Chapter 3

Experiments of Dechlorination with Adsorption

3.1 Experimental Systems of Dechlorination

Experiments dechlorination with activated carbon adsorption consist of 2 parts which are batch adsorption and continuous adsorption column. The former focused on studying adsorption equilibrium and the purpose of latter is to study effects of bed depths and service flow rates on the adsorption column performance. Selected activated carbons, of which the specifications are summarized in Table 3.1, 3.2 and 3.3, are used to adsorb chlorine from chlorinated water. The chlorinated water is prepared from sodiumhypochlorite (NaOCl) 10 % solution diluted with distillation water to the desired concentrations which are varied from 0.1 to 5 ppm.

3.2 Chlorine Decomposition

The purpose of this experiment is to study decomposition of low chlorine content in chlorinated water. The experiment consists of two part which are decomposition without agitation and decomposition with agitation. The chlorine residual content will be analyzed by spectrophotometer.

Table 3.1 Activated carbon model DEO 8/30 specifications (Carbo Karn Co., Ltd.)

TECHNICAL SPECIFICATION

Product	Granular Activated Coconut Shell Based Carbon produced by steam activation process
Grade	DEO ASTM 8/30
Test Method	ASTM . Unless otherwise stated.
Application	recommended for dechlorination, potable water treatment

PHYSICAL PROPERTIES	SPECIFICATION
Particle Size Distribution : +8 (2.36 mm.)	Max. 5 %
(ASTM D 2862) 8/30 (2.36 x 0.60 mm.)	Min. 90 %
-30 (0.60 mm.)	Max. 5 %
Surface Area (Sq.m./gm.) BET	Min. 850
Iodine Number (mg./gm) AWWA B 604	Min. 800
Carbon Tetrachloride Adsorption ASTM D 467-88	Min. 20 % by wt.
pH	9-10
Moisture Content	Max. 8 % (as packed)
Ash	Max. 5 % (as packed)
Hardness No.	Min. 99
Apparent Density (gm./cc.)	Min. 0.58

Table 3.2 Activated carbon model PHO 8/30 specifications (Carbo Karn Co., Ltd.)

TECHNICAL SPECIFICATION

Product	Granular Activated Coconut Shell Based Carbon
Grade	PHO ASTM 8/30
Test Method	ASTM , Unless otherwise stated.
Application	Highly recommended for drinking water treatment.

PHYSICAL PROPERTIES	SPECIFICATION
Particle Size Distribution : +8 (2.36 mm.)	Max. 5 %
(ASTM D 2862) 8x30 (2.36x0.60 mm.)	Min. 90 %
-30 (0.60 mm.)	Max. 5 %
Surface Area (Sq.m./gm.) BET	1100
Iodine Number (mg./gm) AWWA B 604	Min. 1050
Carbon Tetrachloride Adsorption ASTM D 3467-88	Min. 50 % by wt.
pH	9-10
Moisture Content	Max. 5 % (as packed)
Ash	Max. 5 % (as packed)
Hardness No.	Min. 98
Apparent Density (gm./cc.)	Min. 0.50

Table 3.3 Activated carbon model HRO 8/30 specifications (Carbo Karn Co., Ltd.)

TECHNICAL SPECIFICATION

Product	Granular Activated Coconut Shell Based Carbon
Grade	HRO ASTM 8/30
Test Method	ASTM , Unless otherwise stated.
Application	Highly recommended for drinking water treatment

PHYSICAL PROPERTIES	SPECIFICATION
Particle Size Distribution : +4 (4.75 mm.)	Max. 5 %
(ASTM D 2862) 4x8(4.75 x 2.36 mm.)	Min. 90 %
-8 (2.36 mm.)	Max. 5 %
Surface Area (Sq.m./gm.) BET	Min. 1000
Iodine Number (mg./gm) AWWA B 604	Min. 950
Carbon Tetrachloride Adsorption ASTM D 3467-88	Min. 40 % by wt.
pH	9-10
Moisture Content	Max. 5 % (as packed)
Ash	Max. 5 % (as packed)
Hardness No.	Min.98
Apparent Density (gm./cc.)	Min. 0.53
Methylene Blue (ml./g)	MIN. 130

3.2.1 Chlorine Decomposition without Agitation

Chlorine solution about 1.7 ppm concentration was prepared and a sample was taken to check chlorine content at 30 minutes interval for 3 hours.

