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APPENDIX A: BATCH EXPERIMENTAL DATA

Table A.1: Equilibrium data: Effect of bagasse dosage (Initial C_0 =50ml /L, V=100ml)

Sample no	Mass of bagasse (g)	C_e (mg /L)	q_e (mg/ g)	Ln C_e	Ln q_e	1/ C_e	1/ q_e	% Dye removal
1	0	50	-	-	-	-	-	0
2	0.05	29.683	40.634	3.390574	3.704605	0.033689	0.02461	40.634
3	0.1	14.083	35.917	2.644968	3.581211	0.071008	0.027842	71.834
4	0.2	3.7251	23.13745	1.315094	3.141453	0.268449	0.04322	92.5498
5	0.3	1.7392	16.08693	0.553425	2.778007	0.574977	0.062162	96.5216
6	0.5	0.7016	9.85968	-0.35439	2.288454	1.425314	0.101423	98.5968
7	0.75	0.4806	6.602587	-0.73272	1.887461	2.080732	0.151456	99.0388

Table A.2: Equilibrium data: Effect of initial methylene blue concentration (2g of baggase, V=200ml)

Initial Con mg/L C_0	Equli. Con mg/L C_e	q_e	% Dye Removal
10	0.2349	0.97651	97.651
12.5	0.3029	1.21971	97.5768
25	0.6535	2.43465	97.386
50	1.7436	4.82564	96.5128
100	5.4812	9.45188	94.5188

Table A.3: Equilibrium data: Effect of pH (Baggase =0.3 g, C_0=50mg/L, V = 100ml)

pH	C_e	q_e	% Dye removal
0.98	9.556	13.48133	80.888
2.05	3.532	15.48933	92.936
3.89	1.8103	16.06323	96.3794
6	1.7401	16.08663	96.5198
7.6	1.7192	16.0936	96.5616
9.1	1.8011	16.0663	96.3978
10.02	2.5413	15.81957	94.9174
10.47	2.0454	15.98487	95.9092
12.07	2.0945	15.9685	95.811

Table A.4: Effect of contact time (C_0=40mg/L, Bagasse dosage= 2g, V=700ml)

Sample No.	Time (min)	Concentration (C_t)			C_t/C_0
		100 RPM	200 RPM	300 RPM	(300 RPM)
1	0	40	40	40	1
2	1	33.11	29.14	27	0.675
3	2	28.225	22.613	23.242	0.58105
4	3	22.104	19.56	16.131	0.403275
5	5	19.245	14.55	16.219	0.405475
6	8	16.14	13.451	12.467	0.311675
7	12	12.643	9.819	8.643	0.216075
8	32	7.641	6.218	5.172	0.1293

APPENDIX B:FIXED BED EXPERIMENTAL DATA

Table B.1: Fixed bed experimental data with Yoon-Nelson estimation (C_0=50mg/L, F=20ml/min)

