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Lampiran 1. Bagan Kerja

1. Pembuatan Larutan Induk $\text{CuCl}_2 \cdot 2\text{H}_2\text{O}$ 1000 ppm dalam 250 mL

0,6713 g $\text{CuCl}_2 \cdot 2\text{H}_2\text{O}$

- dimasukkan ke dalam gelas kimia 50 mL lalu dilarutkan dengan akuades.
- dipindahkan ke labu ukur 250 mL.
- ditambahkan akuades hingga batas..
- dihomogenkan.

Larutan $\text{CuCl}_2 \cdot 2\text{H}_2\text{O}$ 1000 ppm

2. Pembuatan Larutan $\text{CuCl}_2 \cdot 2\text{H}_2\text{O}$ 10 ppm dari 1000 ppm

Larutan $\text{CuCl}_2 \cdot 2\text{H}_2\text{O}$ 1000 ppm

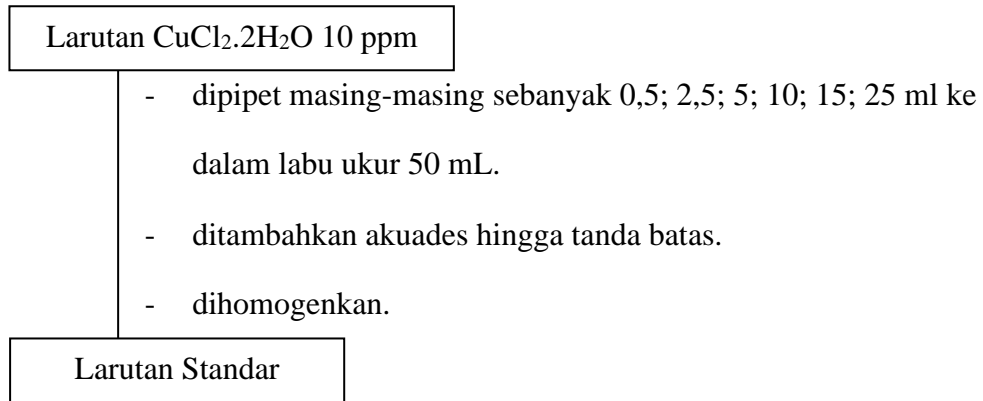
- dipipet sebanyak 10 ml.
- dimasukkan ke dalam labu ukur 100 ml.
- ditambahkan akuades hingga tanda batas..
- dihomogenkan.

Larutan $\text{CuCl}_2 \cdot 2\text{H}_2\text{O}$ 100 ppm

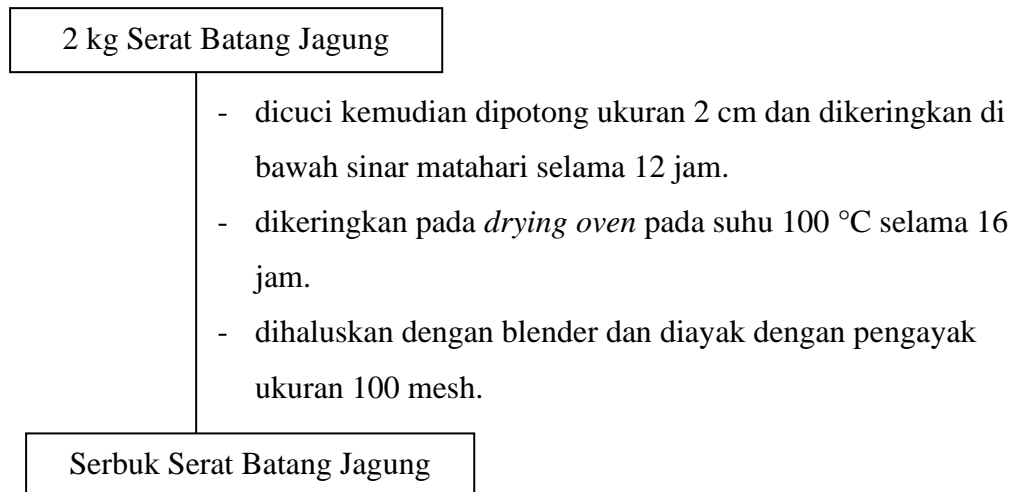
- dipipet sebanyak 10 ml.
- dimasukkan ke dalam labu ukur 100 ml.
- ditambahkan akuades hingga tanda batas..
- dihomogenkan.

Larutan $\text{CuCl}_2 \cdot 2\text{H}_2\text{O}$ 10 ppm

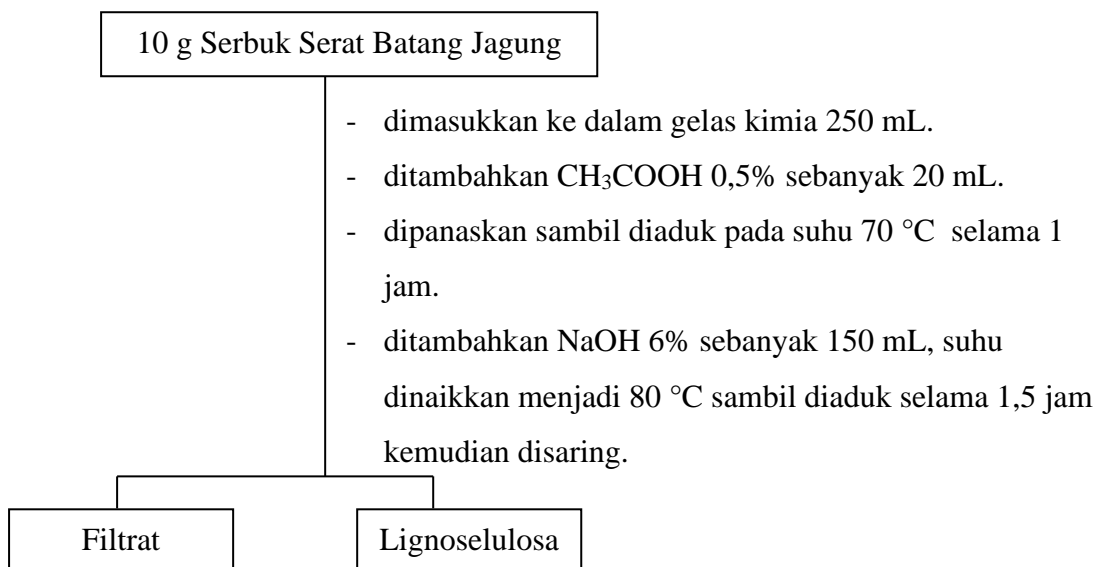
3. Pembuatan Larutan Standar 0,1; 0,5; 1; 2; 3; dan 5 ppm

