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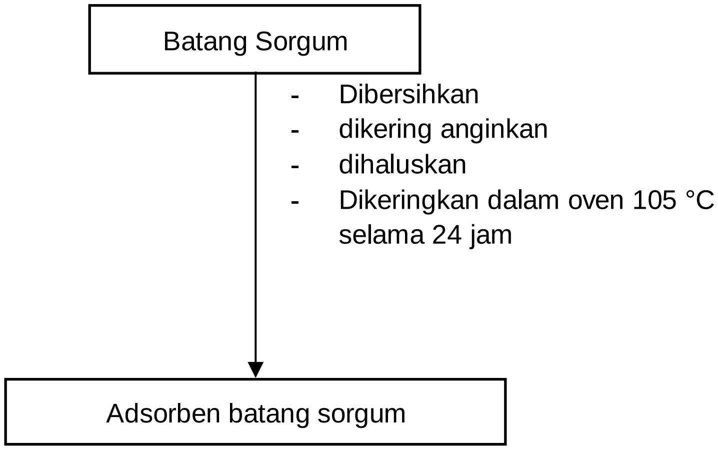
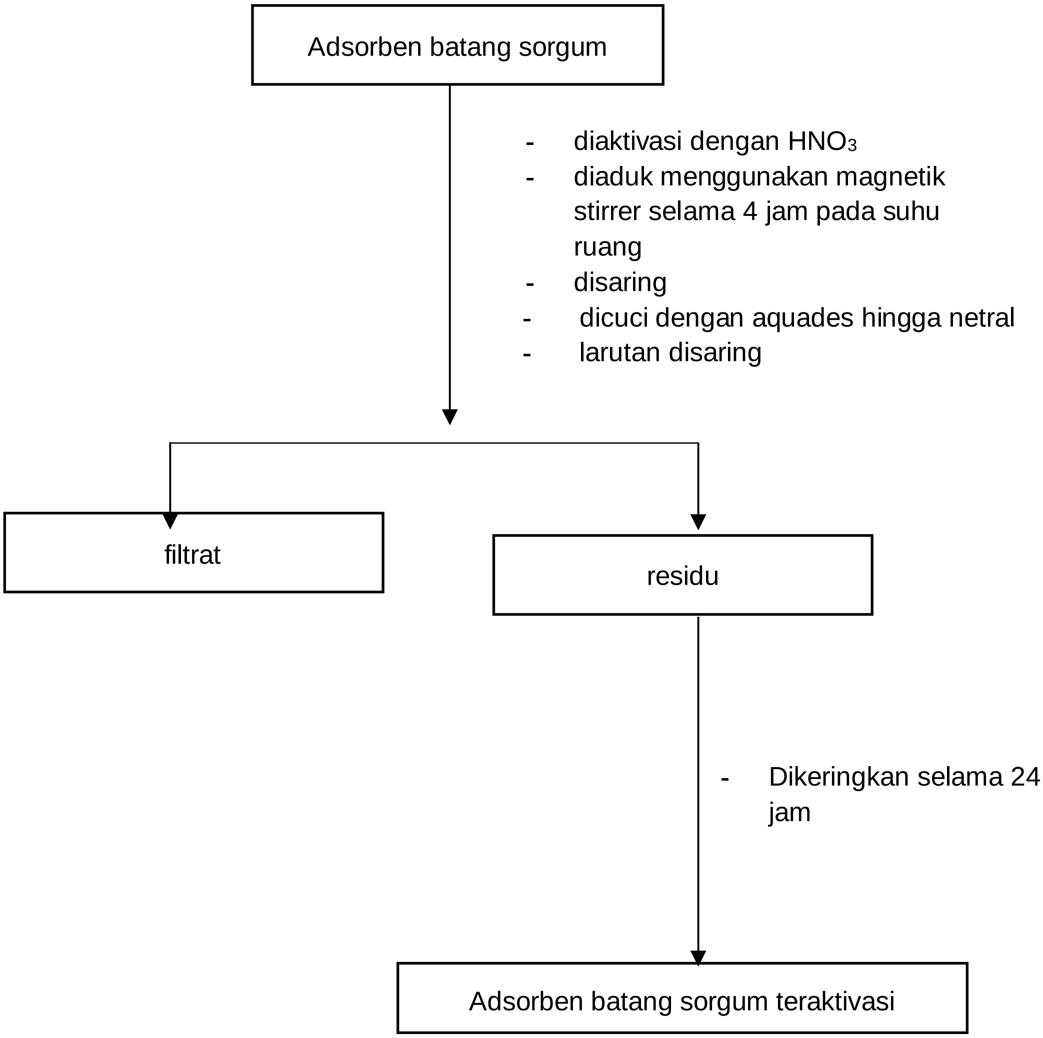
LAMPIRAN

Lampiran 1. Bagan Kerja Penelitian

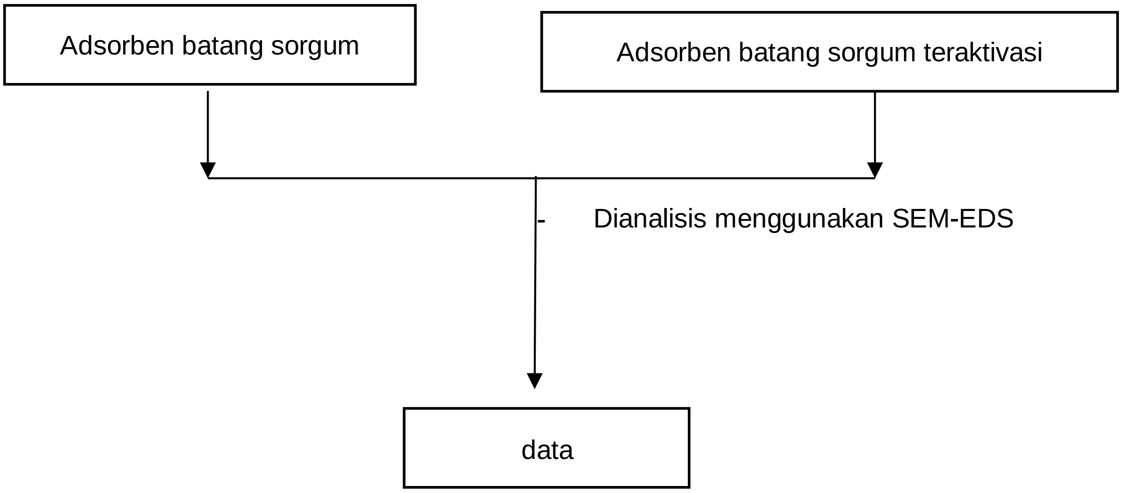
1. Pembuatan Adsorben Batang Sorgum



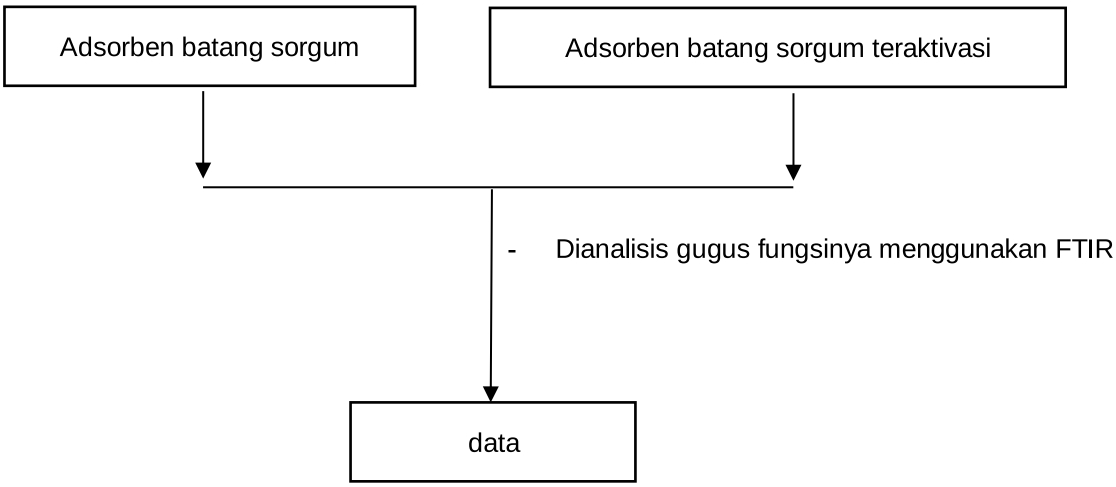
2. Pembuatan Adsorben Batang Sorgum Teraktivasi Asam Nitrat



