

APPENDIX A

Calibration curve and calculations

A.1 Calibration of copper from calibration curve

In order to determine the calibration curve of Cu^{2+} ion from copper nitrate solutions, the various concentrations of standard copper were prepared. The absorbance of Cu^{2+} ion from copper nitrate solutions was measured using atomic absorption spectrophotometer (AAS).



Equation of calibration curve: y = 0.0448x + 0.0070

When y = absorbance (ABS) and x = copper concentration

$$x = \frac{ABS - 0.0070}{0.0448}$$

A.2 Calibration of zinc from calibration curve

In order to determine the calibration curve of Zn^{2+} ion from zinc nitrate solutions, the various concentrations of standard zinc were prepared. The absorbance of Zn^{2+} ion from zinc nitrate solutions was measured using atomic absorption spectrophotometer (AAS).





A.3 Calibration of lead from calibration curve

In order to determine the calibration curve of Pb^{2+} ion from lead nitrate solutions, the various concentrations of standard lead were prepared. The absorbance of Pb^{2+} ion from lead nitrate solutions was measured using atomic absorption spectrophotometer (AAS).



Figure A3 Calibration curve of lead



A.4 Calibration of methylene blue from calibration curve

In order to determine the calibration curve of methylene blue, the various concentrations of standard methylene blue were prepared. The absorbance of methylene blue solutions were measured using UV-Vis spectrophotometer at 644 nm.



Figure A4 Calibration curve of methylene blue



A.5 Calculation of the amount of adsorbed metal ion and the percentage of metal ions removal

The amount of adsorbed metal ion per gram of adsorbent was obtained using the following equation:

$$q_e = \frac{(C_i - C_e)}{M} V$$

The percentage of metal ion removal by adsorbent was calculated using the equation:

$$\% Removal = \frac{(C_i - C_e)}{C_i} \times 100$$

 q_e = the amount of metal ion adsorbed per gram of adsorbent (mg/g)

 C_i = the initial metal ion concentration of the solution (mg/L)

 C_e = the equilibrium metal ion concentration or final metal concentration of the

solution (mg/L)

V = volume of solution (L)

M = the mass of adsorbent used (g)

For example:

The copper concentration was calculated from equation of calibration curve. The initial copper concentration at pH 6 was 50.00 mg/L The equilibrium copper concentration at pH 6 was 20.16 mg/L The volume of solution was 0.0500 L The mass of adsorbent used was 0.400 g

$$q_e = \frac{(50.00 - 20.16)}{0.400} \times 0.0500$$

= 3.73 mg/g

The amount of adsorbed copper ions was 3.73 mg/g

adsorbed copper ions was 3.73 mg/g

$$\% Removal = \frac{(C_i - C_e)}{C_i} \times 100$$

$$= \frac{(50.00 - 20.16)}{50.00} \times 100$$

$$= 59.7\%$$

The percentage of copper ions removal was 59.7%

APPENDIX B

Adsorption of Cu(II) ions on leonardite

B.1 Effect of pH

The adsorption of copper on leonardite was studied at a pH range of 2-6, the initial copper concentrations 5.00 and 20.00 mg/L, in order to investigate the optimum pH for the removal of this ion. All experiments were performed in five experiments.

pН	6	STA			
	1	2	3	4	5
2	43.9	47.0	47.2	45.0	45.7
3	87.6	87.2	88.2	86.3	87.4
4	96.5	96.8	96.4	94.2	94.8
5	98.6	99.1	98.6	98.7	98.4
6	99.3	99.1	99.3	99.6	99.3

 Table B1 % Copper removal at pH 2-6 and the initial concentration of 5.00 mg/L

Table B2 % Copper removal at pH 2-6 and the initial concentration of 20.00 mg/L

pН	%Cu ²⁺ Removal					
	1	2	3	4	5	
2	12.8	8.4	18.2	11.9	8.5	
3	58.1	56.6	60.2	51.2	51.2	
4	69.8	72.3	78.4	76.2	-78.1	
5 🔾	81.4	79.5	81.8	81.0	84.2	
6	91.9	89.2	90.9	91.7	92.7	

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B.2 Contact time

In order to study the effect of contact time on copper removal, the period of times were selected at 10, 20, 30, 40, 50, 60, 120, 180, 240, 300 and 360minutes, at 5.00 and 20.00 mg/L copper initial concentrations. All experiments were performed in five experiments.

Time	The amount of Cu ²⁺ adsorbed (mg/g)							
(min.)	1	2	3	4	5			
0	0.0	0.0	0.0	0.0	0.0			
10	0.5504	0.5624	0.5743	0.5653	0.5624			
20	0.5533	0.5624	0.5743	0.5653	0.5638			
30	0.5533	0.5650	0.5756	0.5680	0.5678			
40	0.5558	0.5676	0.5769	0.5680	0.5678			
50	0.5618	0.5676	0.5757	0.5668	0.5678			
60	0.5606	0.5676	0.5791	0.5702	0.5689			
120	0.5711	0.5738	0.5822	0.5775	0.5762			
180	0.5730	0.5758	0.5832	0.5785	0.5782			
240	0.5748	0.5794	0.5850	0.5803	0.5782			
300	0.5765	0.5802	0.5850	0.5803	0.5798			
360	0.5779	0.5809	0.5865	0.5818	0.5813			

Table B3 The amount of Cu^{2+} adsorbed vs. time at concentration of 5.00 mg/L

Table B4 The amount of Cu^{2+} adsorbed vs. time at concentration of 20.00 mg/L

Time	The amount of Cu ²⁺ adsorbed (mg/g)							
(min.)	1	2	3	4	5			
0	0	0	0 🥑	0	0			
10	1.9299	1.9179	1.8896	1.9000	1.9179			
20	1.9327	1.9151	1.8981	1.9029	1.9208			
30	1.9381	1.9137	1.8994	1.9123	1.9261			
40	1.9228	1.9163	1.8944	1.9034	1.9312			
50	1.9241	1.9175	1.8967	1.9153	1.9240			
60	1.9229	1.9197	1.9068	1.9176	1.9240			
120	1.9824	1.9751	1.9611	1.9698	1.9658			
180	1.9873	1.9780	1.9708	1.9746	1.9697			
240	2.0061	1.9950	1.9833	1.9845	1.9777			
300	2.0151	2.0024	1.9948	1.9869	1.9876			
360	2.0188	2.0083	1.9985	2.0011	1.9913			

B.3 Effect of leonardite quantity

In order to investigate the effect of leonardite quantity, a series of adsorption experiment was carried out with different leonardite dosages at the initial metal concentration of 5.00 and 20.00 mg/L. All experiments were performed in five experiments.

 Table B5
 %Copper removal at leonardite dose 0.400-3.00 g, at the initial concentration of 5.00 mg/L

Leonardite Ouantity	B				
(g)		2	3	4	55
0.400	98.1	98.1	97.6	97.2	96.9
0.700	98.6	98.8	98.1	98.1	98.1
1.00	99.4	99.2	99.4	99.4	98.7
3.00	99.9	99.0	99.9	99.6	99.9

 Table B6 % Copper removal at leonardite dose 0.400-3.00 g, at the initial concentration of 20.00 mg/L

Leonardite Quantity		val			
(g)	1	2	3	4	5
0.400	94.4	93.2	92.5	92.8	93.2
0.700	96.1	95.7	95.2	95.0	94.5
1.00	97.4	97.4	97.1	97.3	97.1
3.00	99.1	99.2	99.1	98.9	98.9

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Figure B1 Effect of leonardite quantity at leonardite dose starting from 0.200-3.00 g at the two concentrations of Cu^{2+}

 Table B7 %Copper removal at leonardite dose 0.200-3.00 g, at the two concentrations

	Leonardite Quantity	%Cu ²⁺ Removal		
	(g)	Cu ²⁺ 5 mg/L	Cu ²⁺ 20 mg/L	
	0.200	86.8	82.9	
	0.400	93.2	89.4	7
lansi	0.700	93.9	91.3	
	1.00	94.8	92.5	
	3.00	96.8	94.5	
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B.4 Adsorption Isotherm

The adsorption capacity of adsorbent for copper was investigated over a range of copper concentrations. The experimental data for the uptake of Cu^{2+} ions by adsorbent over the studied concentration range were processed in accordance with the two of the most widely used adsorption isotherms: Langmuir and Freundlich isotherms.

