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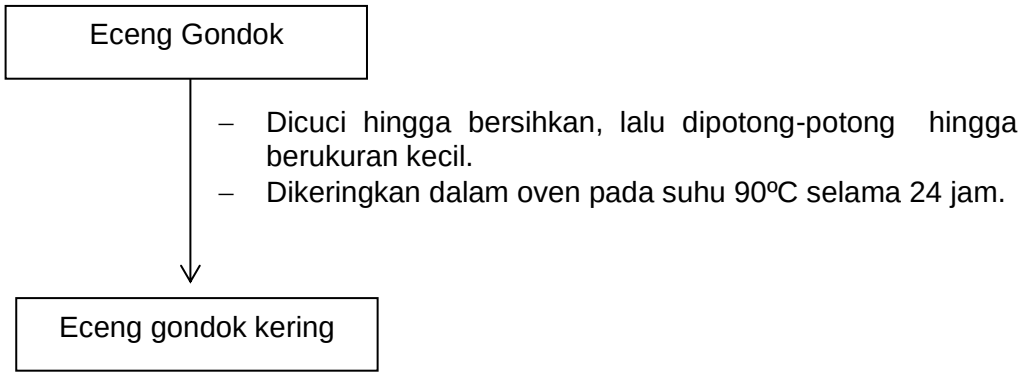
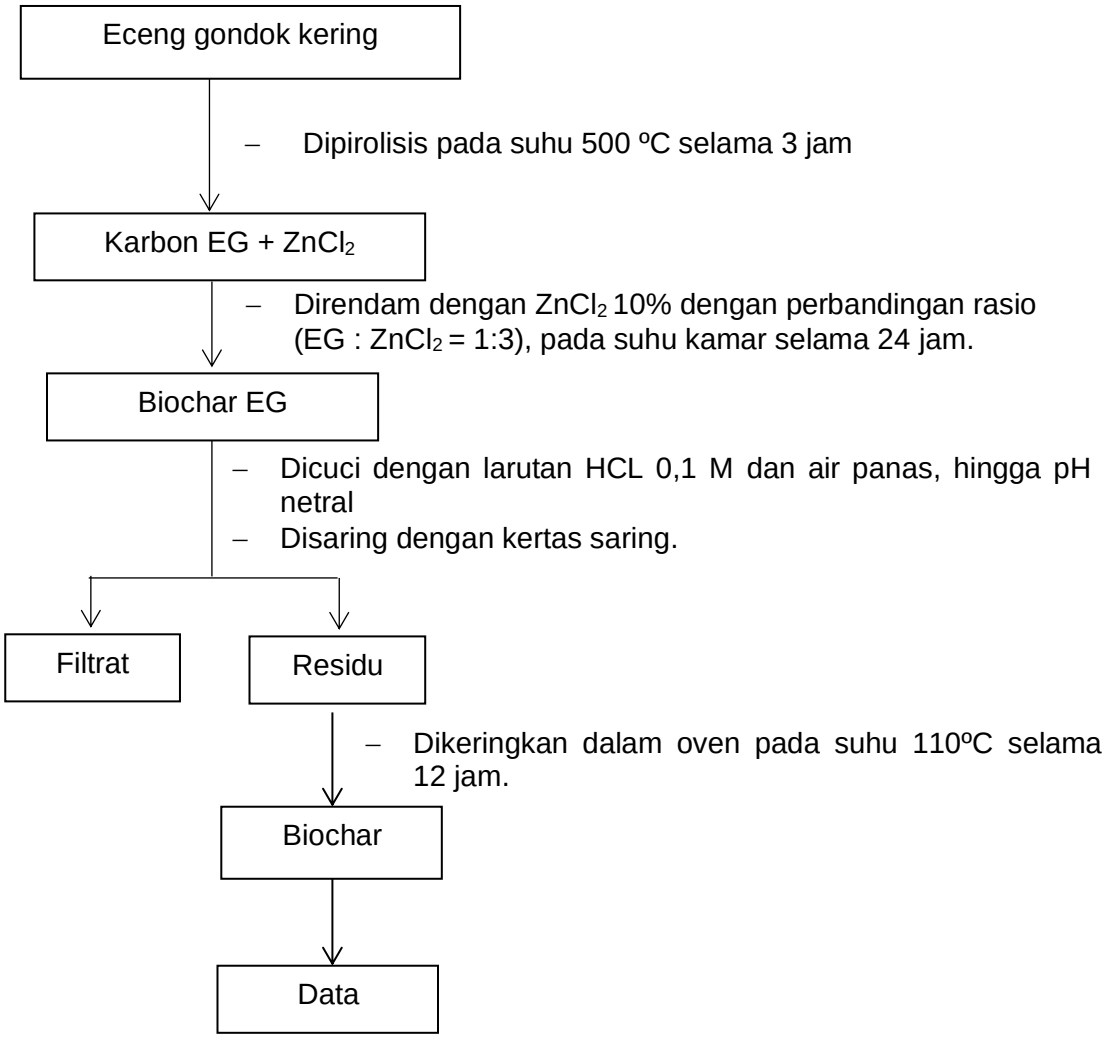
LAMPIRAN

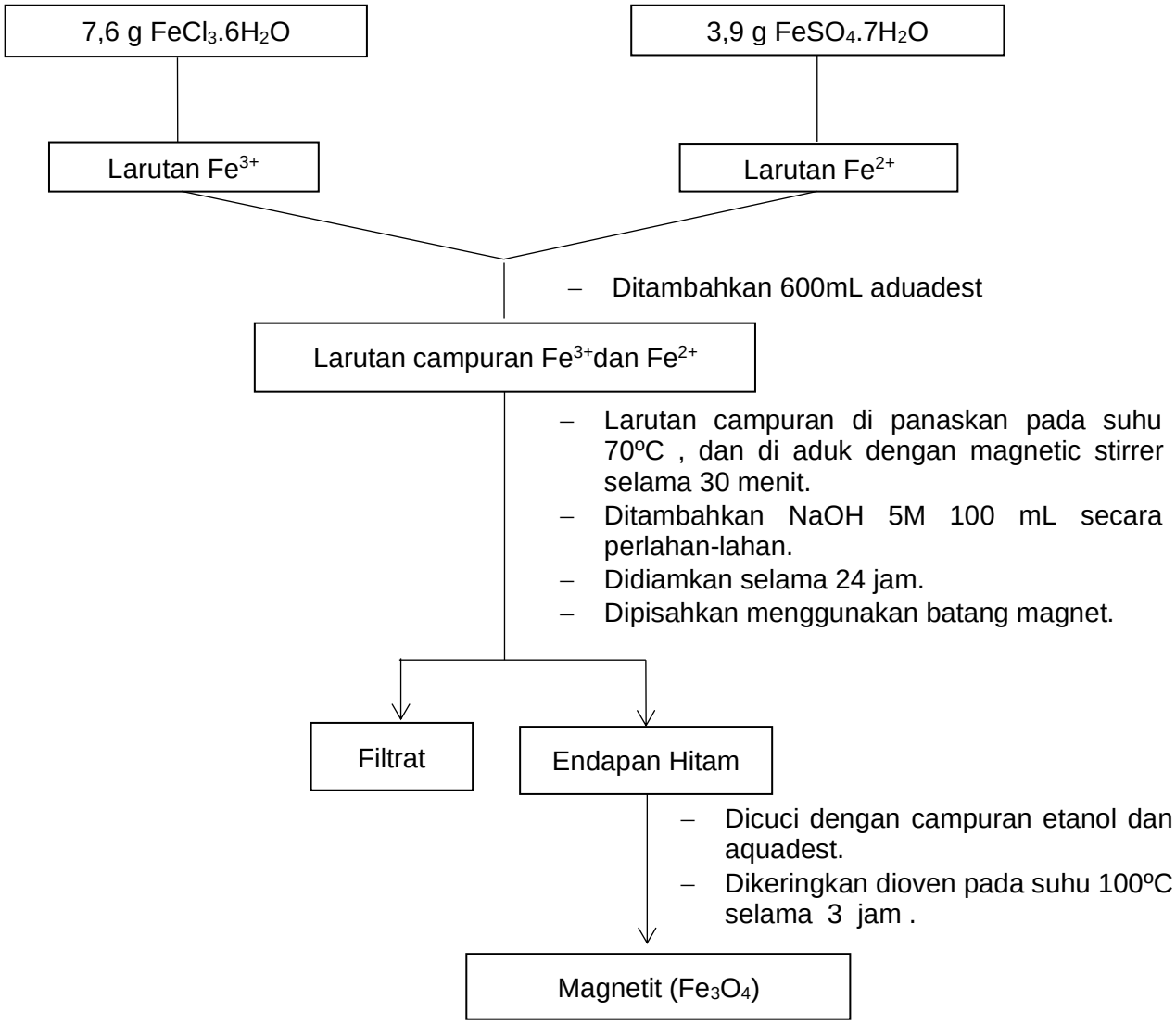
Lampiran 1. Skema Preparasi Bahan Baku



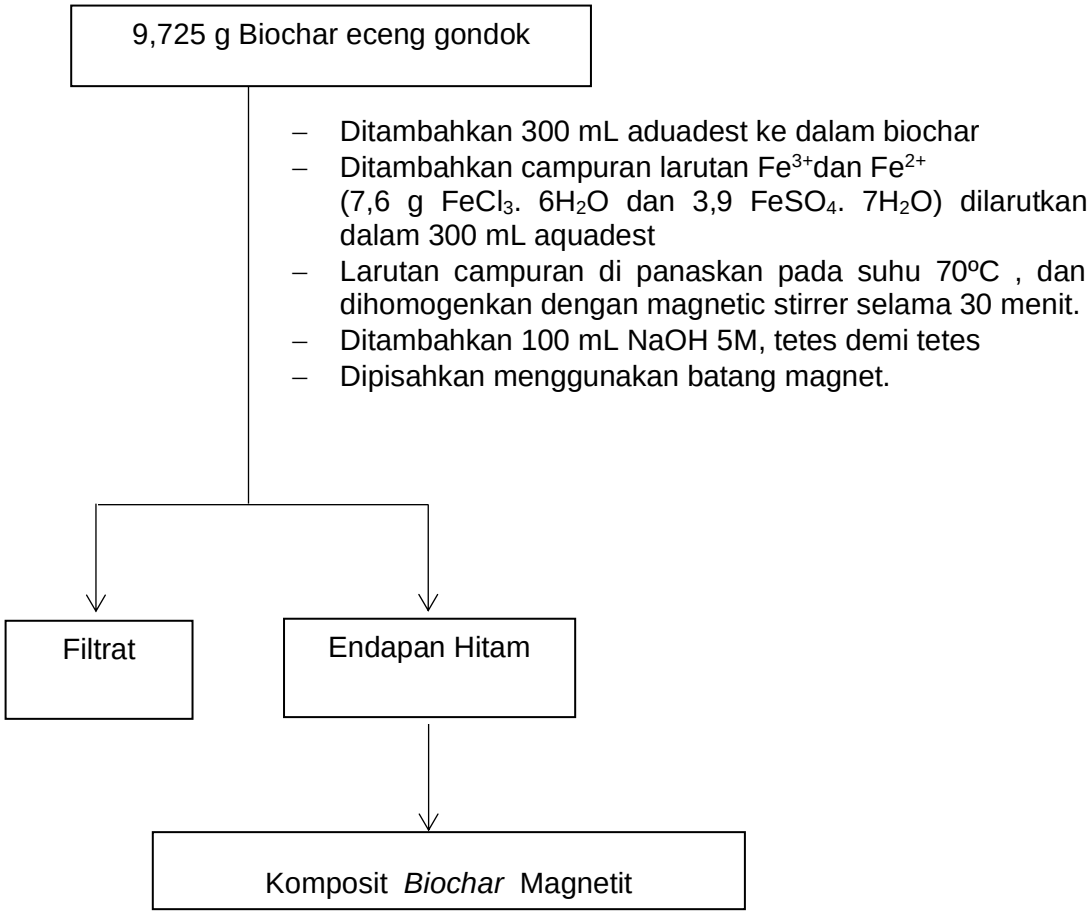
Lampiran 2. Skema Pembuatan *Biochar* dari Eceng Gondok (BEG)



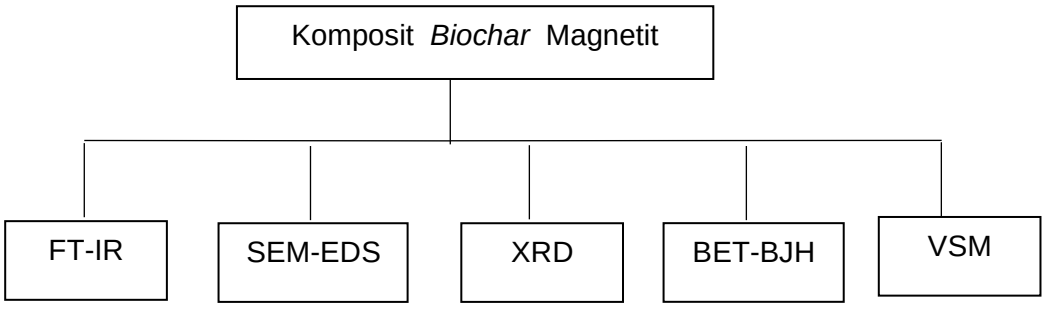
Lampiran 3. Skema Sintesis Magnetit



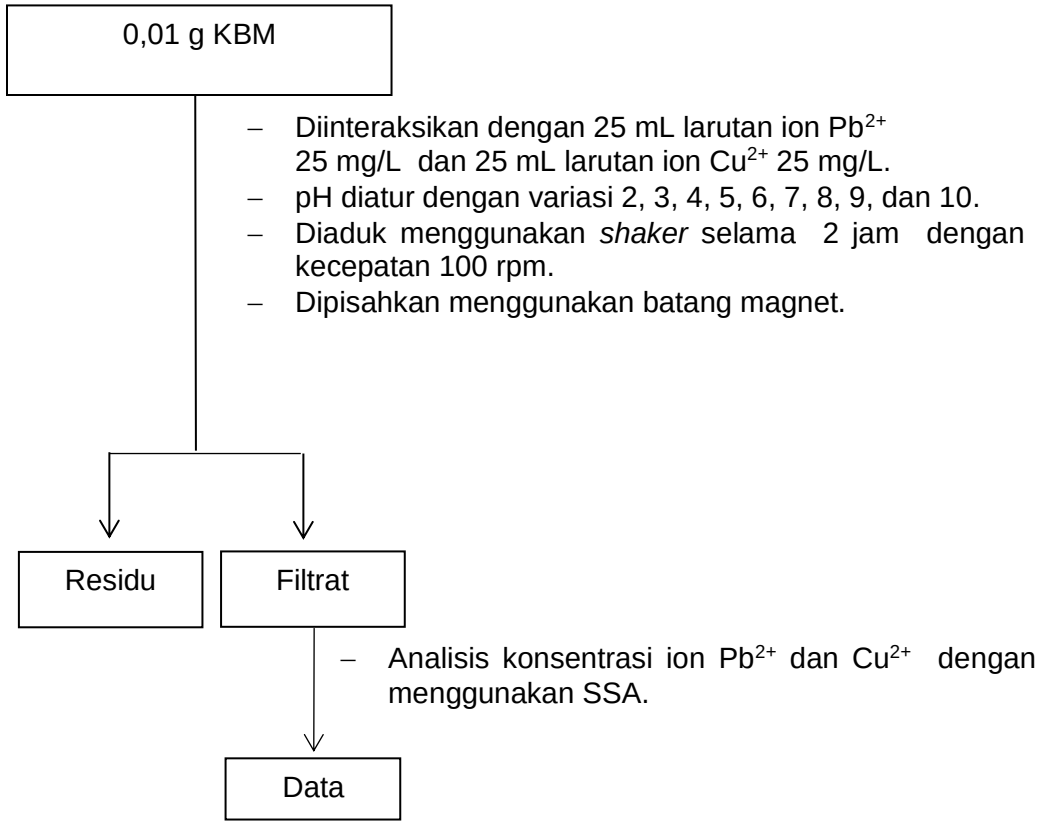
Lampiran 4. Skema Sintesis Komposit *Biochar* Magnetit (KBM)



