MOISTURE EFFECT ON CO_2 *ADSORPTION ON COAL*

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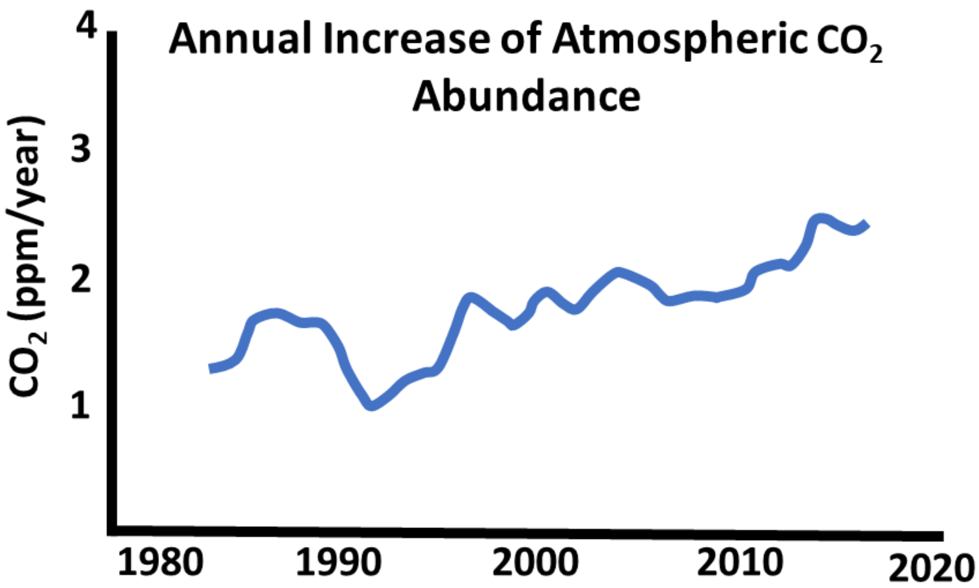
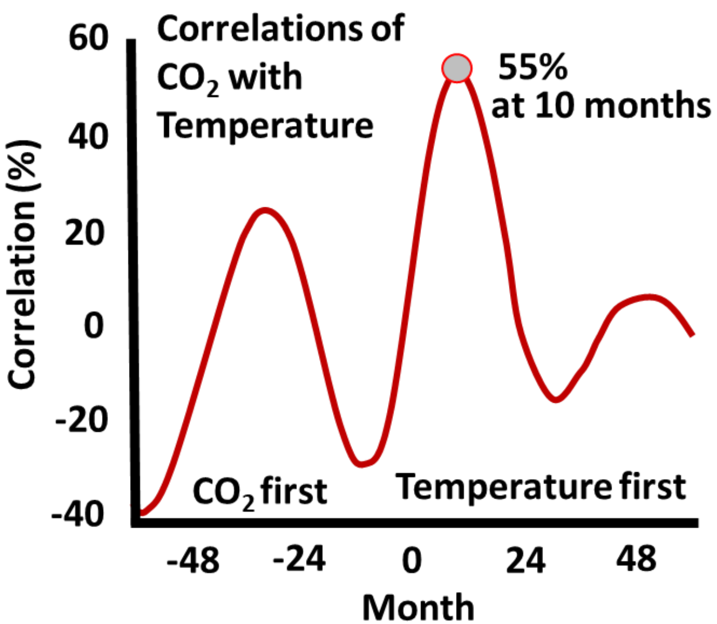
Outline

- Background
- Research purpose
- Experimental work
- Result
- Conclusion

Background

Increasing atmospheric CO_2 concentration leads to increasing global temperature





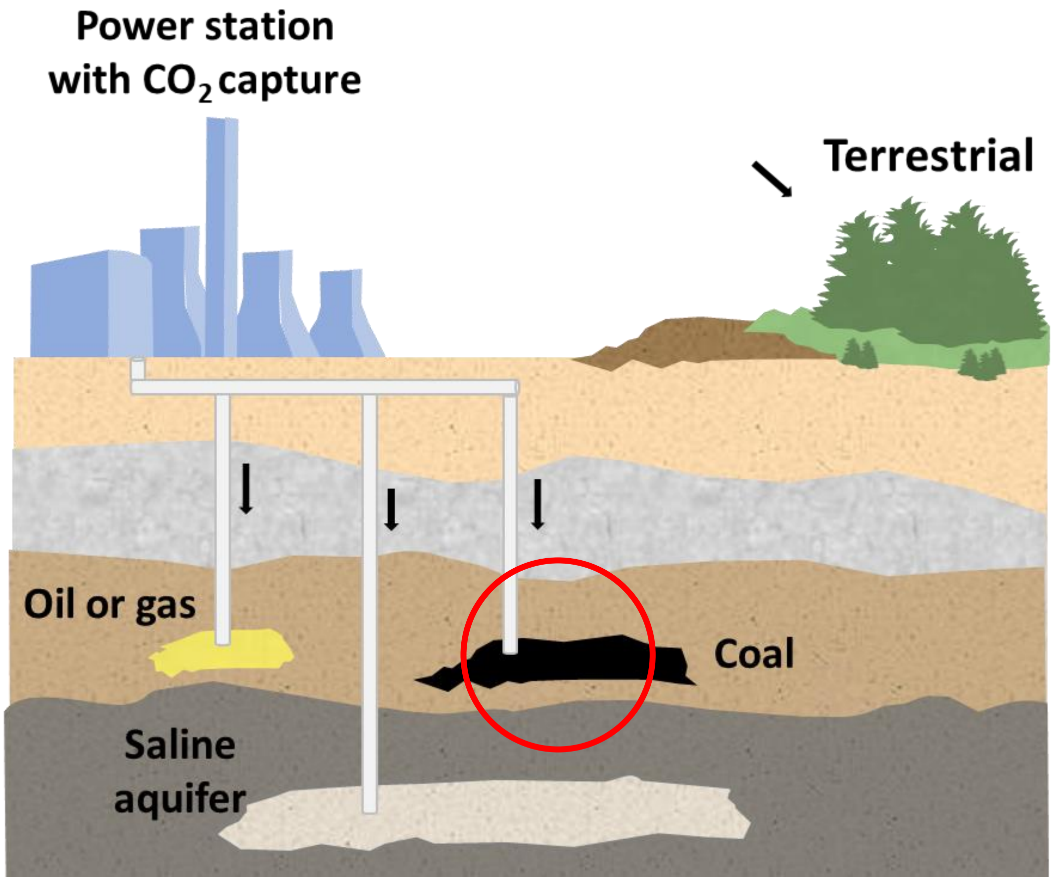
(Hansen et al, 2019)