First experiment

Metal ions		A ª	-505-		
708	C_e	q_e	C_e/q_e	q_{max}	$K_L \qquad R^2$
	$(mg L^{-1})$	$(mg g^{-1})$	$(g L^{-1})$	$(mg g^{-1})$	(g ⁻¹ mg)
	1.52	2.32	0.657		6
	3.40	4.59	0.739		
Cu ²⁺	5.40	6.81	0.794	19.7	0.090 0.9864
	9.51	8.83	1.08		
	13.39	10.84	1.24	25	

Table B8 Langmuir parameters for Cu²⁺

Metal ions		Fre	undlich Iso	otherm	
unic	$log C_e$	$log q_e$	K _F	n	R^2
			$(mg L^{-1})$	Mai	
- / 0	0.183	0.365	0		
l f	0.531	0.662	r		
Cu ²⁺	0.733	0.833	1.85	1.4	0.9834
-	0.978	0.946	-		
-	1.13	1.04	-		

 α^{2+}

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Second experiment

T 11 D10	т ·		c	a^{2+}
Table B10	Langmuir	parameters	tor	Cu ⁻

Metal ions	Langmuir Isotherm							
	C _e	q _e	C_e/q_e	q_{max}	K_L	R^2		
	$(mg L^{-1})$	$(mg g^{-1})$	(g L ⁻¹)	$(mg g^{-1})$	$(g^{-1}mg)$			
	1.46	2.33	0.626	48				
	3.40	4.59	0.739					
Cu ²⁺	5.19	6.84	0.758	19.1	0.093	0.9704		
	9.78	8.79	1.11					
	13.06	10.88	1.20					
Metal ions		F	reundlich Iso	therm	Ś	<u> </u>		
Wietai iolis	log C					\mathbf{p}^2		
	105 Ce	108 Ye	$(\text{mg } \text{L}^{-1})$	n				
	0.164	0.367			5			
	0.531	0.662						
Cu ²⁺	0.715	0.835	1.92	1.4	0.9	813		
	0.990	0.944						
	1.12	1.04	VIN					

Third experiment

Table B12 Langmuir parameters for Cu	1 ²⁺
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Metal ions			Langmuir	Isotherm		
	C _e	q_e	C_e/q_e	q_{max}	K _L	R^2
	$(mg L^{-1})$	$(mg g^{-1})$	$(g L^{-1})$	$(mg g^{-1})$	$(g^{-1}mg)$	
	1.50	2.32	0.647	18		
	3.40	4.59	0.739			
Cu ²⁺	4.97	6.87	0.723	17.5	0.108	0.9611
	10.33	8.72	1.18			
	14.04	10.76	1.31			
Table B13 F	Freundlich pa	arameters for	Cu ²⁺		ST.	22 C
Table B13 F	Freundlich pa	arameters for	Cu ²⁺		NA NA	
Table B13 F Metal ions	Freundlich pa	arameters for F	Cu ²⁺ reundlich Iso	therm	Ř	
Table B13 F Metal ions	Freundlich particular $\log C_e$	arameters for \mathbf{F}_{1} $log q_{e}$	Cu ²⁺ reundlich Iso <i>K_F</i>	therm n	Sé K	2
Table B13 F Metal ions	Freundlich pa $log C_e$	arameters for \mathbf{F}_{1} $log q_{e}$	Cu^{2+} reundlich Iso K_F (mg L ⁻¹)	otherm n	S.	22
Table B13 F Metal ions	Freundlich pa log C_e 0.366	arameters for \mathbf{F}_{1} $log q_{e}$ 0.176	Cu^{2+} reundlich Iso K_F (mg L ⁻¹)	otherm n	S S	2
Table B13 F Metal ions	Freundlich pa $log C_e$ 0.366 0.662	arameters for F_1 $log q_e$ 0.176 0.531	Cu ²⁺ reundlich Iso K _F (mg L ⁻¹)	ntherm n		2
Table B13 F Metal ions Cu ²⁺	Freundlich paragram $log C_e$ 0.366 0.662 0.837	arameters for Friend Prime	Cu^{2+} reundlich Iso K_F (mg L ⁻¹) $-$ 1.96	n n 1.5	0.9	635
Table B13 F Metal ions Cu ²⁺	Freundlich particular $log C_e$ 0.366 0.662 0.837 0.941	arameters for F_1 $log q_e$ 0.176 0.531 0.696 1.01	Cu^{2+} reundlich Iso K_F (mg L ⁻¹) $-$ 1.96	n n 1.5	0.9	635

Fourth experiment

Table B14 Langmuir parameters for Cu ²	2+
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Metal ions			Langmuir	Isotherm		
	C _e	q_e	C_e/q_e	q_{max}	K_L	R^2
	$(mg L^{-1})$	(mg g^{-1})	$(g L^{-1})$	$(mg g^{-1})$	$(g^{-1}mg)$	
	1.68	2.23	0.753	18		
	3.46	4.38	0.790			
Cu ²⁺	5.15	6.78	0.760	17.3	0.099	0.9343
	10.92	8.41	1.30			
	14.52	10.34	1.40			
Table B15 F	Freundlich p	arameters for	Cu ²⁺			
Table B15 F	Freundlich pa	arameters for	Cu ²⁺	thouse		
Table B15 F Metal ions	Freundlich pa	arameters for Finder	Cu ²⁺ reundlich Iso	otherm	Ŕ	2
Table B15 F Metal ions	Freundlich particular $log C_e$	arameters for \mathbf{F}_{i} log q_{e}	Cu^{2+} reundlich Iso K_F (mg L ⁻¹)	o therm n	je j	2 2
Table B15 F Metal ions	Freundlich particular for C_e 0.226	arameters for \mathbf{F}_{1} $log q_{e}$ 0.349	Cu^{2+} reundlich Iso K_F (mg L ⁻¹)	ntherm n	je j	2 2 2
Table B15 F Metal ions	Freundlich paragram $log C_e$ 0.226 0.539	arameters for F_{e} log q_{e} 0.349 0.641	Cu^{2+} reundlich Iso K_F (mg L ⁻¹)	ntherm n		2 2
Table B15 F Metal ions Cu ²⁺	Freundlich parameter C_e $log C_e$ 0.226 0.539 0.712	arameters for F_{e} log q_{e} 0.349 0.641 0.831	Cu^{2+} reundlich Iso K_F (mg L ⁻¹) $-$ 1.79	n n 1.5	0.94	² 477
Table B15 F Metal ions Cu ²⁺	Freundlich parameter C_e $log C_e$ 0.226 0.539 0.712 1.04	arameters for F_{e} $log q_{e}$ 0.349 0.641 0.831 0.925	Cu^{2+} reundlich Iso K_F (mg L ⁻¹) $-$ 1.79	n n 1.5	0.94	477

