

## เอกสารอ้างอิง

1. Wood, F. O., "Selecting a Softening Process," J. AWWA., 64, 820, 1972.
2. Powell, S. T., Water Conditioning for Industry, pp. 84-125, McGraw-Hill Book Company, Inc., New York, 1st ed., 1954.
3. Holden, W.S., Water Treatment and Examination, pp. 382-393, J. & A. Churchill, London, 1970.
4. Nordell, E., Water Treatment for Industry and Other Uses, pp. 489-525, Reinhold Publishing Corporation, New York, 1st ed., 1951.
5. Hartung, H. O., "Calcium Carbonate Stabilization of Lime Softened Water," J. AWWA., 48, 1523, 1956.
6. Alekin, O. A., and N. P. Moritscheva, "The Stability of Carbonate Systems in Natural Waters," C.R. Acad. Sci., U.R.S.S., 1957.
7. Black, A. P., and R. F. Christman, "Electrophoretic Studies of Sludge Particles Produced in Lime-Soda Softening," J. AWWA., 53, 737, 1961.
8. Malina, J. F., and S. Tiyaorn, "Effects of Synthetic Detergents on Lime-Soda Ash Treatment," J. AWWA., 56, 727, 1964.
9. Degremont, Water Treatment Handbook, pp. 283-284, Stephen Austin & Sons Ltd., Great Britain, 4th ed., 1973.
10. Alexander, H. J., and M. A. McClanahan, "Kinetics of Calcium Carbonate Precipitation in Lime-Soda

- Ash Softening," J. AWWA., 67, 618, 1975.
11. Schierholz, P. M., J. D. Stevens, and J. L. Cleasby, "Optimum Calcium Removal in Lime Softening," J. AWWA., 68, 112, 1976.
  12. Burris, M. A., K. W. Cosens, and D. M. Mair, "Softening and Coagulation Sludge-Disposal Studies for a Surface Water Supply," J. AWWA., 68, 247, 1976.
  13. Committee Report, "Lime Softening Sludge Treatment and Disposal," J. AWWA., 73, 600, 1981.
  14. Perers, R. W., and J. D. Stevens, "Effect of Iron as a Trace Impurity on the Water Softening Process," ALChE Symposium series No. 215, pp. 46-67, ALChE, New York, 1982.
  15. Letterman, R. D., J. E. Quon, and R. S. Gemmill, "Influence of Rapid-Mix Parameters on Flocculation," J. AWWA., 65, 716, 1973.
  16. Amirtharajar, A., and K. M. Mills, "Rapid-Mix Design for Mechanisms of Alum Coagulation," J. AWWA., 74, 210, 1982.
  17. Sawyer, C. N., and P. L. McCarty, Chemistry for Environmental Engineering, pp. 377-384, McGraw-Hill Book Company, Inc., New York, 3rd ed., 1978.
  18. Seidell, A., Solubilities of Inorganic and Metal Organic Compounds, D. Van Nostrand Company, Inc., New York, 3rd ed., 1940.
  19. Greenfield, R. E., and A. M. Buswell, "Investigation by means of the Hydrogen Electrode of the

- Chemical Reactions Involved in Water Purification," J. ACS., 44, 1435, 1922.
20. American Water Works Association, "Water Treatment Plant Design," AWWA, Inc., Denver, 1969.
21. Cole, L. D., "Surface Water Treatment in Cold Weather," J. AWWA., 68, 22, 1976.
22. Sanks, R. L., Water Treatment Plant Design for the Practicing Engineer, pp. 567-595, Ann Arbor Science Publishers Inc., Michigan, 1st ed., 1979.
23. James, G. V., Water Treatment, pp. 93-123, T. and A. Constable Ltd., Edinburgh, 4th ed., 1971.
24. McConnel, S., Small Water Supplies, pp. 183-201, Ebenezer Baylis and Son, Ltd., London, 1st ed., 1964.
25. Commonwealth of Virginia, "Water Works Regulations," Commonwealth of Virginia, Virginia, 1977.
26. Camp, T. R., and P. C. Stein, "Velocity Gradients and Internal Work in Fluid Motion," J. BSCE., 30, 219, 1943.
27. Lai, R. J., H. E. Hudson Jr., and J. E. Singley, "Velocity Gradient Calibration of Jar-Test Equipment," J. AWWA., 67, 553, 1975.
28. Kawamura, S., "Coagulation Considerations," J. AWWA., 65, 417, 1973.
29. Camp, T. R., "Flocculation and Flocculation Basins," Trans. ASCE., 120, 1, 1955.

30. Villegas, R. A., and R. D. Letterman, "Optimizing Flocculator Power Input," J. Env. Eng. Div. ASCE., pp.251-263, April, 1976.
31. Setiadi, T., "Flocculation Study on Spiral Flocculator," Master's thesis, Environmental Engineering Division, Asian Institute of Technology, Bangkok, 1985.
32. ณรงค์ วุทธเสถียร, การปรับสภาพน้ำในอุตสาหกรรมและหม้อไอน้ำ, หน้า 161-171, สมาคมส่งเสริมเทคโนโลยี (ไทย-ญี่ปุ่น), กรุงเทพมหานคร, 2526.
33. มั่นสิน ตันกุลเวศม์, วิศวกรรมการประปา เล่ม 2, หน้า 313-353, ภาควิชาวิศวกรรมสิ่งแวดล้อม คณะวิศวกรรมศาสตร์ จุฬาลงกรณ์มหาวิทยาลัย, กรุงเทพมหานคร, 2527.
34. สุรินทร์ พลสมบูรณ์, "พารามิเตอร์ควบคุมการกวนเร็วในท่อแนวระดับ," วิทยานิพนธ์ปริญญาโทบริหารธุรกิจ, ภาควิชาวิศวกรรมสิ่งแวดล้อม บัณฑิตวิทยาลัย จุฬาลงกรณ์มหาวิทยาลัย, 2528.

ศูนย์วิทยทรัพยากร  
จุฬาลงกรณ์มหาวิทยาลัย



ภาคผนวก

ศูนย์วิทยทรัพยากร  
จุฬาลงกรณ์มหาวิทยาลัย

- Note: 1. Table 1 - 16 were ground water.  
 2. Table 17 - 32 were surface water.