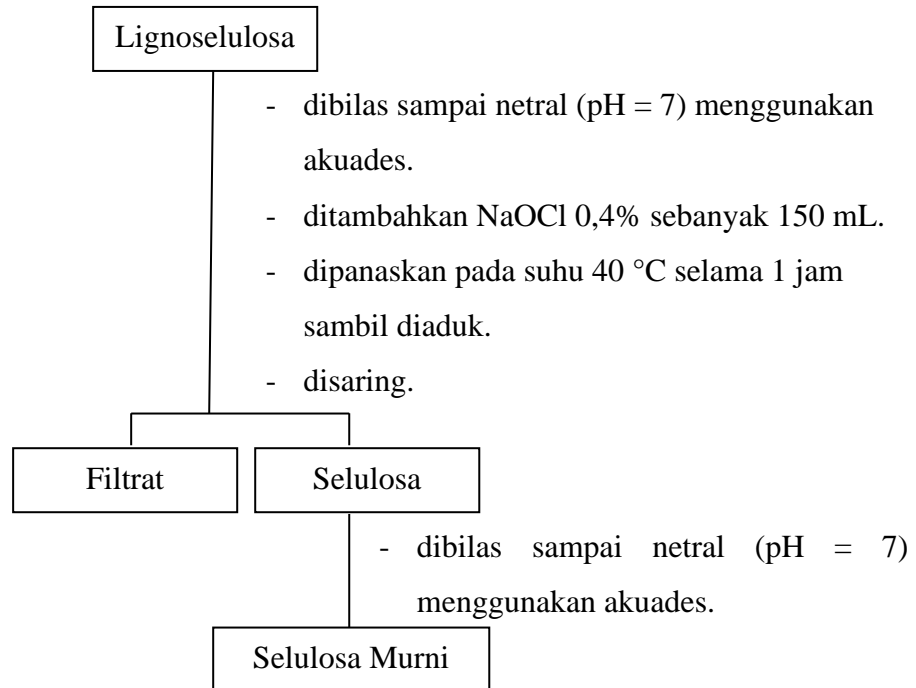


4. Preparasi Sampel Serat Batang Jagung

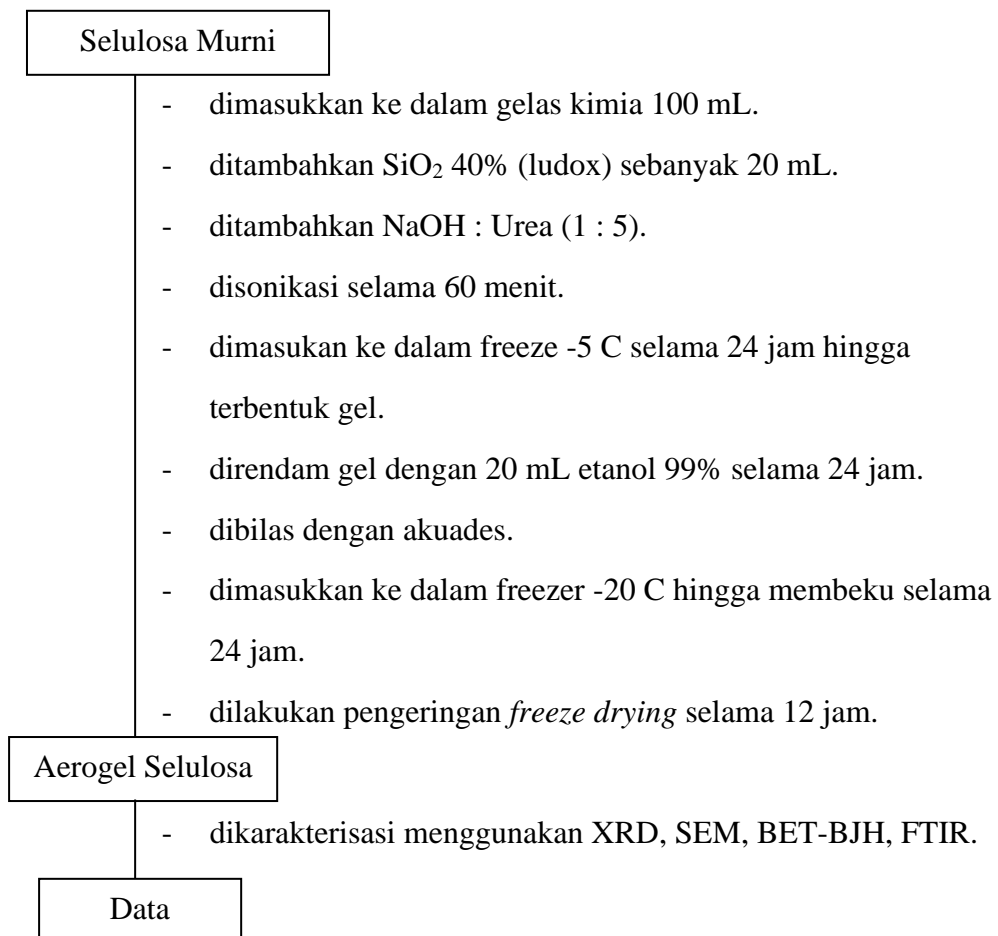


5. Ekstraksi Selulosa (Delignifikasi dan Bleaching)

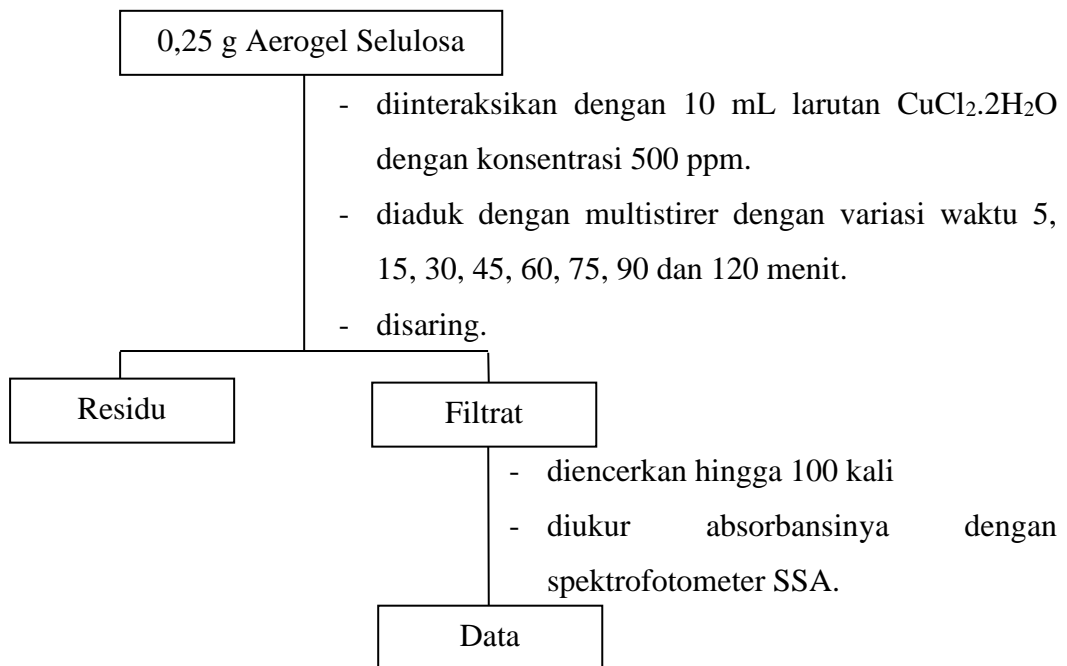




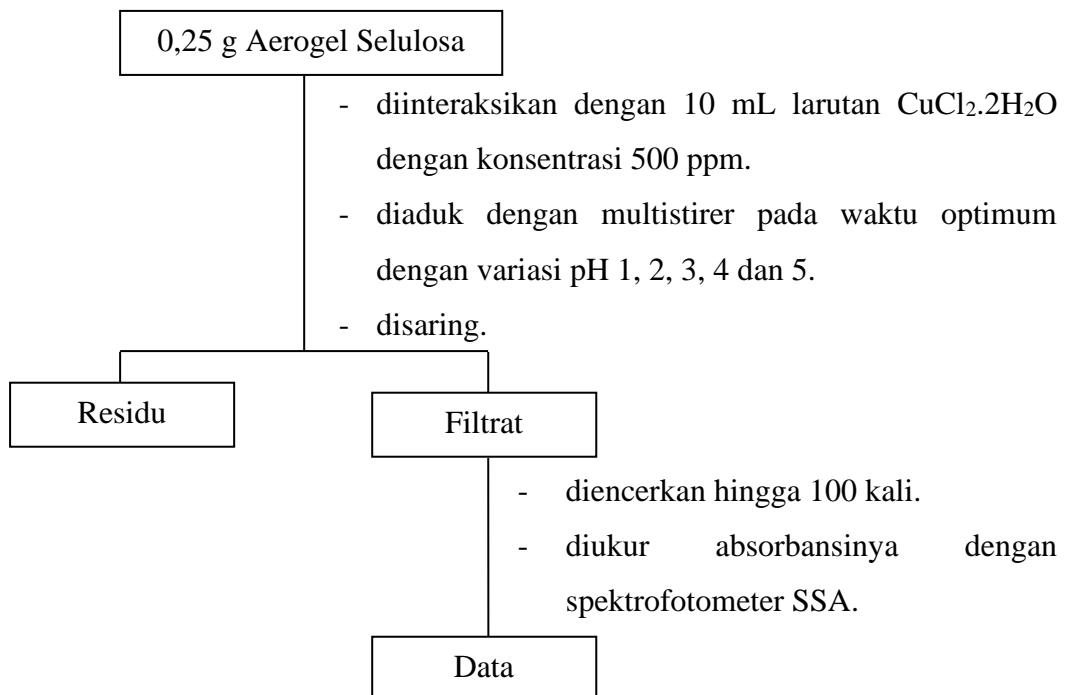
6. Sintesis Aertogel Selulosa



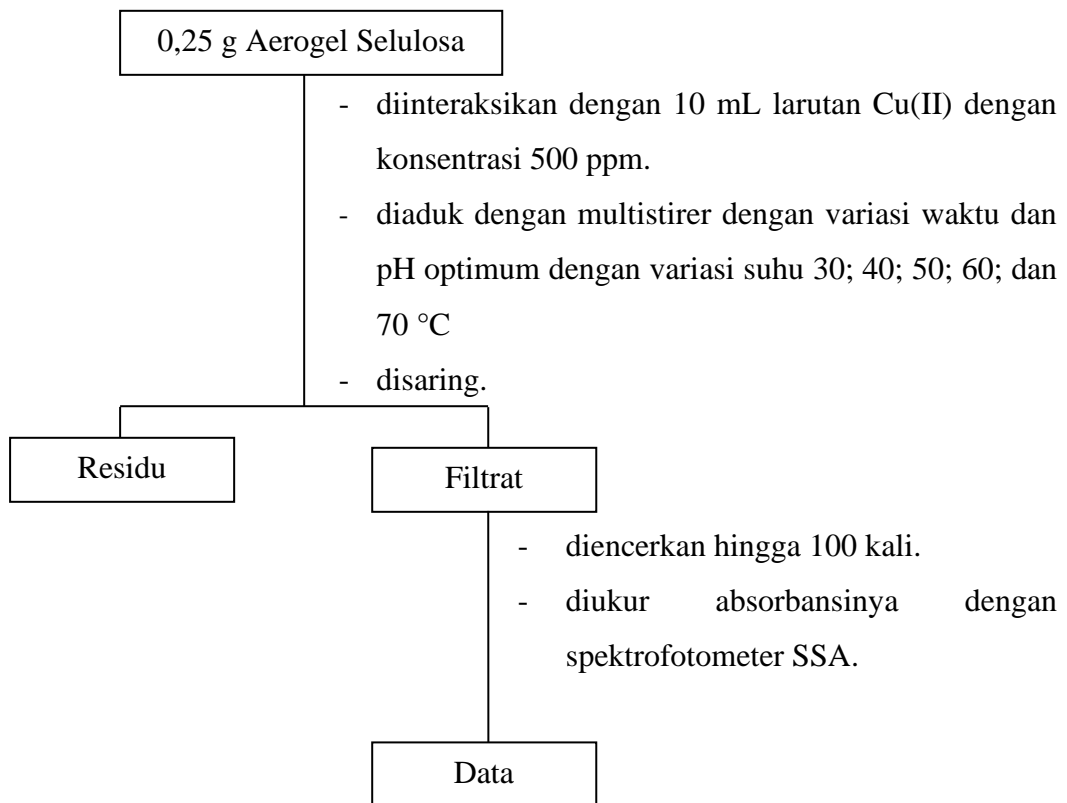
7. Proses Adsorpsi Penentuan Waktu Kontak Optimum pada Adsorbat Logam Cu(II)



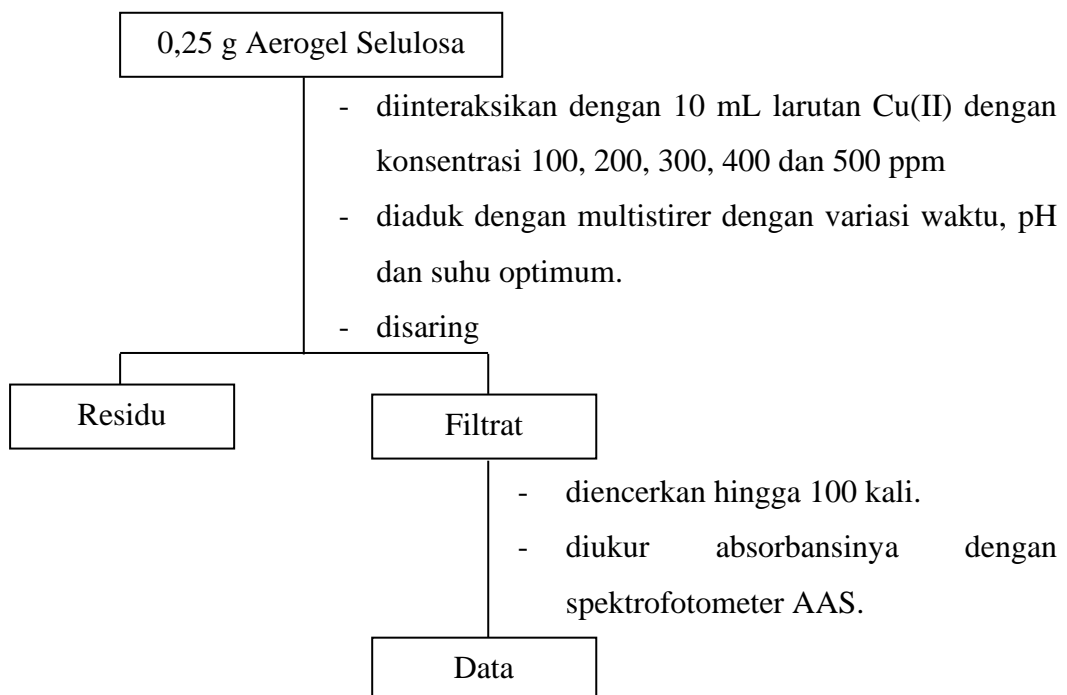
8. Proses Adsorpsi Penentuan pH Optimum pada Adsorbat Logam Cu(II)



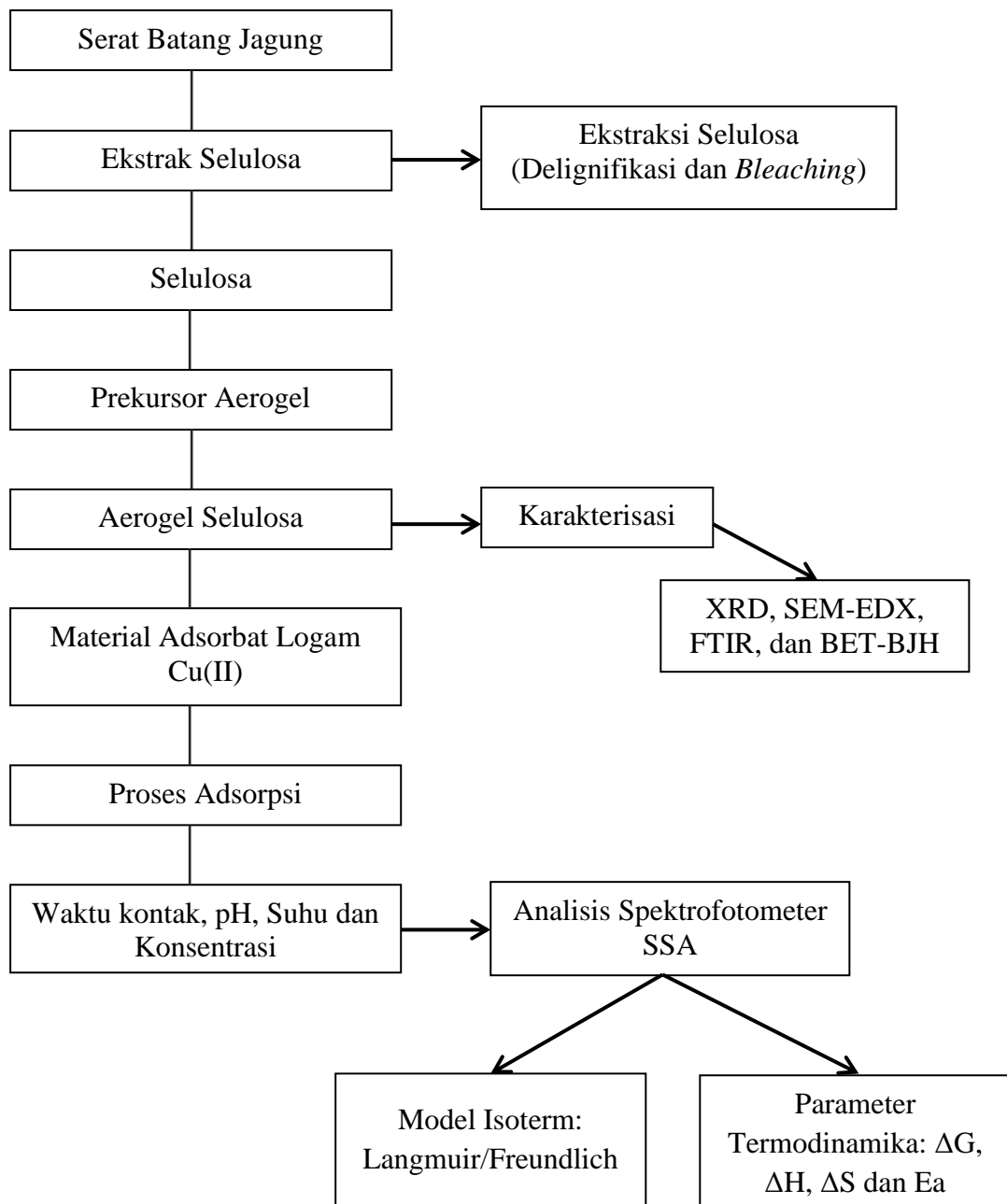
9. Proses Adsorpsi Penentuan Suhu Optimum pada Adsorbat Logam Cu(II)



