

## การลดความต้องการคลอรีนของน้ำทิ้งจากโรงพยาบาล โดยขบวนการแอร์สตรipping

### Reduction of Chlorine Demand in A Hospital Wastewater by Air Stripping Process

จรงรักษ์ ผลประเสริฐ

เกรียงศักดิ์ อุดมสินโรจน์

และ जानาดาน ราช ปันเดย์

Chongrak Polprasert, Ph.D.,

Kriengsak Udomsinrot, Ph.D.

and Janardan Raj Pandey

Associate Professor

Visiting Faculty

Doctoral Student

Division of Environmental Engineering, Asian Institute of Technology, Bangkok, Thailand.

#### บทคัดย่อ

การวิจัยได้ศึกษาการลดปริมาณการใช้คลอรีนที่ผสมลงในน้ำทิ้งที่ได้ผ่านขบวนการกำจัดโดยวิธีแอร์โรบิคฟิลเตอร์ของโรงพยาบาลพระนครศรีอยุธยา โดยใช้หอคอยแอร์สตรipping ปริมาณความเข้มข้นของแอมโมเนีย ไนโตรเจน ในน้ำทิ้งที่ได้ผ่านขบวนการกำจัดโดยวิธีแอร์โรบิคฟิลเตอร์อยู่ในช่วง 20 ถึง 30 มก./ลิตร ซึ่งจะส่งผลให้ต้องใช้ปริมาณคลอรีนในขบวนการฆ่าเชื้อโรคสูงมาก ผลการทดลองได้แสดงว่าขบวนการกำจัดแอมโมเนียแบบหอคอยแอร์สตรipping สามารถลดปริมาณการใช้คลอรีนได้ถึง 60% โดยปราศจากการเปลี่ยนแปลง pH ของน้ำเสีย

#### ABSTRACT

This research focused on a method to minimize the chlorine used in disinfecting the anaerobic filter effluents of the Pranakorn Sri Ayuthya Hospital. The reduction of chlorine demand in the anaerobic filter effluents by air-stripping method was experimentally investigated using a pilot scale air-stripping tower. The anaerobic filter effluents contain ammonia nitrogen in the range of 20-30 mg/L, causing high chlorine demand in the chlorination process. The efficiency of ammonia nitrogen removal in the air-stripping tower was investigated. It appeared that the ammonia stripping process can reduce the chlorine dosage up to 60 percent without wastewater pH adjustment.