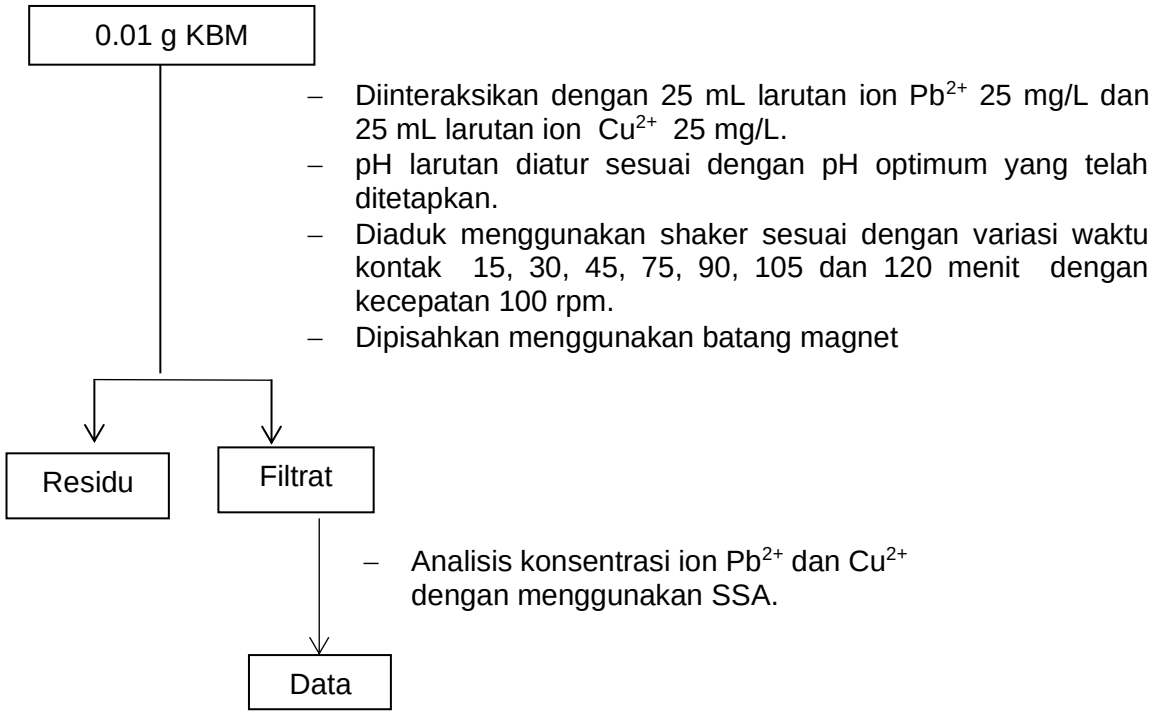
Lampiran 5. Skema Karakterisasi Adsorben



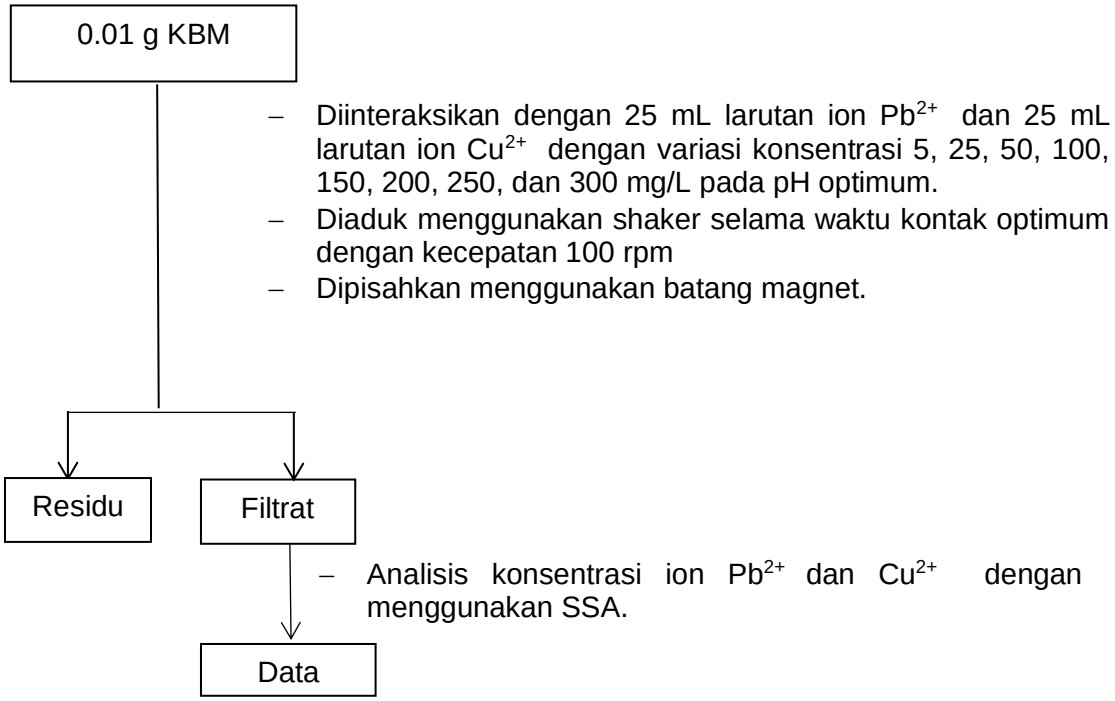
Lampiran 6. Skema Penentuan pH Optimum



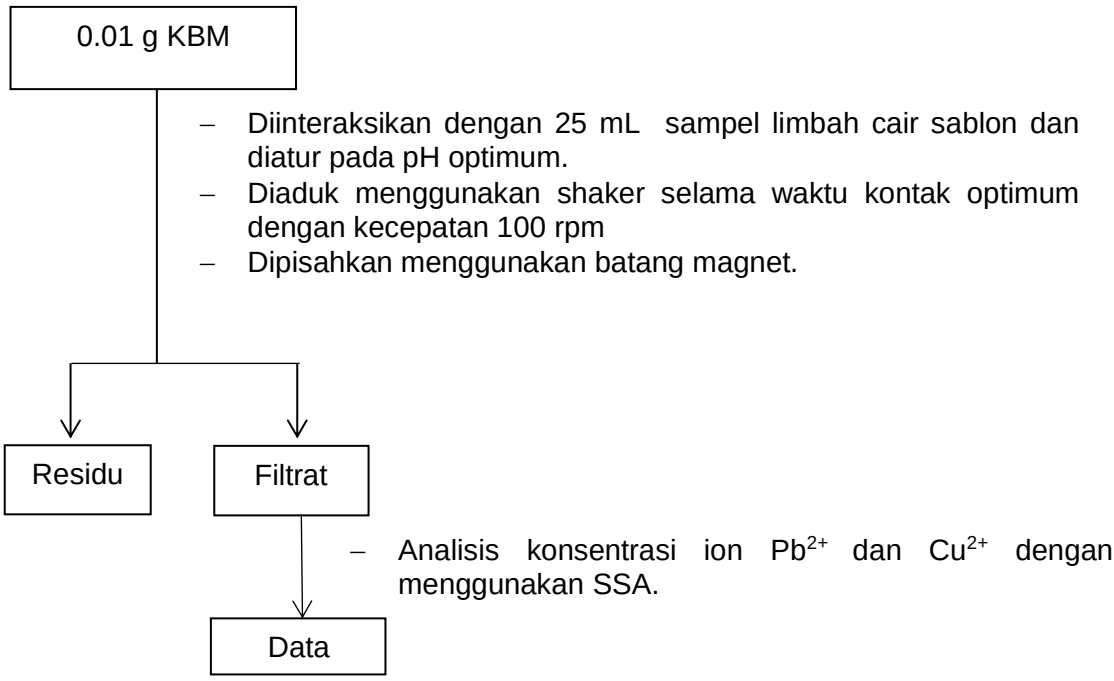
Lampiran 7. Skema Penentuan Waktu Kontak Optimum



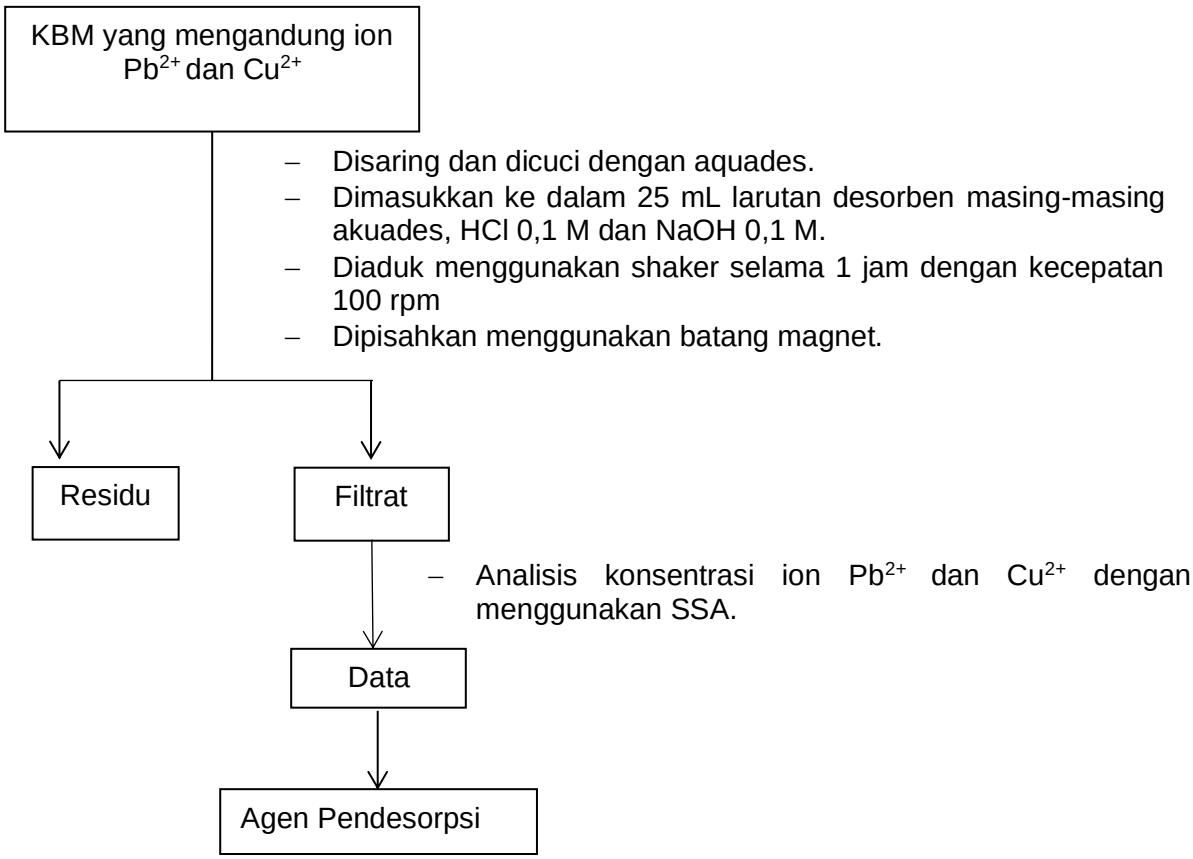
Lampiran 8. Penentuan Kapasitas Adsorpsi Ion Pb^2 dan Cu^{2+}



Lampiran 9. Aplikasi Adsorpsi Ion Pb^{2+} dan Cu^{2+} oleh KBM ke Limbah Cair Industri Sablon.

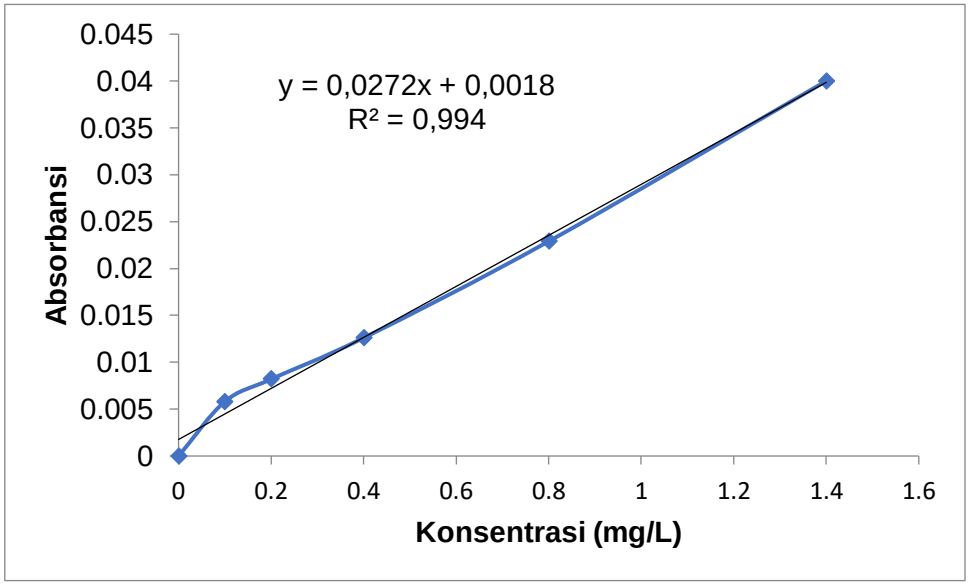


Lampiran 10. Desorpsi Ion Pb^{2+} dan Cu^{2+} oleh KBM



Lampiran 11. Data Absorbansi Kurva Standar Larutan Ion Pb^{2+} dan Hasil Analisis Konsentrasi Ion Pb^{2+} pada Eceng Gondok dengan menggunakan SSA

Konsentrasi	Absorbansi
0	0
0,1	0,0058
0,2	0,0082
0,4	0,0126
0,8	0,0229
1,4	0,0400



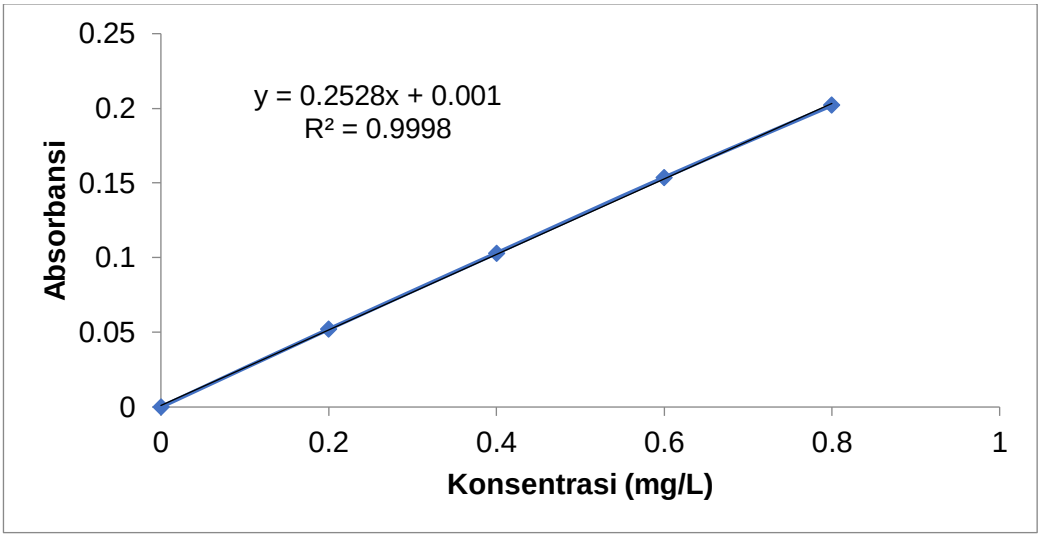
Hasil Analisis Konsentrasi Ion Pb^{2+} pada Eceng Gondok dengan SSA

Konsentrasi	Absorbansi
Sampel Eceng Gondok	0,0000

Kandungan ion Pb^{2+} tidak terdeteksi di sampel eceng gondok, mengindikasikan sampel tidak tercemar ion Pb^{2+}.

