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Adsorption of Ammonium (NH4+) Ions onto various Vietnamese biomass residue-derived biochars (wood, rice husk and bamboo)

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University of Birmingham

School of Geography, Earth, and Environmental Sciences

Adsorption of ammonium nitrogen (NH_4^+-N) ions onto various Vietnamese Biomass Residue–derived Biochars (wood, rice husk and bamboo)

Presented by: Nguyen Van Hien – nvhien.sfi@gmail.com

Alba, Italy 2017

The context in Vietnam

- Low soil organic mater (OC<2%) due to fast decomposition under tropical weather

- Low use effectiveness of N-fertilizers: < 50%

- Several rivers and lakes polluted (ammonia, heavy metals)

- Several agricultural residues are burnt after harvesting



Rice straw after harvesting

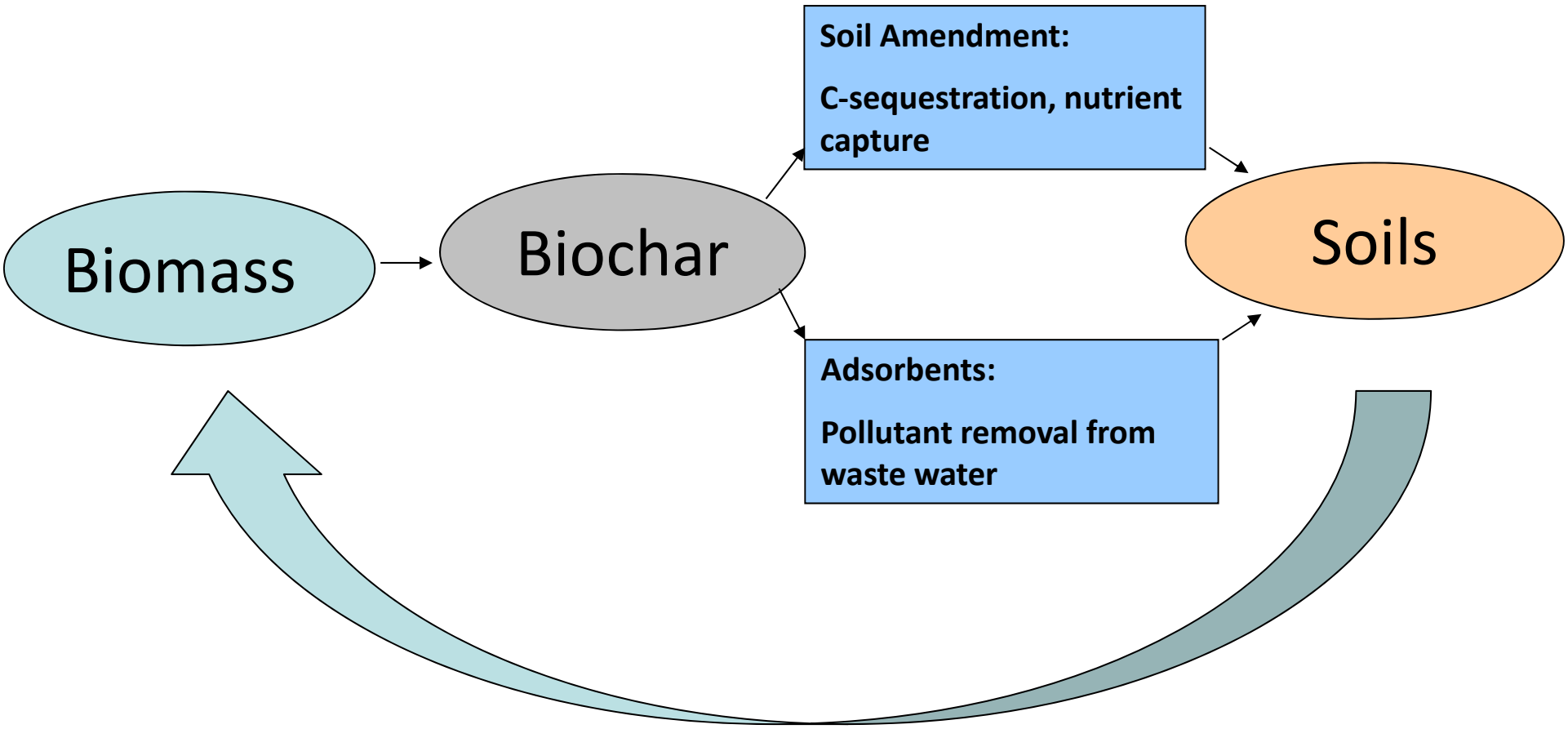


Rice straw burnt on the field



Ash after burning

Research Goals



Methods

Biochar Production:

- Biomass residues: acacia wood chips, rice husk, and bamboo
- Production equipment: Top – Lid Updraft Drum (TLUD)
- Pyrolysis temperature : 450-550 ^{o}C



Biomass



Pyrolysis



Biochar

Biochar production by TLUD Oven



Cut wood and bamboo to fit across the drum. Place rice husk then bamboo/wood in layers about 20cm high



Top layer is wood



Then light fire



Pyrolysis process

Methods (cont.)