Time (min)	At 15cm bed Height				At 20cm bed Height				Error Analysis	
	Ct exp	Ct model	Ct/Co exp	Ct/Co model	Ct exp	Ct model	Ct/Co exp	Ct/Co model	15 cm	20 cm
30	0.1503	0.113093	0.003006	0.002262	0.0078	0.00955	0.000156	0.000191	0.247549	0.225864
35	0.297	0.14254	0.00594	0.002851	0.0099	0.011996	0.000198	0.00024	0.520067	0.214324
40	0.3134	0.179626	0.006268	0.003593	0.0125	0.015067	0.000251	0.000301	0.426846	0.202892
45	0.3393	0.226318	0.006786	0.004526	0.0159	0.018923	0.000318	0.000378	0.332985	0.191565
50	0.2723	0.285077	0.005446	0.005702	0.0201	0.023767	0.000403	0.000475	0.046924	0.180343
55	0.3905	0.358982	0.00781	0.00718	0.0255	0.02985	0.000511	0.000597	0.080711	0.169225
60	0.4414	0.451872	0.008828	0.009037	0.0324	0.037488	0.000647	0.00075	0.023725	0.158208
65	0.4822	0.568524	0.009644	0.01137	0.0410	0.047079	0.000821	0.000942	0.17902	0.147293
70	0.4965	0.714854	0.00993	0.014297	0.0520	0.059122	0.00104	0.001182	0.439786	0.136477
75	0.804	0.898163	0.01608	0.017963	0.0659	0.074239	0.001319	0.001485	0.117118	0.12576
80	1.1	1.127403	0.022	0.022548	0.0836	0.093215	0.001672	0.001864	0.024912	0.115141
85	1.609	1.413468	0.03218	0.028269	0.1051	0.117031	0.002102	0.002341	0.121524	0.113516
90	2.33	1.769491	0.0466	0.03539	0.1514	0.146912	0.003028	0.002938	0.240562	0.029648
95	2.692	2.211107	0.05384	0.044222	0.1401	0.184396	0.002802	0.003688	0.178638	0.316171
100	3.148	2.756639	0.06296	0.055133	0.2155	0.231398	0.00431	0.004628	0.124321	0.073773
105	4.5	3.427114	0.09	0.068542	0.3450	0.290312	0.0069	0.005806	0.238419	0.158517
110	5.6288	4.246007	0.112576	0.08492	0.8707	0.364115	0.017414	0.007282	0.245664	0.581814
115	7.3674	5.238562	0.147348	0.104771	0.5010	0.456508	0.01002	0.00913	0.288954	0.088806
120	8.19	6.430528	0.1638	0.128611	0.6153	0.572075	0.012306	0.011442	0.214832	0.07025
125	10.05	7.84617	0.201	0.156923	0.7708	0.716476	0.015416	0.01433	0.219287	0.070477
130	11.246	9.505466	0.22492	0.190109	0.8838	0.896665	0.017676	0.017933	0.154769	0.014556
135	12.844	11.4206	0.25688	0.228412	1.1540	1.121139	0.02308	0.022423	0.110822	0.028476
140	14	13.59207	0.28	0.271841	1.5050	1.400206	0.0301	0.028004	0.029138	0.069631
145	16.5	16.00513	0.33	0.320103	2.9690	1.746255	0.05938	0.034925	0.029992	0.411837
150	18.965	18.62742	0.3793	0.372548	2.1210	2.174001	0.04242	0.04348	0.0178	0.024989
155	21.2	21.40876	0.424	0.428175	2.7851	2.70066	0.055702	0.054013	0.009847	0.030318
160	24.51	24.28395	0.4902	0.485679	3.4791	3.345978	0.069582	0.06692	0.009223	0.038263
165	27.8	27.17821	0.556	0.543564	4.2214	4.132023	0.084429	0.08264	0.022366	0.02118
170	30.035	30.01482	0.6007	0.600296	3.5676	5.082611	0.071352	0.101652	0.000672	0.424658
175	31.5	33.14026	0.63	0.662805	6.9371	6.423695	0.138742	0.128474	0.052072	0.074009
180	36	35.24457	0.72	0.704891	8.0117	7.574257	0.160234	0.151485	0.020984	0.0546
185	36.456	37.53828	0.72912	0.750766	10.0010	9.158622	0.20002	0.183172	0.029687	0.084229
190	38.754	39.58085	0.77508	0.791617	11.8	10.98856	0.236	0.219771	0.021336	0.068766
195	39.05	41.36563	0.781	0.827313	18.055	13.06715	0.3611	0.261343	0.059299	0.276259