Lampiran 12. Data Absorbansi Kurva Standar Larutan Ion Cu^{2+} dan Hasil Analisis Konsentrasi Ion Cu^{2+} pada Eceng Gondok dengan menggunakan SSA

Konsentrasi	Absorbansi
0	0,000
0,2	0,0521
0,4	0,1030
0,6	0,1537
0,8	0,2020



Hasil Analisis Konsentrasi Ion Cu^{2+} pada Eceng Gondok dengan SSA

Konsentrasi	Absorbansi
Sampel Eceng Gondok	0,0322

Perhitungan Konsentrasi Ion Cu^{2+}

y = 0,2528x + 0,001

$x = \frac{0,0322 - 0,001}{0,2528} = 0,1234$ mg/L

Konsentrasi Ion $Cu^{2+} = \frac{X\ (mg/L)\ x\ Volume\ (L)}{gram\ sampel}$

$= \frac{0,1234\ mg/L\ x\ 0,05\ L)}{2,0015\ gram}$

= 0,0031 mg/g

Lampiran 13. Perhitungan Sintesis Magnetit dan KBM

Stokiometri pembuatan oksida besi Fe_3O_4

2 Fe^{3+}	+ Fe^{2+}	⟶	Fe_3O_4
28 mmol	14 mmol		14 mmol

A. Sintesis Magnetit

Massa yang ditimbang secara teori :

$FeCl_3.6H_2O$ = 28 mmol = 28 x 10^{-3} mol

Massa $FeCl_3.6H_2O$ = (BM $FeCl_3.6H_2O$) x (n $FeCl_3.6H_2O$)

= (270,3188 g/mol) / (28 x 10^{-3} mol)

= 7,5689 g

$FeSO_4.7H_2O$ = 14 mmol = 14 x 10^{-3} mol

Massa $FeSO_4.7H_2O$ = (BM $FeSO_4.7H_2O$) x (n $FeSO_4.7H_2O$)

= (278,0362 g/mol) x (14 x 10^{-3} mol)

= 3,8925 g

Magnetit (Fe_3O_4) = 14 mmol = 14 x 10^{-3} mol

Massa magnetit Fe_3O_4 = (BM Fe_3O_4) x (n Fe_3O_4)

= (231,5386 g/mol) x (14 x 10^{-3} mol)

= 3,2415 g

B. Sintesis KBM

Massa biochar : massa Fe_3O_4 = 3 : 1

= 9,725 g : 3,2415 g

Lampiran 14. Perhitungan Hasil Rendemen Magnetit dan KBM

1. Magnetit

bobot massa wadah kosong = 6,5819 gram
bobot massa wadah kosong + magnetit = 9,6235 gram
bobot massa magnetit (eksperimen) = 3,0416 gram

bobot massa magnetit secara teori = 3.2415 gram

% Rendemen $= \frac{\text{bobot massa magnetit eksperimen}}{\text{bobot massa magnetit teori}} \times 100\%$

$= \frac{3{,}0416 \text{ gram}}{3{,}2415 \text{ gram}} \times 100\%$

$= 93{,}83\%$

2. KBM

bobot massa wadah kosong = 37,3572 gram
bobot massa wadah kosong + KBM = 49,6725 gram
bobot massa KBM (eksperimen) = 12,3153 gram

bobot massa KBM secara teori = 12,9665 gram

% Rendemen $= \frac{\text{bobot massa KBM eksperimen}}{\text{bobot massa KBM teori}} \times 100\%$

$= \frac{12{,}3153 \text{ gram}}{12{,}9665 \text{ gram}} \times 100\%$

$= 94{,}98\ \%$

Lampiran 15 . Perhitungan Pembuatan Larutan Ion Pb^{2+}dan Cu^{2+}

a. Pembuatan Larutan Induk Pb^{2+} 1000 ppm

ppm $= \frac{\text{Ar Pb}}{\text{Mr Pb}(NO_3)_2} \times {}^{mg}/_{L}$

1000 ${}^{mg}/_{L} = \frac{207}{331} \times \frac{X}{1\ L}$

$X = \frac{331}{207} \times 1000\ {}^{mg}/_{L} \times 1L$

$X = 1599\ mg \approx 1{,}59\ g$

Dimana X adalah berat $Pb(NO_3)_2$ yang ditimbang.

b. Pembuatan Larutan Induk Cu^{2+} 1000 ppm

ppm $= \frac{\text{Ar Cu}}{\text{Mr CuSO}_4 .5\ H_2O} \times {}^{mg}/_{L}$

1000 ${}^{mg}/_{L} = \frac{63{,}55}{250} \times \frac{X}{1\ L}$

$X = \frac{250}{63{,}55} \times 1000\ {}^{mg}/_{L} \times 1L$

$X = 3933\ mg \approx 3{,}93\ g$

Dimana X adalah berat $CuSO_4.5H_2O$ yang ditimbang.

Lampiran 16. Data Penentuan pH Optimum Adsorpsi Ion Pb^{2+}oleh KBM

pH	C_o (mg/L)	C_e (mg/L)	Jumlah adsorben (g)	Volume (L)	q_e (mg/g)	qe rata-rata (mg/q)
2a	27,998	26,9318	0,01015	0,025	2,6261	2,5935
2b	27,998	26,9552	0,01018	0,025	2,5609	
3a	26,1245	22,9881	0,01007	0,025	7,7865	7,7701
3b	26,1245	23,0075	0,01005	0,025	7,7537	
4a	26,0021	10,0075	0,01014	0,025	39,4344	38,5479
4b	26,0021	9,4311	0,0110	0,025	37,6614	
5a	25,1114	1,0912	0,01001	0,025	59,9905	59,8035
5b	25,1114	1,2171	0,01002	0,025	59,6165	
6a	25,1107	4,8032	0,01005	0,025	50,5162	50,3457
6b	25,1107	4,9001	0,01007	0,025	50,1753	
7a	25,4521	7,361	0,01004	0,025	45,0476	44,8404
7b	25,4521	7,5631	0,01002	0,025	44,6332	
8a	24,9321	8,0771	0,01010	0,025	41,7203	41,1867
8b	24,9321	8,6221	0,01003	0,025	40,6530	
9a	24,7112	12,0051	0,01014	0,025	31,3267	31,1785
9b	24,7112	12,1005	0,01016	0,025	31,0303	
10a	23,5511	12,7512	0,01003	0,025	26,9190	27,0055
10b	23,5511	12,6601	0,01005	0,025	27,0920	

Keterangan:

a = simplo ; b= duplo

Nilai qe dihitung bedasarkan persamaan (20)

Contoh perhitungan jumlah ion Pb^{2+} yang teradsorpsi pada pH= 5a :

$$q_e = \frac{(25{,}1114\text{-}1{,}0912)\ {}^{mg}/_{L}}{0{,}01001\ g} \times 0{,}025\ L = 59{,}9905\ {}^{mg}/_{g}$$

Lampiran 17 . Data Penentuan pH Optimum Adsorpsi Ion Cu^{2+} oleh KBM

pH	C_o (mg/L)	C_e (mg/L)	Jumlah adsorben (g)	Volume (L)	q_e (mg/g)	qe rata-rata (mg/q)
2a	25,2345	11,6879	0,01001	0,025	33,8327	32,3222
2b	25,2345	11,6157	0,01105	0,025	30,8118	
3a	24,9124	11,2336	0,01004	0,025	34,0608	32,4030
3b	24,9124	11,3599	0,01102	0,025	30,7452	
4a	24,8779	10,8532	0,01007	0,025	34,8180	35,6220
4b	24,8779	10,2638	0,01003	0,025	36,4260	
5a	24,5591	4,7511	0,01003	0,025	49,3719	49,4966
5b	24,5591	4,6709	0,01002	0,025	49,6213	
6a	25,0012	2,0081	0,01002	0,025	57,3680	57,3957
6b	25,0012	2,0089	0,01001	0,025	57,4233	
7a	26,1105	5,8198	0,01007	0,025	50,3741	50,2766
7b	26,1105	5,9586	0,01004	0,025	50,1790	
8a	26,7421	7,9369	0,01007	0,025	46,6862	46,7198
8b	26,7421	7,9659	0,01004	0,025	46,7535	
9a	27,1102	8,9742	0,01002	0,025	45,2495	45,5037
9b	27,1102	8,7155	0,01005	0,025	45,7580	
10a	26,0944	8,2005	0,01001	0,025	44,6901	44,4915
10b	26,0944	8,3241	0,01003	0,025	44,2929	

Keterangan:

a = simplo ; b= duplo

Nilai qe dihitung bedasarkan persamaan (20)

Contoh perhitungan jumlah ion Cu^{2+} yang teradsorpsi pada pH= 6a :

$$q_e = \frac{(25{,}0012 - 2{,}0081)\ {}^{mg}/_{L}}{0{,}01002\ g} \times 0{,}025\ L = 57{,}3680\ {}^{mg}/_{g}$$

Lampiran 18 . Data Penentuan Waktu Optimum Adsorpsi Ion Pb^{2+} oleh KBM

Waktu (menit)	C_o (mg/L)	C_e (mg/L)	Jumlah adsorben (g)	Volume (L)	q_t (mg/g)	q_t rata-rata (mg/q)
15a	25,0017	4,7123	0,01193	0,025	42.5176	43,2811
15b	25,0017	4,8821	0,01142	0,025	44.0447	
30a	25,0017	2,6491	0,01064	0,025	52,5202	52,3009
30b	25,0017	2,1691	0,01096	0,025	52,0817	
45a	25,0017	2,3665	0,01018	0,025	55,5874	54,9939
45b	25,0017	2,9804	0,01012	0,025	54,4004	
60a	25,0017	1,8119	0,01004	0,025	57,7435	57,7682
60b	25,0017	1,8152	0,01003	0,025	57,7929	
75a	25,0017	1,8577	0,01017	0,025	56,8928	56,6602
75b	25,0017	1,8713	0,01014	0,025	57,0276	
90a	25,0017	1,8799	0,01014	0,025	57,0064	56,2500
90b	25,0017	1,8942	0,01041	0,025	55,4935	
105a	25,0017	1,8884	0,0105	0,025	55,0317	54,2548
105b	25,0017	1,8992	0,0108	0,025	53,4780	
120a	25,0017	4,1005	0,01006	0,025	51,9414	52,0032
120b	25,0017	4,1132	0,01003	0,025	52,0651	

Keterangan:

a = simplo ; b= duplo

Nilai qe dihitung bedasarkan persamaan (20)

Contoh perhitungan jumlah ion Pb^{2+} yang teradsorpsi pada waktu kontak 60a menit :

$$q_e = \frac{(25{,}0017 - 1{,}8119)\ {}^{mg}/_{L}}{0{,}01004\ g} \times 0{,}025\ L = 57{,}7435\ {}^{mg}/_{g}$$

Lampiran 19 . Data Kinetika Adsorpsi Ion Pb^{2+} oleh KBM Bentuk Linear

Waktu (menit)	q_t (mg/g)	q_e (mg/g)	q_e-q_t	ln q_e-q_t	t/q_t ($g.mg^{-1}$ $menit^{-1}$)
15	43,2811	57,7682	15,4871	2,7400	0,3548
30	52,3009	57.7682	5,4673	1,6988	0,5736
45	54,9939	57.7682	2,7743	1,0204	0,8183
60	57,7682	57.7682	0	0	1,0386
75	56,6602	57.7682	1,1080	0,1025	1,3237
90	56,2500	57.7682	1,5182	0,4175	1,6000
105	54,2548	57.7682	3,5134	1,2566	1,9353
120	52,0032	57.7682	5,7650	1,7518	2,3076

Keterangan:

q_t = q_e pada waktu t

q_e = q_e pada waktu optimum

Rumus persamaan kinetika orde satu semu

$\ln (q_e - q_t) = -kt + \ln q_e$

Data grafik kinetika orde satu semu ion Pb^{2+} diperoleh persamaan garis :

y = -0.0086x + 1.7039

dari persamaan garis diperoleh nilai slope (a) = -0,0086 dan intercept (b) = 1,7039

Nilai k_1 dapat dihitung sebagai berikut :

slope = $- k_1$

k_1 = - slope

= - (- 0,0086)

= 0,0086 $menit^{-1}$

Nilai adsorpsi dapat dihitung dengan persamaaan sebagai berikut :

Intersep = ln q_e

ln q_e = (1,7039)

q_e = 5,4952 mg/g

Rumus persamaan kinetika orde dua semu :

$$\frac{t}{q_t} = \frac{1}{k_2\ q_e{}^2} + \frac{t}{q_e}$$

Dari grafik kinetika orde dua semu diperoleh persamaa garis :

y = 0,0183x + 0,0060

dari persamaan garis diperoleh nilai slope (a) = 0,0183 dan nilai intersep (b) = 0,0060

Nilai adsorpsi dapat dihitung dengan persamaa sebagai berikut :

Slope $= \frac{1}{q_e}$

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

$= \frac{1}{0.0183}$

= 54,644 mg/g

Nilai k_2 dapat dihitung dengan persamaan sebagai berikut :

Intersep $= \frac{1}{k_2 \ {q_e}^2}$

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

$= \frac{1}{54.644^{\,2} \ . \ 0.0060}$

= 0,0558 $g.mg^{-1}$ $menit^{-1}$

Lampiran 20 . Data Kinetika Adsorpsi Ion Pb^{2+} oleh KBM Bentuk Non Linear (program Solver)

- **Kinetika Orde Satu Semu**

t (waktu)	q_t (mg/g)	q_t model	Residual^2
15	43.24621	43.24621	0.001217
30	52.72282	52.72282	0.178013
45	54.79944	54.79944	0.037816
60	55.25449	55.25449	6.318741
75	55.35421	55.35421	1.705667
90	55.37606	55.37606	0.763712
105	55.38084	55.38084	1.267892
120	55.38189	55.38189	11.41557

Persamaan Kinetika Orde Satu Semu Non Linear :

$$q_t = q_e\,(1 - e^{-k\,t})$$

Parameter	Nilai
K_1	0,101
q_e	55,382
RSS	21,69

- **Kinetika Orde Dua Semu**

t (waktu)	q_t (mg/g)	q_t model	Residual^2
15	43.24621	43.24621	0.001217
30	52.72282	52.72282	0.178013
45	54.79944	54.79944	0.037816
60	55.25449	55.25449	6.318741
75	55.35421	55.35421	1.705667
90	55.37606	55.37606	0.763712
105	55.38084	55.38084	1.267892
120	55.38189	55.38189	11.41557

Persamaan Kinetika Orde Dua Semu Non Linear :

$$q_t = \frac{k_2\ {q_e}^2\ t}{1 + k_2\ q_e\ t}$$

Parameter	Nilai
K_2	0,004
q_e	58,389
RSS	5,545

Lampiran 21. Data Penentuan Waktu Optimum Adsorpsi Ion Cu^{2+} oleh KBM

Waktu (menit)	C_o (mg/L)	C_e (mg/L)	Jumlah adsorben (g)	Volume (L)	q_t (mg/g)	q_t rata-rata (mg/q)
15a	25,6042	12,2752	0,0115	0,025	28,9761	30,0097
15b	25,6042	12,9634	0,01018	0,025	31,0432	
30a	25,6042	10,9465	0,01021	0,025	35,8905	35,9627
30b	25,6042	10,9452	0,01017	0,025	36,0349	
45a	25,6042	9,9595	0,01009	0,025	38,7629	39,4239
45b	25,6042	9,3778	0,01012	0,025	40,0850	
60a	25,6042	5,4993	0,01002	0,025	50,1619	49,9471
60b	25,6042	5,6914	0,01001	0,025	49,7323	
75a	25,6042	5,9749	0,01072	0,025	45,7773	46,4969
75b	25,6042	5,7166	0,01053	0,025	47,2165	
90a	25,6042	5,8801	0,01098	0,025	44,9092	45,1690
90b	25,6042	5,9244	0,01083	0,025	45,4289	
105a	25,6042	7,9957	0,01075	0,025	40,9500	39,8885
105b	25,6042	7,2002	0,01185	0,025	38,8270	
120a	25,6042	8,0095	0,01125	0,025	39,0993	39,0101
120b	25,6042	8,5413	0,01096	0,025	38,9208	

