# Ammonium removal by biochar produced from co-pyrolysis sewage sludge and agriculture biomass

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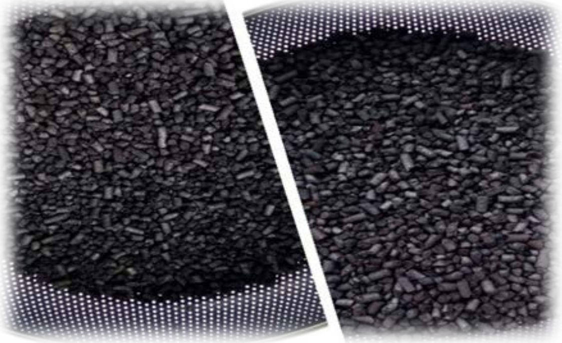
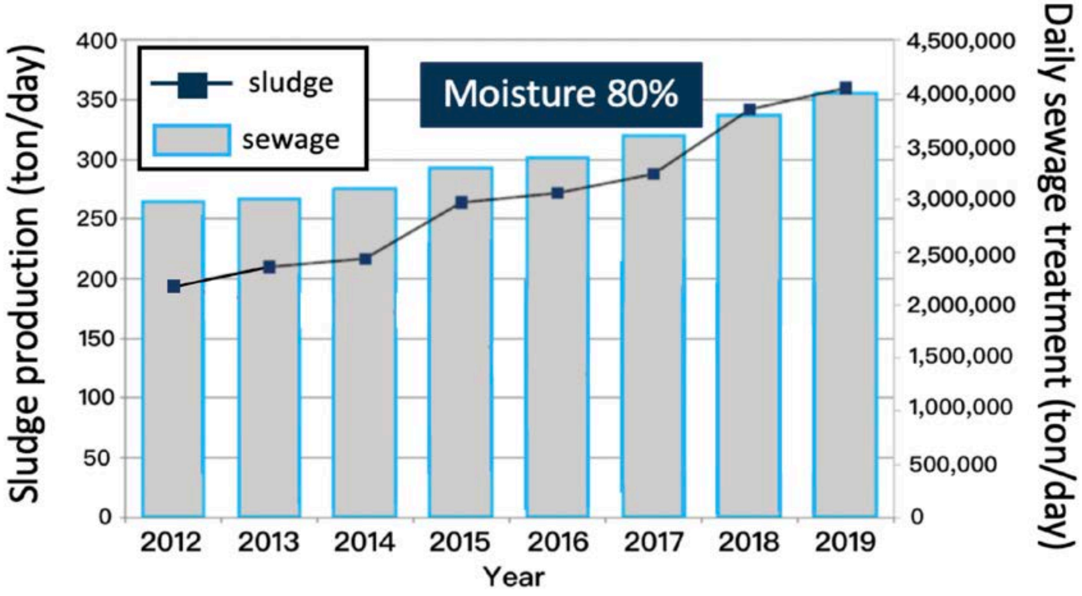


# Current situation of sludge in Taiwan

- With increasing the construction of Wastewater Treatment Plants (WWTPs) in Taiwan, more sewage sludge from WWTPs have been annually produced.

- According to the results obtained by the Construction and Planning Agency of Minister of the Interior (CPAMI), the amount of sludge has a growth trend from 31,800 to 53,400 tons per year in 2016 and 2019.




*(Construction and planning agency, 2018)*

# Disposal methods for sludge

Sanitary landfill

Incineration

Thermal treatment

Fertilization

## 2011

| Methods | Ratio(%) |
|---|---|
| **Sanitary landfill** | **68** |
| Incineration | 16 |
| Thermal treatment | 16 |
| Fertilization | 0.2 |