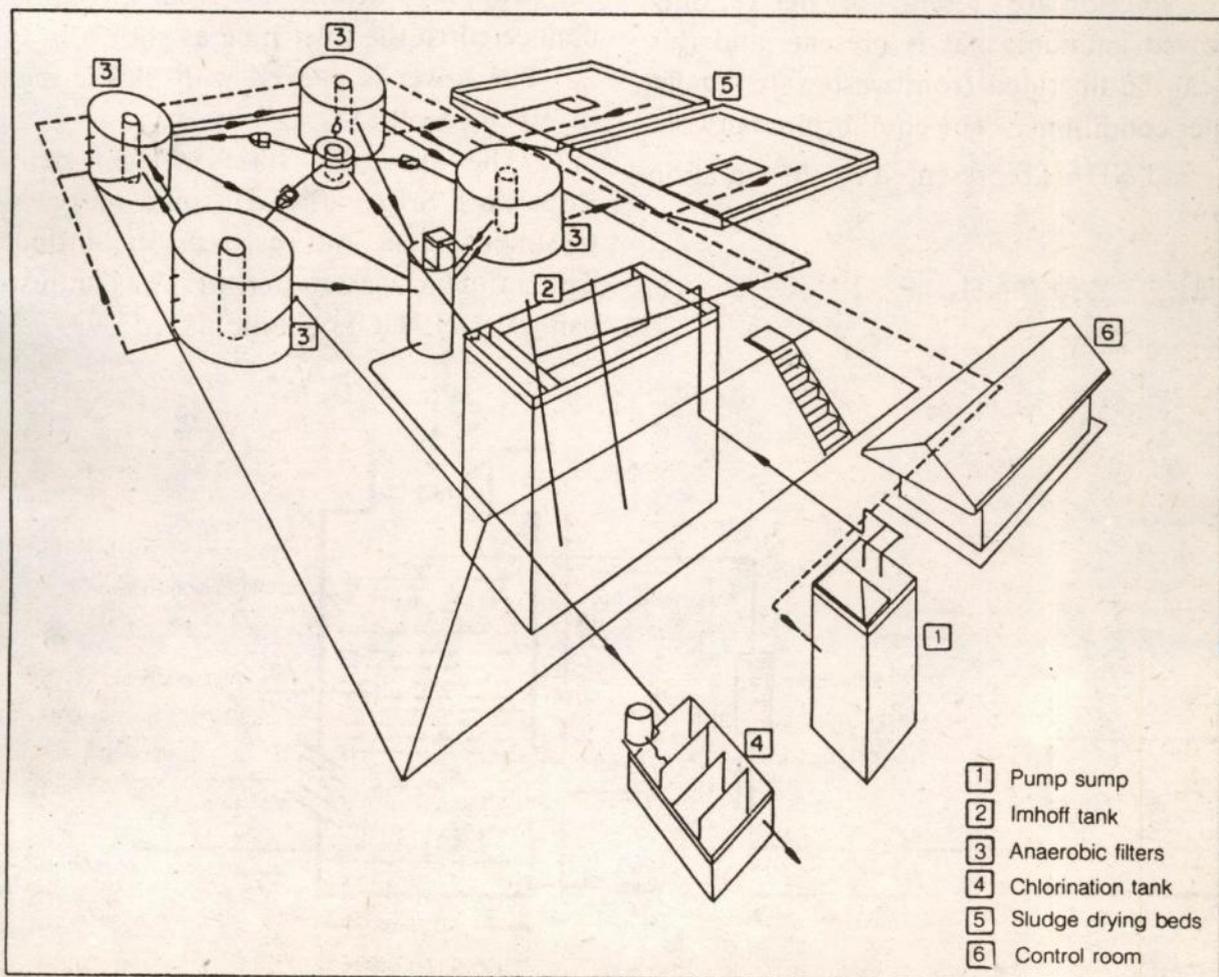
## INTRODUCTION

Although wastewater treatment plants which utilize biological actions are capable of removing or destroying some of the organisms originally present in the wastewater, the discharge of a biologically safe effluent can be assured only with adequate disinfection. From the health control viewpoint, disinfection process is one of the most important processes taking place in the treatment plant. Chlorine ( $\text{Cl}_2$ ) has been mostly employed for disinfection of treated wastewater effluent. The amount of chlorine necessary for wastewater chlorination varies with the amount of polluting substances, the degree of disinfection to be accomplished, and the temperature of wastewater. The high concentration of oxidizable compounds in the wastewater effluent, especially ammonia

nitrogen ( $\text{NH}_3 - \text{N}$ ), significantly increases chlorine demand in the disinfection process.

The amount of chlorine required to reach breakpoint chlorination (or production of residual free chlorine) is in the weight ratio of 7.6 : 1 of  $\text{Cl}_2$  :  $\text{NH}_3 - \text{N}$ ; which is very high. Such a high dose of chlorine application may result in the formation of undesirable trihalomethane compounds. To prevent the build up of such compounds and to reduce the chlorine demand,  $\text{NH}_3 - \text{N}$  should be removed to some extent from the wastewater prior to chlorination.