Atmospheric CO_2 content has significantly increased, which will have a huge impact on the **ecological environment** and **human life**

(Cheng, Wang, and Zhang 2011; Solomon, Qin, and Manning 2007)

Background

CO_2 sequestration technologies to minimize the CO_2 release into the atmosphere



(Mohammadian et al, 2019)

CO_2 can adsorb firmly to the **coal**

CO_2 can access to the finest **coal porosity**

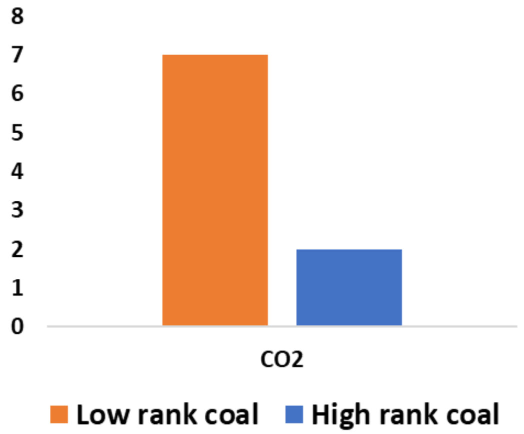
Adsorption is main trapping mechanism for CO_2 storage in coal seams where it constitutes to about **95-98%** of total storage

Minimal chances of its later release

(Kross et. al, 2002; Silva et al, 2012)

Background

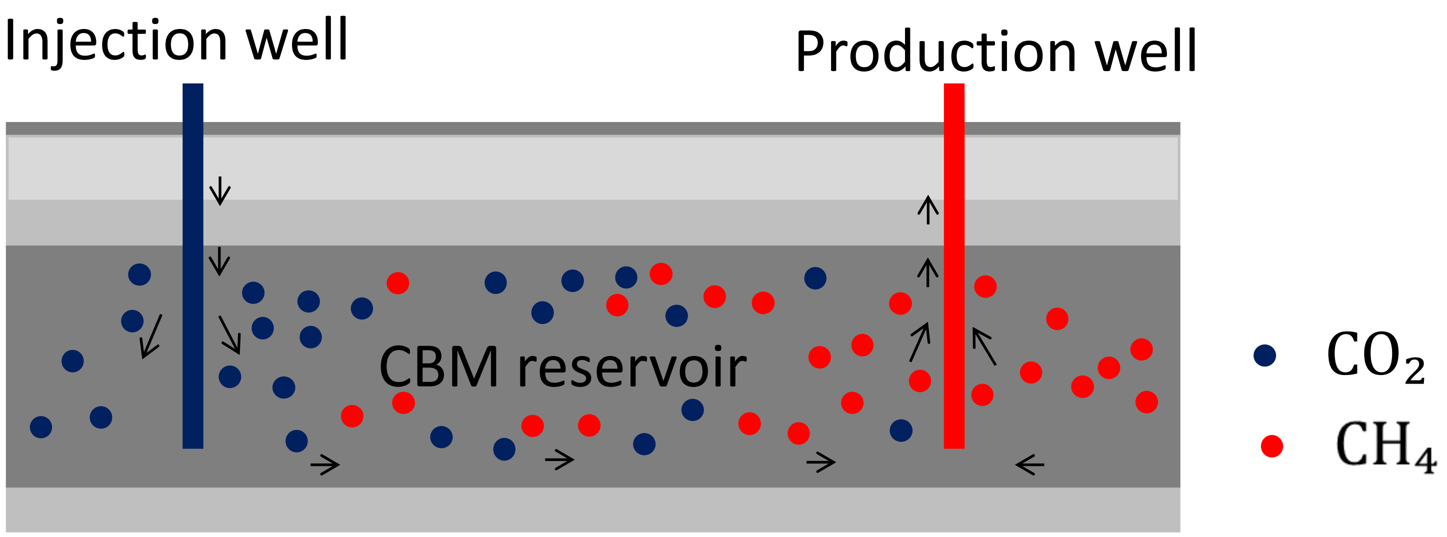
- **Low-rank coal has higher potential than high-rank coal**

