Application of Bamboo Fiber on the Adsorption of Heavy Metals in Water

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Outline

(A)Introduction

(B)Results and Discussion

(C)Conclusion

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Carbon Capture
&
Storage

Ecological features of bamboo

- Fastest growth among all plants on Earth
  - Growth is completed within 40 days after budding.
    (Maximum 25cm growth per day)
- Replacement of diminishing forests
  - Wood can be produced continuously through maintaining a grove
- Best species of plant to protect against landslide and earthquake
- Absorption of carbon dioxide: 29.34 tons/ha (4 times more than pine trees (7.68 tons/ha))
- Emission of oxygen: 35% higher than other species of trees

Bamboo Resource in Taiwan

- Area of Taiwan： 3.59 Mha
- Area of Forest：2.10 Mha(59%)

(1) Natural Forest：73 %

(2) Artificial Forest：20 %

(3) Bamboo：7%

18 genus；58 species

makino bamboo, ma bamboo,
green bamboo, thorny bamboo,
moso bamboo and long-branch bamboo

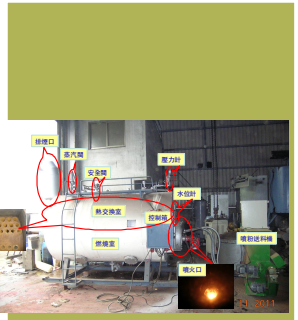
照片來源：中央氣象局

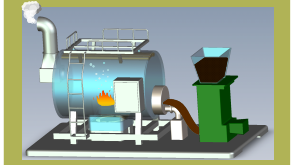
Application of Bamboo on Life

Eco-Material Bamboo

Plant Medium

iF 2012 Design Award



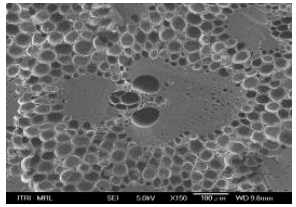


300 °C

Torrefaction

500 °C

Charcoalization
Pyrolysis



900 °C

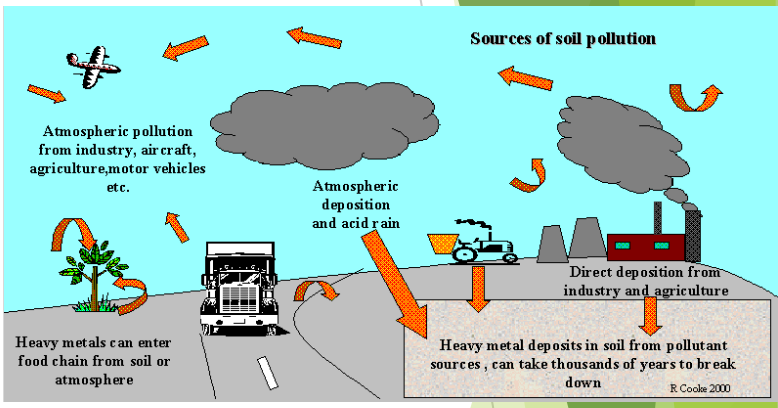
Activation

Modification
Product

Damage of Heavy Metals

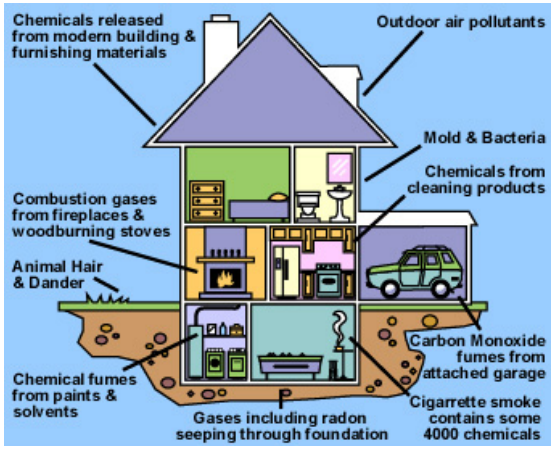
The limit of heavy metal in groundwater for the control standard in Taiwan