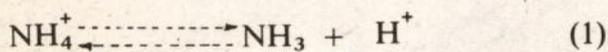
This paper presents results of a study using pilot scale air-stripping tower to reduce  $\text{NH}_3 - \text{N}$  from anaerobic filter effluents of the Pranakorn Sri Ayuthya Hospital wastewater treatment plant. The Pranakorn Sri Ayuthya Hospital wastewater treatment system consists of an Imhoff tank and four upflow anaerobic



**Figure 1:** Wastewater treatment system of Pranakorn Sri Ayuthya Hospital, Thailand

filters followed by a chlorination tank as shown in Fig. 1. Since the main treatment system is the anaerobic filter process, the anaerobic filter effluent contains high levels of  $\text{NH}_3\text{-N}$  which significantly increases the chlorine demand. Hence, it is necessary to remove  $\text{NH}_3\text{-N}$  before chlorination to reduce the chlorine demand.  $\text{NH}_3\text{-N}$  removal may be accomplished by physical, chemical or biological means. Air stripping of  $\text{NH}_3\text{-N}$  is one of the effective physical methods to remove ammonia from wastewater effluent.

Ordinarily more than 90 per cent of the nitrogen in raw domestic wastewater is in the form of ammonia or compounds from which ammonia is readily formed. In wastewater, either ammonium ions ( $\text{NH}_4^+$ ), or dissolved ammonia gas ( $\text{NH}_3$ ) or both may be present; and  $\text{NH}_3\text{-N}$  refers to the concentrations of  $\text{NH}_4^+ + \text{NH}_3$ . At pH 7, only ammonium ions in true solution are present. At pH 12, only dissolved ammonia gas is present, and this gas can be liberated from wastewater under proper conditions. The equilibrium between  $\text{NH}_4^+$  and  $\text{NH}_3$  is represented by the equation below.



As the pH is increased above 7.0, the reaction proceeds to the right (CULP et al., 1978). Once the ammonia is in the gas phase, it can be released from solution by passing the liquid through a stripping tower. Hence the air stripping process was selected for this study to remove  $\text{NH}_3\text{-N}$ .

### EXPERIMENTAL STUDY

The experimental program dealt with  $\text{NH}_3\text{-N}$  removal from the anaerobic filter effluents using a pilot scale air-stripping tower with and without adjustment of the anaerobic filter effluent pH. The experimental unit used for air-stripping of  $\text{NH}_3\text{-N}$  from the wastewater consists of a tower with a fan mounted on top as shown in Fig. 2. The tower is connected with a stock tank from which wastewater is pumped into the tower. The quantity of the wastewater pumped into the tower was determined from a rotameter connected to the inlet pipe as shown in Fig. 2. The tower is packed with plastic media of 50 cm depth.

The anaerobic filter effluent of the Pranakorn Sri Ayuthya Hospital wastewater treatment plant was used as the influent. The influent wastewater pH was adjusted using 0.1 N NaOH solution.