Table 1 Softened Water at  $T_s=5$  min  $G_s=20$  s<sup>-1</sup>

Quality	$T_s$ (min)			
	10	20	30	40
pH	10.55	10.55	10.55	10.55
Turbidity (NTU)				
SOR=3.15 cm/min	2.5	2.4	2.5	2.6
SOR=1.58 cm/min	1.0	1.0	1.2	1.2
P-Alk (mg/lCaCO <sub>3</sub> )	111.3	109.2	109.2	109.2
T-Alk (mg/lCaCO <sub>3</sub> )	159.6	157.5	157.5	155.4
OH <sup>-</sup> (mg/lCaCO <sub>3</sub> )	63.0	60.9	60.9	63.0
CO <sub>3</sub> <sup>=</sup> (mg/lCaCO <sub>3</sub> )	96.6	96.6	96.6	92.4
TH (mg/lCaCO <sub>3</sub> )	18.7	15.8	14.3	14.1
Ca-H (mg/lCaCO <sub>3</sub> )	11.0	8.3	7.3	7.3
Mg-H (mg/lCaCO <sub>3</sub> )	7.7	7.5	7.0	6.8
Ca-H/Mg-H ratio	1.43	1.11	1.04	1.07
Dried solids (mg)	309.0	309.4	308.7	309.7

Note: pH, Alk or Hardness at SOR=3.15 and 1.58 cm/min were equal.

Table 2 Softened Water at  $T_s=5$  min  $G_s=40$  s<sup>-1</sup>

Quality	$T_s$ (min)			
	10	20	30	40
pH	10.55	10.55	10.55	10.55
Turbidity (NTU)				
SOR=3.15 cm/min	3.7	4.1	5.9	6.0
SOR=1.58 cm/min	1.1	1.1	1.2	1.3
P-Alk (mg/lCaCO <sub>3</sub> )	113.4	111.3	109.2	109.2
T-Alk (mg/lCaCO <sub>3</sub> )	159.6	157.5	155.4	155.4
OH <sup>-</sup> (mg/lCaCO <sub>3</sub> )	67.2	65.1	63.0	63.0
CO <sub>3</sub> <sup>=</sup> (mg/lCaCO <sub>3</sub> )	92.4	92.4	92.4	92.4
TH (mg/lCaCO <sub>3</sub> )	17.0	14.3	12.3	11.2
Ca-H (mg/lCaCO <sub>3</sub> )	9.8	7.5	6.2	6.0
Mg-H (mg/lCaCO <sub>3</sub> )	7.2	6.8	6.1	5.2
Ca-H/Mg-H ratio	1.36	1.10	1.02	1.15
Dried solids (mg)	310.8	311.0	312.0	312.7

Note: pH, Alk or Hardness at SOR=3.15 and 1.58 cm/min were equal.

Table 3 Softened Water at  $T_s=5$  min  $G_s=60$  s<sup>-1</sup>

Quality	$T_s$ (min)			
	10	20	30	40
pH	10.55	10.55	10.55	10.55
Turbidity (NTU)				
SOR=3.15 cm/min	5.9	8.9	11.0	12.0
SOR=1.58 cm/min	1.5	1.6	1.9	2.1
P-Alk (mg/lCaCO <sub>3</sub> )	113.4	111.3	109.2	109.2
T-Alk (mg/lCaCO <sub>3</sub> )	161.7	157.5	155.4	155.4
OH <sup>-</sup> (mg/lCaCO <sub>3</sub> )	65.1	65.1	63.0	63.0
CO <sub>3</sub> <sup>=</sup> (mg/lCaCO <sub>3</sub> )	96.6	92.4	92.4	92.4
TH (mg/lCaCO <sub>3</sub> )	16.6	13.7	11.8	11.0
Ca-H (mg/lCaCO <sub>3</sub> )	9.6	7.3	5.8	5.4
Mg-H (mg/lCaCO <sub>3</sub> )	7.0	6.4	6.0	5.6
Ca-H/Mg-H ratio	1.37	1.14	0.97	0.96
Dried solids (mg)	310.9	311.0	311.4	311.1

Note: pH, Alk or Hardness at SOR=3.15 and 1.58 cm/min were equal.

Table 4 Softened Water at  $T_s=5$  min  $G_s=80$  s<sup>-1</sup>

Quality	$T_s$ (min)			
	10	20	30	40
pH	10.55	10.55	10.55	10.55
Turbidity (NTU)				
SOR=3.15 cm/min	14.0	16.0	20.0	21.0
SOR=1.58 cm/min	2.1	2.3	3.0	3.3
P-Alk (mg/lCaCO <sub>3</sub> )	113.4	109.2	109.2	109.2
T-Alk (mg/lCaCO <sub>3</sub> )	159.6	155.4	155.4	155.4
OH <sup>-</sup> (mg/lCaCO <sub>3</sub> )	67.2	63.0	63.0	63.0
CO <sub>3</sub> <sup>=</sup> (mg/lCaCO <sub>3</sub> )	92.4	92.4	92.4	92.4
TH (mg/lCaCO <sub>3</sub> )	16.2	13.9	12.0	10.6
Ca-H (mg/lCaCO <sub>3</sub> )	9.3	7.1	6.2	5.6
Mg-H (mg/lCaCO <sub>3</sub> )	6.9	6.8	5.7	5.0
Ca-H/Mg-H ratio	1.35	1.04	1.09	1.12
Dried solids (mg)	310.5	310.4	311.3	312.9

Note: pH, Alk or Hardness at SOR=3.15 and 1.58 cm/min were equal.

Table 5 Softened Water at  $T_s=5$  min  $G_s=100$  s<sup>-1</sup>

Quality	$T_p$ (min)			
	10	20	30	40
pH	10.55	10.55	10.55	10.55
Turbidity (NTU)				
SOR=3.15 cm/min	20.0	24.5	29.0	30.0
SOR=1.58 cm/min	3.1	3.9	5.5	6.0
P-Alk (mg/lCaCO <sub>3</sub> )	113.4	111.3	109.2	109.2
T-Alk (mg/lCaCO <sub>3</sub> )	159.6	157.5	155.4	155.4
OH <sup>-</sup> (mg/lCaCO <sub>3</sub> )	67.2	65.1	63.0	63.0
CO <sub>3</sub> <sup>2-</sup> (mg/lCaCO <sub>3</sub> )	92.4	92.4	92.4	92.4
TH (mg/lCaCO <sub>3</sub> )	16.4	13.5	11.6	10.6
Ca-H (mg/lCaCO <sub>3</sub> )	9.6	7.1	5.8	5.4
Mg-H (mg/lCaCO <sub>3</sub> )	6.8	6.4	5.8	5.2
Ca-H/Mg-H ratio	1.41	1.11	1.00	1.04
Dried solids (mg)	309.8	309.8	309.8	309.3

Note: pH, Alk or Hardness at SOR=3.15 and 1.58 cm/min were equal.