**High treatment cost**
**Limited landfill locations**

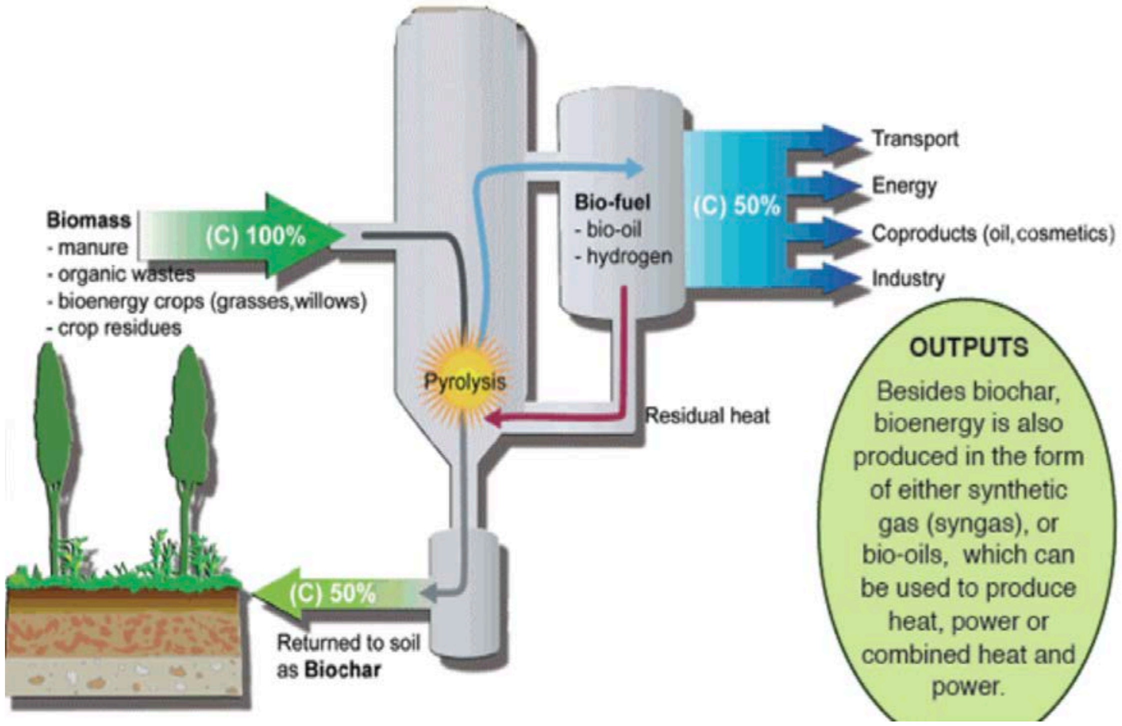
## 2016

| Methods | Ratio (%) |
|---|---|
| **Thermal treatment** | **48** |
| Incineration | 32 |
| Sanitary landfill | 16 |
| Fertilization | 4 |

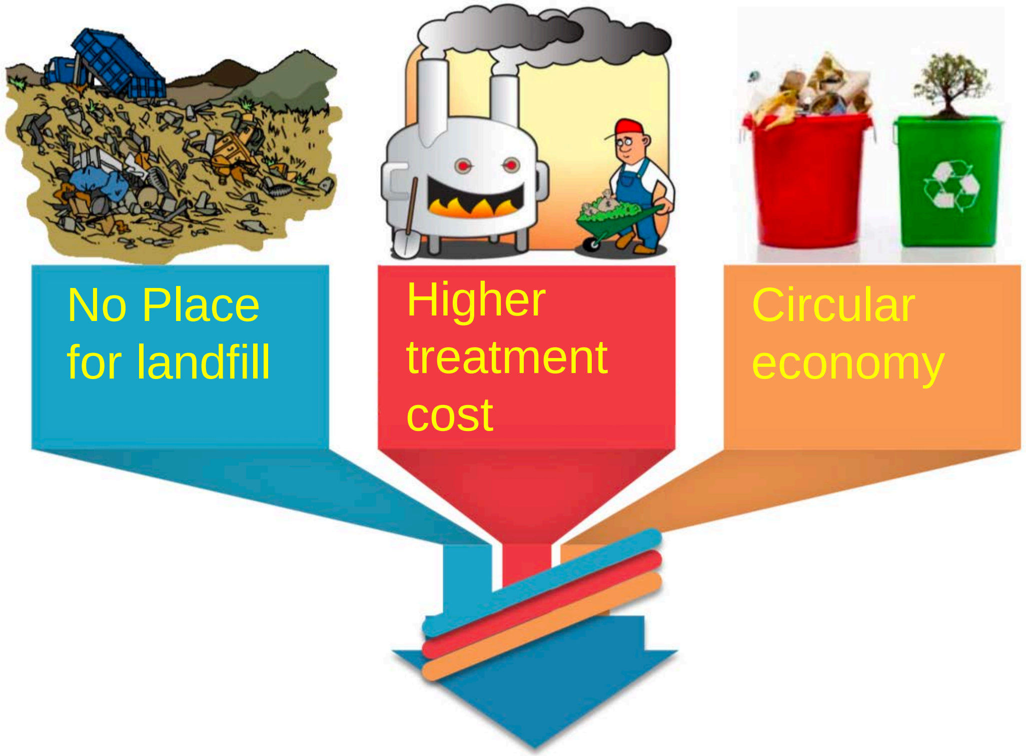
*(Construction and planning agency, 2018)*

# From wastes to biochar

- Biochar is an organic porous material derived from biological waste via thermal decomposition, can be applied as absorbents, electrodes, capacitors.