Keterangan:

a = simplo ; b= duplo

Nilai qe dihitung bedasarkan persamaan (20)

Contoh perhitungan jumlah ion Cu^{2+} yang teradsorpsi pada waktu kontak 60a menit :

$$q_e = \frac{(25,6042 - 5,4993)\ {}^{mg}/_{L}}{0,01002\ g} \times 0,025\ L$$

$$= 50,1619\ {}^{mg}/_{g}$$

Lampiran 22 . Data Kinetika Adsorpsi Ion Cu^{2+} oleh KBM Bentuk Linear

Waktu (menit)	q_t (mg/g)	q_e (mg/g)	q_e-q_t	ln q_e-q_t	t/q_t ($g.mg^{-1}$ $menit^{-1}$)
15	30,0097	49,9471	19,9374	2,9926	0,4998
30	35,9627	49,9471	13,9844	2,6379	0,8342
45	39,4239	49,9471	10,5232	2,3536	1,1414
60	49,9471	49,9471	0	0	1,2013
75	46,4969	49,9471	3,4502	1,2384	1,6130
90	45,1690	49,9471	4,7781	1,5640	1,9925
105	39,8885	49,9471	10,0586	2,3084	2,6323
120	39,0101	49,9471	10,9370	2,3922	3,0761

Keterangan:

q_t = q_e pada waktu t

q_e = q_e pada waktu optimum

Rumus persamaan kinetika orde satu semu

$\ln (q_e - q_t) = -kt + \ln q_e$

Data grafik kinetika orde satu semu ion Cu^{2+} diperoleh persamaan garis :

$y = -0,0055x + 2,3099$

dari persamaan garis diperoleh nilai slope (a) = -0,0055 dan intercept (b) = 2,3099

Nilai k_1 dapat dihitung sebagai berikut :

slope = $- k_1$

k_1 = - slope

= - (- 0,0055)

= 0,0055 $menit^{-1}$

Nilai adsorpsi dapat dihitung dengan persamaaan sebagai berikut :

Intersep = $\ln q_e$

$\ln q_e$ = (2,3099)

q_e = 10,0731 mg/g

Rumus persamaan kinetika orde dua semu :

$$\frac{t}{q_t} = \frac{1}{k_2\ {q_e}^2} + \frac{t}{q_e}$$

Dari grafik kinetika orde dua semu diperoleh persamaa garis :

$y = 0,0238x + 0,0173$

dari persamaan garis diperoleh nilai slope (a) = 0,0238 dan nilai intersep (b) = 0,0173

Nilai adsorpsi dapat dihitung dengan persamaan sebagai berikut :

Slope $= \frac{1}{q_e}$

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

$= \frac{1}{0.0238}$

= 42,0168 mg/g

Nilai k_2 dapat dihitung dengan persamaan sebagai berikut :

Intersep $= \frac{1}{k_2 \ {q_e}^2}$

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

$= \frac{1}{42{,}0168^{\,2} \ . \ 0{,}0173}$

= 0,0327 $g.mg^{-1}$ $menit^{-1}$

Lampiran 23 . Data Kinetika Adsorpsi Ion Cu^{2+} oleh KBM Bentuk Non Linear (program Solver)

- **Kinetika Orde Satu Semu**

t (waktu)	q_t (mg/g)	q_t model	Residual^2
15	30.0097	28.75410	1.5765
30	35.9627	38.50609	6.4688
45	39.4239	41.81349	5.7101
60	49.9471	42.93520	49.1667
75	46.4969	43.31563	10.1205
90	45.169	43.44465	2.9734
105	39.8885	43.48841	12.9594
120	39.0101	43.50325	20.1884

Persamaan Kinetika Orde Satu Semu Non Linear :

$$q_t = q_e\,(1 - e^{-k\,t})$$

Parameter	Nilai
K_1	0,072
q_e	43,511
RSS	140,1639

- **Kinetika Orde Dua Semu**

t (waktu)	q_t (mg/g)	q_t model	Residual^2
15	30.0097	31.2374	1.5073
30	35.9627	37.6199	2.7462
45	39.4239	40.3693	0.8937
60	49.9471	41.9004	64.7493
75	46.4969	42.8761	13.1100
90	45.169	43.5523	2.6139
105	39.8885	44.0484	17.3049
120	39.0101	44.4280	29.3537

Persamaan Kinetika Orde Dua Semu Non Linear :

$$q_t = \frac{k_2\ {q_e}^2\ t}{1 + k_2\ q_e\ t}$$

Parameter	Nilai
K_2	0,003
q_e	47,280
RSS	132,279

Lampiran 24. Data Penentuan Kapasitas Adsorpsi Ion Pb^{2+} oleh KBM

C_o (mg/L)	C_e (mg/L)	Jumlah adsorben (g)	Volume (L)	q_e (mg/g)	qe rata-rata (mg/q)
9,1799	4,2006	0,01160	0,025	10,7313	10,7777
9,1799	4,1791	0,01155	0,025	10,8242	
27,1176	17,0805	0,01091	0,025	22,9998	23,4057
27,1176	17,2024	0,01041	0,025	23,8117	
57,0023	36,6157	0,01105	0,025	46,1235	44,7403
57,0023	36,9713	0,01155	0,025	43,3571	
101,8879	74,5977	0,01017	0,025	67,0851	67,1505
101,8879	74,9209	0,01003	0,025	67,2159	
144,9612	99,7004	0,01202	0,025	94,1364	93,7189
144,9612	99,9899	0,01205	0,025	93,3015	
188,5508	148,9007	0,01095	0,025	90,5253	90,6587
188,5508	148,6023	0,01100	0,025	90,7920	
216,0077	179,0132	0,01027	0,025	90,0548	89,7127
216,0077	179,1155	0,01032	0,025	89,3706	
280,1111	240,5621	0,01124	0,025	87,9649	88,3214
280,1111	240,1351	0,01127	0,025	88,6779	

Keterangan:

a = simplo ; b= duplo

Nilai qe dihitung bedasarkan persamaan (20)

Contoh perhitungan jumlah ion Pb^{2+} yang teradsorpsi konsentrasi 200a mg/L:

$$q_e = \frac{(144{,}9612 - 99{,}7004)\ {}^{mg}/_{L}}{0{,}01202\ g} \times 0{,}025\ L$$

$$= 94{,}1364\ {}^{mg}/_{g}$$

Lampiran 25 . Data Penentuan Kapasitas Adsorpsi Ion Cu^{2+} oleh KBM

C_o (mg/L)	C_e (mg/L)	Jumlah adsorben (g)	Volume (L)	q_e (mg/g)	qe rata-rata (mg/q)
9,2472	5,9491	0,0130	0,025	6,3425	7,4011
9,2472	5,0512	0,0124	0,025	8,4597	
23,3489	13,9471	0,01057	0,025	22,2370	22,0033
23,3489	14,1969	0,01051	0,025	21,7697	
48,5917	34,2455	0,01055	0,025	33,9957	34,0333
48,5917	34,3501	0,01045	0,025	34,0708	
110,5957	88,9465	0,01080	0,025	50,1139	52,0382
110,5957	88,8812	0,01006	0,025	53,9625	
148,1003	126,5992	0,01005	0,025	53,4853	54,0353
148,1003	126,0915	0,01008	0,025	54,4853	
211,5645	185,3177	0,01010	0,025	64,9673	65,0928
211,5645	185,4511	0,01001	0,025	65,2183	
255,5533	227,3277	0,01090	0,025	64,7376	64,3881
255,5533	227,3763	0,01100	0,025	64,0386	
297,5595	271,4024	0,01020	0,025	64,1105	63,9354
297,5595	271,0352	0,01040	0,025	63,7603	

Keterangan:

a = simplo ; b= duplo

Nilai qe dihitung bedasarkan persamaan (18)

Contoh perhitungan jumlah ion Cu^{2+} yang teradsorpsi konsentrasi 200a mg/L:

$$q_e = \frac{(211{,}5645 - 185{,}3177)\ {}^{mg}/_{L}}{0{,}0101\ g} \times 0{,}025\ L$$

$$= 64{,}9673\ {}^{mg}/_{g}$$

Lampiran 26. Data Penentuan Kapasitas Adsorpsi Ion Pb^{2+} oleh KBM untuk Permodelan Persamaan Isoterm Adsorpsi Bentuk Linear.

C_e (mg/L)	q_e(mg/g)	C_e/q_e	log C_e	log q_e	ln C_e	ln (q/qm-q)
4,1899	10,7777	0,3888	0,6222	1,0325	1,4327	-2,1036
17,1415	23,4057	0,7324	1,2340	1,3693	2,8415	-1,1739
36,7935	44,7403	0,8224	1,5658	1,6507	3,6053	-0,1949
74,7593	67,1505	1,1133	1,8737	1,8270	4,3143	0,7425
99,8451	93,7189	1,0654	1,9993	1,9718	4,6036	2,8556
148,7515	90,6587	1,6408	2,1725	1,9574	5,0023	2,3728
179,0644	89,7127	1,9960	2,2530	1,9529	5,1877	2,2562
240,3486	88,3214	2,7213	2,3808	1,9461	5,4821	2,1025

Isoterm Langmuir	
Parameter	**Nilai**
1/ q_{max} K	0,4103
1/ q_{max}	0,0090
q_{max}	111,2725
K_L	0,0219
R^2	0,9676

Isoterm Freundlich	
Parameter	**Nilai**
Log K_f	0,7134
K_F	5,1689
n_F	1,7625
R^2	0,9533

Isoterm Sips	
Parameter	**Nilai**
ln K_s	-4,2612
K_s	0.0264
n_S	0.5508
q_{max}	99.1098
R^2	0.8774

- Model persamaan isotherm Langmuir dapat dilihat pada persamaan (21) :

$$\frac{C_e}{q_e} = \frac{1}{q_m\ K_L} + \frac{1}{q_m}\ .C_e$$

Berdasakan model Langmuir ion Pb^{2+} diperoleh persamaan garis :

y = 0,0090x + 0,4103

dari persamaan garis diperoleh nilai slope (a) = 0,0090 dan nilai intercept (b) = 0,413

Nilai kapasitas adsorpsi dapat dihitung sebagai berikut

$$\frac{1}{q_{max}} = (\text{slope})$$

$$q_{max} = \frac{1}{0,0090}$$

$$= 111,2725 \text{ mg/g}$$

$$\frac{1}{q_{max} \text{ x } K_L} = \text{intercept}$$

$$K_L = \frac{1}{111{,}2725 \text{ mg/g x } 0{,}4103}$$

$$= 0{,}0219 \text{ L mg}^{-1}$$

- Model persamaan Isoterm Freundlich dapat dilihat pada persamaan (23) :

$$\text{Log } q_e = \text{Log } K_f + \frac{1}{n} \log Ce$$

Berdasarkan model isotherm Freundlich diperoleh persamaan garis :

y= 0,5674x + 0,7134

dari persamaan garis diperoleh nilai slope (a)= 0,5674 dan nilai intersep (b) = 0,7134

Nilai kapasitas adsorpsi dapat dihitung sebagai berikut:

Log K_F = intersep

Log K_F = 0,7134

K_F = inv log (0,7134)

= 5,1689

Intensitas adsorpsi dapat dihitung sebagai berikut:

$\frac{1}{n}$ = slope

n = $\frac{1}{0{,}5674}$ = 1,7625 L^{-1}

- Model persamaan Isoterm Sips dapat dilihat pada persamaan (25) :

$$\ln \frac{q_e}{q_m - q_e} = \ln K_s + \frac{1}{n} \ln C_e$$

Lampiran 27 . Data Penentuan Kapasitas Adsorpsi Ion Cu^{2+} oleh KBM untuk Permodelan Persamaan Isoterm Adsorps Bentuk Linear.

C_e (mg/L)	q_e(mg/g)	C_e/q_e	log C_e	log q_e	ln C_e	ln (q/qm-q)
5,5002	7,4011	0,7432	0,7404	0,8693	1,7048	-2,2227
14,0720	22,0033	0,6395	1,1484	1,3425	2,6442	-0,8927
34,2978	34,0333	1,0078	1,5353	1,5319	3,5351	-0,2031
88,9139	52,0382	1,7086	1,9490	1,7163	4,4877	0,7869
126,3454	54,0353	2,3382	2,1016	1,7327	4,8390	0,9126
185,3844	65,0928	2,8480	2,2681	1,8135	5,2224	1,8115
227,3520	64,3881	3,5310	2,3567	1,8088	5,4265	1,7365
271,2188	63,9354	4,2421	2,4333	1,8057	5,6029	1,6903

Isoterm Langmuir	
Parameter	**Nilai**
1/ q_{max} K	0,6436
1/ q_{max}	0,0132
q_{max}	75,5741
K_L	0,0206
R^2	0,9942

Isoterm Freundlich	
Parameter	**Nilai**
Log K_f	0,6436
K_F	4,4015
n_F	1,9449
R^2	0,9205

Isoterm Sips	
Parameter	**Nilai**
ln K_s	-3,7896
K_s	0,0245
n_s	0,9784
q_{max}	75,7293
R^2	0,9999

Model persamaan isotherm Langmuir dapat dilihat pada persamaan (25)

$$\frac{C_e}{q_e} = \frac{1}{q_m\ K_L} + \frac{1}{q_m}.C_e$$

Berdasakan model Langmuir ion Cu^{2+} diperoleh persamaan garis :

y = 0,0132x + 0,6436

dari persamaan garis diperoleh nilai slope (a) = 0,0132 dan nilai intercept (b) = 0,6436

Nilai kapasitas adsorpsi dapat dihitung sebagai berikut

$$\frac{1}{q_{max}} = (\text{slope})$$

$$q_{max} = \frac{1}{0,0132}$$

$$= 75,5741 \text{ mg/g}$$

$$\frac{1}{q_{max}\ x\ K_L} = \text{intercept}$$

$$K_L = \frac{1}{75{,}5741\ \text{mg/g x}\ 0{,}6436}$$

$$= 0{,}0206\ \text{L mg}^{-1}$$

- Model persamaan Isoterm Freundlich dapat dilihat pada persamaan (23) :

$$\text{Log } q_e = \text{Log } K_f + \frac{1}{n} \log Ce$$

Berdasarkan model isotherm Freundlich diperoleh persamaan garis :

y= 0,5142x + 0,6436

dari persamaan garis diperoleh nilai slope (a)= 0.5142 dan nilai intersep (b) = 0.6436

Nilai kapasitas adsorpsi dapat dihitung sebagai berikut:

Log K_F = intersep

Log K_F = 0,6436

K_F = inv log (0.6436)

= 4,4015

Intensitas adsorpsi dapat dihitung sebagai berikut:

$\frac{1}{n}$ = slope

n_F = $\frac{1}{0{,}5142}$ = 1,9449 L^{-1}

- Model persamaan Isoterm Sips dapat dilihat pada persamaan (25) :

$$\ln \frac{q_e}{q_m - q_e} = \ln K_s + \frac{1}{n} \ln C_e$$

Lampiran 28. Data Penentuan Kapasitas Adsorpsi Ion Pb^{2+} oleh KBM untuk Permodelan Persamaan Isoterm Adsorpsi Bentuk Non-Linear (Program Solver).