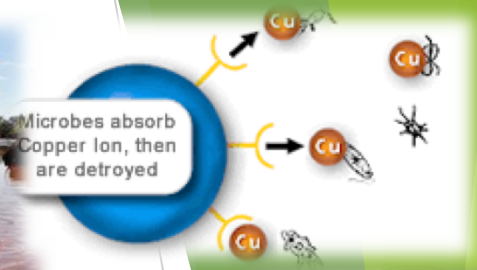
重金屬	Groundwater for drinking	Other Groundwater
	mg/L	
Arsenic（As）	0.050	0.500
Cadmium（Cd）	0.005	0.050
Chrome （Cr）	0.050	0.500
Copper（Cu）	1.000	10.00
Lead（Pb）	0.050	0.500
Mercury（Hg）	0.002	0.020
Nickel （Ni）	0.100	1.000
Zinc （Zn）	5.000	50.00



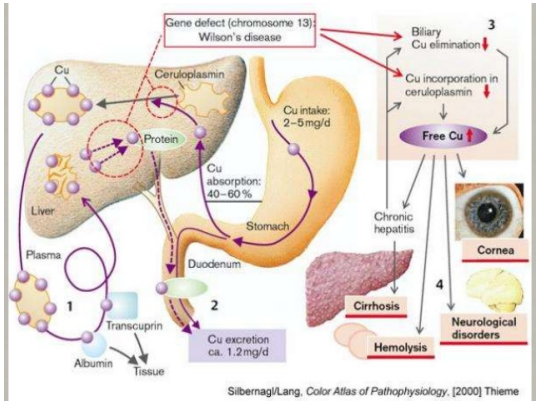
Ref: Environmental Protection Department in Taiwan

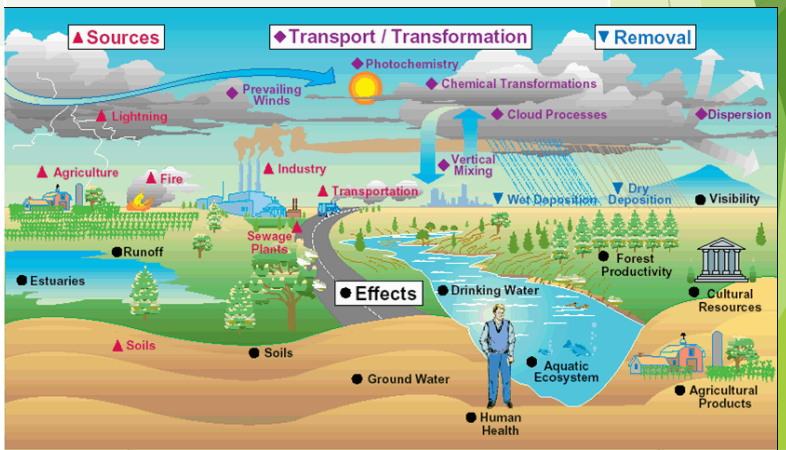
Lead & Copper





Heavy Metal	Source	Damage
Lead (Pb)	✓ Battery Industry ✓ Petrochemical industry ✓ Textile Industry ✓ Steel Industry ✓ Paint Industry	● *Blood circulatory system* ● *Nervous system* ● *Kidney disease* ● *Fetal health*
Copper (Cu)	• Electroplating industry • Paper Industry • Chemical fertilizers	◘ *Visceral damage* ◘ *Teratogen at high concentration*





Method to remove the Heavy Metal in water

➢ Traditional Method

- ✓ Deposition by chemical
- ✓ Membrane separation
- ✓ Electrolysis
- ✓ Composite method
- ✓ Ion Exchange
- ✓ Conservation Process
- ✓ Evaporation
- ✓ Surface Deposition
- ✓ Biological Treatment

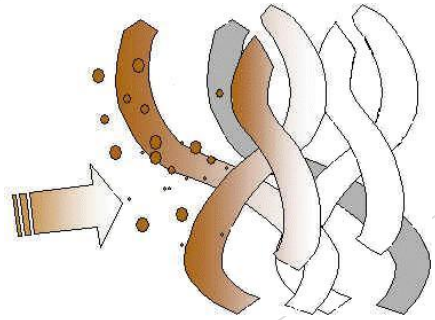
- Produce secondary sludge
- Only remove the heavy metal with high concentration
- High cost for maintenance and operation

Activated Carbon

➢ Biosorption (Biological Adsorption)

- ✓ Metabolism dependent
- ✓ non–Metabolism dependent
- ✓ Extracellular accumulation/precipitation
- ✓ Cell Surface Sorption/Precipitation
- ✓ Intracellular Accumulation

