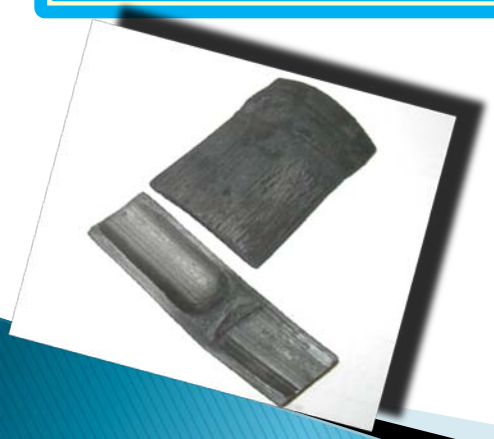
Preparation and characterization of activated carbon from *Bambusa arundinacea (Retz) Wild*, *Bambusa oldhamii* and *Gigantochloa verticiliata*

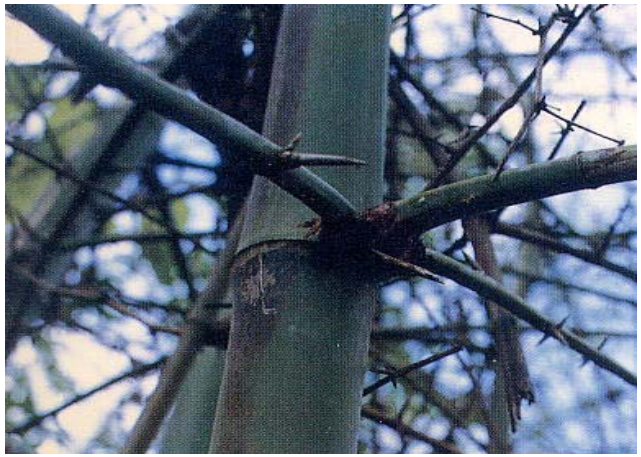


Mr. PITSANU KHORBOOT

Contents

Introduction

Bamboo；*Bambusa arundinacea (Retz) Wild* (BAW)



Familia: *Poaceae*

Genus: *Bambusa*

Synonyms: *Bambusa arundinacea (Retz) Wild*

Common name: Paipa

Introduction

Bamboo；*Bambusa oldhamii* (GO)

Familia: *Poaceae*

Genus: *Bambusa*

Synonyms: *Bambusa oldhamii*

Common name: Oldham bamboo or

Green bamboo or Lu Chu

Introduction

Bamboo；*Gigantochloa verticiliata* (GV)

Familia: *Poaceae*

Genus: *Gigantochloa*

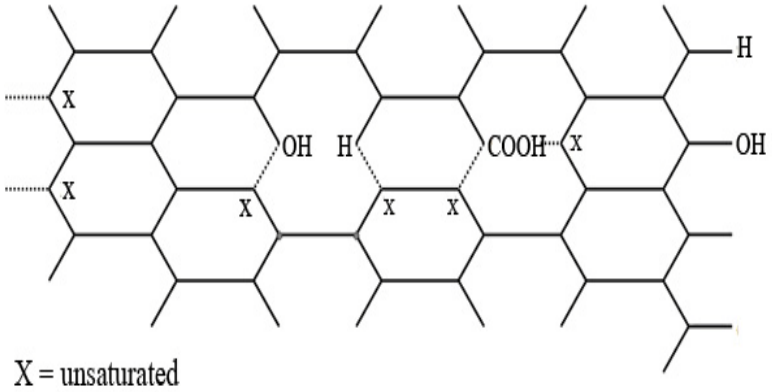
Synonyms: *Gigantochloa verticiliata*

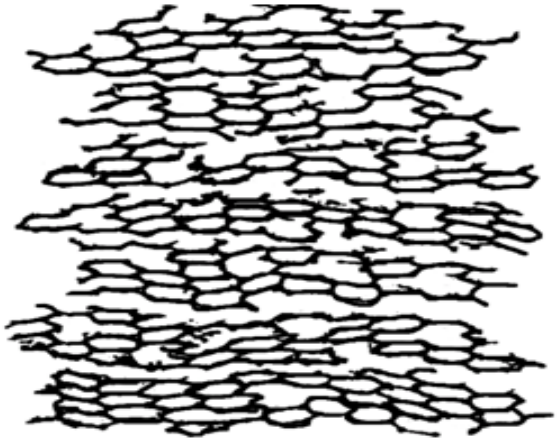
Common name: Manmoo

Activated carbon

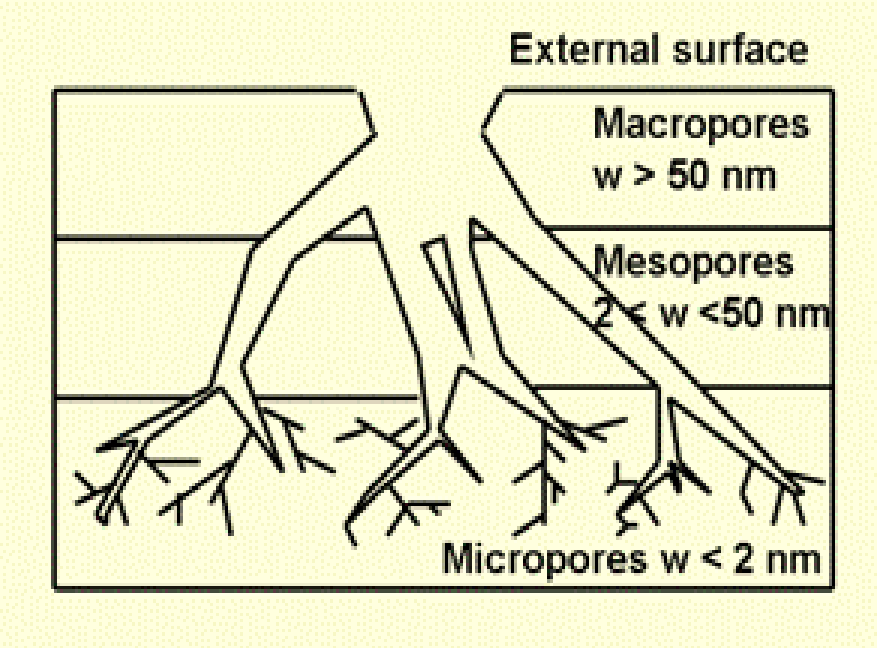
- Activated charcoal or activated coal
- Form of carbon
- Microcrystalline structure forms
- Granular and powdered forms

Structure



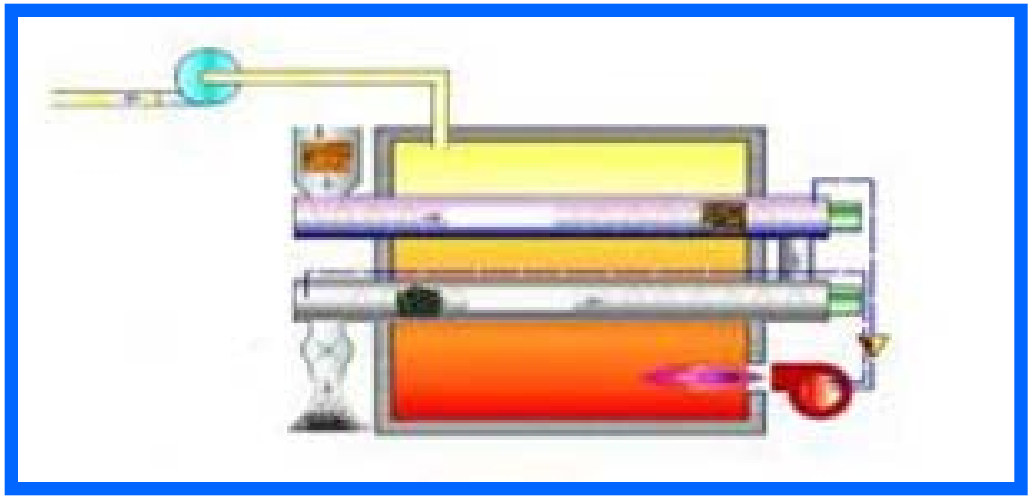


Porous structure



Carbonization

The carbonization is the process using the calcination of a carbonaceous raw material at temperatures below 800°C.



Activation

The pore structure in carbonized char is further developed and enhanced during the activated carbon process which is producing an extended and extremely high surface area of the activated carbon.

Physical

H_2O , CO_2 , O_2 , etc.

Chemical

H_3PO_4 , KOH , $ZnCl_2$, etc.

Chemical activation

H_3PO_4

$$2H_3PO_4 \longrightarrow P_2O_5 + 3H_2O$$

$$2P_2O_5 + 5C \longrightarrow P_4 + 5CO_2$$

KOH

$$2KOH \longrightarrow K_2O + H_2O$$

$$H_2O + C \longrightarrow H_2 + CO$$

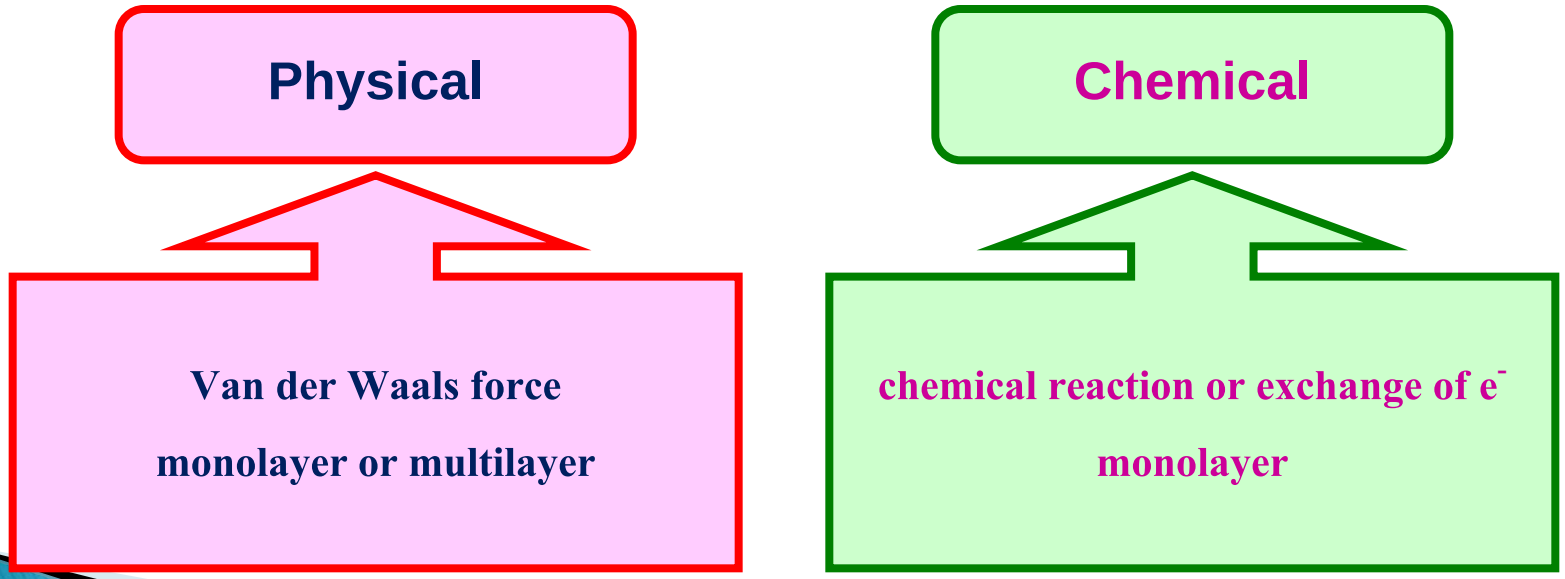
$$K_2O + C \longrightarrow 2K + CO$$

Benefits

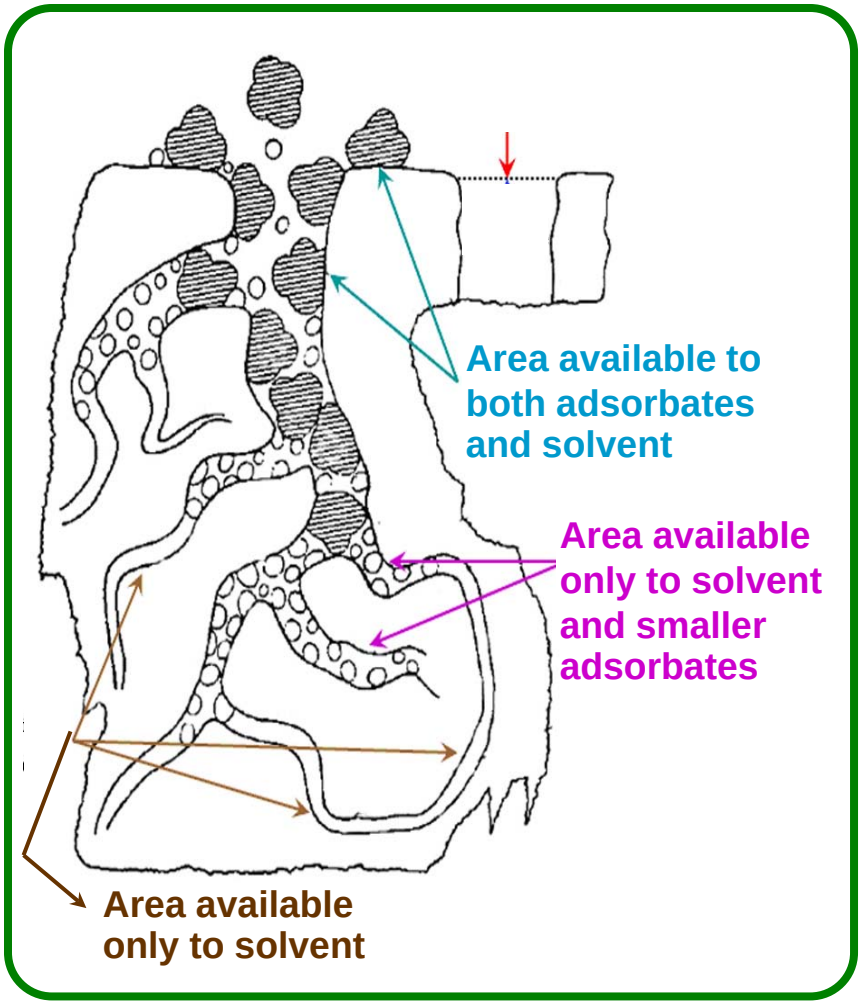
- gas purification
- metal extraction
- water purification
- medicine
- sewage treatment
- air filters in gas masks
- filters in compressed air

Adsorption

Adsorption is a process that occurs when a gas or liquid solute accumulates on the surface of a solid or a liquid (adsorbent), forming a film of molecules or atoms (adsorbate).



Adsorption


Area available to both adsorbates and solvent
Area available only to solvent and smaller adsorbates
Area available only to solvent

Effects of adsorption

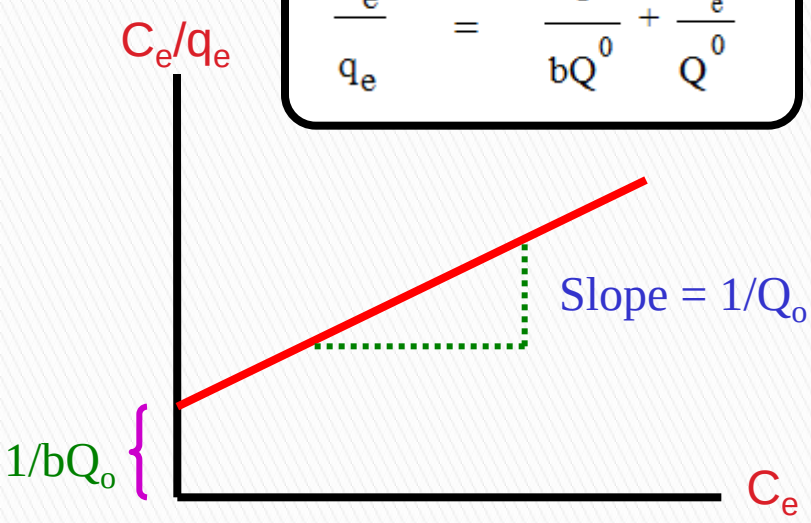
- Adsorbent
- Adsorbate
- Time
- Temperature
- Sovent
- pH

Adsorption isotherm

Langmuir

$$q_e = \frac{X}{m} = \frac{Q^0 bC_e}{1 + bC_e}$$

$$\frac{C_e}{q_e} = \frac{1}{bQ^0} + \frac{C_e}{Q^0}$$



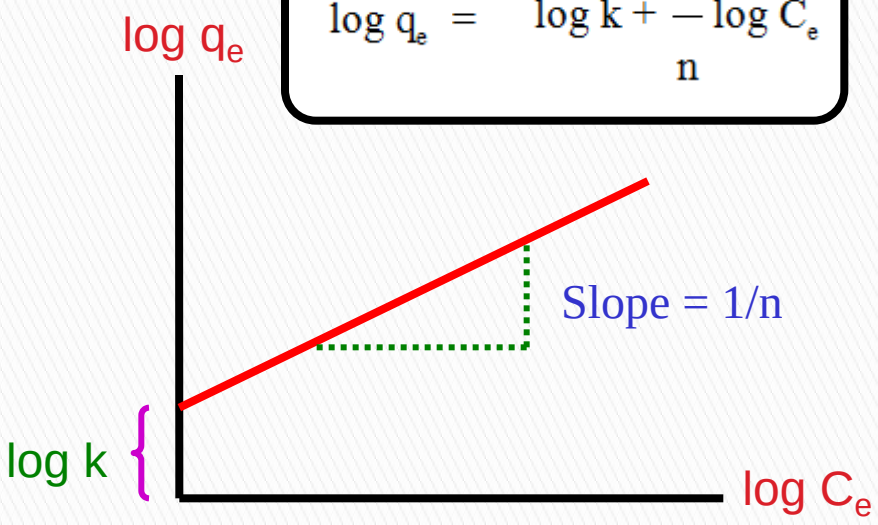
q_e = the amount of adsorbate adsorbed per unit mass of adsorbent (mg/g)
C_e = the equilibrium concentration of the adsorbate (mg/L)
Q_0 = the maximum surface coverage (formation of monolayer) of adsorbent (mg/g)
X = the amount of absorbate (mg)
m = the mass of adsorbent used (g)
b = the adsorption energy constant of Langmuir adsorption isotherm (m/g)