Time (min)	At 15cm bed Height				At 20cm bed Height				Error Analysis	
	Ct exp	Ct model	Ct/Co exp	Ct/Co model	Ct exp	Ct model	Ct/Co exp	Ct/Co model	15 cm	20 cm
200	41.41	42.89953	0.8282	0.857991	16.001	15.38387	0.32002	0.307677	0.03597	0.038568
205	42.832	44.19914	0.85664	0.883983	19.39	17.91213	0.3878	0.358243	0.031919	0.076218
210	44.2712	45.28702	0.885424	0.90574	22.28	20.60852	0.4456	0.41217	0.022945	0.075021
215	45.5	46.18847	0.91	0.923769	24.44	23.41463	0.4888	0.468293	0.015131	0.041955
220	47.152	46.92919	0.94304	0.938584	27.18	26.26143	0.5436	0.525229	0.004725	0.033796
225	47.308	47.53365	0.94616	0.950673	31.84	29.0758	0.6368	0.581516	0.00477	0.086815
230	47.67	48.02414	0.9534	0.960483	37.76	31.78791	0.7552	0.635758	0.007429	0.158159
235	48.391	48.42032	0.96782	0.968406	33.254	34.33784	0.66508	0.686757	0.000606	0.032593
240	48.99	48.73915	0.9798	0.974783	38.48	36.68034	0.7696	0.733607	0.00512	0.046769
245	49.096	48.99497	0.98192	0.979899	39.451	38.7869	0.78902	0.775738	0.002058	0.016834
250	49.4035	49.19973	0.98807	0.983995	41.2	40.64527	0.824	0.812905	0.004125	0.013464
255	49.5178	49.36332	0.990356	0.987266	43.001	42.25713	0.86002	0.845143	0.00312	0.017299
260	49.5586	49.49381	0.991172	0.989876	44.8	43.63475	0.896	0.872695	0.001307	0.02601
265	49.6095	49.59778	0.99219	0.991956	42.11	44.79744	0.8422	0.895949	0.000236	0.06382
270	49.7277	49.68053	0.994554	0.993611	47.12	45.76835	0.9424	0.915367	0.000949	0.028685
275	49.6607	49.74634	0.993214	0.994927	47.31	46.57193	0.9462	0.931439	0.001725	0.015601
280	49.6866	49.79865	0.993732	0.995973	47.1	47.23214	0.942	0.944643	0.002255	0.002806
285	49.703	49.84021	0.99406	0.996804	42.51	47.77129	0.8502	0.955426	0.002761	0.123766
290	49.8497	49.87321	0.996994	0.997464	48.01	48.20939	0.9602	0.964188	0.000472	0.004153
295					48.68	48.56397	0.9736	0.971279		0.002384
300					42.92	48.85001	0.8584	0.977		0.138164
305					49.32	49.08015	0.9864	0.981603		0.004863
310					49.46	49.26493	0.9892	0.985299		0.003944
315					49.57	49.41303	0.9914	0.988261		0.003167

Table B.2: Fixed bed experimental data and BDST estimation (C_0=50mg/L, F=20ml/min).

Time (min)	Bed Height 15 cm					Bed Height 20 cm				
	Exp. Ct	Model. Ct	Exp Ct/Co	Model. Ct/Co	% Error	Exp. Ct	Model. Ct	Exp Ct/Co	Model. Ct/Co	% Error
30	0.1503	0.139732	0.003006	0.002795	0.070311	0.007791	0.008941	0.000156	0.000179	0.147585
35	0.297	0.174954	0.00594	0.003499	0.41093	0.009878	0.011258	0.000198	0.000225	0.139631
40	0.3134	0.219014	0.006268	0.00438	0.301167	0.012525	0.014175	0.000251	0.000284	0.131731
45	0.3393	0.27411	0.006786	0.005482	0.192131	0.015881	0.017849	0.000318	0.000357	0.123885
50	0.2723	0.34297	0.005446	0.006859	0.259531	0.020136	0.022473	0.000403	0.000449	0.116092
55	0.3905	0.42898	0.00781	0.00858	0.09854	0.02553	0.028296	0.000511	0.000566	0.108352