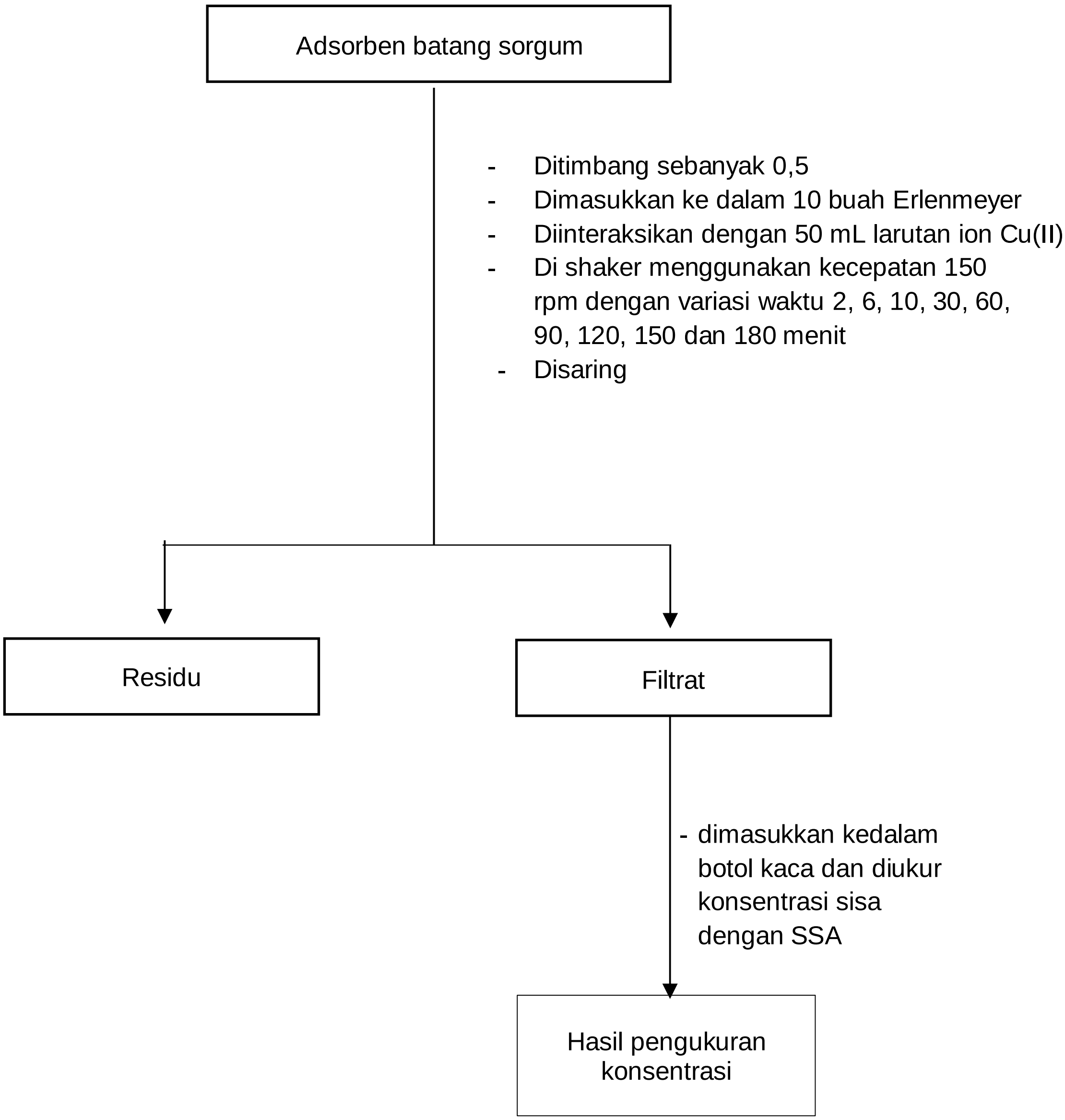
3. Karakterisasi Adsorben Batang Sorgum dengan SEM-EDS



4. Karakterisasi Adsorben Batang Sorgum dengan FTIR

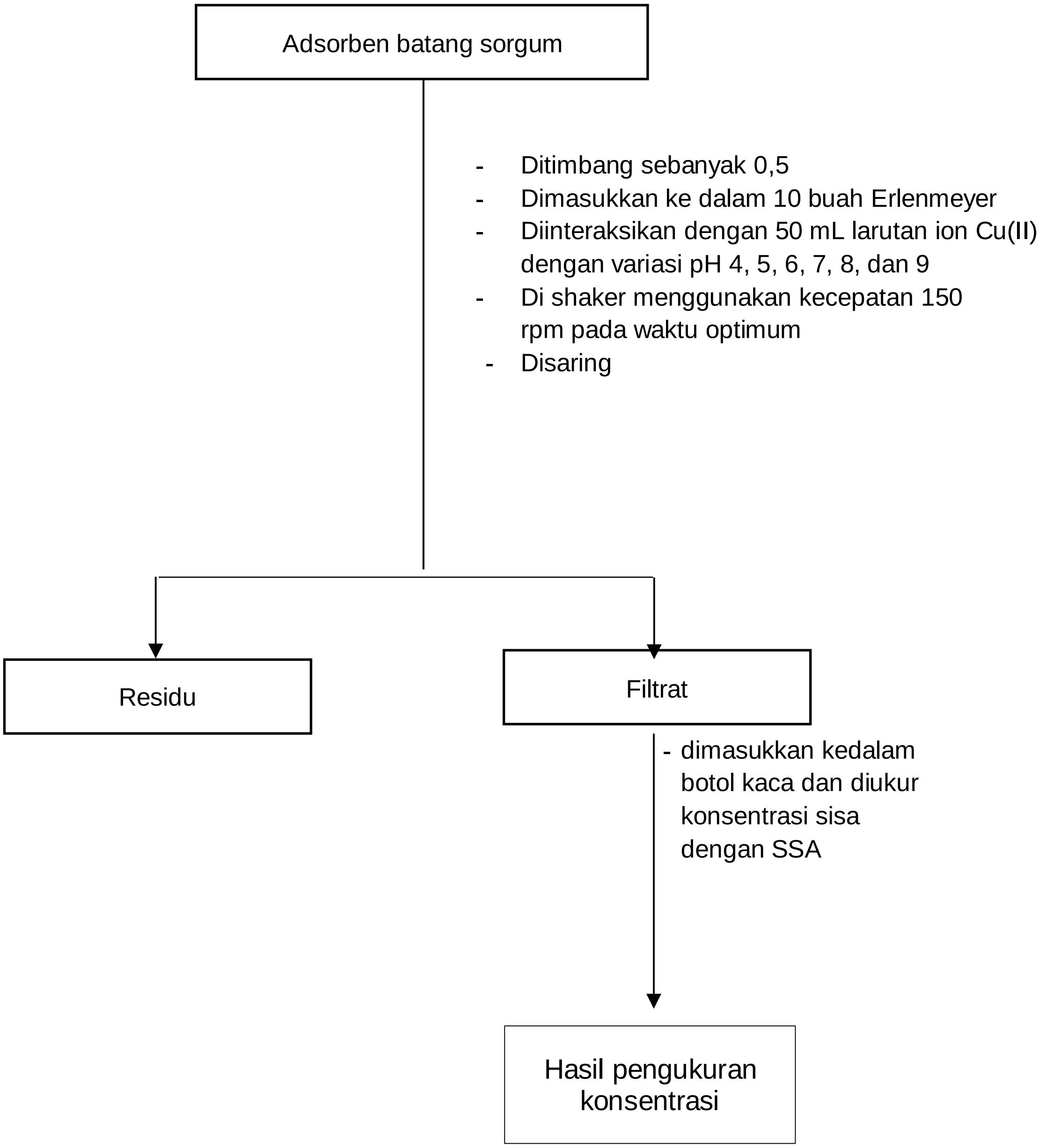


5. Penentuan Kondisi Waktu Optimum Adsorpsi Ion Cu(II) dan Pb(II)



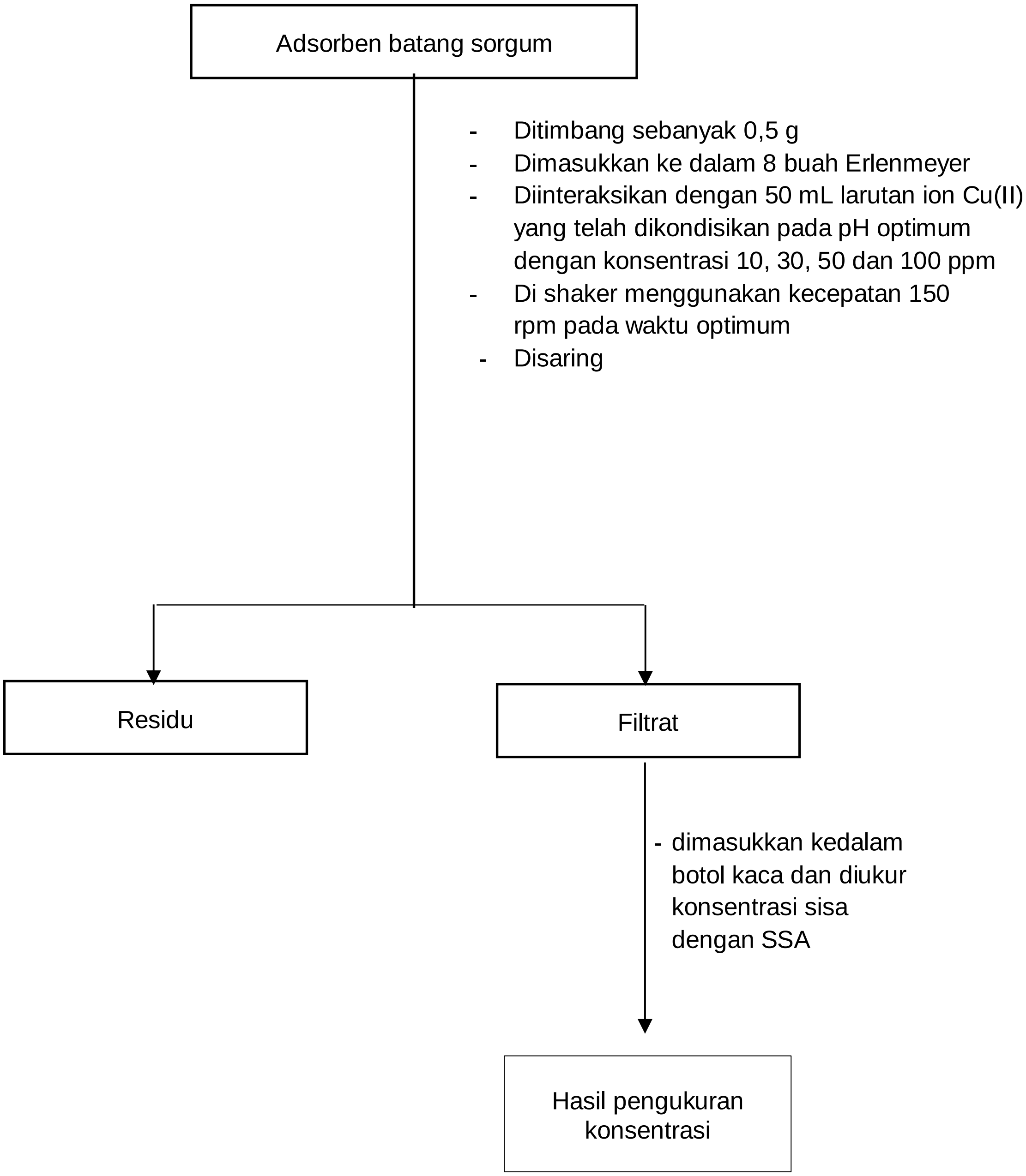
catatan: hal yang sama dilakukan untuk ion Pb(II)