Adsorption isotherm

Freundlich

$$q_e = \frac{X}{m} = kC_e^{1/n}$$

$$\log q_e = \log k + \frac{1}{n} \log C_e$$



q_e = the amount of adsorbate adsorbed per unit mass of adsorbate (mg/g)

C_e = the equilibrium concentration of the adsorbate (mg/L)

X = the amount of absorbate (mg)

m = the mass of adsorbent used (g)

k = the Freundlich isotherm constant related to adsorption capacity [$(mg^{-1})(mg^{-1})^{1/n}$]

n = the Freundlich isotherm constant related to adsorption intensity

Iodine

Atomic number

53

Atomic weight

126.90

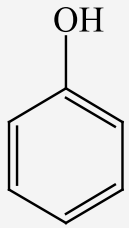
Cross sectional area

32 $Å^2$

Phenol

C_6H_5OH

FW = 94.11



Hydroxy benzene

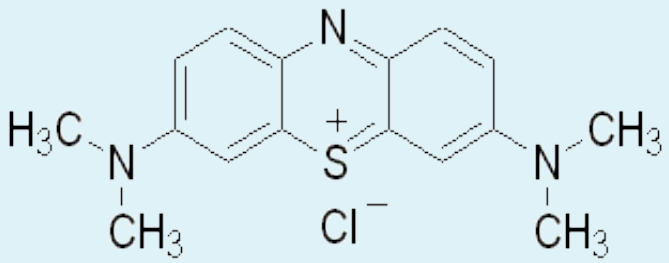
Cross sectional area

52.2 $Å^2$

Methylene blue

$C_{16}H_{18}N_3ClS$

FW = 319.85



Cross sectional area

120 Å^2

3,7-bis(dimethylamino)-phenazathionium chloride

Cadmium (II)

Atomic number

48

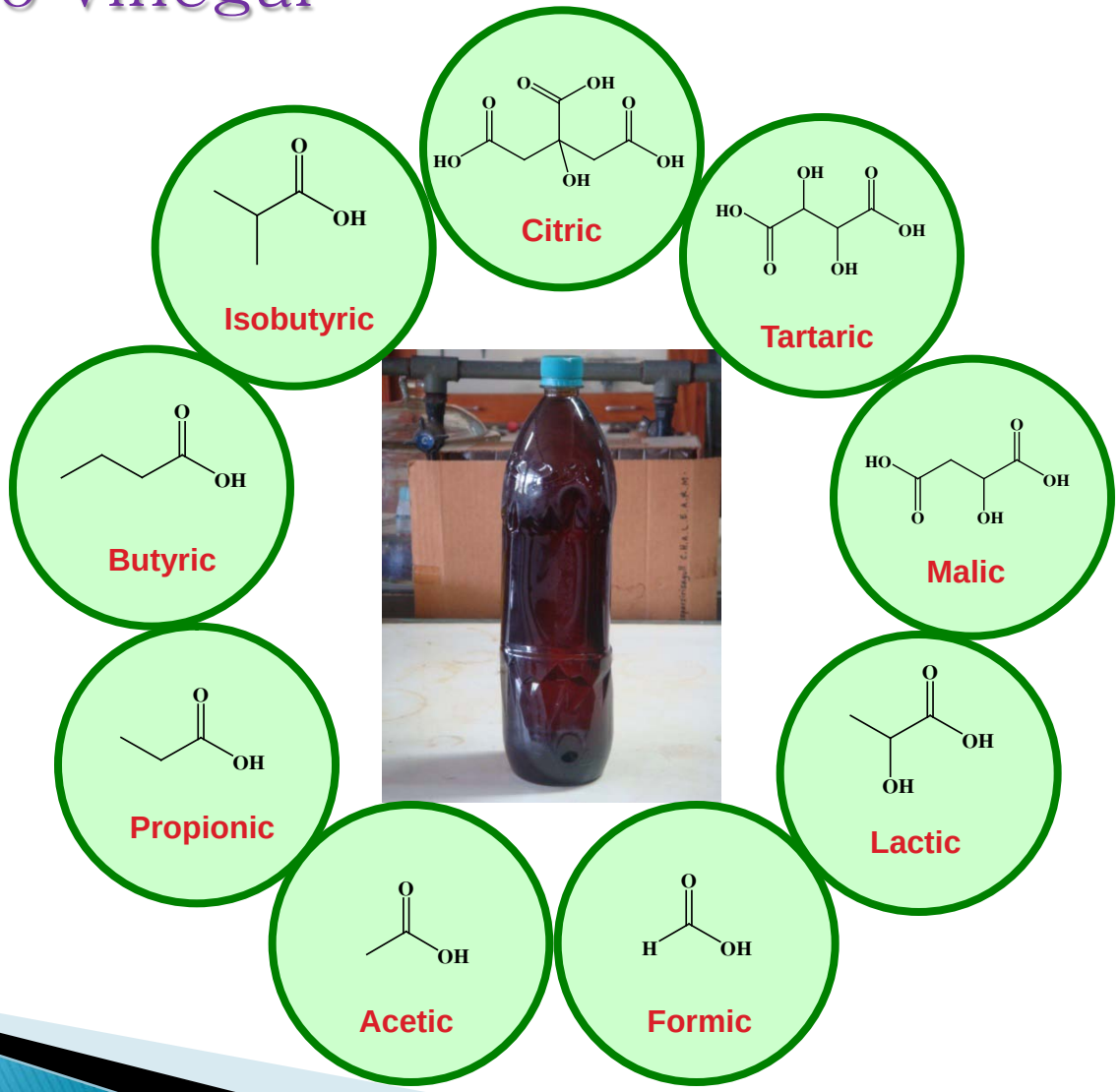
Atomic weight

112.41

Cross sectional area

61 $Å^2$

Bamboo vinegar



Carbonization

Bamboo

carbonized

450°C

Charcoal

Wood vinegar

sieved

150 μm

General procedure for activation

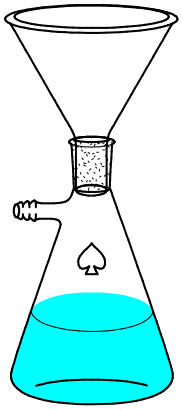
refluxed at 250°C

Chemical activation H_3PO_4 or KOH (20, 40, 60 and 80%)

Activation time (4, 8 and 12 h.)

washed

until pH 7



dried at 120°C for 1 h.

(Activated Carbon)

Iodine number
(ASTM D4607-94)

Characterization

(Activated Carbon)

Proximate analysis

- Moisture (ASTM D3173-95)
- Volatile (ASTM D3175-95)
- Ash (ASTM D3174-95)
- Fixed carbon

% fixed carbon = 100 - % ash content - % volatile matter content

Scanning Electron Microscopy (SEM)

Fourier Transform Infrared Spectroscopy (FT-IR)

Adsorption study

(Activated Carbon)

→ Iodine (ASTM D4607-94)

$2\ Na_2S_2O_3\ (aq) + I_2 \rightarrow Na_2S_4O_6\ (aq) + 2NaI\ (aq)$

→ Phenol (AWWA B600-96)

UV-Vis spectrophotometer at 270 nm wavelength

→ Methylene blue

UV-Vis spectrophotometer at 665 nm wavelength

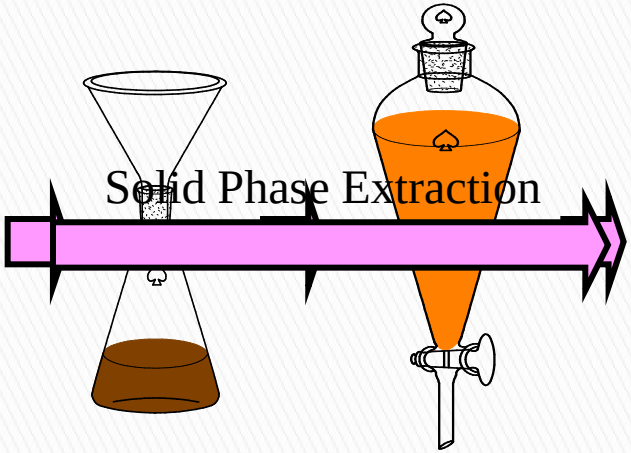
→ Cadmium (II)

Atomic absorption spectrophotometer

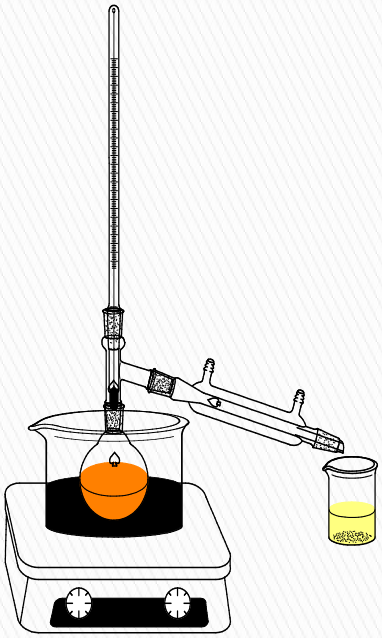
Experiments

Wood vinegar study

Bamboo vinegar



1 : 1
(vinegar : solvent)



Diluted 1/100

[solvent = 2:1 hexane/diethylether]

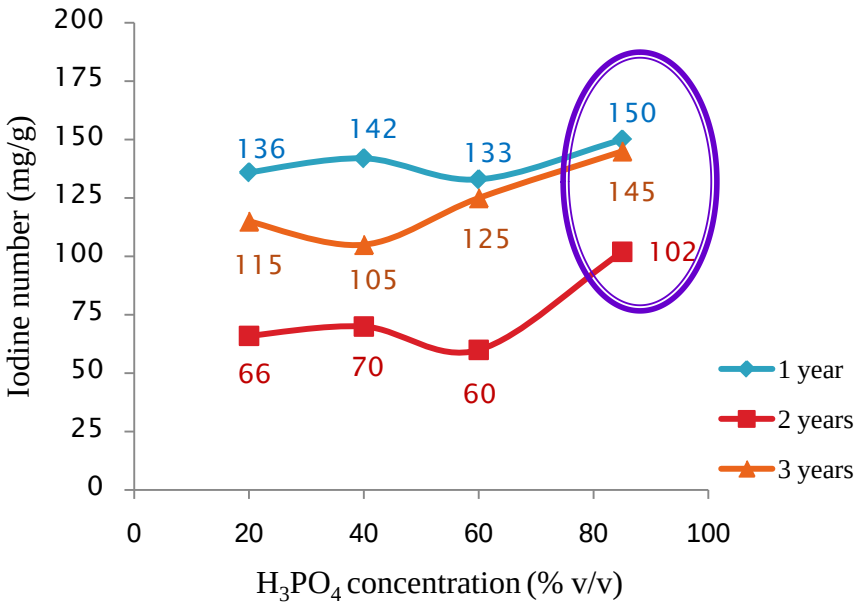
HPLC : High Performance Liquid Chromatography

The %yield of charcoal from all types of bamboos

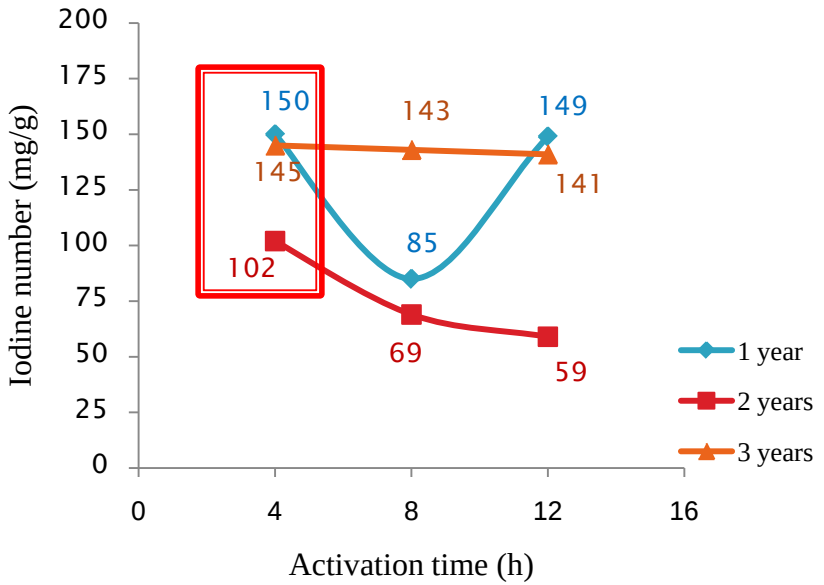
Type of bamboo	Age of bamboo (year)	Yield $_{charcoal}$ (%)
BAW	1	57.92
	2	54.75
	3	51.64
GO	1	47.13
	2	52.89
	3	51.26
GV	1	50.58
	2	48.45
	3	49.39

results & discussion

The variation of concentration and activation time of BAWP



Activation time for 4 h.

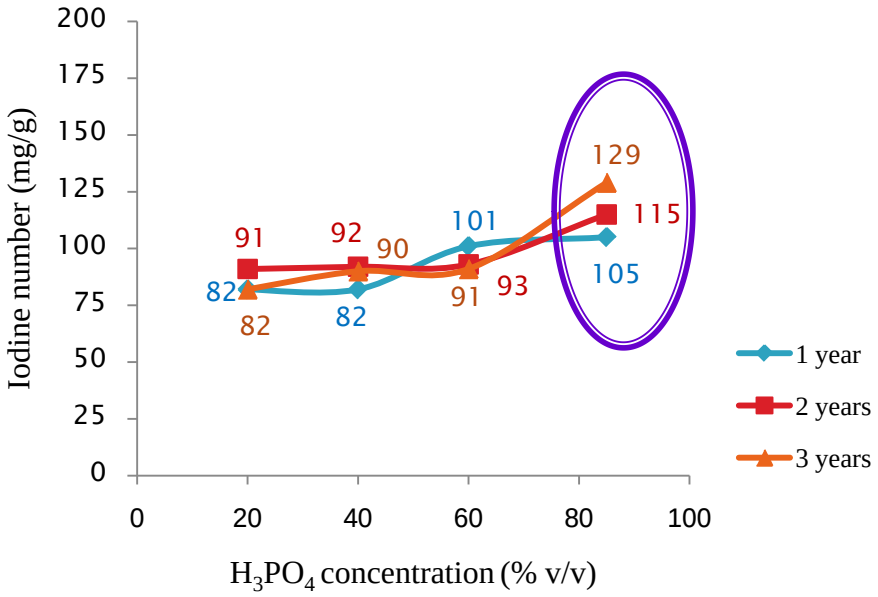


All three ages : conc. H_3PO_4 (85%)

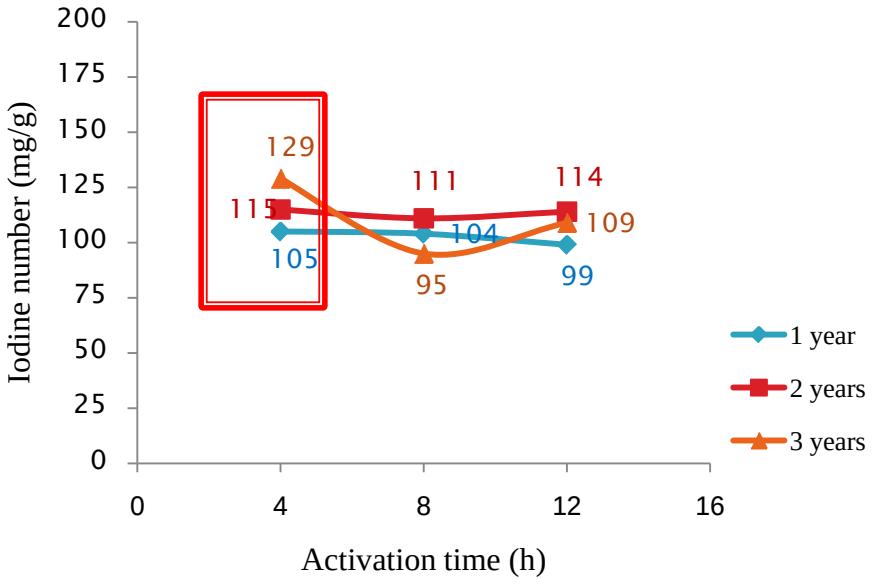
BAWP ; BAW activated by H_3PO_4

results & discussion

The variation of concentration and activation time of GOP



Activation time for 4 h.