1. Isoterm Adsorpsi Langmuir Bentuk Non-Linear (Program Solver)

Konsentrasi (mg/L)	C_e(mg/g)	q_e (mg/g)	q_e L (mg/g)	Res^2
5	4,1899	10,7777	8,8932	3,5512
25	17,1415	23,4057	29,4822	36,9234
50	36,7935	44,7403	49,1392	19,3505
100	74,7593	67,1505	69,7351	6,6801
150	99,8451	93,7189	77,6607	257,8656
200	148,7515	90,6587	87,3926	10,6673
250	179,0644	89,7127	91,3488	2,6769
300	240,3486	88,3214	96,8338	72,4601

Persamaan Isoterm Langmuir Non Linear:

$$q_e = \frac{q_m . K_L . C_e}{1 + K_L . C_e}$$

Parameter	Nilai
q_m	117,4369
K_L	0,0196
RSS	410.1752
R^2	0,9998

2. Isoterm Adsorpsi Freundlich Bentuk Non-Linear (Program Solver)

Konsentrasi (mg/L)	C_e(mg/g)	q_e (mg/g)	q_e F (mg/g)	Res^2
5	4,1899	10,7777	2,1811	73,9010
25	17,1415	23,4057	8,9233	209,7392
50	36,7935	44,7403	19,1535	654,6824
100	74,7593	67,1505	38,9173	797,1114
150	99,8451	93,7189	51,9762	1742,4515
200	148,7515	90,6587	77,4354	174,8570
250	179,0644	89,7127	93,2153	12,2682
300	240,3486	88,3214	125,1179	1353,9838

Persamaan Isoterm Freundlich Non Linear:

$$q_{e} = K_F \cdot C_e^{1/n}$$

Parameter	Nilai
K_F	0,0739
n_F	0,1419
RSS	5018,9944
R^2	0,9739

3. Isoterm Adsorpsi Sips Bentuk Non-Linear (Program Solver)

Konsentrasi (mg/L)	C_e(mg/g)	q_e (mg/g)	q_e S (mg/g)	Res^2
5	4,1899	10,7777	3,1533	58,1322
25	17,1415	23,4057	22,4065	0,9983
50	36,7935	44,7403	48,4147	13,5010
100	74,7593	67,1505	73,4836	40,1086
150	99,8451	93,7189	81,0619	160,2008
200	148,7515	90,6587	88,4925	4,6923
250	179,0644	89,7127	90,9274	1,4754
300	240,3486	88,3214	93,7644	29,6266

Persamaan Isoterm Sips Non Linear:

$$q_e = \frac{q_m \cdot K_S \cdot C_e^{\,n}}{1 + K_S \cdot C_e^{\,n}}$$

Parameter	Nilai
q_m	99,1098
K_S	0,0264
n_S	0,5508
RSS	308,7352
R^2	0,9977

Lampiran 29. Data Penentuan Kapasitas Adsorpsi Ion Cu^{2+} oleh KBM untuk Permodelan Persamaan Isoterm Adsorpsi Bentuk Non-Linear (Program Solver).

1. Isoterm Adsorpsi Langmuir Bentuk Non-Linear (Program Solver)

Konsentrasi (mg/L)	C_e(mg/g)	q_e (mg/g)	q_e L (mg/g)	Res^2
5	5,5002	7,4011	9,1368	3,0126
25	14,0720	22,0033	19,6415	5,5780
50	34,2978	34,0333	34,7668	0,5380
100	88,9139	52,0382	51,8212	0,0471
150	126,3454	54,0353	57,0256	8,9417
200	185,3844	65,0928	61,7141	11,4153
250	227,3520	64,3881	63,7859	0,3627
300	271,2188	63,9354	65,3533	2,0104

Persamaan Isoterm Langmuir Non Linear:

$$q_e = \frac{q_m . K_L . C_e}{1 + K_L . C_e}$$

Parameter	Nilai
q_m	74,8913
K_L	0,0253
RSS	31,9058
R^2	0,9999

2. Isoterm Adsorpsi Freundlich Bentuk Non-Linear (Program Solver)

Konsentrasi (mg/L)	C_e(mg/g)	q_e (mg/g)	q_e F (mg/g)	Res^2
5	5,5002	7,4011	1,6962	32,5458
25	14,0720	22,0033	4,3397	312,0040
50	34,2978	34,0333	10,5771	550,1931
100	88,9139	52,0382	27,4202	606,0473
150	126,3454	54,0353	38,9637	227,1538
200	185,3844	65,0928	57,1707	62,7593
250	227,3520	64,3881	70,1131	32,7759
300	271,2188	63,9354	83,6412	388,3189

Persamaan Isoterm Freundlich Non Linear:

$$q_{e} = K_F \cdot C_e^{1/n}$$

Parameter	Nilai
K_F	0,0701
n_F	0,2272
RSS	2211,7980
R^2	0,9664

3. Isoterm Adsorpsi Sips Bentuk Non-Linear (Program Solver)

Konsentrasi (mg/L)	C_e(mg/g)	q_e (mg/g)	q_e S (mg/g)	Res^2
5	5,5002	7,4011	9,3565	3,8237
25	14,0720	22,0033	19,7752	4,9644
50	34,2978	34,0333	34,6830	0,4221
100	88,9139	52,0382	51,6569	0,1454
150	126,3454	54,0353	56,9204	8,3237
200	185,3844	65,0928	61,7150	11,4092
250	227,3520	64,3881	63,8537	0,2855
300	271,2188	63,9354	65,4817	2,3911

Persamaan Isoterm Sips Non Linear:

$$q_e = \frac{q_m \cdot K_S \cdot C_e^{\,n}}{1 + K_S \cdot C_e^{\,n}}$$

Parameter	Nilai
q_m	75,7293
K_S	0,0245
n_S	0,9784
RSS	31,7650
R^2	0.9999

Lampiran 30 . Efektifitas Adsorben KBM

Ion Logam	C_o (mg/L)	C_e (mg/L)	Jumlah adsorben (g)	Volume (L)	qe (mg/g)	qe rata-rata (mg/q)	%E	%E rata-rata
Pb^{2+} a	0,8741	0,0211	0,01002	0,025	2,1282	2,1198	97,59	97,35
Pb^{2+} b	0,8741	0,0253	0,01005	0,025	2,1114		97,11	
Cu^{2+} a	4,1089	0,2055	0,01001	0,025	9,7488	9,7458	95,00	95,06
Cu^{2+} b	4,1089	0,2028	0,01003	0,025	9,7428		95,13	

Keterangan:

a = simplo ; b= duplo

Nilai qe dan %E dihitung bedasarkan persamaan (1) dan persamaan (2)

Contoh perhitungan jumlah ion Pb^{2+} dan % efektifitas adsorben KBM yang teradsorpsi pada air limbah cair sablon:

$$q_e = \frac{(0{,}8741 - 0{,}0211)\ {}^{mg}/_{L}}{0{,}01002\ g} \times 0.025\ L = 2.1282\ {}^{mg}/_{g}$$

$$\%E = \frac{(0{,}8741 - 0{,}0211)\ {}^{mg}/_{L}}{(0{,}8741)\ {}^{mg}/_{L}} \times 100\% = 97{,}59\%$$

Contoh perhitungan jumlah ion Cu^{2+} dan % efektifitas adsorpsi adsorben KBM yang teradsorpsi pada air limbah cair sablon:

$$q_e = \frac{(4{,}1089 - 0{,}2055)\ {}^{mg}/_{L}}{0{,}01001\ g} \times 0{,}025\ L = 9{,}7488\ {}^{mg}/_{g}$$

$$\%E = \frac{(4{,}1089 - 0{,}2055)\ {}^{mg}/_{L}}{4{,}1089\ {}^{mg}/_{L}} \times 100\% = 95{,}00\%$$

Lampiran 31 . Data Desorpsi

Ion Logam	Agen Pendesorpsi	qe Adsorpsi (mg/g)	qe Desorpsi (mg/g)	% Rasio Desorpsi
Pb^{2+}	HCl	65,5718	60,1964	91,80
	NaOH	67,8656	13,9487	20,56
	H_2O	61,4765	5,7010	9,27
Cu^{2+}	HCl	50,3993	45,4331	90,15
	NaOH	38,1709	5,3402	13,99
	H_2O	45,0247	10,3520	23,02

Nilai % rasio desorpsi dihitung bedasarkan persamaan (16)

Contoh perhitungan %rasio desorpsi dengan menggunakan agen pendesorpsi HCl untuk ion Pb^{2+} :

$$q_e = \frac{60,1964 \ mg/g}{65,5718 \ mg/g} \times 100\%$$

$$= 91,80\ \%$$

Contoh perhitungan %rasio desorpsi dengan menggunakan agen pendesorpsi HCl untuk ion Cu^{2+} :

$$q_e = \frac{45,4331 \ mg/g}{50,3993 \ mg/g} \times 100\%$$

$$= 90,15\ \%$$

Lampiran 32. FTIR Biochar (BEG)

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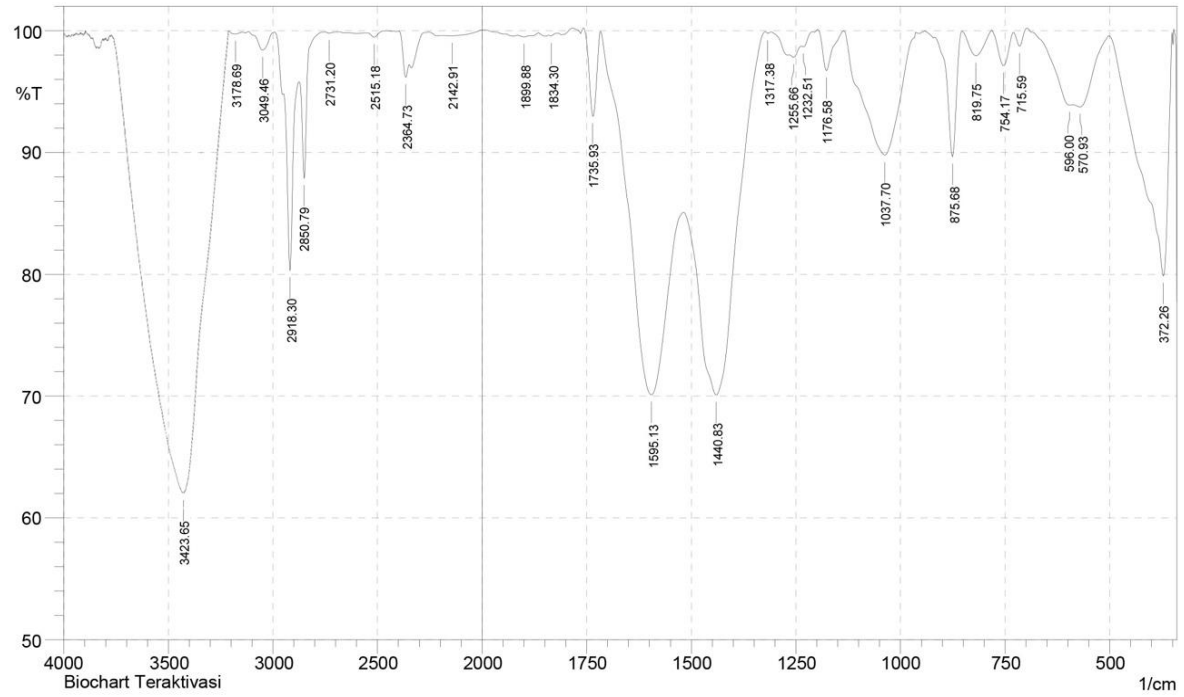

No.	Peak	Intensity	Corr. Intensity	Base (H)	Base (L)	Area	Corr. Area
1	372.26	79.861	18.988	501.49	352.97	6.983	6.432
2	570.93	93.733	1.233	586.36	503.42	1.386	0.222
3	596	93.883	0.482	696.3	588.29	1.316	0.066
4	715.59	98.717	1.3	731.02	698.23	0.083	0.087
5	754.17	97.124	2.809	781.17	731.02	0.341	0.328
6	819.75	97.941	2.052	852.54	781.17	0.356	0.354
7	875.68	89.648	10.118	918.12	854.47	1.158	1.074
8	1037.7	89.79	9.82	1136.07	970.19	4.422	4.18
9	1176.58	96.721	3.328	1197.79	1136.07	0.367	0.376
10	1232.51	98.686	0.289	1238.3	1211.3	0.096	0.016
11	1255.66	97.801	0.495	1267.23	1238.3	0.238	0.031
12	1317.38	99.774	0.133	1323.17	1309.67	0.009	0.004
13	1440.83	70.086	20.917	1517.98	1325.1	16.834	10.092
14	1595.13	70.106	20.654	1716.65	1519.91	16.972	9.975
15	1735.93	92.967	7.104	1757.15	1716.65	0.598	0.611
16	1834.3	99.56	0.119	1840.09	1822.73	0.026	0.003
17	1899.88	99.491	0.111	1915.31	1888.31	0.053	0.007
18	2142.91	99.564	0.132	2181.49	1998.25	0.227	0.093
19	2364.73	96.164	1.927	2397.52	2349.3	0.468	0.168
20	2515.18	99.46	0.418	2547.97	2455.38	0.097	0.058
21	2731.2	99.793	0.098	2750.49	2696.48	0.036	0.01
22	2850.79	87.897	8.671	2873.94	2752.42	1.604	0.777
23	2918.3	80.324	14.909	2949.16	2875.86	3.433	1.908
24	3049.46	98.411	1.49	3116.97	2991.59	0.416	0.363
25	3178.69	99.724	0.198	3211.48	3147.83	0.056	0.034
26	3423.65	61.985	37.903	3695.61	3103.46	65.358	65.11

Comment;

Biochart Teraktivasi

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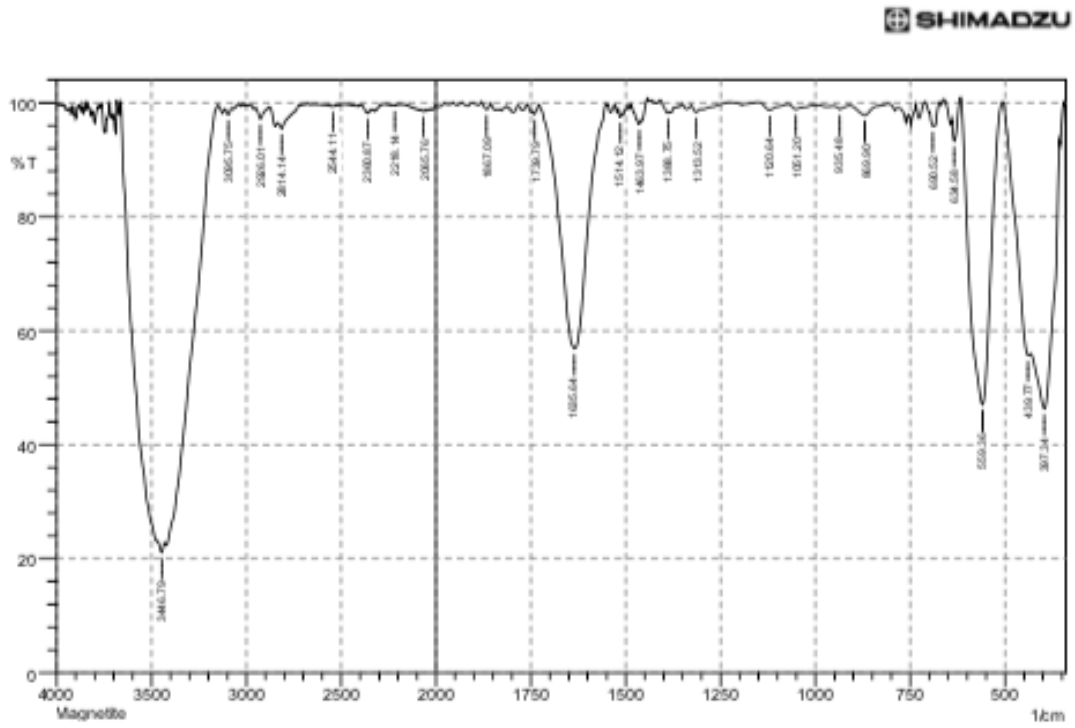
Lampiran 33. FTIR Magnetit (Fe_3O_4)