Table 6 Softened Water at  $T_s=7.5$  min  $G_s=20$  s<sup>-1</sup>

Quality	$T_p$ (min)			
	10	20	30	40
pH	10.55	10.55	10.55	10.55
Turbidity (NTU)				
SOR=3.15 cm/min	2.5	2.6	2.6	2.7
SOR=1.58 cm/min	1.0	1.1	1.1	1.2
P-Alk (mg/lCaCO <sub>3</sub> )	113.4	113.4	111.3	111.3
T-Alk (mg/lCaCO <sub>3</sub> )	163.8	163.8	159.6	159.6
OH <sup>-</sup> (mg/lCaCO <sub>3</sub> )	63.0	63.0	63.0	63.0
CO <sub>3</sub> <sup>2-</sup> (mg/lCaCO <sub>3</sub> )	100.8	100.8	96.6	96.6
TH (mg/lCaCO <sub>3</sub> )	16.0	13.3	12.3	12.1
Ca-H (mg/lCaCO <sub>3</sub> )	8.2	6.8	6.0	6.0
Mg-H (mg/lCaCO <sub>3</sub> )	7.8	6.5	6.3	6.1
Ca-H/Mg-H ratio	1.05	1.05	0.95	0.98
Dried solids (mg)	296.8	298.1	297.4	297.4

Note: pH, Alk or Hardness at SOR=3.15 and 1.58 cm/min were equal.



Table 7 Softened Water at  $T_a=7.5$  min  $G_s=40$  s<sup>-1</sup>

Quality	$T_a$ (min)			
	10	20	30	40
pH	10.55	10.55	10.55	10.55
Turbidity (NTU)				
SOR=3.15 cm/min	5.1	6.4	8.0	8.2
SOR=1.58 cm/min	1.1	1.3	1.5	1.5
P-Alk (mg/lCaCO <sub>3</sub> )	113.4	111.3	113.4	111.3
T-Alk (mg/lCaCO <sub>3</sub> )	161.7	159.6	161.7	159.6
OH <sup>-</sup> (mg/lCaCO <sub>3</sub> )	65.1	63.0	65.1	63.0
CO <sub>3</sub> <sup>=</sup> (mg/lCaCO <sub>3</sub> )	96.6	96.6	96.6	96.6
TH (mg/lCaCO <sub>3</sub> )	14.1	12.3	11.0	10.6
Ca-H (mg/lCaCO <sub>3</sub> )	7.3	6.0	5.4	5.2
Mg-H (mg/lCaCO <sub>3</sub> )	6.8	6.3	5.6	5.4
Ca-H/Mg-H ratio	1.07	0.95	0.96	0.96
Dried solids (mg)	297.3	298.2	299.0	297.9

Note: pH, Alk or Hardness at SOR=3.15 and 1.58 cm/min were equal.

Table 8 Softened Water at  $T_a=7.5$  min  $G_s=60$  s<sup>-1</sup>

Quality	$T_a$ (min)			
	10	20	30	40
pH	10.55	10.55	10.55	10.55
Turbidity (NTU)				
SOR=3.15 cm/min	9.5	12.0	14.0	15.0
SOR=1.58 cm/min	1.6	1.6	1.9	2.2
P-Alk (mg/lCaCO <sub>3</sub> )	113.4	111.3	111.3	111.3
T-Alk (mg/lCaCO <sub>3</sub> )	161.7	159.6	159.6	159.6
OH <sup>-</sup> (mg/lCaCO <sub>3</sub> )	65.1	63.0	63.0	63.0
CO <sub>3</sub> <sup>=</sup> (mg/lCaCO <sub>3</sub> )	96.6	96.6	96.6	96.6
TH (mg/lCaCO <sub>3</sub> )	13.5	11.6	10.8	10.2
Ca-H (mg/lCaCO <sub>3</sub> )	6.9	5.6	5.2	4.6
Mg-H (mg/lCaCO <sub>3</sub> )	6.6	6.0	5.6	5.6
Ca-H/Mg-H ratio	1.05	0.93	0.93	0.82
Dried solids (mg)	298.3	298.8	298.4	298.5

Note: pH, Alk or Hardness at SOR=3.15 and 1.58 cm/min were equal.

Table 9 Softened Water at  $T_s=7.5$  min  $G_s=80$  s<sup>-1</sup>

Quality	$T_s$ (min)			
	10	20	30	40
pH	10.55	10.55	10.55	10.55
Turbidity (NTU)				
SOR=3.15 cm/min	17.5	20.0	24.5	27.0
SOR=1.58 cm/min	3.1	3.4	3.8	3.9
P-Alk (mg/lCaCO <sub>3</sub> )	113.4	113.4	111.3	111.3
T-Alk (mg/lCaCO <sub>3</sub> )	161.7	161.7	159.6	159.6
OH <sup>-</sup> (mg/lCaCO <sub>3</sub> )	65.1	65.1	63.0	63.0
CO <sub>3</sub> <sup>=</sup> (mg/lCaCO <sub>3</sub> )	96.6	96.6	96.6	96.6
TH (mg/lCaCO <sub>3</sub> )	13.5	11.6	10.4	10.2
Ca-H (mg/lCaCO <sub>3</sub> )	6.9	5.8	5.0	4.8
Mg-H (mg/lCaCO <sub>3</sub> )	6.6	5.8	5.4	5.4
Ca-H/Mg-H ratio	1.05	1.00	0.93	0.89
Dried solids (mg)	297.0	297.1	297.1	297.6

Note: pH, Alk or Hardness at SOR=3.15 and 1.58 cm/min were equal.