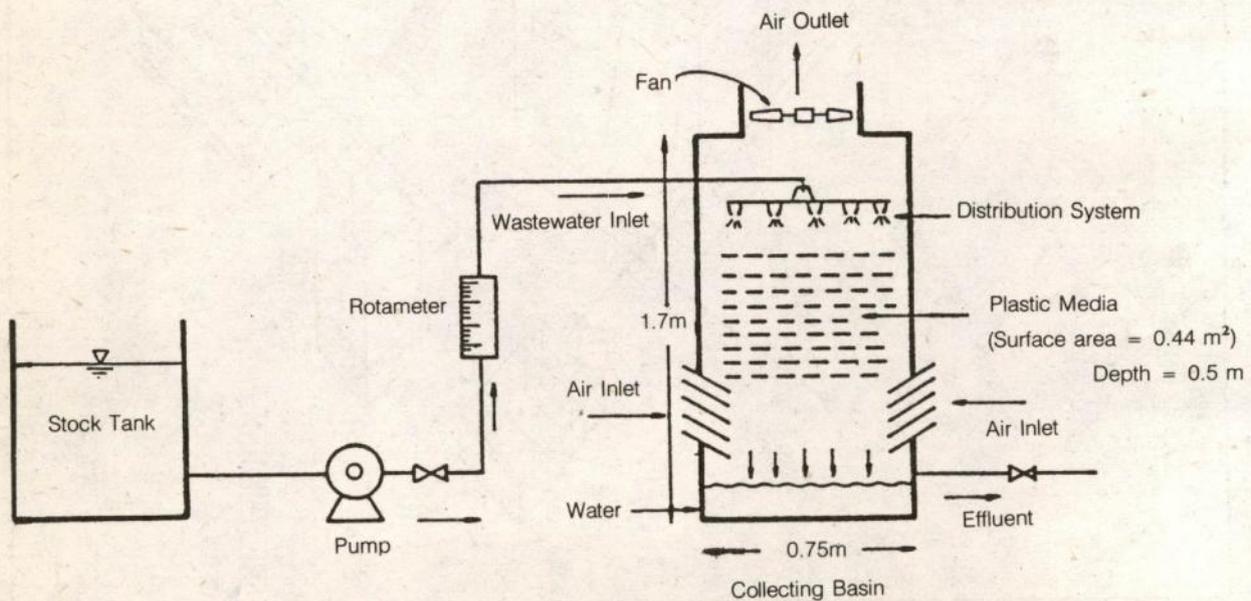


Figure 2: Experimental set-up for air-stripping of ammonia from wastewater

NH<sub>3</sub>-N in the influent and effluent samples were analysed by the distillation and titration methods (STANDARD METHODS, 1985).

The effect of NH<sub>3</sub>-N removal from wastewater on chlorine demand was investigated by measuring the chlorine demand of the anaerobic filter effluent (the influent of the stripping tower) and effluent of the stripping tower. The chlorine demand of the samples were determined by measuring the chlorine dosage applied and the total chlorine residual. Total chlorine residual was meas-

ured by the DPD ferrous titrimetric method (STANDARD METHODS, 1985).

## RESULTS AND DISCUSSION

Table I shows the pH values and NH<sub>3</sub>-N concentrations of the influent and effluent of the air-stripping tower when the wastewater flow rate was maintained at 8.2 L/min. As expected, the increase in pH increased the percent NH<sub>3</sub>-N removal because NH<sub>4</sub><sup>+</sup> was converted to NH<sub>3</sub> gas. As the pH was increased from 7.6 to 10.5, the percent NH<sub>3</sub>-N removal increased from 28.8 to 71.2 percent.

**Table I:** Experimental Results of Ammonia Stripping from Anaerobic Filter Effluent

Run No.	Air Flow Rate, m <sup>3</sup> /sec	pH		NH <sub>3</sub> -N Concentration, mg/L		NH <sub>3</sub> -N Removal, %
		Influent	Effluent	Influent	Effluent	
1	1.53	7.6	7.8	29.1	20.7	28.8
2	1.53	8.5	8.6	29.1	16.1	42.3
3	1.53	9.5	9.1	29.1	14.3	51.0
4	1.53	10.5	10.4	29.1	8.4	71.2

The amounts of NaOH required to raise the wastewater pH (whose volume was 1,500 ml) are given in Table II. The amount of NaOH required to raise the wastewater pH up to 8.4 was 34.9 mg/L, whereas if the wastewater pH was to be raised to 9.4 the required amount of NaOH was 178.7 mg/L. For maximum NH<sub>3</sub>-N removal, it would be desirable to increase the pH to as high as 12, because at this pH only dissolved NH<sub>3</sub> gas is present. However, from an economical point of view the amount of NaOH required to raise this wastewater pH may be too high. From Table II the amount of NaOH required to raise the wastewater pH to 9.8, where NH<sub>3</sub>-N removal efficiency was about 51% (see Table I) was 266.7 mg/L. The average flow rate of the Pranakorn Sri Ayuthya

Hospital wastewater system is 171 m<sup>3</sup>/day. So, the amount of NaOH required for this treatment system (to raise the effluent pH of the anaerobic filters to 9.8) will be 45 kg/day which is rather expensive for the hospital.

