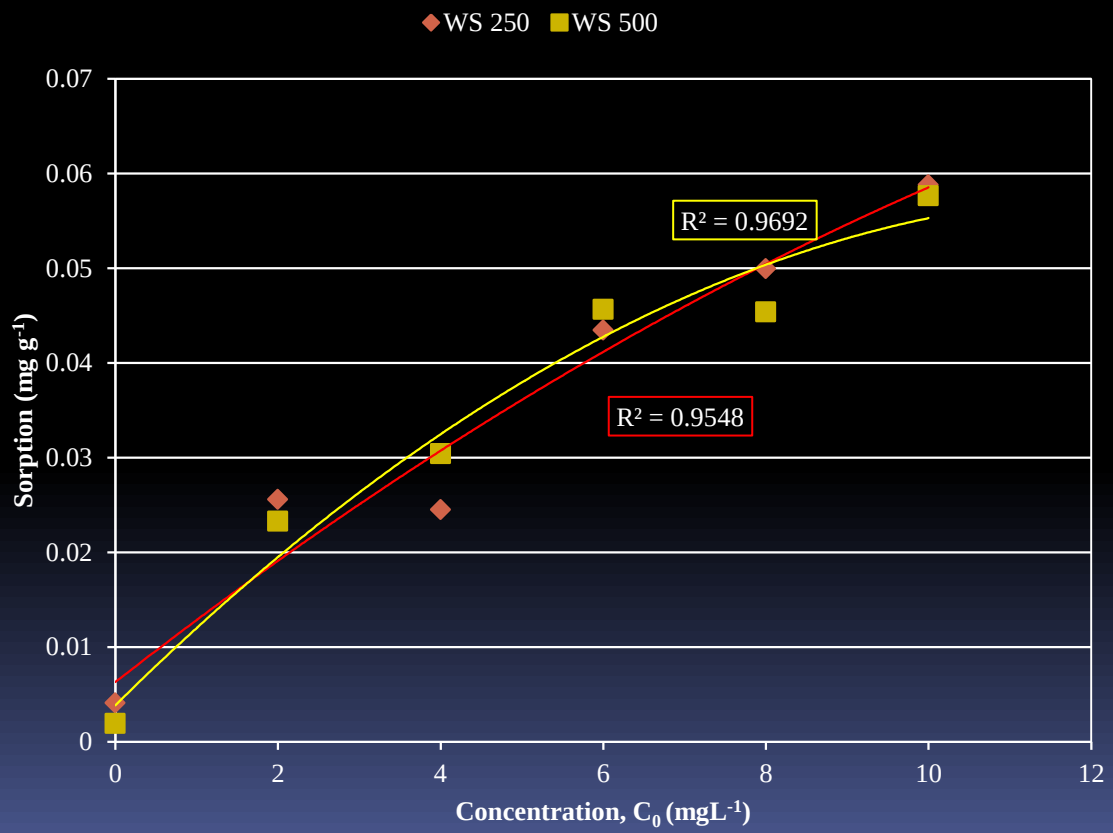
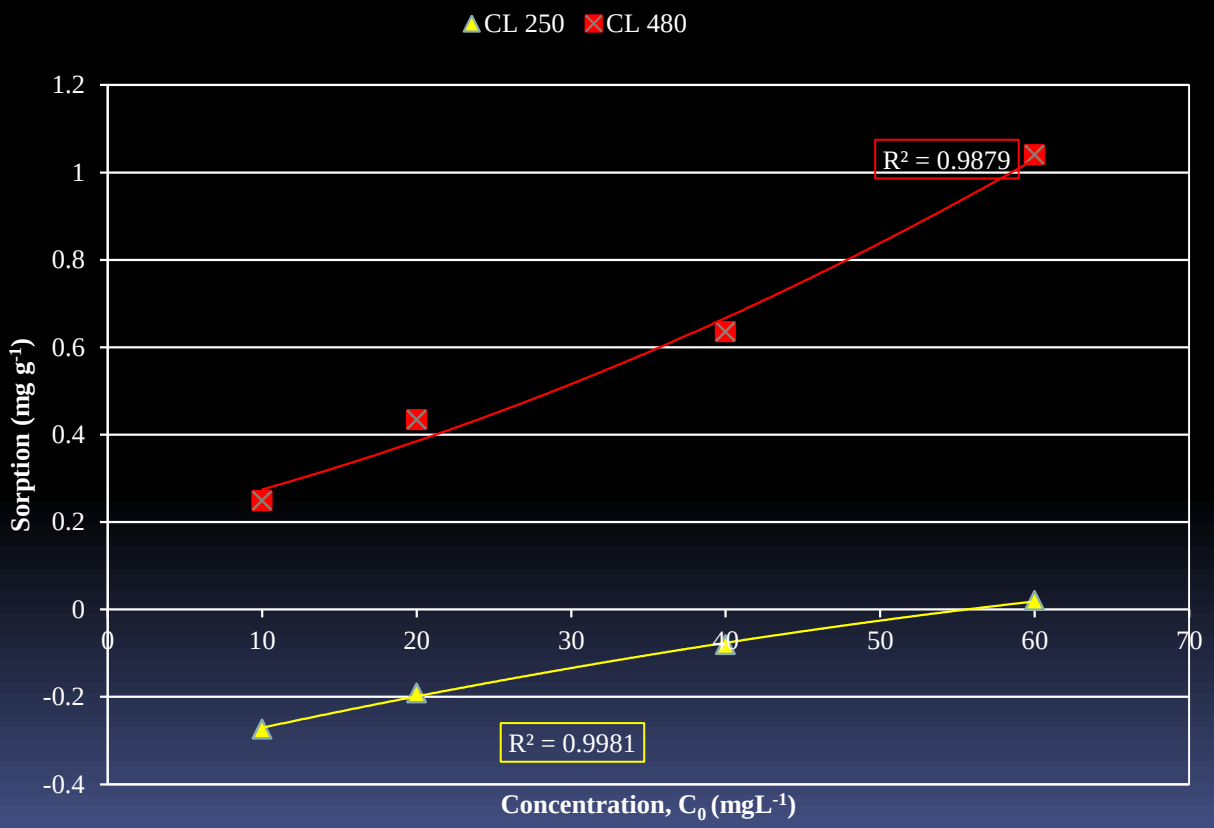


Sorption of NH_4-N using