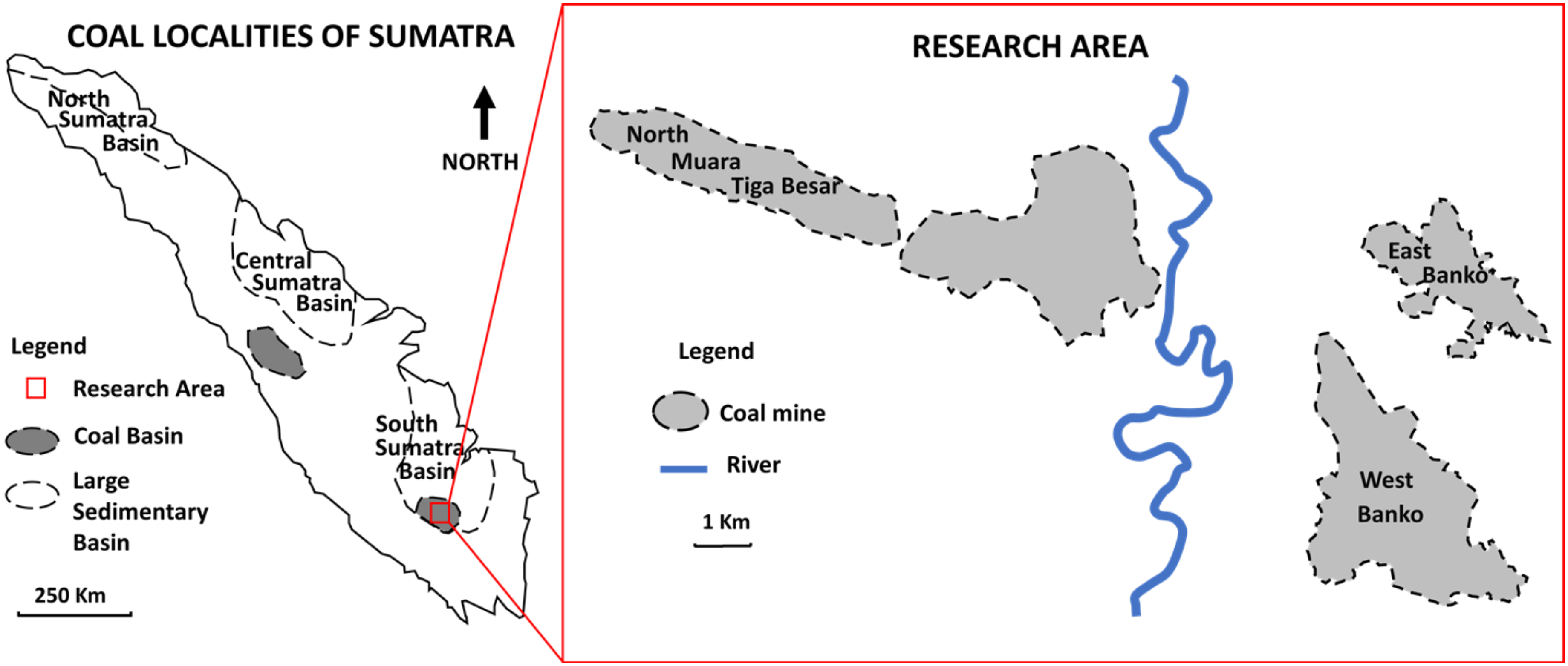


- Low rank coal can adsorb CO_2 in higher volume than high rank coal
- Low rank coal remains undeveloped and has high potential to be used

(Mares et al, 2009)