Fifth experiment

Table B16 Langmuir parameters	for	Cu ²⁺
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Metal ions			Langmuir	Isotherm		
	C _e	q_e	C_e/q_e	q_{max}	K_L	R^2
	$(mg L^{-1})$	$(mg g^{-1})$	(g L ⁻¹)	$(mg g^{-1})$	$(g^{-1}mg)$	
	1.68	2.23	0.753	18		
	3.46	4.38	0.790			
Cu ²⁺	5.15	6.78	0.760	17.3	0.099	0.9343
	10.92	8.41	1.30			
	14.52	10.34	1.40			
Table B17 F	reundlich p	arameters for	Cu ²⁺		No.	No.
Table B17 F Metal ions	Freundlich pa	arameters for	Cu ²⁺	therm	S.	No.
Table B17 F Metal ions	Freundlich pa	arameters for Fi	Cu ²⁺ reundlich Iso	therm	Sec.	22
Table B17 F Metal ions	Freundlich pa $log C_e$	arameters for $\mathbf{F}_{log \ q_e}$	Cu^{2+} reundlich Iso K_F (mg L ⁻¹)	therm n	No.	22
Table B17 F Metal ions	Freundlich pa log C_e 0.226	arameters for $\mathbf{F}_{log \ q_e}$ 0.349	Cu^{2+} reundlich Iso K_F (mg L ⁻¹)	therm <i>n</i>		22
Table B17 F Metal ions	Freundlich pa log C_e 0.226 0.539	arameters for Friction Prime Prim	Cu ²⁺ reundlich Iso K _F (mg L ⁻¹)	therm n	A A	22
Table B17 F Metal ions Cu ²⁺	Freundlich parameter $log C_e$ 0.226 0.539 0.712	arameters for Friend Prime	Cu^{2+} reundlich Iso K_F (mg L ⁻¹) $-$ 1.79	therm n 1.5	0.94	477
Table B17 F Metal ions Cu ²⁺	Freundlich parameter $log C_e$ 0.226 0.539 0.712 1.04	arameters for Fr $log q_e$ 0.349 0.641 0.831 0.925	Cu^{2+} reundlich Iso K_F (mg L ⁻¹) $-$ 1.79	ntherm n 1.5	0.94	477

APPENDIX C

Adsorption of Zn(II) ions on leonardite

C.1 Effect of pH

The adsorption of zinc on leonardite was studied at a pH range of 2-6, the initial zinc concentrations of 5.00 and 20.00 mg/L, in order to investigate the optimum pH for the removal of this ion. All experiments were performed in five experiments.

pН	2	%	Zn ²⁺ Remov	val	
	1	2	3	4	5
2	5.7	9.1	6.9	5.2	6.8
3	11.9	14.2	12.6	11.1	13.0
4	22.7	21.6	20.5	19.7	20.6
5	29.3	29.9	29.9	28.5	29.6
6	43.6	43.4	41.7	45.1	43.7

TableC1 % Zinc removal at pH 2-6 and the initial concentration of 5.00 mg/L

TableC2 % Zinc removal at pH 2-6 and the initial conce	entration of 20.00 mg/L
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	pН	1	UIN	%Removal			
		1	2	3	4	5	
	2	2.9	6.2	2.1	2.1	3.6	
	3	11.3	11.8	10.3	11.0	13.0	
dan	4	22.2	19.9	18.8	17.3	20.6	
	5	28.9	25.2	24.9	26.0	29.6	
	. 6 C	38.2	42.3	40.4	36.9	43.7	
	siit –	UY	CIIIa	ing iv		mve	

C.2 Contact time

In order to study the effect of contact time on zinc removal, the period of times were selected at 10, 20, 30, 40, 50, 60, 120, 180, 240, 300 and 360minutes, at 5.00 and 20.00 mg/L zinc initial concentrations. All experiments were performed in five experiments.

Time		The amou	nt of Zn ²⁺ adsorl	bed (mg/g)	
(min.)	1	2	3	4	5
0	0	0	0	0	0
10	0.2496	0.2491	0.2436	0.2538	0.2232
20	0.2589	0.2751	0.2674	0.2696	0.2597
30	0.2626	0.2931	0.2728	0.2717	0.2756
40	0.2662	0.2950	0.2815	0.2737	0.2815
50	0.2706	0.2988	0.2874	0.2806	0.2900
60	0.2748	0.3005	0.2902	0.2849	0.2928
120	0.3014	0.3076	0.2960	0.3008	0.2980
180	0.3306	0.3546	0.3315	0.3333	0.3402
240	0.3339	0.3574	0.3329	0.3375	0.3443
300	0.3339	0.3602	0.3337	0.3398	0.3497
360	0.3337	0.3613	0.3337	0.3405	0.3499

Table C3 The amount of Zn^{2+} adsorbed vs. time at concentration of 5.00 mg/L

Table C4 The amount of Zn^{2+} adsorbed vs. time at concentration of 20.00 mg/L

Time		The amou	nt of Zn ²⁺ adsor	bed (mg/g)	
(min.)	1	2	3	4	5
0	0	0	0	0	0
10	0.6862	0.6026	0.7030	0.5859	0.7615
20	0.7101	0.6741	0.7586	0.6415	0.7694
30	0.7477	0.7117	0.7962	0.6791	0.7995
40	0.8046	0.7331	0.8175	0.7005	0.8138
50	0.8246	0.7799	0.8443	0.7071	0.8204
60	0.8748	0.7924	0.8964	0.7322	0.8393
120	0.8982	0.8041	0.8752	0.7673	0.8451
180	0.9509	0.8623	0.9333	0.8255	0.8978
240	0.9526	0.8791	0.9401	0.8473	0.9196
300	0.9577	0.8841	0.9636	0.8570	0.9293
360	0.9709	0.8848	0.9725	0.8618	0.9383

C.3 Effect of leonardite quantity

In order to investigate the effect of leonardite quantity, a series of adsorption experiment was carried out with different leonardite dosages at the initial metal concentration of 5.00 and 20.00 mg/L. All experiments were performed in five experiments.

 Table C5 %Zinc removal at leonardite dose 0.400-3.00 g, at the initial concentration

 of 5.00 mg/L

Leonardite Quantity	%Zn ²⁺ removal				
(g)		2	3	4	5
0.400	40.0	43.2	41.6	40.6	41.8
0.700	49.4	47.8	47.2	45.9	49.9
1.00	66.8	68.0	67.9	64.3	66.9
3.00	85.2	84.1	87.0	83.6	87.8

 Table C6 %Zinc removal at leonardite dose 0.400-3.00 g, at the initial concentration

 of 20.00 mg/L

Leonardite Quantity	%Zn ²⁺ removal				
(g)	1	2	3	4	5
0.400	37.1	40.3	37.0	36.7	36.7
0.700	41.3	42.4	39.5	42.6	43.7
1.00	52.7	55.5	53.3	59.5	54.9
- 3.00	63.7	67.8	66.9	63.6	66.9



Figure C1 Effect of leonardite quantity at leonardite dose starting from 0.200-3.00 g

at the two concentrations of Zn^{2+}

Table C7 %Zinc removal at leonardite dose 0.200-3.00 g, at the two concentrations

	Leonardite Quantity	% Zn ²⁺ Removal		
	(g)	Zn ²⁺ 5 mg/L	Zn ²⁺ 20 mg/L	
	0.200	21.9	19.6	
<u> </u>	0.400	40.8	36.7	?
adansi	0.700	48.4	44.6	IAIX1
	1.00	65.3	61.7	
	3.00	84.1	70.0	
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C.4 Adsorption Isotherm

The adsorption capacity of adsorbent for copper was investigated over a range of zinc concentrations. The experimental data for the uptake of Zn^{2+} ions by adsorbent over the studied concentration range were processed in accordance with the two of the most widely used adsorption isotherms: Langmuir and Freundlich isotherms.