No.	Peak	Intensity	Corr. Intensity	Base (H)	Base (L)	Area	Corr. Area
1	397.34	46.301	27.3	432.05	345.26	18.718	8.052
2	439.77	55.665	3.822	505.35	433.98	9.407	0.585
3	559.36	47.048	53.455	617.22	507.28	17.833	18.079
4	634.58	93.294	4.646	640.37	617.22	0.375	0.264
5	690.52	95.891	1.133	709.8	684.73	0.265	0.056
6	869.9	97.795	1.673	910.4	835.18	0.424	0.251
7	935.48	98.836	0.612	952.84	910.4	0.143	0.042
8	1051.2	98.884	0.842	1072.42	1006.84	0.208	0.12
9	1120.64	98.732	1.247	1151.5	1072.42	0.212	0.193
10	1313.52	98.392	0.821	1327.03	1300.02	0.147	0.054
11	1388.75	98.197	0.546	1408.04	1384.89	0.101	0.042
12	1463.97	96.241	1.242	1485.19	1458.18	0.304	0.095
13	1514.12	97.47	1.003	1519.91	1508.33	0.109	0.031
14	1635.64	56.895	42.801	1728.22	1552.7	18.137	17.904
15	1739.79	97.995	0.993	1747.51	1728.22	0.115	0.039
16	1867.09	98.846	1.155	1880.6	1855.52	0.074	0.075
17	2065.76	98.554	0.153	2077.33	2052.26	0.152	0.01
18	2218.14	99.517	0.233	2276	2198.85	0.117	0.035
19	2360.87	98.147	0.939	2391.73	2341.58	0.283	0.104
20	2544.11	99.394	0.342	2603.9	2476.6	0.228	0.084
21	2814.14	95.489	1.407	2833.43	2696.48	1.319	0.211
22	2926.01	97.2	1.939	2951.09	2879.72	0.527	0.266
23	3095.75	97.941	1.004	3113.11	3078.39	0.244	0.084
24	3446.79	21.128	6.82	3660.89	3431.36	94.584	20.046

Comment;
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Lampiran 34. FTIR KBM

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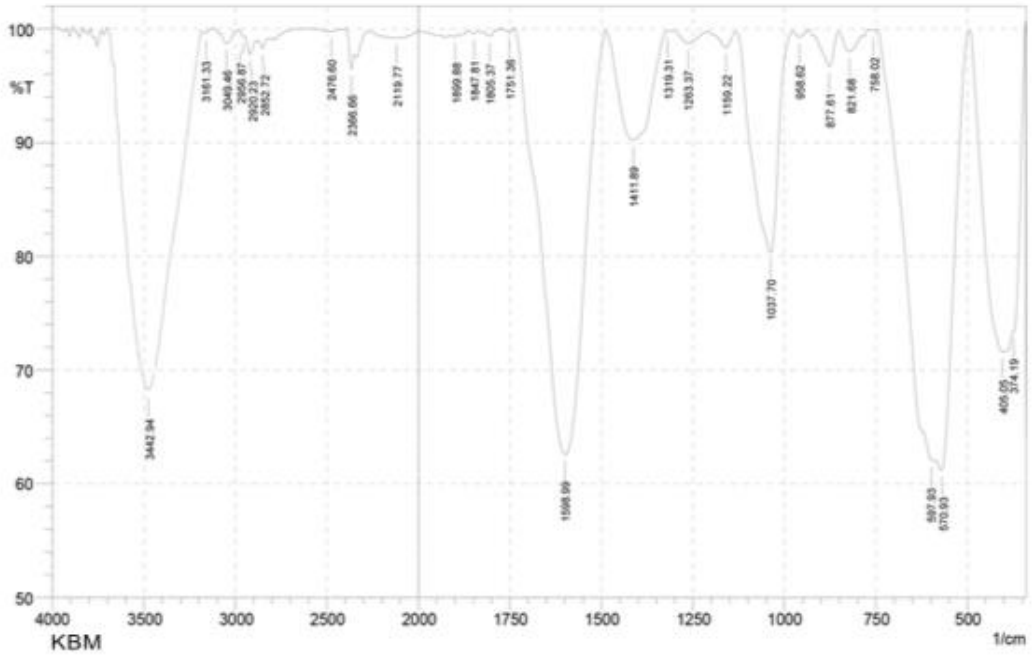


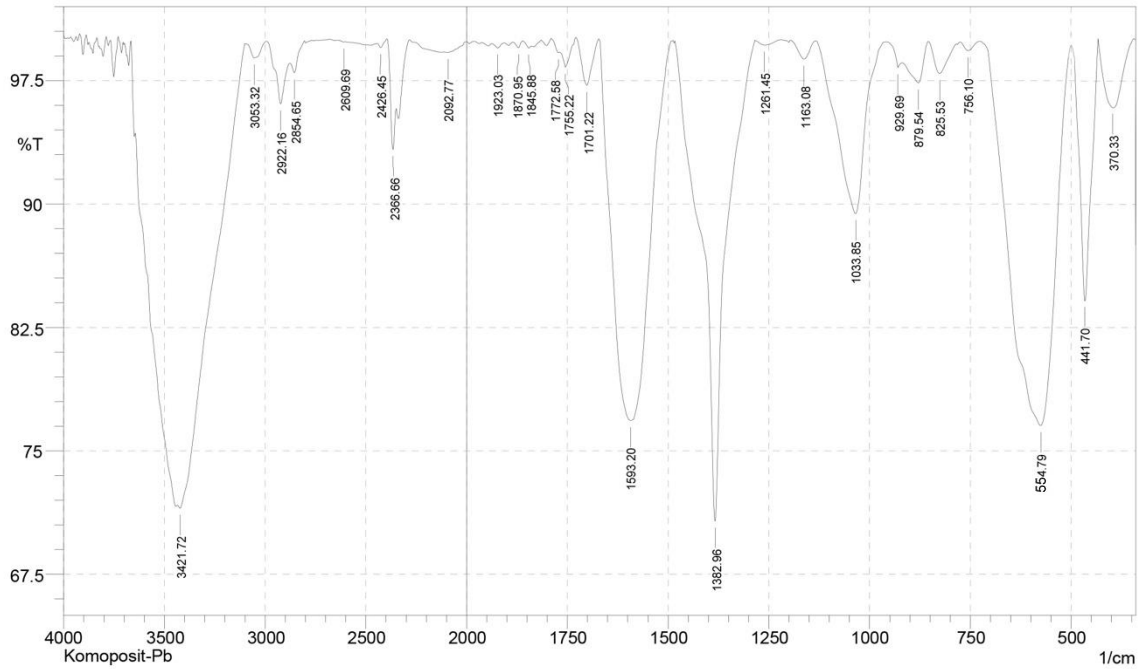
No.	Peak	Intensity	Corr. Intensity	Base (H)	Base (L)	Area	Corr. Area
1	374.19	73.381	1.532	376.12	343.33	2.617	0.495
2	405.05	71.575	1.807	493.78	399.26	8.606	1.63
3	570.93	61.202	8.61	590.22	495.71	11.15	1.945
4	597.93	62.036	1.52	742.59	592.15	16.608	1.364
5	758.02	99.842	0.101	769.6	744.52	0.012	0.006
6	821.68	98.03	1.577	852.54	785.03	0.374	0.253
7	877.61	96.674	2.982	921.97	852.54	0.552	0.434
8	958.62	99.257	0.424	977.91	945.12	0.074	0.031
9	1037.7	80.314	19.471	1132.21	977.91	7.181	7.034
10	1159.22	98.356	1.305	1195.87	1134.14	0.266	0.168
11	1263.37	98.751	1.087	1301.95	1209.37	0.297	0.229
12	1319.31	99.768	0.075	1325.1	1307.74	0.015	0.003
13	1411.89	90.251	9.581	1487.12	1325.1	4.359	4.24
14	1598.99	62.57	37.417	1737.86	1489.05	24.441	24.44
15	1751.36	99.755	0.088	1770.65	1747.51	0.015	0.006
16	1805.37	99.388	0.457	1826.59	1782.23	0.071	0.042
17	1847.81	99.603	0.171	1865.17	1840.09	0.033	0.011
18	1899.88	99.335	0.122	1913.39	1886.38	0.071	0.007
19	2119.77	99.205	0.596	2266.36	2000.18	0.695	0.464
20	2366.66	96.494	2.136	2395.59	2349.3	0.41	0.189
21	2476.6	99.75	0.281	2569.18	2395.59	0.077	0.099
22	2852.72	98.283	0.763	2881.65	2812.21	0.364	0.079
23	2920.23	97.741	1.438	2951.09	2881.65	0.436	0.181
24	2956.87	99.338	0.127	2980.02	2951.09	0.056	0.011
25	3049.46	98.736	1.02	3088.03	2991.59	0.32	0.224
26	3161.33	99.574	0.328	3186.4	3136.25	0.055	0.033
27	3442.94	57.043	2.404	3666.68	3429.43	36.894	5.786

Comment;
KBM

Date/Time; 12/21/2022 1:39:50 PM
No. of Scans;
Resolution;
Apodization;

Lampiran 35. FTIR KBM Setelah Diinteraksikan dengan larutan ion Pb^{2+}

SHIMADZU



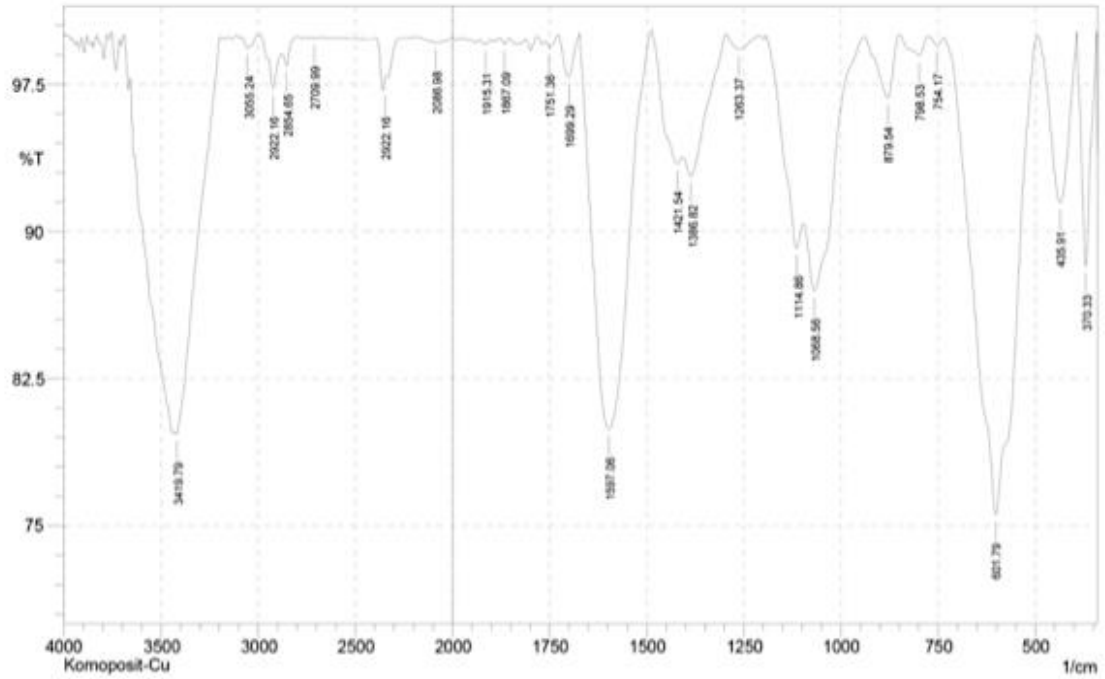
No.	Peak	Intensity	Corr. Intensity	Base (H)	Base (L)	Area	Corr. Area
1	370.33	84.137	15.74	403.12	343.33	2.288	2.259
2	441.7	95.874	4.216	491.85	403.12	0.909	0.943
3	554.79	76.543	23.469	727.16	493.78	13.936	13.921
4	756.1	99.325	0.543	775.38	727.16	0.083	0.056
5	825.53	97.937	1.886	854.47	783.1	0.356	0.297
6	879.54	97.372	2.005	918.12	854.47	0.499	0.287
7	929.69	98.292	0.642	960.55	918.12	0.148	0.004
8	1033.85	89.423	10.464	1134.14	960.55	3.623	3.541
9	1163.08	98.813	1.126	1197.79	1134.14	0.164	0.147
10	1261.45	99.66	0.307	1284.59	1220.94	0.054	0.046
11	1382.96	70.735	29.199	1483.26	1284.59	9.265	9.208
12	1593.2	76.837	23.138	1670.35	1489.05	11.256	11.233
13	1701.22	97.207	2.879	1730.15	1672.28	0.334	0.356
14	1755.22	98.317	1.227	1768.72	1730.15	0.154	0.1
15	1772.58	99.193	0.19	1789.94	1768.72	0.038	0.006
16	1845.88	99.487	0.207	1861.31	1840.09	0.029	0.008
17	1870.95	99.496	0.394	1886.38	1861.31	0.032	0.019
18	1923.03	99.489	0.29	1938.46	1907.6	0.047	0.018
19	2092.77	99.209	0.143	2112.05	2004.04	0.268	0.059
20	2366.66	93.323	4.073	2395.59	2349.3	0.776	0.35
21	2426.45	99.51	0.365	2445.74	2395.59	0.058	0.038
22	2609.69	99.856	0.028	2638.62	2601.97	0.016	0.002
23	2854.65	97.987	1.008	2877.79	2804.5	0.357	0.116
24	2922.16	96.094	2.99	2991.59	2877.79	1.004	0.616
25	3053.32	98.886	0.908	3089.96	2993.52	0.28	0.202
26	3421.72	71.507	1.32	3435.22	3101.54	25.057	1.017

Comment;
Komoposit-Pb

Date/Time; 3/16/2023 2:11:34 PM
No. of Scans;
Resolution;
Apodization;

Lampiran 36. FTIR KBM Setelah Diinteraksikan dengan larutan ion Cu^{2+}

SHIMADZU



No.	Peak	Intensity	Corr. Intensity	Base (H)	Base (L)	Area	Corr. Area
1	370.33	88.24	11.68	393.48	343.33	1.37	1.35
2	435.91	91.47	8.31	493.78	395.41	2.01	1.92
3	601.79	75.56	24.36	734.88	495.71	13.76	13.67
4	754.17	99.51	0.39	771.53	734.88	0.05	0.03
5	798.53	98.96	0.61	819.75	775.38	0.14	0.06
6	879.54	96.81	2.76	920.05	848.68	0.57	0.41
7	1068.56	86.98	5.07	1095.57	941.26	4.72	1.49
8	1114.86	89.13	3	1192.01	1097.5	2.62	0.52
9	1263.37	99.28	0.75	1296.16	1211.3	0.15	0.15
10	1386.82	92.83	2.06	1406.11	1296.16	2	0.51
11	1421.54	93.44	1.44	1487.12	1408.04	1.55	0.46
12	1597.06	79.94	20.2	1672.28	1489.05	9.41	9.53
13	1699.29	97.9	2.16	1728.22	1672.28	0.27	0.28
14	1751.36	99.36	0.41	1761.01	1728.22	0.05	0.03
15	1867.09	99.55	0.3	1878.67	1853.59	0.03	0.01
16	1915.31	99.52	0.23	1928.82	1897.95	0.05	0.01
17	2086.98	99.62	0.04	2179.56	2075.41	0.12	0.02
18	2358.94	93.323	4.073	2391.73	2343.51	0.776	0.35
19	2709.99	99.85	0.03	2723.49	2677.2	0.03	0
20	2854.65	98.45	0.84	2877.79	2794.85	0.26	0.07
21	2922.16	97.27	2.15	2995.45	2877.79	0.65	0.41
22	3055.24	99.33	0.62	3084.18	2995.45	0.13	0.12
23	3419.79	79.66	1.12	3431.36	3196.05	11.98	0.58