As it appears from the data in Table II that raising the wastewater pH to 8.2 may not require so much quantity of NaOH, an experiment was conducted to compare the efficiencies of NH<sub>3</sub>-N stripping between without adjusting the wastewater pH and with adjusting the wastewater pH to 8.2. The NH<sub>3</sub>-N removal by air-stripping in case of without adjusting the wastewater pH was 35 percent, while with adjusting the wastewater pH to 8.2 the NH<sub>3</sub>-N removal increased

**Table II:** Amount of NaOH Required to Raise the Wastewater pH\*

Volume of 0.1 N NaOH added, mL	Measured pH of Wastewater	Amount of NaOH Required, mg/L
0.0	7.8	0.0
4.1	8.0	10.9
7.6	8.2	20.3
13.1	8.4	34.9
23.5	8.7	62.7
32.6	8.9	86.9
44.0	9.1	117.3
50.0	9.2	133.3
67.0	9.4	178.7
83.3	9.6	222.1
100.0	9.8	266.7
121.2	10.0	322.9
142.7	10.2	380.5
164.1	10.4	437.6
184.3	10.6	491.5
205.2	10.8	547.2
237.7	11.1	633.9

\*Volume of wastewater sample used = 1,500 mL

to only 38.1 percent. So there was not significant advantage in the percent  $\text{NH}_3\text{-N}$  removal in the case of adjusting the wastewater pH to 8.2.

The results of chlorine demand tests of the influent and effluent of the air-stripping tower without wastewater pH adjustment and with wastewater pH adjusted to 8.2 are presented in Table III. For the influent (i.e. the anaerobic filter effluent of the Pranakorn Sri Ayuthya Hospital wastewater treatment plant), the chlorine demand was 5.9 mg  $\text{Cl}_2/\text{L}$  to keep the total chlorine residual of 1.0 mg  $\text{Cl}_2/\text{L}$ . After air-stripping without wastewater pH adjustment, the chlorine demand was reduced to 1.6 mg  $\text{Cl}_2/\text{L}$  to keep the total chlorine residual of 1.1 mg  $\text{Cl}_2/\text{L}$ . In case of wastewater pH adjusted to 8.2, the total chlorine residual of 1.0 mg  $\text{Cl}_2/\text{L}$ .

Assuming the reduction of chlorine demand in the air-stripping tower used in this study will be the same as that in the proposed

air-stripping tower to be installed at the Pranakorn Sri Ayuthya Hospital wastewater treatment plant, the comparative operating costs of chlorination in the present treatment system and in the proposed treatment system with air-stripping tower are shown in Table IV. The total operating costs of chlorination system in the present treatment system to maintain different total chlorine residuals is presented in Table IV (A). The estimated operating costs of chlorination system with the provision of air-stripping tower without wastewater pH adjustment and with wastewater pH adjusted to 8.2 are shown in Table IV (B) and IV (C), respectively. The amount of chlorine dosage required in the present treatment system is 7.44 mg  $\text{Cl}_2/\text{L}$  to keep the total chlorine residual of 1.2 mg  $\text{Cl}_2/\text{L}$ . For the Pranakorn Sri Ayuthya Hospital wastewater treatment plant, assuming a wastewater flow rate of 171  $\text{m}^3/\text{day}$ , the operating cost of chlorination is estimated to be 102

**Table III:** Measurement of Chlorine Demand in the Influent and Effluent of Air-Stripping Tower without Wastewater pH Adjustment and with Wastewater pH Adjusted to 8.2

**INFLUENT**

Volume of Sample Used, mL	Volume of Chlorine Dosage, (53.2 mg Cl <sub>2</sub> /L) mL	Chlorine Dosage, mg Cl <sub>2</sub> /L	Total Chlorine Residual, mg Cl <sub>2</sub> /L	Chlorine Demand, mg Cl <sub>2</sub> /L
100	8	4.3	0.2	4.1
100	9	4.8	0.4	4.4
100	10	5.3	0.5	4.8
100	11	5.9	0.6	5.3
100	12	6.4	0.8	5.6
100	13	6.9	1.0	5.9
100	14	7.4	1.2	6.2