6. Penentuan Kondisi pH Optimum Adsorpsi Ion Cu(II) dan Pb(II)



catatan: hal yang sama dilakukan untuk adsorben batang sorgum teraktivasi

7. Penentuan kapasitas adsorpsi ion Cu(II)



catatan: hal yang sama dilakukan untuk adsorben batang sorgum teraktivasi

8. Penentuan efektivitas adsorpsi ion Cu(II) dan Pb(II)

Adsorben batang sorgum

- Ditimbang sebanyak 0,5 g
- Dimasukkan ke dalam 2 buah Erlenmeyer
- Diinteraksikan dengan 25 mL larutan ion Cu(II) dan Pb(II)
- Di shaker menggunakan kecepatan 150 rpm pada waktu optimum
- Disaring

Residu

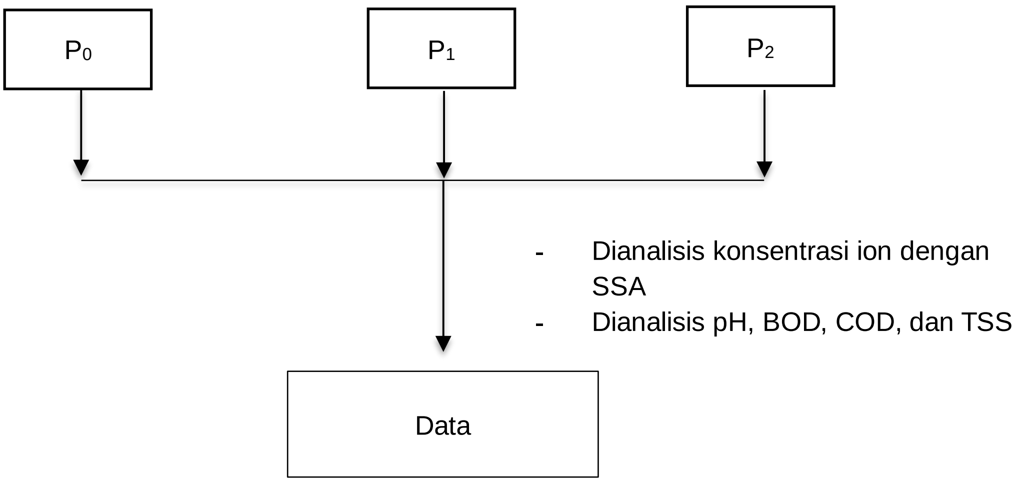
Filtrat

- Dimasukkan kedalam botol kaca dan diukur konsentrasi sisa dengan SSA

Hasil pengukuran konsentrasi

catatan: hal yang sama dilakukan untuk adsorben batang sorgum teraktivasi

9. Aplikasi air limbah laboratorium



10. Pembuatan Larutan

a. Pembuatan Larutan Baku Cu(II)

Padatan $CuSO4.5H_2O$

- Ditimbang 3,9291 g
- Dilarutkan kedalam gelas kimia
- Dimasukkan kedalam labu takar 1.000 mL
- Ditambahkan dengan aquades hingga tanda batas
- Dikocok

↓

Larutan baku Cu(II)

b. Pembuatan Larutan Baku Pb(II)

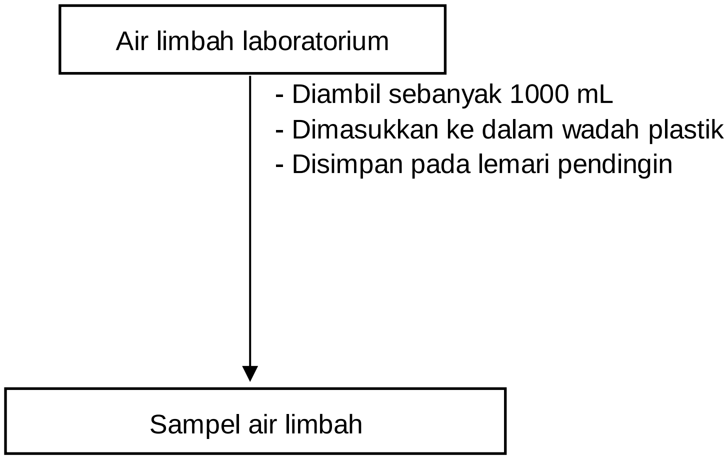
Padatan $Pb(NO_3)_2.4H_2O$

- Ditimbang 1,5984 g
- Dilarutkan kedalam gelas kimia
- Dimasukkan kedalam labu takar 1.000 mL
- Ditambahkan dengan aquades hingga tanda batas
- Dikocok

↓

Larutan baku Pb(II)

11. Penentuan Awal Parameter Kualitas Air Limbah



Lampiran 2. Dokumentasi Penelitian

Pengambilan sampel

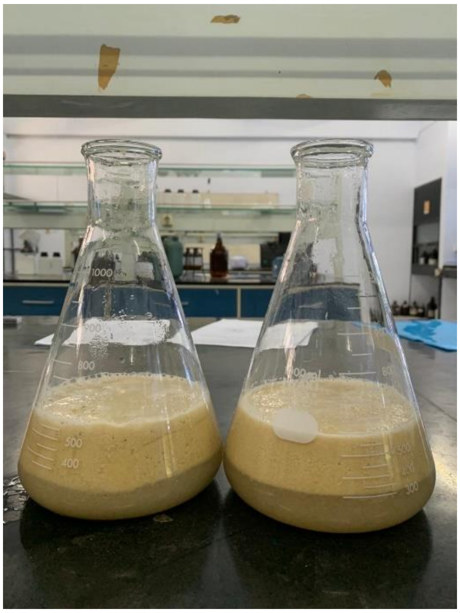
Pencucian

Pengeringan

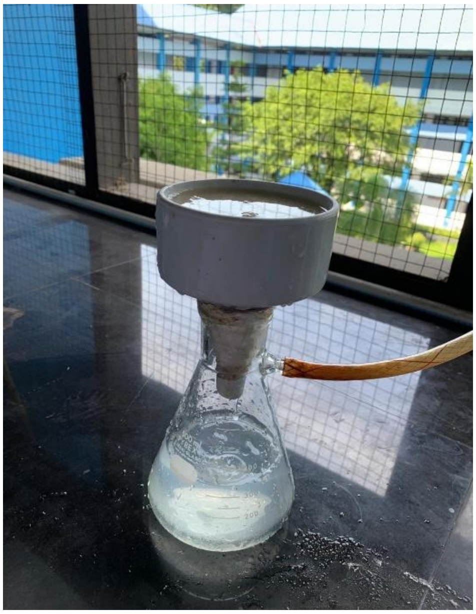
Proses penghalusan

Proses Pencucian

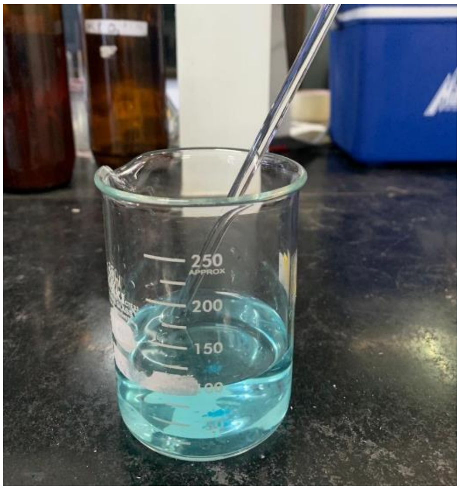
Pengeringan dengan oven



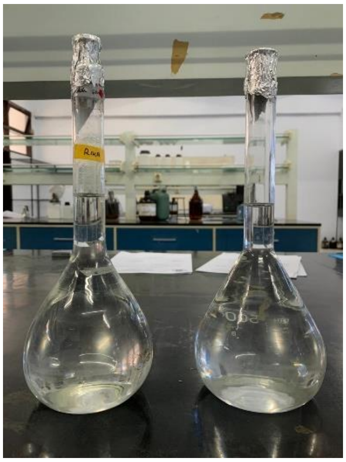
Proses Aktivasi



Proses Penyaringan

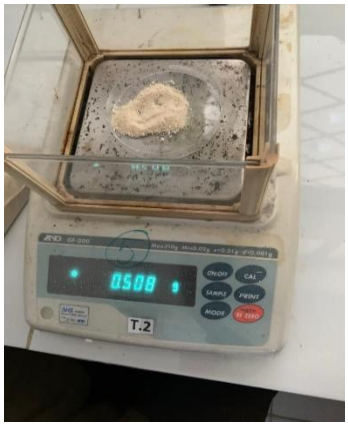


Pembuatan Larutan Cu(II)



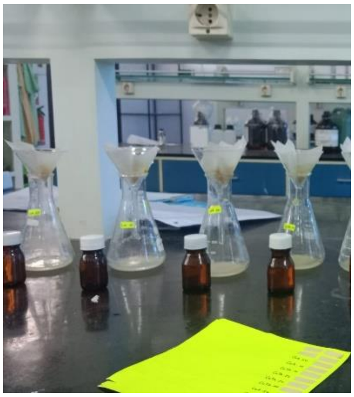
Pembuatan Larutan Pb(II)