10. Proses Adsorpsi Penentuan Konsentrasi Optimum pada Adsorbat Logam Cu(II)



Lampiran 2. Diagram Alir



Lampiran 3. Perhitungan Pembuatan Larutan Pereaksi

1. Pembuatan Larutan NaOH 6% dalam 500 mL

$$\%b/v = \frac{\text{gram zat terlarut}}{\text{volume larutan}} \times 100\%$$

$$6\% = \frac{x}{500 \text{ mL}} \times 100\%$$

$$x = 30 \text{ g}$$

2. Pembuatan Larutan Induk CuCl₂.2H₂O 1000 ppm dalam 250 mL

$$\text{ppm} = \frac{\text{mg}}{\text{L}} \times \frac{\text{Ar Cu}}{\text{Mr Cu}}$$

$$1000 \text{ ppm} = \frac{\text{mg}}{0,25 \text{ L}} \times \frac{63,5 \text{ g/mol}}{170,5 \text{ g/mol}}$$

$$\text{mg} = 671,3211 \text{ mg}$$

$$\text{g} = 0,6713 \text{ g}$$

3. Pembuatan Larutan Standar CuCl₂.2H₂O 0,1; 0,5; 1; 2; 3; dan 5 ppm

a. Konsentrasi 0,1 ppm

$$V_1 \times C_1 = V_2 \times C_2$$

$$V_1 \times 10 \text{ ppm} = 50 \text{ mL} \times 0,1 \text{ ppm}$$

$$V_1 = 0,5 \text{ mL}$$

b. Konsentrasi 0,5 ppm

$$V_1 \times C_1 = V_2 \times C_2$$

$$V_1 \times 10 \text{ ppm} = 50 \text{ mL} \times 0,5 \text{ ppm}$$

$$V_1 = 2,5 \text{ mL}$$

c. Konsentrasi 1 ppm

$$V_1 \times C_1 = V_2 \times C_2$$

$$V_1 \times 10 \text{ ppm} = 50 \text{ mL} \times 1 \text{ ppm}$$

$$V_1 = 5 \text{ mL}$$

d. Konsentrasi 2 ppm

$$V_1 \times C_1 = V_2 \times C_2$$

$$V_1 \times 10 \text{ ppm} = 50 \text{ mL} \times 2 \text{ ppm}$$

$$V_1 = 10 \text{ mL}$$

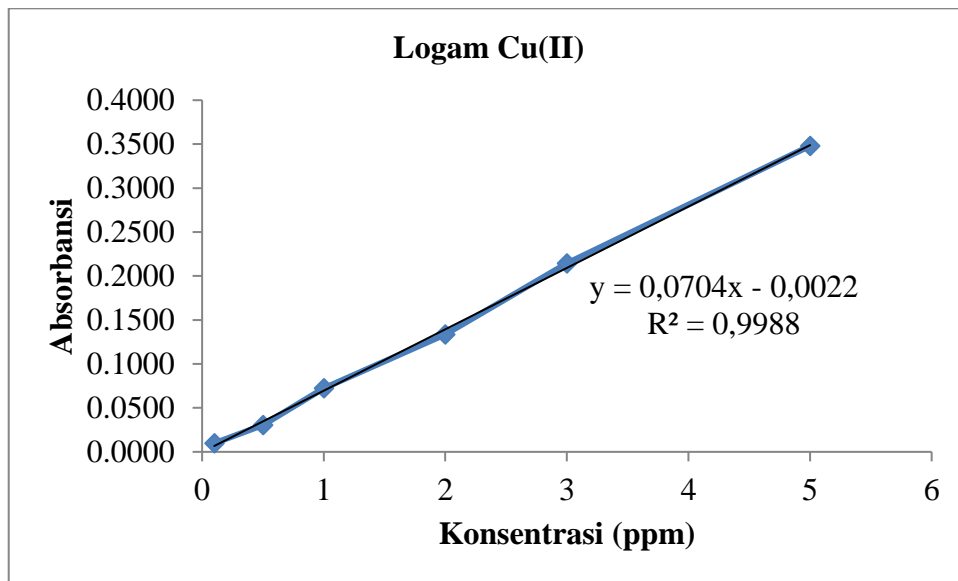
e. Konsentrasi 3 ppm

$$\begin{aligned}V_1 \times C_1 &= V_2 \times C_2 \\V_1 \times 10 \text{ ppm} &= 50 \text{ mL} \times 3 \text{ ppm} \\V_1 &= 15 \text{ mL}\end{aligned}$$

f. Konsentrasi 5 ppm

$$\begin{aligned}V_1 \times C_1 &= V_2 \times C_2 \\V_1 \times 10 \text{ ppm} &= 50 \text{ mL} \times 5 \text{ ppm} \\V_1 &= 25 \text{ mL}\end{aligned}$$

Lampiran 4. Kurva Kalibrasi Standar $\text{CuCl}_2 \cdot 2\text{H}_2\text{O}$



Lampiran 5. Data Pengaruh Variasi Waktu Kontak Interaksi Logam Cu(II) dengan Aerogel Selulosa

Berdasarkan persamaan garis pada kurva kalibrasi Cu(II), maka nilai C_{Sisa} dapat dihitung. Waktu kontak 5 menit diperoleh absorbansi 0,315 dengan factor pengenceran (FP) = 100 kali.

Diketahui:

$$C_0 = 500 \text{ ppm}$$

$$V = 10 \text{ ml} = 0,01 \text{ L}$$

$$y = 0,0704x - 0,0022$$

$$0,315 = 0,0704x - 0,0022$$

$$0,0704x = 0,315 + 0,0022$$

$$x = 4,52857$$

$$C_{\text{Sisa}} = 4,52857 \times \text{FP}$$

$$= 4,52857 \times 100$$

$$= 452,857$$

Rumus Perhitungan Kapasitas Adsorpsi

$$Q = \frac{C_0 - C_{\text{Sisa}}}{m} \times V = \frac{500 - 452,857}{0,25} \times 0,01 = 1,8857 \text{ mg/g}$$

Waktu (menit)	Absorbansi	C_{Sisa} (mg/L)	Q (mg/g)
5	0,315	452,857	1,88571
15	0,303	435,714	2,5714
30	0,289	415,714	3,3714
45	0,269	387,143	4,5143
60	0,281	404,286	3,8286
75	0,288	414,286	3,4286
90	0,291	418,571	3,2571
120	0,293	421,429	3,1429

Lampiran 6. Data Pengaruh Variasi pH Interaksi Logam Cu(II) dengan Aerogel Selulosa

Rumus Perhitungan Kapasitas Adsorpsi

$$Q = \frac{C_0 - C_{\text{sisia}}}{m} \times V$$

$$C_0 = 500 \text{ ppm}$$

$$V = 10 \text{ ml} = 0,01 \text{ L}$$

$$y = 0,0704x - 0,0022$$

$$FP = 100 \text{ kali}$$

pH	Absorbansi	Csisa (mg/L)	Q (mg/g)
1	0,220	317,143	7,3143
2	0,132	191,429	12,3429
3	0,048	71,4286	17,1429
4	0,024	37,1429	18,5143
5	0,022	34,2857	18,6286

Lampiran 7. Data Pengaruh Variasi Suhu Interaksi Logam Cu(II) dengan Aerogel Selulosa

Rumus Perhitungan Kapasitas Adsorpsi

$$Q = \frac{C_0 - C_{\text{sisa}}}{m} \times V$$

$$C_0 = 500 \text{ ppm}$$

$$V = 10 \text{ ml} = 0,01 \text{ L}$$

$$y = 0,0704x - 0,0022$$

$$FP = 100 \text{ kali}$$

Suhu (° C)	Absorbansi	Csisa (mg/L)	Q (mg/g)
30	0,194	280,0000	8,8000
40	0,191	275,7143	8,9714
50	0,19	274,2857	9,0286
60	0,207	298,5714	8,0571
70	0,231	332,8571	6,6857

Lampiran 8. Data Pengaruh Variasi Konsentrasi Interaksi Logam Cu(II) dengan Aerogel Selulosa

Rumus Perhitungan Kapasitas Adsorpsi

$$Q = \frac{C_0 - C_{\text{sisia}}}{m} \times V$$

$$C_0 = 500 \text{ ppm}$$

$$V = 10 \text{ ml} = 0,01 \text{ L}$$

$$y = 0,0704x - 0,0022$$

$$FP = 100 \text{ kali}$$

Konsentrasi (ppm)	Absorbansi	Csisia (mg/L)	Q (mg/g)
100	0,018	28,5714	2,8571
200	0,046	68,5714	5,2571
300	0,094	137,1429	6,5143
400	0,142	205,7143	7,7714
500	0,19	274,2857	9,0286

Lampiran 9. Data Kinetika Orde Satu Semu dan Orde Dua Semu Interaksi Logam Cu(II) dengan Aerogel Selulosa

Rumus kinetika orde satu semu larutan logam Cu(II)

$$\ln (q_e - q_t) = -k_1 t + \ln q_e$$

Waktu (t)	Qe	q	qe-q	ln (qe-q)	t/q
5	4,5143	1,88571	2,62859	0,96645	2,65152
15	4,5143	2,5714	1,9429	0,66418	5,8334
30	4,5143	3,3714	1,1429	0,13357	8,89838
45	4,5143	4,5143	0	0	9,96832
60	4,5143	3,8266	0,6877	-0,3744	15,6797
75	4,5143	3,4286	1,0857	0,08222	21,8748
90	4,5143	3,2571	1,2572	0,22889	27,6319
120	4,5143	3,1429	1,3714	0,31583	38,1813

Dari grafik kinetika orde satu semu larutan logam Cu(II) diperoleh persamaan garis $y = -0,0047x + 0,5087$, dimana nilai slope (a) sebesar -0,0047 dan intercept (b) sebesar 0,5087.

Nilai k_1 dapat dihitung sebagai berikut:

$$k = 0,0047$$

$$\ln q_e = \text{intercept}$$

$$\ln q_e = 0,5087 = 1,6631$$

$$R^2 = 0,1967$$

Rumus kinetika orde dua semu logam Cu(II)

$$\frac{t}{qt} = \frac{1}{kq_e^2} + \frac{1}{q_e} t$$

Dari grafik kinetika orde dua semu larutan logam Cu(II) diperoleh persamaan garis $y = 0,3062x - 0,5031$, dimana nilai slope (a) sebesar 0,3062 dan intercept (b) sebesar -0,5031.