Adsorption experiments:

- Biochar dosages: 0.25, 0.5, 1.0, 2.0g BC + 40 mL NH_4^+ (40mg/L, pH=7), shaking 24h, T^o = 22±0.5 ^oC
- Adsorbate concentrations: 20, 40, 80, 160, 320 mg NH_4^+/L (40mL) + 0.5g BC, pH=7, shaking 24h, T^o = 22±0.5 ^oC
- Contact times: 30, 60, 90, 120, 240, 360 mins; 0.5g BC+ 40 mL NH_4^+ (40mg/L, pH=7), T^o = 22±0.5 ^oC

Data analysis:

- Langmuir, Freundlich, and Temkin Isotherm models
- Pseudo-First Order and Pseudo-Second Order kinetic models, Intraparticle Diffusion model

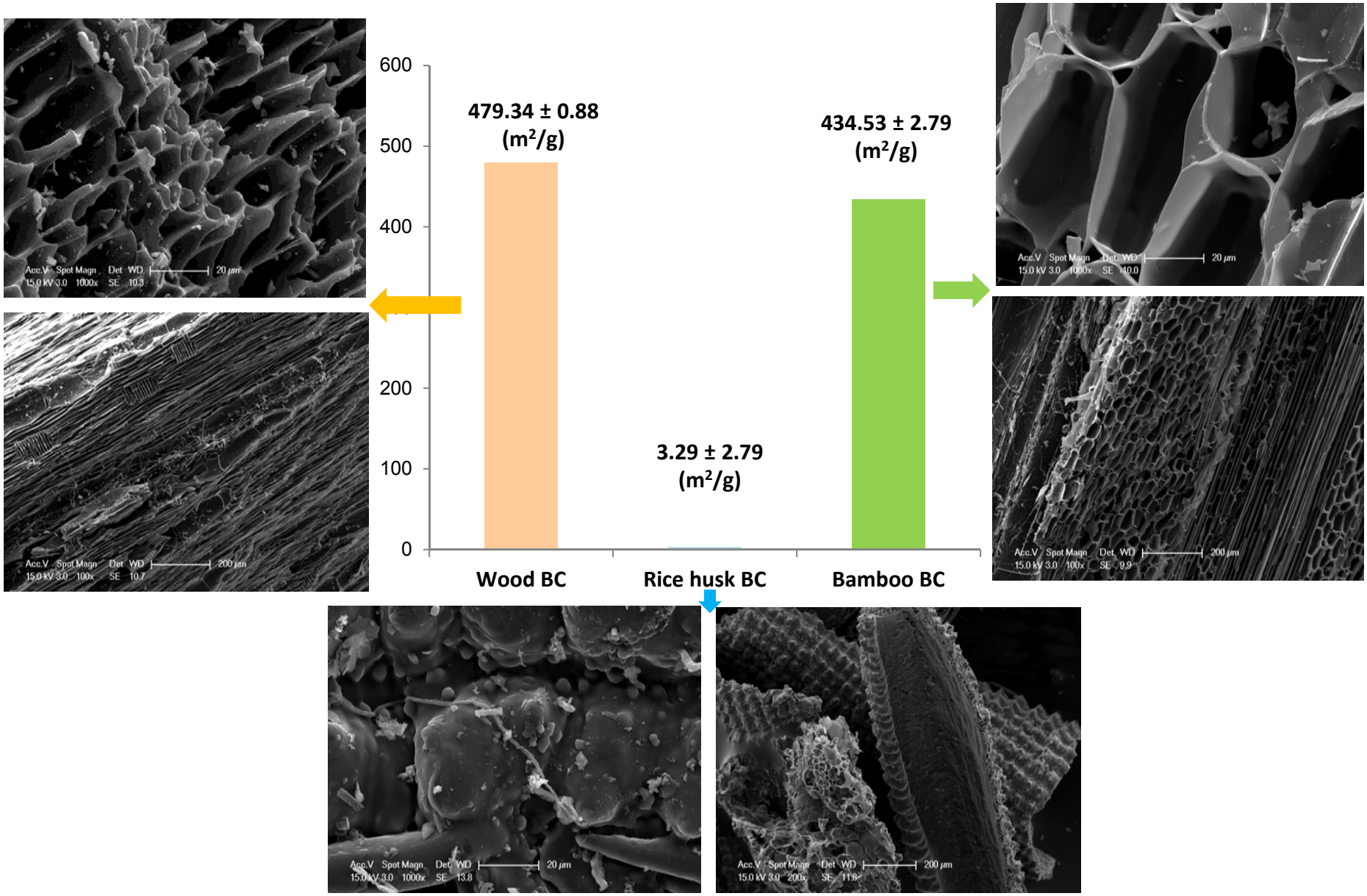
Results and Discussion

Chemical Properties of the Biochars

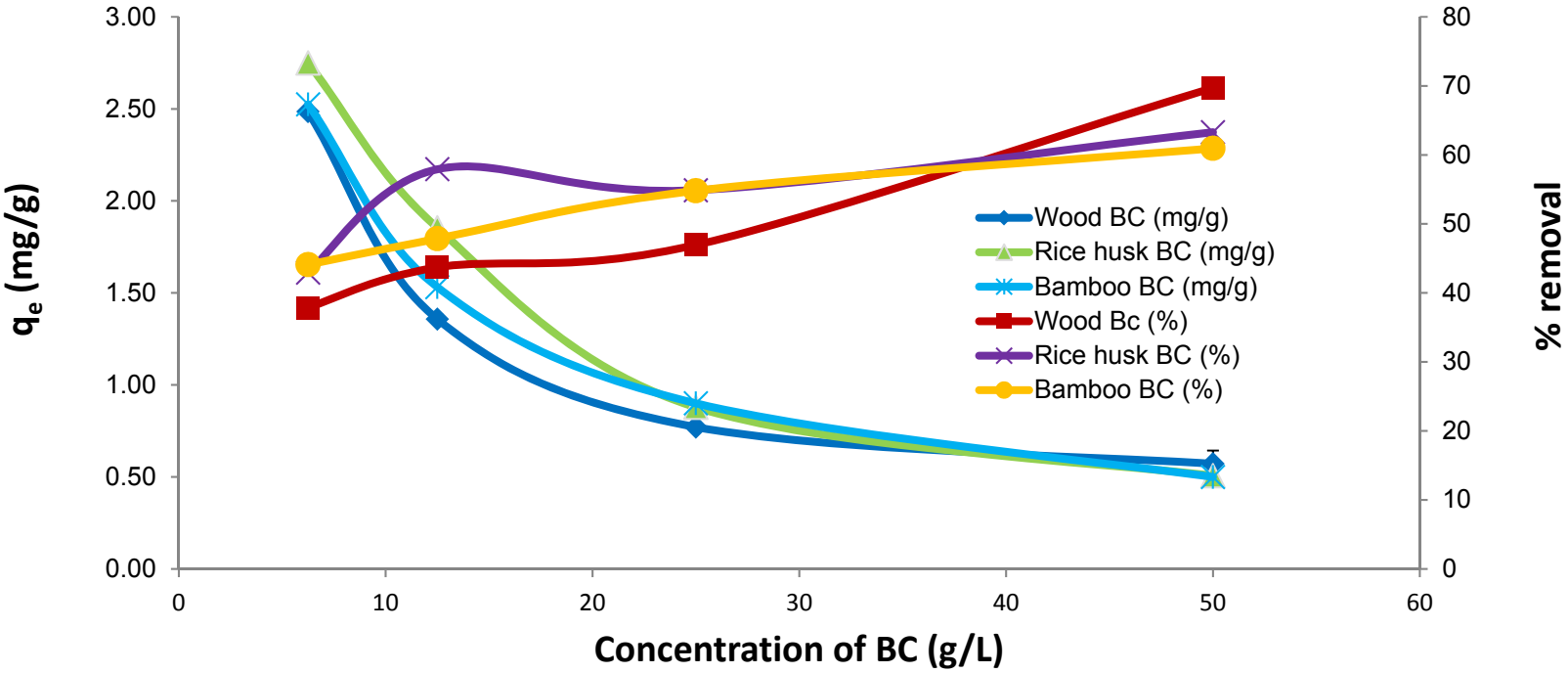
Parameters	Wood BC	Rice husk BC	Bamboo BC
pH	10.11	9.51	9.94
CEC, Cmol/kg	13.53	26.70	20.77
C,%	82.11	47.82	80.27
Volatile mater,%	46.56	45.61	48.72
Fixed carbon,%	46.06	7.82	37.09
Ash, %	1.93	41.24	8.08

- pH of the biochars: alkaline
- CEC and Ash: rice husk BC > bamboo BC > wood BC
- C and fixed carborn: rice husk BC < bamboo BC < wood BC