Limbah Laboratorium



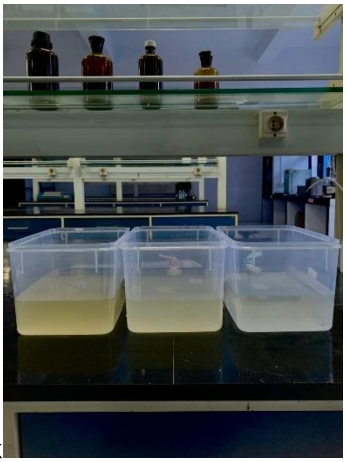
Penimbangan adsorben

Proses pengadukan menggunakan *shaker*



Proses Penyaringan setelah di*shaker*

reik

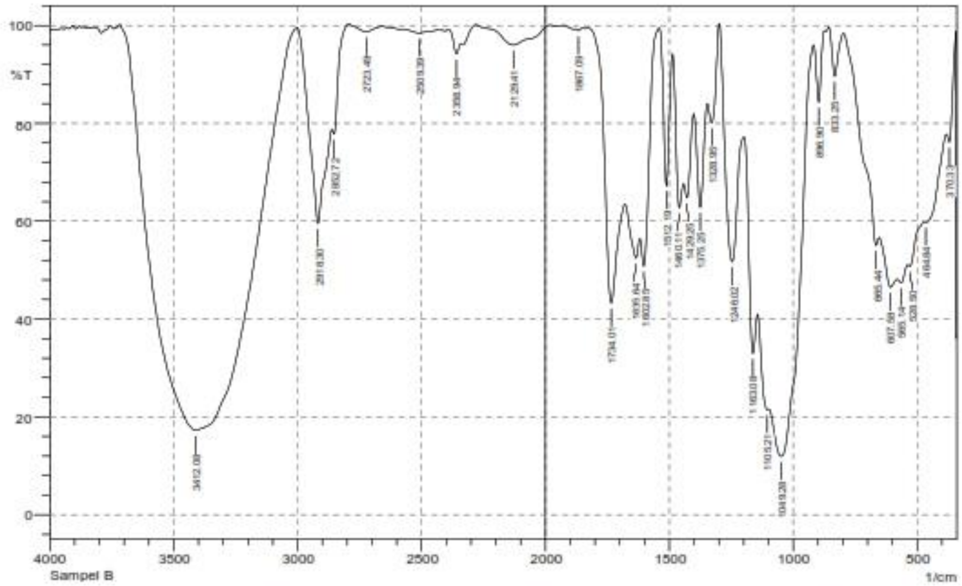


Aplikasi pada limbah laboratorium

Hasil aplikasi

Analisis AAS

Lampiran 3. Data Karakterisasi FTIR



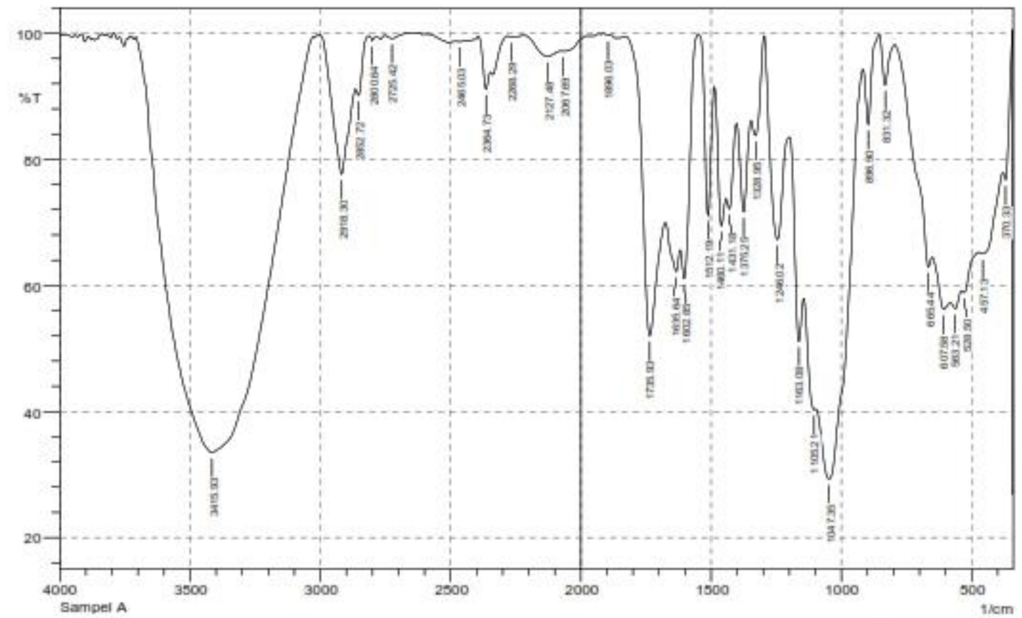
No.	Peak	Intensity	Corr. Intensity	Base (H)	Base (L)	Area	Corr. Area
1	370.33	76.168	7.684	381.91	345.26	2.941	0.85
2	464.84	59.764	0.826	468.7	383.83	15.14	1.139
3	526.5	50.791	1.536	538.14	470.63	17.11	0.208
4	565.14	47.416	1.697	578.64	540.07	12.066	0.324
5	607.58	46.499	4.616	651.94	580.57	21.661	1.435
6	665.44	55.041	4.962	796.6	653.87	17.516	0.582
7	833.25	69.643	9.506	856.39	796.53	1.365	1.132
8	896.9	84.386	13.027	918.12	875.68	1.684	1.211
9	1049.28	11.961	29.766	1097.5	920.05	95.392	35.926
10	1105.21	21.446	2.616	1143.79	1099.43	25.198	1.618
11	1163.08	33.034	19.898	1197.79	1145.72	17.322	4.148
12	1246.02	51.749	36.342	1298.09	1199.72	16.725	11.161
13	1328.95	80.135	9.965	1346.31	1300.02	3.043	1.392
14	1375.25	62.842	19.959	1400.32	1348.24	7.273	3.024
15	1429.25	64.801	7.029	1440.83	1402.25	5.72	0.853
16	1460.11	62.737	15.582	1485.19	1442.75	6.337	2.005
17	1512.19	67.346	29.243	1541.12	1487.12	4.384	3.565
18	1602.85	50.879	14.344	1618.28	1543.05	10.205	2.168
19	1635.64	52.488	5.772	1678.07	1620.21	14.343	1.373
20	1734.01	43.284	33.417	1826.59	1680	24.035	10.338
21	1867.09	98.935	0.421	1878.67	1847.81	0.104	0.021
22	2129.41	96.009	4.087	2279.86	1980.89	2.546	2.671
23	2358.94	94.166	3.236	2387.87	2339.65	0.801	0.308
24	2509.39	98.445	0.736	2576.83	2434.17	0.752	0.233
25	2723.49	98.702	1.105	2779.42	2661.77	0.381	0.262
26	2852.72	77.814	3.351	2860.43	2794.85	2.522	0.203
27	2918.3	59.547	27.557	3001.24	2862.36	16.787	9.346
28	3412.08	17.243	82.663	3716.83	3003.17	274.917	274.478

Comment;
Sampel B

Date/Time; 1/4/2024 12:04:25 PM
No. of Scans;
Resolution;
Apodization;

Batang sorgum tanpa aktivasi

SHIMADZU

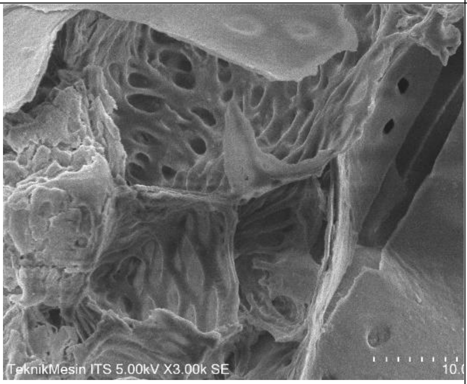
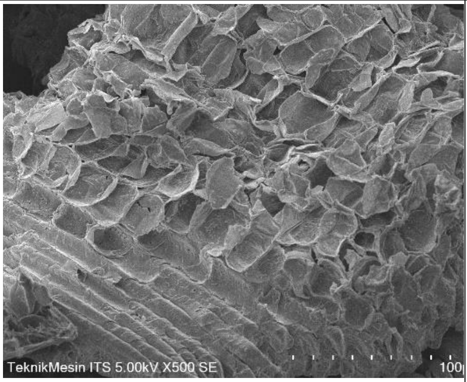


No.	Peak	Intensity	Corr. Intensity	Base (H)	Base (L)	Area	Corr. Area
1	370.33	76.751	6.079	378.05	345.26	2.445	0.693
2	457.13	65.033	2.097	470.63	379.98	14.348	1.111
3	526.5	58.881	1.164	538.14	472.56	13.423	0.151
4	563.21	56.326	1.723	580.57	540.07	9.768	0.274
5	607.58	56.188	3.715	650.01	582.5	15.542	0.868
6	665.44	62.921	4.725	794.67	651.94	13.896	0.558
7	831.32	91.797	7.356	854.47	796.6	1.095	0.832
8	896.9	85.559	10.461	916.19	856.39	1.767	0.993
9	1047.35	29.319	26.125	1097.5	918.12	59.216	22.145
10	1105.21	40.28	2.377	1143.79	1099.43	15.116	0.99
11	1163.08	51.151	15.265	1197.79	1145.72	10.856	2.546
12	1246.02	67.294	23.954	1296.16	1199.72	10.491	6.566
13	1328.95	83.784	7.137	1346.31	1298.09	2.568	1.009
14	1375.25	71.671	14.21	1402.25	1348.24	5.568	2.02
15	1431.18	72.145	5.172	1442.75	1404.18	4.411	0.63
16	1460.11	69.472	10.857	1485.19	1444.68	4.941	1.35
17	1512.19	71.172	23.685	1548.84	1487.12	4.16	2.931
18	1602.85	61.075	12.358	1618.28	1550.77	7.322	1.794
19	1635.64	62.196	4.596	1676.14	1620.21	10.424	0.937
20	1735.93	52.02	29.55	1824.66	1678.07	20.302	9.126
21	1896.03	99.654	0.155	1913.39	1888.31	0.024	0.008
22	2067.69	97.163	0.253	2077.33	1977.04	0.841	0.129
23	2127.48	96.325	1.746	2214.28	2079.26	1.516	0.572
24	2268.29	99.424	0.17	2281.79	2214.28	0.141	0.03
25	2364.73	91.143	4.728	2391.73	2349.3	1.082	0.425
26	2465.03	98.687	0.156	2478.53	2393.66	0.42	0.096
27	2725.42	99.195	0.615	2754.35	2663.69	0.165	0.118
28	2800.64	98.826	0.685	2814.14	2785.21	0.093	0.03
29	2852.72	90.154	2.984	2864.29	2816.07	1.12	0.224
30	2918.3	77.671	16.653	3007.02	2866.22	7.957	5.034
31	3415.93	33.498	65.925	3707.18	3028.24	176.414	174.717