3.2.2 Chlorine Decomposition with Agitation

Agitation effect to chlorine decomposition was checked by dividing the known chlorinated water into 2 flasks; one was adjusted with magnetic stirrer for 30 minute and the other was left for 30 minutes. Afterwards, a sample was taken to analyze.

3.3 Batch Adsorption

Batch adsorption consists of two parts. The difference between these parts were the method of chlorine method which were oxidation reduction potential (ORP) measurement and spectrophotometry measurement.

3.3.1 Batch Adsorption Using ORP

ORP instrument measure electrical potential of HOCL and OCl^- in water. As HOCl and OCl^- quantities in water depend on pH, the pH-ORP relation known chlorine concentration must be prepared to use as standard calibration curve for chlorine analysis. The pH of chlorinated water is adjusted by 9.8 % by weight sulfuric acid (H_2SO_4) and 5 % by weight sodiumhydroxide solution (NaOH).

Experiment 1 pH-ORP Calibration Curve Preparation

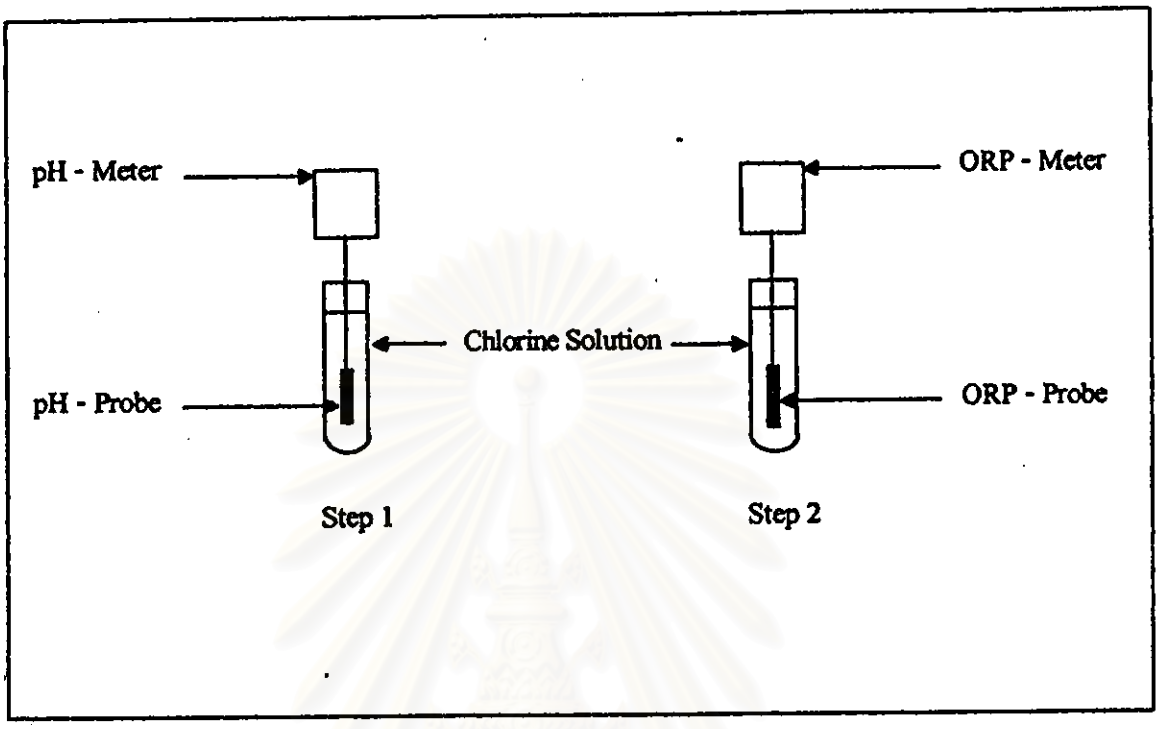

Figure 3.1 pH-ORP calibration configuration

The ORP of chlorinated water was measured after the pH adjusting step according to conditions in table 3.4

Table 3.4 pH - ORP calibration condition

Condition No.	Chlorine Conc.(ppm)	pH varied range
1	0.1	5 to 9
2	0.2	5 to 9
3	0.3	5 to 9
4	0.5	5 to 9
5	1	5 to 9
6	2	5 to 9
7	3	5 to 9

Experiments procedure for each condition in Table 3.4

1. Calibrate pH meter and ORP meter.
2. Prepare chlorinated water.
3. Adjust pH of prepared chlorinated water.
4. Measure ORP value of adjusted pH chlorinated water

The experiment at each condition was carried out twice. Afterwards the relationship between pH and ORP at each chlorine concentration was determined.