- **Promising for enhanced coal bed methane (ECBM) recovery**





Coal characteristic

Coal thickness: 4-13 m
Depth: 240-350m

Coal rank: Sub-bituminous (low-rank coal)
Seam B is the thickest seam

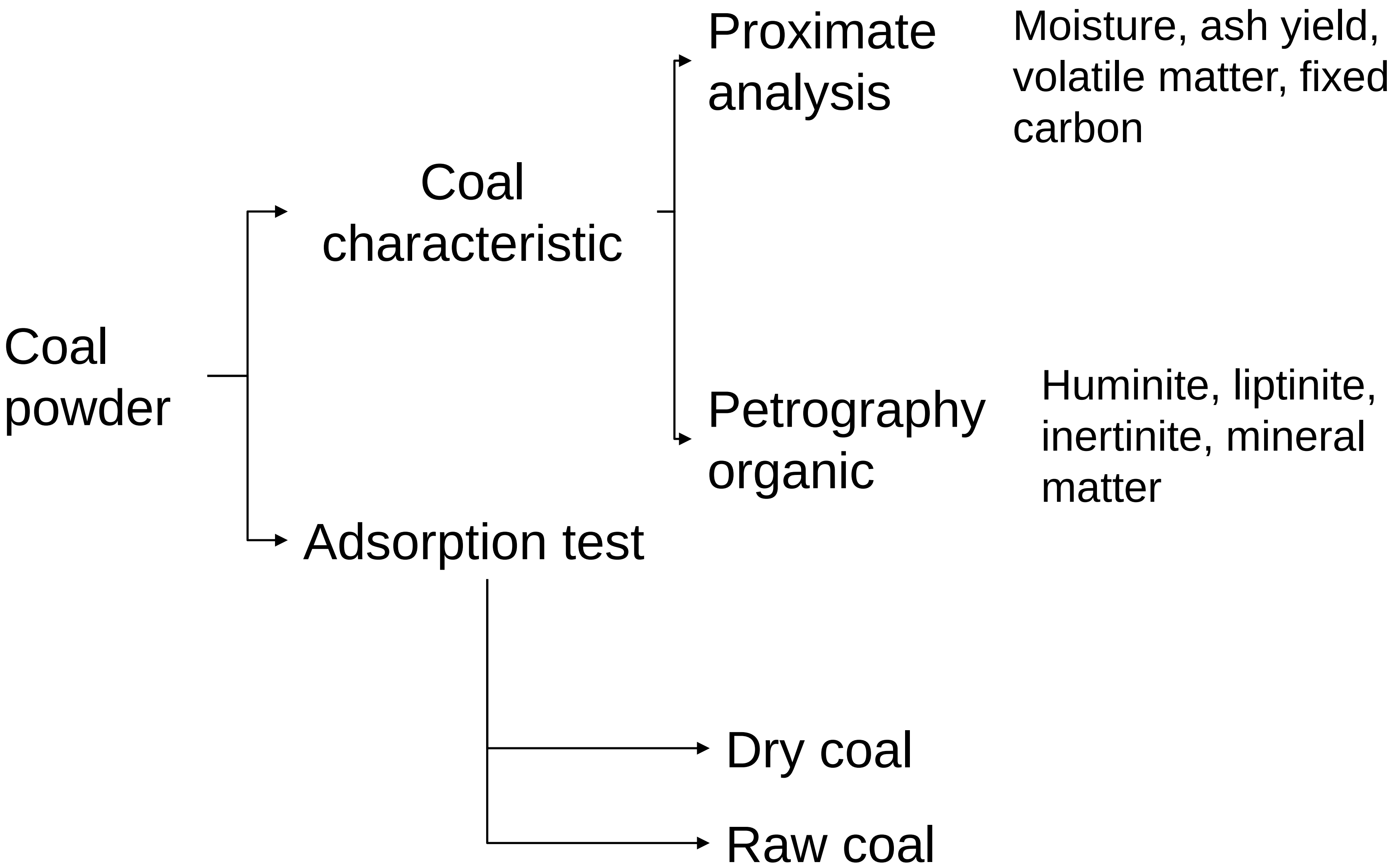
Challenges

- Coal samples in dry condition have been mainly used to analyze CO_2 adsorption on coal, meanwhile underground storage conditions saturated by water
- Previous studies in South Sumatera only made predictions using numerical simulation based on literature study

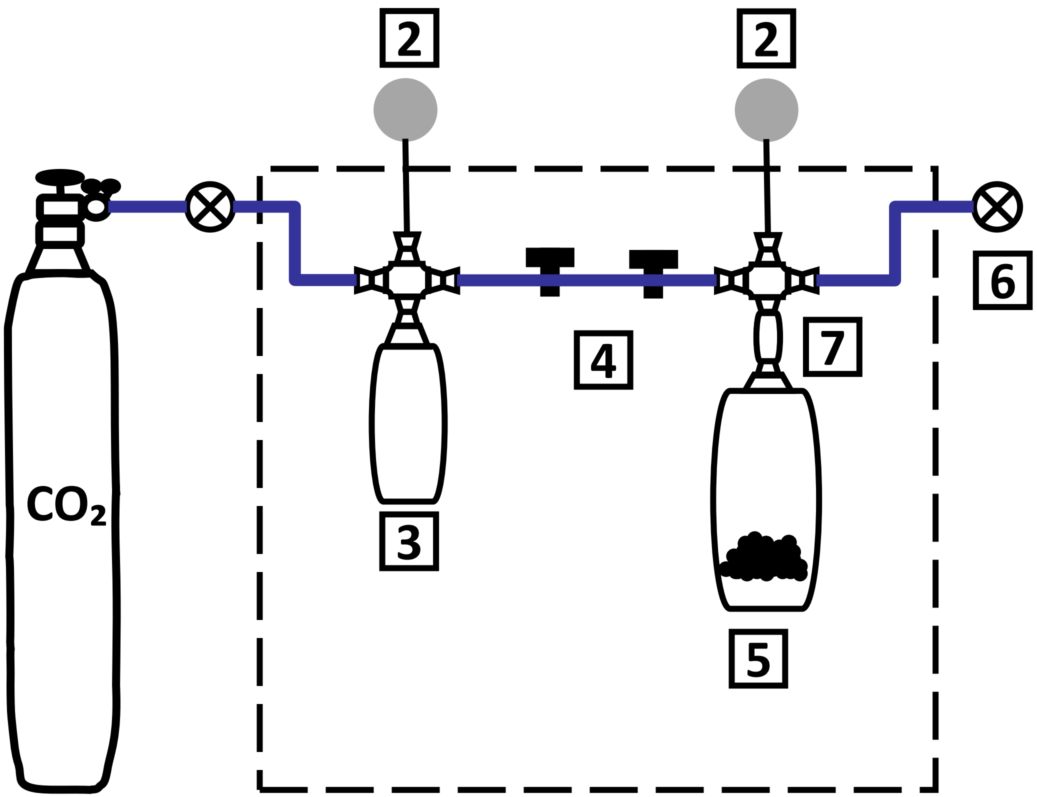
Research purpose

- Describes CO_2 adsorption in coal samples with in-situ condition
- Examine the coal capability to hold CO_2 in seam B with in-situ condition from South Sumatra

Experimental work



Experimental work



Crushed coal(0.25 mm)
5 gr

1 Intake flow valve
2 Pressure sensor
3 Reference cell
4 Connecting valve
5 Sample cell
6 Exhaust flow valve
7 Filter
8 Temperature chamber (45 ℃)

CO_2 adsorption measurement

$$\Delta n^{ex} = \left(\frac{1}{RTm}\right)\left(V_{rc}\left(\frac{P_{rci}}{Z_{rci}} - \frac{P_{rcf}}{Z_{rcf}}\right) - V_{void}\left(\frac{P_{scf}}{Z_{scf}} - \frac{P_{sci}}{Z_{sci}}\right)\right)$$

n^{ex} : Gibbs excess adsorption (mmol g^{-1})
R : molar gas constant (8.314 J mol^{-1} K^{-1})
T : temperature (K)
m : mass of coal (g)
P : pressure (MPa)

rc : reference cells
sc : sample cells
i : initial condition
f : final condition

Adsorption Isotherms (Langmuir model)

$$G_a = V_L\left(\frac{P}{P + P_L}\right)$$

G_a : adsorbed-gas storage capacity
P : pressure
V_L : Langmuir isotherm
P_L : Langmuir pressure

Adsorption Isotherms (Freundlich model)

$$Q_e = K_f PCO_2^{\frac{1}{n}}$$

Q_e : the adsorption capacity
K_f : constant of Freundlich isotherm
n : heterogeneity factor