**EFFLUENT (without wastewater pH adjustment)**

Volume of Sample Used, mL	Volume of Chlorine Dosage, (53.2 mg Cl <sub>2</sub> /L) mL	Chlorine Dosage, mg Cl <sub>2</sub> /L	Total Chlorine Residual, mg Cl <sub>2</sub> /L	Chlorine Demand, mg Cl <sub>2</sub> /L
100	3	1.6	0.6	1.0
100	4	2.1	0.8	1.3
100	5	2.7	1.1	1.6
100	6	3.2	1.2	2.0
100	7	3.7	1.5	2.2
100	11	5.9	2.6	3.3

**EFFLUENT (with wastewater pH adjusted to 8.2)**

Volume of Sample Used, mL	Volume of Chlorine Dosage, (53.2 mg Cl <sub>2</sub> /L) mL	Chlorine Dosage, mg Cl <sub>2</sub> /L	Total Chlorine Residual, mg Cl <sub>2</sub> /L	Chlorine Demand, mg Cl <sub>2</sub> /L
100	2	1.1	0.4	0.7
100	3	1.6	0.7	0.9
100	4	2.1	1.0	1.1
100	5	2.7	1.2	1.5
100	6	3.2	1.3	1.9

**Table IV:** Estimated Operating Costs of Ammonia Stripping and Chlorination at The Pranakorn Sri Ayuthya Hospital

A. Operating costs of chlorination for the present treatment system.

Total Chlorine Residual, mg Cl <sub>2</sub> /L	Chlorine Added,		Chlorine Cost, Baht/day <sup>b</sup>	Total Operating Costs, Baht/day
	mg Cl <sub>2</sub> /L	kg Cl <sub>2</sub> /day <sup>a</sup>		
0.50	5.32	0.91	73	73
0.80	6.38	1.09	87	87
1.20	7.44	1.27	102	102

a Assume wastewater flow rate of 171 m<sup>3</sup>/day

b Assume 60 Baht/kg (60% Cl<sub>2</sub>)

B. Operating costs of ammonia stripping without wastewater pH adjustment and chlorination for the proposed treatment system.

Total Chlorine Residual, mg Cl <sub>2</sub> /l	Chlorine Added,		Chlorine Cost, Baht/day <sup>b</sup>	Fan and Pump		Total Operating Costs, Baht/day
	mg Cl <sub>2</sub> /L	kg Cl <sub>2</sub> /day <sup>a</sup>		Power (W)	Electrical <sup>c</sup> Power Costs (Baht/day)	
0.60	1.59	0.27	22	800	38	60
0.80	2.13	0.36	29	800	38	67
1.20	3.19	0.55	44	800	38	82
1.50	3.72	0.64	51	800	38	89

a Assume wastewater flow rate of 171 m<sup>3</sup>/day

b Assume 60 Baht/kg (60% Cl<sub>2</sub>)

c Assume 2 Baht/kW-hr

C. Operating costs of ammonia stripping with wastewater pH adjusted to 8.2 and chlorination for the proposed treatment system.