SEM and BET Surface Area

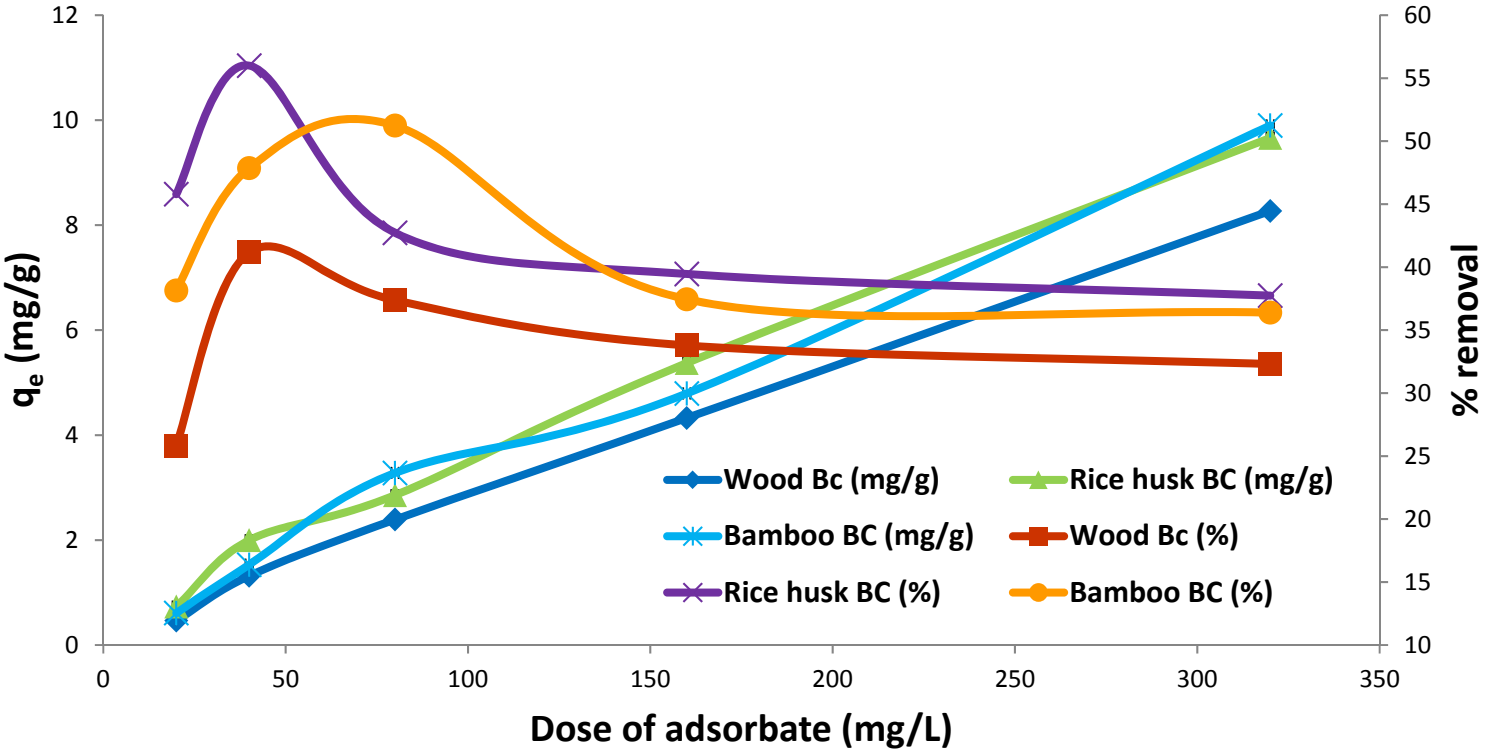


Effect of Adsorbent Dosage on NH_4^+-N Adsorption



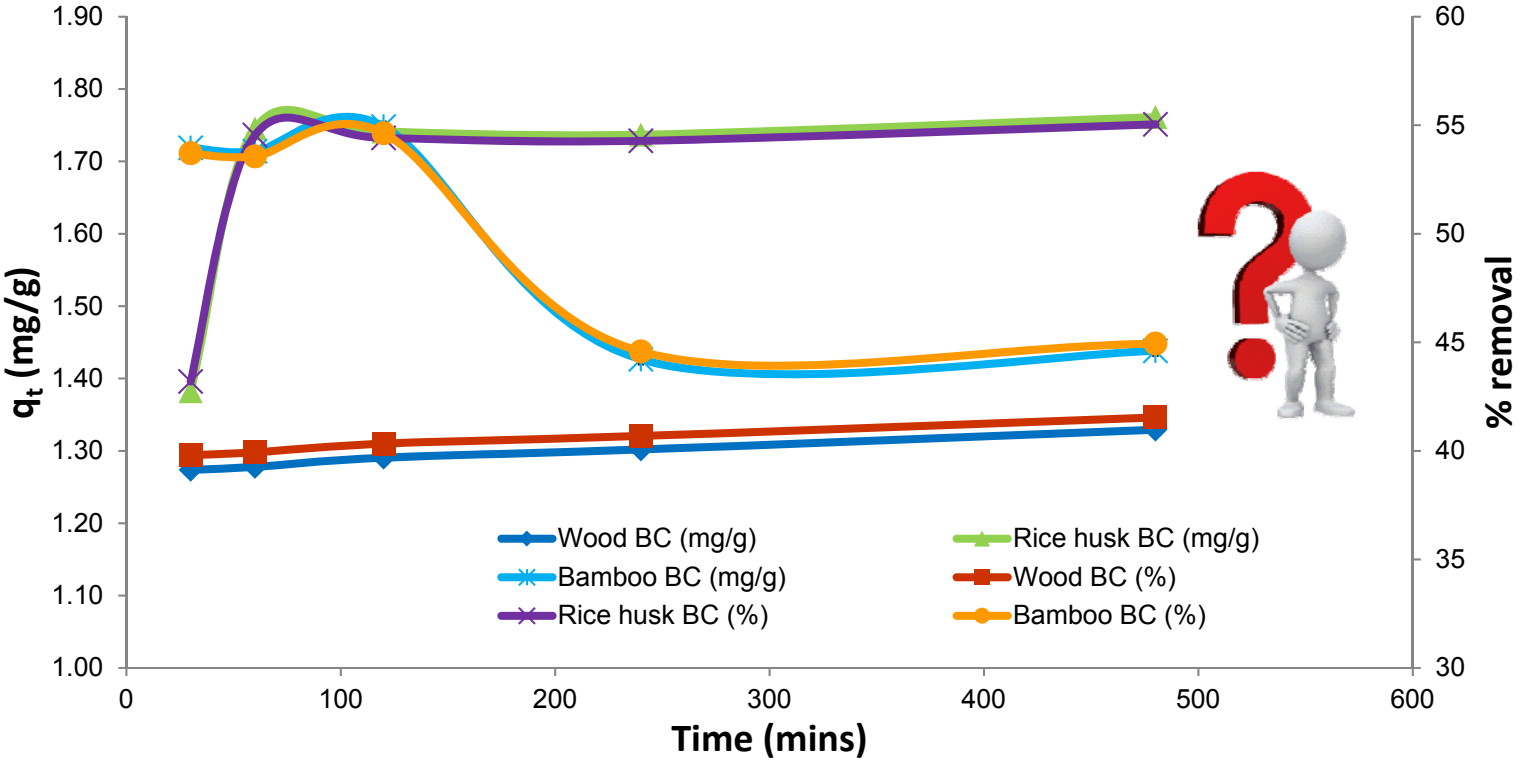
- NH_4^+ adsorption decrease when increasing adsorbent dosages
- The adsorption: rice husk BC > bamboo BC > wood BC for 6.25 - 25g/L, but the same with BC dosages being higher 25g/L
- Increase in NH_4^+ removal with increasing adsorbent dosages

Effect of Adsorbate Concentrations on NH_4^+-N Adsorption