Time (min)	Bed Height 15 cm					Bed Height 20 cm				
	Exp. Ct	Model. Ct	Exp Ct/Co	Model. Ct/Co	% Error	Exp. Ct	Model. Ct	Exp Ct/Co	Model. Ct/Co	% Error
60	0.4414	0.536326	0.008828	0.010727	0.215057	0.032367	0.035626	0.000647	0.000713	0.100664
65	0.4822	0.670171	0.009644	0.013403	0.389819	0.041035	0.044853	0.000821	0.000897	0.093028
70	0.4965	0.836853	0.00993	0.016737	0.685504	0.052022	0.056467	0.00104	0.001129	0.085443
75	0.804	1.044113	0.01608	0.020882	0.298648	0.065946	0.071084	0.001319	0.001422	0.077909
80	1.1	1.301347	0.022	0.026027	0.183043	0.083591	0.089478	0.001672	0.00179	0.070427
85	1.609	1.619857	0.03218	0.032397	0.006748	0.1051	0.112621	0.002102	0.002252	0.071557
90	2.33	2.013101	0.0466	0.040262	0.136008	0.151401	0.141733	0.003028	0.002835	0.06386
95	2.692	2.496884	0.05384	0.049938	0.07248	0.1401	0.178343	0.002802	0.003567	0.272967
100	3.148	3.089444	0.06296	0.061789	0.018601	0.2155	0.224367	0.00431	0.004487	0.041146
105	4.5	3.811347	0.09	0.076227	0.153034	0.345	0.282201	0.0069	0.005644	0.182026
110	5.6288	4.685087	0.112576	0.093702	0.167658	0.8707	0.354837	0.017414	0.007097	0.592469
115	7.3674	5.734264	0.147348	0.114685	0.221671	0.501	0.446001	0.01002	0.00892	0.109779
120	8.19	6.98219	0.1638	0.139644	0.147474	0.6153	0.560321	0.012306	0.011206	0.089352
125	10.05	8.449856	0.201	0.168997	0.159218	0.7708	0.703529	0.015416	0.014071	0.087274
130	11.246	10.15321	0.22492	0.203064	0.097171	0.8838	0.882685	0.017676	0.017654	0.001261
135	12.844	12.09995	0.25688	0.241999	0.05793	1.154	1.10644	0.02308	0.022129	0.041213
140	14	14.28611	0.28	0.285722	0.020437	1.505	1.385315	0.0301	0.027706	0.079525
145	16.5	16.69329	0.33	0.333866	0.011715	2.969	1.73199	0.05938	0.03464	0.416642
150	18.965	19.28704	0.3793	0.385741	0.016981	2.121	2.161563	0.04242	0.043231	0.019124
155	21.2	22.01738	0.424	0.440348	0.038556	2.7851	2.691738	0.055702	0.053835	0.033522
160	24.51	24.82186	0.4902	0.496437	0.012724	3.4791	3.342864	0.069582	0.066857	0.039158
165	27.8	27.63083	0.556	0.552617	0.006085	4.221435	4.13772	0.084429	0.082754	0.019831
170	30.035	30.3742	0.6007	0.607484	0.011293	3.5676	5.100913	0.071352	0.102018	0.429788
175	31.5	33.39085	0.63	0.667817	0.060027	6.9371	6.462435	0.138742	0.129249	0.068424
180	36	35.42127	0.72	0.708425	0.016076	8.0117	7.632294	0.160234	0.152646	0.047357
185	36.456	37.63671	0.72912	0.752734	0.032387	10.001	9.244982	0.20002	0.1849	0.075594
190	38.754	39.6142	0.77508	0.792284	0.022196	11.8	11.10908	0.236	0.222182	0.058553
195	39.05	41.34811	0.781	0.826962	0.05885	18.055	13.22706	0.3611	0.264541	0.267402
200	41.41	42.84482	0.8282	0.856896	0.034649	16.001	15.58699	0.32002	0.31174	0.025874
205	42.832	44.11944	0.85664	0.882389	0.030058	19.39	18.16005	0.3878	0.363201	0.063432
210	44.2712	45.19248	0.885424	0.90385	0.02081	22.28	20.89989	0.4456	0.417998	0.061944
215	45.5	46.08708	0.91	0.921742	0.012903	24.44	23.74483	0.4888	0.474897	0.028444
220	47.152	46.8269	0.94304	0.936538	0.006895	27.18	26.62274	0.5436	0.532455	0.020503
225	47.308	47.43463	0.94616	0.948693	0.002677	31.84	29.4581	0.6368	0.589162	0.074808
230	47.67	47.9311	0.9534	0.958622	0.005477	37.76	32.17975	0.7552	0.643595	0.147782
235	48.391	48.33487	0.96782	0.966697	0.00116	33.254	34.72775	0.66508	0.694555	0.044318
240	48.99	48.66203	0.9798	0.973241	0.006695	38.48	37.05796	0.7696	0.741159	0.036955
245	49.096	48.92635	0.98192	0.978527	0.003456	39.451	39.14377	0.78902	0.782875	0.007788
250	49.4035	49.13937	0.98807	0.982787	0.005346	41.2	40.97528	0.824	0.819506	0.005454
255	49.5178	49.31072	0.990356	0.986214	0.004182	43.001	42.55657	0.86002	0.851131	0.010335