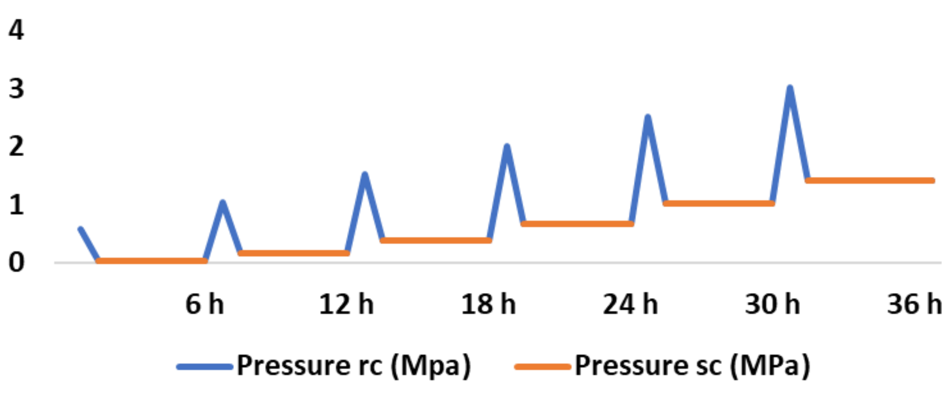
Result

Coal characteristic

Proximate analysis				
Sample	**Moisture (%)**	ash (%, d.b)	VM (%, d.a.f b)	FC (%, d.a.f b)
WB	**16.67**	2.12	49.58	50.42
EB	**22.68**	1.09	49.46	50.54
NMTB	**23.40**	1.76	49.39	50.61

Petrography analysis				
Sample	Total Huminite	Total Liptinite	Total Inertinite	Mineral Matter
WB	64.43	20.69	13.43	1.45
EB	58.92	25.95	12.07	3.06
NMTB	52.00	24.73	21.27	2.00

Equilibrium time in every pressure steps



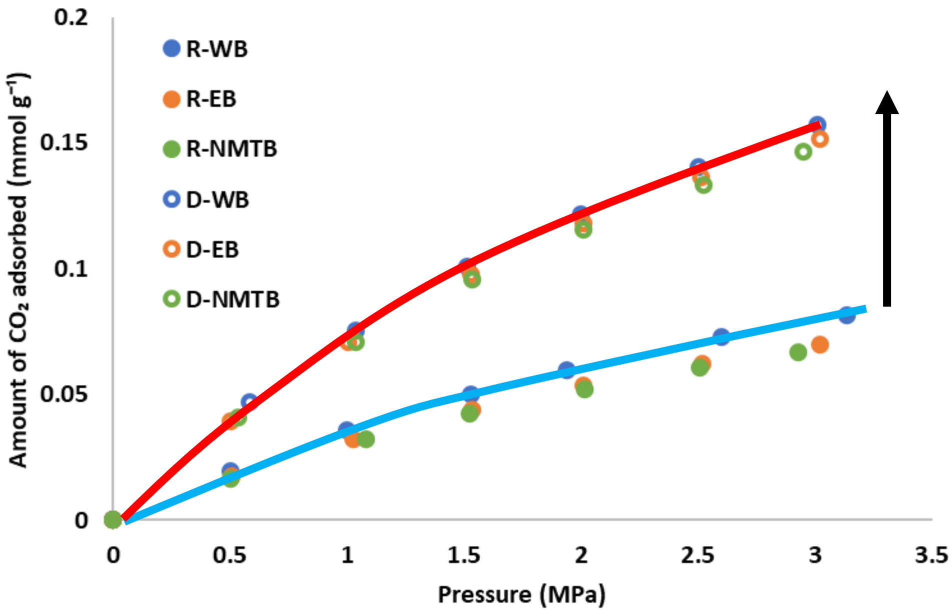
raw	11-12 h

dry	6-10 h

Based on Thomas (2013), these coal samples are **low-rank coal** and classified as **high volatile bituminous C**

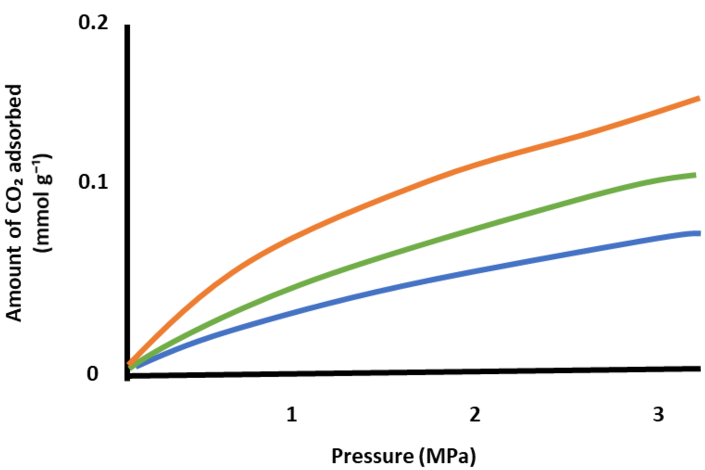
Raw coal took longer time to reach equilibrium than dry coal

Result



The drying process increased adsorption capacity

Compare with similar coal characteristic



US subbituminous coal-wet condition (Romanov et al., 2013)

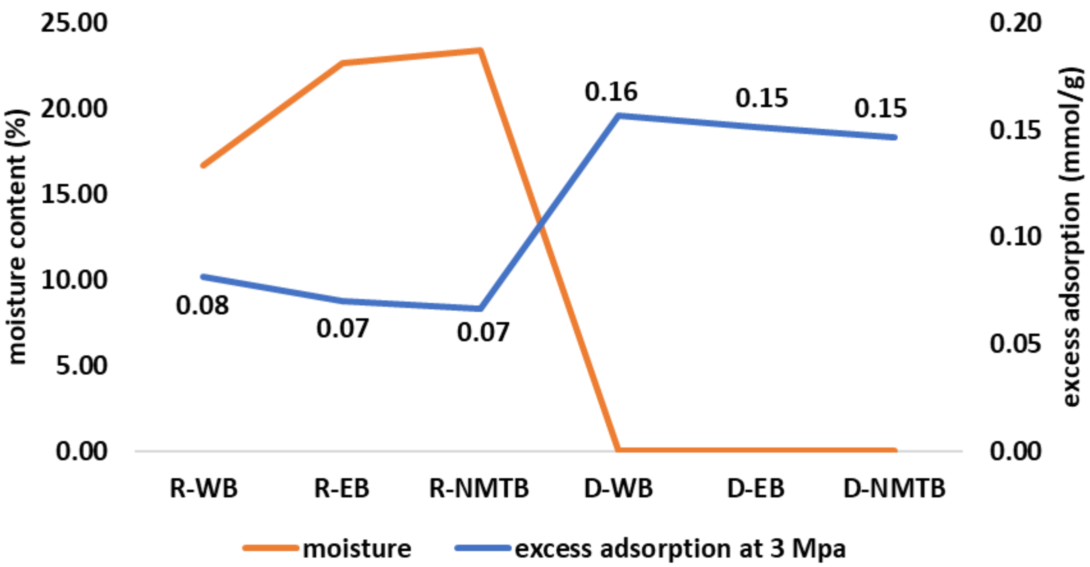
Malaysian subbituminous coal-wet condition (Abunowara et al., 2020)