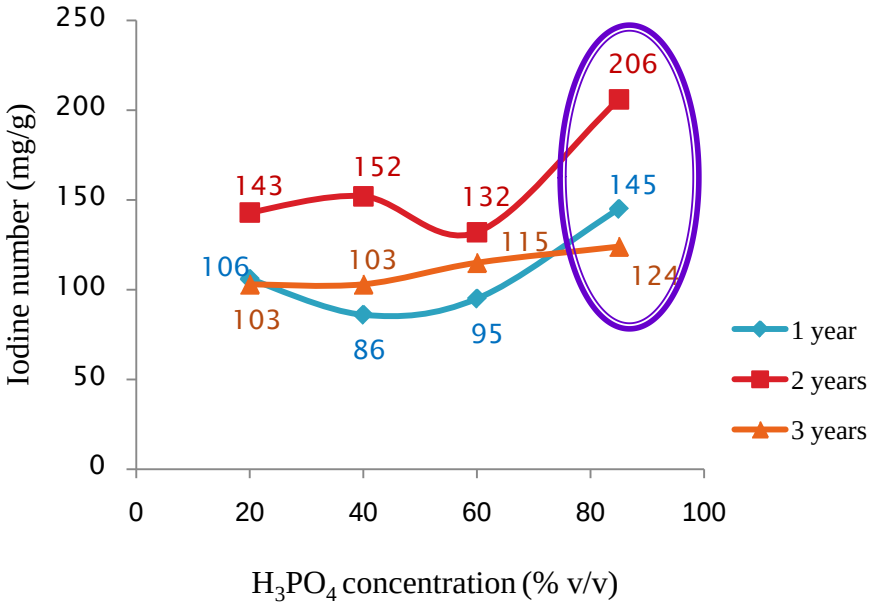


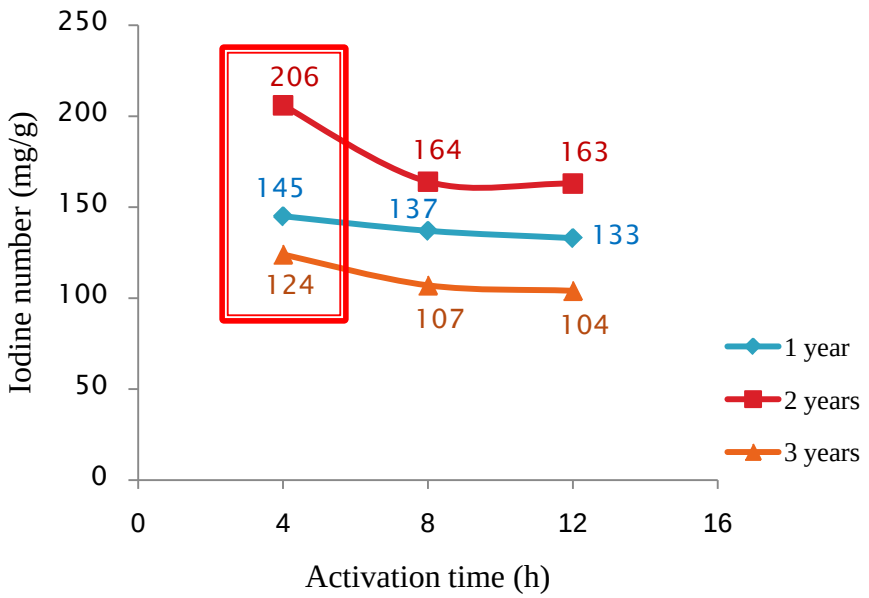
All three ages : conc. H_3PO_4 (85%)

GOP ; GO activated by H_3PO_4

results & discussion

The variation of concentration and activation time of GVP





Activation time for 4 h.

All three ages : conc. H_3PO_4 (85%)

GVP ; GV activated by H_3PO_4

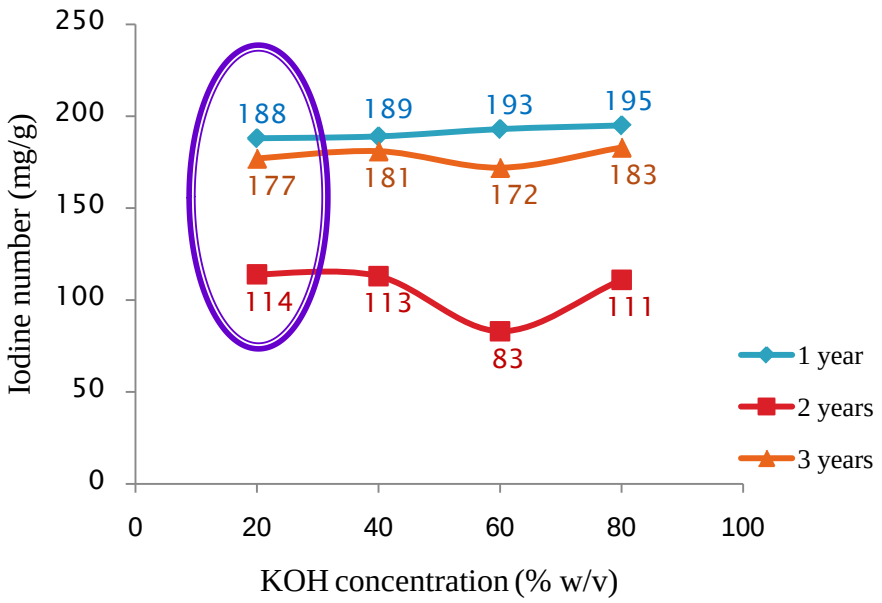
The variation of concentration and activation time

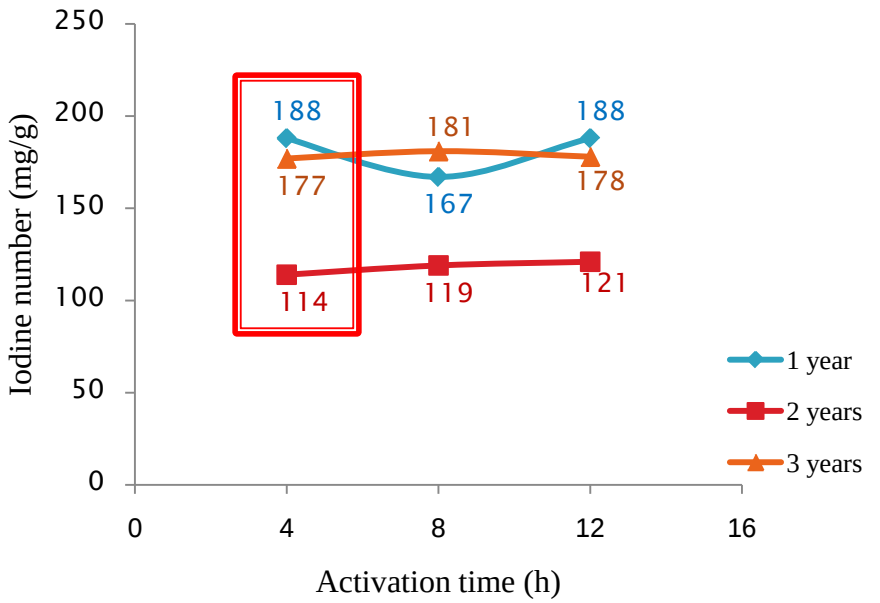
Activation with H_3PO_4

- BAW 1, 2 and 3 years which activated 85%H_3PO_4 for 4 hours
- GO 1, 2 and 3 years which activated 85%H_3PO_4 for 4 hours
- GV 1, 2 and 3 years which activated 85%H_3PO_4 for 4 hours

results & discussion

The variation of concentration and activation time of BAWK





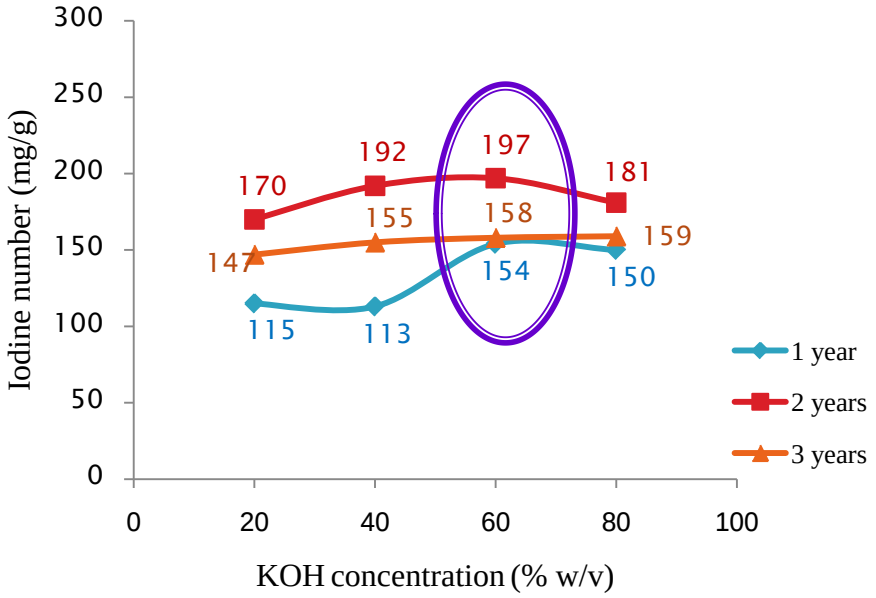
Activation time for 4 hour

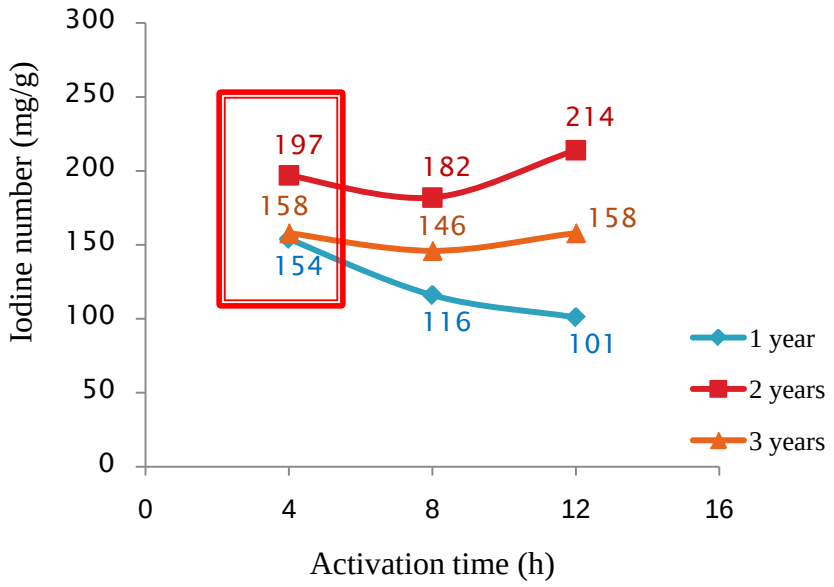
All three ages : 20% KOH

BAWK ; BAW activated by KOH

results & discussion

The variation of concentration and activation time of GOK





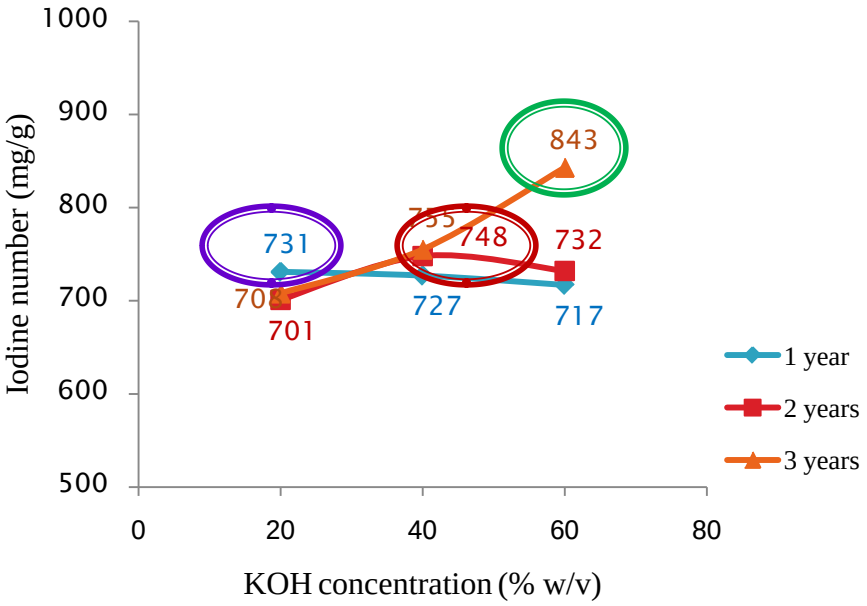
Activation time for 4 hour

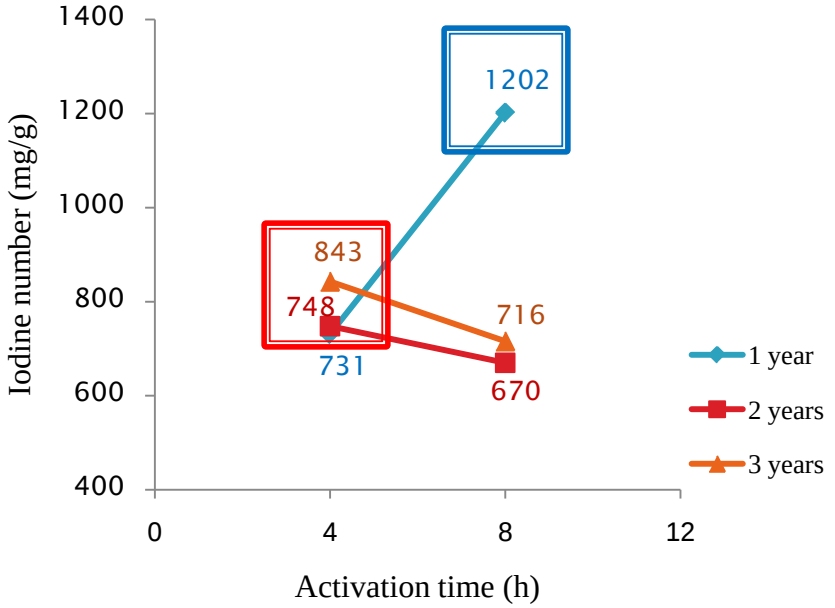
All three ages : 60% KOH

GOK ; GO activated by KOH

results & discussion

The variation of concentration and activation time of GVK





Activation time for 4 hour

1 y. : 20% KOH
2 y. : 40% KOH
3 y. : 60% KOH

GVK ; GV activated by KOH

The variation of concentration and activation time

Activation with KOH

- BAW 1, 2 and 3 years which activated 20%KOH for 4 hours
- GO 1, 2 and 3 years which activated 60%KOH for 4 hours
- GV 1 year which activated 20%KOH for 8 hours
- GV 2 years which activated 40%KOH for 4 hours
- GV 3 years which activated 60%KOH for 4 hours

Proximate analysis

Activated carbon			Moisture (%)	Proximate analysis properties (Wt %)		
Type of bamboo	Age of bamboo	Chemical activation		Ash	Volatile matter	Fixed carbon
BAW	1 year	-	7.29	8.00	44.95	47.05
		H_3PO_4	4.81	6.37	37.35	56.28
		KOH	6.35	5.59	34.42	59.99
	2 years	-	8.32	11.26	46.31	42.43
		H_3PO_4	6.16	10.25	46.21	43.54
		KOH	6.63	9.87	45.18	44.95
	3 years	-	8.74	8.48	44.91	46.61
		H_3PO_4	8.28	4.98	39.99	55.03
		KOH	6.04	5.03	38.23	56.74

Proximate analysis

Activated carbon			Moisture (%)	Proximate analysis properties (Wt %)		
Type of bamboo	Age of bamboo	Chemical activation		Ash	Volatile matter	Fixed carbon
GO	1 year	-	4.81	11.70	48.12	40.18
		H_3PO_4	4.66	8.71	47.93	43.36
		KOH	7.04	7.16	44.98	47.86
	2 years	-	6.37	11.42	44.49	44.09
		H_3PO_4	5.27	8.32	40.79	50.89
		KOH	8.08	10.81	40.40	48.79
	3 years	-	5.84	7.05	44.13	48.82
		H_3PO_4	5.82	5.52	40.21	54.27
		KOH	9.36	6.70	43.82	49.48

Proximate analysis

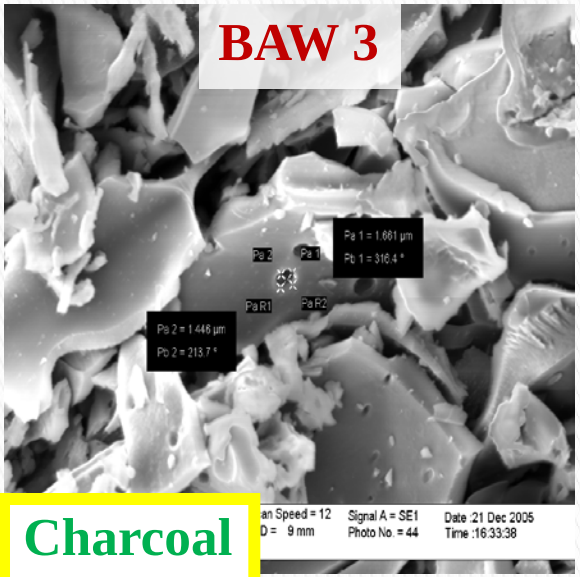
Activated carbon			Moisture (%)	Proximate analysis properties (Wt %)		
Type of bamboo	Age of bamboo	Chemical activation		Ash	Volatile matter	Fixed carbon
GV	1 year	-	5.21	9.66	38.79	51.55
		H_3PO_4	6.81	7.12	37.95	54.93
		KOH	6.57	7.51	34.85	57.64
	2 years	-	6.46	8.54	39.22	52.24
		H_3PO_4	5.95	6.36	37.30	56.34
		KOH	7.62	8.36	34.79	56.85
	3 years	-	5.62	10.73	45.30	43.97
		H_3PO_4	7.68	8.64	44.80	46.56
		KOH	6.93	8.24	35.50	43.50