First experiment

Metal ions	Langmuir Isotherm						
S	C_e	q_e	C_e/q_e	q_{max}	KL	R^2	
	$(mg L^{-1})$	$(mg g^{-1})$	$(g L^{-1})$	$(mg g^{-1})$	(g ⁻¹ mg)		
	2.09	0.351	5.96				
	4.51	0.685	6.58				
Zn ²⁺	9.16	1.31	6.97	10.9	0.015	0.9360	
	13.74	1.88	7.32				
	19.58	2.55	7.69				

 Table C8 Langmuir parameters for Zn²⁺

Table C9 Freundlich parameters for Zn²

Metal ions					
ງສີກອິ	log C _e	$log q_e$	K_F (mg L ⁻¹)		R^2
nvriah	1.14	0.274	iona M		nivorsi
pyngi	1.29	0.406	angiv		
Zn ²⁺	1.50	0.535	0.330	1.5	0.9859
	1.64	0.653	_		
-	1.77	0.694	-		

Second experiment

Table C10 Langmuir parameters for Zn^{2+}

Metal ions			Langmuir	Isotherm		
	C_e	q_e	C_{e}/q_{e}	<i>q_{max}</i>	K _L	R^2
	$(\operatorname{mg} L^{-1})$	(mg g^{-1})	$(g L^{-1})$	(mg g^{-1})	$(g^{-1}mg)$	
	2.09	0.351	5.95	48		
	4.53	0.683	6.64			
Zn ²⁺	9.20	1.18	7.77	7.0	0.024	0.9119
	14.35	1.81	7.93			
	19.22	2.25	8.52			
Metal ions		F.	reundlich Iso	therm		
Metal lons		F	reunalich Iso	tnerm		.2
	log C _e	$log q_e$	K_F (mg L ⁻¹)	n	, ch	
	1.16	0.258			1	
	1.28	0.353	1000 60			
Zn ²⁺	1.50	0.517	0.254	1.3	0.9	817
	1.63	0.654	VIN			
	1 77	0.699				

Third experiment

Table C12 Langmuir parameters f	for Zn^{2+}
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Metal ions	Langmuir Isotherm							
	C _e	q_e	C_e/q_e	<i>q_{max}</i>	K _L	R^2		
	$(mg L^{-1})$	$(mg g^{-1})$	$(g L^{-1})$	(mg g^{-1})	$(g^{-1}mg)$			
	2.00	0.350	5.71	18				
	4.51	0.683	6.61					
Zn ²⁺	9.16	1.34	6.82	9.3	0.019	0.9227		
	14.35	1.95	7.34					
	19.76	2.51	7.86					
Table C13 F	Freundlich p	arameters for	- Zn ²⁺		No.	No.		
Table C13 F	Freundlich p	arameters for	Zn ²⁺		No.			
Table C13 F Metal ions	Freundlich p	arameters for F	Zn ²⁺ reundlich Iso	otherm	No.			
Table C13 F Metal ions	Freundlich p $log C_e$	arameters for \mathbf{F}	Zn^{2+} reundlich Iso K_F	otherm n	Ř	2		
Table C13 F Metal ions	Freundlich p log C _e	arameters for \mathbf{F}	Zn^{2+} reundlich Iso K_F (mg L ⁻¹)	otherm n	R	2 2 2		
Table C13 F Metal ions	Freundlich p $log C_e$ 1.16	arameters for \mathbf{F} log q_e 0.291	Zn^{2+} reundlich Iso K_F (mg L ⁻¹)	otherm <i>n</i>	K	2		
Table C13 F Metal ions	Freundlich p $log C_e$ 1.16 1.30	arameters for \mathbf{F} log q_e 0.291 0.400	Zn^{2+} reundlich Iso K_F (mg L ⁻¹)	otherm n	K	2 ²		
Table C13 F Metal ions	Freundlich p $log C_e$ 1.16 1.30 1.51	arameters for \mathbf{F} log q_e 0.291 0.400 0.542	$\frac{Zn^{2+}}{reundlich Iso}$ $\frac{K_F}{(mg L^{-1})}$ 0.315	otherm n 1.4	R 0.9'	743		
Table C13 F Metal ions Zn ²⁺	Freundlich p $log C_e$ 1.16 1.30 1.51 1.63	arameters for F $log q_e$ 0.291 0.400 0.542 0.673	$\frac{^{2}Zn^{2+}}{reundlich Iso}$ $\frac{K_{F}}{(mg L^{-1})}$ 0.315	otherm n 1.4	0.9	743		

Fourth experiment

Table	C14	Langmuir	parameters	for Zn^{2+}
Lanc		Dangman	parameters	

Metal ions	Langmuir Isotherm							
	C_e	q_e	C_e/q_e	q_{max}	K_L	R^2		
	$(mg L^{-1})$	$(mg g^{-1})$	$(g L^{-1})$	$(mg g^{-1})$	$(g^{-1}mg)$			
	2.12	0.334	6.35	18				
	4.51	0.663	6.80					
Zn ²⁺	9.20	1.33	6.94	15.5	0.011	0.9120		
	14.01	1.98	7.08					
	19.04	2 49	7.64					
Table C15 F	Freundlichpa	rameters for	Zn ²⁺		Š			
Table C15 F	Freundlichpa	urameters for	Zn ²⁺	thorm	ST.			
Table C15 F Metal ions	Freundlichpa	trameters for F	Zn ²⁺ reundlich Iso	therm	Ś	2		
Table C15 F Metal ions	Freundlichpa $log C_e$	$\frac{2.49}{F}$	Zn^{2+} reundlich Iso K_F (mg L ⁻¹)	otherm n	R	2		
Table C15 F Metal ions	Freundlichpa log C_e 1.15	rameters for F $log q_e$ 0.296	Zn^{2+} reundlich Iso K_F (mg L ⁻¹)	ntherm		<u>2</u>		
Table C15 F Metal ions	Freundlichpa $log C_e$ 1.15 1.28	$\frac{2.49}{\text{trameters for}}$ F $log q_e$ 0.296 0.396	Zn^{2+} reundlich Iso K_F (mg L ⁻¹)	n n		2 2		
Table C15 F Metal ions	Freundlichpa $log C_e$ 1.15 1.28 1.50	$\frac{2.49}{100}$	Zn^{2+} reundlich Iso K_F (mg L ⁻¹) 0.326	n n	0.99	954		
Table C15 F Metal ions	Freundlichpa $log C_e$ 1.15 1.28 1.50 1.63	2.49 arameters for F log q _e 0.296 0.396 0.548 0.634	Zn^{2+} reundlich Iso K_F (mg L ⁻¹) 0.326	n n 1.5	0.99	954		