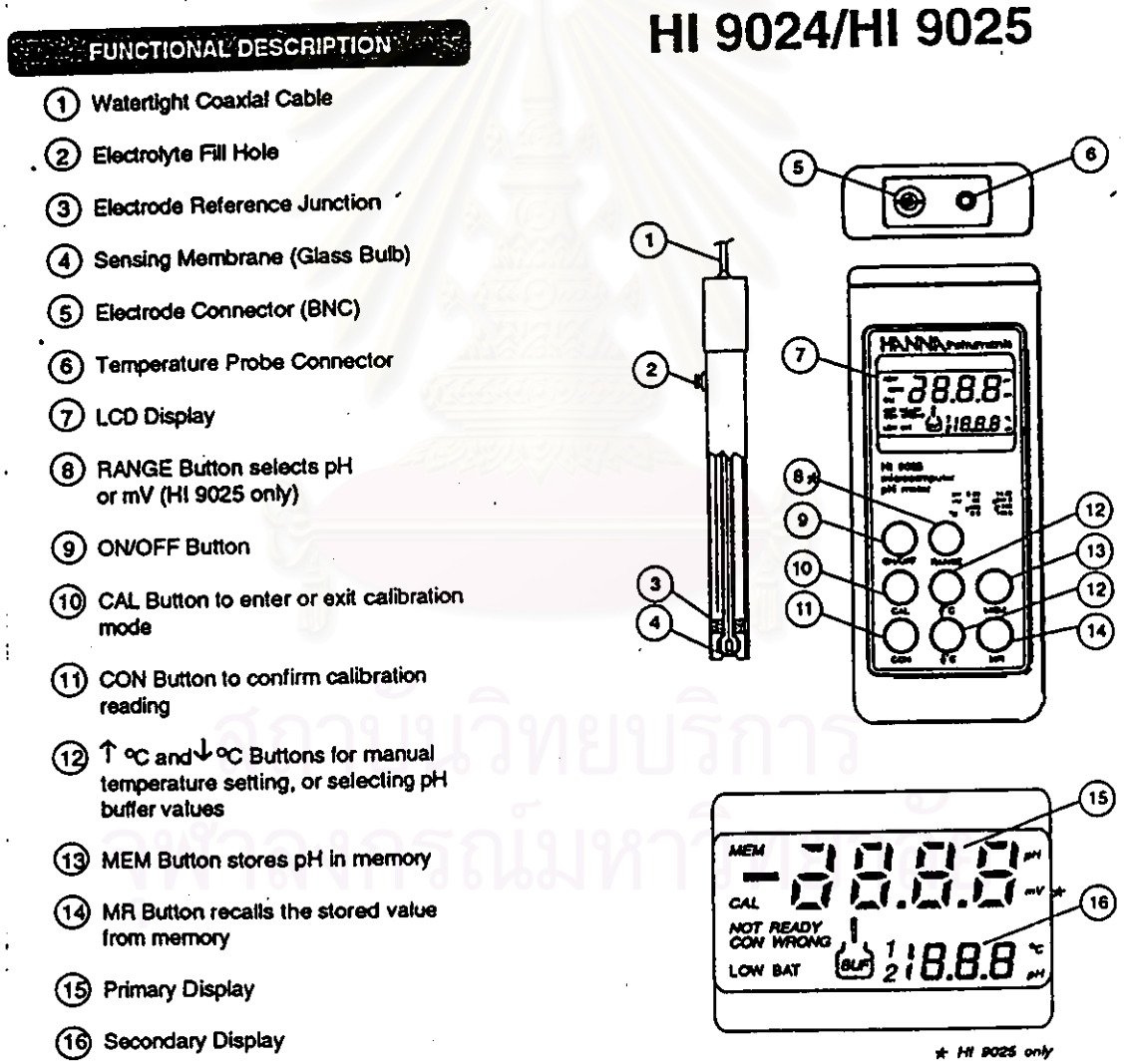

Figure 3.2 "HANNA" HI 9025 microcomputer pH/ORP meter

Experiment 2 Batch Adsorption Testing

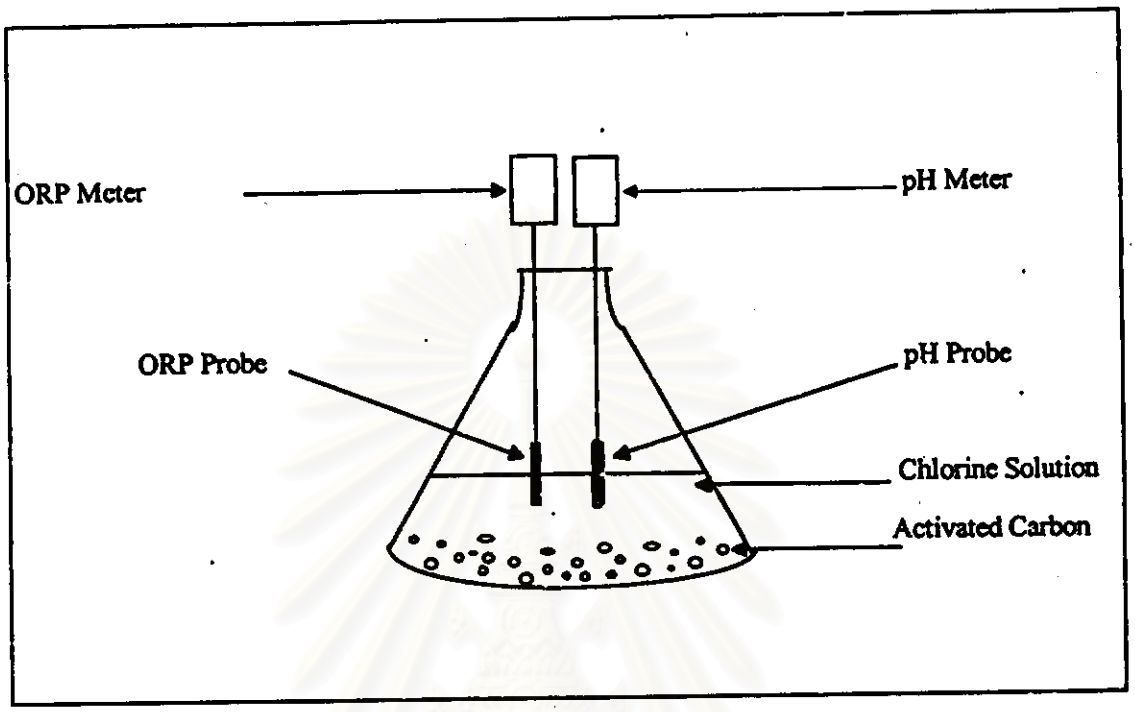

Figure 3.3 Batch adsorption configuration using ORP for chlorine content analysis

Chlorine concentration is analyzed by using pH-ORP value during adsorption period until the concentration is reduced to the constant level. Chlorinated water is prepared at 3 ppm chlorine concentration. Activated carbon is varied from 10 g to 40 g.

Table 3.5 Batch adsorption condition using ORP for chlorine content analysis

Condition No.	Activated carbon (g)	adsorption time(min)
1	10	0 to 180
2	20	0 to 180
3	30	0 to 180
4	40	0 to 180

Experiments procedure for each condition in table 3.5

1. Weigh activated carbon model PHO 8/30.
2. Prepare chlorinated water.
3. Calibrate pH/ORP meter.
4. Add activated carbon into chlorinated water.
5. Measure pH and ORP value at selected time until 3 hours.
6. Repeat from item 1 to item 5 for each condition.
7. Convert pH-ORP value to chlorine concentration using calibration curve.

Final chlorine concentration was used to calculate adsorption isotherm.