- ✓ Low Cost
- ✓ High Efficiency
- ✓ Easy to operate
- ✓ Reduce Agricultural Waste



The Removal Amount of the Heavy Metal by Eco-Materials

Adsorbent	Reference	Cd^{2+}	Pb^{2+}	Zn^{2+}	Cu^{2+}	Ni^{2+}
		mg/g				
Tree Bark	Masri et al., 1974	25.90	153.30	–	–	–
Peat Moss	Sharma and Forster, 1993	–	230.00	104.00	114.00	132.00
Rice Husk	Roy et al., 1993	21.36	11.40	–	–	164.31
Lignin	Srivastava et al., 1994	–	1865.00	95.00	–	–
Xanthan gum	Lin, 2005	–	44.55	–	57.22	–
Tea Leaves Residue	Zhong, 2005	–	–	2.90	2.88	2.06
Barley residue	Tsai, 2006	–	29.22	16.42	12.38	–
Hyacinth	Guo, 2007	8.47	27.60	5.00	27.55	–
Water Cabbage	Guo, 2007	10.40	30.90	12.09	30.84	6.22
Common Duckweed	Guo, 2007	9.87	44.64	4.52	44.64	5.04
Floating Moss	Guo, 2007	4.03	31.85	3.82	31.85	6.11