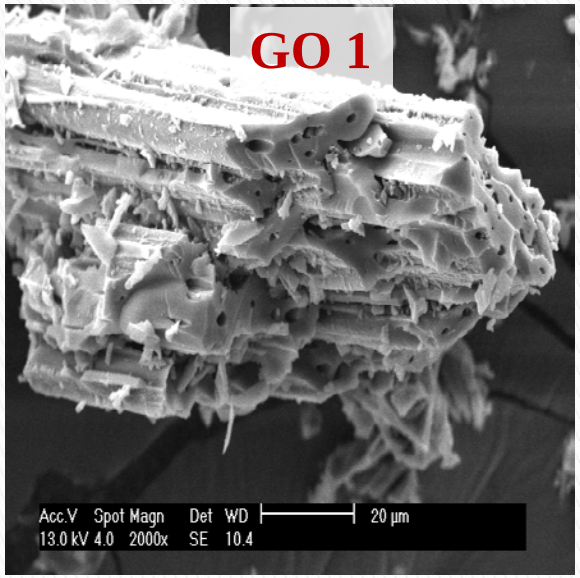
Proximate analysis

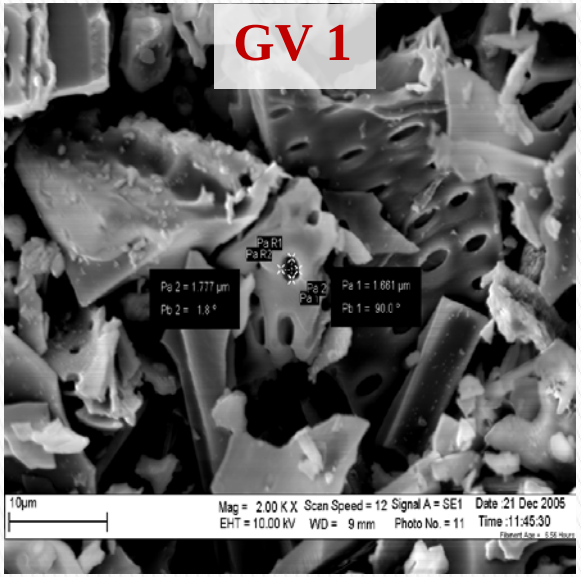
Activated carbon	Moisture (%)	Proximate analysis properties (Wt %)		
		Ash	Volatile matter	Fixed carbon
Fluka	6.05	2.12	26.59	71.29
Bunton	7.29	8.69	38.21	53.1