3.3.2 Batch Adsorption Using DR/2000 Spectrophotometer

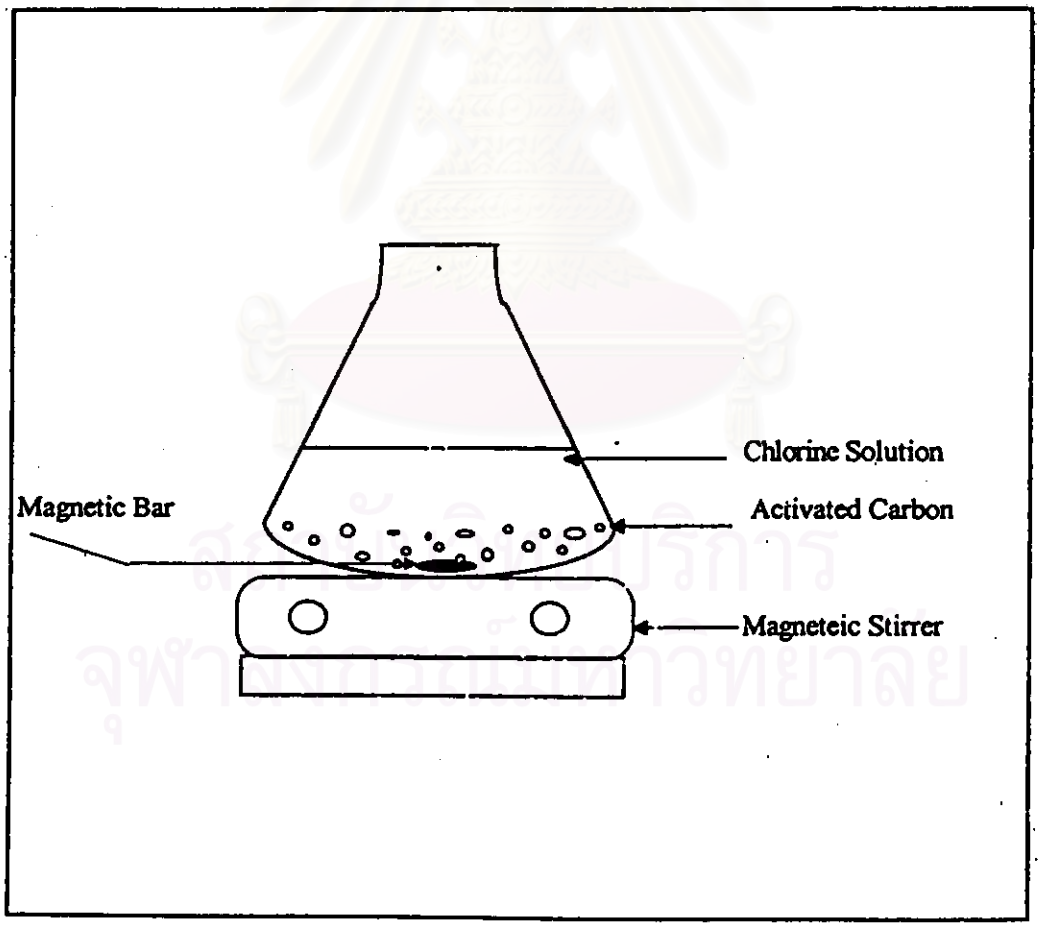

Figure 3.4 Batch adsorption configuration using spectrophotometer for chlorine analysis

Chlorine concentration was analyzed by DR/2000 spectrophotometer. This instrument consists of 2 steps for analysis which were reaction of sample with DPD total chlorine DP 25 ml, PK/100 reagent following by checking the color generated from reaction and converting to chlorine concentration value.

In this experiment, activated carbon was weighed 250 mg using another activated carbon model DEO 8/30. Initial chlorine concentrations were varied at about 2, 3, 4 to 5 ppm. At each initial value, activated carbon and chlorinated water mixed together until the final concentration was not changed.

Experiment 3 Batch Adsorption Testing

Table 3.6 Batch adsorption condition using spectrophotometer

Condition No	Approx.Initial Conc.(ppm)	Adsorption Time(min)
1	2	0 to 200
2	3	0 to 200
3	4	0 to 200
4	5	0 to 200

Experiments procedure for each condition in Table 3.6

1. Weigh activated carbon model DEO 8/30 250 mg.
2. Prepare chlorinated water.
3. Take a sample of 25 ml to analyze initial chlorine concentration.(C_{A0})
4. Add activated carbons into chlorinated water.
5. Mix activated carbons and chlorinated water by magnetic stirrer for the selected adsorption period
6. Take a sample to analyze chlorine concentration (C_{At})

7. Repeat from item 1 to item 6

After attaining experimental results, determine the variation of C_{At}/C_{A0} with time. The final concentration was determined when the C_{At}/C_{A0} became almost constant.