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Application of Bamboo fiber

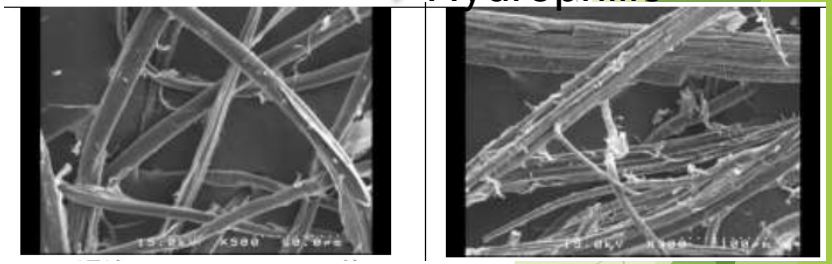
Crop

Defiberization

>90%

@200℃, 10 Kg/m^2

Hydrophilic



- *Makino bamboo* ***(MB)***
- *Thorny bamboo* ***(TB)***

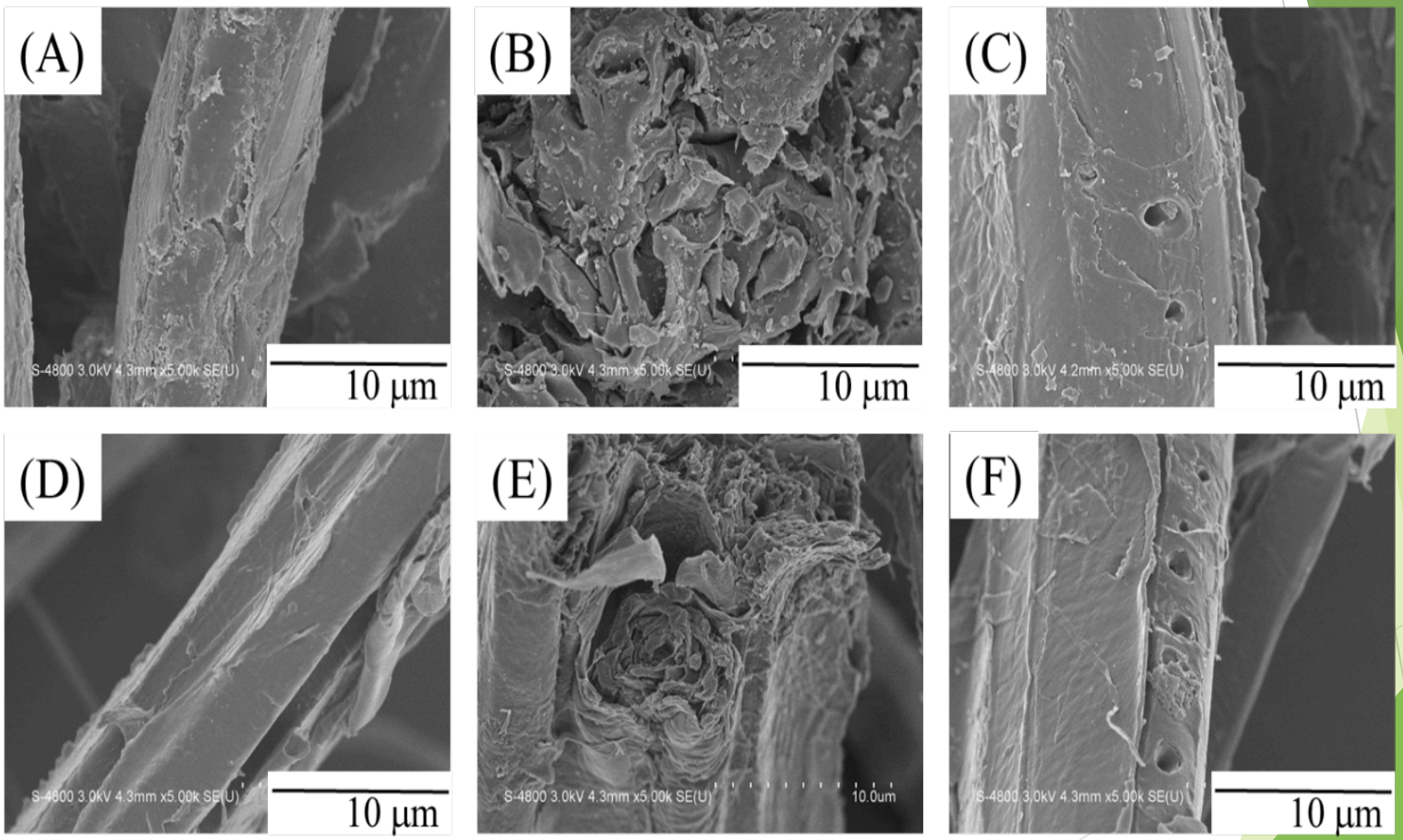
Chemical Surface Modification

✓Phosphorylation ***(P-MB, P-TB)***

✓Sulfonation ***(S-MB, S-TB)***

SEM graphs

(A) MB, (B) P-MB, (C) S-MB, (D) TB, (E) P-TB and (F) S-TB



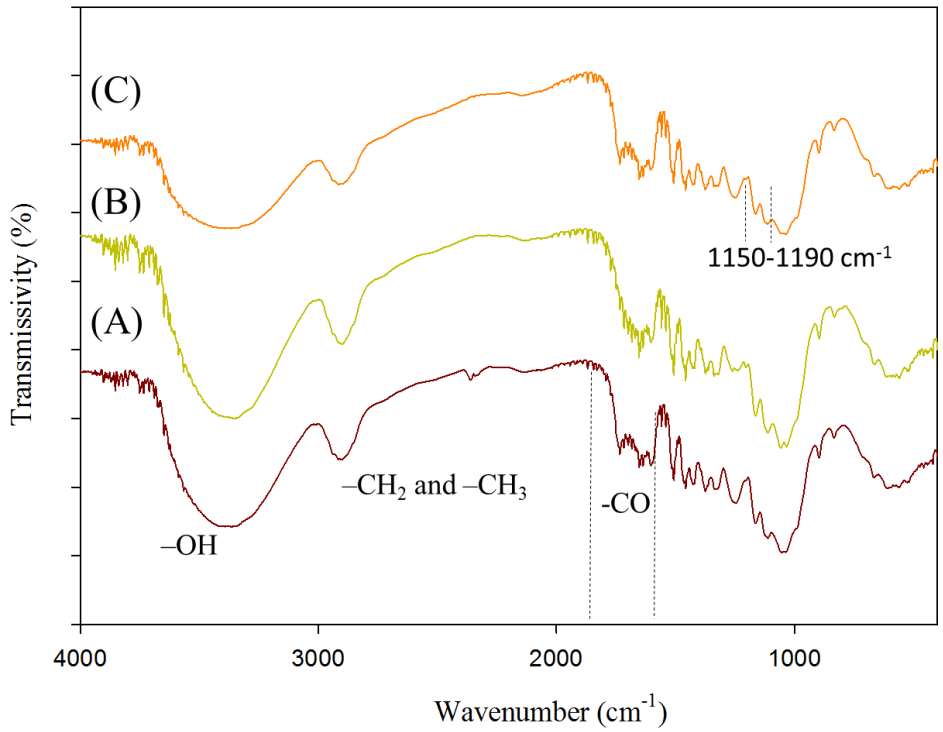
✓Phosphorylation ***(P-MB, P-TB)***
✓Sulfonation ***(S-MB, S-TB)***