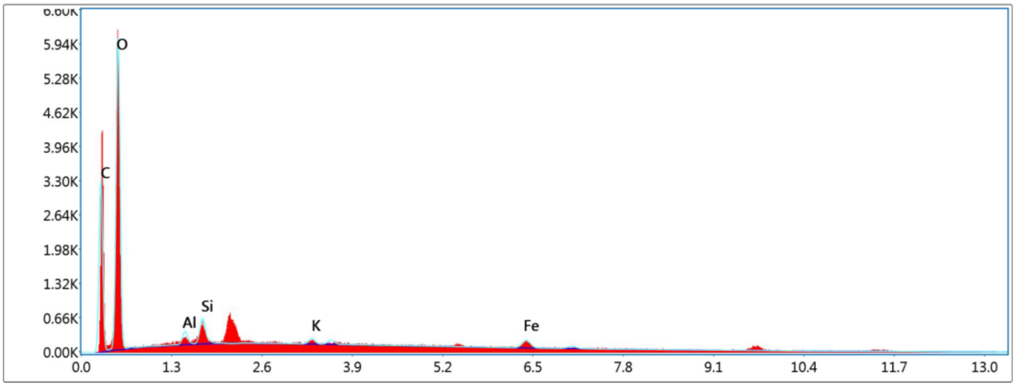
Date/Time; 1/4/2024 12:00:28 PM
No. of Scans;
Resolution;
Apodization;

Batang sorgum teraktivasi

Lampiran 4. Hasil Analisis SEM Batang Sorgum

	Adsorben teraktivasi	**Adsorben tanpa aktivasi**
3K		
0,5 K		

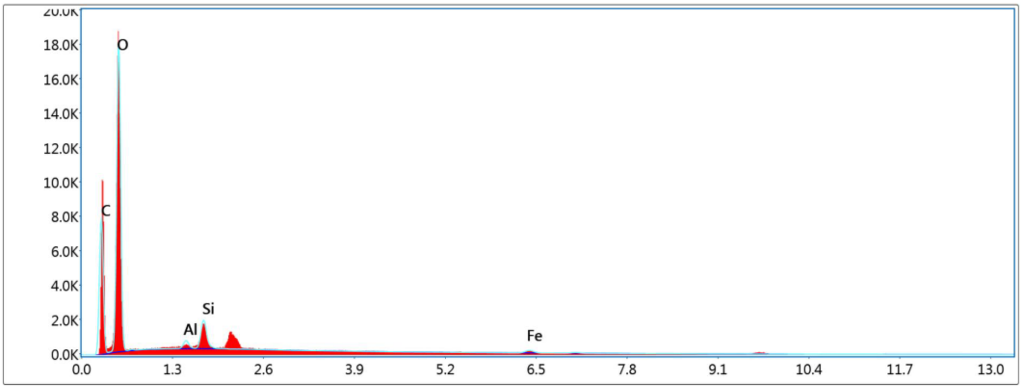
Lampiran 5. Data SEM-EDS



Smart Quant Results

Element	Weight %	Atomic %	Net Int.	Error %	Kratio	Z	A	F
C K	33.84	41.54	216.82	7.43	0.1495	1.0362	0.4263	1.0000
O K	61.23	56.43	434.34	9.08	0.1445	0.9906	0.2382	1.0000
AlK	0.96	0.53	22.09	10.35	0.0049	0.8798	0.5796	1.0032
SiK	1.54	0.81	45.42	6.87	0.0100	0.8989	0.7141	1.0040
K K	0.50	0.19	11.83	14.12	0.0043	0.8326	1.0120	1.0308
FeK	1.92	0.51	22.74	11.43	0.0169	0.7550	1.0310	1.1290

Batang sorgum tanpa aktivasi



Smart Quant Results

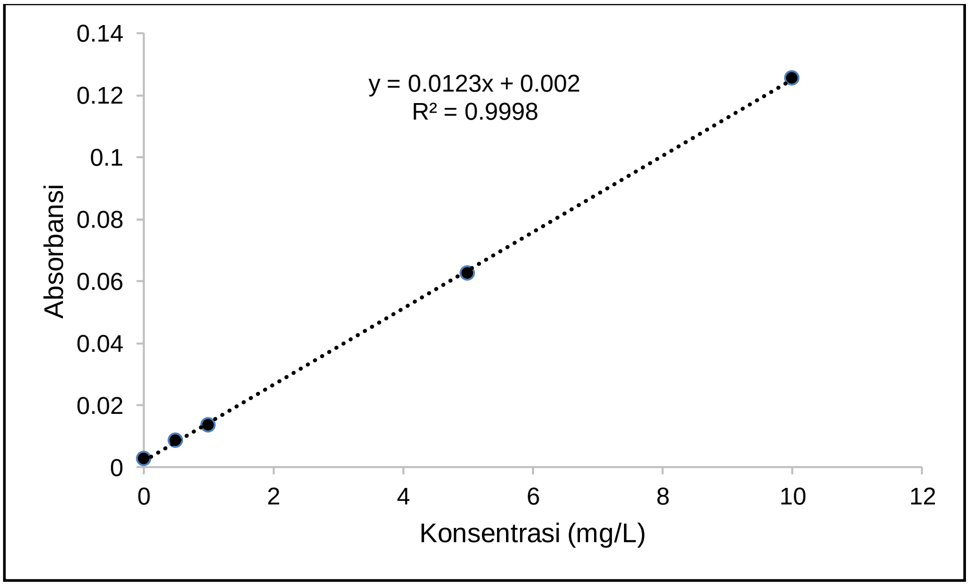
Element	Weight %	Atomic %	Net Int.	Error %	Kratio	Z	A	F
C K	31.57	38.65	514.47	7.21	0.1370	1.0344	0.4194	1.0000
O K	64.99	59.73	1291.96	8.60	0.1668	0.9888	0.2596	1.0000
AlK	0.68	0.37	40.10	9.62	0.0035	0.8780	0.5842	1.0035
SiK	2.02	1.06	152.85	5.09	0.0131	0.8970	0.7218	1.0037
FeK	0.74	0.20	23.38	12.16	0.0068	0.7532	1.0314	1.1794

Batang sorgum teraktivasi

Lampiran 6. Data Absorbansi Untuk penentuan Waktu Optimum, pH Optimum dan Kapasitas adsorpsi ion Cu(II) dan Pb(II)

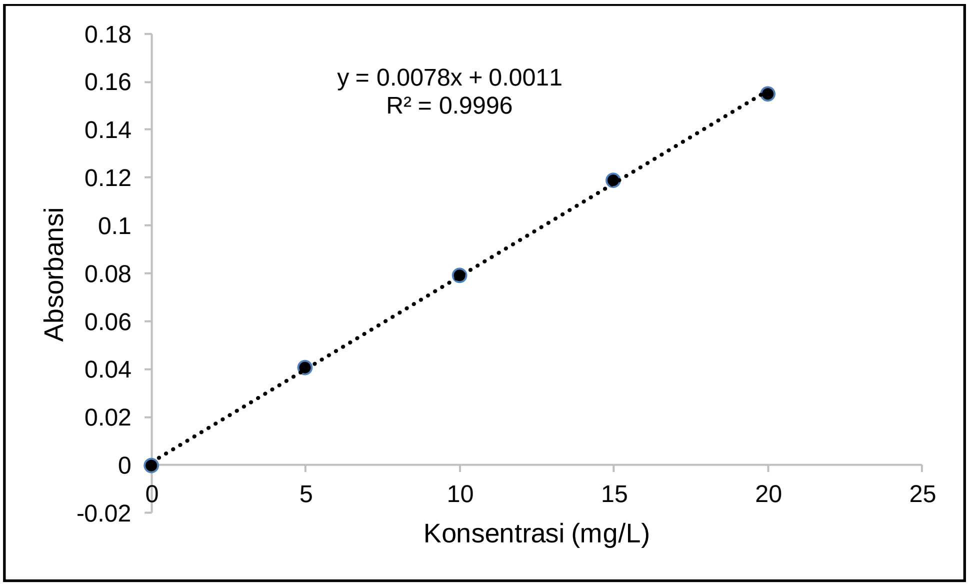
A. Data Absorbansi ion Cu(II)

Konsentrasi (mg/L)	Absorbansi
0	0.0027
0.5	0.0086
1	0.0135
5	0.0625
10	0.01256



B. Data Absorbansi ion Pb(II)

Konsentrasi (mg/L)	Absorbansi
0	-0,0001
5	0,0408
10	0,0792
15	0,1189
20	0,1549



Lampiran 7. Data Hasil Penentuan Waktu optimum

Data ion Cu(II) adsorben tanpa aktivasi

Waktu (menit)	C_o (mg/L)	Ce (mg/L)	Volume (L)	Jumlah adsorben (g)	q_e (mg/g)	q_e rata-rata (mg/g)
2	10	5,2601	0,05	0,5	0,4739	0,4752
	10	5,2357	0,05	0,5	0,4764	
6	10	4,3170	0,05	0,5	0,5682	0,5695
	10	4,2926	0,05	0,5	0,5707	
10	10	3,5040	0,05	0,5	0,6495	0,6483
	10	3,4878	0,05	0,5	0,6512	
30	10	3,8861	0,05	0,5	0,6113	0,6101
	10	3,9105	0,05	0,5	0,6089	
60	10	4,1219	0,05	0,5	0,5878	0,5873
	10	4,1300	0,05	0,5	0,5869	
90	10	4,0650	0,05	0,5	0,5934	0,5939
	10	4,0569	0,05	0,5	0,5943	
120	10	4,0569	0,05	0,5	0,5943	0,5934
	10	4,0731	0,05	0,5	0,5926	
150	10	4,0569	0,05	0,5	0,5934	0,5926
	10	4,0894	0,05	0,5	0,5943	
180	10	4,1382	0,05	0,5	0,5861	0,5861
	10	4,1382	0,05	0,5	0,5861	

Nilai q_e dihitung berdasarkan persamaan (3)
Contoh perhitungan jumlah ion Cu(II) yang teradsorpsi :

$$q_e = \frac{(10-5{,}2601)\ \text{mg/L}}{0{,}5\ \text{g}} \times 0{,}05\ \text{L} = 0{,}4739\ \text{mg/g}$$

Data ion Cu(II) adsorben teraktivasi

Waktu (menit)	C_o (mg/L)	Ce (mg/L)	Volume (L)	Jumlah adsorben (g)	q_e (mg/g)	q_e rata-rata (mg/g)
2	10	4,4878	0,05	0,5	0,5512	0,5495
	10	4,5203	0,05	0,5	0,5479	
6	10	3,9918	0,05	0,5	0,6008	0,6016
	10	3,9756	0,05	0,5	0,6024	
10	10	2,9918	0,05	0,5	0,7008	0,6995
	10	3,0162	0,05	0,5	0,6983	
30	10	3,0243	0,05	0,5	0,6975	0,6955
	10	3,0650	0,05	0,5	0,6934	
60	10	3,3089	0,05	0,5	0,6691	0,6678
	10	3,3333	0,05	0,5	0,6666	
90	10	3,3414	0,05	0,5	0,6658	0,6662
	10	3,3333	0,05	0,5	0,6666	
120	10	3,4065	0,05	0,5	0,6593	0,6609
	10	3,3739	0,05	0,5	0,6626	
150	10	3,4959	0,05	0,5	0,6504	0,6508
	10	3,4878	0,05	0,5	0,6512	
180	10	3,5121	0,05	0,5	0,6487	0,6483
	10	3,5203	0,05	0,5	0,6479	