Nilai k_2 dapat dihitung sebagai berikut:

$$\text{slope} = \frac{1}{q_e}$$

$$q_e = 3,2658$$

$$\text{intercept} = \frac{1}{k_2 q_e^2}$$

$$k_2 = 0,1863$$

$$R^2 = 0,9748$$

Lampiran 10. Data Isoterm Langmuir Adsorpsi Logam Cu(II) dengan Aerogel Selulosa

Konsentrasi (ppm)	Ce (mg/L)	Q (mg/g)	Ce/Q
100	28,5714	2,8571	10,0000
200	68,5714	5,2571	13,0435
300	137,1429	6,5143	21,0526
400	205,7143	7,7714	26,4706
500	274,2857	9,0286	30,3797

Persamaan adsorpsi isotermal Langmuir

$$\frac{C_e}{Q} = \frac{1}{Q_0 \cdot b} + \frac{1}{Q_0}$$

Berdasarkan model isotermal Langmuir larutan logam Cu(II) diperoleh persamaan garis $y = 0,086x + 7,9087$, dimana nilai slope (a) sebesar 0,086 dan intercept (b) sebesar 7,9087.

$$\frac{1}{Q_0} = \text{kemiringan (slope)}$$

$$Q_0 = 11,6279 \text{ mg/g}$$

$$\frac{1}{Q_0 \cdot b} = \text{intercept}$$

$$b = 0,0109 \text{ L/mg}$$

$$R^2 = 0,9848$$

Lampiran 11. Data Isoterm Freundlich Adsorpsi Logam Cu(II) dengan Aerogel Selulosa

Konsentrasi (ppm)	Ce (mg/L)	Q (mg/g)	Log Ce	Log Q
100	28,5714	2,8571	1,4559	0,4559
200	68,5714	5,2571	1,8361	0,7207
300	137,1429	6,5143	2,1372	0,8139
400	205,7143	7,7714	2,3133	0,8905
500	274,2857	9,0286	2,4382	0,9556

Persamaan adsorpsi isotermal Freundlich

$$\log \frac{X_m}{m} = \log k + \frac{1}{n} \log C$$

Berdasarkan model isotermal Freundlich larutan logam Cu(II) diperoleh persamaan garis $y = 0,487x - 0,2243$, dimana nilai slope (a) sebesar 0,487 dan intercept (b) sebesar -0,2243.

$$\frac{1}{n} = \text{kemiringan (slope)}$$

$$n = 2,0534 \text{ g/L}$$

$$\log k = \text{intercept}$$

$$k = 0,5966 \text{ mg/g}$$

$$R^2 = 0,9762$$

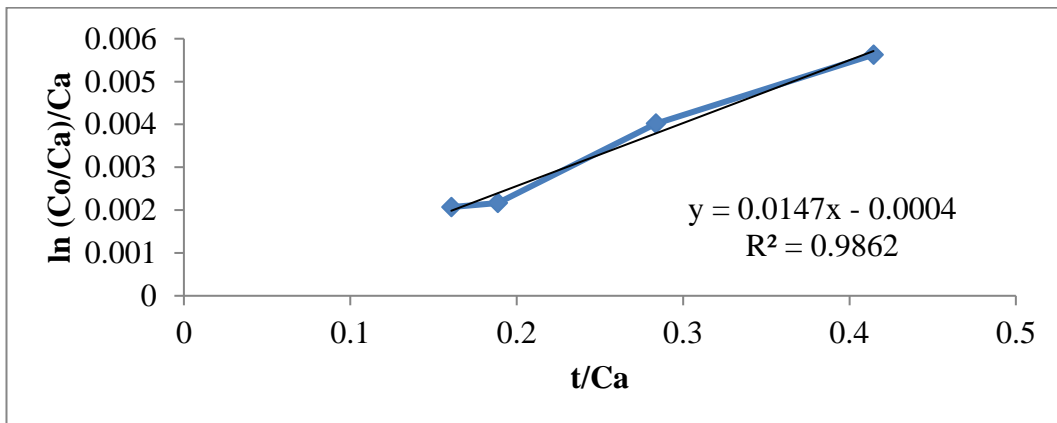
Lampiran 12. Data dan Grafik Isotermal Langmuir-Hinshelwood dan Termodinamika Adsorpsi Logam Cu(II) dengan Aerogel Selulosa

Persamaan Langmuir-Hinshelwood:

$$\frac{\ln \frac{C_0}{C_a}}{C_a} = k_1 \frac{t}{C_a} + K$$

Suhu 30 ° C, t = 45 menit

Co (ppm)	Ca (ppm)	Co/Ca	t/Ca	Ln (Co/Ca)/Ca
200	108,5714	1,8421	0,4145	0,0056
300	158,5714	1,8919	0,2838	0,0040
400	238,5714	1,6766	0,1886	0,0022
500	280,0000	1,7857	0,1607	0,0021



Berdasarkan model Langmuir-Hinselwood diperoleh persamaan garis ,dari persamaan garis diperoleh nilai slope (a) = 0,0147 dan intercept (b) = -0,0004

Nilai k_1 = slope = 0,0147

Nilai K = -intercept = 0,0004

$$\Delta G = -R T \ln K$$

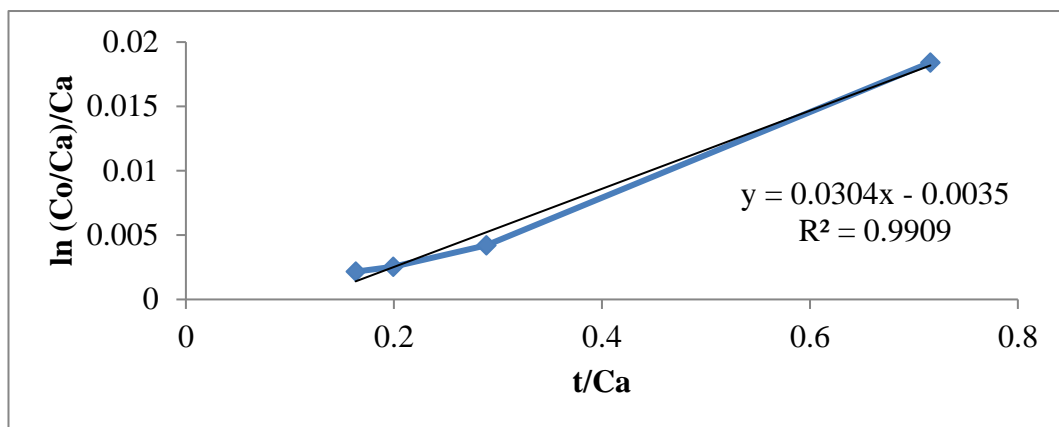
$$= -8,314 \times 303 \times \ln (0,0004)$$

$$= -19.709,9 \text{ J/mol}$$

$$= -19,7099 \text{ kJ/mol}$$

Suhu 40 ° C, t = 45 menit

Co (ppm)	Ca (ppm)	Co/Ca	t/Ca	Ln (Co/Ca)/Ca
200	62,8571	3,1818	0,7159	0,0184
300	155,7143	1,9266	0,2890	0,0042
400	225,7143	1,7722	0,1994	0,0025
500	275,7143	1,8135	0,1632	0,0022



Berdasarkan model Langmuir-Hinselwood diperoleh persamaan garis ,dari persamaan garis diperoleh nilai slope (a) = 0,0304 dan intercept (b) = -0,0035

Nilai k_1 = slope = 0,0304

Nilai K = -intercept = 0,0035

$$\Delta G = -R T \ln K$$

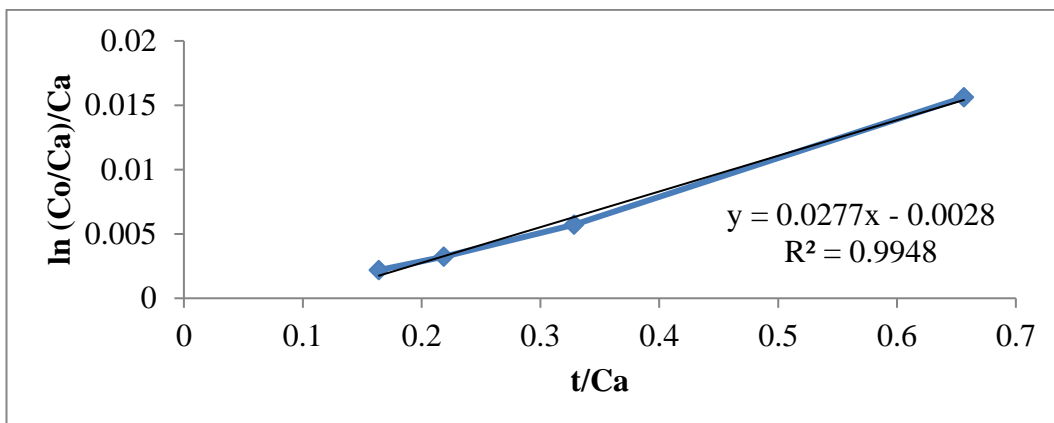
$$= -8,314 \times 313 \times \ln (0,0035)$$

$$= -14.715,9 \text{ J/mol}$$

$$= -14,7159 \text{ kJ/mol}$$

Suhu 50 ° C, t = 45 menit

Co (ppm)	Ca (ppm)	Co/Ca	t/Ca	Ln (Co/Ca)/Ca
200	68,5714	2,9167	0,6563	0,0156
300	137,1429	2,1875	0,3281	0,0057
400	205,7143	1,9444	0,2188	0,0032
500	274,2857	1,8229	0,1641	0,0022



Berdasarkan model Langmuir-Hinselwood diperoleh persamaan garis ,dari persamaan garis diperoleh nilai slope (a) = 0,0277 dan intercept (b) = -0,0028

Nilai $k_1 = \text{slope} = 0,0277$

Nilai $K = -\text{intercept} = 0,0028$

$$\Delta G = -R T \ln K$$

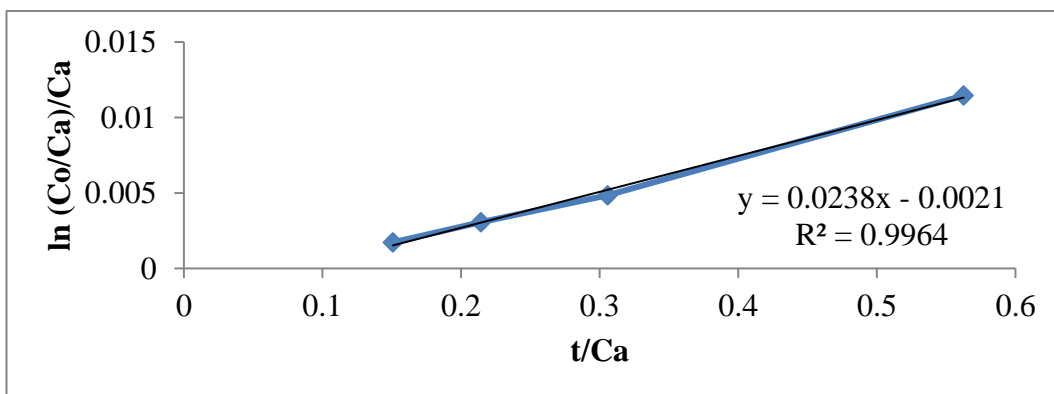
$$= -8,314 \times 323 \times \ln (0,0028)$$

$$= -15.785,3 \text{ J/mol}$$

$$= -15,7853 \text{ kJ/mol}$$

Suhu 60° C , $t = 45$ menit

Co (ppm)	Ca (ppm)	Co/Ca	t/Ca	Ln (Co/Ca)/Ca
200	80,0000	2,5000	0,5625	0,0115
300	147,1429	2,0388	0,3058	0,0048
400	210,0000	1,9048	0,2143	0,0031
500	298,5714	1,6746	0,1507	0,0017



Berdasarkan model Langmuir-Hinselwood diperoleh persamaan garis ,dari persamaan garis diperoleh nilai slope (a) = 0,0238 dan intercept (b) = -0,0021

Nilai $k_1 = \text{slope} = 0,0238$

Nilai $K = -\text{intercept} = 0,0021$

$$\Delta G = -R T \ln K$$

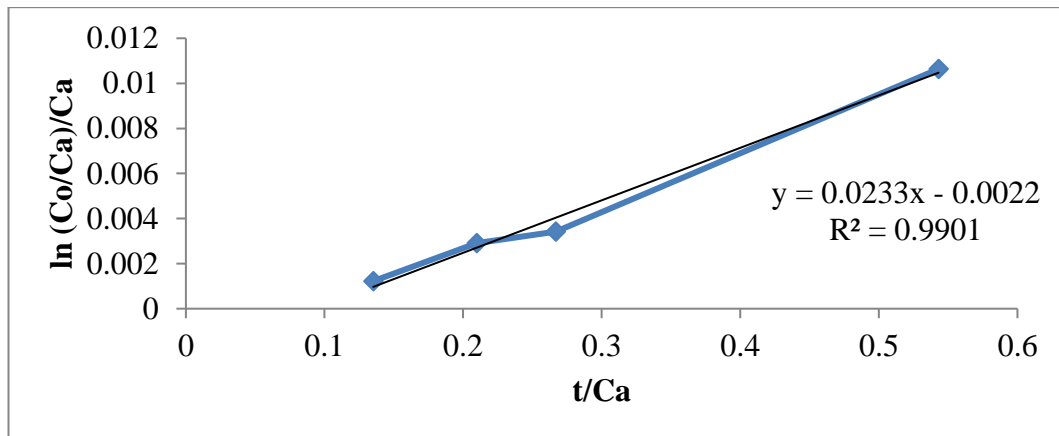
$$= -8,314 \times 333 \times \ln (0,0021)$$

$$= -17.070,4 \text{ J/mol}$$

$$= -17,0704 \text{ kJ/mol}$$

Suhu 70° C , $t = 45$ menit

Co (ppm)	Ca (ppm)	Co/Ca	t/Ca	Ln (Co/Ca)/Ca
200	82,8571	2,4138	0,5431	0,0106
300	168,5714	1,7797	0,2669	0,0034
400	214,2857	1,8667	0,2100	0,0029
500	332,8571	1,5021	0,1352	0,0012