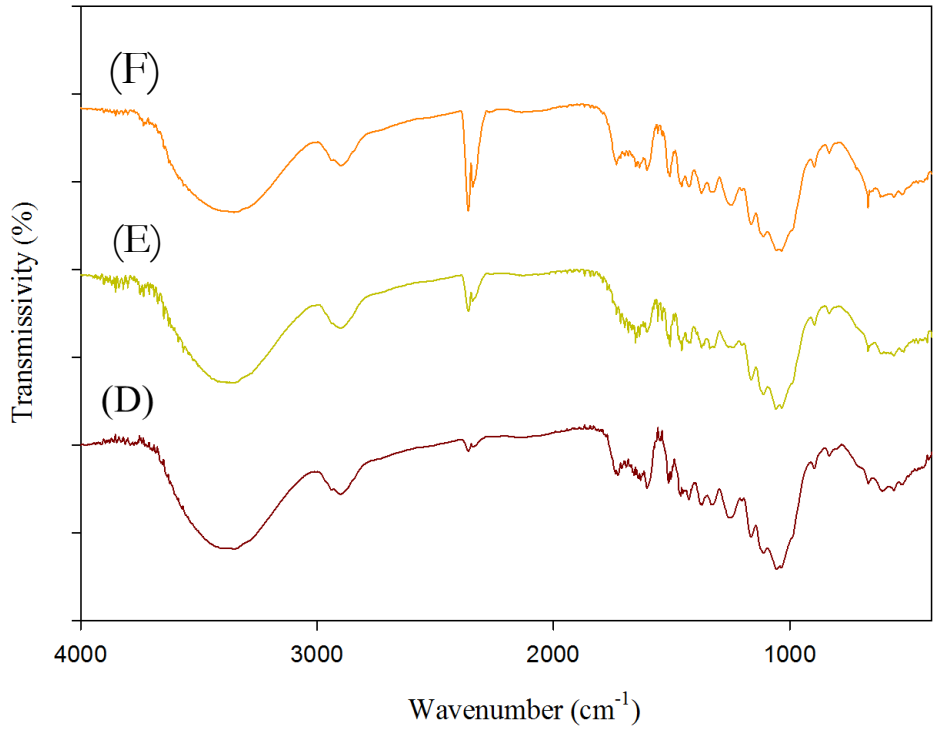
The elemental analysis

Sample	Element			
	N%	C%	S%	H%
MB	0.31±0.02	45.84±0.20	0.05±0.01	6.25±0.01
P-MB	0.52±0.00	45.97±0.07	0.18±0.01	6.54±0.05
S-MB	0.39±0.01	45.51±0.03	0.39±0.05	6.26±0.01
TB	0.35±0.01	45.57±0.12	0.13±0.03	6.22±0.01
P-TB	0.61±0.01	45.55±0.11	0.20±0.03	6.30±0.17
S-TB	0.40±0.04	45.38±0.13	0.79±0.39	6.22±0.01