3.4 Column Adsorption

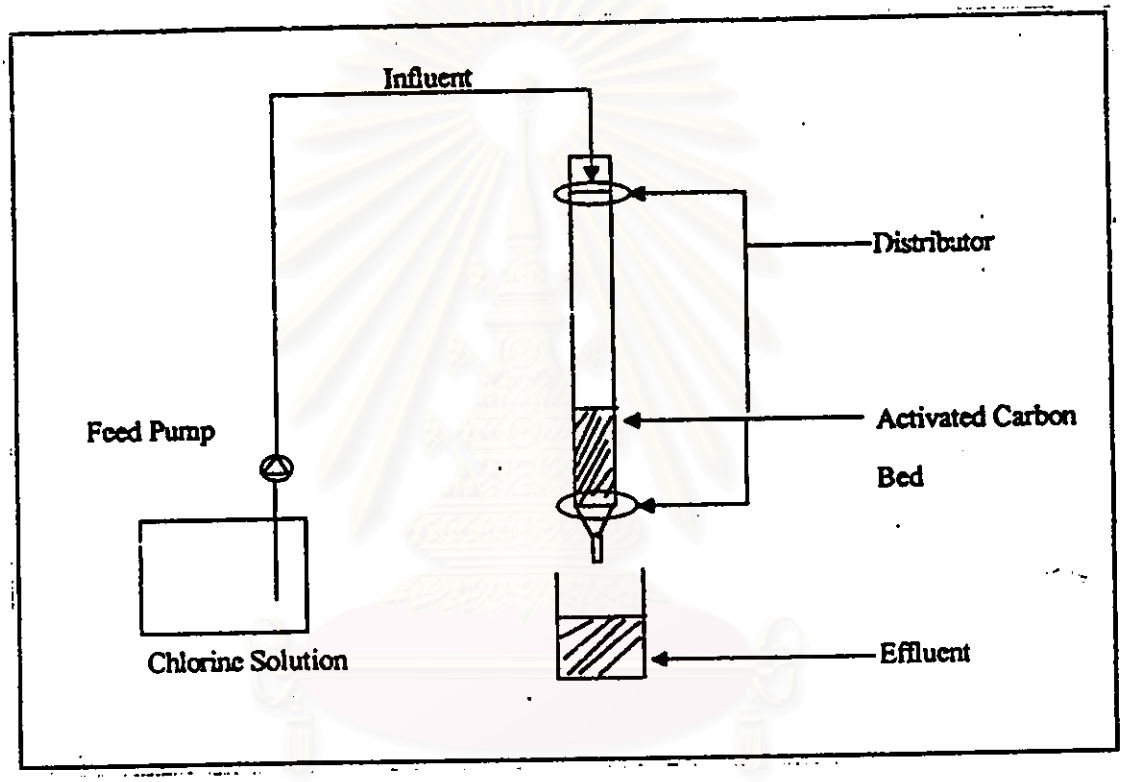

Figure 3.5 Activated carbon adsorption column configuration

The purpose is to find the effect of bed depth and velocity which are the important parameter to achieve optimum residence time for a good condition of adsorption. Chlorine concentration was analyzed by spectrophotometer. Ratio of column diameter to carbon particle size should be at least 25:1 to prevent the wall effect. The diameter of selected activated carbon for the experiments were in a range from 1.18 to 2 mm. Therefore, the column diameter should be 2" at least. The experiments were divided into 3 parts which are fixed bed depth with various flow

rates, various bed depths with fixed flow rate and experiments for the other 2 models of activated carbon with the same conditions as the follows.