Time (min)	Bed Height 15 cm					Bed Height 20 cm				
	Exp. Ct	Model. Ct	Exp Ct/Co	Model. Ct/Co	% Error	Exp. Ct	Model. Ct	Exp Ct/Co	Model. Ct/Co	% Error
260	49.5586	49.44834	0.991172	0.988967	0.002225	44.8	43.90202	0.896	0.87804	0.020044
265	49.6095	49.55873	0.99219	0.991175	0.001023	42.11	45.03265	0.8422	0.900653	0.069405
270	49.7277	49.64718	0.994554	0.992944	0.001619	47.12	45.97289	0.9424	0.919458	0.024345
275	49.6607	49.71801	0.993214	0.99436	0.001154	47.31	46.748	0.9462	0.93496	0.011879
280	49.6866	49.77468	0.993732	0.995494	0.001773	47.1	47.38242	0.942	0.947648	0.005996
285	49.703	49.82001	0.99406	0.9964	0.002354	42.51	47.89864	0.8502	0.957973	0.126762
290	49.8497	49.85624	0.996994	0.997125	0.000131	48.01	48.31667	0.9602	0.966333	0.006388
295						48.68	48.65388	0.9736	0.973078	0.000537
300						42.92	48.92504	0.8584	0.978501	0.139912
305						49.32	49.14254	0.9864	0.982851	0.003598
310						49.46	49.31664	0.9892	0.986333	0.002898
315						49.57	49.45579	0.9914	0.989116	0.002304

B.1 Determining BDST Parameters

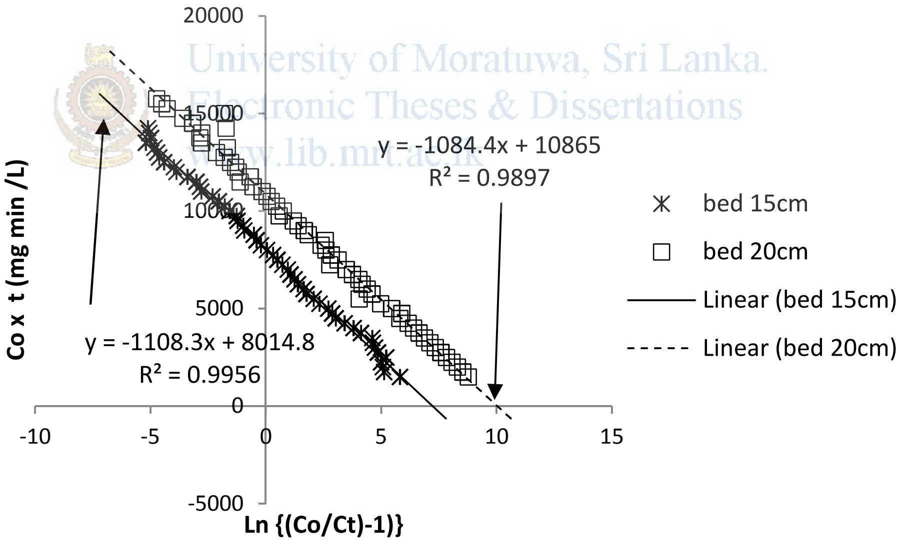

Fig B.1:Plot of determining BDST parameters, (C_0=50mg/L, F=20ml/min).