Nilai q_e dihitung berdasarkan persamaan (3)
Contoh perhitungan jumlah ion Cu(II) yang teradsorpsi :

$$q_e = \frac{(10 - 4{,}4878)\ \text{mg/L}}{0{,}5\ \text{g}} \times 0{,}05\ \text{L} = 0{,}5512\ \text{mg/g}$$

Data ion Pb(II) adsorben tanpa aktivasi

Waktu (menit)	C_o (mg/L)	Ce (mg/L)	Volume (L)	Jumlah adsorben (g)	q_e (mg/g)	q_e rata-rata (mg/g)
2	10	3,6153	0,05	0,5	0,6384	0,6403
	10	3,5769	0,05	0,5	0,6423	
6	10	1,6538	0,05	0,5	0,8346	0,8326
	10	1,6923	0,05	0,5	0,8307	
10	10	1,3846	0,05	0,5	0,8615	0,8602
	10	1,4102	0,05	0,5	0,8589	
30	10	1,1666	0,05	0,5	0,8833	0,8839
	10	1,1538	0,05	0,5	0,8846	
60	10	1,3333	0,05	0,5	0,8666	0,8673
	10	1,3205	0,05	0,5	0,8679	
90	10	1,3974	0,05	0,5	0,8602	0,8615
	10	1,3717	0,05	0,5	0,8628	
120	10	1,4230	0,05	0,5	0,8576	0,8596
	10	1,3846	0,05	0,5	0,8615	
150	10	1,3717	0,05	0,5	0,8628	0,8641
	10	1,3461	0,05	0,5	0,8653	
180	10	1,4358	0,05	0,5	0,8564	0,8551
	10	1,4615	0,05	0,5	0,8538	

Nilai q_e dihitung berdasarkan persamaan (3)

Contoh perhitungan jumlah ion Cu(II) yang teradsorpsi :

$$q_e = \frac{(10 - 3{,}6153)\ \text{mg/L}}{0{,}5\ \text{g}} \times 0{,}05\ \text{L} = 0{,}6385\ \text{mg/g}$$

Data ion Pb(II) adsorben teraktivasi

Waktu (menit)	C_o (mg/L)	Ce (mg/L)	Volume (L)	Jumlah adsorben (g)	q_e (mg/g)	q_e rata-rata (mg/g)
2	10	2,3846	0,05	0,5	0,7615	0,7589
	10	2,4358	0,05	0,5	0,7564	
6	10	1,5256	0,05	0,5	0,8474	0,8455
	10	1,5641	0,05	0,5	0,8435	
10	10	1,1923	0,05	0,5	0,8807	0,8820
	10	1,1666	0,05	0,5	0,8833	
30	10	0,8589	0,05	0,5	0,9141	0,9134
	10	0,8717	0,05	0,5	0,9128	
60	10	0,9871	0,05	0,5	0,9012	0,9019
	10	0,9743	0,05	0,5	0,9025	
90	10	1,0384	0,05	0,5	0,8961	0,9006
	10	0,9487	0,05	0,5	0,9051	
120	10	1,0512	0,05	0,5	0,8948	0,8967
	10	1,0128	0,05	0,5	0,8987	
150	10	1,1410	0,05	0,5	0,8858	0,8871
	10	1,1153	0,05	0,5	0,8884	
180	10	1,2307	0,05	0,5	0,8769	0,8794
	10	1,1794	0,05	0,5	0,8820	

Nilai q_e dihitung berdasarkan persamaan (3)
Contoh perhitungan jumlah ion Cu(II) yang teradsorpsi :

$$q_e = \frac{(10 - 2{,}3846)\ \text{mg/L}}{0{,}5\ \text{g}} \times 0{,}05\ \text{L} = 0{,}7589\ \text{mg/g}$$

Lampiran 8. Data Hasil Penentuan pH Optimum

Data ion Cu(II) adsorben tanpa aktivasi

pH	C_o (mg/L)	Ce (mg/L)	Volume (L)	Jumlah adsorben (g)	q_e (mg/g)	q_e rata-rata (mg/g)
4	10	4,5691	0,05	0,5	0,5430	0,5430
	10	4,5691	0,05	0,5	0,5430	
5	10	4,3333	0,05	0,5	0,5666	0,5792
	10	4,0813	0,05	0,5	0,5918	
6	10	4,0243	0,05	0,5	0,5975	0,5983
	10	4,0081	0,05	0,5	0,5991	
7	10	4,1382	0,05	0,5	0,5861	0,5873
	10	4,1138	0,05	0,5	0,5886	
8	10	4,1788	0,05	0,5	0,5821	0,5825
	10	4,1707	0,05	0,5	0,5829	
9	10	4,4308	0,05	0,5	0,5569	0,5581
	10	4,4065	0,05	0,5	0,5593	

Nilai q_e dihitung berdasarkan persamaan (3)
Contoh perhitungan jumlah ion Cu(II) yang teradsorpsi :

$$q_e = \frac{(10 - 4{,}5691)\ \text{mg/L}}{0{,}5\ \text{g}} \times 0{,}05\ \text{L} = 0{,}5430\ \text{mg/g}$$

Data ion Cu(II) adsorben teraktivasi

pH	C_o (mg/L)	Ce (mg/L)	Volume (L)	Jumlah adsorben (g)	q_e (mg/g)	q_e rata-rata (mg/g)
4	10	8,4878	0,05	0,5	0,1512	0,1479
	10	8,5528	0,05	0,5	0,1447	
5	10	3,2113	0,05	0,5	0,6788	0,6780
	10	3,2276	0,05	0,5	0,6772	
6	10	0,0081	0,05	0,5	0,9991	0,9987
	10	0,0162	0,05	0,5	0,9983	
7	10	0,1382	0,05	0,5	0,9861	0,9869
	10	0,1219	0,05	0,5	0,9878	
8	10	0,6260	0,05	0,5	0,9373	0,9373
	10	0,6260	0,05	0,5	0,9373	
9	10	4,1382	0,05	0,5	0,5861	0,5845
	10	4,1707	0,05	0,5	0,5829	

Nilai q_e dihitung berdasarkan persamaan (3)
Contoh perhitungan jumlah ion Cu(II) yang teradsorpsi :

$$q_e = \frac{(10 - 8{,}4878)\ \mathrm{mg/L}}{0{,}5\ \mathrm{g}} \times 0{,}05\ \mathrm{L} = 0{,}1512\ \mathrm{mg/g}$$

Data ion Pb(II) adsorben tanpa aktivasi

pH	C_o (mg/L)	Ce (mg/L)	Volume (L)	Jumlah adsorben (g)	q_e (mg/g)	q_e rata-rata (mg/g)
4	10	8,4230	0,05	0,5	0,1576	0,1570
	10	8,4358	0,05	0,5	0,1564	
5	10	1,1410	0,05	0,5	0,8858	0,8865
	10	1,1282	0,05	0,5	0,8871	
6	10	0,2820	0,05	0,5	0,9717	0,9724
	10	0,2692	0,05	0,5	0,9730	
7	10	1,6667	0,05	0,5	0,8333	0,8326
	10	1,6794	0,05	0,5	0,8320	
8	10	0,4743	0,05	0,5	0,9525	0,9532
	10	0,4615	0,05	0,5	0,9538	
9	10	0,7692	0,05	0,5	0,9230	0,9230
	10	0,7692	0,05	0,5	0,9230	

Nilai q_e dihitung berdasarkan persamaan (3)
Contoh perhitungan jumlah ion Cu(II) yang teradsorpsi :

$$q_e = \frac{(10 - 8{,}4231)\ \text{mg/L}}{0{,}5\ \text{g}} \times 0{,}05\ \text{L} = 0{,}1576\ \text{mg/g}$$

Data ion Pb(II) adsorben teraktivasi

pH	C_o (mg/L)	Ce (mg/L)	Volume (L)	Jumlah adsorben (g)	q_e (mg/g)	q_e rata-rata (mg/g)
4	10	8,9615	0,05	0,5	0,1038	0,1012
	10	9,0128	0,05	0,5	0,0987	
5	10	0,94871	0,05	0,5	0,9051	0,9051
	10	0,94871	0,05	0,5	0,9051	
6	10	0,0128	0,05	0,5	0,9987	0,9980
	10	0,0256	0,05	0,5	0,9974	
7	10	0,2051	0,05	0,5	0,9794	0,9788
	10	0,2179	0,05	0,5	0,9782	
8	10	0,3333	0,05	0,5	0,9666	0,9653
	10	0,3589	0,05	0,5	0,9641	
9	10	0,5769	0,05	0,5	0,9423	0,9429
	10	0,5641	0,05	0,5	0,9435	

Nilai q_e dihitung berdasarkan persamaan (3)
Contoh perhitungan jumlah ion Cu(II) yang teradsorpsi :

$$q_e = \frac{(10 - 8{,}9615)\ \text{mg/L}}{0{,}5\ \text{g}} \times 0{,}05\ \text{L} = 0{,}1038\ \text{mg/g}$$

Lampiran 9. Data Hasil Penentuan Kapasitas Adsorpsi

Data ion Cu(II) adsorben teraktivasi

C_o (mg/L)	C_e (mg/L)	q_e (mg/g)	c_e/q_e	log c_e	log q_e
10	2,0040	0,7995	2,5063	0,3019	-0,0971
30	6,0284	2,3971	2,5148	0,7802	0,3796
50	21,8008	2,8199	7,7310	1,3384	0,4502
100	45,9552	5,4044	8,5031	1,6623	0,7327