Berdasarkan model Langmuir-Hinselwood diperoleh persamaan garis ,dari persamaan garis diperoleh nilai slope (a) = 0,0233 dan intercept (b) = -0,0022

Nilai $k_1 = \text{slope} = 0,0233$

Nilai $K = -\text{intercept} = 0,0022$

$$\Delta G = -R T \ln K$$

$$= -8,314 \times 343 \times \ln (0,0022)$$

$$= -17.450,4 \text{ J/mol}$$

$$= -17,4504 \text{ kJ/mol}$$

Nilai Energi Bebas Gibbs (ΔG)

Suhu	R (J/mol K)	T (K)	K	Ln K	ΔG (kJ/mol)
30	8,314	303	-0,0004	7,8240	-19,7099
40	8,314	313	-0,0035	5,6550	-14,7159
50	8,314	323	-0,0028	5,8781	-15,7853
60	8,314	333	-0,0021	6,1658	-17,0704
70	8,314	343	-0,0022	6,1193	-17,4504

Nilai Perubahan Entalpi (ΔH)

$$\ln K = - \frac{\Delta H}{R} \frac{1}{T} + C$$

Suhu	T (K)	1/T	K	Ln k
30	303	0,00330	0,0147	-4,2199
40	313	0,00319	0,0304	-3,4933
50	323	0,00310	0,0277	-3,5863
60	333	0,00300	0,0238	-3,7381
70	343	0,00292	0,0233	-3,7593

Dari membuat grafik $\ln K$ terhadap $1/T$ diperoleh persamaan garis $y =$

$$3152,2x - 3,4495$$

$$\frac{\Delta H}{R} = - \text{slope}$$

$$\Delta H = -26.207,4 \text{ J/mol}$$

$$= -26,2074 \text{ kJ/mol}$$

Nilai Perubahan Entropi (ΔS)

$$\Delta G = \Delta H - T\Delta S$$

Suhu	T (K)	ΔG (kJ/mol)	ΔH (kJ/mol)	ΔS (kJ/mol)
30	303	-19,7099	-26,2074	-0,0214
40	313	-14,7159	-26,2074	-0,0367
50	323	-15,7853	-26,2074	-0,0323
60	333	-17,0704	-26,2074	-0,0274
70	343	-17,4504	-26,2074	-0,0255

Energi Aktivasi

$$\ln K = -\frac{E_a}{R} \frac{1}{T} + \ln A$$

Suhu	K	Ln k	T (K)	1/T
30	0,0147	-4,2199	303	0,00330
40	0,0304	-3,4933	313	0,00319
50	0,0277	-3,5863	323	0,00310
60	0,0238	-3,7381	333	0,00300
70	0,0233	-3,7593	343	0,00292

Dari membuat grafik $\ln K$ terhadap $1/T$, maka diperoleh persamaan garis y

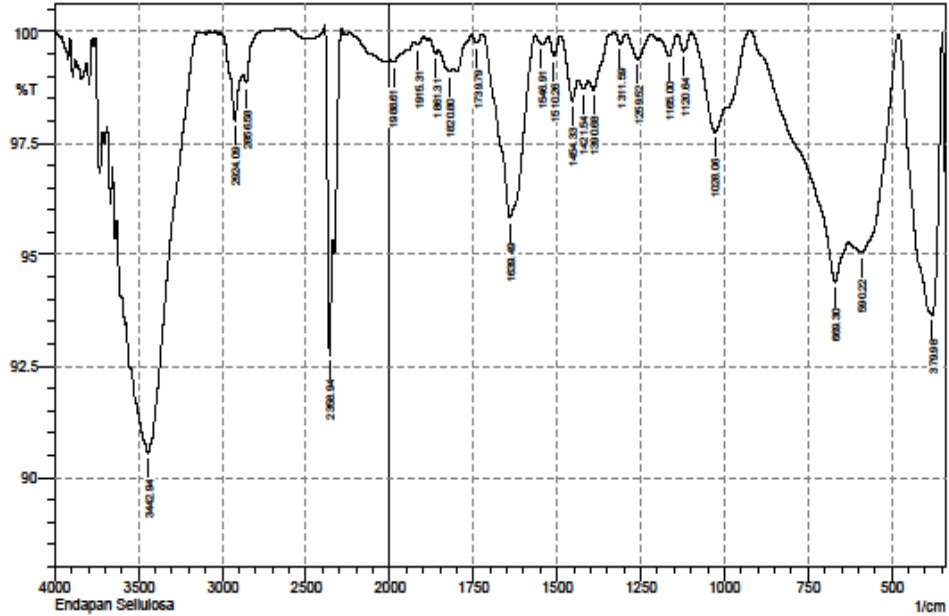
$$= -753,66x - 1,4216$$

$$-\frac{E_a}{R} = \text{slope}$$

$$E_a = 6.265,9 \text{ J/mol}$$

$$= 6,2659 \text{ kJ/mol}$$

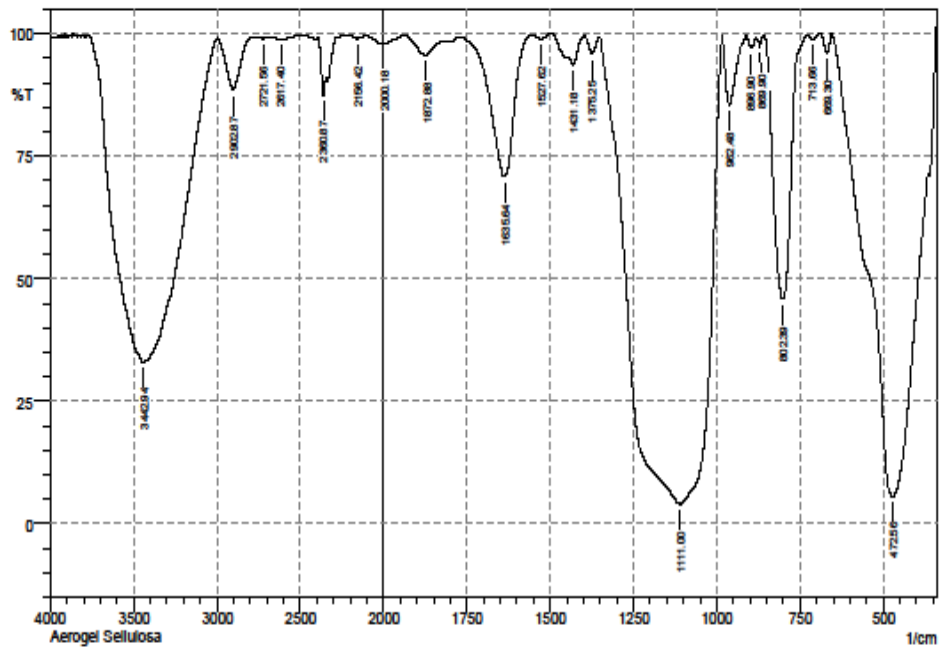
Lampiran 13. Analisis Hasil FTIR



No.	Peak	Intensity	Corr. Intensity	Base (H)	Base (L)	Area	Corr. Area
1	379.98	93.656	6.262	478.35	351.04	2.328	2.285
2	590.22	95.051	1.434	628.79	480.28	2.351	0.792
3	669.3	94.392	1.506	921.97	630.72	3.596	0.53
4	1028.06	97.75	2.248	1097.5	923.9	0.894	0.896
5	1120.64	99.567	0.389	1141.86	1097.5	0.045	0.037
6	1165	99.449	0.439	1192.01	1141.86	0.073	0.048
7	1259.52	99.376	0.572	1294.24	1219.01	0.109	0.091
8	1311.59	99.727	0.238	1328.95	1294.24	0.022	0.017
9	1390.68	98.689	0.457	1406.11	1342.46	0.221	0.058
10	1421.54	98.708	0.196	1436.97	1406.11	0.161	0.013
11	1454.33	98.439	0.787	1490.97	1436.97	0.217	0.075
12	1510.26	99.444	0.444	1525.69	1490.97	0.051	0.034
13	1546.91	99.711	0.046	1566.2	1543.05	0.021	0.002
14	1639.49	95.831	4.097	1722.43	1566.2	1.478	1.43
15	1739.79	99.74	0.199	1755.22	1722.43	0.023	0.014
16	1820.8	99.094	0.179	1853.59	1809.23	0.143	0.022
17	1861.31	99.507	0.15	1880.6	1853.59	0.043	0.009
18	1915.31	99.707	0.107	1926.89	1899.88	0.028	0.007
19	1988.61	99.313	0.119	2002.11	1950.03	0.128	0.012
20	2358.94	92.749	4.576	2385.95	2339.65	0.883	0.414
21	2856.58	98.835	0.349	2875.86	2746.63	0.207	-0.057
22	2924.09	98.009	1.36	3010.88	2875.86	0.561	0.267
23	3442.94	90.536	3.885	3549.02	3138.18	10.102	3.21

Comment;
Endapan Selulosa

Date/Time; 8/24/2020 12:00:31 PM
No. of Scans;
Resolution;
Apodization;



No.	Peak	Intensity	Corr. Intensity	Base (H)	Base (L)	Area	Corr. Area
1	472.56	5.559	76.291	653.87	366.48	127.75	106.445
2	669.3	96.1	3.937	690.52	653.87	0.299	0.303
3	713.66	98.846	0.866	729.09	690.52	0.113	0.072
4	802.39	45.853	53.855	858.32	729.09	17.746	17.57
5	869.9	97.187	2.268	881.47	858.32	0.139	0.084
6	896.9	97.003	2.372	910.4	881.47	0.237	0.156
7	962.48	85.367	14.254	983.7	910.4	2.408	2.289
8	1111	3.996	94.701	1350.17	985.62	262.665	260.842
9	1375.25	95.82	3.691	1398.39	1352.1	0.458	0.36
10	1431.18	93.703	2.675	1442.75	1398.39	0.742	0.234
11	1527.62	98.754	0.682	1544.98	1517.98	0.105	0.042
12	1635.64	70.828	28.691	1766.8	1562.34	11.31	10.83
13	1872.88	95.702	3.369	1934.6	1815.02	1.329	0.853
14	2000.18	97.983	0.05	2002.11	1934.6	0.359	0.001
15	2156.42	98.944	0.689	2222	2106.27	0.34	0.152
16	2360.87	87.392	6.486	2393.66	2343.51	1.698	0.584
17	2617.4	98.783	0.164	2684.91	2596.19	0.388	0.017
18	2721.56	99.026	0.255	2760.14	2684.91	0.278	0.043
19	2902.87	88.465	10.667	2997.38	2787.14	5.192	4.403
20	3442.94	32.976	3.163	3718.76	3429.43	86.032	13.011

Comment;
Aerogel Selulosa

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No. of Scans;
Resolution;
Apodization;

Lampiran 14. Analisis Hasil XRD

1. Selulosa

```

*** Basic Data Process ***

Group      : Standard
Data       : selulosa

# Strongest 3 peaks
no. peak  2Theta      d      I/I1  FWHM      Intensity  Integrated Int
          (deg)      (Å)      (deg)  (Counts)  (Counts)
  1  43  44.0683  2.05326  100  0.57090  194  5253
  2  15  22.5600  3.93806   87  0.00000  169   0
  3  14  22.0600  4.02618   85  0.00000  164   0

# Peak Data List
peak      2Theta      d      I/I1  FWHM      Intensity  Integrated Int
no.      (deg)      (Å)      (deg)  (deg)  (Counts)  (Counts)
  1      12.7300  6.94829   6  0.30000   11      347
  2      13.1600  6.72220   4  0.00000    8         0
  3      14.0000  6.32070   7  0.48000   14      572
  4      14.4600  6.12065   3  0.00000    6         0
  5      14.9200  5.93296   4  0.00000    8         0
  6      15.2200  5.81668   6  0.32000   11      252
  7      16.7250  5.29651   6  0.45000   11      356
  8      18.0400  4.91328   9  0.60000   18      891
  9      18.5000  4.79213  18  0.00000   34         0
 10      19.1200  4.63812  30  0.00000   59         0
 11      19.5400  4.53936  42  0.00000   81         0
 12      20.4000  4.34989  63  0.00000  122         0
 13      21.2600  4.17584  76  0.00000  148         0
 14      22.0600  4.02618  85  0.00000  164         0
 15      22.5600  3.93806  87  0.00000  169         0
 16      23.3400  3.80819  76  0.00000  147         0
 17      24.5000  3.63045  47  0.00000   91         0
 18      25.3000  3.51744  37  0.00000   71         0
 19      25.6400  3.47156  32  0.00000   62         0
 20      25.9000  3.43729  30  0.00000   58         0
 21      26.6000  3.34841  26  1.32000   50      3329
 22      27.5000  3.24083  16  0.00000   31         0
 23      27.9400  3.19079  13  0.00000   25         0
 24      28.3600  3.14448  13  0.00000   26         0
 25      28.7000  3.10800   8  0.88000   15      629
 26      29.2833  3.04740   9  0.27330   17      282
 27      29.8000  2.99573   8  0.16000   15      306
 28      30.1000  2.96655   6  0.00000   11         0
 29      30.6000  2.91921   5  0.24000   10      294
 30      30.7600  2.90439   4  0.00000    8         0
 31      30.9000  2.89155   5  0.16000    9      109
 32      31.1933  2.86502   4  0.14670    7      119
 33      34.0316  2.63229  13  0.52330   26      755
 34      35.0300  2.55951   7  0.34000   14      289
 35      35.9300  2.49744   4  0.54000    8      263
 36      37.1400  2.41881   3  0.20000    6         58
 37      37.8263  2.37648  40  0.57930   78     2167
 38      39.5183  2.27854  24  0.57670   46     1321
 39      40.9200  2.20367   5  0.16000    9      174
 40      41.6500  2.16672   5  0.22000   10      236
 41      42.5200  2.12438   7  0.36000   13      461
 42      43.3700  2.08469   4  0.18000    8      110
 43      44.0683  2.05326 100  0.57090  194     5253
 44      44.9741  2.01399  10  0.40170   20      488
 45      45.4800  1.99276   6  0.00000   11         0
 46      45.6600  1.98532   4  0.00000    8         0
 47      46.1900  1.96376   5  0.54000   10      410
 48      47.2700  1.92138   4  0.42000    8      363