Non-activated Chicken Litter Biochar



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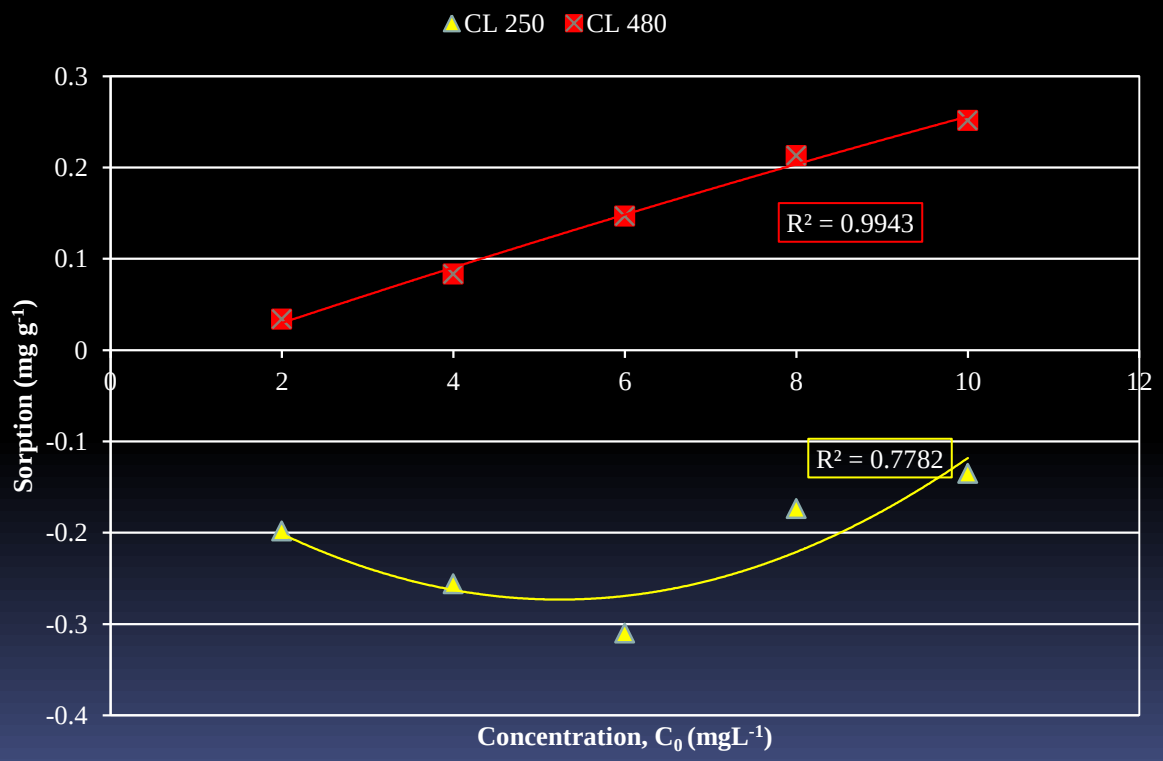