Data ion Cu(II) adsorben tanpa aktivasi

C_o (mg/L)	C_e (mg/L)	qe (mg/g)	ce/qe	log ce	log qe
10	0,9146	0,9085	1,0067	-0,0387	-0,0416
30	6,6341	2,3365	2,8392	0,8217	0,3685
50	24,1300	2,5869	9,3274	1,3825	0,4127
100	73,0243	2,6975	27,0705	1,8634	0,4309

Data ion Pb(II) adsorben teraktivasi

C_o (mg/L)	C_e (mg/L)	qe (mg/g)	ce/qe	log ce	log qe
10	1,3333	0,8666	1,5384	0,1249	-0,0621
30	5,2435	2,4756	2,1180	0,7196	0,3936
50	10,3846	3,9615	2,6213	1,0163	0,5978
100	31,1346	6,8865	4,5210	1,4932	0,8380

Data ion Pb(II) adsorben tanpa aktivasi

C_o (mg/L)	C_e (mg/L)	qe (mg/g)	ce/qe	log ce	log qe
10	0,6923	0,9307	0,7438	-0,1597	-0,03115
30	9,6858	2,0314	4,7681	0,9861	0,3077
50	25,1346	2,4865	10,1083	1,4002	0,3955
100	54,6410	4,5358	12,0464	1,7375	0,6566

Nilai q_e dihitung berdasarkan persamaan (3)
Contoh perhitungan jumlah ion Cu(II) yang teradsorpsi :

$$q_e = \frac{(10 - 2{,}0040)\ \text{mg/L}}{0{,}5\ \text{g}} \times 0{,}05\ \text{L} = 0{,}7995\ \text{mg/g}$$

Lampiran 10. Data Hasil Efektivitas adsorpsi ion Cu(II) dan Pb(II)

Data ion Cu(II) dan Pb(II) pada batang sorgum teraktivasi

Ion Logam	C_o (mg/L)	C_e (mg/L)	Volume (L)	W (g)	q_e (mg/g)	%E	q_e rata-rata (mg/g)	%E rata rata
Cu(II)	10	3,9268	0,05	0,5	0,6073	60,73	0,6057	60,57
	10	3,9593	0,05	0,5	0,6041	60,41		
Pb(II)	10	1,0385	0,05	0,5	0,8962	89,62	0,8974	89,74
	10	1,0128	0,05	0,5	0,8987	89,87		

Data ion Cu(II) dan Pb(II) pada batang sorgum tanpa aktivasi

Ion Logam	C_o (mg/L)	C_e (mg/L)	Volume (L)	W (g)	q_e (mg/g)	%E	q_e rata-rata (mg/g)	%E rata rata
Cu(II)	10	6,9837	0,05	0,5	0,3016	30,16	0,3004	30,04
	10	7,0081	0,05	0,5	0,2992	29,92		
Pb(II)	10	2,3462	0,05	0,5	0,7654	76,54	0,7686	76,86
	10	2,2821	0,05	0,5	0,7718	77,18		

Nilai %E dihitung berdasarkan persamaan berikut :

$$\%E = \frac{(C_o - C_e)}{C_o} \times 100\%$$

Contoh perhitungan :

$$\%E = \frac{(10 - 6{,}9837)\ \text{mg/L}}{10\ \text{mg/L}} \times 100\% = 30{,}1630\ \text{mg/g}$$

Nilai q_e dihitung berdasarkan persamaan (3). Contoh perhitungan :

$$q_e = \frac{(10-6{,}9837)\ \text{mg/L}}{0{,}5\ \text{g}} \times 0{,}05\ \text{L} = 0{,}3016\ \text{mg/g}$$

Lampiran 11. Data hasil aplikasi batang sorgum pada adsorpsi ion Cu(II) dan Pb(II), BOD, COD, TSS, dan pH dari limbah cair laboratorium

Perlakuan	Parameter	Satuan	Hasil	Metode Pengujian	Baku Mutu
P_0	Cu	mg/L	0,109	SNI 6989.84:2019	2
	Pb	mg/L	3,815	SNI 6989.84:2019	0,1
	pH		2,22	SNI 6989.11:2019	6-9
	BOD	mg/L	44,2	SNI 6989.72:2009	30
	COD	mg/L	136	SNI 6989.73:2009	100
	TSS	mg/L	28	SNI 6989.3:2019	30
P_1	Cu	mg/L	0,105	SNI 6989.84:2019	2
	Pb	mg/L	3,704	SNI 6989.84:2019	0,1
	pH		2,26	SNI 6989.11:2019	6-9
	BOD	mg/L	28,1	SNI 6989.72:2009	30
	COD	mg/L	96	SNI 6989.73:2009	100
	TSS	mg/L	16	SNI 6989.3:2019	30
P_2	Cu	mg/L	0,098	SNI 6989.84:2019	2
	Pb	mg/L	3,327	SNI 6989.84:2019	0,1
	pH		2,08	SNI 6989.11:2019	6-9
	BOD	mg/L	21,1	SNI 6989.72:2009	30
	COD	mg/L	40	SNI 6989.73:2009	100
	TSS	mg/L	5	SNI 6989.3:2019	30

Lampiran 12. Perhitungan Kapasitas adsorpsi ion Cu(II) oleh batang sorgum tanpa aktivasi

Isoterm adsorpsi Langmuir ion Cu(II)

$$\frac{C_e}{q_e} = \frac{1}{q_{max} \cdot b} + \frac{C_e}{q_{max}}$$

Berdasarkan model isoterm Langmuir diperoleh persamaan garis :

Y = 0,3629x + 0,5614

Dari persamaan garis tersebut, nilai *slope* = 0,3629x dan *intercept* = 0,5614
Nilai kapasitas adsorpsi dapat dihitung sebagai berikut:

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

$$q_{max} = \frac{1}{0{,}3629}$$

$$= 2{,}7555\ mg/g$$

konstanta Langmuir dapat dihitung sebagai berikut:

$$\frac{1}{q_{max} \times b} = \text{intercept}$$

$$b = \frac{1}{2{,}7555\frac{mg}{g} \times 0{,}5614}$$

$$= 0{,}6464$$

Isoterm adsorpsi Freundlich ion Cu(II)

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

Berdasarkan model isoterm Freundlich diperoleh persamaan garis :

Y = 0,2493x+ 0,0416

Dari persamaan garis tersebut, nilai *slope* = 0,2493 dan *intercept* = 0,0416
Nilai kapasitas adsorpsi dapat dihitung sebagai berikut:

Y = log q_e ; x = log C_e

Intercept = log k
0,0416 = log k
k = inv 0,0416
k = 1,1005 mg/g

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

0,2493 = $\frac{1}{n}$

n = $\frac{1}{0,2493}$

n = 4,0112 L/mg

Lampiran 13. Perhitungan Kapasitas adsorpsi ion Pb(II) oleh batang sorgum tanpa aktivasi

Isoterm adsorpsi Langmuir ion Pb(II)

$$\frac{C_e}{q_e} = \frac{1}{q_{max} \cdot b} + \frac{C_e}{q_{max}}$$

Berdasarkan model isoterm Langmuir diperoleh persamaan garis :

Y = 0,1997x +2,4159

Dari persamaan garis tersebut, nilai *slope* = 0,1997 dan *intercept* = 2,4159
Nilai kapasitas adsorpsi dapat dihitung sebagai berikut:

$$Y = \frac{C_e}{q_e} \text{ ; } X = C_e$$

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

0,1997 = $\frac{1}{Q_o}$

Q_o = $\frac{1}{0,1997}$

Q_o = 5,0075 mg/g

konstanta Langmuir dapat dihitung sebagai berikut:

Intercept = $\frac{1}{Q_0 \cdot b}$

2,4159 = $\frac{1}{2,7555 \cdot b}$

b = $\frac{1}{(5.0075)(2,4159)}$

b = 0,0826 L/mg

Isoterm adsorpsi Freundlich ion Pb(II)

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

Berdasarkan model isoterm Freundlich diperoleh persamaan garis :

Y = 0,335x + 0,0002

Dari persamaan garis tersebut, nilai *slope* = 0,335 dan *intercept* = 0,0002
Nilai kapasitas adsorpsi dapat dihitung sebagai berikut:

Y = log q_e ; x = log C_e

Intercept = log k
0,0002 = log k
k = inv 0,0002
k = 1,0004 mg/g

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

0,335 = $\frac{1}{n}$

n = $\frac{1}{0,335}$

n = 2,9850 L/mg

Lampiran 14. Perhitungan Kapasitas adsorpsi ion Cu(II) oleh batang sorgum teraktivasi

Isoterm adsorpsi Langmuir ion Cu(II)

$$\frac{C_e}{q_e} = \frac{1}{q_{max} \, . \, b} + \frac{C_e}{q_{max}}$$

Berdasarkan model isoterm Langmuir diperoleh persamaan garis :

Y = 0,1483x + 2,5031

Dari persamaan garis tersebut, nilai *slope* = 0,1483 dan *intercept* = 2,5031
Nilai kapasitas adsorpsi dapat dihitung sebagai berikut:

$$Y = \frac{C_e}{q_e} \; ; \; X = C_e$$

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

0,1483 = $\frac{1}{Q_m}$

Q_m = $\frac{1}{0,1483}$

Q_m = 6,7430 mg/g

konstanta Langmuir dapat dihitung sebagai berikut:

Intercept = $\frac{1}{Q_0 \cdot b}$

2,5031 = $\frac{1}{6,7430 \cdot b}$

b = $\frac{1}{(6,7430)(2,5031)}$

b = 0,5924 L/mg

Isoterm adsorpsi Freundlich ion Cu(II)

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

Berdasarkan model isoterm Freundlich diperoleh persamaan garis :

Y = 0,5442x- 0,1891

Dari persamaan garis tersebut, nilai *slope* = 0,5442 dan *intercept* = 0,1891
Nilai kapasitas adsorpsi dapat dihitung sebagai berikut:

Y = log q_e ; x = log C_e

Intercept = log k
0,1891 = log k
k = inv 0,1891
k = 0,6469 mg/g

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

0,5442 = $\frac{1}{n}$

n = $\frac{1}{0,5442}$

n = 1,8375 L/mg

Lampiran 15. Perhitungan Kapasitas adsorpsi ion Pb(II) oleh batang sorgum tanpa aktivasi

Isoterm adsorpsi Langmuir ion Pb(II)

$$\frac{C_e}{q_e} = \frac{1}{q_{max} \, . \, b} + \frac{C_e}{q_{max}}$$

Berdasarkan model isoterm Langmuir diperoleh persamaan garis :