Fifth experiment

Table (2 16 Lai	nomuir	parameters	for Zn^{2+}
I abic C		ngmun	parameters	

Metal ions	Langmuir Isotherm							
	C_e	q_e	C_e/q_e	q_{max}	K _L	R^2		
	(mg L ⁻¹)	(mg g ⁻¹)	$(g L^{-1})$	$(mg g^{-1})$	$(g^{-1}mg)$			
	2.09	0.352	5.93	18				
	4.62	0.689	6.71					
Zn ²⁺	9.43	1.28	7.37	7.0	0.024	0.9492		
	14.01	1.86	7.53					
	19.94	2.28	8.76					
Table C17 F	Freundlich p	arameters for	² Zn ²⁺					
Table C17 F	Freundlich p	arameters for	- Zn ²⁺					
Table C17 F Metal ions	Freundlich p	arameters for	Zn ²⁺ reundlich Iso	otherm	Ę			
Table C17 F Metal ions	Freundlich p	arameters for \mathbf{F}	Zn ²⁺ reundlich Iso K _F	otherm n	R.			
Table C17 F Metal ions	Freundlich p	arameters for \mathbf{F} log q_e	Zn^{2+} reundlich Iso K_F (mg L ⁻¹)	o therm n	A A A A A A A A A A A A A A A A A A A	2 2		
Table C17 F Metal ions	Freundlich p $log C_e$ 1.15	arameters for \mathbf{F} log q_e 0.270	Zn^{2+} reundlich Iso K_F (mg L ⁻¹)	otherm n	A A A A A A A A A A A A A A A A A A A	3 2 2		
Table C17 F Metal ions	Freundlich p $log C_e$ 1.15 1.30	arameters for F $log q_e$ 0.270 0.357	Zn^{2+} reundlich Iso K_F (mg L ⁻¹)	otherm n	A A	<u>}</u>		
Table C17 F Metal ions Zn ²⁺	Freundlich p $log C_e$ 1.15 1.30 1.52	arameters for F log q _e 0.270 0.357 0.519	$\frac{Zn^{2+}}{reundlich Iso}$ $\frac{K_F}{(mg L^{-1})}$ 0.284	n n 1.4	0.9	952		
Table C17 F Metal ions Zn ²⁺	Freundlich p $log C_e$ 1.15 1.30 1.52 1.64	arameters for F log q _e 0.270 0.357 0.519 0.628	$\frac{7 \text{Zn}^{2+}}{\text{reundlich Iso}}$ $\frac{K_F}{(\text{mg L}^{-1})}$ $-$ 0.284	n n 1,4	0.9	952		

APPENDIX D

Adsorption of Pb(II) ions on leonardite

D.1 Effect of pH

The adsorption of lead on leonardite was studied at a pH range of 2-6, the initial lead concentrations 5.00 and 20.00 mg/L, in order to investigate the optimum pH for the removal of this ion. All experiments were performed in five experiments.

pН	%Pb ²⁺ Removal						
	1	2	3	4	5		
2	84.7	83.8	85.1	81.8	81.6		
3	99.8	99.8	99.8	99.8	99.8		
4	99.8	99.8	99.8	99.8	99.8		
5	99.8	99.8	99.8	99.8	99.8		
6	99.8	99.8	99.8	99.8	99.8		

Table D1 % Lead removal at pH 2-6 and the initial concentration of 5.00 mg/L

Table D2 % Lead removal at pH 2-6 and the initial concentration of 20.00 mg/L

pН	%Pb ²⁺ Removal							
	1	2	3	4	5			
2	58.00	58.5	57.2	57.9	56.7			
3	92.0	89.4	90.00	90.8	90.6			
4	98.8	98.1	98.4	97.5	97.4			
5	99.9	99.9	99.9	99.9	99.9			
6	99.9	99.9	99.9	99.9	99.9			

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D.2 Contact time

In order to study the effect of contact time on lead removal, the period of times were selected at 10, 20, 30, 40, 50, 60, 120, 180, 240, 300 and 360minutes, at 5.00 and 20.00 mg/L lead initial concentrations. All experiments were performed in five experiments.

Time	The amount of Pb ²⁺ adsorbed (mg/g)							
(min.)	1	2	3	4	5			
0	0	0	0	0	0			
10	0.5209	0.5129	0.4969	0.5049	0.4969			
20	0.5285	0.5357	0.5273	0.5277	0.5197			
30	0.5381	0.5381	0.5369	0.5373	0.5365			
40	0.5381	0.5381	0.5369	0.5373	0.5365			
50	0.5381	0.5381	0.5369	0.5373	0.5365			
60	0.5381	0.5381	0.5369	0.5373	0.5365			
120	0.5381	0.5381	0.5369	0.5373	0.5365			
180	0.5381	0.5381	0.5369	0.5373	0.5365			
240	0.5381	0.5381	0.5369	0.5373	0.5365			
300	0.5381	0.5381	0.5369	0.5373	0.5365			
360	0.5381	0.5381	0.5369	0.5373	0.5365			

Table D3 The amount of Pb^{2+} adsorbed vs. time at concentration of 5.00 mg/L

Table D4 The amount of Pb^{2+} adsorbed vs. time at concentration of 20.00 mg/L

Time	The amount of Pb ²⁺ adsorbed (mg/g)							
(min.)		2	3	4	5			
0	0	0	0	0	0			
10	2.3798	2.3448	2.3478	2.3397	2.3718			
20	2.3874	2.4091	2.4010	2.3702	2.3946			
30	2.4235	2.4091	2.4227	2.3918	2.3946			
40	2.4303	2.4295	2.4227	2.4054	2.4219			
50	2.4452	2.4295	2.4440	2.4396	2.4283			
60	2.4452	2.4434	2.4440	2.4516	2.4422			
120	2.4452	2.4434	2.4440	2.4534	2.4422			
180	2.4452	2.4434	2.4440	2.4534	2.4422			
240	2.4452	2.4434	2.4440	2.4534	2.4422			
300	2.4452	2.4434	2.4440	2.4534	2.4422			
360	2.4452	2.4434	2.4440	2.4534	2.4422			

D.3 Effect of leonardite quantity

In order to investigate the effect of leonardite quantity, a series of adsorption experiment was carried out with different leonardite dosages at the initial metal concentration of 5.00 and 20.00 mg/L. All experiments were performed in five experiments.

 Table D5 % Lead removal at leonardite dose 0.400-3.00 g, at the initial concentration of 5.00 mg/L

Leonardite Quantity		%]	COC S		
(g)	E C	~ 2 5	3	4	5
0.400	99.8 📈	99.8	99.8	99.8	99.8
0.700	99.8	99.8	99.8	99.8	99.8
1.00	99.8	99.8	99.8	99.8	99.8
3.00	99.8	99.8	99.8	99.8	99.8

 Table D6 % Lead removal at leonardite dose 0.400-3.00 g, at the initial concentration

 of 20.00 mg/L

	Leonardite Quantity	%Pb ²⁺ removal				
2.2.	(g)	1	2	3	- 4	5
	0.400	99.1	99.2	99.2	99.2	99.2
	0.700	99.9	99.9	99.9	99.9	99.9
Conve	-1.00	99.9	99.9	-99.9	99.9	99.9
COPYI	3.00	99.9	99.9	99.9	99.9	99.9



Figure D1 Effect of leonardite quantity at leonardite dose starting from 0.200-3.00 g

at the two concentrations of Pb^{2+}

Table D7 %Lead removal at leonardite dose 0.200-3.00 g, at the two concentrations

	Leonardite Quantity	%Pb ²⁺		
	(g)	Pb ²⁺ 5 mg/L	Pb ²⁺ 20 mg/L	
	0.200	99.8	88.1	
	0.400	99.8	97.3	?
adans:	0.700	99.8	99.9	IAIXII
	1.00	99.8	99.9	
	3.00	99.8	99.9	
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D.4 Adsorption Isotherm

The adsorption capacity of adsorbent for lead was investigated over a range of lead concentrations. The experimental data for the uptake of Pb^{2+} ions by adsorbent over the studied concentration range were processed in accordance with the two of the most widely used adsorption isotherms: Langmuir and Freundlich isotherms

First experiment

Metal ions		157	Langmuir	Isotherm		
-SB3	C_e (mg L ⁻¹)	q_e (mg g ⁻¹)	C_{e}/q_{e} (g L ⁻¹)	q_{max} (mg g ⁻¹)	$\frac{K_L}{(g^{-1}mg)}$	R^2
	0.652	2.39	0.272			
	1.61	4.63	0.347			
Pb ²⁺	2.67	6.36	0.420	16.1	0.260	0.9942
	4.36	8.85	0.492			
	7.73	10.65	0.726			