This study-raw condition

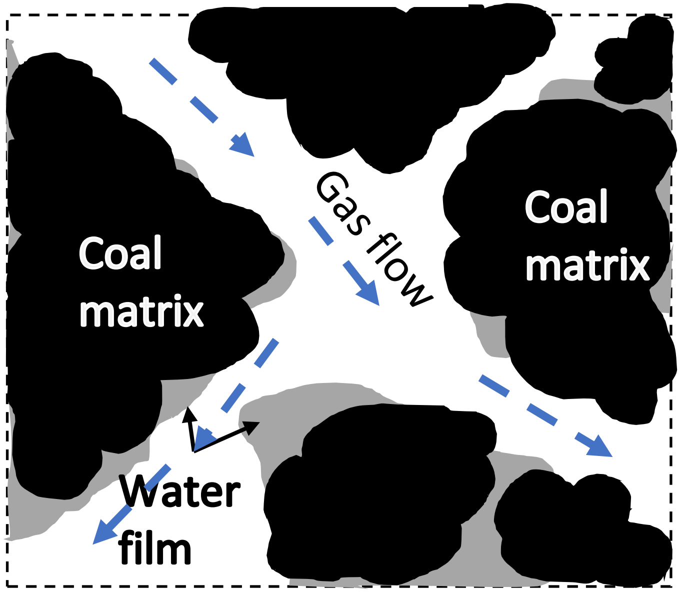
Result

Adsorption factor with different water content

Drying process



Dry condition



Drying process increasing adsorption capacity until 100-110%

Water content invading adsorption site and reduces the permeability

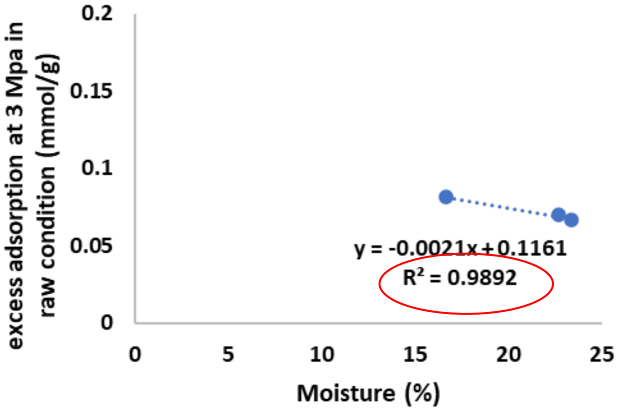
(Wang et al, 2011; Zhao et al. 2018)