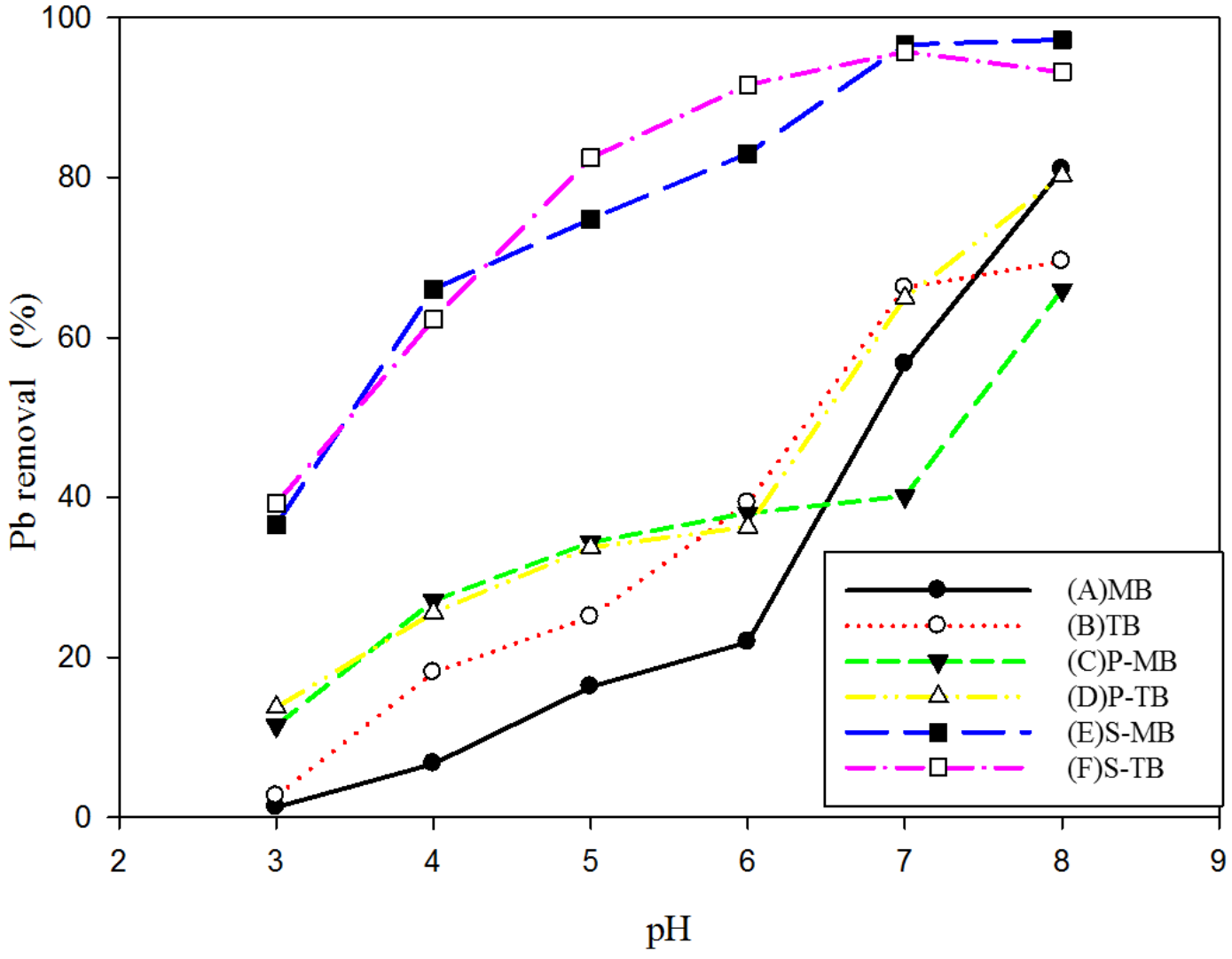
FT-IR curves

(A) MB, (B) P-MB, (C) S-MB, (D) TB, (E) P-TB and (F) S-TB



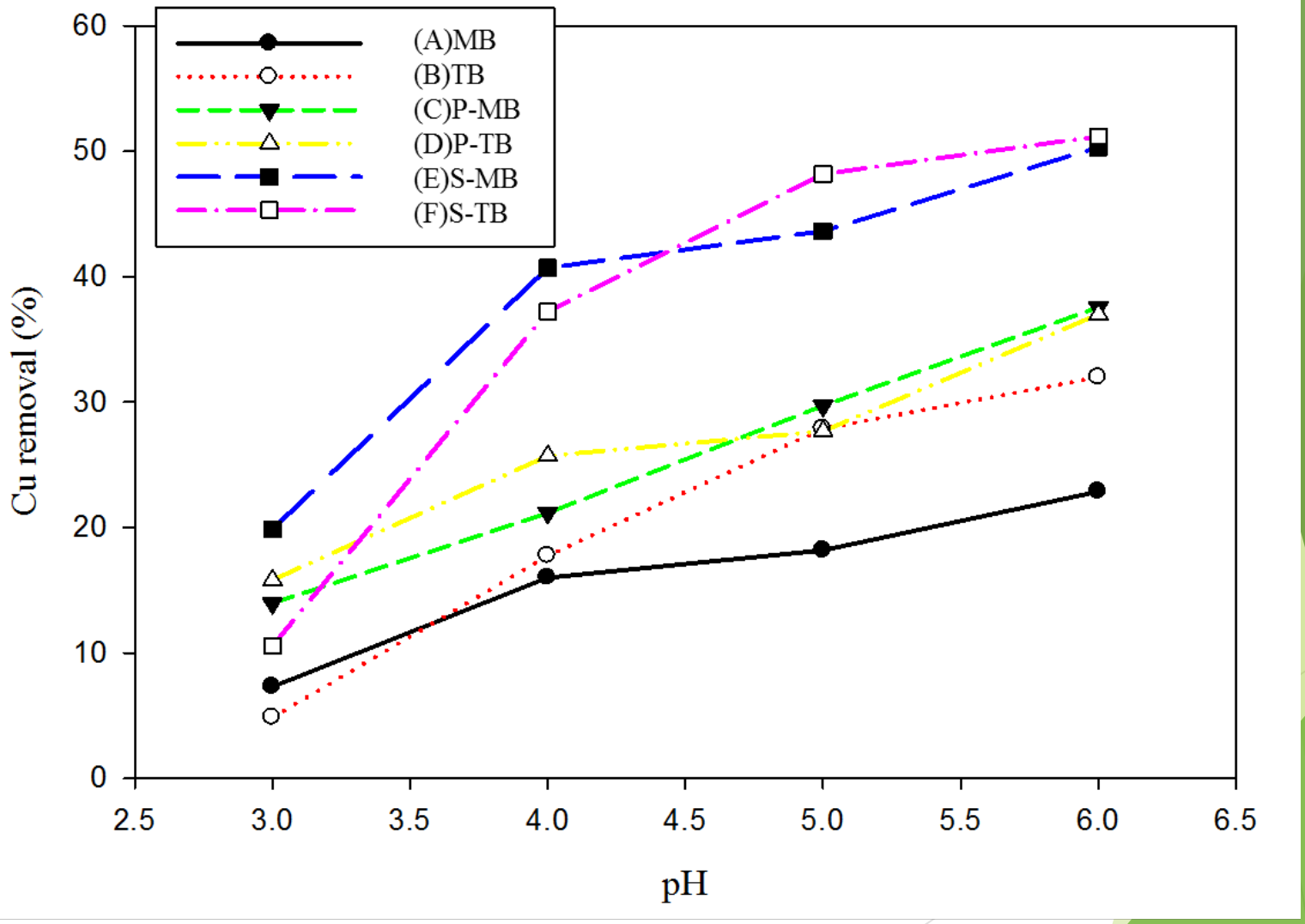


Removing yield



25 ppm

Removing yield



25 ppm

Isothermal Adsorption of Bamboo Fiber for Pb^{2+}/Cu^{2+} in water

	Pb^{2+} mg/L			Cu^{2+} mg/L		
Sample	25	50	100	25	50	100
Raw Bamboo	2.29* 21.90%**	5.37 22.62%	3.71 9.22%	2.43 22.85%	5.19 23.39%	5.38 13.28 %
Phosphorylated	4.69 38.02%	12.86 57.69%	20.40 48.61%	3.99 37.54%	5.12 23.07%	8.03 19.84%
Sulfonated	10.23 82.99%	20.57 93.72%	16.76 35.76%	5.34 50.30%	7.69 34.66%	9.91 24.46%

*Adsorption (mg g^{-1})；**Removing Yield(%)　　pH=6.5 at 30℃

Isothermal Adsorption Equation

Langmuir isotherm

$$q_e = k_L q_m C_e / (1 + k_L C_e) \Rightarrow C_e/q_e = 1/k_L q_m + 1/q_m \, C_e$$

Sample	Temperature (K)	Pb^{+2}			Cu^{+2}		
		r^2	K_L ppm^{-1}	q_m mg g^{-1}	r^2	K_L ppm^{-1}	q_m mg g^{-1}
Raw bamboo	303	0.9876	0.0007	123.4568	0.9087	0.0096	13.0719
Phosphorylated	303	0.9717	0.0034	53.4759	0.9335	0.0242	10.3199
Sulfonated	303	0.9223	0.0064	68.4932	1.0000	0.0251	13.8313

q_e：Adsorption capacity (mg/g)
q_m：Adsorption capacity per unit adsorbent (mg/g)
C_e： Equilibrium concentration (ppm_v)
K_L：Langmuir constant

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Conclusion

- Bamboo is a sustainable material
- Bamboo fiber can be efficiently manufactured by the physical process.
- Bamboo fiber can be used as a hydrophilic filter to purify the environment.
- The adsorption of bamboo fiber for heavy metal can be promoted by the simple chemical surface modification.

Thanks for your attention

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