Comment;
Komoposit-Cu

Date/Time; 3/16/2023 2:16:28 PM
No. of Scans;
Resolution;
Apodization;

Ukuran kristal sampel Magnetit dan komposit biochar magnentit dihitung menggunakan persamaan *Debye-Scherrer*

$$D = \frac{k\,\lambda}{\beta \cos\theta}$$

Dimana

k= 0.9 θ
λ = 0.15406 nm
β = nilai FWHM
θ = sudut difraksi

Sampel	**2θ**	**θ**	**cos θ**	**FWHW**		**D (nm)**
				deg	**rad**	
Magnetit (Fe_3O_4)	18,269	9,1345	0,98732	0,36	0,00628	22,3509
	30,095	15,0475	0,96571	0,55	0,0096	14,957
	35,4325	17,7163	0,95258	0,565	0,00986	14,7607
	43,08	21,54	0,9316	0,56	0,00977	15,2514
	53,34	26,67	0,89361	0,28	0,00489	31,7505
	57,06	28,53	0,87857	0,72	0,01257	12,5588
	62,65	31,325	0,85423	0,62	0,01082	14,9999
Ukuran rata-rata kristal						**18,090**
Komposit *biochar* magnetit (KBM)	18,78	9,39	0,9866	0,6	0,01047	13,4203
	30,6166	15,3083	0,96452	0,7533	0,01315	10,9339
	35,9716	17,9858	0,95113	0,7567	0,01321	11,038
	43,64	21,82	0,92836	0,76	0,01326	11,2597
	53,94	26,97	0,89124	0,72	0,01257	12,3801
	57,05	28,525	0,87861	0,72	0,01257	12,5582
	63,1383	31,5692	0,85201	0,823	0,01436	11,3295
Ukuran rata-rata kristal						**11,8457**

A. Sampel Magnetit (Fe_3O_4)

2θ = 35,4325

$$D = \frac{k\lambda}{\beta \cos\theta}$$

$$D = \frac{(0,9)\ (0,15405\ nm)}{Rad\ (0,565)\ cos\ (35,4325)}$$

$$= \frac{(0,9)(0,15405\ nm)}{0,00986\ cos\ (Rad\ 35,4325/2)}$$

$$= \frac{0,13865}{(0,00986)\ (0,95258)}$$

= 14,7607 nm

B. Sampel Komposit Biochar Magnetit (KBM)

2θ = 35,9716

$$D = \frac{k\lambda}{\beta \cos\theta}$$

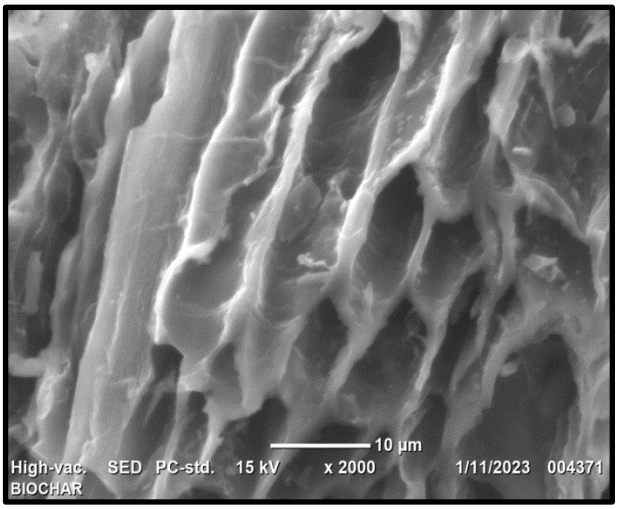
$$D = \frac{(0,9)\ (0,15405\ nm)}{Rad\ (0,7567)\ cos\ (35,9716)}$$

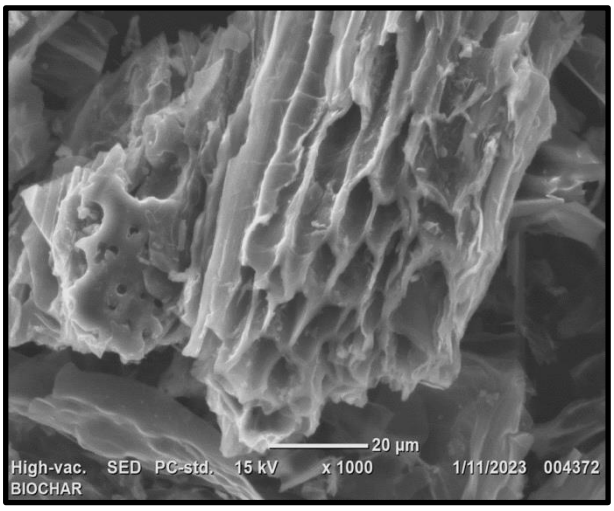
$$= \frac{(0,9)(0,15405\ nm)}{(0,01321)\ cos\ (Rad\ 35,9716/2)}$$

$$= \frac{0,13865}{(0,00986)\ (0,95113)}$$

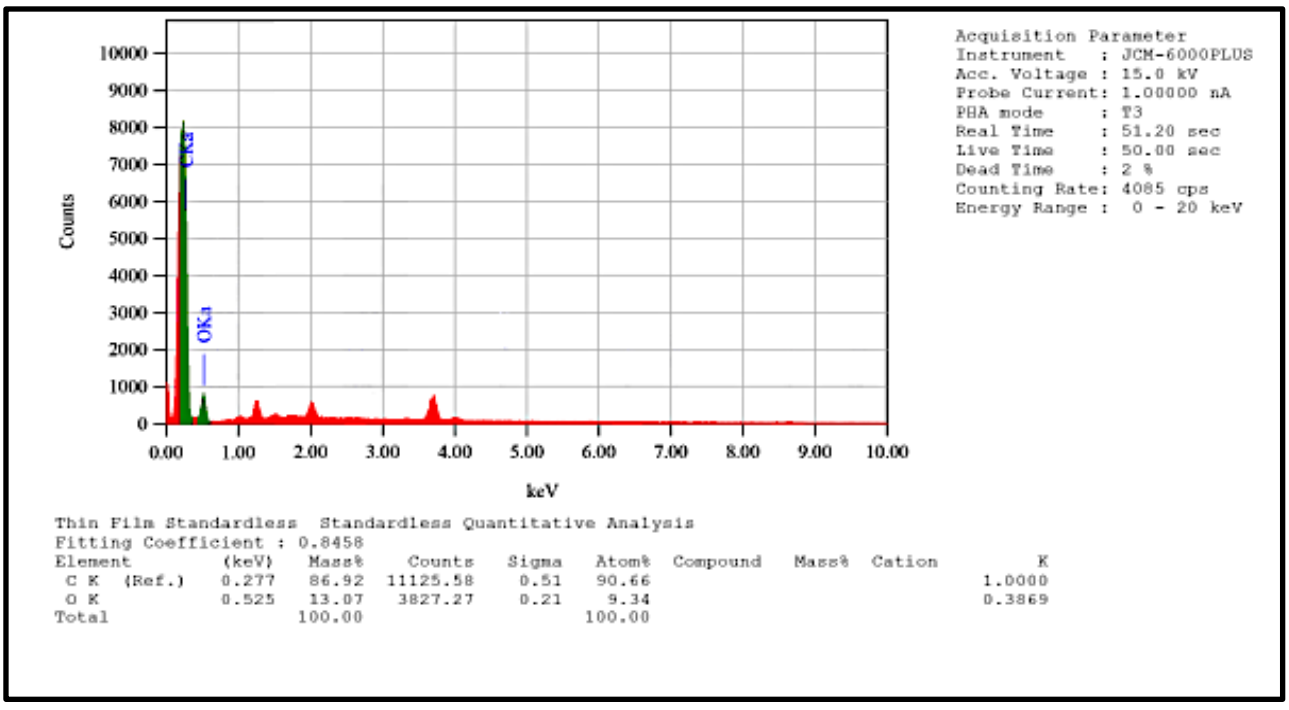
= 11,0380 nm

Lampiran 38. SEM-EDX BEG



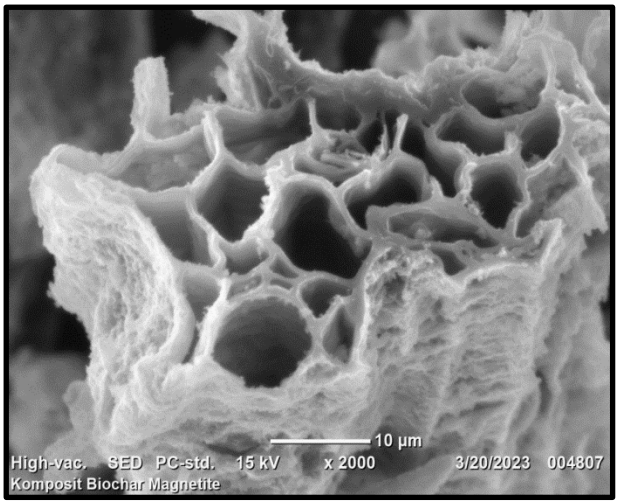


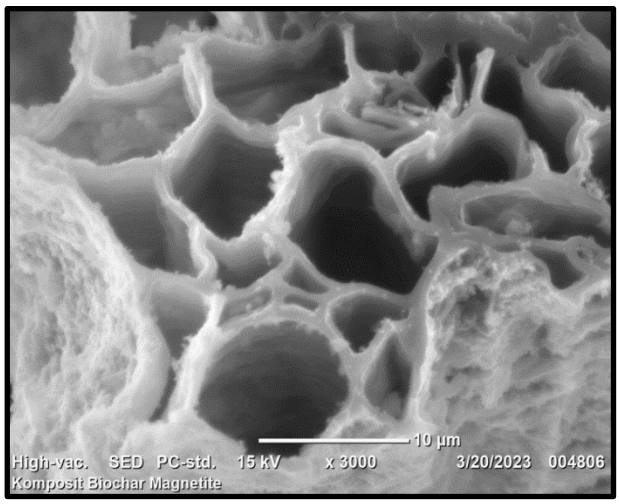
SEM BEG



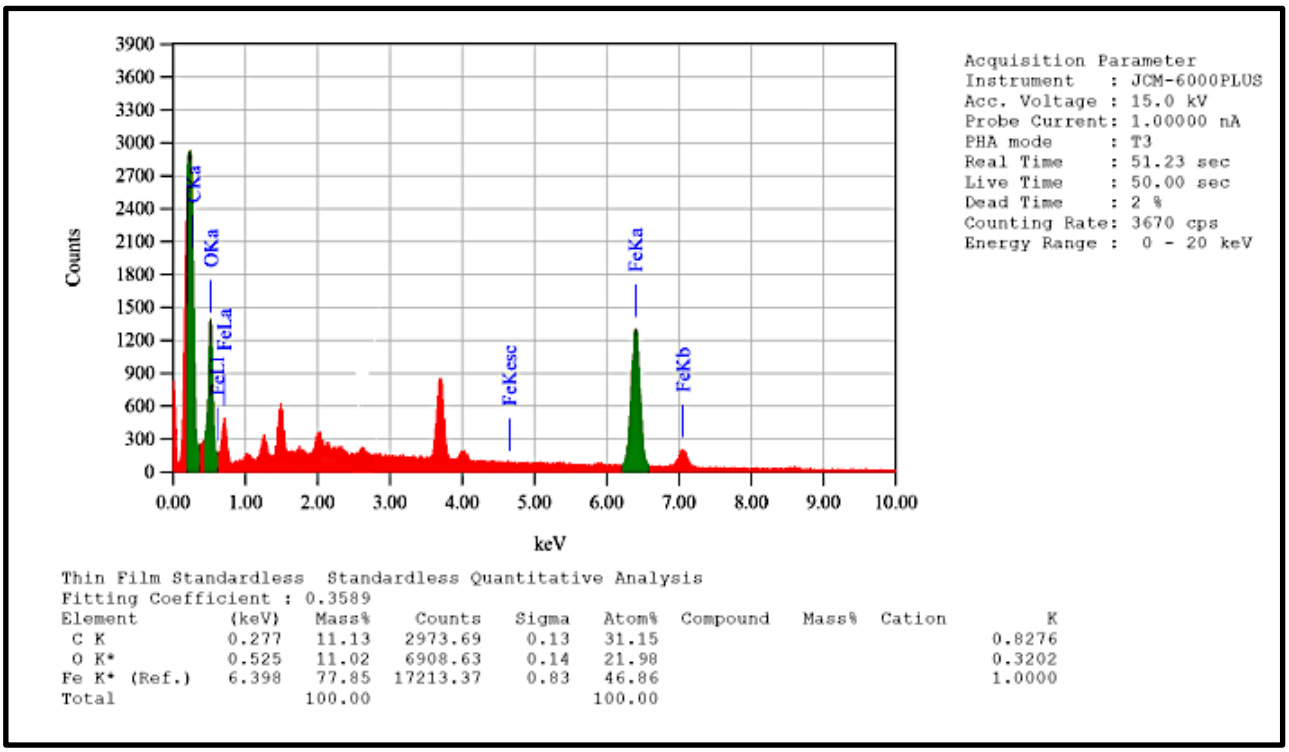
EDX BEG

Lampiran 39. SEM-EDX KBM





SEM (KBM)



EDX KBM

Lampiran 40. BET-BJH BEG

POLITEKNIK NEGERI UJUNG PANDANG

JURUSAN TEKNIK KIMIA

Quantachrome Touchwin v1.2.2

Report date: Fri Dec 23 2022 Operator: Rifai

Filename: Composite.acuPhysiso

Analysis Data

Sample

ID: BIOCHAR Weight: 0.1721 g

Description:

Analysis

Data ID: {8be89325-de6f-4d00-8534-2bddd3d31f87}

Operator: Rifai Date: 2022.12.20 Duration: 149.2 min

Instrument: St 2 on NOVA touch 2LX [s/n:1050025524] Firmware: 1.07

Comments:

Ambient Temp.: 29.75K Void Volume Mode: NOVA mode Cell ID: 5_A

Cell Type: 9mm with rod Thermal Delay: 600 sec Po Mode: Measure

Adsorbate

Name: Nitrogen Molecular Weight: 28.013 g/mol Cross Section Area: 16.2 Å²/mol

Non-ideality: 6.580000e-05 /atm Bath Temperature: 77.35K

Degas Information

Type: Vacuum Degassing

Operator: Rifai

Description:

Heating: Heat to 125.0 °C at 10.0 °C/min then hold for 60 min
Heat to 300.0 °C at 10.0 °C/min then hold for 30 min

Data Reduction Parameters

Data Reduction Parameters

Thermal Transpiration: no

Temp. Comp: no

Thickness Method: deBoer

P-tags below 0.35: included Moving Pt. Average: off

Adsorbate Model

Name: Nitrogen Molecular Weight: 28.0134 g Cross Section Area: 16.2 Å²/mol

Bath Temperature: 77.35K

Multipoint BET Summary/Results

Isotherm Branch: Adsorption Slope: 105.216 Intercept: -16.9711

Correlation coeff., r: 0.948052 C constant: -5.19974 Surface area: 39.464 m²/g

BET-Multi-point BET

Relative Pressure	Volume Adsorbed @STP cc/g	1 / [W((P/Po) - 1)]
0.0988092	19.6318	4.4685
0.140051	20.6820	6.3004
0.180716	21.6029	8.1695
0.223728	22.5209	10.2394
0.266055	23.4374	12.3751
0.308441	24.2824	14.6950
0.349306	25.2825	16.9857
0.391833	26.1329	19.7261
0.434275	27.2857	22.5100
0.476041	28.3243	25.6648
0.519105	29.5490	29.2290
0.560438	30.9601	32.9501
0.602264	32.4197	37.3709
0.643398	33.9949	42.4651
0.688493	36.8278	48.0152
0.730157	39.8439	54.3357
0.771853	43.5550	62.1486
0.814169	47.8008	73.3350
0.853173	53.3201	87.1946
0.896850	70.1256	99.2032