- Strong adsorption increase when increasing adsorbate concentrations.
- Decrease in the removals for wood and rice husk BCs with >40 mg NH_4^+-N/L and > 80mg/L for bamboo BC.

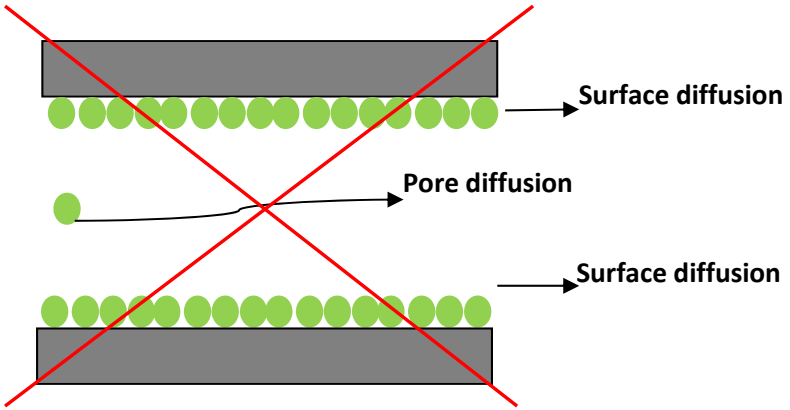
Effect of Contact Times on NH_4^+-N Adsorption



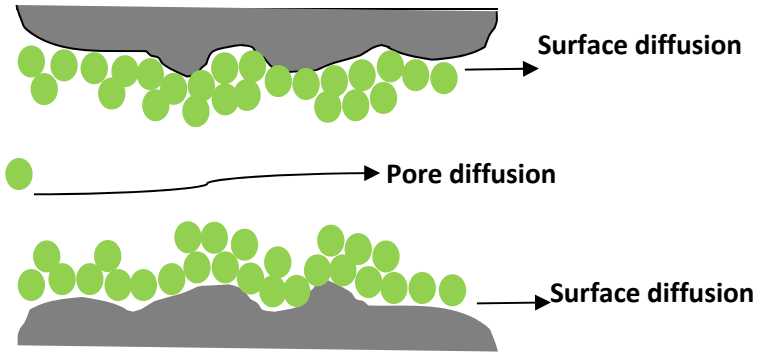
- Nearly equilibrium adsorption for wood BC after 30 mins.
- Strong NH_4^+ adsorption onto rice husk BC during 30-60 mins.
- Dramatic decrease in adsorption for bamboo BC during 90-120 mins before reaching equilibrium.