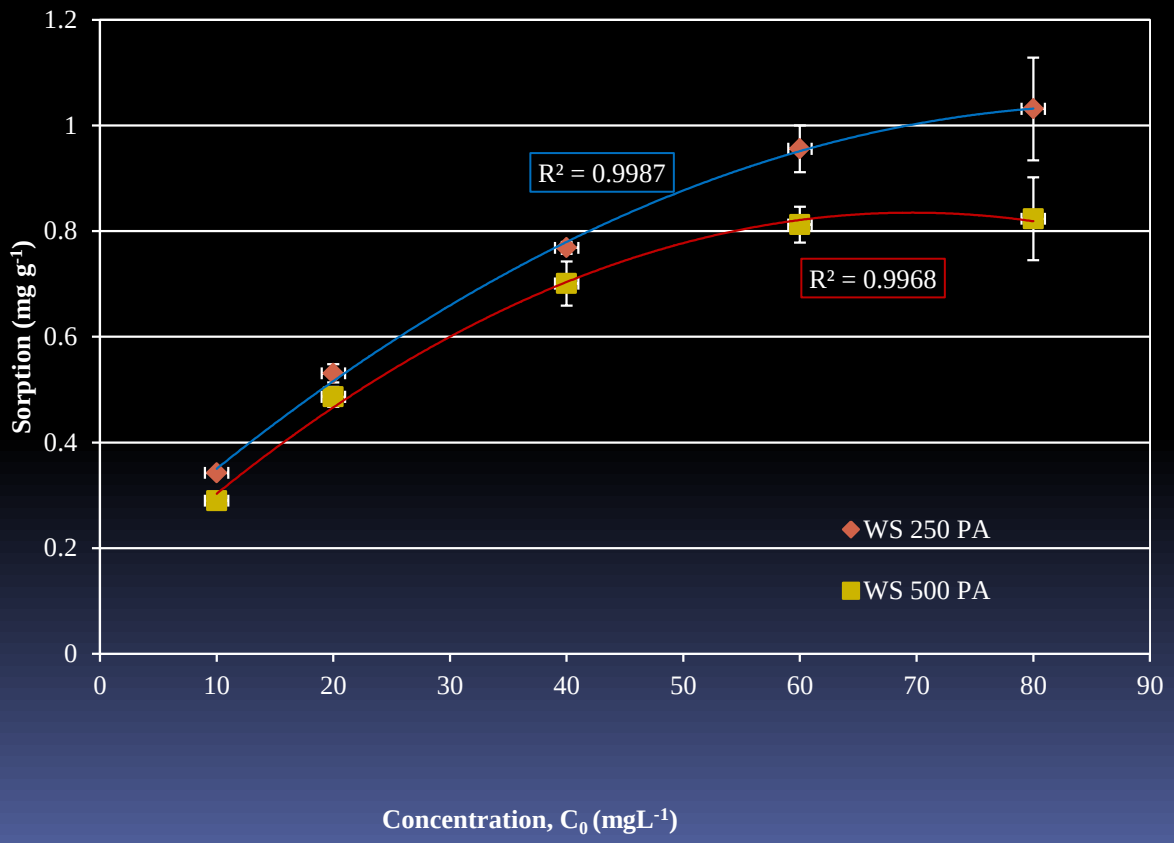
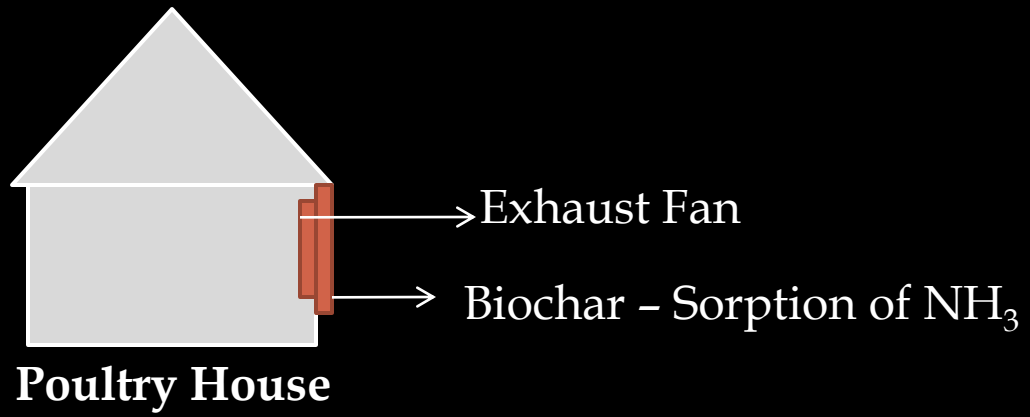
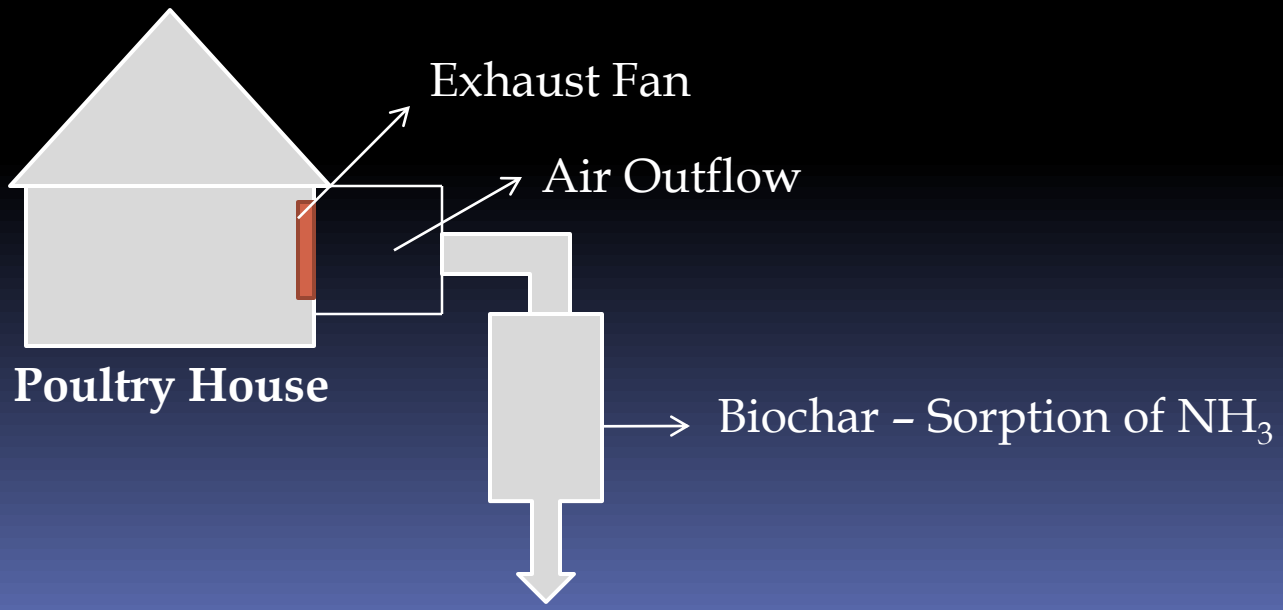