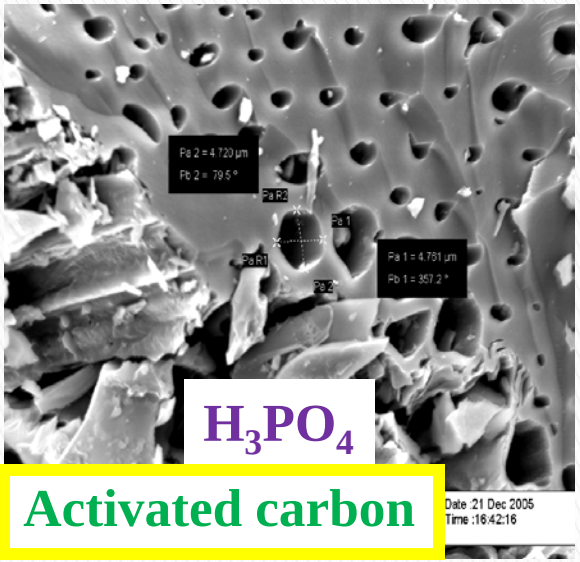
results & discussion

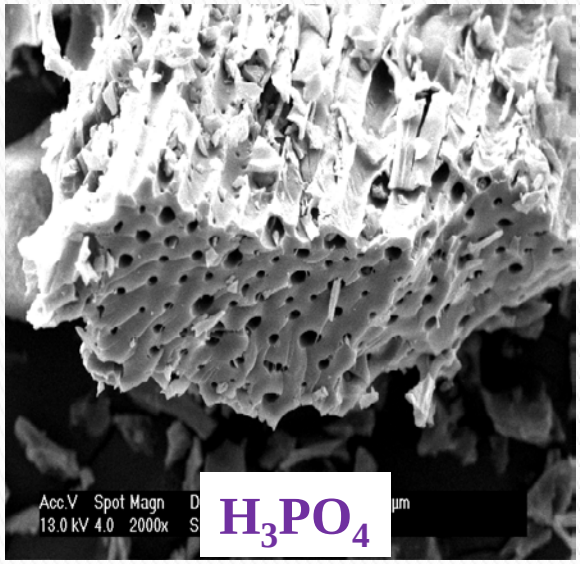
SEM images

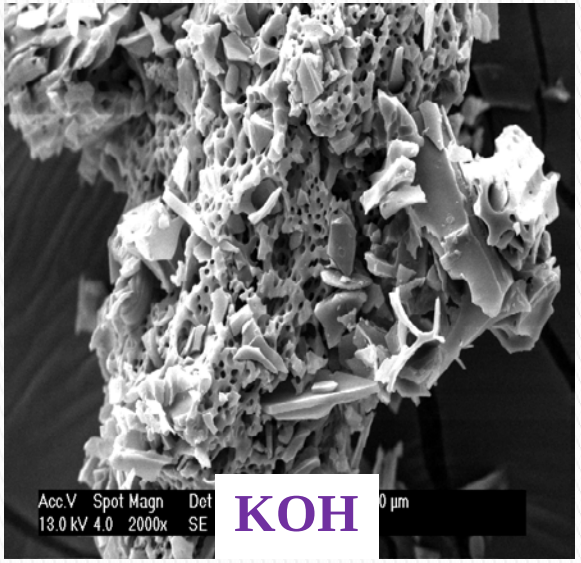






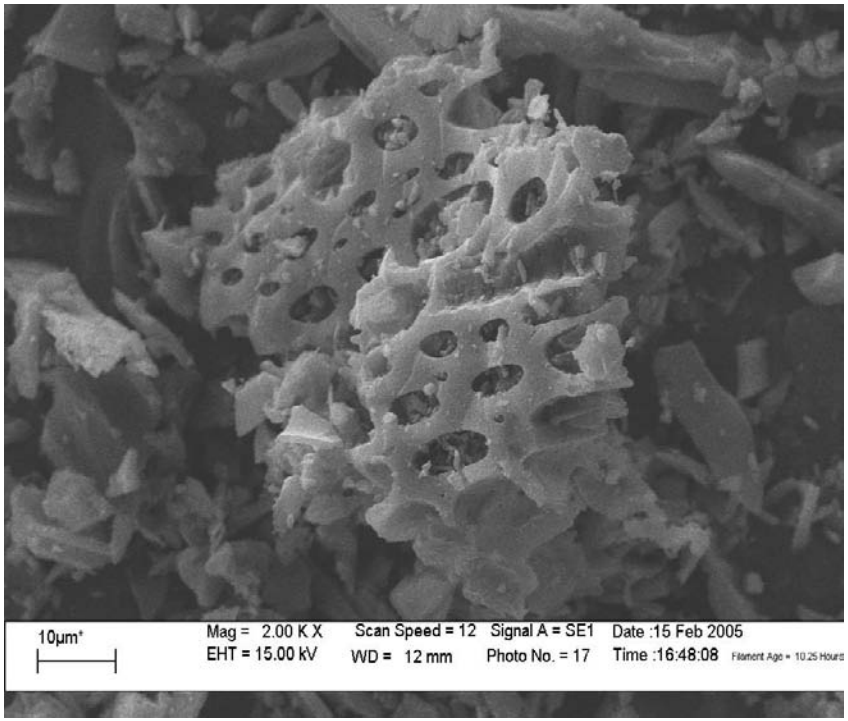






results & discussion

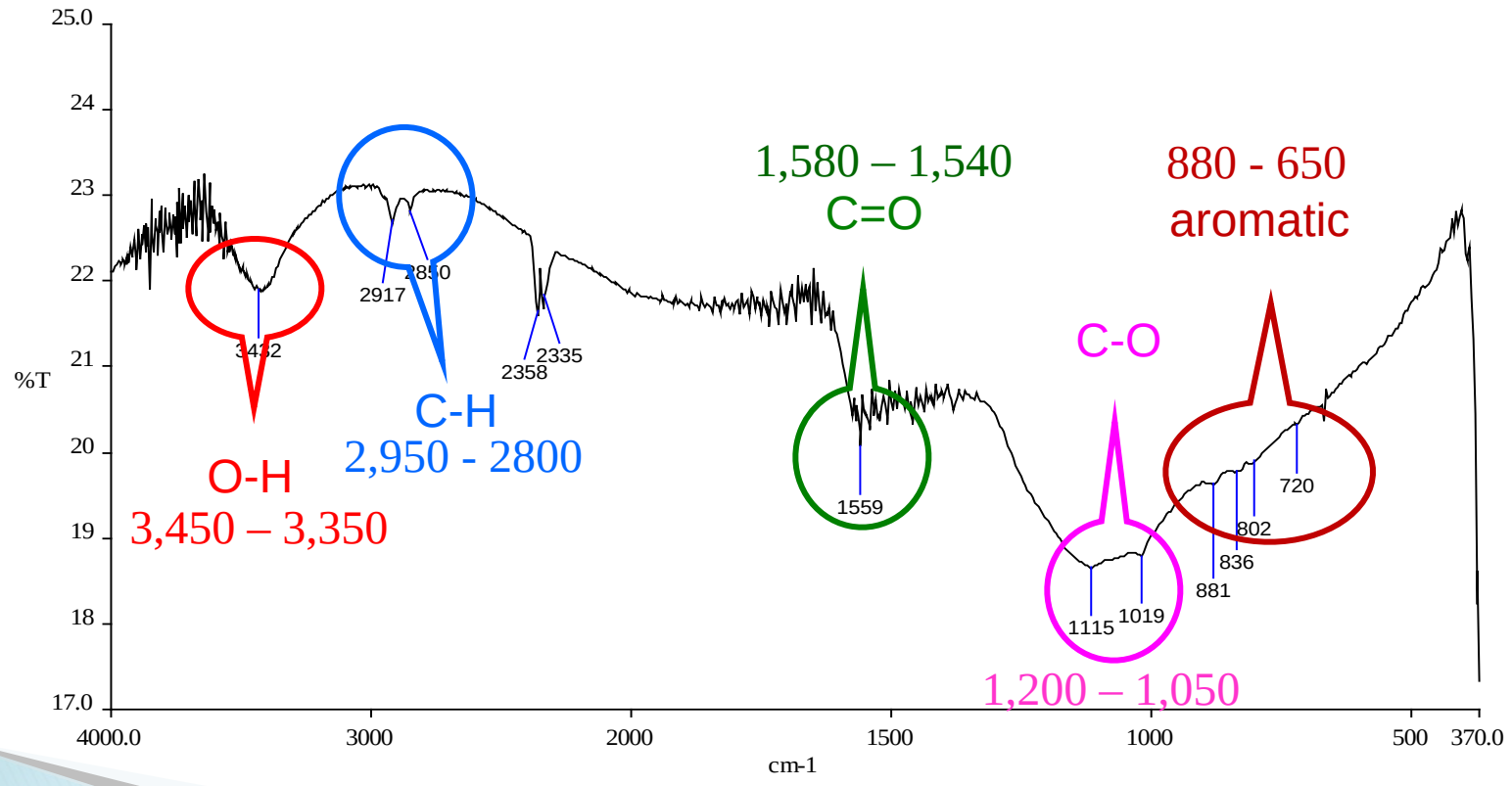
SEM image



Fluka

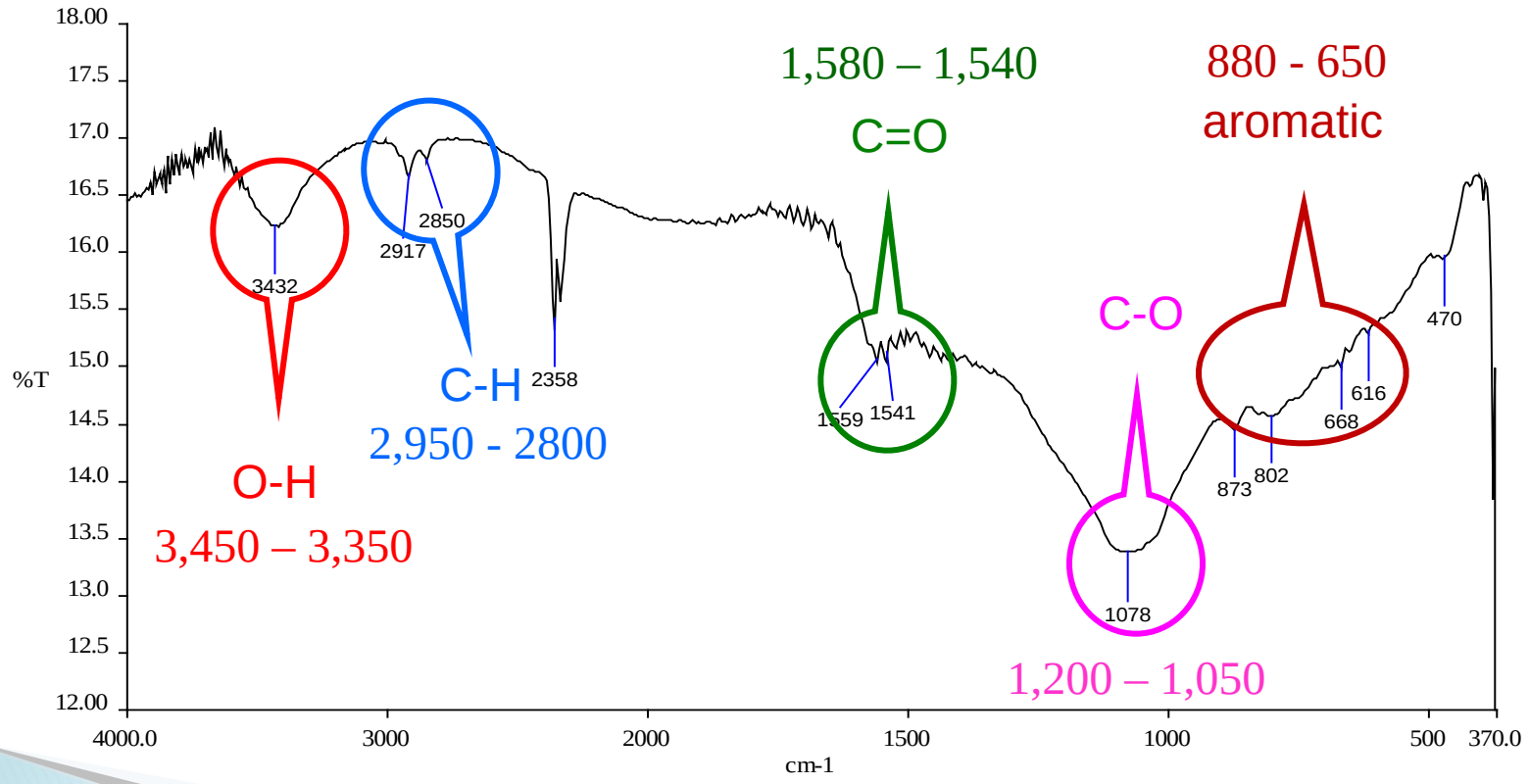
FT-IR results

Fluka



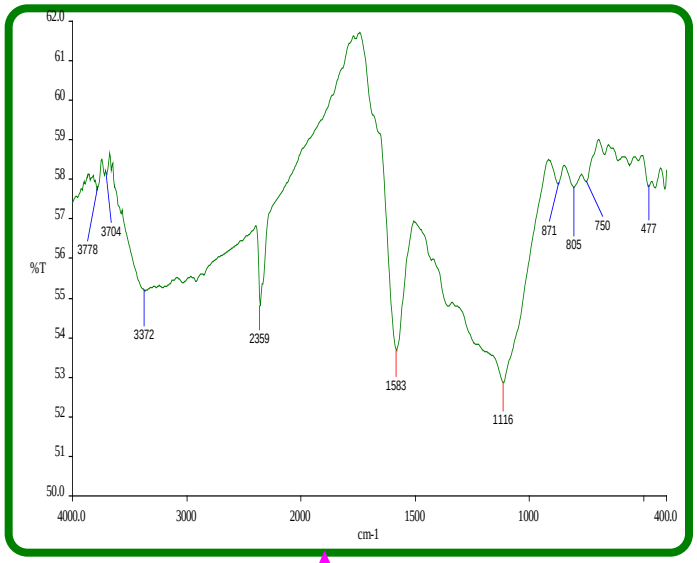
FT-IR results

Bunton



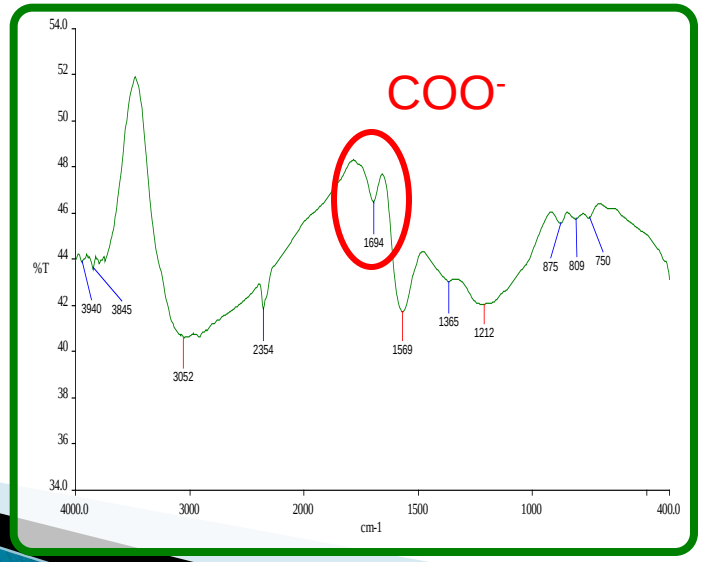
results & discussion

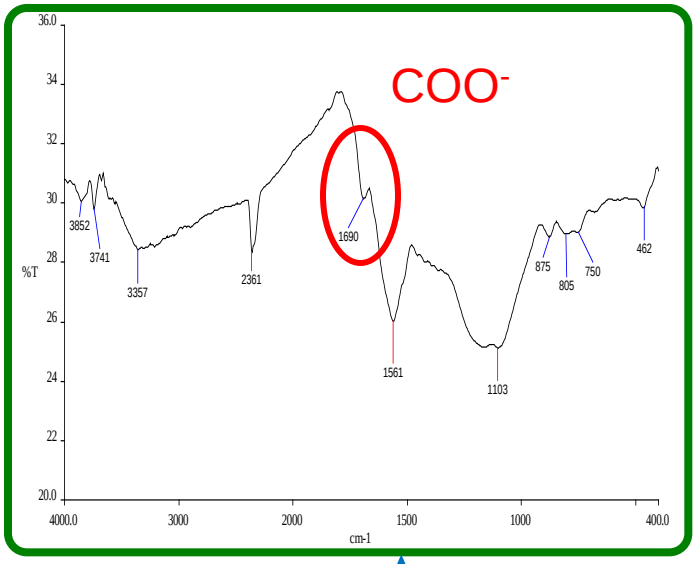
FT-IR results



BAW 1 y.
non-act

BAW 1 y.
KOH

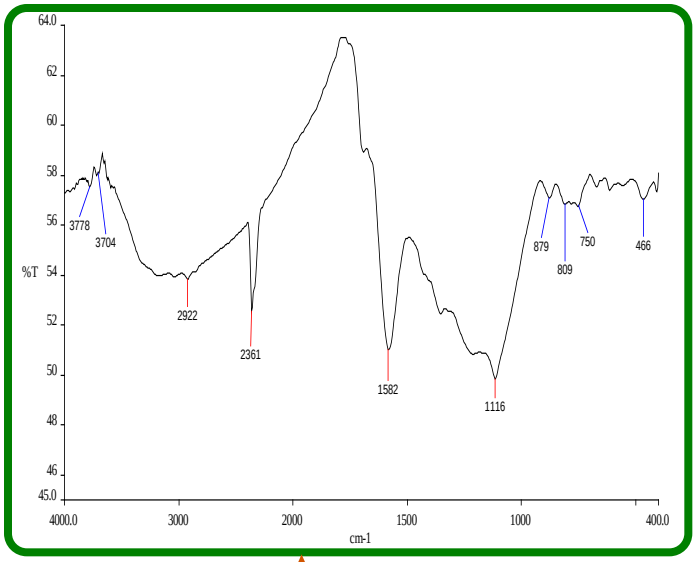




BAW 1 y.
H_3PO_4

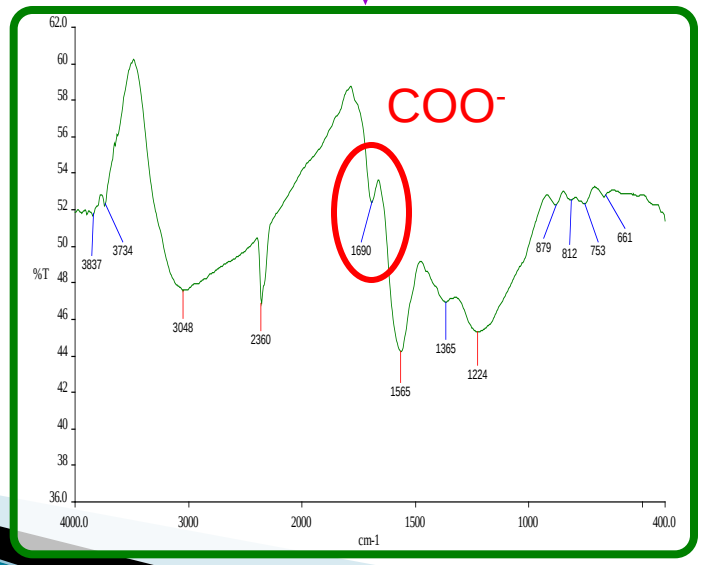
results & discussion

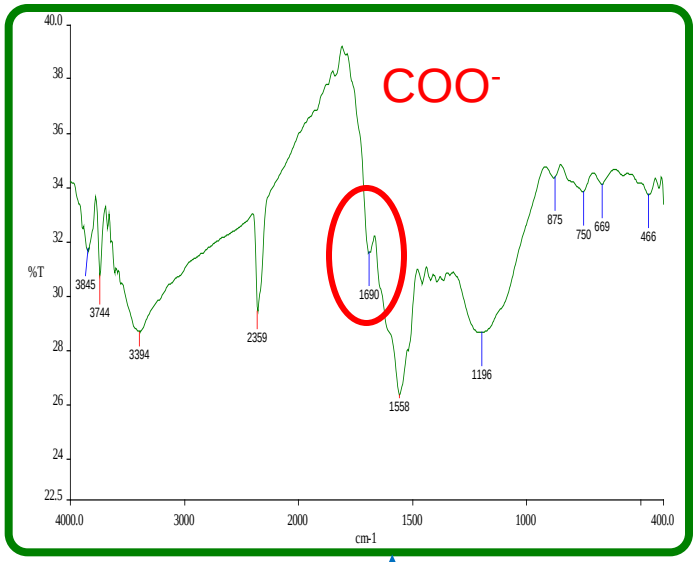
FT-IR results



BAW 2 y. non-act

BAW 2 y. KOH

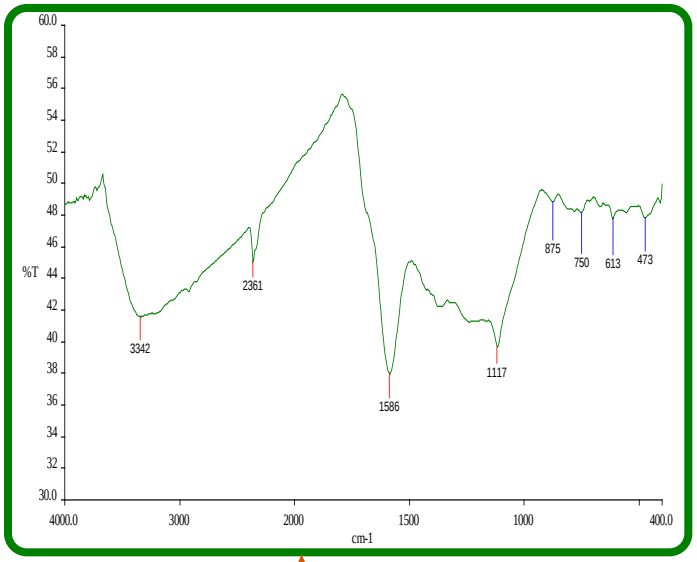




BAW 2 y. H_3PO_4

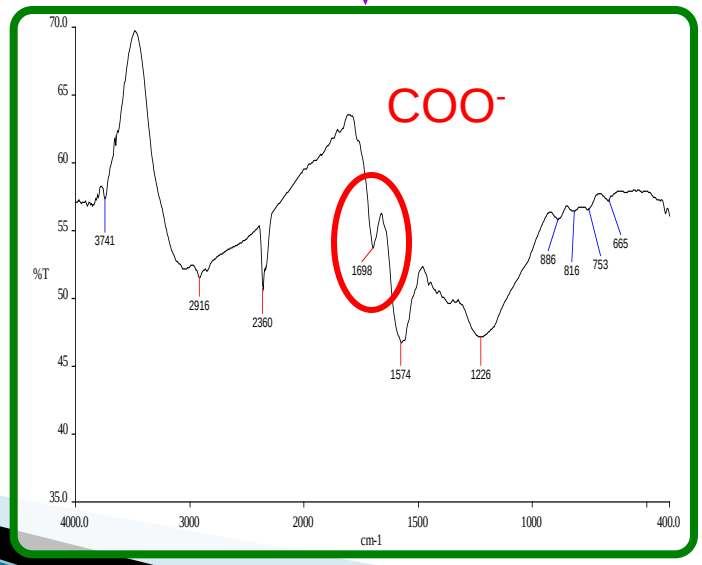
results & discussion

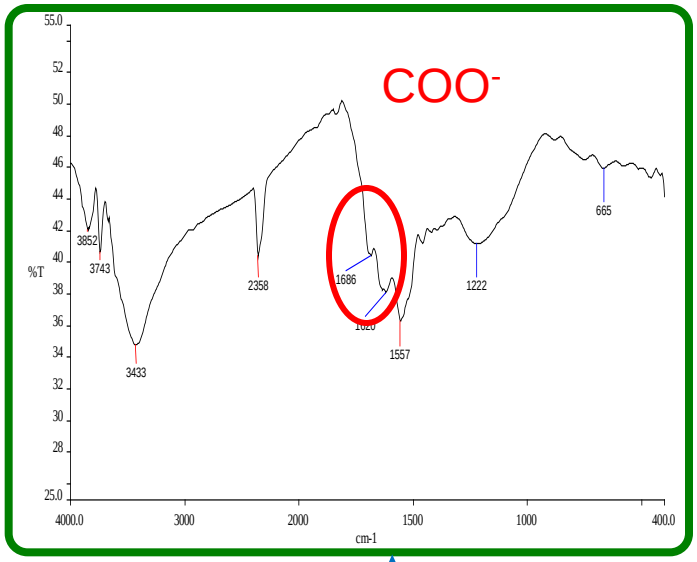
FT-IR results



BAW 3 y. non-act

BAW 3 y. KOH

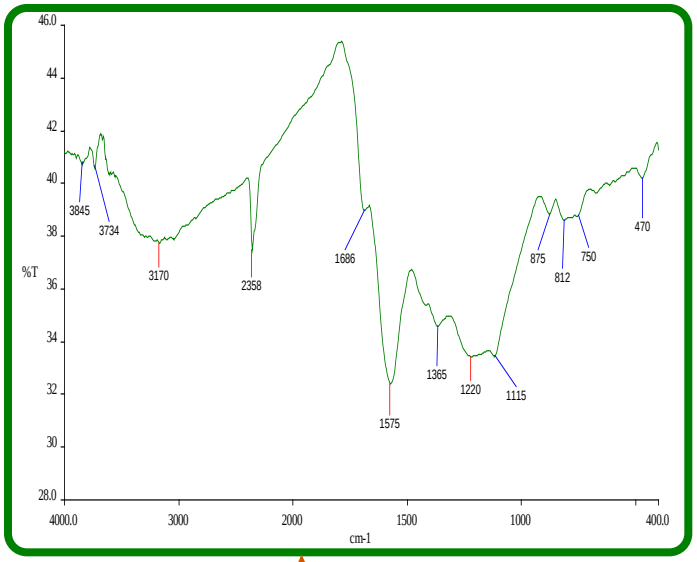




BAW 3 y. H_3PO_4

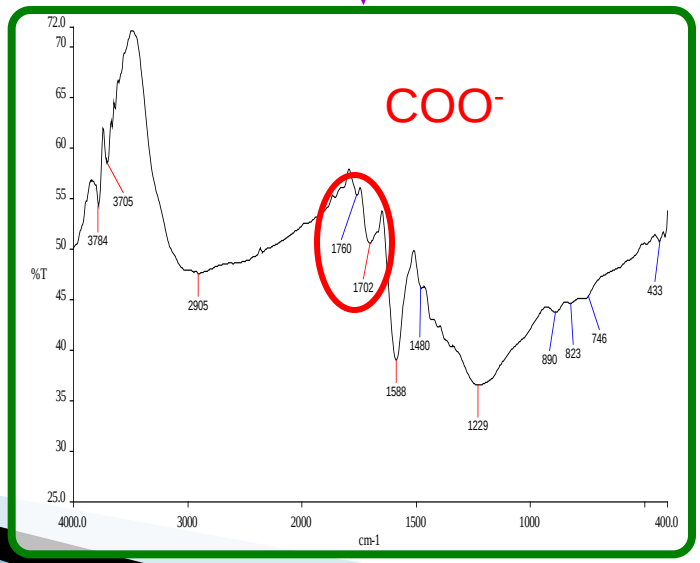
results & discussion

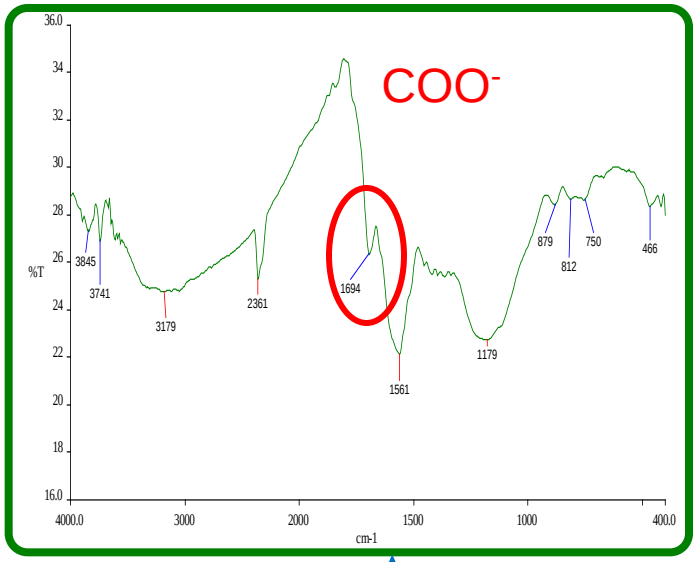
FT-IR results



GO 1 y.
non-act

GO 1 y.
KOH

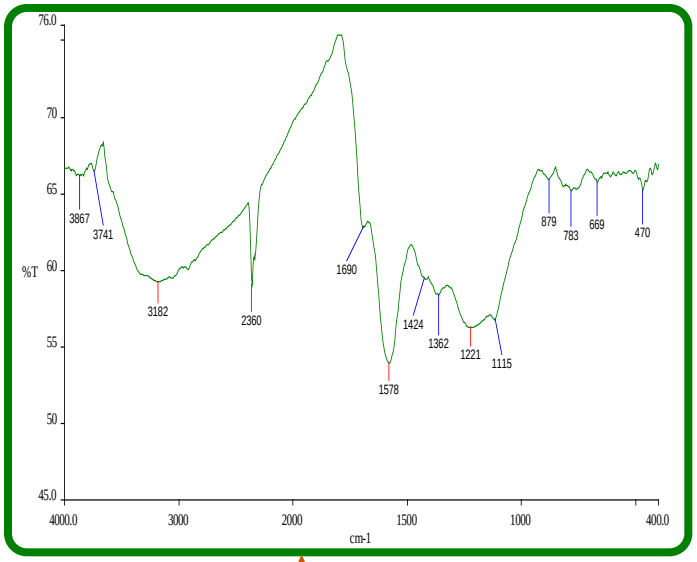




GO 1 y.
H_3PO_4

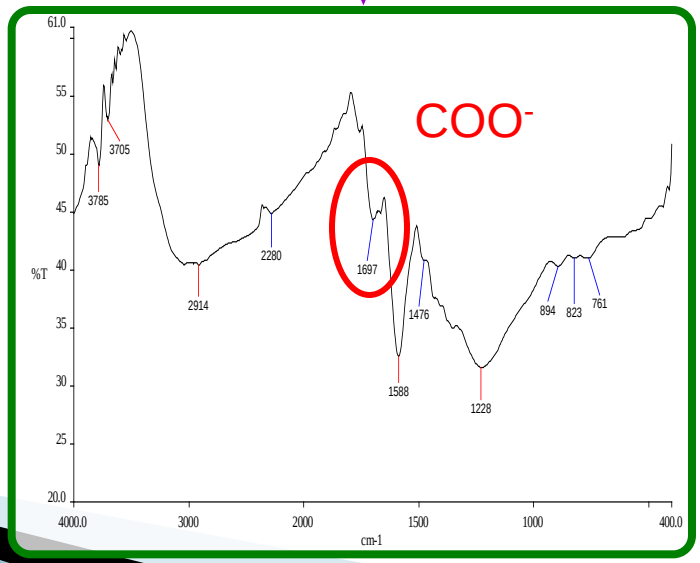