Isotherm Adsorption

Adsorbent	Langmuir model			Freundlich model			Temkin model		
	q_{max}	K_L	R^2	K_F	1/n	R^2	B	A	R^2
Wood BC	-8.097	-0.28	0.9295	0.04	0.985	0.9658	2.645	-2.662	0.9114
Rice husk BC	88.50	6.73	0.9111	0.14	0.801	0.9489	2.803	-2.317	0.8994
Bamboo BC	-12.55	-0.64	0.9425	0.08	0.911	0.9460	3.063	-2.516	0.9109



a) Monolayer adsorption on homogenous surface

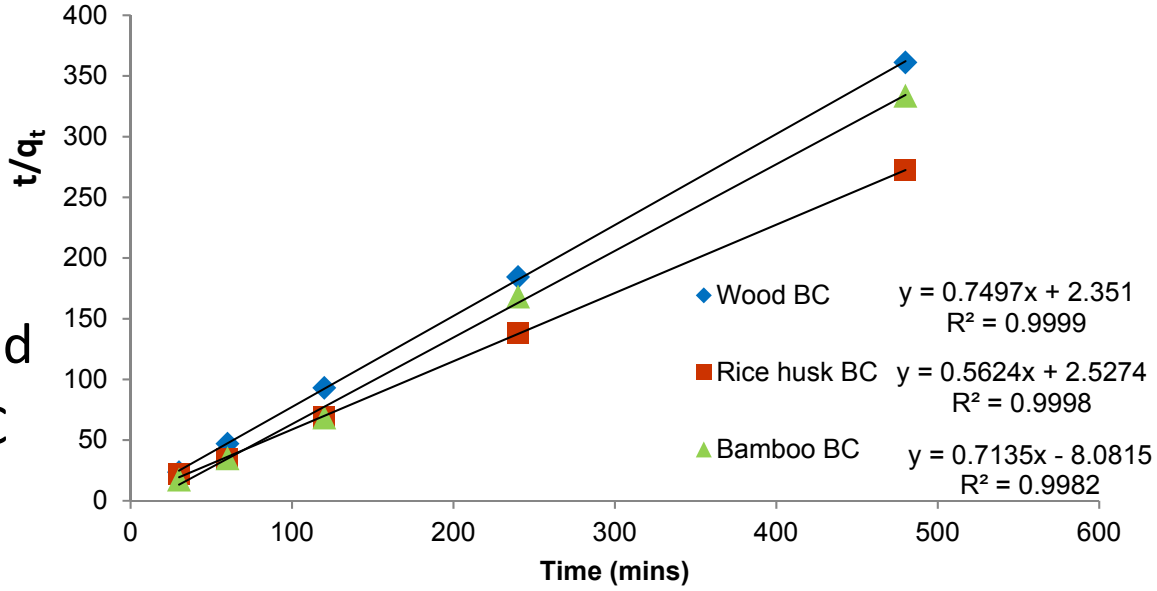


b) Multilayer adsorption on heterogeneous surface

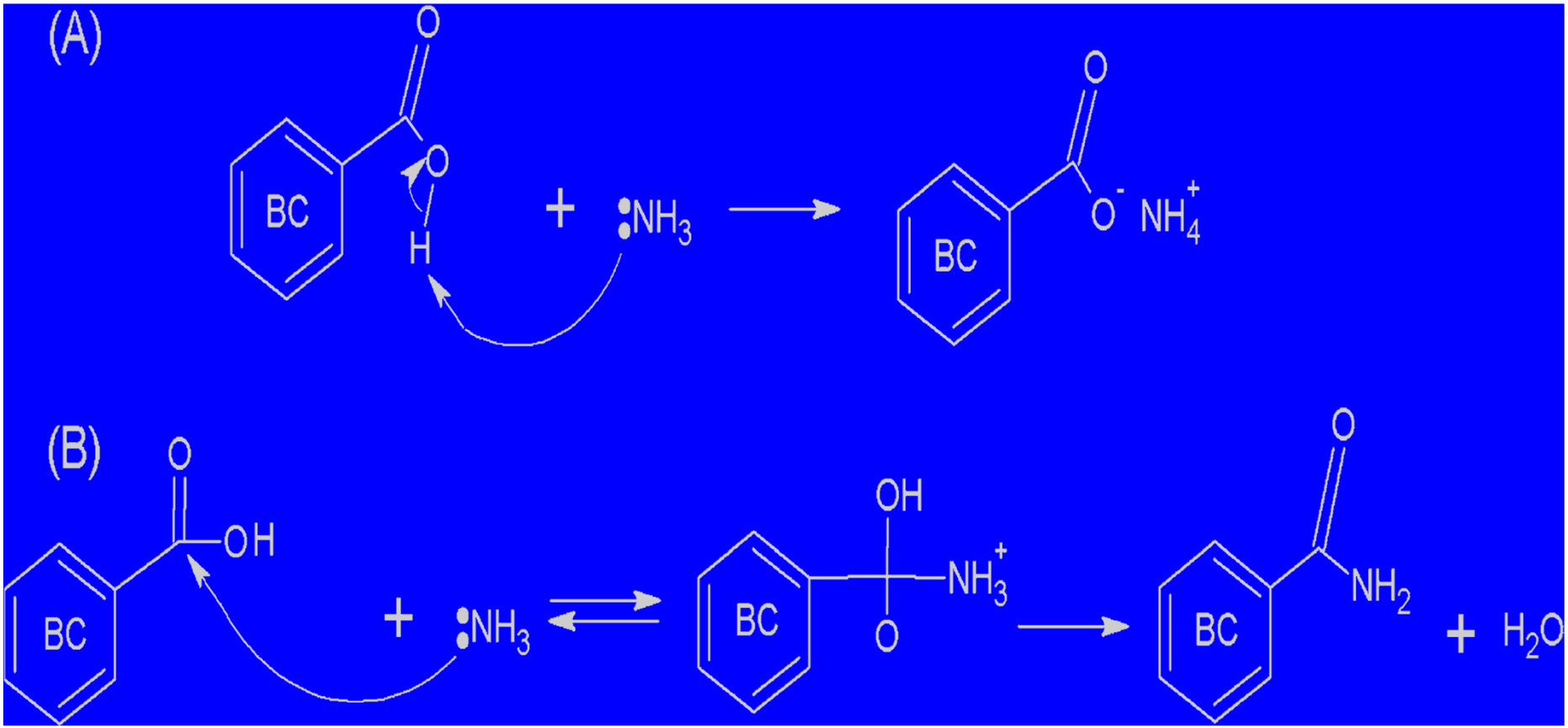
Kinetics of Adsorption

Adsorbents		Pseudo - First Order			Pseudo - Second Order		