B.2 Determining Yoon-Nelson Parameters

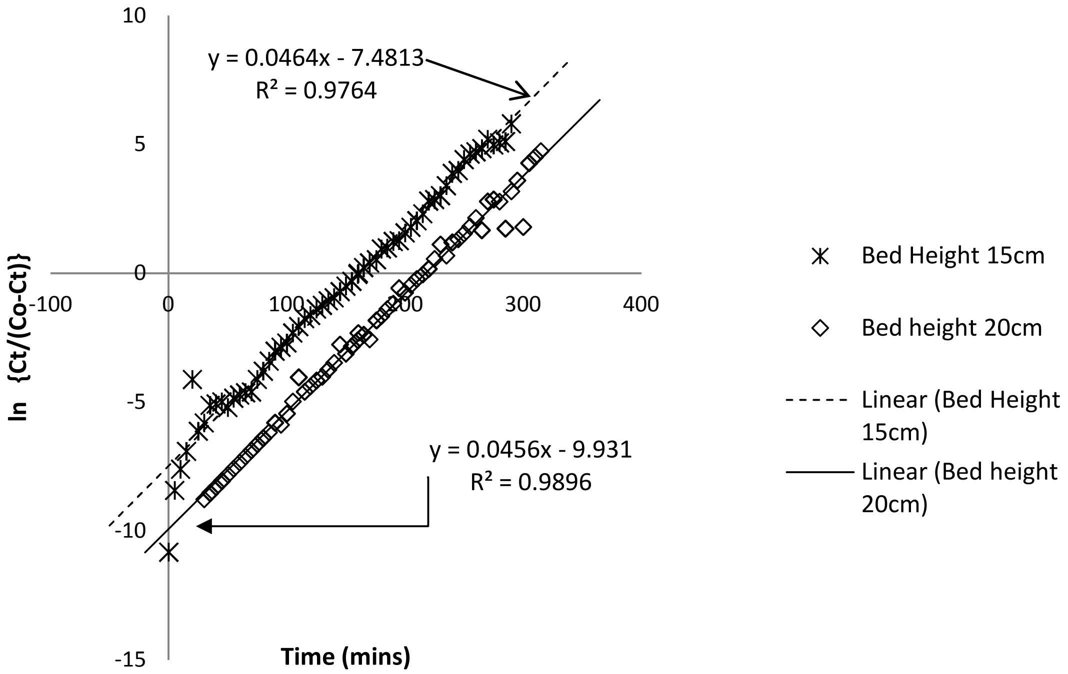

Fig B.2: Plot of determining Yoon-Nelson parameters, (C_0=50mg/L, F=20ml/min).

APPENDIX C: MATLAB CODE

Matlab code contains in three files.