Table D8 Langmuir parameters for Pb²⁺

Table D9 Freundlich parameters for Pb²⁺

Metal ions					
agna	log C _e	$log q_e$	K _F	n	R^2
			$(mg L^{-1})$		
onvrigh	- 0.186	0.379	ang		Univorsit
JPYIISI	0.206	0.665	ang		
Pb ²⁺	0.427	0.803	3.32	e 1.6	0.9843
	0.639	0.947			
_	0.888	1.03	-		

Second experiment

Table D10 Langmuir parameters	for	Pb ²⁺
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			Langmuir	Isotherm		
	C_e	q_e	C_e/q_e	q_{max}	K_L	R^2
	$(mg L^{-1})$	(mg g^{-1})	$(g L^{-1})$	$(mg g^{-1})$	$(g^{-1}mg)$	
	0.652	2.40	0.271	48		
	1.66	4.65	0.358			
Pb ²⁺	2.62	6.37	0.411	16.9	0.239	0.9958
	4.81	8.94	0.538			
	7.67	11.00	0.698			
	reundlich p	arameters for	Pb^{2+}			
	reundlich pa	arameters for	Pb^{2+}			
Metal ions	reunalich pa	arameters for	Pb ²⁺ reundlich Iso	therm		
Metal ions	$\log C_e$	arameters for \mathbf{F} $log q_e$	$\frac{Pb^{2+}}{reundlich Iso}$	therm n	R	2
Metal ions	$\log C_e$	arameters for \mathbf{F}	$\frac{Pb^{2+}}{reundlich Iso}$ K_F $(mg L^{-1})$	therm n	R	2
Metal ions	$log C_e$	arameters for \mathbf{F} log q_e 0.381	$\frac{Pb^{2+}}{reundlich Iso}$ $\frac{K_F}{(mg L^{-1})}$	therm n	R	2
Metal ions	-reundlich pa log C _e - 0.186	arameters for \mathbf{F} log q_e 0.381 0.667	$\frac{Pb^{2+}}{reundlich Iso}$ $\frac{K_F}{(mg L^{-1})}$	therm n	R	2
Metal ions Pb ²⁺		arameters for F log q _e 0.381 0.667 0.804	$\frac{Pb^{2+}}{reundlich Iso}$ $\frac{K_F}{(mg L^{-1})}$ $\frac{1}{3.29}$	n 1.6	R 0.99	922
Metal ions Pb ²⁺		arameters for F log q _e 0.381 0.667 0.804 0.951	$\frac{Pb^{2+}}{reundlich Iso}$ K_F (mg L ⁻¹) 3.29	therm <i>n</i> 1.6	0.99	922

Third experiment

Table D12 Lang	gmuir paramete	ers for Pb^2
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Metal ions			Langmuir	Isotherm		
	C _e	q_e	C_e/q_e	<i>q_{max}</i>	K_L	R^2
	$(mg L^{-1})$	(mg g^{-1})	$(g L^{-1})$	$(mg g^{-1})$	$(g^{-1}mg)$	
	0.708	2.35	0.302	18		
	1.44	4.63	0.311			
Pb ²⁺	2.67	6.54	0.409	16.9	0.241	0.9939
	4.81	8.99	0.535			
	7.45	10.86	0.686			
Metal ions		F	noundlich Ico	41		0
Metal lons		E.				
	lag C	100.0				2
	log C _e	log q _e	$\frac{K_F}{(\text{mg L}^{-1})}$	n	R	2
	log C _e	<i>log q_e</i>	$\frac{K_F}{(\text{mg L}^{-1})}$	n	R	2
		<i>log q_e</i> 0.370 0.665	$\frac{K_F}{(\text{mg } \text{L}^{-1})}$	n		2
Pb ²⁺	$ \begin{array}{r} log C_e \\ \hline -0.150 \\ 0.158 \\ 0.427 \\ \end{array} $	log q _e 0.370 0.665 0.816	$\frac{K_F}{(\text{mg L}^{-1})}$	n 1.6	0.9	749
Pb ²⁺	$ \begin{array}{r} log C_e \\ - 0.150 \\ 0.158 \\ 0.427 \\ 0.682 \\ \end{array} $	log q _e 0.370 0.665 0.816 0.954	$\frac{K_F}{(\text{mg L}^{-1})}$	n 1.6	0.9	749

Fourth experiment

Table D14 Langmuir parameters for	r Pb ²⁺
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Metal lons	Langmuir Isotherm						
	C_e	q_e	C_e/q_e	q_{max}	K _L	R^2	
	$(mg L^{-1})$	$(mg g^{-1})$	$(g L^{-1})$	$(mg g^{-1})$	$(g^{-1}mg)$		
	0.652	2.33	0.280	18			
	1.44	4.65	0.309				
Pb ²⁺	2.62	6.59	0.397	16.5	0.257	0.9961	
	4.92	9.01	0.546				
	7.39	10.95	0.675				
Table D15 F	Freundlich p	arameters for	Pb ²⁺		No.		
Table D15 F	Freundlich pa	arameters for	Pb ²⁺	thorm			
Table D15 F Metal ions	Freundlich pa	arameters for F	Pb ²⁺ reundlich Iso	therm		2 2	
Table D15 F Metal ions	Freundlich particular $\log C_e$	arameters for \mathbf{F}	Pb ²⁺ reundlich Iso K_F (mg L ⁻¹)	therm n	K	2	
Table D15 F Metal ions	Freundlich particular for $log C_e$ - 0.186	arameters for \mathbf{F} log q_e 0.368	Pb^{2+} reundlich Iso K_F (mg L ⁻¹)	therm <i>n</i>		2	
Table D15 F Metal ions	Freundlich paragram $log C_e$ - 0.186 0.158	arameters for F $log q_e$ 0.368 0.667	Pb^{2+} reundlich Iso K_F (mg L ⁻¹)	therm n		2	
Table D15 F Metal ions Pb ²⁺	Freundlich parameter $log C_e$ - 0.186 0.158 0.418	arameters for F $log q_e$ 0.368 0.667 0.819	$\frac{F}{F}$ reundlich Iso K_F (mg L ⁻¹) K_F 3.36	n n 1.6	0.9	804	
Table D15 F Metal ions Pb ²⁺	Freundlich particular for C_e - 0.186 0.158 0.418 0.692	arameters for F log q _e 0.368 0.667 0.819 0.955	$\frac{F}{F}$ reundlich Iso K_F (mg L ⁻¹) K_F (mg L ⁻¹)	n n 1.6	0.9	804	