Table 10 Softened Water at  $T_s=7.5$  min  $G_s=100$  s<sup>-1</sup>

Quality	$T_s$ (min)			
	10	20	30	40
pH	10.55	10.55	10.55	10.55
Turbidity (NTU)				
SOR=3.15 cm/min	24.0	29.0	34.0	37.0
SOR=1.58 cm/min	5.6	6.0	6.5	6.5
P-Alk (mg/lCaCO <sub>3</sub> )	113.4	113.4	111.3	111.3
T-Alk (mg/lCaCO <sub>3</sub> )	161.7	161.7	159.6	159.6
OH <sup>-</sup> (mg/lCaCO <sub>3</sub> )	65.1	65.1	63.0	63.0
CO <sub>3</sub> <sup>=</sup> (mg/lCaCO <sub>3</sub> )	96.6	96.6	96.6	96.6
TH (mg/lCaCO <sub>3</sub> )	13.9	12.1	10.8	10.4
Ca-H (mg/lCaCO <sub>3</sub> )	7.1	6.0	5.2	5.0
Mg-H (mg/lCaCO <sub>3</sub> )	6.8	6.1	5.6	5.4
Ca-H/Mg-H ratio	1.04	0.98	0.93	0.93
Dried solids (mg)	297.2	297.4	298.3	298.6

Note: pH, Alk or Hardness at SOR=3.15 and 1.58 cm/min were equal.

Table 11 Softened Water at  $T_s=10$  min  $G_s=20$  s<sup>-1</sup>

Quality	$T_s$ (min)			
	10	20	30	40
pH	10.55	10.55	10.55	10.55
Turbidity (NTU)				
SOR=3.15 cm/min	2.6	2.6	2.7	2.7
SOR=1.58 cm/min	1.1	1.0	1.1	1.1
P-Alk (mg/lCaCO <sub>3</sub> )	115.5	115.5	115.5	113.4
T-Alk (mg/lCaCO <sub>3</sub> )	165.9	165.9	165.9	161.7
OH <sup>-</sup> (mg/lCaCO <sub>3</sub> )	65.1	65.1	65.1	65.1
CO <sub>3</sub> <sup>=</sup> (mg/lCaCO <sub>3</sub> )	100.8	100.8	100.8	96.6
TH (mg/lCaCO <sub>3</sub> )	14.6	12.4	11.0	10.6
Ca-H (mg/lCaCO <sub>3</sub> )	8.0	6.9	6.0	5.6
Mg-H (mg/lCaCO <sub>3</sub> )	6.6	5.5	5.0	5.0
Ca-H/Mg-H ratio	1.21	1.26	1.20	1.12
Dried solids (mg)	302.0	302.2	303.2	303.8

Note: pH, Alk or Hardness at SOR=3.15 and 1.58 cm/min were equal.

Table 12 Softened Water at  $T_s=10$  min  $G_s=40$  s<sup>-1</sup>

Quality	$T_s$ (min)			
	10	20	30	40
pH	10.55	10.55	10.55	10.55
Turbidity (NTU)				
SOR=3.15 cm/min	6.5	7.7	9.5	9.6
SOR=1.58 cm/min	1.5	1.4	1.9	2.0
P-Alk (mg/lCaCO <sub>3</sub> )	117.6	115.5	113.4	113.4
T-Alk (mg/lCaCO <sub>3</sub> )	165.9	163.8	161.7	161.7
OH <sup>-</sup> (mg/lCaCO <sub>3</sub> )	69.3	67.2	65.1	65.1
CO <sub>3</sub> <sup>=</sup> (mg/lCaCO <sub>3</sub> )	96.6	96.6	96.6	96.6
TH (mg/lCaCO <sub>3</sub> )	12.0	10.2	8.9	8.7
Ca-H (mg/lCaCO <sub>3</sub> )	6.6	5.6	4.8	4.2
Mg-H (mg/lCaCO <sub>3</sub> )	5.4	4.6	4.1	4.5
Ca-H/Mg-H ratio	1.22	1.22	1.17	0.93
Dried solids (mg)	303.4	304.3	304.8	305.5

Note: pH, Alk or Hardness at SOR=3.15 and 1.58 cm/min were equal.

Table 13 Softened Water at  $T_s=10$  min  $G_s=60$  s<sup>-1</sup>

Quality	$T_s$ (min)			
	10	20	30	40
pH	10.55	10.55	10.55	10.55
Turbidity (NTU)				
SOR=3.15 cm/min	13.5	16.0	18.0	19.0
SOR=1.58 cm/min	2.1	2.1	2.8	3.2
P-Alk (mg/lCaCO <sub>3</sub> )	115.5	115.5	113.4	113.4
T-Alk (mg/lCaCO <sub>3</sub> )	163.8	163.8	161.7	161.7
OH <sup>-</sup> (mg/lCaCO <sub>3</sub> )	67.2	67.2	65.1	65.1
CO <sub>3</sub> <sup>=</sup> (mg/lCaCO <sub>3</sub> )	96.6	96.6	96.6	96.6
TH (mg/lCaCO <sub>3</sub> )	12.0	9.8	8.9	8.7
Ca-H (mg/lCaCO <sub>3</sub> )	6.6	5.4	4.6	4.4
Mg-H (mg/lCaCO <sub>3</sub> )	5.4	4.4	4.3	4.3
Ca-H/Mg-H ratio	1.22	1.23	1.07	1.02
Dried solids (mg)	302.5	302.6	303.7	303.8

Note: pH, Alk or Hardness at SOR=3.15 and 1.58 cm/min were equal.

Table 14 Softened Water at  $T_s=10$  min  $G_s=80$  s<sup>-1</sup>

Quality	$T_s$ (min)			
	10	20	30	40
pH	10.55	10.55	10.55	10.55
Turbidity (NTU)				
SOR=3.15 cm/min	21.5	25.0	28.0	31.0
SOR=1.58 cm/min	3.1	3.8	4.1	4.3
P-Alk (mg/lCaCO <sub>3</sub> )	117.6	113.4	115.5	113.4
T-Alk (mg/lCaCO <sub>3</sub> )	165.9	161.7	163.8	161.7
OH <sup>-</sup> (mg/lCaCO <sub>3</sub> )	69.3	65.1	67.2	65.1
CO <sub>3</sub> <sup>=</sup> (mg/lCaCO <sub>3</sub> )	96.6	96.6	96.6	96.6
TH (mg/lCaCO <sub>3</sub> )	12.3	10.0	9.1	8.9
Ca-H (mg/lCaCO <sub>3</sub> )	7.1	5.6	4.8	4.4
Mg-H (mg/lCaCO <sub>3</sub> )	5.2	4.4	4.3	4.5
Ca-H/Mg-H ratio	1.37	1.27	1.12	0.98
Dried solids (mg)	303.2	303.8	304.0	303.8

Note: pH, Alk or Hardness at SOR=3.15 and 1.58 cm/min were equal.