	$q_{e\text{-}exp,\ mg/g}$	$q_{e\text{-}cal1}$	K_1	R^2	$q_{e\text{-}cal2}$	K_2	R^2
Wood BC	1.36	0.09	0.002	0.9912	1.33	0.24	0.9999
Rice husk BC	1.85	0.02	0.002	0.3158	1.78	0.13	0.9998
Bamboo BC	1.53	-	-	-	1.40	-0.06	0.9982

- Pseudo - Second Order fits well with the experimental data
- The NH_4^+ adsorption governed by chemical adsorption via CEC and functional groups



NH_4^+ adsorption by biochar



(Skurt A at al ,2011)

Intraparticle diffusion

Step 1: NH_4^+-N ions from bulk solution transport to external film around BC

↓

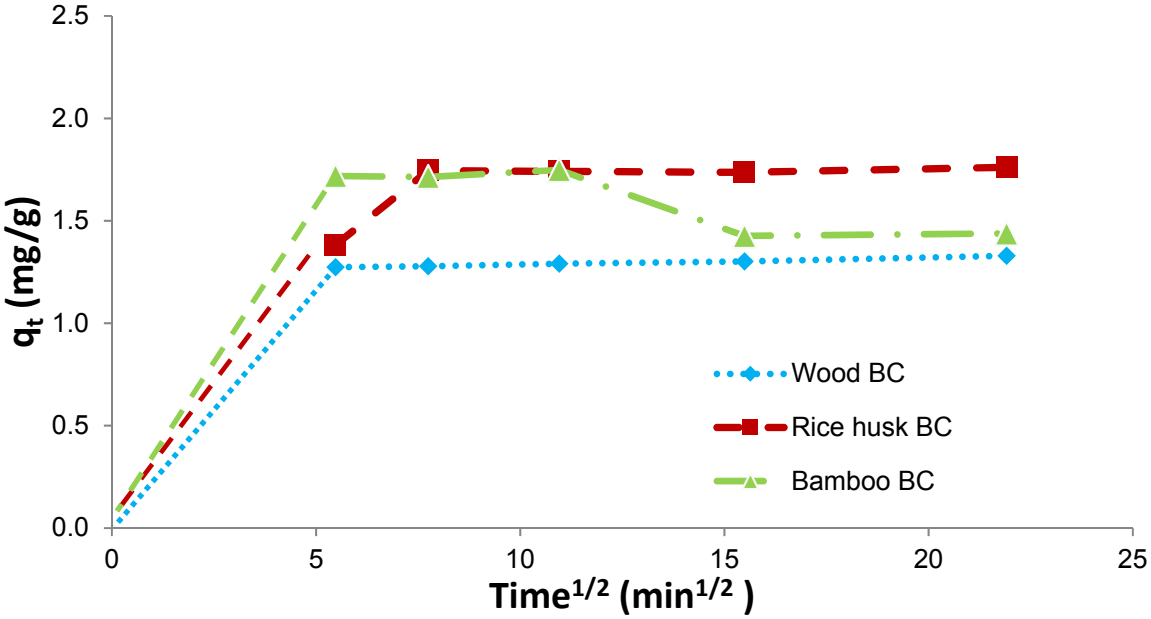
Step 2: Move to external BC surface by film diffusion