Drying process might not depict natural situation

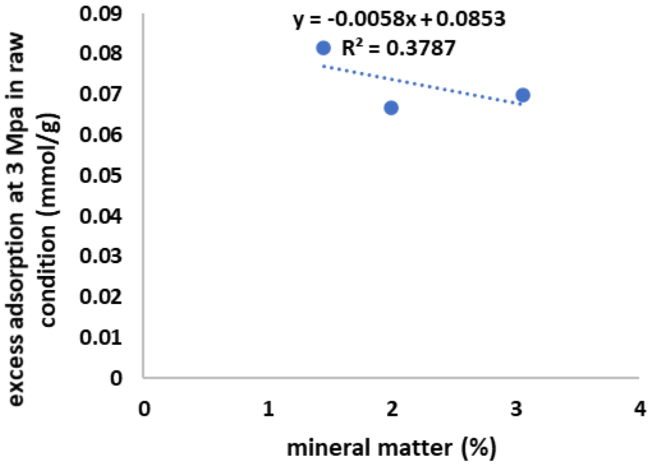
Result

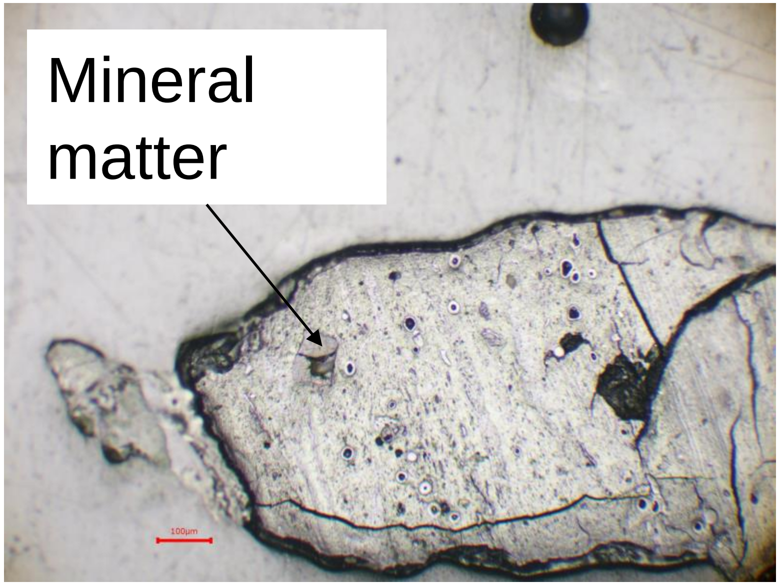
Adsorption factor at raw condition

Negative factor



Depicting **negative** correlation between adsorption capacity and moisture



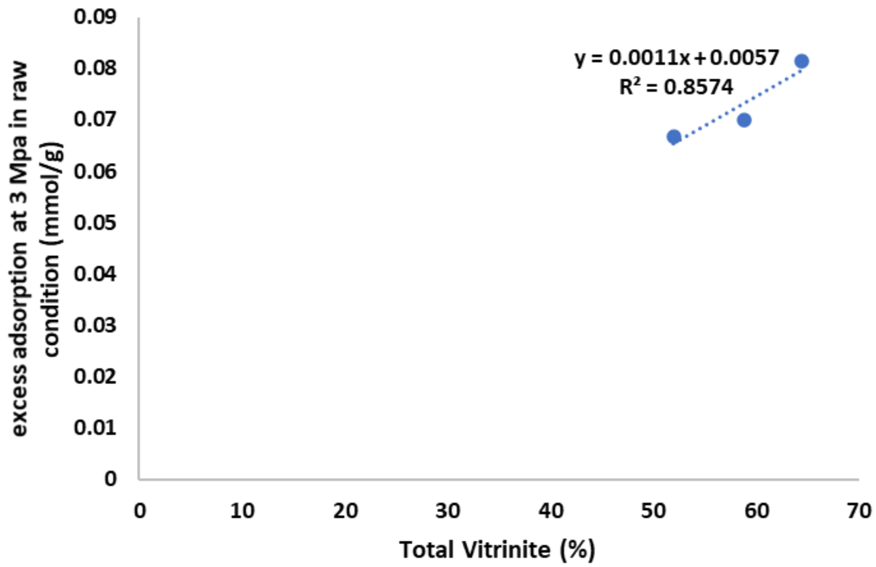


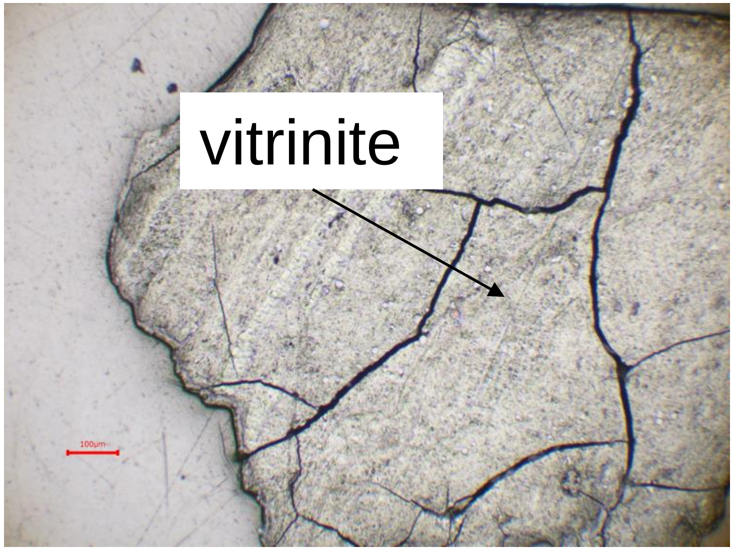
possibly blocks coal pore and fracture on coal

Result

Adsorption factor in raw condition

Positive factor





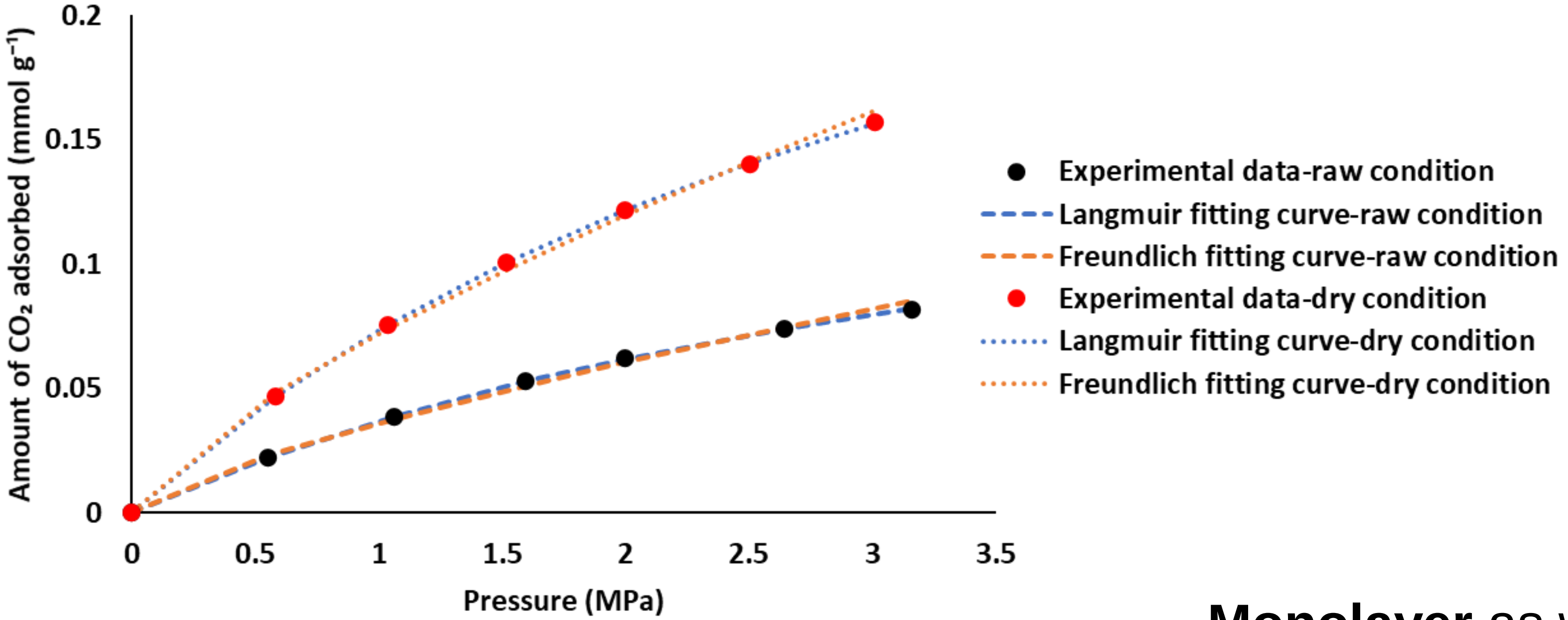
Depicting **positive correlation** between adsorption capacity and vitrinite content