Table 15 Softened Water at  $T_x=10$  min  $G_x=100$  s<sup>-1</sup>

Quality	$T_x$ (min)			
	10	20	30	40
pH	10.55	10.55	10.55	10.55
Turbidity (NTU)				
SOR=3.15 cm/min	29.0	34.0	38.0	40.0
SOR=1.58 cm/min	6.0	6.6	8.0	8.1
P-Alk (mg/lCaCO <sub>2</sub> )	117.6	113.4	113.4	113.4
T-Alk (mg/lCaCO <sub>2</sub> )	165.9	163.8	163.8	161.7
OH <sup>-</sup> (mg/lCaCO <sub>2</sub> )	69.3	67.2	67.2	65.1
CO <sub>2</sub> <sup>-</sup> (mg/lCaCO <sub>2</sub> )	96.6	96.6	96.6	96.6
TH (mg/lCaCO <sub>2</sub> )	12.5	10.2	9.1	8.7
Ca-H (mg/lCaCO <sub>2</sub> )	6.9	5.6	5.0	4.2
Mg-H (mg/lCaCO <sub>2</sub> )	5.6	4.6	4.1	4.5
Ca-H/Mg-H ratio	1.23	1.22	1.22	0.93
Dried solids (mg)	301.5	302.3	303.2	303.4

Note: pH, Alk or Hardness at SOR=3.15 and 1.58 cm/min were equal.

Table 16 Softened Water at  $T_x=15$  min  $G_x=60$  s<sup>-1</sup>

Quality	$T_x$ (min)			
	10	20	30	40
pH	10.55	10.55	10.55	10.55
Turbidity (NTU)				
SOR=3.15 cm/min	19.0	20.0	22.0	23.0
SOR=1.58 cm/min	3.6	4.4	4.4	4.6
P-Alk (mg/lCaCO <sub>2</sub> )	113.4	113.4	113.4	111.3
T-Alk (mg/lCaCO <sub>2</sub> )	161.7	159.6	159.6	159.6
OH <sup>-</sup> (mg/lCaCO <sub>2</sub> )	65.1	67.2	67.2	63.0
CO <sub>2</sub> <sup>-</sup> (mg/lCaCO <sub>2</sub> )	96.6	92.4	92.4	96.6
TH (mg/lCaCO <sub>2</sub> )	11.8	10.0	9.4	9.2
Ca-H (mg/lCaCO <sub>2</sub> )	6.2	4.8	4.4	4.4
Mg-H (mg/lCaCO <sub>2</sub> )	5.6	5.2	5.0	4.8
Ca-H/Mg-H ratio	1.11	0.92	0.88	0.92
Dried solids (mg)	296.4	299.2	301.2	301.0

Note: pH, Alk or Hardness at SOR=3.15 and 1.58 cm/min were equal.

Table 17 Softened Water at  $T_n=5$  min  $G_n=20$  s<sup>-1</sup>

Quality	$T_n$ (min)			
	10	20	30	40
pH	10.45	10.45	10.45	10.45
Turbidity (NTU)				
SOR=3.15 cm/min	3.1	3.3	3.6	3.6
SOR=1.58 cm/min	1.2	1.2	1.4	1.5
P-Alk (mg/lCaCO <sub>3</sub> )	88.6	88.6	84.4	84.4
T-Alk (mg/lCaCO <sub>3</sub> )	126.6	126.6	120.3	120.3
OH <sup>-</sup> (mg/lCaCO <sub>3</sub> )	50.6	50.6	48.5	48.5
CO <sub>3</sub> <sup>=</sup> (mg/lCaCO <sub>3</sub> )	76.0	76.0	71.8	71.8
TH (mg/lCaCO <sub>3</sub> )	33.8	25.5	20.8	17.9
Ca-H (mg/lCaCO <sub>3</sub> )	29.1	20.3	17.0	13.7
Mg-H (mg/lCaCO <sub>3</sub> )	4.7	5.2	3.8	4.2
Ca-H/Mg-H ratio	6.19	3.90	4.47	3.26
Dried solids (mg)	185.0	188.3	189.0	189.9

Note: pH, Alk or Hardness at SOR=3.15 and 1.58 cm/min were equal.

Table 18 Softened Water at  $T_n=5$  min  $G_n=40$  s<sup>-1</sup>

Quality	$T_n$ (min)			
	10	20	30	40
pH	10.45	10.45	10.45	10.45
Turbidity (NTU)				
SOR=3.15 cm/min	4.1	6.4	7.1	7.6
SOR=1.58 cm/min	1.2	1.4	1.6	1.5
P-Alk (mg/lCaCO <sub>3</sub> )	88.6	86.5	84.4	84.4
T-Alk (mg/lCaCO <sub>3</sub> )	126.6	122.4	120.3	120.3
OH <sup>-</sup> (mg/lCaCO <sub>3</sub> )	50.6	50.6	48.5	48.5
CO <sub>3</sub> <sup>=</sup> (mg/lCaCO <sub>3</sub> )	76.0	71.8	71.8	71.8
TH (mg/lCaCO <sub>3</sub> )	31.3	24.3	19.7	16.8
Ca-H (mg/lCaCO <sub>3</sub> )	26.4	19.9	16.0	13.3
Mg-H (mg/lCaCO <sub>3</sub> )	4.9	4.4	3.7	3.5
Ca-H/Mg-H ratio	5.39	4.52	4.32	3.80
Dried solids (mg)	185.4	187.0	188.2	188.9

Note: pH, Alk or Hardness at SOR=3.15 and 1.58 cm/min were equal.

Table 19 Softened Water at  $T_n=5$  min  $G_s=60$  s<sup>-1</sup>

Quality	$T_n$ (min)			
	10	20	30	40
pH	10.45	10.45	10.45	10.45
Turbidity (NTU)				
SOR=3.15 cm/min	11.0	14.0	16.0	17.0
SOR=1.58 cm/min	2.1	2.1	2.4	2.6
P-Alk (mg/lCaCO <sub>3</sub> )	88.6	86.5	84.4	84.4
T-Alk (mg/lCaCO <sub>3</sub> )	126.6	122.4	120.3	120.3
OH <sup>-</sup> (mg/lCaCO <sub>3</sub> )	50.6	50.6	48.5	48.5
CO <sub>3</sub> <sup>=</sup> (mg/lCaCO <sub>3</sub> )	76.0	71.8	71.8	71.8
TH (mg/lCaCO <sub>3</sub> )	30.5	23.5	19.7	16.6
Ca-H (mg/lCaCO <sub>3</sub> )	25.7	19.1	16.0	13.1
Mg-H (mg/lCaCO <sub>3</sub> )	4.8	4.4	3.7	3.5
Ca-H/Mg-H ratio	5.35	4.34	4.32	3.74
Dried solids (mg)	185.5	188.4	189.0	189.3

Note: pH, Alk or Hardness at SOR=3.15 and 1.58 cm/min were equal.