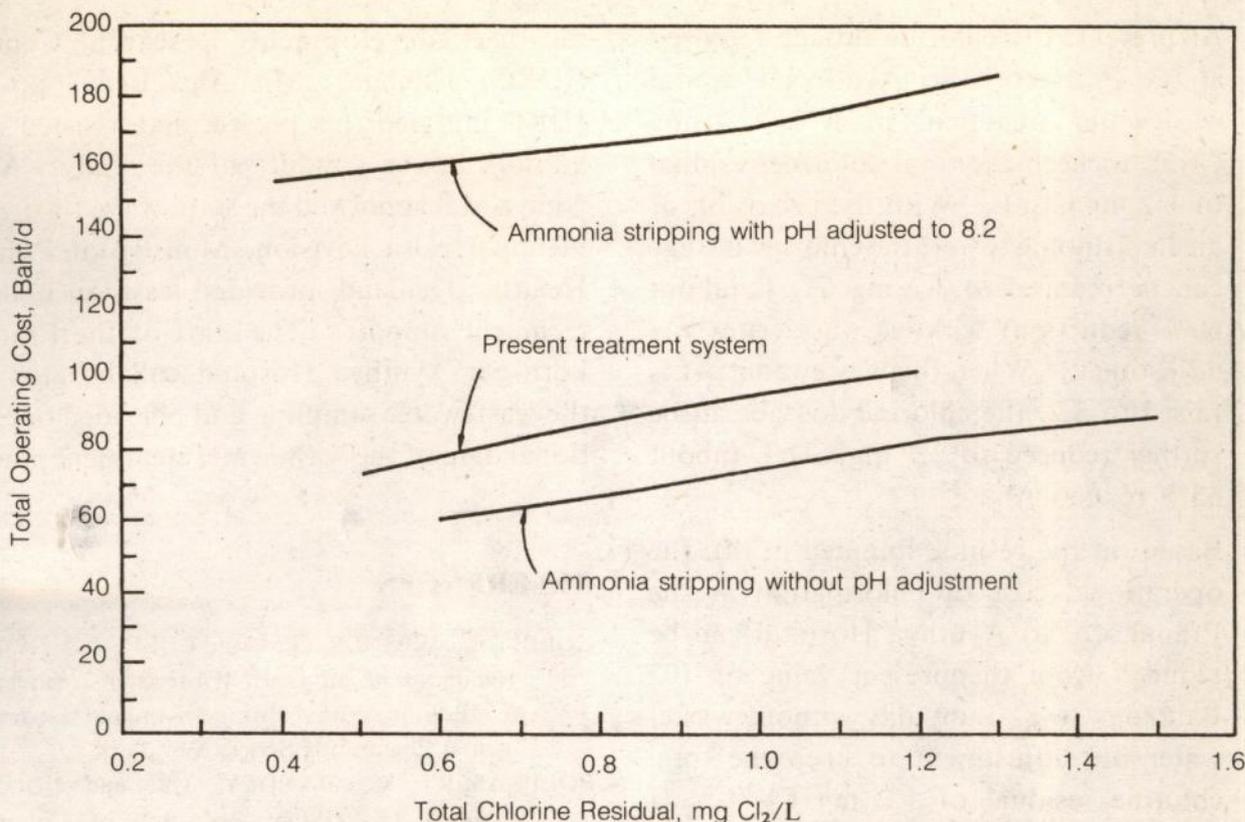
Total Chlorine Residual, mg Cl <sub>2</sub> /L	Chlorine Added		Chlorine Cost, Baht/day <sup>b</sup>	NaOH Added,		NaOH Cost, Baht/day <sup>c</sup>	Fan and Pump		Total Operating Costs, Baht/day
	mg Cl <sub>2</sub> /L	kg Cl <sub>2</sub> /day <sup>a</sup>		mg/L	kg NaOH/L		Power (W)	Electrical <sup>d</sup> Power Costs (Baht/day)	
1.40	1.06	0.18	14	20.27	3.46	104	800	38	156
1.00	2.13	0.36	29	20.27	3.46	104	800	38	171
1.30	3.19	0.55	44	20.27	3.46	104	800	38	186

a Assume wastewater flow rate of 171 m<sup>3</sup>/day

b Assume 60 Baht/kg (60% Cl<sub>2</sub>)

c Assume 22 Baht/kg (73% NaOH)

d Assume 2 Baht/KW-hr.