(Lehmann, 2007)

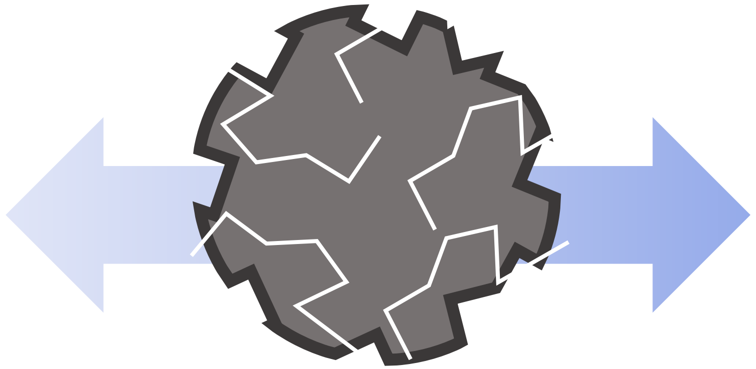


# Biochar for ammonium adsorption

- Many researchers have extensively studied biochar use as sorbent for water pollutant treatment in recent years (Regkouzas and Diamadopoulos, 2019; Tan *et al.*, 2019; Gao *et al.*, 2019; Fan *et al.*, 2017).

Specific surface area
Metal elements
Cationic species
Surface functional group

Characteristics



Biochar

Electrostatic attraction
Complexation / Precipitation
Ion exchange
Formation of amine/amide…

Mechanism

Hypothesis: Co-pyrolysis of sludge and biomass can be considered as a better approach for ammonium removal because of synergistic effects in the properties after the co-pyrolysis process.

# Objectives

- There are few studies that have investigated the association between the mixing ratio of sludge and agriculture wastes and adsorption properties.
- The aim of this work is to investigate synergistic effect of the two materials during pyrolysis and the effect of mixing ratio of the two materials on the ammonium adsorption properties by co-pyrolyzed biochar.

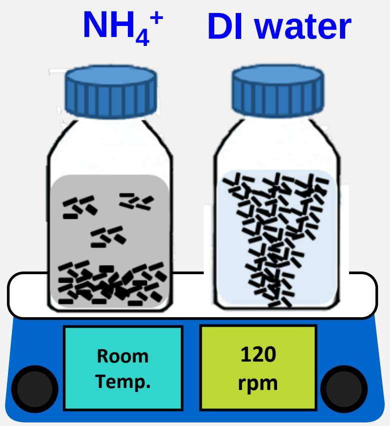
# Preparation of biochar

- Sewage sludge and wood were collected and dried at 105°C for 24 h, then crushed to 40–60 mesh for further use.
- The mixing ratio of sewage sludge to wood was 50%, 70%, and 90%, respectively. The samples were pyrolyzed at 500°C in the tube furnace under $N_2$ flow of 500 ml $min^{-1}$ and hold time of 4 hrs.