Main program Adsim.mat

```
 % Defining parameters
 adpar;
% Simulation time
NL = 20; % No. slices along column axis
dz = 1/NL;
NRp = 10; % No. of onion layers in particles
dr = 1/NRp;
par=[NPe, NBi, kap, e, NL, NRp];
tau=4.09; % dimensionless time conversion factor

tspan = [0,tfin]; % min
% Inputs
u = c0;
% Defining anonymous model function
adm = @(t,x) admod(t,x,u,par);
% Initial values for states
x0 = [c;reshape(cp,NL*(NRp-2),1)];
% Simulating system
[time,X] = ode15s(adm,tspan,x0);
% Decomposing the data
C = X(:,1:NL-2);
Cp = X(:,NL-1:end);
dz = 1/NL;
C1 = (C(:,1)+dz*NPe)/(c0+dz*NPe);
CNL = C(:,end);
C = [C1,C,CNL];
Ntime = length(time);
Cp = reshape(Cp,Ntime,NL,NRp-2);
dr = 1/NRp;
Cp1 = Cp(:,:,1);
CpNRp = Cp(:,:,end) + dr*NBi*(C - Cp(:,:,end));
CCp = zeros(Ntime,NL,NRp);
CCp(:,:,1) = Cp1;
CCp(:,:,end) = CpNRp;
CCp(:,:,2:end-1) = Cp;
Cp = CCp;
% Plots
figure(1);
plot(time*tau,C);

hold on;
```

```
plot(time*tau,C(:,end),'kx');
hold off;
xlabel('time $t$ [min]', 'Interpreter', 'LaTeX');
ylabel('$Ct/Co(t,z)$','Interpreter', 'LaTeX');
title('Liquid dye concentration in adsorber column [x: z*=1]');
figure(2);
plot(time*tau,Cp(:,:,1));
plot(time*tau,Cp(:,:,1),'ko');
hold on;
for I=2:NRp
plot(time*tau,Cp(:,:,I));
end
hold off;
xlabel('time $t^*$ [s]', 'Interpreter', 'LaTeX');
ylabel('$c^*_p(t^*,z^*)$','Interpreter', 'LaTeX');
title('Particle dye concentration in adsorber column [o: r*=0]');

 %ploting experimental data 20cm
% ttt=[30    35    40    45    50    55    60    65    70    75    80
        85    90    95    100   105   110   115   120   125   130
        135   140   145   150   155   160   160   165   170   175
        180   185   190   195   200   205   210   215   220   225
        230   235   240   245   250   255   260   265   270   275
        280   285   290   295   300   305   310   315
% ];
% xx=[0.000155816  0.000197568  0.000250505  0.000317623  0.000402715
        0.000510593  0.00064735   0.000820705  0.001040435  0.001318917
        0.001671813  0.002102     0.00302802   0.002802     0.00431
        0.0069 0.009414    0.01002      0.01106      0.015416     0.017676
        0.02308      0.0301 0.05938     0.04242      0.055702     0.0700832
        0.069582     0.0844287    0.071352     0.138742     0.160234
        0.20002      0.236  0.3611 0.32002     0.3878 0.4456 0.4888 0.5436
        0.6368 0.6752 0.66508      0.7696 0.78902      0.824  0.86002
        0.896  0.8422 0.9424 0.9462 0.942  0.9502 0.9602 0.9736 0.9784 0.9864
        0.9892 0.9914
% ];

% ploting experimental data 15cm
ttt=[30 35    40    45    50    55    60    65    70    75    80    85
        90    95    100   105   110   115   120   125   130   135
        140   145   150   155   160   165   170   175   180   185
        190   195   200   205   210   215   220   225   230   235
        240   245   250   255   260   265   270   275   280   285
        290
];
xx=[0.003006 0.00594      0.006268     0.006786     0.005446     0.00781
        0.008828     0.009644     0.00993      0.01608      0.022  0.03218
```

```
	0.0466 0.05384		0.06296		0.09	0.112576	0.147348
	0.1638 0.201	0.22492		0.25688		0.28	0.33	0.3793 0.424
	0.4902 0.556	0.6007 0.63	0.72	0.72912		0.77508		0.781
	0.8282 0.85664		0.885424	0.91	0.94304		0.94616
	0.9534 0.96782		0.9798 0.98192		0.98807		0.990356
	0.991172	0.99219		0.994554	0.993214	0.993732
	0.99406		0.996994
];
figure(3);
plot(time*tau,C(:,end));
hold on
plot(ttt,xx,'-ro')
hold off

xlabel('time $t$ [min]', 'Interpreter', 'LaTeX');
ylabel('$Ct/Co(t,L)$','Interpreter', 'LaTeX');
hleg1 = legend('Model Co=50mg/L','Experimental Co=50mg/L');
```