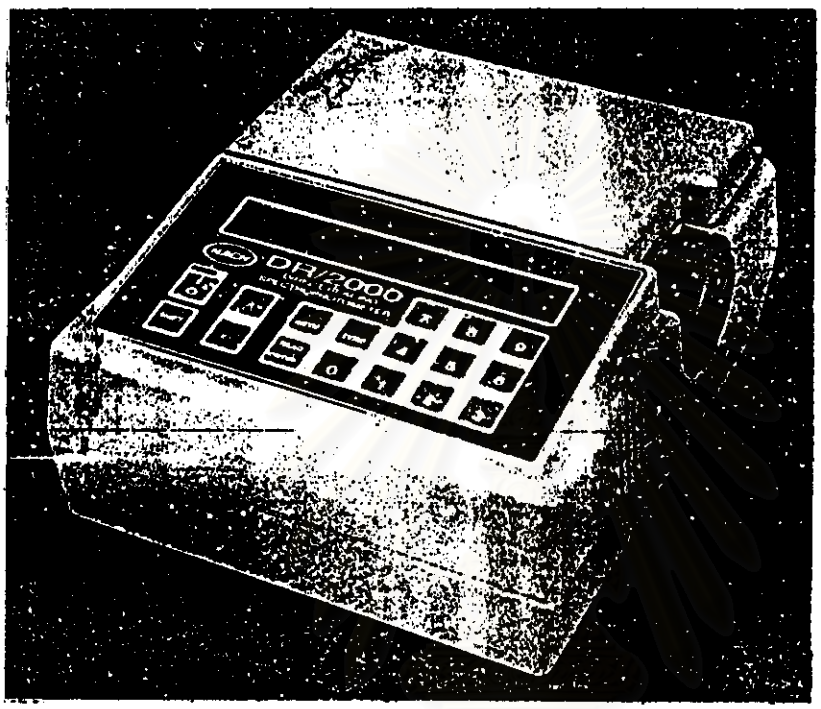

Figure 3.6 DR/2000 Spectrophotometer

3.4.1 Fixed Bed Depth and Various Flow Rates

Experiment 4 Adsorption Performance at Various Flow Rates

This experiment is expected to study effect of service flow rate or residence time on adsorption performance at fixed bed depth. Chlorinated water was prepared at 4 ppm. Chlorinated water flow rates were adjusted by using variable frequency peristaltic pump as a feed pump. After feeding influent through the packed bed, a sample was taken from the bottom of the column to analyze at the selected time until 3 hours. Variable conditions were shown in table 3.7

Table 3.7 Various service flow rate at fixed 1 in. bed depth condition

Condition number	1	2	3	4	5
Flow rate (gal/min)	.003	.004	.007	.013	.020
Bed Depth (in.)	1	1	1	1	1

3.4.2 Various Bed Depths with Fixed Flow Rate

The purpose was to study effects of bed depths at each fixed flow rate. Bed depths were varied from 1 inch to 5 inches. Selected flow rates are .013, .026 and .052 gal/min which are equivalent to 0.622, 1.256 and 2.512 gal/min/ft^2 service flow rate, respectively. After feeding influent through the packed bed, a sample was taken from the bottom of the column to analyze at the selected time until 3 hours. Variable conditions were shown in table 3.8,3.9 and 3.10, respectively.

Experiment 5

Table 3.8 Various bed depth and fixed 0.622 gal/min/ft.^{2} service flow rate condition

Condition Number	1	2	3	4	5
Bed Depth (")	1	2	3	4	5
Flow Rate (gal/min)	.013	.013	.013	.013	.013

Experiment 6

Table 3.9 Various bed depth with 1.256 gal/min/ft.^{2} service flow rate condition

Condition Number	1	2	3	4	5
Bed Depth (“)	1	2	3	4	5
Flow Rate (gpm)	.026	.026	.026	.026	.026

Experiment 7

Table 3.10 2.512 gal/min/ft.^{2} service flow rate at selected bed depth condition

Bed Depth (in.)	Flow rate (gal/min)	Service Flow Rate (gal/min/ft^2.)
4	0.054	2.512

Experiments procedure for each condition in table 3.7 to 3.10

1. Prepare chlorinated water 4 ppm chlorine concentration.
2. Pack activated carbon model DEO 8/30 column with indicated bed depth.
3. Feed chlorinated water into the column with indicated flow rate.
4. Analyze the effluent chlorine concentration from the bottom of the column at 0.17, 0.33 0.5, 1, 1.5 2, 2.5 and 3 hour.

3.4.3 Effects of Various Bed Depths and Flow Rates on The Other Activated Carbons Model PHO 8/30 and HRO 8/30

Do the experiments as same as item 3.4.2 with activated carbon model PHO 8/30 and HRO 8/30.