**Figure 3:** Estimated operating cost curve of chlorination at the Pranakorn Sri Ayuthya Hospital to maintain different total chlorine residual

Baht/day. With the introduction of ammonia stripping tower at the Pranakorn Sri Ayuthya Hospital wastewater treatment plant, the chlorine dosage required is expected to be reduced from 7.44 mg Cl<sub>2</sub>/L to 3.19 mg Cl<sub>2</sub>/L to keep the total chlorine residual of 1.2 mg Cl<sub>2</sub>/L. Accordingly, the operating cost of chlorination can be reduced from 102 Baht/day to 82 Baht/day without wastewater pH adjustment. If the wastewater pH is raised to 8.2, this operating cost will increase to 186 Baht/day, due to the additional cost of NaOH required for pH adjustment, to maintain the total chlorine residual of 1.3 mg Cl<sub>2</sub>/L.

The estimate operating cost curves of chlorination at the Pranakorn Sri Ayuthya Hospital with and without ammonia stripping are shown in Fig. 3.

### CONCLUSION

The conclusions obtained from this experimental study are summarised below:

- 1) The anaerobic filter effluents of the Pranakorn Sri Ayuthya Hospital wastewater treatment plant contain ammonia nitrogen in the range of 20-30 mg/L with causes high chlorine demand in the chlorination process.
- 2) The efficiency of ammonia nitrogen removal in the pilot scale air-stripping tower used in this study depended mainly on the influent wastewater pH. As the influent wastewater pH increased, the percent removal of ammonia nitrogen increased. The maximum ammonia nitrogen removal in this study was 71.1 percent when the wastewater pH was raised to 10.5.
- 3) It appeared that raising the wastewater pH to a very high value (above 9) may be inappropriate from the economical point of view because of the large quantity of chemical (NaOH) used.

- 4) At present, the chlorine dosage required at the Pranakorn Sri Ayuthya Hospital wastewater treatment plant is 7.4 mg Cl<sub>2</sub>/L to keep the total chlorine residual of 1.2 mg Cl<sub>2</sub>/L. With the provision of an air stripping tower, the chlorine dosage can be reduced to 3.2 mg Cl<sub>2</sub>/L (about 60% reduction) without wastewater pH adjustment. When the wastewater pH is raised to 8.2, the chlorine dosage can be further reduced to 2.7 mg Cl<sub>2</sub>/L (about 65% reduction).
- 5) Based on the results obtained in (4), the operational cost of chlorination at the Pranakorn Sri Ayuthya Hospital can be reduced from the present value of 102 Baht/day to 82 Baht/day without wastewater pH adjustment to keep the total chlorine residual of 1.2 mg Cl<sub>2</sub>/L. If the wastewater pH is raised to 8.2, this operational cost will be increase to 186 Baht/day due to the additional cost of NaOH needed for pH adjustment.

#### ACKNOWLEDGEMENTS

This research was funded by Inter-

national development Research Center (IDRC), Canada. Mr. Alex Redekopp of IDRC initiated this project and assisted the authors in the conduct of the study. Ms. Nitaya Mahabhol and the staff of the Environmental Health Division, Ministry of Public Health, Thailand provided assistance and technical support. The staff of the Pranakorn Sri Ayuthya Hospital collaborated in the wastewater sampling and provided operational data of the wastewater treatment plant.

#### REFERENCES

- CULP, R.L., WESNER, G.M. and CULP, G.Z. (1978): *Handbook of Advanced Wastewater Treatment*, 2<sup>nd</sup> Edition, Van Nostrand Reinhold Environmental Engineering Series, New York.
- POLPRASERT, C., PANDEY, J.R. and UDOMSINROT, K. (1988): Reduction of Chlorine Demand in Anaerobic Filter Effluent by Air-Stripping Process, *AIT Research Report No. 213*, Asian Institute of Technology, Bangkok, Thailand.
- STANDARD METHODS for the Examination of Water and Wastewater*, (1985): 16<sup>th</sup> Edition, APHA-AWWA-WPCF, American Public Health Association, Washington, D.C.