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Step 3: Move into pores and Intraparticle diffusion occurs

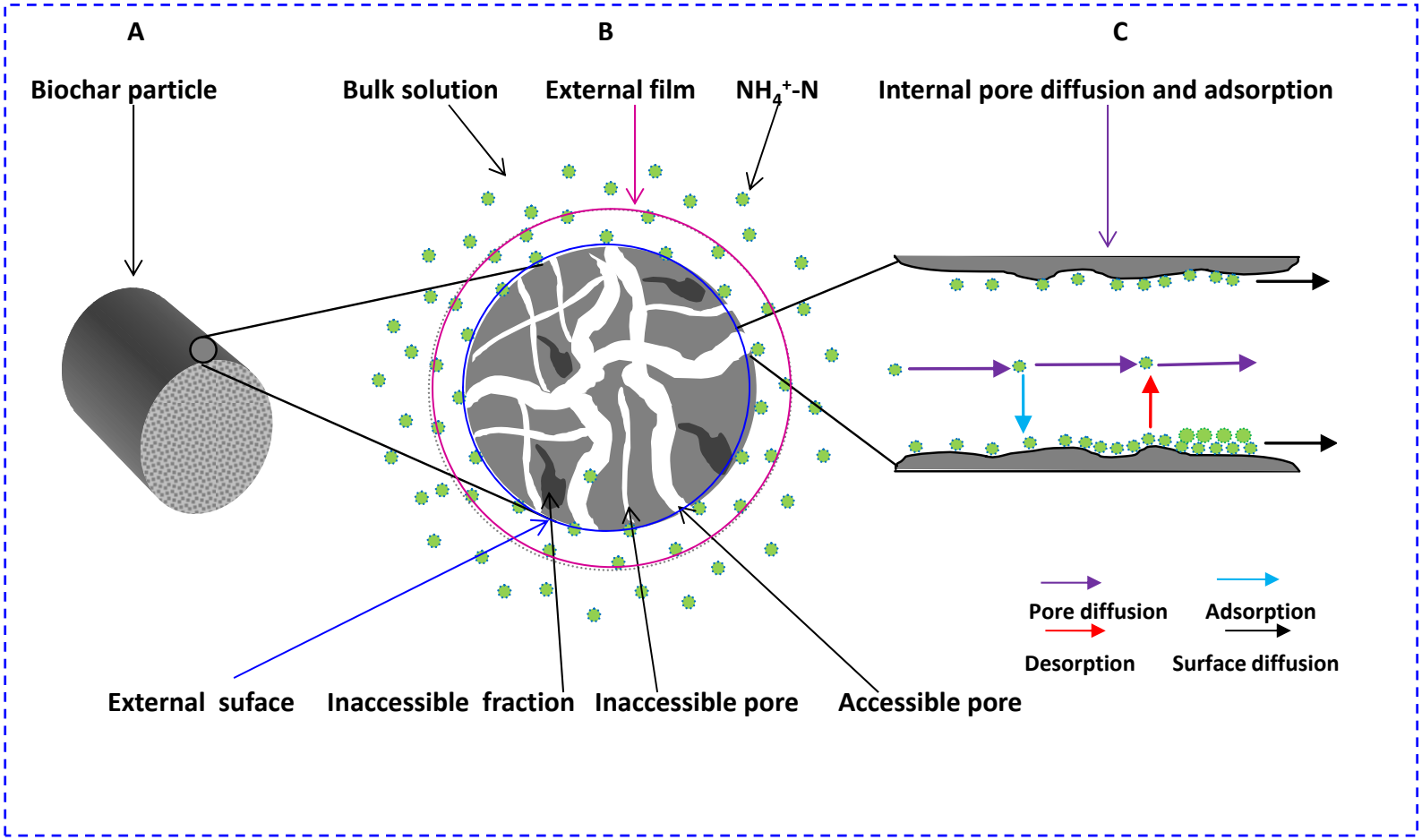
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Step 4: Adsorption



Adsorbent	Intraparticle diffusion		
	K_{id}	C	R^2
Wood BC	0.013	1.574	0.9189
Rice husk BC	0.086	1.7148	0.7339
Bamboo BC	-0.084	1.9907	0.6863

Intraparticle Diffusion Schemature



Conclusion

- The three biochars are alkaline, high carbon content, with significant differences in morphology (SEM).
- The results showed good adsorption for NH_4^+-N in aqueous solution, particularly rice husk BC.
- The adsorption was governed by chemical adsorption (CEC, functional groups) on heterogeneous surface with multilayer adsorption.

Acknowledgements

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Thank You & Questions?