Table 20 Softened Water at  $T_n=5$  min  $G_s=80$  s<sup>-1</sup>

Quality	$T_n$ (min)			
	10	20	30	40
pH	10.45	10.45	10.45	10.45
Turbidity (NTU)				
SOR=3.15 cm/min	16.5	19.0	22.0	24.0
SOR=1.58 cm/min	3.0	3.1	3.4	3.6
P-Alk (mg/lCaCO <sub>3</sub> )	86.5	84.4	84.4	84.4
T-Alk (mg/lCaCO <sub>3</sub> )	122.4	120.3	120.3	120.3
OH <sup>-</sup> (mg/lCaCO <sub>3</sub> )	50.6	48.5	48.5	48.5
CO <sub>3</sub> <sup>=</sup> (mg/lCaCO <sub>3</sub> )	71.8	71.8	71.8	71.8
TH (mg/lCaCO <sub>3</sub> )	30.0	23.0	19.5	17.0
Ca-H (mg/lCaCO <sub>3</sub> )	25.4	19.1	16.0	13.3
Mg-H (mg/lCaCO <sub>3</sub> )	4.6	3.9	3.5	3.7
Ca-H/Mg-H ratio	5.52	4.90	4.57	3.60
Dried solids (mg)	185.6	186.6	188.5	188.7

Note: pH, Alk or Hardness at SOR=3.15 and 1.58 cm/min were equal.

Table 21 Softened Water at  $T_s=5$  min  $G_s=100$  s<sup>-1</sup>

Quality	$T_s$ (min)			
	10	20	30	40
pH	10.45	10.45	10.45	10.45
Turbidity (NTU)				
SOR=3.15 cm/min	21.0	26.5	30.0	32.0
SOR=1.58 cm/min	4.5	5.5	6.1	6.1
P-Alk (mg/lCaCO <sub>3</sub> )	86.5	86.5	84.4	84.4
T-Alk (mg/lCaCO <sub>3</sub> )	122.4	122.4	120.3	120.3
OH <sup>-</sup> (mg/lCaCO <sub>3</sub> )	50.6	50.6	48.5	48.5
CO <sub>3</sub> <sup>=</sup> (mg/lCaCO <sub>3</sub> )	71.8	71.8	71.8	71.8
TH (mg/lCaCO <sub>3</sub> )	30.2	23.3	19.7	17.0
Ca-H (mg/lCaCO <sub>3</sub> )	25.2	19.1	16.2	13.5
Mg-H (mg/lCaCO <sub>3</sub> )	5.0	4.2	3.5	3.5
Ca-H/Mg-H ratio	5.04	4.55	4.63	3.86
Dried solids (mg)	185.3	186.1	186.0	187.7

Note: pH, Alk or Hardness at SOR=3.15 and 1.58 cm/min were equal.

Table 22 Softened Water at  $T_s=7.5$  min  $G_s=20$  s<sup>-1</sup>

Quality	$T_s$ (min)			
	10	20	30	40
pH	10.45	10.45	10.45	10.45
Turbidity (NTU)				
SOR=3.15 cm/min	3.0	3.1	3.5	3.9
SOR=1.58 cm/min	1.4	1.6	1.6	1.7
P-Alk (mg/lCaCO <sub>3</sub> )	84.4	84.4	82.3	82.3
T-Alk (mg/lCaCO <sub>3</sub> )	120.3	120.3	118.2	118.2
OH <sup>-</sup> (mg/lCaCO <sub>3</sub> )	48.5	48.5	46.4	46.4
CO <sub>3</sub> <sup>=</sup> (mg/lCaCO <sub>3</sub> )	71.8	71.8	71.8	71.8
TH (mg/lCaCO <sub>3</sub> )	19.3	17.2	15.2	13.8
Ca-H (mg/lCaCO <sub>3</sub> )	13.5	11.6	11.0	8.8
Mg-H (mg/lCaCO <sub>3</sub> )	5.8	5.6	4.2	5.0
Ca-H/Mg-H ratio	2.33	2.07	2.62	1.76
Dried solids (mg)	174.5	175.4	176.1	176.4

Note: pH, Alk or Hardness at SOR=3.15 and 1.58 cm/min were equal.



Table 23 Softened Water at  $T_x=7.5$  min  $G_s=40$  s<sup>-1</sup>

Quality	$T_s$ (min)			
	10	20	30	40
pH	10.45	10.45	10.45	10.45
Turbidity (NTU)				
SOR=3.15 cm/min	5.6	7.0	8.4	8.6
SOR=1.58 cm/min	1.3	1.5	1.6	1.8
P-Alk (mg/lCaCO <sub>3</sub> )	84.4	84.4	84.4	82.3
T-Alk (mg/lCaCO <sub>3</sub> )	120.3	120.3	120.3	118.2
OH <sup>-</sup> (mg/lCaCO <sub>3</sub> )	48.5	48.5	48.5	46.4
CO <sub>3</sub> <sup>=</sup> (mg/lCaCO <sub>3</sub> )	71.8	71.8	71.8	71.8
TH (mg/lCaCO <sub>3</sub> )	18.3	15.8	13.5	12.3
Ca-H (mg/lCaCO <sub>3</sub> )	12.0	11.0	9.3	7.5
Mg-H (mg/lCaCO <sub>3</sub> )	6.3	4.8	4.2	4.8
Ca-H/Mg-H ratio	1.91	2.29	2.21	1.56
Dried solids (mg)	173.0	174.3	175.9	176.0

Note: pH, Alk or Hardness at SOR=3.15 and 1.58 cm/min were equal.