2. Model parameters contain with Adpar.mat

```
% Parameters
 NPe = 40.5; % dimensionless
 NBi = 15.7; % dimensionless number
 kap = 2.94; % dimensionless number
 e = 0.86; % porosity of column
NL = 20; % No. slices along column axis
dz = 1/NL;
NRp = 10; % No. of onion layers in particles
dr = 1/NRp;
%par=[NPe, NBi, kap, e, NL, NRp];
% Input
c0 = 1;
% Initial states
c = zeros(NL-2,1);
c(1) = 1*(c0 + dz*NPe) - dz*NPe;
cp = zeros(NL,NRp-2);

% Simulation time
tfin = 150; % min, Final time for simulation starting at t=0
```

3.Admod.mat file contains the discritized model function

```
function dxdt = admod(t,x,u,par)

% Naming parameters
NPe = par(1);
NBi = par(2);
```

```
kap = par(3);
e = par(4);
NL = par(5);
NRp = par(6);
rho= 2200;
qm= 040.82;% lang cons
inc=50; %
b=0.0414;
nita=3.34;;

% Naming inputs
c0 = u(1);
% b doesnot effect b.through time
%low value of b smooth the shape of  graph,
%rho b applies their multification does not effect
% Naming parameters
c = x(1:NL-2);
dcdt = zeros(size(c));
cp = x(NL-1:end);
cp = reshape(cp, NL, NRp-2);
dcpdt = zeros(size(cp));

% Geometry quantities
dz = 1/NL;
dr = 1/NRp;

% Differential equations
c1 = (c(1) + dz*NPe)/(c0+dz*NPe);
cNL = c(end);
dcdt(1) = 1/NPe*(c(2)-2*c(1)+c1)/dz^2 - (c(1)-c1)/dz - kap*NBi*(c(1) - cp(2,end));

dcdt(end) = 1/NPe*(cNL-2*c(end)+c(end-1))/dz^2 - (c(end)-c(end-1))/dz -
kap*NBi*(c(end)-cp(end,end-1));

dcdt(2:end-1) = 1/NPe*(c(1:end-2)-2*c(2:end-1)+c(3:end))/dz^2 - (c(2:end-1)-
c(1:end-2))/dz- kap*NBi*(c(2:end-1)-cp(3:end-2,end));


cc = [c1;c;cNL];
cpj1 = cp(:,1);
cpjNRp = cp(:,end) + dr*NBi*(cc - cp(:,end));
mkm1 = repmat(2:NRp-3,NL,1);
dcpdt(:,1) = nita./(e+(1-e)*rho*qm*b*((1./(1+b*inc.*cp(:,1)))-
(b*inc.*cp(:,1)./(1+b*inc.*cp(:,1)).^2))).*((cp(:,2)-2*cp(:,1)+cpj1)/dr^2 + 2/((2-
1)*dr)*(cp(:,1)-cpj1)/dr);
```

```
dcpdt(:,end) = nita./(e+(1-e)*rho*qm*b*((1./(1+b*inc.*cp(:,end)))-
(b*inc.*cp(:,end)./(1+b*inc.*cp(:,end)).^2))).*((cpjNRp-2*cp(:,end)+cp(:,end-
1))/dr^2 + 2/((NRp-2)*dr)*(cp(:,end)-cp(:,end-1))/dr);

dcpdt(:,2:end-1) = nita./(e+(1-e)*rho*qm*b*((1./(1+b*inc.*cp(:,2:end-1)))-
(b*inc.*cp(:,2:end-1)./(1+b*inc.*cp(:,2:end-1)).^2))).*( (cp(:,3:end)-2*cp(:,2:end-
1)+cp(:,1:end-2))/dr^2+ 2./(mkm1*dr).*(cp(:,2:end-1) - cp(:,1:end-2))/dr);


dxdt = [dcdt;reshape(dcpdt,NL*(NRp-2),1)];
```