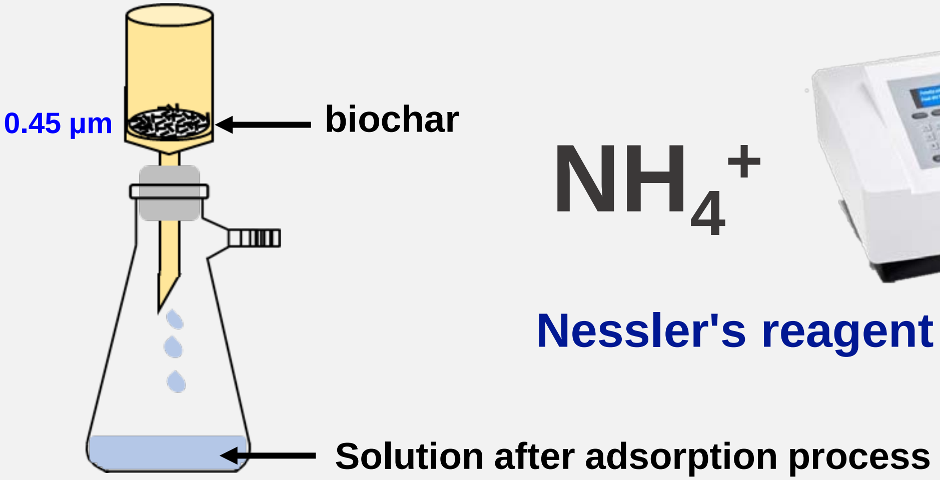
**Biochar**

- The biochar was characterized for composition and physicochemical as well as specific surface area (SSA), surface charge, morphology, and surface functional group.

# Ammonium adsorption experiment




- Dosage: 1 g/L
- $[NH_4\text{-}N]$: 50 mg/L
- Solution: 100 ml
- Contact time: 24 hr
- Room temperature
- pH: 7




$NH_4^+$

**Nessler's reagent colorimetry**

## Adsorption capacity

($mg\ NH_4^+\text{-}N/g$)

$$Qe = \frac{(C_o - C_e) \times V}{W}$$

*Qe: amount of absorbed per gram of biochar (mg/g)*

*V : Volume of solution (L)*

*W : Weight of biochar (g)*

*$C_o$ : Initial concentration (mg/L)*

*$C_e$ : Final concentration (mg/L)*

# Elemental composition

| Sample | C % | H % | O % | N % | S % | H/C | O/C |
|---|---|---|---|---|---|---|---|
| Wood | 41.2 | 5.85 | 47.7 | 0.44 | 0.1 | 1.70 | 1.74 |
| Wood biochar | ▲83.8 | 2.76 | 6.59 | 1.37 | 0.11 | 0.40 | 0.12 |
| Sludge | 26.5 | 4.19 | 21.2 | 4.29 | 0.67 | 1.90 | 1.20 |
| Sludge biochar | ▼17.2 | 0.88 | 4.37 | 2.76 | 0.69 | 0.61 | 0.38 |

IBI: H/C < 0.7 ; EBC: H/C < 0.7 O/C < 0.4

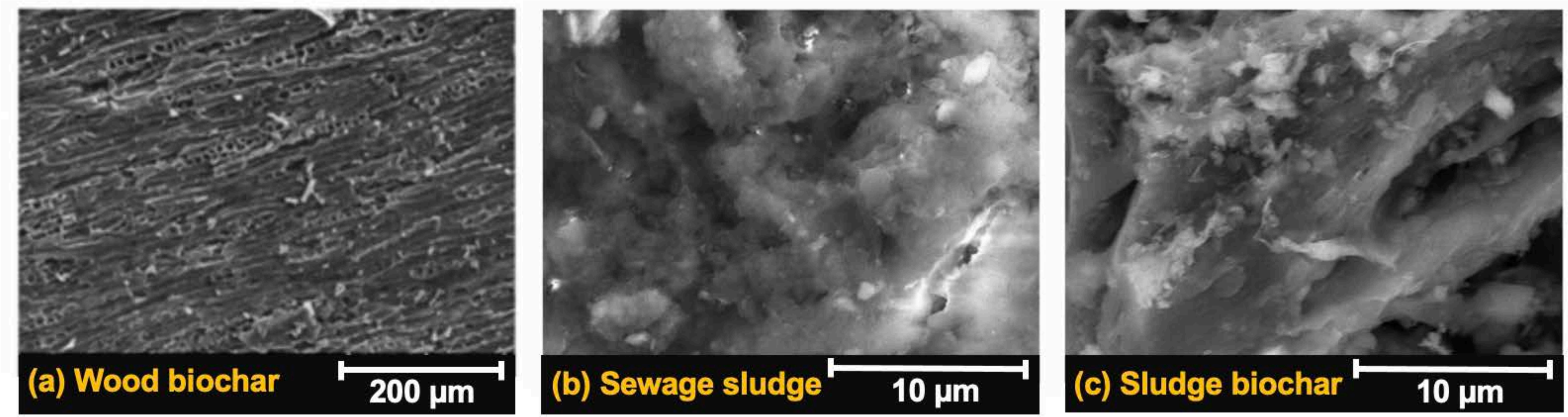
- Results indicated the carbon content in wood was higher than that in sludge.
- The opposite trend of carbon content indicated that the pyrolysis mechanisms of sewage sludge and wood were different.
- The results showed that biochars can be accepted according to IBI and EBC guideline while produced at a pyrolysis temperature at 500°C.