Table 24 Softened Water at  $T_x=7.5$  min  $G_s=60$  s<sup>-1</sup>

Quality	$T_s$ (min)			
	10	20	30	40
pH	10.45	10.45	10.45	10.45
Turbidity (NTU)				
SOR=3.15 cm/min	14.0	16.0	18.0	19.5
SOR=1.58 cm/min	2.8	3.0	3.2	3.1
P-Alk (mg/lCaCO <sub>3</sub> )	86.5	82.3	84.4	82.3
T-Alk (mg/lCaCO <sub>3</sub> )	122.4	118.2	120.3	118.2
OH <sup>-</sup> (mg/lCaCO <sub>3</sub> )	50.6	46.4	48.5	46.4
CO <sub>3</sub> <sup>=</sup> (mg/lCaCO <sub>3</sub> )	71.8	71.8	71.8	71.8
TH (mg/lCaCO <sub>3</sub> )	18.3	14.7	12.9	11.8
Ca-H (mg/lCaCO <sub>3</sub> )	12.9	10.4	8.5	7.3
Mg-H (mg/lCaCO <sub>3</sub> )	5.4	4.3	4.4	4.5
Ca-H/Mg-H ratio	2.39	2.42	1.93	1.62
Dried solids (mg)	172.6	174.3	174.9	174.8

Note: pH, Alk or Hardness at SOR=3.15 and 1.58 cm/min were equal.

Table 25 Softened Water at  $T_a=7.5$  min  $G_s=80$  s<sup>-1</sup>

Quality	$T_a$ (min)			
	10	20	30	40
pH	10.45	10.45	10.45	10.45
Turbidity (NTU)				
SOR=3.15 cm/min	19.0	22.0	26.0	29.0
SOR=1.58 cm/min	3.2	3.6	3.7	3.9
P-Alk (mg/lCaCO <sub>3</sub> )	84.4	82.3	82.3	82.3
T-Alk (mg/lCaCO <sub>3</sub> )	120.3	118.2	118.2	118.2
OH <sup>-</sup> (mg/lCaCO <sub>3</sub> )	48.5	46.4	46.4	46.4
CO <sub>3</sub> <sup>=</sup> (mg/lCaCO <sub>3</sub> )	71.8	71.8	71.8	71.8
TH (mg/lCaCO <sub>3</sub> )	18.1	14.3	12.2	12.0
Ca-H (mg/lCaCO <sub>3</sub> )	13.1	10.0	8.1	7.7
Mg-H (mg/lCaCO <sub>3</sub> )	5.0	4.3	4.1	4.3
Ca-H/Mg-H ratio	2.62	2.33	1.98	1.79
Dried solids (mg)	174.5	175.8	176.2	175.8

Note: pH, Alk or Hardness at SOR=3.15 and 1.58 cm/min were equal.

Table 26 Softened Water at  $T_a=7.5$  min  $G_s=100$  s<sup>-1</sup>

Quality	$T_a$ (min)			
	10	20	30	40
pH	10.45	10.45	10.45	10.45
Turbidity (NTU)				
SOR=3.15 cm/min	26.0	32.0	35.0	39.0
SOR=1.58 cm/min	5.5	6.1	6.5	6.6
P-Alk (mg/lCaCO <sub>3</sub> )	86.5	84.4	84.4	82.3
T-Alk (mg/lCaCO <sub>3</sub> )	122.4	120.3	120.3	118.2
OH <sup>-</sup> (mg/lCaCO <sub>3</sub> )	50.6	48.5	48.5	46.4
CO <sub>3</sub> <sup>=</sup> (mg/lCaCO <sub>3</sub> )	71.8	71.8	71.8	71.8
TH (mg/lCaCO <sub>3</sub> )	17.8	14.3	12.5	12.0
Ca-H (mg/lCaCO <sub>3</sub> )	12.9	9.8	7.9	7.3
Mg-H (mg/lCaCO <sub>3</sub> )	4.9	4.5	4.6	4.7
Ca-H/Mg-H ratio	2.63	2.18	1.72	1.55
Dried solids (mg)	173.8	174.3	174.7	175.8

Note: pH, Alk or Hardness at SOR=3.15 and 1.58 cm/min were equal.

Table 27 Softened Water at  $T_R=10$  min  $G_s=20$  s<sup>-1</sup>

Quality	$T_s$ (min)			
	10	20	30	40
pH	10.45	10.45	10.45	10.45
Turbidity (NTU)				
SOR=3.15 cm/min	3.1	3.4	3.6	3.8
SOR=1.58 cm/min	1.2	1.3	1.6	1.6
P-Alk (mg/lCaCO <sub>3</sub> )	88.6	86.5	84.4	84.4
T-Alk (mg/lCaCO <sub>3</sub> )	126.6	122.4	120.3	120.3
OH <sup>-</sup> (mg/lCaCO <sub>3</sub> )	50.6	50.6	48.5	48.5
CO <sub>3</sub> <sup>=</sup> (mg/lCaCO <sub>3</sub> )	76.0	71.8	71.8	71.8
TH (mg/lCaCO <sub>3</sub> )	24.5	20.8	18.3	16.8
Ca-H (mg/lCaCO <sub>3</sub> )	19.1	16.0	13.7	12.3
Mg-H (mg/lCaCO <sub>3</sub> )	5.4	4.8	4.6	4.5
Ca-H/Mg-H ratio	3.54	3.33	2.98	2.73
Dried solids (mg)	176.6	177.7	177.6	178.0

Note: pH, Alk or Hardness at SOR=3.15 and 1.58 cm/min were equal.

Table 28 Softened Water at  $T_R=10$  min  $G_s=40$  s<sup>-1</sup>

Quality	$T_s$ (min)			
	10	20	30	40
pH	10.45	10.45	10.45	10.45
Turbidity (NTU)				
SOR=3.15 cm/min	7.2	8.0	9.6	10.0
SOR=1.58 cm/min	1.4	1.6	2.1	2.0
P-Alk (mg/lCaCO <sub>3</sub> )	86.5	86.5	84.4	84.4
T-Alk (mg/lCaCO <sub>3</sub> )	122.4	122.4	120.3	120.3
OH <sup>-</sup> (mg/lCaCO <sub>3</sub> )	50.6	50.6	48.5	48.5
CO <sub>3</sub> <sup>=</sup> (mg/lCaCO <sub>3</sub> )	71.8	71.8	71.8	71.8
TH (mg/lCaCO <sub>3</sub> )	21.8	18.5	15.4	14.5
Ca-H (mg/lCaCO <sub>3</sub> )	16.4	13.5	11.6	10.8
Mg-H (mg/lCaCO <sub>3</sub> )	5.4	5.0	3.8	3.7
Ca-H/Mg-H ratio	3.04	2.70	3.05	2.92
Dried solids (mg)	174.3	178.6	178.5	178.7

Note: pH, Alk or Hardness at SOR=3.15 and 1.58 cm/min were equal.