results & discussion

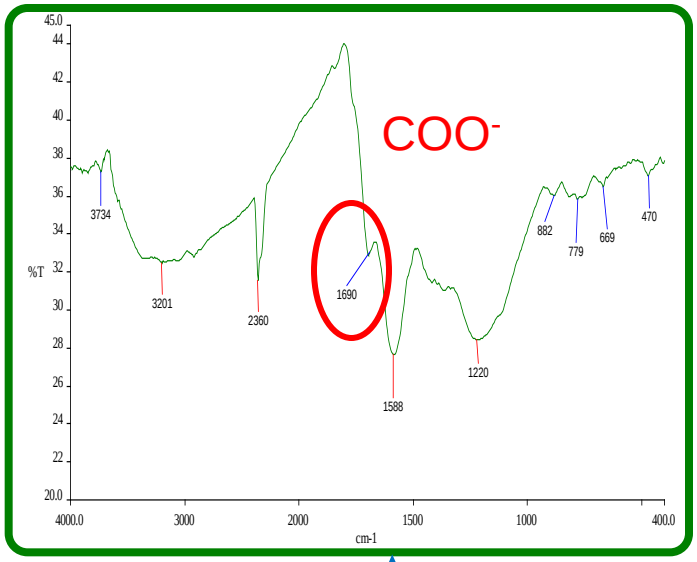
FT-IR results



GO 2 y.
non-act

GO 2 y.
KOH

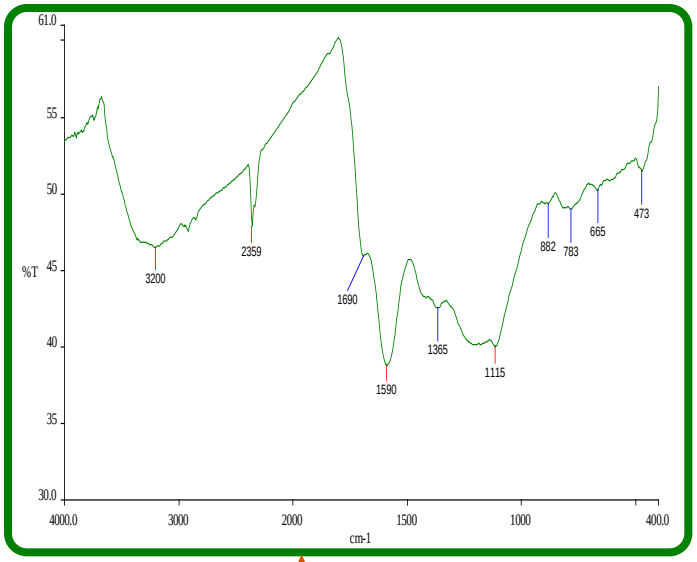




GO 2 y.
H_3PO_4

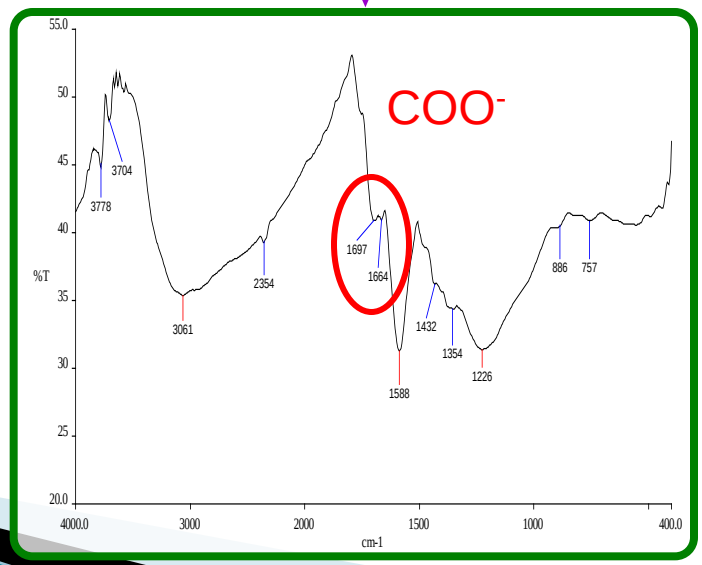
results & discussion

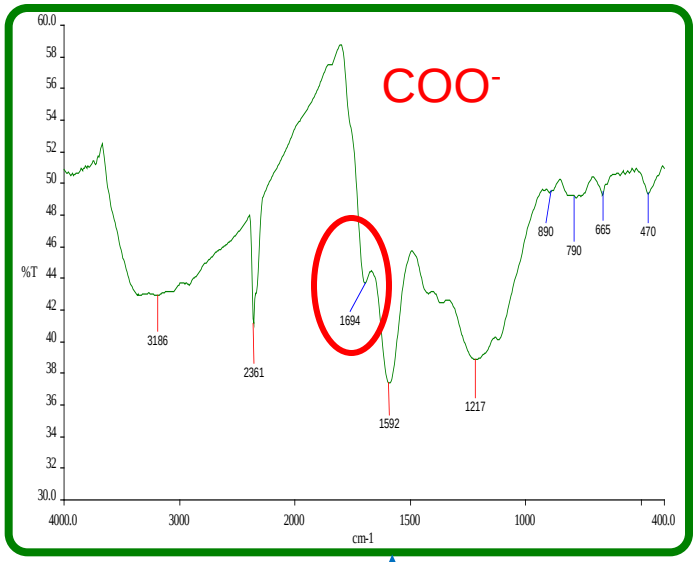
FT-IR results



GO 3 y.
non-act

GO 3 y.
KOH

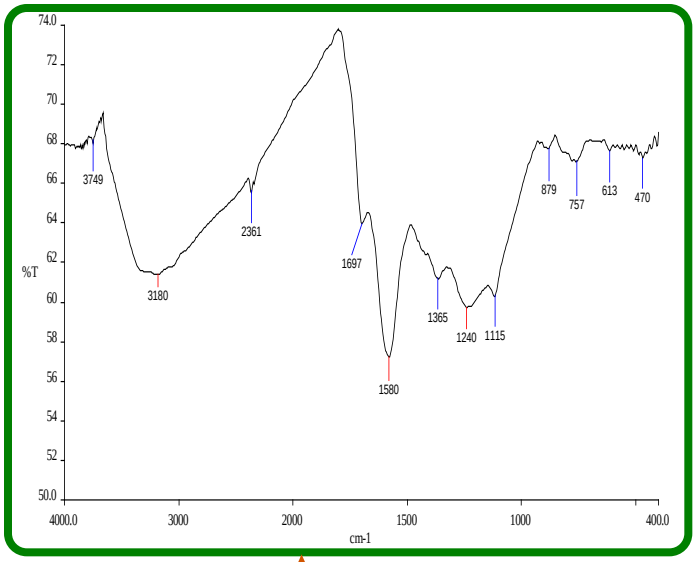




GO 3 y.
H_3PO_4

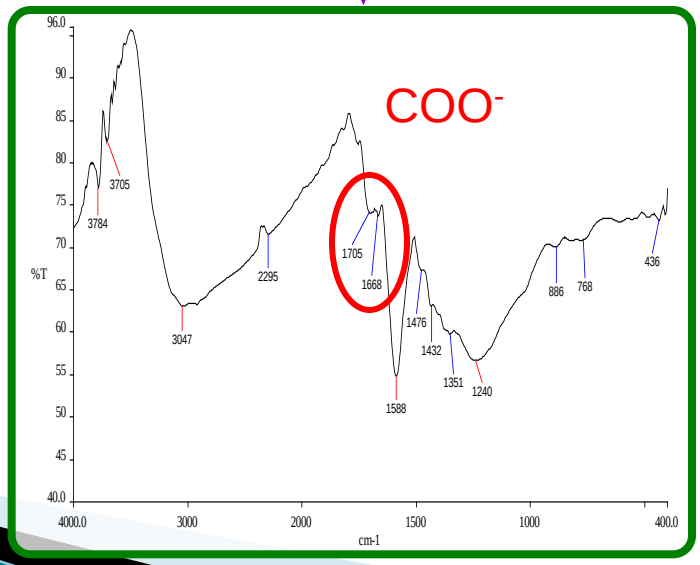
results & discussion

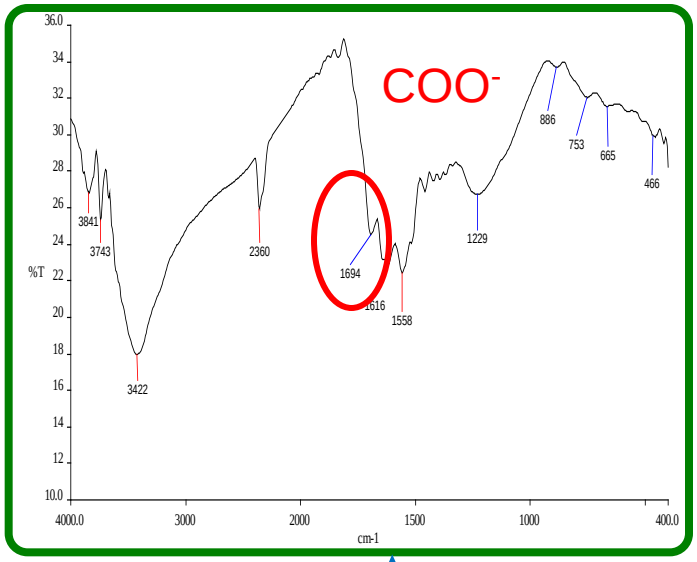
FT-IR results



GV 1 y.
non-act

GV 1 y.
KOH

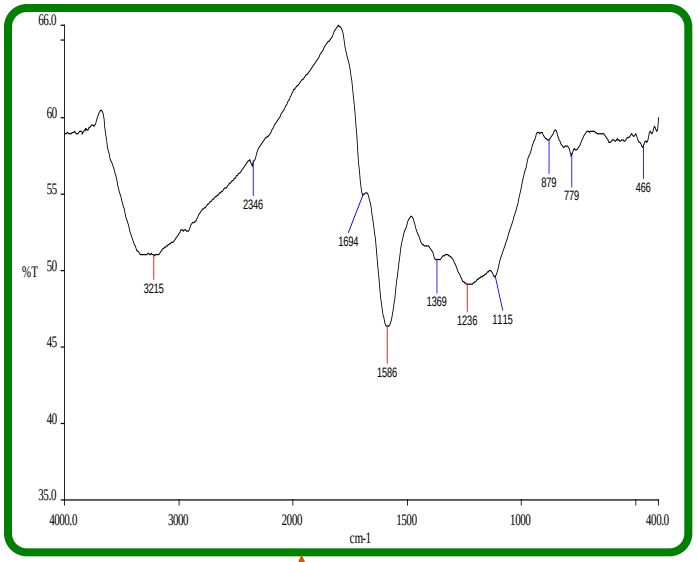




GV 1 y.
H_3PO_4

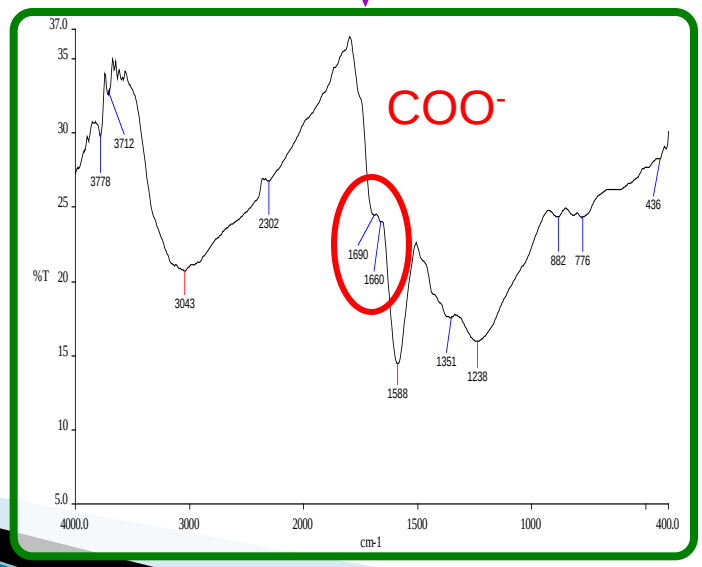
results & discussion

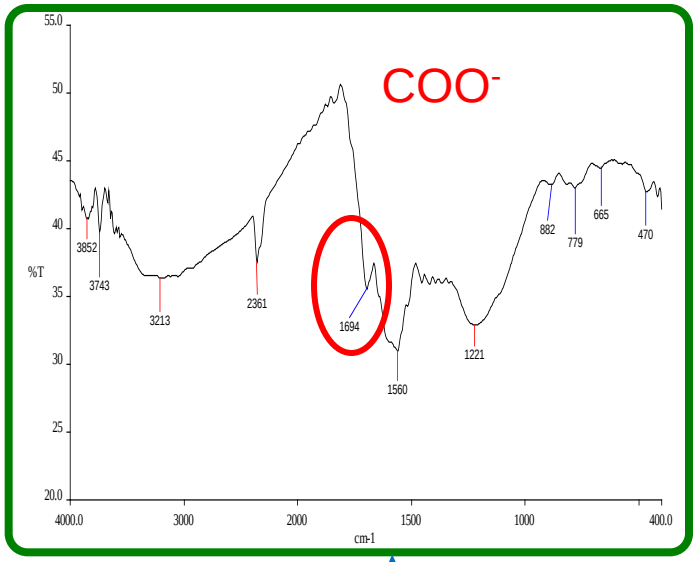
FT-IR results



GV 2 y.
non-act

GV 2 y.
KOH

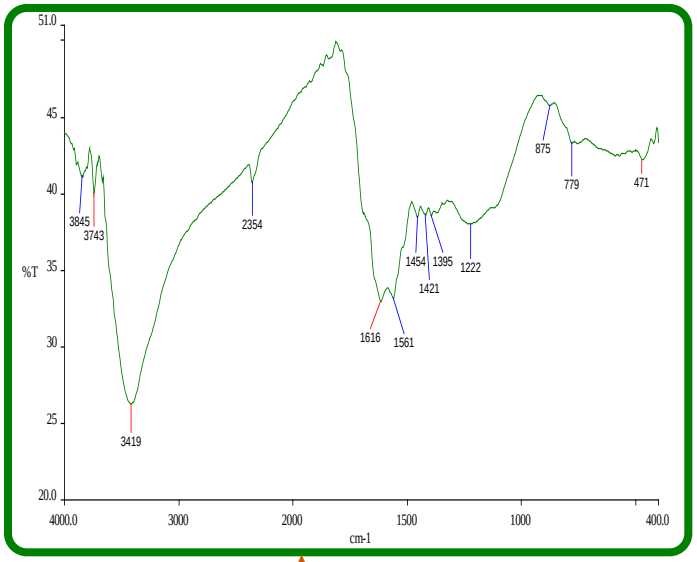




GV 2 y.
H_3PO_4

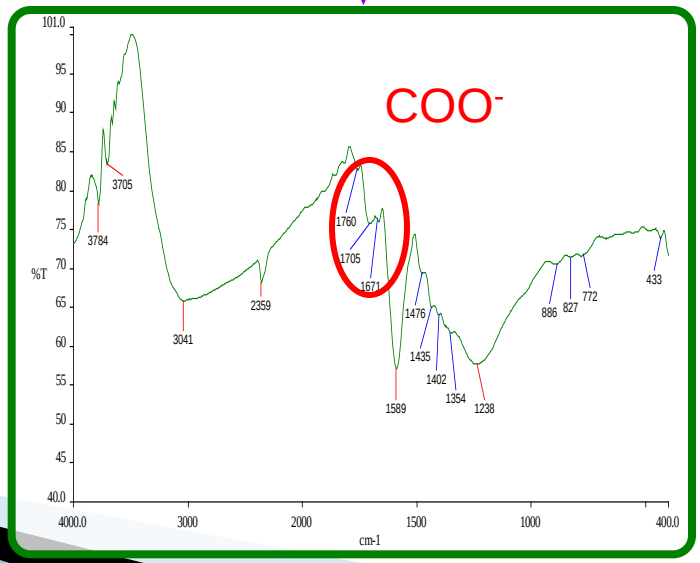
results & discussion

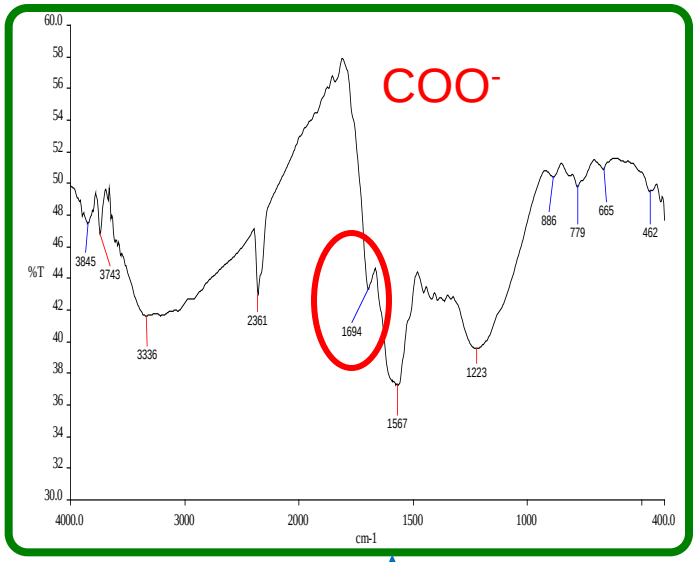
FT-IR results



GV 3 y.
non-act

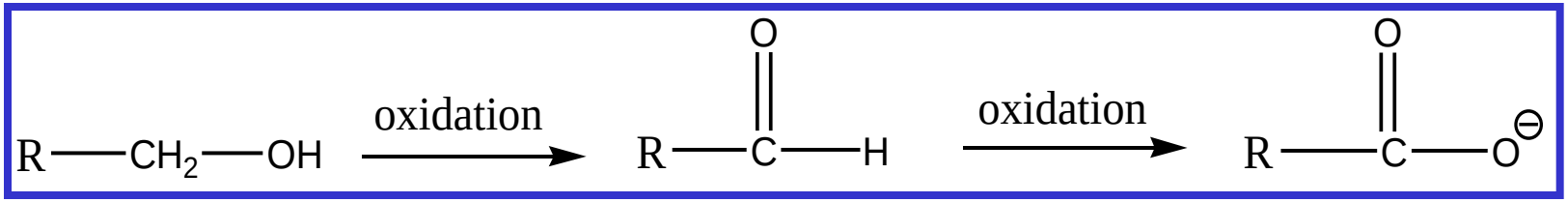
GV 3 y.
KOH





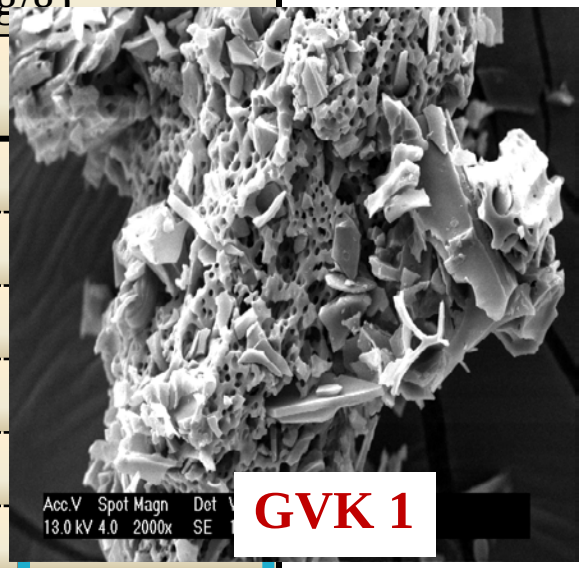
GV 3 y.
H_3PO_4

FT-IR results



Iodine number

Type of bamboo	Iodine number (mg/g)		
	H_3PO_4	non-activated	
BAW 1	150	178	
BAW 2	102	92	
BAW 3	145	140	
GO 1	105	71	
GO 2	115	82	
GO 3	129	89	
GV 1	145	125	1,202
GV 2	206	147	748
GV 3	124	92	643