Vitrinite adsorb high amount of gas due to the presence of more micropores

(Bakshi et al. 2020)

Result

Experiment data fitted with isotherm model



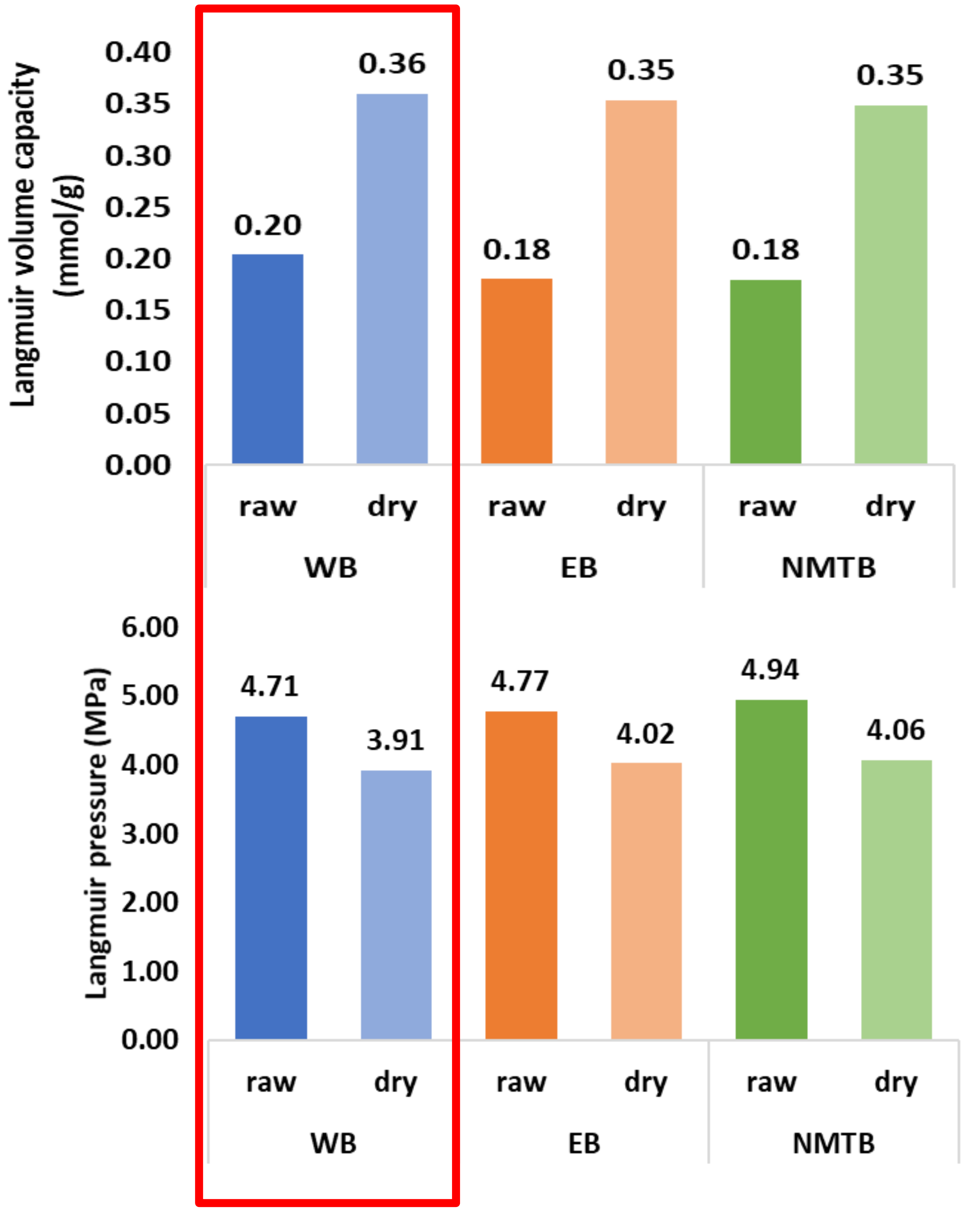
Coal condition	Langmuir isotherm model			Freundlich isotherm model		
	VL	PL	R2	n	K	R2
Raw	0.19	4.08	0.999602	0.75	0.04	0.999017
Dry	0.36	3.91	0.999727	0.74	0.07	0.999285

Monolayer as well as **multilayer** adsorption of gas was exhibited by the coal samples at various condition

Result

Langmuir parameter

The existence water content leads to **decreasing of Langmuir volume** and **increase of Langmuir pressure**



Conclusion

- One coal seam could have different CO_2 adsorption capacities mainly influenced by the **moisture**, followed by vitrinite content and mineral matter.
- On coal with different water content conditions resulted in different CO_2 adsorption capacity. The drying process increases adsorption capacity to **100-110%**, even though changing coal conditions might not depict a realistic situation.
- **Monolayer**, as well as **multilayer** adsorption of gas, was exhibited by the coal samples at the various condition
- Due to the in-situ situation, **seam B from WB coalfield** is a potential seam for CO_2 sequestrate.

Thank you