Fifth experiment

Table 1	D16	Langmuir	parameters	for	Pb^2
I abit		Lungmun	purumeters	101	10

Wietai ions	Langmuir Isotherm							
	C_e	q_e	C_e/q_e	<i>q_{max}</i>	K _L	R^2		
	$(mg L^{-1})$	$(mg g^{-1})$	$(g L^{-1})$	$(mg g^{-1})$	$(g^{-1}mg)$			
	0.596	2.37	0.252	48				
	1.44	4.58	0.314					
Pb ²⁺	2.67	6.70	0.399	15.9	0.281	0.9978		
	4.81	8.99	0.535					
	7.67	11.00	0.698					
Table D17 F	Freundlich pa	arameters for	Pb ²⁺					
Table D17 F	Freundlich pa	arameters for	Pb ²⁺		S.	Real Provide P		
Table D17 F Metal ions	Freundlich pa	arameters for	Pb ²⁺ reundlich Iso	therm	SEX.			
Table D17 F Metal ions	Freundlich particular $\frac{1}{\log C_e}$	arameters for \mathbf{F}	Pb ²⁺ reundlich Iso K_F	otherm n	K	2		
Table D17 F Metal ions	Freundlich particular C_e	arameters for \mathbf{F} log q_e	Pb ²⁺ reundlich Iso K_F (mg L ⁻¹)	o therm n		2		
Table D17 F Metal ions	Freundlich particular for C_e - 0.225	arameters for \mathbf{F} log q_e 0.374	Pb ²⁺ reundlich Iso K_F (mg L ⁻¹)	n n		2		
Table D17 F Metal ions	Freundlich particular for C_e - 0.225 - 0.158	arameters for \mathbf{F} log q_e 0.374 0.661	Pb ²⁺ reundlich Iso K_F (mg L ⁻¹)	ntherm n		2		
Table D17 F Metal ions Pb ²⁺	Freundlich parameter C_e $log C_e$ -0.225 0.158 0.427	arameters for F log q_e 0.374 0.661 0.826	Pb ²⁺ reundlich Iso K_F (mg L ⁻¹) - 3.46	n n 1.7	0.9	878		
Table D17 F Metal ions Pb ²⁺	Freundlich parameter C_e $log C_e$ -0.225 0.158 0.427 0.682	arameters for F $log q_e$ 0.374 0.661 0.826 0.954	$\frac{Pb^{2+}}{reundlich Iso}$ $\frac{K_F}{(mg L^{-1})}$ $$	n n 1.7	0.9	878		

APPENDIX E

Adsorption of methylene blue on leonardite

E.1 Contact time

In order to study the effect of contact time on methylene blue removal, the period of times were selected at 10, 20, 30, 40, 50, 60, 120, 180, 240 and 300 minutes, at 60.00 and 110.0 mg/L methylene blue initial concentrations. All experiments were performed in five experiments.

Table E1 The amount of methylene blue adsorbed vs. time at concentration of 60.00mg/L, using unwashed leonardite

Time	The amount of methylene blue adsorbed (mg/g)						
(min.)	1	2	3	4	5		
0	0	0	0	0	0		
10	7.1599	6.9036	6.6343	6.7876	6.8959		
20	7.1688	6.9951	6.6505	6.8005	6.9984		
30	7.1886	7.0384	6.7579	6.8462	7.0297		
40	7.2179	7.0548	6.7637	6.8664	7.0540		
50	7.2280	7.1036	6.7800	6.8853	7.0819		
60	7.3497	7.2457	7.0560	7.1731	7.2636		
120	7.4028	7.3616	7.2732	7.3006	7.3582		
180	7.4036	7.3629	7.2772	7.3072	7.3606		
240	7.4036	7.3633	7.2780	7.3096	7.3610		
300	7.4040	7.3633	7.2784	7.3122	7.3614		

Copyright[©] by Chiang Mai University All rights reserved Table E2 The amount of methylene blue adsorbed vs. time at concentration of 60.00

Time	The amount of methylene blue adsorbed (mg/g)						
(min.)	1	2019	3	4	5		
0	0 0		000	0	0		
10	6.6378	6.3726	6.0147	6.2080	6.3521		
20	6.6378	6.4946	6.1573	6.3753	6.4124		
30	6.6604	6.5062	6.1941	6.4606	6.5151		
40	6.6924	6.6480	6.2405	6.5297	6.5582		
50	6.7727	6.7508	6.3496	6.5838	6.6292		
60	6.9817	7.0435	6.8861	6.8753	6.9836		
120	7.2473	7.2405	7.1401	7.1946	7.2178		
180	7.2481	7.2409	7.1454	7.1990	7.2182		
240	7.2488	7.2413	7.1462	7.2011	7.2186		
300	7.2488	7.2413	7.1462	7.2025	7.2200		

mg/L, using washed leonardite

Table E3 The amount of methylene blue adsorbed vs. time at concentration of 110.0

Time	The amount of methylene blue adsorbed (mg/g)					
(min.)	1	2	3	4	5	
0	0	0	0	0	0	
10	9.2372	9.0832	8.8233	8.8857	8.7145	
20	9.2610	9.1551	8.8978	8.9812	8.8830	
30	9.2837	9.4050	9.1569	9.1168	9.0883	
40	9.6679	9.6624	9.3570	9.3090	9.1314	
50	9.8487	9.6422	9.4198	9.4095	9.3139	
60	9.7734	9.9072	9.6160	9.5791	9.4279	
120	11.8980	11.9022	11.7912	11.7759	11.7116	
180	12.4256	12.4192	12.3308	12.3366	12.2803	
240	12.4316	12.4249	12.3406	12.3381	12.2867	
300	12.4340	12.4277	12.3449	12.3395	12.2958	
240 300	12.4316 12.4340	12.4249 12.4277	12.3406 12.3449	12.3381 12.3395		

mg/L, using unwashed leonardite

amount of	f methylene blue ac	lsorbed vs. tir	ne at concentra	tion o
ashed leor	ardite			
	The amount of m	ethylene blue	e adsorbed (m	g/g)
1		3	4	

Table E4 The of 110.0

Time		The amount of methylene blue adsorbed (mg/g)							
(min.)	1		3	4	5				
0	0			0	0				
10	9.5637	9.4365	9.1111	9.4133	9.1960				
20	9.7545	9.5804	9.6082	9.5327	9.3886				
30	9.8449	9.7848	9.7259	9.6683	9.5255				
40	9.9517	9.8277	9.9928	9.7538	9.6332				
50	9.9517	9.9287	10.1812	9.8342	9.8156				
60	9.8952	10.0044	10.3186	9.8719	9.3487				
120	12.2395	12.2180	12.5738	12.1785	12.5148				
180	12.5300	12.5168	12.8830	12.4808	12.4628				
240	12.5368	12.5232	12.8842	12.4872	12.4677				
300	12.5378	12.5246	12.8863	12.4921	12.4705				

mg/L, using wa



E.2 Effect of leonardite quantity

In order to investigate the effect of leonardite quantity, a series of adsorption experiment was carried out with different leonardite dosages at the initial methylene blue concentration of 60.00 and 110.0 mg/L. All experiments were performed in five experiments.

 Table E5 % Methylene blue removal at leonardite dose 0.200-3.00 g, at the initial concentration of 60.00 mg/L

Leonardite Quantity	13	emoval	224		
(g)	T A	2	3	4	5
0.200	99.5	99.5	99.5	99.4	99.4
0.400	99.7	99.7	99.6	99.6	99.6
0.700	99.7	99.7	99.7	99.6	99.6
1.00	99.7	99.7	99.7	99.7	99.7
3.00	99.7	99.7	99.7	99.7	99.7

 Table E6 %Methylene blue removal at leonardite dose 0.2-3 g, at the initial concentration 110 mg/L

	Leonardite Quantity		%Methylene blue removal				
	(g)	1	2	3	4	5	
	0.200	92.8	99.2	99.0	95.1	93.8	
OC	0.400	99.7	99.6	99.6	99.7	99.6	
	0.700	99.7	99.7	99.7	99.8	99.7	
onv	1.00	99.8	99.8	99.7	99.8	99.6	
JUPY	3.00	99.8	99.8	99.8	99.8	99.8	
	ri	ght	t s	re	s e i	rνe	

	at
the initial concentration 60.00 mg/L	

Leonardite

The amount of methylene blue adsorbed

Quantity					
(g)	917		93	4	5
0.200	14.9209	14.9297	14.9246	14.907	14.9096
0.400	7.4755	7.4736	7.4705	7.4709	7.4697
0.700	4.2728	4.2717	4.2707	4.2698	4.2695
1.00	2.9917	2.9902	2.9902	2.9897	2.9897
3.00	0.9972	0.9970	0.9968	0.9966	0.9966