# Physical-chemical properties of biochars

| Sample | Yield (%) | pH | Moisture (%) | Volatile matter (%) | Ash content (%) | zeta potential (mV) | Surface area ($m^2/g$) | pore volume (cm3/g) |
|---|---|---|---|---|---|---|---|---|
| Wood biochar | 27.7 | 9.2 | 6.2 | 62.9 | 1.3 | -22 | 295 | 0.163 |
| Sludge biochar | 55 | 7.73 | 2.3 | 21.3 | 74.1 | -19 | 31 | 0.013 |

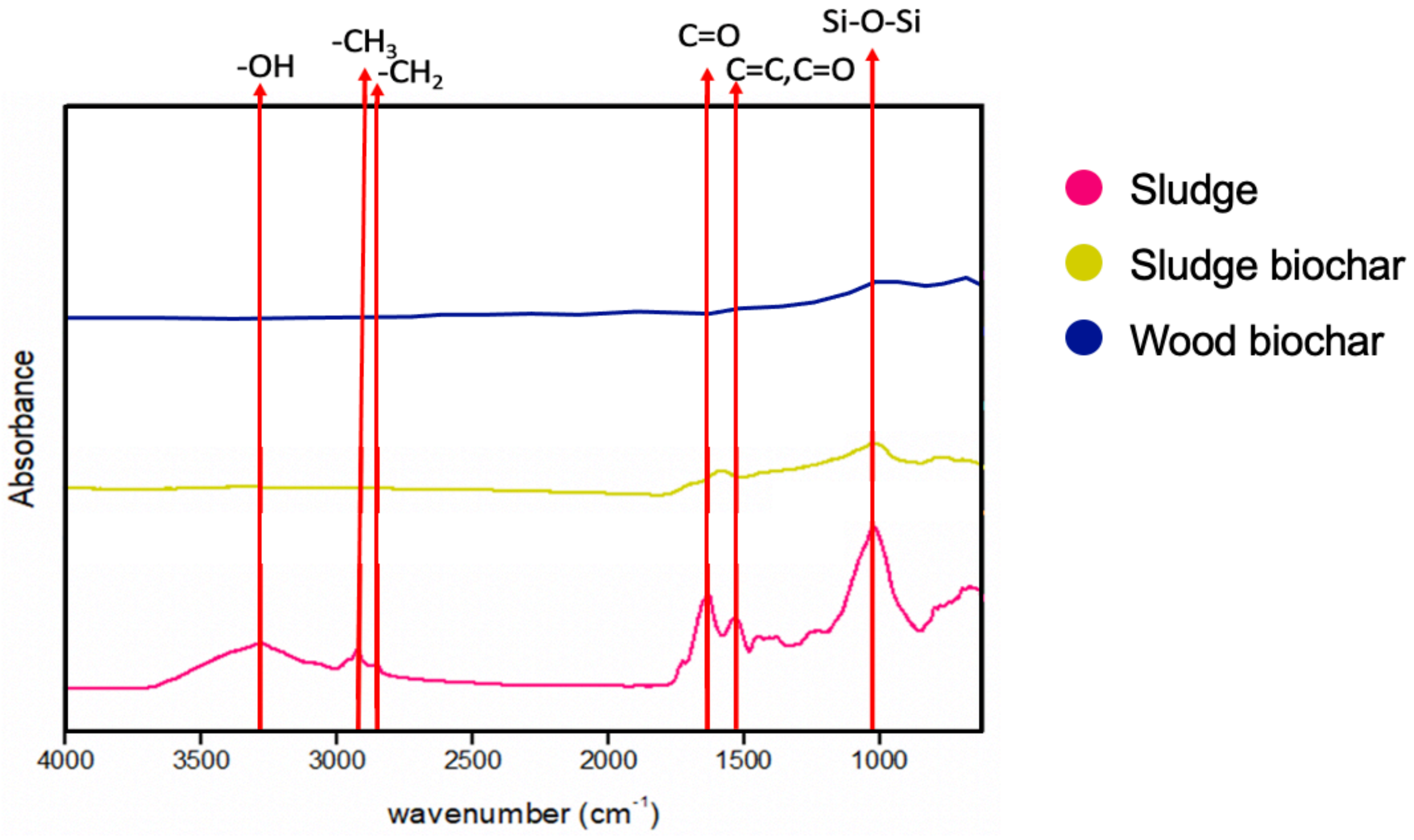
- The ash content is significantly higher in sludge biochar, it might be heavy metals entirely remain in the solid-phase after pyrolysis (Chen *et al*., 2014).
- Lignocellulosic content is a factor that affects the porous structure on surface of biochar. The porous structure on the surface of biochar can influence adsorption performance (Yin *et al*., 2019).