```

*** Basic Data Process ***

```
# Data Information
  Group           : Standard
  Data            : selulosa
  Sample Name    : serbuk
  Comment        :
  Date & Time    : 09-11-20 11:36:21

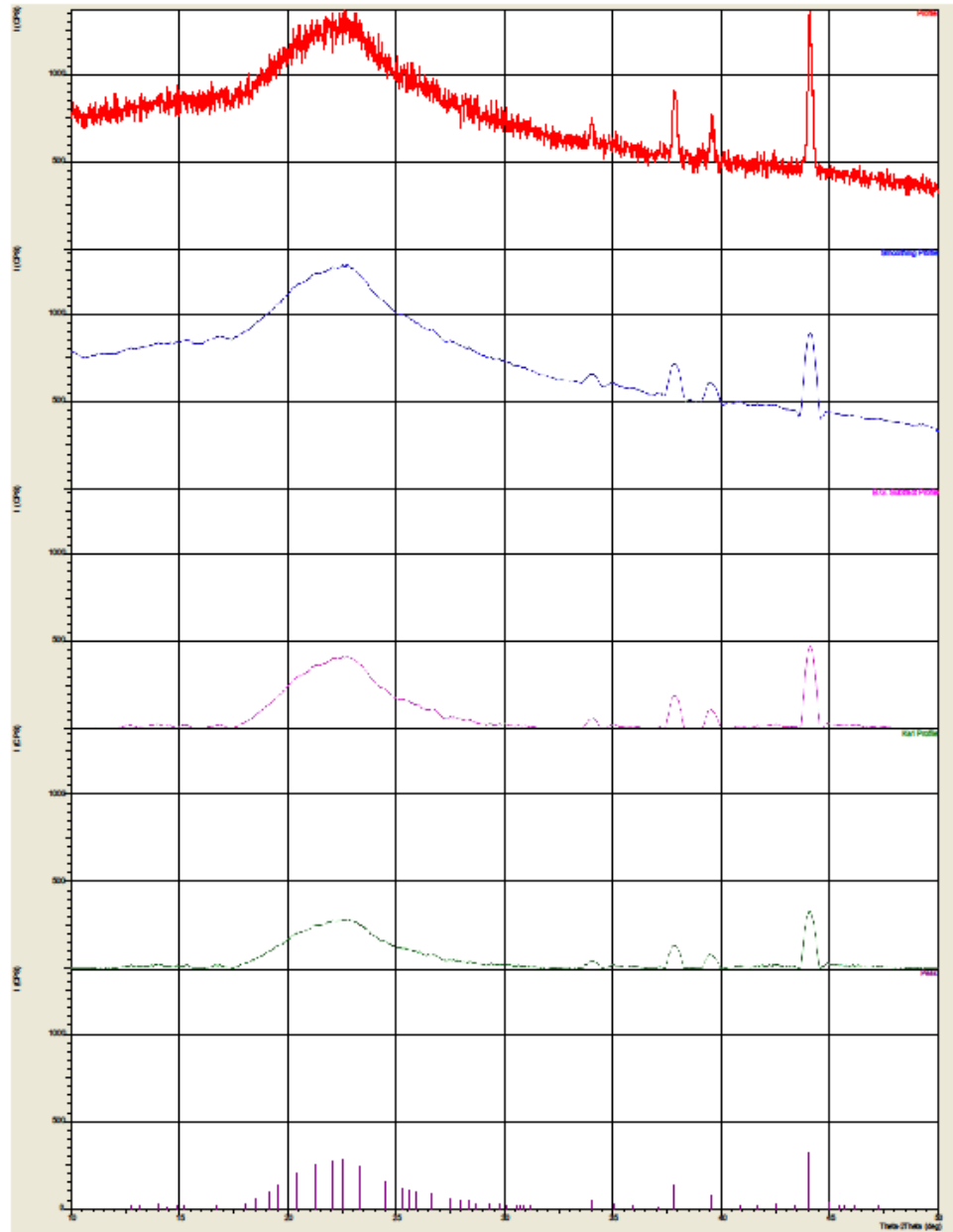
# Measurement Condition
  X-ray tube
    target        : Cu
    voltage       : 40.0 (kV)
    current       : 30.0 (mA)

  Slits
    Auto Slit     : Used
    divergence slit : 1.00000 (deg)
    scatter slit  : 1.00000 (deg)
    receiving slit : 0.30000 (mm)

  Scanning
    drive axis    : Theta-2Theta
    scan range    : 10.0000 - 50.0000 (deg)
    scan mode     : Continuous Scan
    scan speed    : 2.0000 (deg/min)
    sampling pitch : 0.0200 (deg)
    preset time   : 0.60 (sec)

# Data Process Condition
  Smoothing [ AUTO ]
    smoothing points : 51
  B.G.Subtraction [ AUTO ]
    sampling points : 51
    repeat times : 30
  Kal-a2 Separate [ MANUAL ]
    Kal a2 ratio : 50 (%)
  Peak Search [ AUTO ]
    differential points : 29
    FWHM threshold : 0.050 (deg)
    intensity threshold : 30 (par mil)
    FWHM ratio (n-1)/n : 2
  System error Correction [ NO ]
  Precise peak Correction [ NO ]
```

< Group: Standard Data: selulosa >



2. Aerogel Selulosa

```

*** Basic Data Process ***

Group      : Standard
Data       : aerogel selulosa

# Strongest 3 peaks
no. peak  2Theta          d          I/I1    FWHM      Intensity  Integrated Int
          (deg)          (A)          (deg)    (Counts)  (Counts)
1         10         22.5600    3.93806   100    2.22400    631    59865
2         9          20.7800    4.27120    84    2.60880    528    53568
3         8          19.3000    4.59526    36    0.00000    227     0

# Peak Data List
peak      2Theta          d          I/I1    FWHM      Intensity  Integrated Int
no.       (deg)          (A)          (deg)    (deg)    (Counts)  (Counts)
1         10.6000    8.33923    4      0.34660    24        539
2         11.6800    7.57045   11     1.28000    72       8637
3         13.0200    6.79417   20     0.00000   125        0
4         14.8800    5.94882   32     0.00000   205        0
5         15.6000    5.67584   32     0.00000   204        0
6         16.5600    5.34891   27     0.00000   169        0
7         18.4200    4.81277   23     0.00000   144        0
8         19.3000    4.59526   36     0.00000   227        0
9         20.7800    4.27120   84     2.60880   528       53568
10        22.5600    3.93806  100     2.22400   631       59865
11        25.0400    3.55337    6     0.76000    39       2536
12        31.3350    2.85239    5     0.81000    30       1389
13        34.8791    2.57024   20     1.70830   125      11462
14        36.5800    2.45454    7     0.00000    43        0
15        37.7891    2.37874    8     0.76830    52       3464
16        39.5550    2.27651    8     0.71000    48       1870
17        41.2200    2.18832    6     1.56000    36       2501
18        41.9000    2.15437    6     0.00000    38        0
19        43.1800    2.09342    5     0.52000    29       2250
20        44.0643    2.05344   15     0.57530    92       2584
21        45.6000    1.98779    4     1.10000    27       1155
22        46.3000    1.95935    3     1.12000    19       1475

*** Basic Data Process ***

# Data Infomation
Group      : Standard
Data       : aerogel selulosa
Sample Nmae : serbuk
Comment    :
Date & Time : 09-11-20 10:47:31

# Measurement Condition
X-ray tube
target     : Cu
voltage    : 40.0 (kV)
current    : 30.0 (mA)

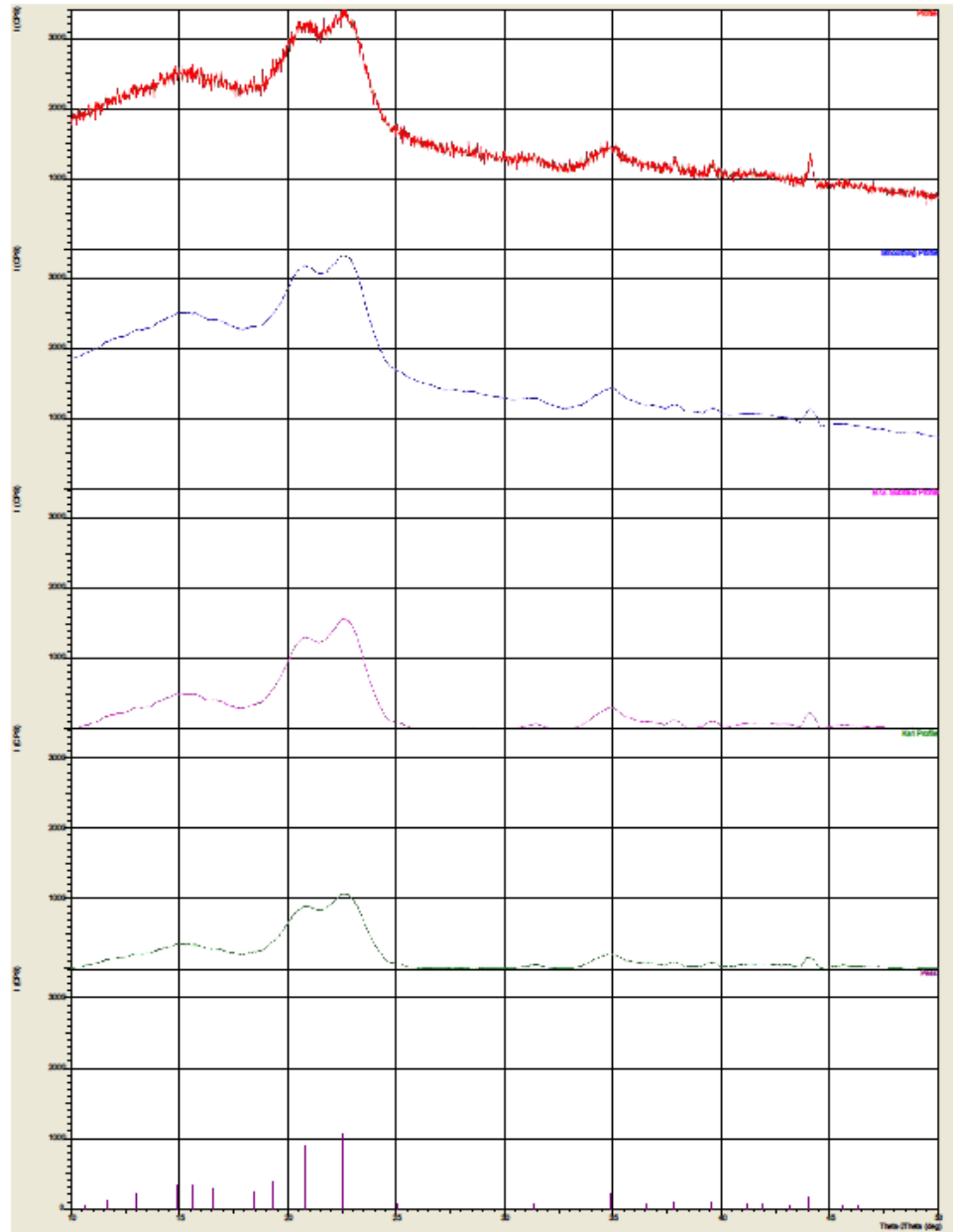
Slits
Auto Slit  : Used
divergence slit : 1.00000 (deg)
scatter slit : 1.00000 (deg)
receiving slit : 0.30000 (mm)

Scanning
drive axis : Theta-2Theta
scan range : 10.0000 - 50.0000 (deg)
scan mode  : Continuous Scan
scan speed : 2.0000 (deg/min)
sampling pitch : 0.0200 (deg)
preset time : 0.60 (sec)

# Data Process Condition
Smoothing [ AUTO ]
smoothing points : 51
B.G.Subtruction [ AUTO ]
sampling points : 51
repeat times : 30
Kal-a2 Separate [ MANUAL ]
Kal a2 ratio : 50 (%)
Peak Search [ AUTO ]
differential points : 51
FWHM threshold : 0.050 (deg)
intensity threshold : 30 (par mil)
FWHM ratio (n-1)/n : 2
System error Correction [ NO ]
Precise peak Correction [ NO ]