Table E8 The amount of methylene blue adsorbed at leonardite dose 0.200-3.00 g, atthe initial concentration of 110 mg/L

Leonardite Quantity	The amount of methylene blue adsorbed							
(g)	1	2	3	4	5			
0.200	25.5174	25.3639	25.3110	26.1465	25.7967			
0.400	13.7041	13.6972	13.6947	13.7123	13.6960			
0.700	7.8349	7.8299	7.8309	7.8385	7.8324			
1.00	5.4884	5.4879	5.4839	5.4879	5.4864			
3.00	1.8301	1.8295	1.8297	1.8298	1.8298			

E.3 Adsorption Isotherm

First experiment

 Table E9 Langmuir parameters for methylene blue isotherm

Methylene	00		Langmui	r Isotherm		
blue						
1 9	C_e	q_e	C_e/q_e	<i>q_{max}</i>	K _L	R^2
	$(mg L^{-1})$	$(mg g^{-1})$	(g L ⁻¹)	$(mg g^{-1})$	$(g^{-1}mg)$	
6	0.247	9.97	0.024	\square		
	0.263	12.47	0.021			
	0.482	14.94	0.032			
	0.517	17.44	0.030	26.4	3.3	0.9976
	0.578	19.93	0.029			
	1.79	22.28	0.080			
	4.01	24.50	0.164			

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Methylene		Fre	undlich Isotl	herm	
blue					
	$log C_e$	$log q_e$	K_F	n	R^2
			$(mg L^{-1})$		
	-0.625	0.999		45	
	-0.580	1.10			
	-0.317	1.17	18.6	3.6	0.7982
	-0.286	1.24			
	-0.238	1.30			
	0.253	1.35			
	0.603	1.39			
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Table E10 Freundlich parametersfor methylene blue isotherm

Second experiment

Methylene			Langmui	r Isotherm		
blue						
	C_e	q_e	C_e/q_e	q_{max}	K_L	R^2
	$(mg L^{-1})$	$(mg g^{-1})$	$(g L^{-1})$	$(mg g^{-1})$	$(g^{-1}mg)$	
6	0.242	9.97	0.024	>	-31	
	0.263	12.47	0.021			
	0.451	14.94	0.030	26.6	3.2	0.9979
	0.568	17.43	0.033			
	0.624	19.92	0.031			
	1.72	22.28	0.077			
	3.80	24.52	0.155			

 Table E11 Langmuir parameters for methylene blue isotherm



Methylene					
blue					
	$log C_e$	$log q_e$	K _F	n	R^2
			$(mg L^{-1})$		
	-0.616	0.999		US)	
	-0.580	1.10			
	-0.346	1.17	18.6	3.4	0.8244
	-0.245	1.24			
	-0.205	1.30			
	0.237	1.35			
	0.580	1.39			
			¥ /		

Table E12 Freundlich parameters for methylene blue isotherm

Third experiment

Methylene	Langmuir Isotherm						
blue							
	C_e	q_e	C_e/q_e	<i>q_{max}</i>	K_L	R^2	
	$(mg L^{-1})$	$(mg g^{-1})$	$(g L^{-1})$	$(mg g^{-1})$	$(g^{-1}mg)$		
9	0.258	9.97	0.027	>	. 31		
	0.309	12.46	0.025				
	0.482	14.94	0.032	26.6	3.0	0.9981	
	0.584	17.43	0.033				
	0.680	19.91	0.034				
	1.75	22.28	0.079				
	4.22	24.47	0.173				

Table E13 Langmuir parameters for methylene blue isotherm



Methylene		Freu	ndlich Isot	herm	
blue					
	$log C_e$	$log q_e$	K _F	n	R^2
			$(mg L^{-1})$		
	-0.589	0.999		45	
	-0.511	1.10			
	-0.317	1.17	18.2	3.4	0.8166
	-0.234	1.24			
	-0.167	1.30			
	0.244	1.35			
	0.626	1.39			
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Table E14 Freundlich parameters for for Methylene blue isotherm

Fourth experiment

Methylene	e Langmuir Isotherm						
blue							
	C_e	q_e	C_{e}/q_{e}	<i>q_{max}</i>	K _L	R^2	
	$(mg L^{-1})$	$(mg g^{-1})$	(g L ⁻¹)	$(mg g^{-1})$	(g ⁻¹ mg)		
9	0.229	9.97	0.023	> /			
	0.249	12.47	0.020				
	0.451	14.94	0.030	26.2	3.4	0.9984	
	0.561	17.43	0.032				
	0.607	19.92	0.030				
	1.75	22.28	0.078				
	4.13	24.48	0.169				

Table E15 Langmuir parameters for methylene blue isotherm



Methylene		Fre	undlich Isoth	erm	
blue					
	log C _e	$log q_e$	K _F	n	R^2
			$(mg L^{-1})$		
	-0.639	0.999	0	4	
	-0.603	1.10			
	-0.346	1.17	18.6	3.6	0.8192
	-0.251	1.24			
	-0.217	1.30			
	0.243	1.35			
	0.616	1.39			
E.					9

Table E16 Freundlich parameters for for Methylene blue isotherm

Fifth experiment

		Langmuir	Isotherm		
C_e	q_e	C_{e}/q_{e}	<i>q_{max}</i>	K _L	R^2
$(mg L^{-1})$	$(mg g^{-1})$	$(g L^{-1})$	$(mg g^{-1})$	(g ⁻¹ mg)	
0.204	9.97	0.020	> \	2	
0.234	12.47	0.019			
0.451	14.94	0.030	26.1	3.6	0.9986
0.521	17.43	0.030			
0.597	19.93	0.030			
1.80	22.28	0.081			
4.08	24.49	0.167			
	$ \begin{array}{c} C_e \\ (mg L^{-1}) \\ 0.204 \\ 0.234 \\ 0.451 \\ 0.521 \\ 0.597 \\ 1.80 \\ 4.08 \\ \end{array} $	C_e q_e (mg L ⁻¹)(mg g ⁻¹)0.2049.970.23412.470.45114.940.52117.430.59719.931.8022.284.0824.49	C_e q_e $C_{e'}/q_e$ (mg L ⁻¹)(mg g ⁻¹)(g L ⁻¹)0.2049.970.0200.23412.470.0190.45114.940.0300.52117.430.0300.59719.930.0301.8022.280.0814.0824.490.167	Langmuir Isotherm C_e q_e C_{e}/q_e q_{max} (mg L ⁻¹)(mg g ⁻¹)(g L ⁻¹)(mg g ⁻¹)0.2049.970.020	Langmuir Isotherm C_e q_e $C_{e'}q_e$ q_{max} K_L (mg L ⁻¹)(mg g ⁻¹)(g L ⁻¹)(mg g ⁻¹)(g ⁻¹ mg)0.2049.970.020

 Table E17 Langmuir parameters for methylene blue isotherm



Methylene		Freu	undlich Isot	herm	
blue					
	log C _e	$log q_e$	$K_{\rm F}$ (mg L ⁻¹)	n	R^2
	-0.690	0.999			
	-0.630	1.10	18 7	37	0 8325
	-0.346	1.17	10.7	5.7	0.8325
	-0.283	1.24			
	-0.224	1.30			
	0.255	1.35			
	0.611	1.39			
E				•	5

Table E18 Freundlich parameters for for Methylene blue isotherm

CURRICULUM VITAE

Miss Suttasinee Kantanyoo

Date of birth June 8, 1982

Academic status:

- High school certificate holder from Uttaraditdarunee School, Uttaradit,

2001.

Name

- B.Sc. (Chemistry), Naresuan University, 2005.

- M.S. (Material Science), Chiang Mai University, 2007.

Grants:

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