Sorption of NH_4-N using Phosphoric acid activated-wood shavings

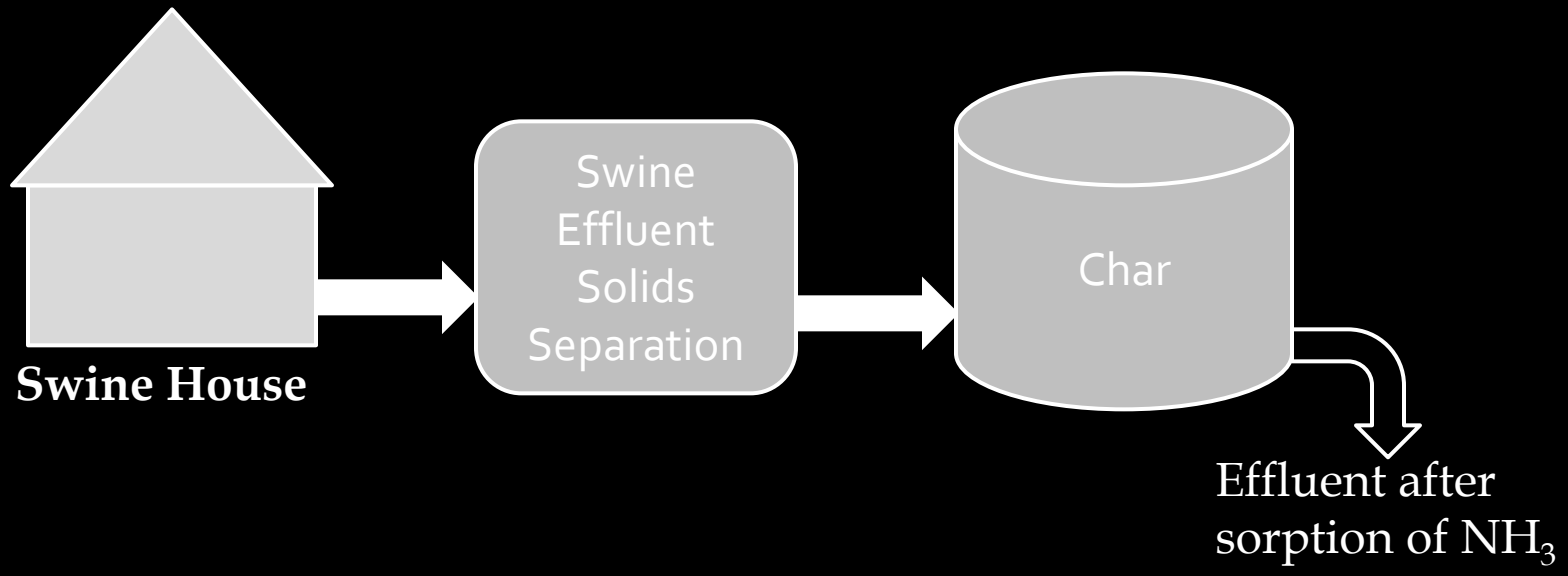


Biochar Applications Poultry





Biochar Applications
Swine Wastewater Treatment



Biochar Benefits