Average Pore Size Summary/Results

Average Pore radius: 5.3221e+00 nm

Total Pore Volume Summary/Results

Total Pore Volume: 4.5820e-02 cc/g for pores smaller than 5.12 nm (radius) at relative pressure 0.51911

POLITEKNIK NEGERI UJUNG PANDANG

JURUSAN TEKNIK KIMIA

Quantachrome TouchWin v1.2.2

Report date: Fri Dec 23 2022 Operator: Rifai

Filename: Composite.acuPhysIso

Isotherm-Isotherm

Relative Pressure, P/Po	Volume Adsorbed @STP cc/g
0.098802	19.6318
0.140051	20.6820
0.180716	21.6029
0.223728	22.5209
0.266055	23.4374
0.308441	24.2824
0.349306	25.2825
0.391833	26.1329
0.434275	27.2857
0.476041	28.3243
0.519105	29.5490
0.560438	30.9601
0.602264	32.4197
0.643398	33.9949
0.688493	36.8278
0.730157	39.8439
0.771853	43.5550
0.814169	47.8008
0.853173	53.3201
0.896850	70.1256
0.860945	66.4963
0.819038	59.1694
0.776915	53.5796
0.735572	48.9164
0.692239	42.9187
0.649435	39.4349
0.606308	36.9112
0.567812	35.6311
0.524964	34.1847
0.481167	32.2972
0.439512	31.1920
0.397818	29.8839
0.355390	28.7649
0.312287	27.8202
0.270512	26.9829
0.230366	26.1577
0.188555	25.2622
0.146149	24.3464
0.103423	23.2389

Lampiran 41. BET KBM

POLITEKNIK NEGERI UJUNG PANDANG

JURUSAN TEKNIK KIMIA

Quantachrome TouchWin v1.2.2

Report date:	Fri Dec 23 2022	Operator:	Rifai
Filename:	Composite.qcuPhysIso		

Analysis Data

Sample	KBM				
ID		Weight	0.1721 g		
Description					
Analysis					
Data ID	{8be89325-de6f-4d00-8534-2bddd3d31f87}				
Operator	Rifai	Date	2022.12.20	Duration	149.2 min
Instrument	St 2 on NOVA touch 2LX [s/n:1050025524]			Firmware	1.07
Comments					
Ambient Temp.	29.75K	Void Volume Mode	NOVA mode	Cell ID	5_A
Cell Type	9mm with rod	Thermal Delay	600 sec	Po Mode	Measure
Adsorbate					
Name	Nitrogen	Molecular Weight	28.013 g/mol	Cross Section Area	16.2 Å²/mol
Non-ideality	6.580000e-05 1/atm	Bath Temperature	77.35K		
Degas Information					
Type	Vacuum Degassing				
Operator	Rifai				
Description					
Heating	Heat to 125.0 °C at 10.0 °C/min then hold for 60 min Heat to 300.0 °C at 10.0 °C/min then hold for 30 min				

Data Reduction Parameters

Data Reduction Parameters					
Thermal Transpiration	no				
Temp. Comp	no				
Thickness Method	deBoer				
P-tags below 0.35	included			Moving Pt. Average	off
Adsorbate Model					
Name	Nitrogen	Molecular Weight	28.0134 g	Cross Section Area	16.2 Å²/molec
Bath Temperature	77.35K				

Multipoint BET Summary/Results

Isotherm Branch	Adsorption	Slope	46.738	Intercept	1.274
Correlation coeff., r	0.997448	C constant	37.681	Surface area	72.537 m²/g

BET-Multi-point BET

Relative Pressure	Volume Adsorbed @STP cc/g	1 / [W((P/Po) - 1)]
0.034663	12.0034	2.3935
0.060734	13.1959	3.9206
0.092358	14.2742	5.7037
0.120151	15.2532	7.1732
0.154077	16.5187	8.8223
0.185305	17.7388	10.2590
0.217836	19.0988	11.6670
0.247148	20.4044	12.8730
0.277089	21.8764	14.0190
0.306611	23.3040	15.1820

Average Pore Size Summary/Results

Average Pore radius	10.0586e+00 nm

Total Pore Volume Summary/Results

Total Pore Volume	1.824e-01 cc/g	for pores smaller than	13.76 nm (radius)	at relative pressure	0.98585

POLITEKNIK NEGERI UJUNG PANDANG

JURUSAN TEKNIK KIMIA

Quantachrome T ouchWin v1 .2 2

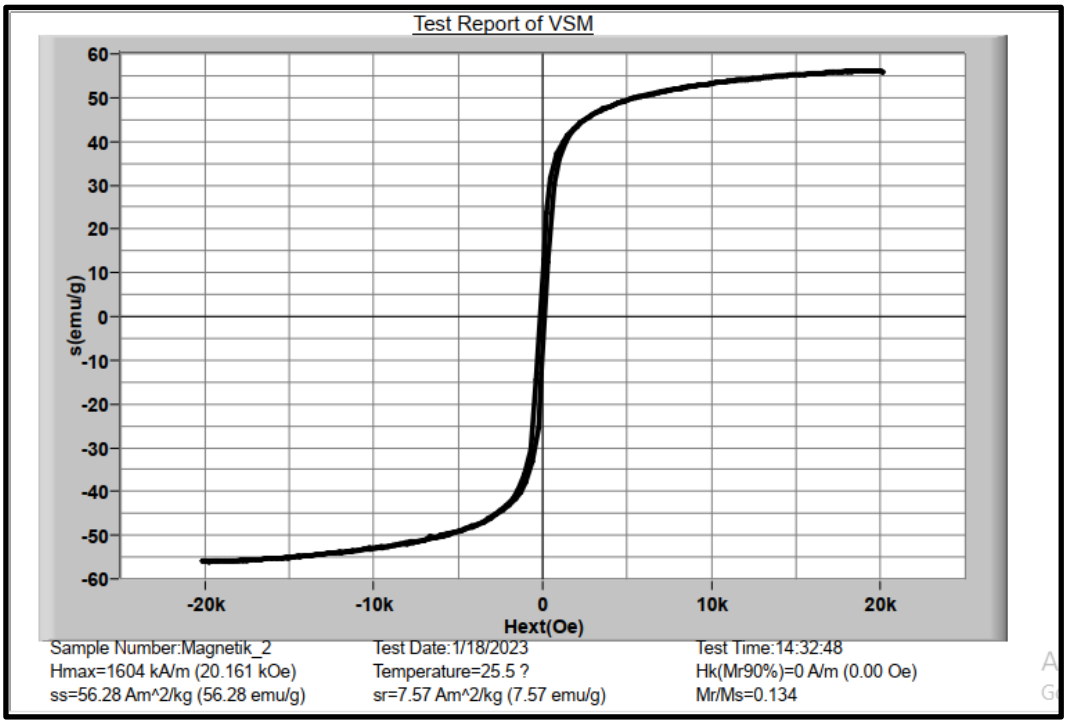
Report date: Fri Dec 23 2022 Operator: Rifal

Filename: Composite qcuPhysI so

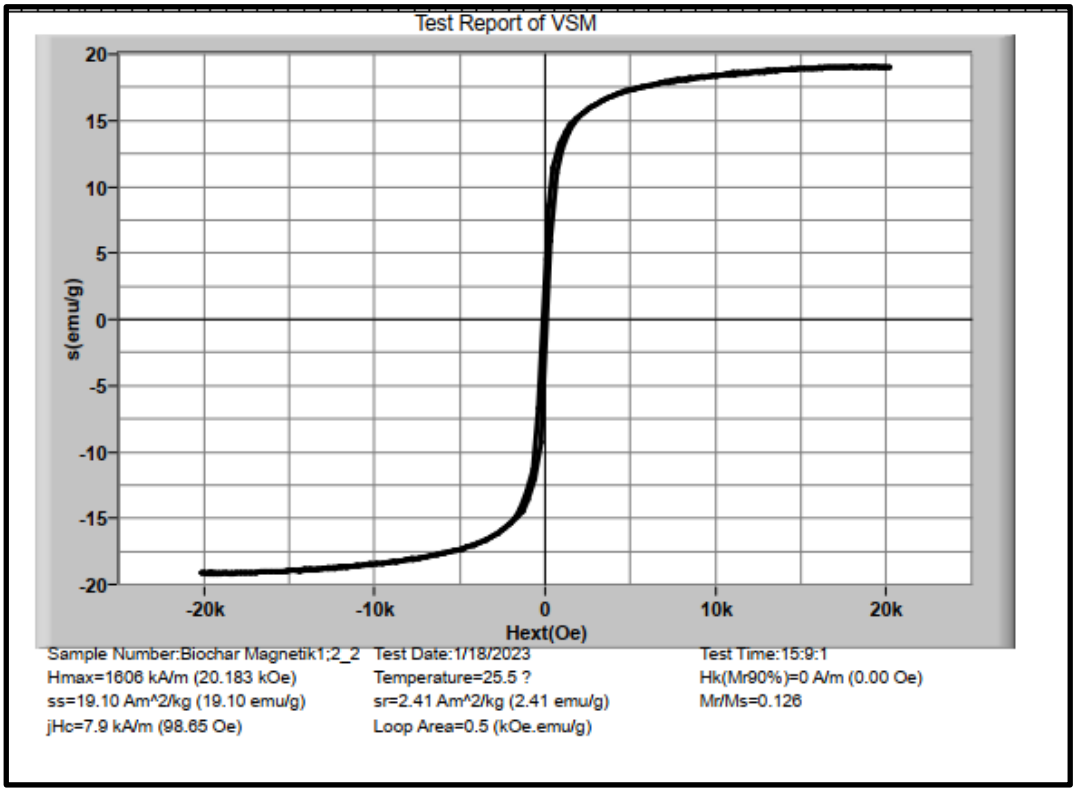
Isotherm-Isotherm

Relative Pressure, P/Po	Volume Adsorbed @STP cc/g
0.034663	12.0034
0.060734	13.1959
0.092358	14.2742
0.120151	15.2532
0.154077	16.5187
0.185305	17.7388
0.217836	19.0988
0.247148	20.4044
0.277089	21.8764
0.306611	23.3040
0.339390	25.0893
0.368879	26.8161
0.400117	28.7281
0.429313	30.6345
0.458835	32.8527
0.491947	35.2973
0.522020	37.8777
0.555844	41.0336
0.588485	44.6665
0.614502	48.0123
0.642992	52.0447
0.674538	57.3478
0.704828	63.5580
0.741996	73.6404
0.769192	82.8518
0.801614	93.5133
0.832361	98.8917
0.864194	101.6196
0.900385	104.4932
0.930232	107.4772
0.955908	110.7548
0.985849	117.9007
0.948881	113.7236
0.871282	108.9326
0.798171	105.2022
0.721671	101.3686
0.642853	86.9513
0.564841	60.7067
0.479346	49.1466
0.412237	42.0076
0.332023	35.7769
0.258090	30.1990
0.181699	24.4574
0.101035	18.3388

Lampiran 42. VSM Magnetit



Lampiran 43. VSM KBM



Lampiran 44. Dokumentasi Kegiatan Penelitian

Pengeringan tanaman eceng gondok

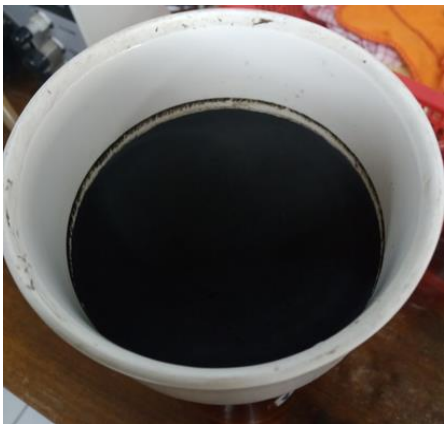
Proses Pirolisis

Proses penumbuhan tanaman eceng gondok selama 90 hari

Hasil BEG setelah proses pirolisis

Aktivasi BEG dengan $ZnCl_2$

Proses penyaringan BEG hingga pH netral

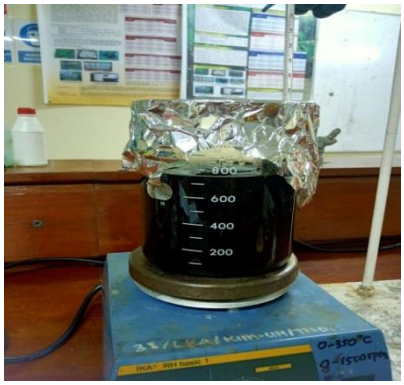


BEG setelah dioven

Larutan Fe^{3+} dan Fe^{2+}

Sintesis magnetit dari larutan campuran Fe^{3+} dan Fe^{2+} dan NaOH

Terbentuknya magnetit yang dapat ditarik oleh magnet



Sintesis KBM

Proses pemisahan KBM dengan menggunakan magnet

Hasil magnetit dan KBM setelah dioven

Magnetit dan KBM yang dapat ditarik dengan magnet

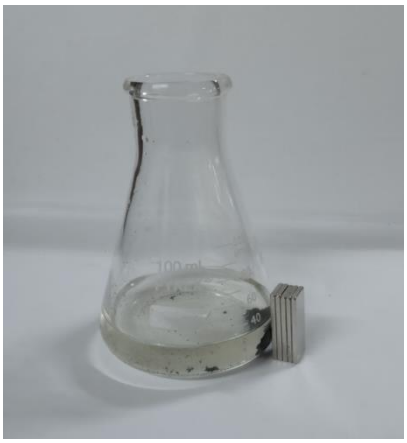
Larutan induk Pb^{2+} 1000 mg/L dan Cu^{2+} 1000 mg/L

Proses adsorpsi ion Pb^{2+} dan Cu^{2+} dengan KBM

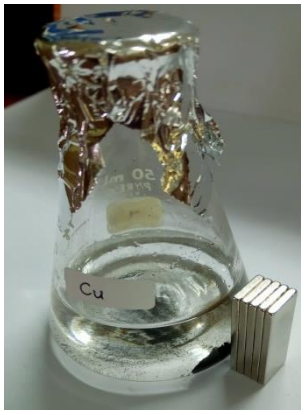
Hasil fitrat setelah proses adsorpsi

Analisis ion Pb^{2+} dan Cu^{2+} dengan SSA

Air limbah sablon

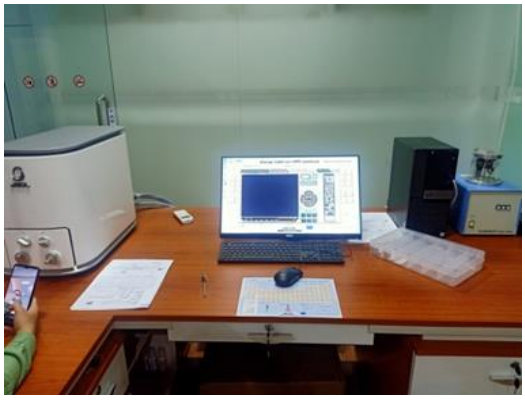


Aplikasi KBM pada air limbah sablon



Desorpsi ion Cu^{2+} dari KBM

Desorpsi ion Pb^{2+} dari KBM



Karakterisasi dengan SEM-EDX

Karakterisasi dengan BET-BJH

Karakterisasi dengan XRD

Karakterisasi dengan FTIR

Karakterisasi dengan VSM