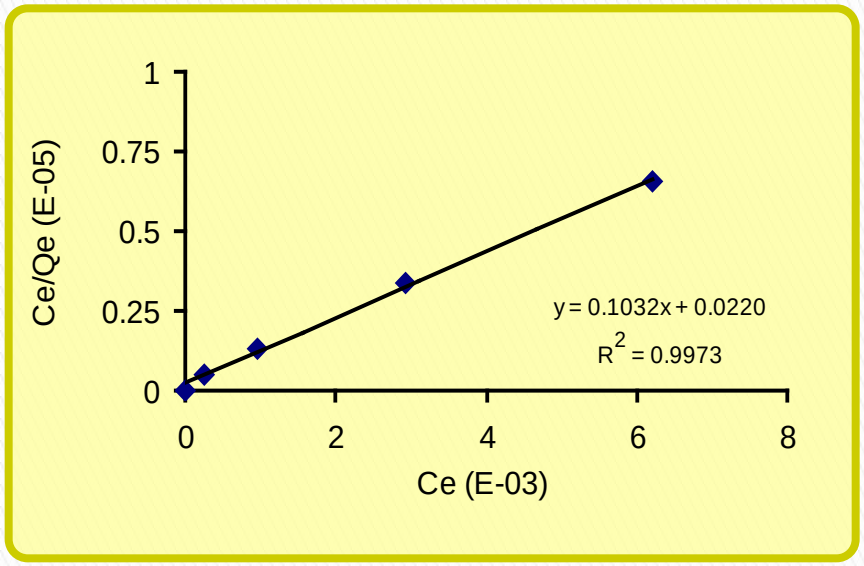


Fluka = 708 mg/g

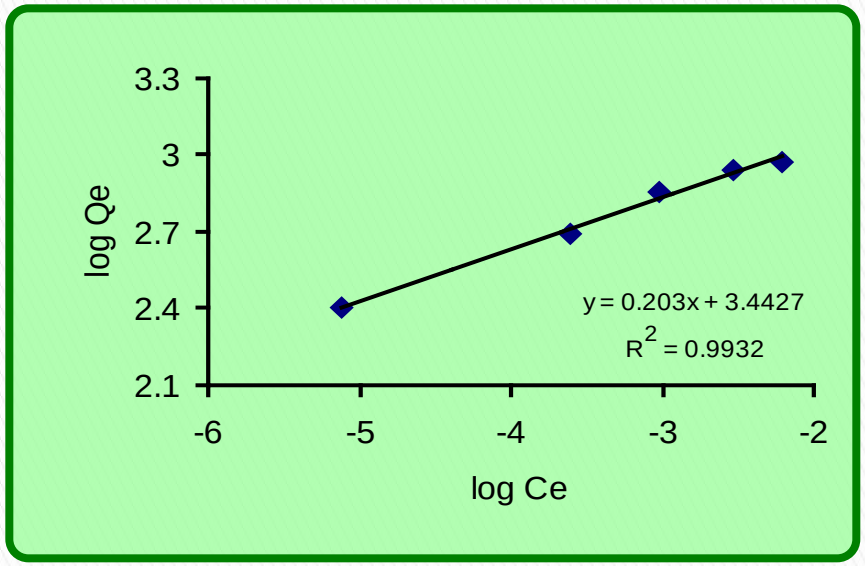
Adsorption isotherms of iodine

Fluka

Langmuir



Freundlich



C_e : remaining concentration of adsorbate after equilibrium (mg/l)

Q_e : amount adsorbed at equilibrium (mg/g)

Adsorption isotherms of iodine

Charcoal	Langmuir Isotherm		Freundlich Isotherm	
	$C_e/Q_e = C_e/Q_0 + 1/bQ_0$	R^2	Log X/M = (log C_e)/n + log k	R^2
Fluka	y = 0.1032x + 0.0220	0.997	y = 0.2030x + 3.4427	0.993
Bunton	y = 0.1457x + 0.0317	0.993	y = 0.1891x + 3.2530	0.993
BAWC 1	y = 0.0758x + 0.5097	0.996	y = 0.3734x + 1.7513	0.976
BAWP 1	y = 0.1454x + 0.2049	0.985	y = 0.2780x + 1.9483	0.989
BAWK 1	y = 0.1251x + 0.8221	0.978	y = 0.3346x + 1.6595	0.987
GOC 3	y = 0.1744x + 0.3452	0.959	y = 0.2433x + 1.9765	0.982
GOP 3	y = 0.1665x + 0.0448	0.974	y = 0.3804x + 1.5975	0.991
GOK 3	y = 0.1322x + 0.3152	0.982	y = 0.3438x + 1.7499	0.986
GVC 1	y = 0.1324x + 0.4541	0.990	y = 0.2492x + 1.9738	0.989
GVP 2	y = 0.1386x + 0.1771	0.988	y = 0.2972x + 1.9321	0.984
GVK 1	y = 0.0827x + 0.2720	0.996	y = 0.3100x + 1.9982	0.973

Adsorption isotherms of iodine

Sample	Langmuir isotherm		Freundlich isotherm	
	Q_o (mg/g)	b (l/mg)	1/n	K
Fluka	9.69	4.691	0.203	2,771.41
Bunton	6.86	4.600	0.189	1,790.61
BAWC 1	12.98	0.156	0.373	56.36
BAWP 1	6.62	0.878	0.278	88.72
BAWK 1	7.35	0.194	0.334	45.60
GOC 3	6.29	0.511	0.243	94.62
GOP 3	5.85	2.440	0.380	39.54
GOK 3	7.09	0.536	0.343	56.10
GVC 1	7.25	0.339	0.249	93.97
GVP 2	6.99	0.923	0.297	85.51
GVK 1	11.90	0.331	0.310	99.54

Adsorption isotherms of iodine

Sample	Specific surface areal (m^2/g)
Fluka	14.71
Bunton	10.41
BAWC 1	19.70
BAWP 1	10.05
BAWK 1	11.16
GOC 3	9.55
GOP 3	8.88
GOK 3	10.76
GVC 1	11.01
GVP 2	10.61
GVK 1	18.06

Phenol value

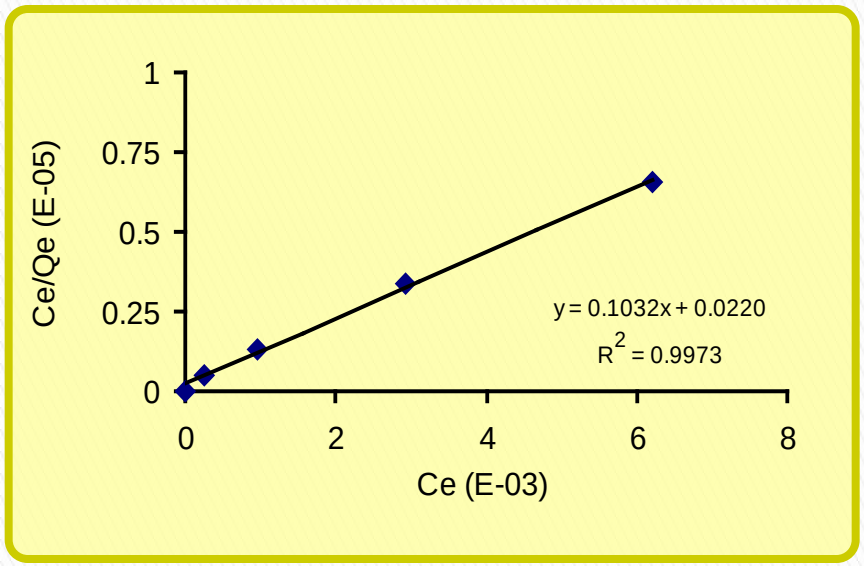
Type of bamboo	Phenol value (mg/g)		
	H_3PO_4	non-activated	KOH
BAW 1	24.62	4.90	13.30
BAW 2	13.45	28.01	11.28
BAW 3	24.86	12.64	35.52
GO 1	10.97	11.37	10.30
GO 2	56.84	19.08	12.41
GO 3	17.52	17.81	22.53
GV 1	23.23	23.40	18.27
GV 2	7.34	11.04	12.56
GV 3	14.65	13.45	29.39

Fluka = 2.32 mg/g
Bunton = 7.71 mg/g

Adsorption isotherms of phenol

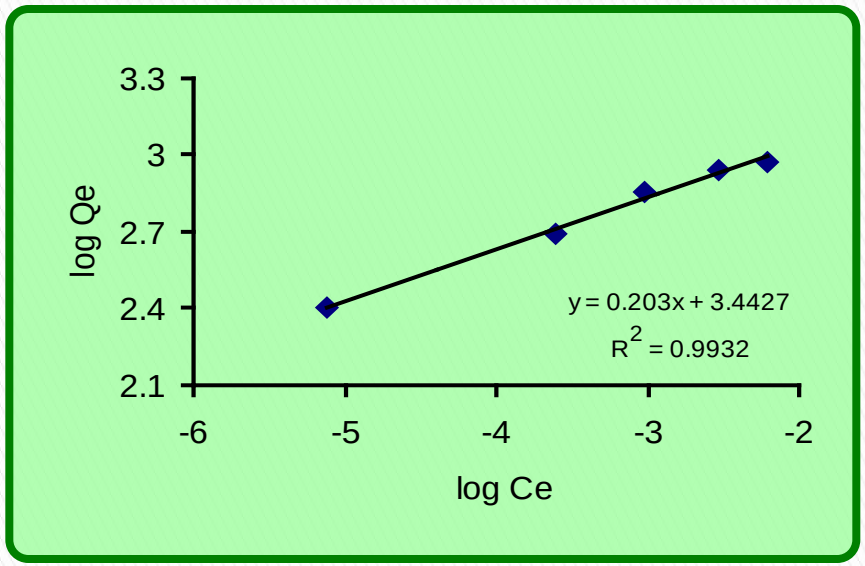
Fluka

Langmuir



C_e : remaining concentration of adsorbate after equilibrium (mg/l)

Freundlich



Q_e : amount adsorbed at equilibrium (mg/g)

Adsorption isotherms of phenol

Charcoal	Langmuir Isotherm		Freundlich Isotherm	
	$C_e/Q_e = C_e/Q_0 + 1/bQ_0$	R^2	Log X/M = (log C_e)/n + log k	R^2
Fluka	y = 0.1032x + 0.0220	0.983	y = 0.2030x + 3.4427	0.981
Bunton	y = 0.1457x + 0.0317	0.988	y = 0.1891x + 3.2530	0.988
BAWC 1	y = 0.3988x + 0.3366	0.995	y = 0.2870x + 0.1356	0.997
BAWP 2	y = 0.2061x + 1.0851	0.998	y = 0.4093x + 0.0835	0.993
BAWK 2	y = 0.6259x + 1.2718	0.997	y = 0.2546x – 0.1737	0.994
GOC 1	y = 0.3359x + 1.9270	0.998	y = 0.9340x – 0.6843	0.999
GOP 1	y = 0.2283x + 4.3442	0.998	y = 0.4116x – 0.1977	0.999
GOK 1	y = 0.6271x + 1.0044	0.995	y = 0.3091x – 0.1859	0.990
GVC 2	y = 0.1170x + 3.4970	0.991	y = 0.9217x – 0.5443	0.994
GVP 2	y = 0.4016x + 0.6149	0.994	y = 0.7001x – 0.1416	0.998
GVK 2	y = 0.2310x + 3.6242	0.997	y = 0.4781x – 0.2502	0.992

Adsorption isotherms of phenol

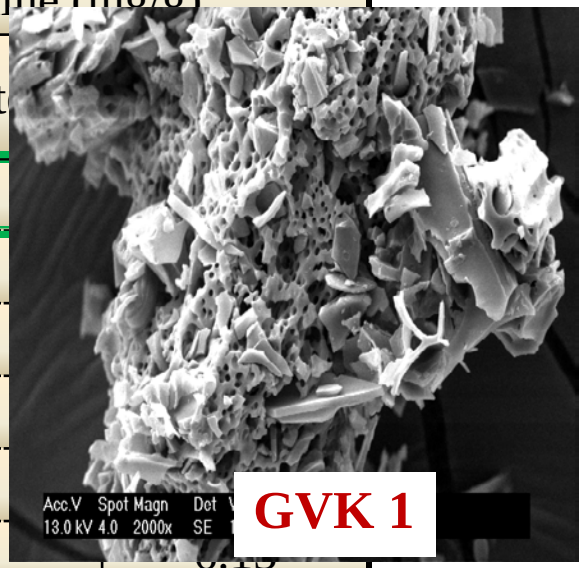
Type of sample	Langmuir isotherm		Freundlich isotherm	
	Q_o (mg/g)	b (L/mg)	1/n	K_F
Fluka	2.59	2.171	0.447	1.60
Bunton	2.51	2.328	0.404	1.56
BAWC 1	2.51	1.186	0.287	1.36
BAWP 2	4.85	0.190	0.409	1.21
BAWK 2	1.60	0.492	0.254	1.48
GOC 1	2.98	0.174	0.934	4.83
GOP 1	4.38	0.052	0.411	1.57
GOK 1	1.59	0.626	0.309	1.53
GVC 2	8.55	0.033	0.921	3.50
GVP 2	2.49	0.654	0.700	1.38
GVK 2	4.33	0.064	0.478	1.78

Adsorption isotherms of phenol

Sample	Specific surface areal (m^2/g)
Fluka	8.65
Bunton	8.38
BAWC 1	8.38
BAWP 2	16.19
BAWK 2	5.34
GOC 1	9.95
GOP 1	14.62
GOK 1	5.31
GVC 2	28.55
GVP 2	8.31
GVK 2	14.46

Methylene blue value

Type of bamboo	Methylene blue value (mg/g)		
	H_3PO_4	non-activat	
BAW 1	6.33	13.80	
BAW 2	6.66	7.25	
BAW 3	7.31	7.62	
GO 1	5.77	7.28	
GO 2	5.53	6.94	
GO 3	6.25	6.43	
GV 1	7.61	14.50	15.50
GV 2	7.97	8.60	10.01
GV 3	7.16	7.22	8.77