```

< Group: Standard Data: aerogel selulosa >

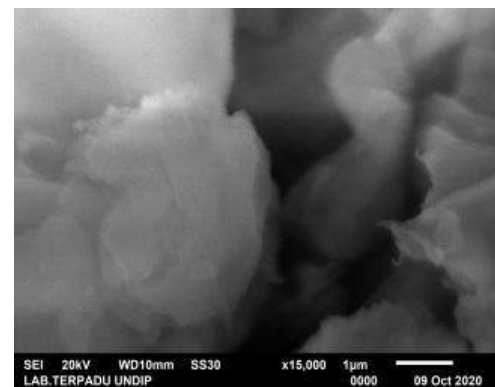
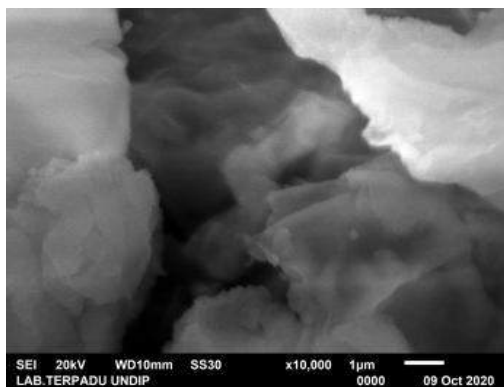
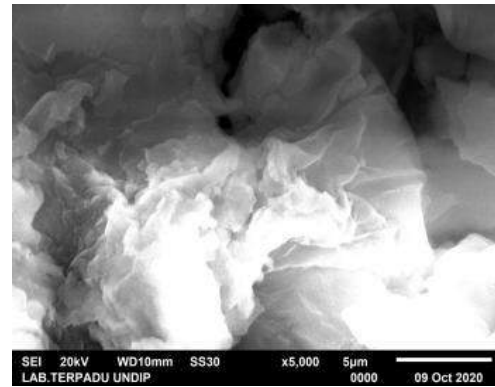
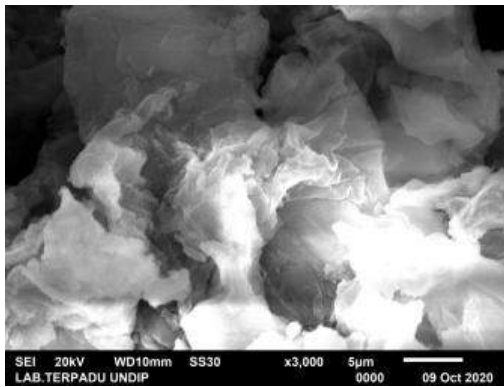


Lampiran 15. Analisis Hasil SEM



KEMENTERIAN RISET TEKNOLOGI DAN PENDIDIKAN TINGGI
UNIVERSITAS DIPONEGORO
UPT LABORATORIUM TERPADU
Jalan Prof. Soedarto, SH Tembalang Semarang Kotak Pos 1269
Telepon (024) 76918147- Faksimile (024) 76918148, Website : <http://labterpadu.undip.ac.id>;
E-mail : labterpadu@live.undip.ac.id

Hasil Uji Citra SEM sbb: Aerogel Selulosa sebelum adsorpsi



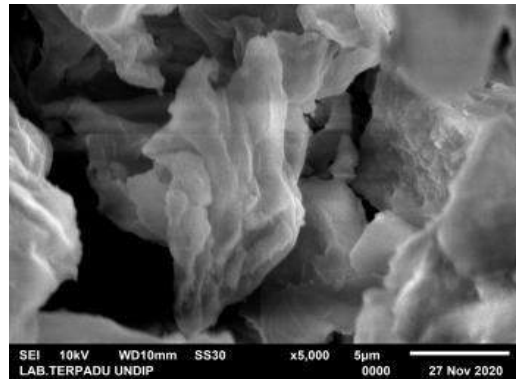
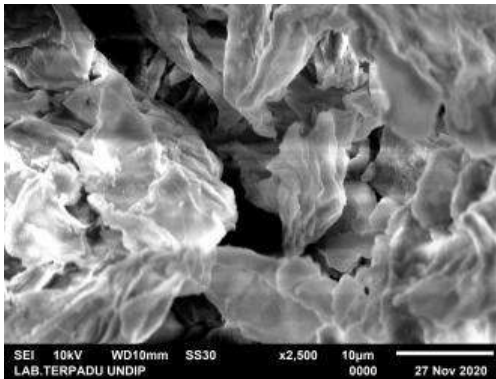
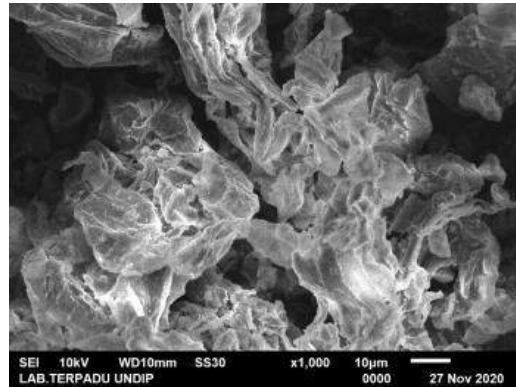
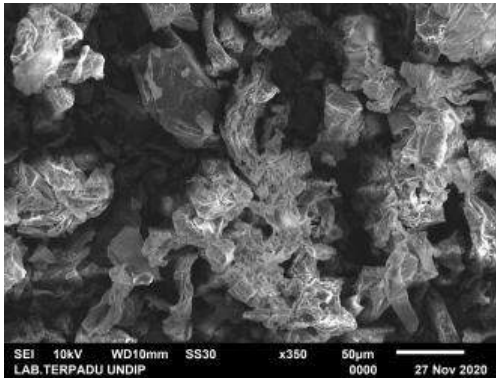


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Telepon (024) 76918147- Faksimile (024) 76918148, Website : <http://labterpadu.undip.ac.id>;
E-mail : labterpadu@live.undip.ac.id

**Hasil Uji Citra SEM sbb:
Aerogel Selulosa setelah adsorpsi**



Lampiran 16. Analisis Hasil BET-BJH

Quantachrome® ASiQwin™ - Automated Gas Sorption Data
Acquisition and Reduction
© 1994-2013, Quantachrome Instruments
version 3.01



Analysis		Date: 2020/12/23	Report	Date: 2021/01/06
Operator:	UNDIP	Filename:	Operator: UNDIP	
Sample ID:	01154	Comment:	20201223 AEROGEL SELULOSA.qps	
Sample Desc:		Instrument:	Autosorb IQ Station 1	
Sample Weight:	0.0488 g	Outgas Temp.:	300 °C	
Outgas Time:	3.0 hrs	Non-Ideality:	6.58e-05 1/Torr	CellType: 9mm w/o rod
Analysis gas:	Nitrogen	Bath Temp.:	77.35 K	VoidVol Remeasure: off
Analysis Time:	10:42 hr:min	Cold Zone V:	0 cc	Warm Zone V: 0 cc
Analysis Mode:	Standard			
VoidVol. Mode:	He Measure			

BJH Pore Size Distribution Adsorption

Data Reduction Parameters Data

Method	Thermal Transpiration: on	Eff. mol. diameter (D): 3.54 Å	Eff. cell stem diam. (d): 4.0000 mm
BJH/DH method	Calc. method: de Boer	Ignoring P-tags below 0.35 P/Po	
Adsorbate	Moving pt. avg.: off	Temperature 77.350K	Liquid Density: 0.808 g/cc
	Nitrogen	Cross Section: 16.200 Å²	
	Molec. WL: 28.013		

BJH Pore Size Distribution Adsorption Data

Radius	Pore Volume	Pore Surf Area	dV(r)	dS(r)	dV(logr)	dS(logr)
[Å]	[cc/g]	[m²/g]	[cc/Å/g]	[m²/Å/g]	[cc/g]	[cc/g]
15.2718	4.6962e-03	6.1502e+00	2.8827e-03	3.7752e+00	1.0127e-01	1.3263e+02
17.0310	1.1818e-02	1.4513e+01	3.7694e-03	4.4265e+00	1.4767e-01	1.7341e+02
19.1236	2.0022e-02	2.3094e+01	3.5734e-03	3.7372e+00	1.5716e-01	1.6437e+02
21.5658	3.0924e-02	3.3204e+01	4.2119e-03	3.9061e+00	2.0890e-01	1.9373e+02
24.4977	4.4365e-02	4.4177e+01	4.0986e-03	3.3459e+00	2.3087e-01	1.8847e+02
28.1282	5.5963e-02	5.2423e+01	2.9156e-03	2.0731e+00	1.8852e-01	1.3404e+02
32.6827	7.1303e-02	6.1810e+01	2.9896e-03	1.8295e+00	2.2452e-01	1.3739e+02
39.0366	9.8119e-02	7.5549e+01	3.5393e-03	1.8133e+00	3.1713e-01	1.6248e+02
47.8764	1.3776e-01	9.2108e+01	3.9234e-03	1.6390e+00	4.3091e-01	1.8001e+02
61.4236	2.2403e-01	1.2020e+02	5.0777e-03	1.6533e+00	7.1354e-01	2.3234e+02
86.4603	3.7254e-01	1.5455e+02	4.4890e-03	1.0384e+00	8.8266e-01	2.0418e+02
157.5650	4.4314e-01	1.6351e+02	6.4701e-04	8.2126e-02	2.2504e-01	2.8564e+01
962.2872	4.5538e-01	1.6377e+02	8.1575e-06	1.6954e-04	1.3494e-02	2.8045e-01

BJH adsorption summary

Surface Area = 163.769 m²/g
Pore Volume = 0.455 cc/g
Pore Radius Dv(r) = 61.424 Å



Analysis	UNDIP	Date: 2020/12/23	Report	UNDIP	Date: 2021/01/06
Operator:	01154	Filename:	20201223 AEROGEL SELULOSA.qps		
Sample ID:		Comment:			
Sample Desc:		Instrument:	Autosorb IQ Station 1		
Sample Weight:	0.0488 g	Outgas Temp.:	300 °C	CellType:	9mm w/o rod
Outgas Time:	3.0 hrs	Non-ideality:	6.58e-05 1/Torr	VoidVol Remassure:	off
Analysis gas:	Nitrogen	Bath temp.:	77.35 K	Warm Zone V:	0 cc
Analysis Time:	10:42 hr:min	Cold Zone V:	0 cc		
Analysis Mode:	Standard				
VoidVol. Mode:	He Measure				

BJH Pore Size Distribution Desorption

Data Reduction Parameters Data

t-Method	Thermal Transpiration: on	Eff. mol. diameter (D): 3.54 Å	Eff. cell stem diam. (d): 4.0000 mm
BJH/DH method	Calc. method: de Boer	Ignoring P-pages below 0.35 P/Po	
Adsorbate	Moving pt. avg.: off	Temperature 77.350K	
	Nitrogen	Cross Section: 16.200 μ²	Liquid Density: 0.808 g/cc
	Molec. WL: 28.013		