Table 29 Softened Water at  $T_R=10$  min  $G_s=60$  s<sup>-1</sup>

Quality	$T_s$ (min)			
	10	20	30	40
pH	10.45	10.45	10.45	10.45
Turbidity (NTU)				
SOR=3.15 cm/min	16.0	18.0	19.5	21.0
SOR=1.58 cm/min	2.5	2.4	3.2	3.4
P-Alk (mg/lCaCO <sub>3</sub> )	88.6	86.5	84.4	84.4
T-Alk (mg/lCaCO <sub>3</sub> )	124.5	122.4	120.3	120.3
OH <sup>-</sup> (mg/lCaCO <sub>3</sub> )	52.7	50.6	48.5	48.5
CO <sub>3</sub> <sup>=</sup> (mg/lCaCO <sub>3</sub> )	71.8	71.8	71.8	71.8
TH (mg/lCaCO <sub>3</sub> )	22.0	17.6	15.0	13.7
Ca-H (mg/lCaCO <sub>3</sub> )	17.0	12.9	11.0	9.6
Mg-H (mg/lCaCO <sub>3</sub> )	5.0	4.7	4.0	4.1
Ca-H/Mg-H ratio	3.40	2.75	2.75	2.34
Dried solids (mg)	174.4	176.2	177.2	177.1

Note: pH, Alk or Hardness at SOR=3.15 and 1.58 cm/min were equal.

Table 30 Softened Water at  $T_R=10$  min  $G_s=80$  s<sup>-1</sup>

Quality	$T_s$ (min)			
	10	20	30	40
pH	10.45	10.45	10.45	10.45
Turbidity (NTU)				
SOR=3.15 cm/min	22.0	26.5	29.0	32.0
SOR=1.58 cm/min	3.5	4.0	4.1	4.4
P-Alk (mg/lCaCO <sub>3</sub> )	86.5	84.4	84.4	84.4
T-Alk (mg/lCaCO <sub>3</sub> )	122.4	120.3	120.3	120.3
OH <sup>-</sup> (mg/lCaCO <sub>3</sub> )	50.6	48.5	48.5	48.5
CO <sub>3</sub> <sup>=</sup> (mg/lCaCO <sub>3</sub> )	71.8	71.8	71.8	71.8
TH (mg/lCaCO <sub>3</sub> )	21.6	17.4	15.4	13.5
Ca-H (mg/lCaCO <sub>3</sub> )	16.2	12.7	11.6	9.8
Mg-H (mg/lCaCO <sub>3</sub> )	5.4	4.7	3.8	3.7
Ca-H/Mg-H ratio	3.00	2.70	3.05	2.65
Dried solids (mg)	175.0	177.8	177.3	177.3

Note: pH, Alk or Hardness at SOR=3.15 and 1.58 cm/min were equal.

Table 31 Softened Water at  $T_r=10$  min  $G_s=100$  s<sup>-1</sup>

Quality	$T_r$ (min)			
	10	20	30	40
pH	10.45	10.45	10.45	10.45
Turbidity (NTU)				
SOR=3.15 cm/min	30.0	36.0	38.0	41.0
SOR=1.58 cm/min	5.9	7.1	7.6	7.8
P-Alk (mg/lCaCO <sub>3</sub> )	88.6	86.5	84.4	84.4
T-Alk (mg/lCaCO <sub>3</sub> )	124.5	122.4	120.3	120.3
OH <sup>-</sup> (mg/lCaCO <sub>3</sub> )	52.7	50.6	48.5	48.5
CO <sub>3</sub> <sup>=</sup> (mg/lCaCO <sub>3</sub> )	71.8	71.8	71.8	71.8
TH (mg/lCaCO <sub>3</sub> )	22.0	17.0	15.6	13.9
Ca-H (mg/lCaCO <sub>3</sub> )	16.2	11.8	10.6	9.6
Mg-H (mg/lCaCO <sub>3</sub> )	5.8	5.0	5.0	4.3
Ca-H/Mg-H ratio	2.79	2.36	2.12	2.23
Dried solids (mg)	174.1	175.2	175.8	175.3

Note: pH, Alk or Hardness at SOR=3.15 and 1.58 cm/min were equal.


Table 32 Softened Water at  $T_r=15$  min  $G_s=60$  s<sup>-1</sup>

Quality	$T_r$ (min)			
	10	20	30	40
pH	10.45	10.45	10.45	10.45
Turbidity (NTU)				
SOR=3.15 cm/min	20.0	21.0	23.5	24.0
SOR=1.58 cm/min	3.9	4.3	4.6	4.7
P-Alk (mg/lCaCO <sub>3</sub> )	84.4	84.4	82.3	82.3
T-Alk (mg/lCaCO <sub>3</sub> )	120.3	120.3	118.2	118.2
OH <sup>-</sup> (mg/lCaCO <sub>3</sub> )	48.5	48.5	46.4	46.4
CO <sub>3</sub> <sup>=</sup> (mg/lCaCO <sub>3</sub> )	71.8	71.8	71.8	71.8
TH (mg/lCaCO <sub>3</sub> )	13.9	12.0	11.6	10.4
Ca-H (mg/lCaCO <sub>3</sub> )	8.7	7.3	7.1	6.2
Mg-H (mg/lCaCO <sub>3</sub> )	5.2	4.7	4.5	4.2
Ca-H/Mg-H ratio	1.67	1.55	1.58	1.48
Dried solids (mg)	170.4	173.5	173.2	173.8

Note: pH, Alk or Hardness at SOR=3.15 and 1.58 cm/min were equal.

Table 33 Floc Size at any  $G_s$ -Value

Quality	$G_s$ ( $s^{-1}$ )				
	20	40	60	80	100
Floc size ( $\mu m$ )	145	135	120	105	95



ศูนย์วิจัยทรัพยากร  
จุฬาลงกรณ์มหาวิทยาลัย

## ประวัติผู้วิจัย

ชื่อ	นาย เสกสรร ลัดนาวิพุธ
การศึกษา	วศ.บ. (โยธา) จุฬาลงกรณ์มหาวิทยาลัย ปีการศึกษา 2524
การทำงาน	นักวิชาการสิ่งแวดล้อม 3 กองอนามัยสิ่งแวดล้อม กรมอนามัย 2525 - 2526 วิศวกรสนาม บ. ฟาร์อีสท์ เอ็นจิเนียริง คอนซัลแตนท์ จก. 2526 - 2527



ศูนย์วิทยทรัพยากร  
จุฬาลงกรณ์มหาวิทยาลัย