Y =0,0971x + 1,532

Dari persamaan garis tersebut, nilai *slope* = 0,0971 dan *intercept* = 1,532
Nilai kapasitas adsorpsi dapat dihitung sebagai berikut:

$$Y = \frac{C_e}{q_e} \; ; X = C_e$$

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

0,0971 = $\frac{1}{Q_o}$

Q_o = $\frac{1}{0,0971}$

Q_o = 10,2986 mg/g

konstanta Langmuir dapat dihitung sebagai berikut:

Intercept = $\frac{1}{Q_0 \cdot b}$

1,532 = $\frac{1}{10,2986 \cdot b}$

b = $\frac{1}{(10,2986)(1,532)}$

b = 0,0633 L/mg

Isoterm adsorpsi Freundlich ion Pb(II)

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

Berdasarkan model isoterm Freundlich diperoleh persamaan garis :

Y = 0,6633x – 0,1144

Dari persamaan garis tersebut, nilai *slope* = 0,6633 dan *intercept* = - 0,1144
Nilai kapasitas adsorpsi dapat dihitung sebagai berikut:

Y = log q_e ; x = log C_e

Intercept = log k
- 0,1144= log k
k = inv (-0,1144)
k = 0,7684 mg/g

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

0,6633 = $\frac{1}{n}$

n = $\frac{1}{0,6633}$

n = 1,5076 L/mg

Lampiran 16. Isoterm Adsorpsi Ion Cu(II) oleh Batang Sorgum Tanpa Aktivasi Bentuk Non-Linear (Program Solver)

1. Isoterm adsorpsi Langmuir ion logam Cu(II) bentuk non-linier (program solver)

Konsentrasi (mg/L)	C_e (mg/L)	q_e (mg/g)	q_eL (mg/g)	Res^2
10	0,9146	0,9085	0,9760	0,0045
30	6,6341	2,3365	2,2265	0,0121
50	24,1300	2,5869	2,6150	0,0007
100	73,0243	2,6975	2,7362	0,0014

$$q_e = \frac{q_{max} \,.\, b \,.\, C_e}{1 + b \,.\, C_e}$$

Parameter	Nilai
q_{max}	2,8002
b	0,5849
RSS	0,0189
R^2	0,9999

2. Isoterm adsorpsi Freundlich ion logam Cu(II) bentuk non-linier (program solver)

Konsentrasi (mg/L)	C_e (mg/L)	q_e (mg/g)	q_eF (mg/g)	Res^2
10	0,914634146	0,908537	1,0139	0,1112
30	6,634146341	2,336585	1,6598	0,4579
50	24,1300813	2,586992	2,2884	0,0891
100	73,02439024	2,697561	3,014	0,1001

$$q_e = K_f \,.\, C_e^{\frac{1}{n}}$$

Parameter	Nilai
K_f	2,8002
n	0,2487
RSS	0,6584
R^2	0,8234

3. Isoterm adsorpsi Sips ion logam Cu(II) bentuk non-linier (program solver)

Konsentrasi (mg/L)	C_e (mg/L)	q_e (mg/g)	q_eS (mg/g)	Res^2
10	0,9146	0,9085	0,9941	0,0073
30	6,6341	2,336	0,1888	0,0218
50	24,1300	2,5869	2,5636	0,0005
100	73,0243	2,6975	2,6842	0,0001

$$q_e = \frac{q_{max}\ .\ \mathrm{b}\ .\ C_e}{1 + \mathrm{b}\ .\ C_e}$$

Parameter	Nilai
q_{max}	2,8002
b	0,5849
SS	0,0189
R^2	0,9999

Lampiran 17. Isoterm Adsorpsi Ion Pb(II) oleh Batang Sorgum Tanpa Aktivasi Bentuk Non-Linear (Program Solver)

1. Isoterm adsorpsi Langmuir ion logam Pb(II) bentuk non-linier (program solver)

Konsentrasi (mg/L)	C_e (mg/L)	q_e (mg/g)	q_eL (mg/g)	Res^2
10	0,6923	0,9307	0,1532	0,6046
30	9,6858	2,0314	1,6469	0,1478
50	25,1346	2,4865	3,0572	0,3257
100	54,6410	4,5358	4,3055	0,053

$$q_e = \frac{q_{max} \cdot b \cdot C_e}{1 + b \cdot C_e}$$

Parameter	Nilai
q_{max}	6,6015
b	0,0343
RSS	1,1312
R^2	0,8455

2. Isoterm adsorpsi Freundlich ion logam Pb(II) bentuk non-linier (program solver)

Konsentrasi (mg/L)	C_e (mg/L)	q_e (mg/g)	q_eF (mg/g)	Res^2
10	0,6923	0,9307	0,7985	0,0174
30	9,6858	2,0314	2,1558	0,0154
50	25,1346	2,4865	3,0868	0,3603
100	54,6410	4,5358	4,1348	0,1607

$$q_e = K_f \cdot C_e^{\frac{1}{n}}$$

Parameter	Nilai
K_f	0,9171
n	0,3764
RSS	0,6548
R^2	0,8234

3. Isoterm adsorpsi Sips ion logam Pb(II) bentuk non-linier (program solver)

Konsentrasi (mg/L)	C_e (mg/L)	q_e (mg/g)	q_e S(mg/g)	Res^2
10	0,6923	0,9307	5,0689	17,1241
30	9,6858	2,0314	5,7151	13,5697
50	25,1346	2,4865	5,729	10,5139
100	54,6410	4,5358	5,7323	1,4135

$$q_e = \frac{q_{max}\ .\ \mathrm{b}\ .\ C_e^{\frac{1}{n}}}{(1 + \mathrm{b}\ .\ C_e^{\frac{1}{n}})}$$

Parameter	Nilai
q_{max}	2,6964
b	1,2704
RSS	0,0014
R^2	0,9916

Lampiran 18. Isoterm Adsorpsi Ion Pb(II) oleh Batang Sorgum Teraktivasi Bentuk Non-Linear (Program Solver)

1. **Isoterm adsorpsi Langmuir ion logam Pb(II) bentuk non-linier (program solver)**

Konsentrasi (mg/L)	C_e (mg/L)	q_e (mg/g)	q_eL (mg/g)	Res^2
10	1,3333	0,8666	0,7613	0,011
30	5,2435	2,4756	2,4782	6,7175
50	10,3846	3,9615	4,0016	0,0016
100	31,1346	6,8865	6,8739	0,0001

$$q_e = \frac{q_{max} \cdot b \cdot C_e}{1 + b \cdot C_e}$$

Parameter	Nilai
q_{max}	10,7275
b	0,0573
RSS	0,0128
R^2	0,9943

2. **Isoterm adsorpsi Freundlich ion logam Pb(II) bentuk non-linier (program solver)**

Konsentrasi (mg/L)	C_e (mg/L)	q_e (mg/g)	q_eF (mg/g)	Res^2
10	1,3333	0,8666	1,1341	0,0715
30	5,2435	2,4756	2,4972	0,0004
50	10,3846	3,9615	3,7027	0,0669
100	31,1346	6,8865	6,9726	0,0074

$$q_e = K_f \cdot C_e^{\frac{1}{n}}$$

Parameter	Nilai
K_f	0,9608
n	0,5764
RSS	0,1463
R^2	0,9891

3. Isoterm adsorpsi Sips ion logam Pb(II) bentuk non-linier (program solver)

Konsentrasi (mg/L)	C_e (mg/L)	q_e (mg/g)	q_e S (mg/g)	Res^2
10	1,3333	0,8666	0,8357	0,0009
30	5,2435	2,4756	2,5049	0,0008
50	10,3846	3,9615	3,9675	3,5932
100	31,1346	6,8865	6,8856	8,2376

$$q_e = \frac{q_{max}\ .\ \mathrm{b}\ .\ C_e^{\frac{1}{n}}}{(1 + \mathrm{b}\ .\ C_e^{\frac{1}{n}})}$$

Parameter	Nilai
q_{max}	11,8781
b	0,9212
RSS	0,0018
R^2	0,9980

Lampiran 19. Isoterm Adsorpsi Ion Cu(II) oleh Batang Sorgum Teraktivasi Bentuk Non-Linear (Program Solver)

1. Isoterm adsorpsi Langmuir ion logam Pb(II) bentuk non-linier (program solver)

Konsentrasi (mg/L)	C_e (mg/L)	q_e (mg/g)	q_eL (mg/g)	Res^2
10	2,0040	0,7995	0,6762	0,0152
30	6,0284	2,3971	1,702	0,4831
50	21,8008	2,8199	3,7534	0,8715
100	45,9552	5,4044	4,9526	0,2041

$$q_e = \frac{q_{max} \cdot \mathrm{b} \cdot C_e}{1 + \mathrm{b} \cdot C_e}$$

Parameter	Nilai
q_{max}	6.9593
b	0,0537
RSS	1,5740
R^2	0,8264

2. Isoterm adsorpsi Freundlich ion logam Pb(II) bentuk non-linier (program solver)

Konsentrasi (mg/L)	C_e (mg/L)	q_e (mg/g)	q_eF (mg/g)	Res^2
10	2,0040	0,7995	0,9206	0,0146
30	6,0284	2,3971	1,6902	0,4997
50	21,8008	2,8199	3,435	0,3784
100	45,9552	5,4044	5,1833	0,0489

$$q_e = K_f \cdot C_e^{\frac{1}{n}}$$

Parameter	Nilai
K_f	0,6274
n	0,5517
RSS	0,9417
R^2	0,9039

3. Isoterm adsorpsi Sips ion logam Pb(II) bentuk non-linier (program solver)

Konsentrasi (mg/L)	C_e (mg/L)	q_e (mg/g)	q_e S (mg/g)	Res^2
10	2,0040	0,7995	0,9511	0,0229
30	6,0284	2,3971	1,7642	0,4005
50	21,8008	2,8199	3,4898	0,4487
100	45,9552	5,4044	5,0254	0,1436

$$q_e = \frac{q_{max} \cdot b \cdot C_e^{\frac{1}{n}}}{(1 + b \cdot C_e^{\frac{1}{n}})}$$

Parameter	Nilai
q_{max}	23,9535
b	0,5936
RSS	0,0159
R^2	0,8880