BJH Pore Size Distribution Desorption Data

Radius	Pore Volume	Pore Surf Area	dV(r)	dS(r)	dV(logr)	dS(logr)
[Å]	[cc/g]	[m²/g]	[cc/Å/g]	[m²/Å/g]	[cc/g]	[cc/g]
15.2933	5.4006e-03	7.0627e+00	3.2031e-03	4.1889e+00	1.1268e-01	1.4736e+02
17.0925	1.1874e-02	1.4637e+01	3.3849e-03	3.9607e+00	1.3308e-01	1.5572e+02
19.1217	1.5885e-02	1.8832e+01	1.8689e-03	1.9547e+00	8.2200e-02	8.5976e+01
21.5199	2.3488e-02	2.5898e+01	2.8687e-03	2.6661e+00	1.4197e-01	1.3194e+02
24.4680	3.1152e-02	3.2163e+01	2.3611e-03	1.9300e+00	1.3283e-01	1.0857e+02
28.1124	4.4203e-02	4.1448e+01	3.2280e-03	2.2965e+00	2.0859e-01	1.4840e+02
32.7716	6.6404e-02	5.4997e+01	4.2086e-03	2.5684e+00	3.1689e-01	1.9339e+02
39.0675	1.1624e-01	8.0508e+01	6.8112e-03	3.4869e+00	6.1092e-01	3.1275e+02
47.9281	2.4236e-01	1.3314e+02	1.2121e-02	5.0581e+00	1.3324e+00	5.5601e+02
61.8450	4.2550e-01	1.9236e+02	1.0508e-02	3.3982e+00	1.4864e+00	4.8069e+02
87.2937	4.4150e-01	1.9603e+02	4.7816e-04	1.0955e-01	9.4922e-02	2.1748e+01
151.5829	4.5005e-01	1.9716e+02	8.9801e-05	1.1848e-02	3.0287e-02	3.9960e+00
740.1371	4.6012e-01	1.9743e+02	9.3132e-06	2.5166e-04	1.2465e-02	3.3682e-01
1496.7910	4.6012e-01	1.9743e+02	0.0000e+00	0.0000e+00	0.0000e+00	0.0000e+00

BJH desorption summary

Surface Area = 197.430 m²/g
Pore Volume = 0.460 cc/g
Pore Radius DV(r) = 47.928 Å



Analysis	UNDIP	Date: 2020/12/23	Report	UNDIP	Date: 2021/01/06
Operator:	01154	Filename:	20201223 AEROGEL SELULOSA.qps		
Sample ID:		Comment:			
Sample Desc:		Instrument:	Autosorb IQ Station 1		
Sample Weight:	0.0488 g	Outgas Temp.:	300 °C	CellType:	9mm w/o rod
Outgas Time:	3.0 hrs	Non-ideality:	6.58e-05 1/Torr	VoidVol Remasure:	off
Analysis gas:	Nitrogen	Bath temp.:	77.35 K	Warm Zone V:	0 cc
Analysis Time:	10:42 hr:min	Cold Zone V:	0 cc		
Analysis Mode:	Standard				
VoidVol. Mode:	He Measure				

Raw Analysis Data

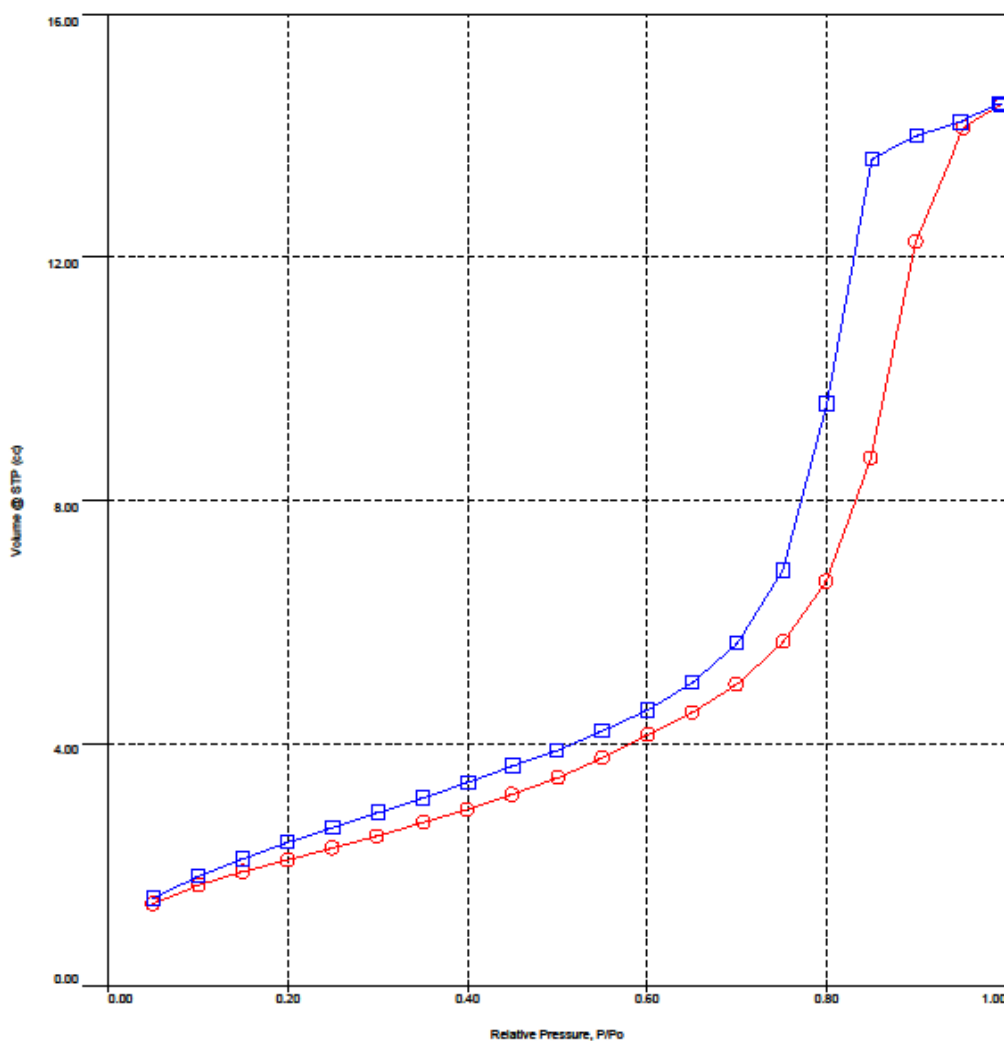
Raw Analysis Data

Press	P0	Volume @ STP	Time	Tol	Equ
[Torr]	[Torr]	[cc]	[min]		
37.5664	760.00	1.36323	25.7	0	1
76.3602	760.00	1.67466	59.9	0	1
113.54	760.00	1.89408	65.3	0	1
151.623	760.00	2.08573	70.0	0	1
189.759	760.00	2.28313	74.5	0	1
227.405	760.00	2.47938	79.5	0	1
266.593	760.00	2.70718	90.0	0	1
303.61	760.00	2.9142	95.7	0	1
341.346	760.00	3.16263	102.4	0	1
380.689	760.00	3.44218	112.4	0	1
417.961	760.00	3.76477	122.4	0	1
456.697	760.00	4.14823	135.7	0	1
494.104	760.00	4.51543	146.9	0	1
531.312	760.00	4.97048	158.9	0	1
571.216	760.00	5.68309	179.2	0	1
607.502	760.00	6.67115	200.4	0	1
645.396	760.00	8.70357	240.6	0	1
683.38	760.00	12.266	293.9	0	1
723.923	760.00	14.1378	329.1	0	1
755.728	760.00	14.5113	351.1	0	1
754.274	760.00	14.5321	357.9	0	1
721.473	760.00	14.2276	377.6	0	1
684.168	760.00	14.0011	388.4	0	1
646.47	760.00	13.6145	401.2	0	1
608.093	760.00	9.58933	459.5	0	1
570.779	760.00	6.85669	492.2	0	1
532.322	760.00	5.65776	515.3	0	1
494.244	760.00	5.00982	533.8	0	1
456.182	760.00	4.55308	547.8	0	1
417.764	760.00	4.20829	561.9	0	1
379.474	760.00	3.88592	573.6	0	1
342.703	760.00	3.63977	581.1	0	1
304.677	760.00	3.36473	590.8	0	1
266.425	760.00	3.11141	596.1	0	1
228.237	760.00	2.86454	598.3	0	1
190.199	760.00	2.61613	601.1	0	1
151.965	760.00	2.37808	605.6	0	1
113.999	760.00	2.10586	626.0	0	1
76.3661	760.00	1.82366	632.8	0	1
37.9613	760.00	1.4578	642.3	0	1

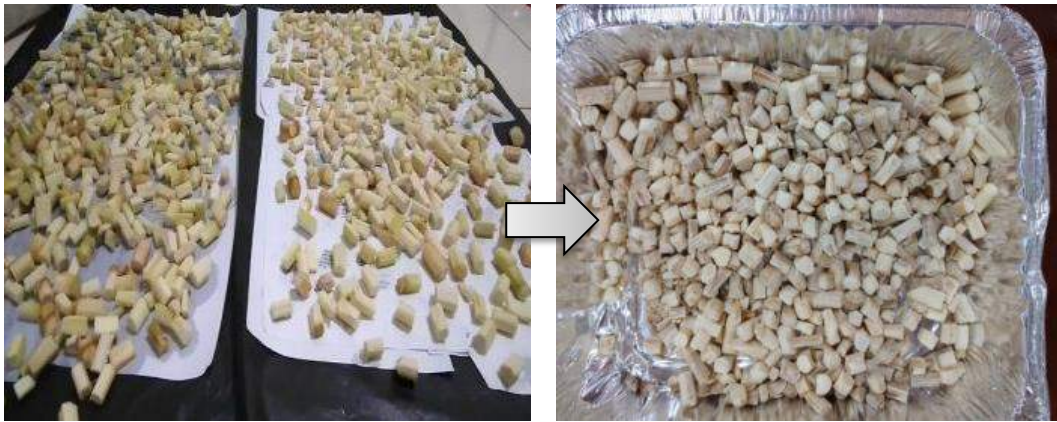


Analyte:		Date: 2020/12/23	Report Operator: UNIP	Date: 2021/01/06
Operator:	UNIP	Filename:	20201223 AEROGEL SELULOSA.qps	
Sample ID:	01154	Comment:		
Sample Desc:		Instrument:	Autosorb IQ Station 1	
Sample Weight:	0.0488 g	Outgas Temp.:	300 °C	CellType: 9mm w/o rod
Outgas Time:	3.0 hrs	Non-ideality:	6.58e-05 1/Torr	VoidVol Remassure: off
Analysis gas:	Nitrogen	Bath Temp.:	77.35 K	Warm Zone V: 0 cc
Analysis Time:	10:42 hr:min	Cold Zone V:	0 cc	
Analysis Mode:	Standard			
VoidVol. Mode:	He Measure			

Raw Data : Raw Linear



Lampiran 17. Dokumentasi Kegiatan Penelitian



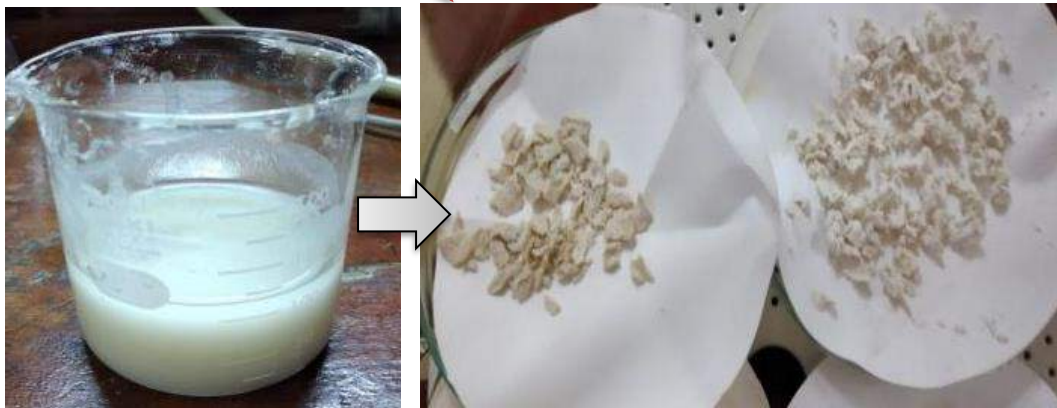
Sampel limbah batang jagung yang telah dicuci dan dipotong-potong

Sampel yang telah dioven selama 16 jam



Sampel diayak dengan pengayak 100 mesh hingga didapatkan serat batang jagung

Proses delignifikasi



Proses *bleaching*

Selulosa murni yang diperoleh dari tahap ekstraksi



Penambahan prekursor SiO_2 dan proses koagulasi



Hasil produk aerogel selulosa setelah *freeze dryer*



Proses adsorpsi antara logam Cu(II) dengan adsorben aerogel selulosa