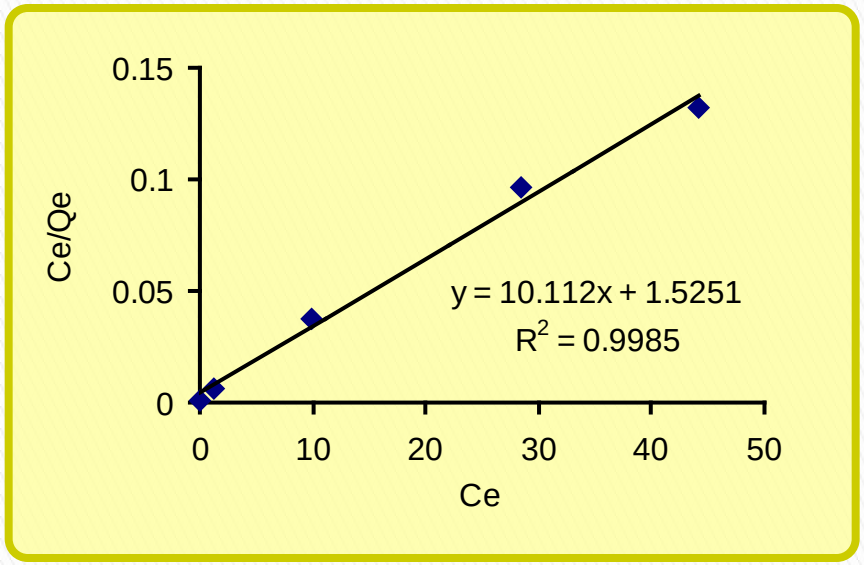


Fluka = 15.5 mg/g

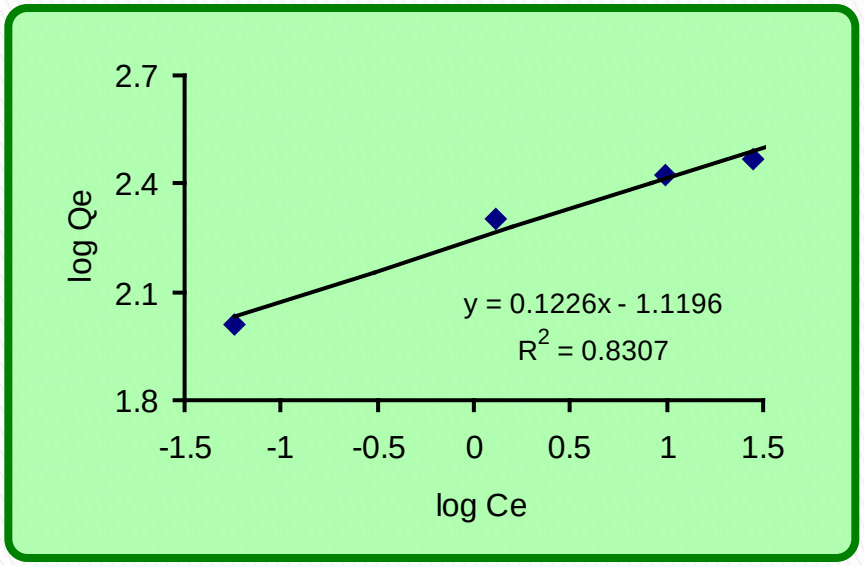
Adsorption isotherms of methylene blue

Fluka

Langmuir



Freundlich



C_e : remaining concentration of adsorbate after equilibrium (mg/l)

Q_e : amount adsorbed at equilibrium (mg/g)

Adsorption isotherms of methylene blue

Charcoal	Langmuir Isotherm		Freundlich Isotherm	
	$C_e/Q_e = C_e/Q_0 + 1/bQ_0$	R^2	Log X/M = (log C_e)/n + log k	R^2
Fluka	y = 0.1032x + 0.0220	0.992	y = 0.2030x + 3.4427	0.984
Bunton	y = 0.1457x + 0.0317	0.995	y = 0.1891x + 3.2530	0.990
BAWC 1	y = 0.0715x + 0.1415	0.999	y = 0.1763x + 0.8505	0.957
BAWP 3	y = 0.0913x + 0.0988	0.998	y = 0.1010x + 0.8538	0.984
BAWK 1	y = 0.0902x + 0.1456	0.997	y = 0.0877x + 0.8847	0.956
GOC 1	y = 0.0955x + 0.2689	0.999	y = 0.1382x + 0.7544	0.961
GOP 2	y = 0.1275x + 0.0155	0.992	y = 0.1506x + 0.6918	0.962
GOK 3	y = 0.9528x + 0.6448	0.994	y = 0.3356x + 0.5640	0.962
GVC 1	y = 0.0436x + 0.0047	0.994	y = 0.1613x + 1.1595	0.985
GVP 2	y = 0.0823x + 0.0154	0.997	y = 0.2651x + 0.8427	0.971
GVK 1	y = 0.0267x + 0.0200	0.999	y = 0.3574x + 1.1978	0.973

Adsorption isotherms of methylene blue

Type of sample	Langmuir isotherm		Freundlich isotherm	
	Q_o (mg/g)	b (L/mg)	1/n	K
Fluka	333.33	0.750	0.172	175.27
Bunton	15.29	0.512	0.072	10.80
BAWC 1	13.99	0.505	0.176	7.08
BAWP 3	10.95	0.924	0.101	7.13
BAWK 1	11.09	0.619	0.087	7.66
GOC 1	10.47	0.355	0.138	5.68
GOP 3	7.84	8.230	0.150	4.91
GOK 2	1.05	1.480	0.335	3.66
GVC 1	22.94	9.270	0.161	14.42
GVP 2	12.15	5.340	0.265	6.95
GVK 1	37.45	1.340	0.357	15.74

Adsorption isotherms of methylene blue

Sample	Specific surface areal (m^2/g)
Fluka	752.84
Bunton	34.53
BAWC 1	31.6
BAWP 3	24.73
BAWK 1	25.05
GOC 1	23.65
GOP 2	17.71
GOK 3	2.37
GVC 1	51.81
GVP 2	27.44
GVK 1	84.58

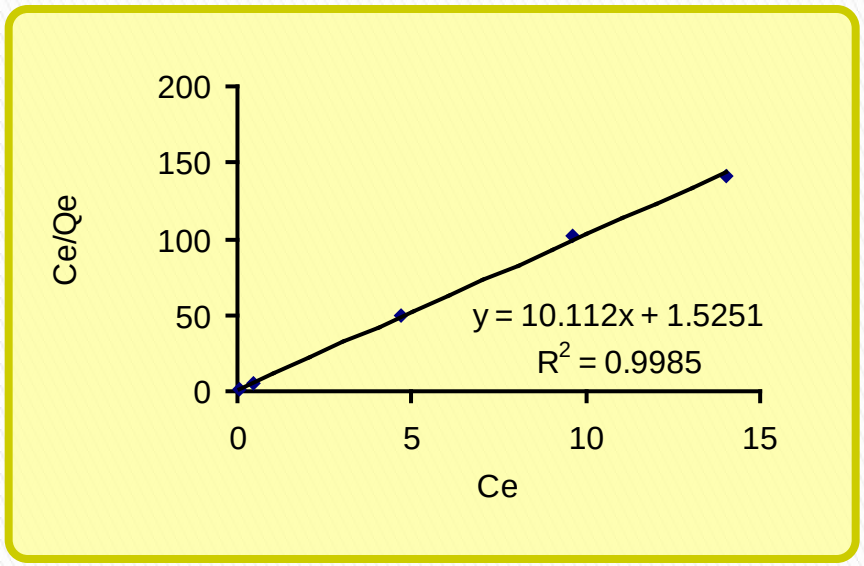
Cadmium value

Activated carbon	Cadmium value (mg/g)
BAWC 1	0.35
BAWP 1	0.43
BAWK 1	0.36
GOC 3	0.28
GOP 3	0.44
GOK 3	0.47
GVC 1	0.47
GVP 2	0.41
GVK 1	0.48

Adsorption isotherms of Cd (II)

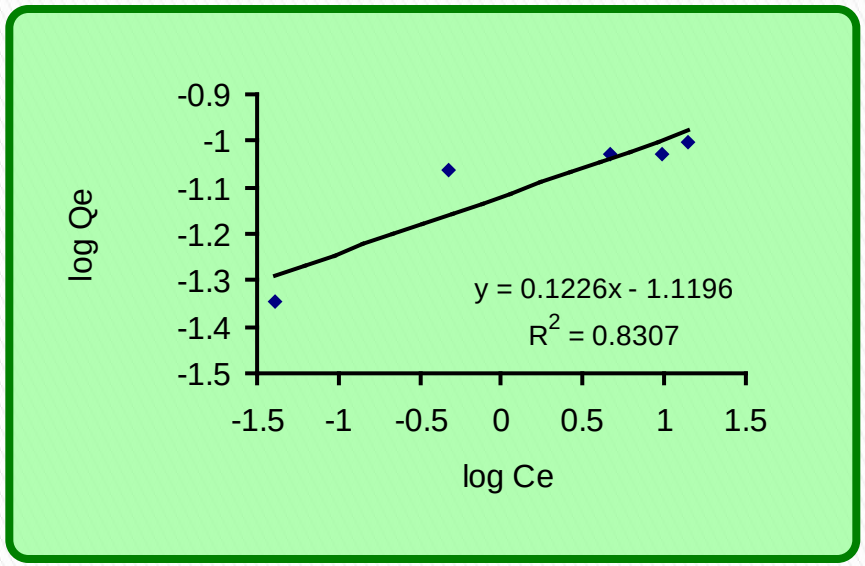
Fluka

Langmuir



C_e : remaining concentration of adsorbate after equilibrium (mg/l)

Freundlich



Q_e : amount adsorbed at equilibrium (mg/g)

Adsorption isotherms of Cd (II)

Charcoal	Langmuir Isotherm		Freundlich Isotherm	
	$C_e/Q_e = C_e/Q_0 + 1/bQ_0$	R^2	Log X/M = (log C_e)/n + log k	R^2
Fluka	y = 0.1032x + 0.0220	1.000	y = 0.2030x + 3.4427	0.784
Bunton	y = 0.1457x + 0.0317	0.999	y = 0.1891x + 3.2530	0.782
BAWC 1	y = 0.0613x + 0.0671	0.998	y = 0.4680x – 0.8486	0.996
BAWP 1	y = 0.1458x + 0.0643	0.998	y = 0.5699x – 0.6542	0.966
BAWK 1	y = 0.1047x + 0.0551	0.999	y = 0.5974x – 0.7567	0.996
GOC 3	y = 0.0192x + 0.0793	0.983	y = 0.4778x – 1.0476	0.999
GOP 3	y = 0.1523x + 0.0414	0.996	y = 0.7096x – 0.6959	0.993
GOK 3	y = 0.9124x + 0.0381	0.999	y = 0.9038x – 0.1238	0.999
GVC 1	y = 0.3158x – 0.0116	0.997	y = 1.0249x – 0.5048	0.994
GVP 2	y = 0.1224x + 0.0470	0.999	y = 0.5729x – 0.7649	0.998
GVK 1	y = 0.5379x + 0.0679	0.987	y = 0.7616x – 0.1855	0.992

Adsorption isotherms of Cd (II)

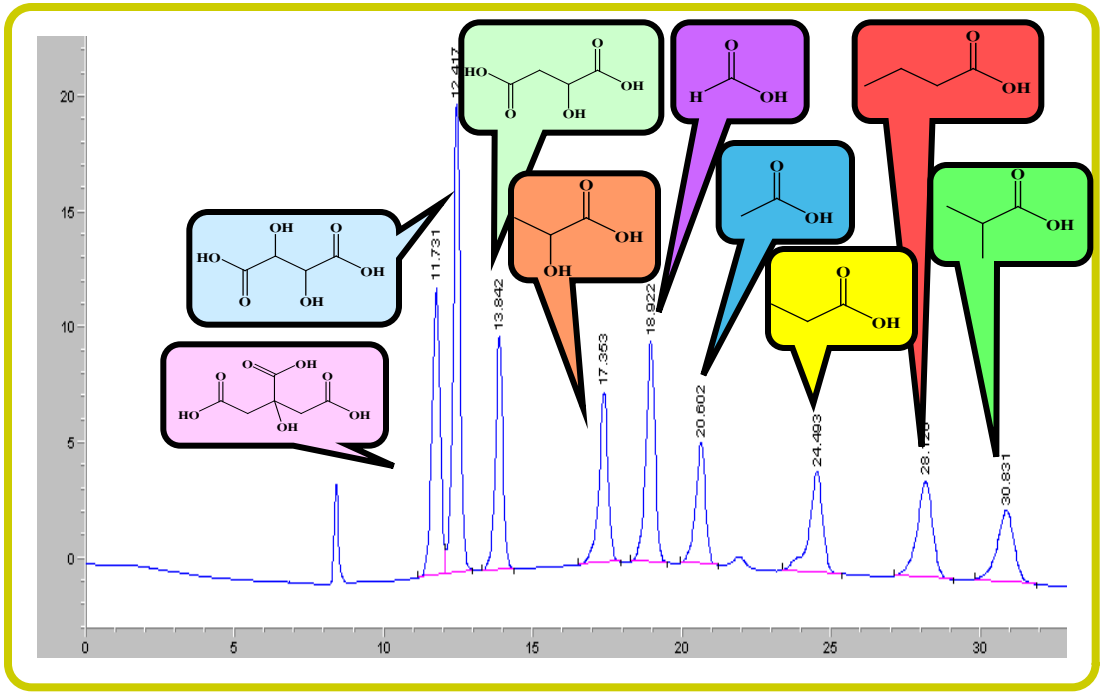
Type of sample	Langmuir isotherm		Freundlich isotherm	
	Q_o (mg/g)	b (L/mg)	1/n	K
Fluka	0.12	23.072	0.136	13.84
Bunton	0.08	5.210	0.142	8.57
BAWC 1	16.39	0.911	0.468	7.05
BAWP 1	6.90	2.264	0.569	4.51
BAWK 1	9.62	1.890	0.597	5.70
GOC 3	52.63	0.241	0.477	11.14
GOP 3	6.58	1.000	0.709	4.95
GOK 3	1.10	0.997	0.903	1.33
GVC 1	3.17	1.000	1.024	3.19
GVP 2	8.20	1.000	0.572	5.81
GVK 1	1.86	8.024	0.761	1.53

Adsorption isotherms of Cd (II)

Sample	Specific surface areal (m^2/g)
Fluka	0.39
Bunton	0.26
BAWC 1	53.54
BAWP 1	22.54
BAWK 1	31.42
GOC 3	171.93
GOP 3	21.5
GOK 3	3.59
GVC 1	10.36
GVP 2	26.79
GVK 1	6.08

results & discussion

Wood vinegar



Condition :

λ_{max} = 210 nm

flow rate = 0.5 ml/min

mobile phase = 0.1% H_3PO_4

column = SUPELCO C-610H

[sulfonated polystylene/

divinylbenzene]

Column temp = 25 ^oC

results & discussion

Wood vinegar

Type of bamboo	years	Amount of organic acids (ppm)								
		Citric acid	Tartaric acid	Malic acid	Lactic acid	Fomic acid	Acetic acid	Propionic acid	Isobutyric acid	Butyric acid
BAW	1	10,900	6,123	5,965	4,080	46,404	164,929	10,618	45,467	92,498
	2	12,314	11,672	9,966	2,644	52,383	268,691	12,696	41,877	138,442
	3	8,650	10,054	1,880	2,157	50,517	273,409	18,135	44,780	123,547
GO	1	12,689	13,162	8,960	2,148	33,426	179,332	10,829	26,934	100,419
	2	8,622	9,188	7,952	2,276	38,537	181,872	16,479	31,107	89,465
	3	9,972	107,277	8,246	16,757	33,433	166,801	17,562	28,795	106,927
GV	1	11,501	12,416	15,625	9,645	93,306	323,915	19,631	57,645	146,980
	2	8,292	8,569	12,109	3,990	34,540	175,283	12,436	255,113	106,732
	3	9,940	7,505	9,588	0	71,723	199,626	11,761	22,980	59,514

results & discussion

Wood vinegar

Type of bamboo	years	Amount of organic acids (ppm)								
		Citric acid	Tartaric acid	Malic acid	Lactic acid	Fomic acid	Acetic acid	Propionic acid	Isobutyric acid	Butyric acid
BAW	1	12,578	5,503	11,163	49,999	22,502	179,701	22,744	24,294	85,333
	2	15,174	5,391	22,074	13,034	64,603	333,912	20,187	18,167	80,042
	3	11,768	4,418	10,329	10,374	43,038	277,873	27,421	25,135	119,296
GO	1	10,893	5,423	6,173	57,974	47,754	183,961	17,374	15,873	75,023
	2	9,198	4,684	3,788	8,722	35,518	187,952	25,208	18,905	71,241
	3	10,347	12,814	6,189	38,949	14,520	166,475	18,910	8,591	103,067
GV	1	10,488	9,263	9,403	13,580	69,212	340,321	31,513	45,834	107,321
	2	8,446	8,216	4,580	31,846	16,855	198,858	21,341	17,834	78,369
	3	8,653	6,386	2,799	34,661	34,504	224,899	20,932	17,506	43,410

conclusion

1) Proximate analysis properties of bamboo charcoal and activated carbon had a higher amount of ash and volatile matters but a lower amount of fixed carbon than the commercial activated carbon.

2) From the SEM result, the surface morphology of the activated carbon prepared from BAW, GO and GV have higher number of pores when the charcoal was activated by H_3PO_4 or KOH.

3) The C=O or COO^- functional groups increased when activated by H_3PO_4 and KOH. The occurrence of COO- on the activated carbon surface had an impact on the adsorption efficiency.

4) For the adsorption of iodine, methylene blue and Cd(II) of all samples, the activated carbon which was prepared from one-year-GV activated by 20%w/v KOH for 8 hours had the highest adsorption capacity in each adsorbate species (1,202 mg/g for iodine, 15.50 mg/g for methylene blue and 0.48 mg/g for Cd(II)). In case of the adsorption of phenol, the bamboo charcoal prepared from one-year BAW provided the highest adsorption capacity (4.90 mg/g).

5) Acetic acid was found with the highest concentration in organic acid.

Thank you for your attend this final oral examination