# Surface morphology



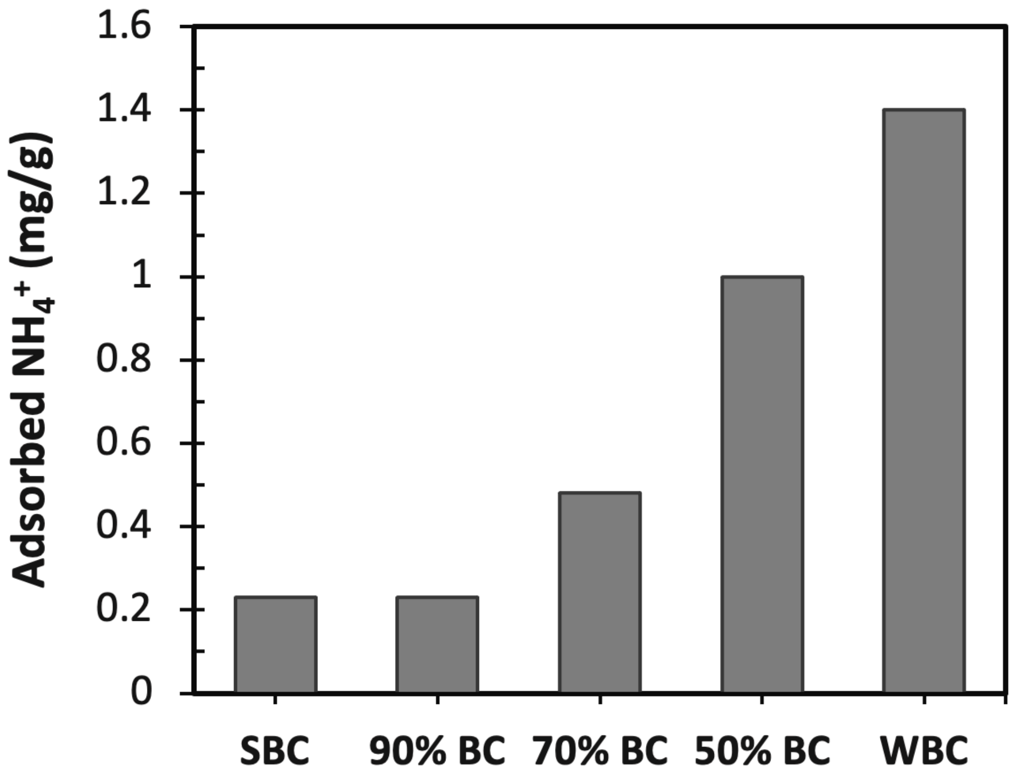

- The raw sludge had relatively rough surface, after pyrolysis, the biochars had more smoothly with flaky structure on the surface.
- Compared with sludge biochar, wood biochar has porous structure which can influence adsorption performance (Yin *et al.*, 2019).

# Surface functional group




- Compared with original sludge, the peaks of biochars are fewer and weaker, and this means that the surface functional group species is poorer.

# Results of adsorption experiment




- Wood biochar has more effective for ammonium removal due to its higher surface area. Moreover, multiple functional groups not only affect pH, surface area, and ash content of biochar but also provide active sites for sorption and interaction with ammonium.

# Conclusions

- The results showed that biochars can be accepted according to IBI and EBC guidelines (H/C molar ratio is less than 0.7, O/C molar ratio is less than 0.4) while biochar produced at 500°C.
- Multiple functional groups and large specific surface area, which contributed to the generation of surface adsorption active sites, and the pore structure of biochar was increased ammonium adsorption after the addition of wood.
- The adsorption amount of ammonium ranges from 0.25 to 1.40 mg/g, if biochar will be used as an ammonium adsorbent, we can mix with other biomass which has multiple functional groups for increasing the adsorption capacity.

# Acknowledgment

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# Thank you for your attention!

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