CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 Summary of experimental results

5.1.1 Physical and Chemical Characteristics of Shrimp Farm Effluents

- Temperature of both shrimp farm effluents were in a range from 23 to 34°C.
- pH of shrimp farm effluents ranged from 7 to 10.
- Salinity in shrimp farm effluents ranged from 0 to 15 ppt.
- Alkalinity was in a range from 40 to 180 mg/L as $CaCO_3$.
- Conductivity of shrimp farm effluents ranged from 680 to 31,700 μs/cm.
- Turbidity of shrimp farm effluents and river ranged from 16 to 160 NTU.

5.1.2 Surrogate parameters for predicting THMFP

TOC and DOC of shrimp farm effluents ranged from 3 to 18 mg/L and from 4 to 15 mg/L, respectively and SUVA of shrimp farm ranged from 1 – 22 L/mg-m. SUVA values increased as salinity and conductivity values increased and the contrary was true for DOC.

5.1.3 Hydrophobic and Hydrophilic Fractionation

Hydrophilic fraction was a dominant species in shrimp farm effluents at 56-77% by weight of the total organic content, while hydrophobic content ranged from 23 to 44 %. Shrimp farm effluents with hydrophilic content of more than 60% exhibited SUVA of less than 3 L/mg-m. In other words, SUVA of more than 3 L/mg-m represented the samples with less than 60% of hydrophilic content.

5.1.4 Trihalomethane Formation Potential

THMFP of shrimp farm effluents ranged from 810 to 3,350 μg/L. This leads to the conclusion that shrimp farm effluents had considerably high THMFP compared with other studies. In shrimp farm effluents, the farms with high salinity also had higher potential to form THMs than the low salinity farms. Chloroform was the dominant trihalomethane species found to be present in most of the samples while bromoform was the least common species. However, high salinity samples were often found to have low chloroform content but high bromoform.

5.2 Contributions of this work

This study intended to emphasize one of the most serious, but silent problems. The information from this work will be useful in both academic and application points of view as list below:

5.2.1 New finding on the formation potential of THMs from shrimp farm effluents was provided which contributed greatly to the limited knowledge on the kinetics of THM formation.

5.2.2 The results can be further analyzed by the authorities for the development of managing strategies for the shrimp farm effluents. The three possible strategies to escape the risk from shrimp farm effluents are zoning shrimp farming areas, indicating the dangerous zone and determining the suitable location for water treatment plants, and reducing organic content in shrimp farm effluents at the sources by coagulation or adjusting the optimum coagulant dose in water treatment plant not only removing turbidity but THMs precursors. In addition, this will facilitate the reference of local drinking water standards and municipal water quality standards.

5.2.3 The application of the data about cancer risk is noticed herein to find the possible linkage between the number of cancer patients and shrimp farmers in the studied areas. It is worth noting that farmers usually applied calcium hypochlorite to kill shrimp disease and reduce the problem of over-blooming phytoplankton (Funge-Smith et al., 1998, Sara 2001). Free chlorine including Br ions in shrimp farms might react with organic matters and form DBPs, potentially c arcinogenic substances. The information about cancer patients in Aumphurs Bangkla and Banpho (sub-division of Province) and Chachoengsao Province from 1998 to 2002 is shown in Table 5-1 where the cancer patient rate is the number of cancer patients per a population of 100,000 or

$$\text{Cancer patient rate} = \frac{(100{,}000 * \text{Total number of patients})}{\text{Population in the area}} \quad (5\text{-}1)$$

Population used for the calculation is summarized in Table 5-2. According to this table, the trend of cancer patients in Thailand (except for Bangkok) increased from year to year. Cancer rate in Chachoengsao Province (918:100,000) was higher than that of the whole country (820:100000). This shows that the number of cancer patients in the areas was more than the average. Although, the relevance between this figure and the high THMFP level in shrimp farm effluents cannot be confidently concluded with only the existing information in hand, further investigation should be conducted to find out exactly whether the high THMFP in Bangpakong river was really responsible for this high cancer risk in the area.

5.3 Recommendation of this work

Now that the problem of THMs formation in the shrimp farm effluent became clear, further study should be conducted towards the minimization and reduction of the problem intensity. Firstly, shrimp farm management technique should be thoroughly revised in order to minimize the chance of having high organic contents which will eventually lead to THMs formation when water is reused. Secondly, the methods of controlling the formation of THMs from the chlorination of shrimp farm effluent such as coagulation, etc. should be promptly investigated. In this work, preliminary experiment of coagulation was conducted to examine whether coagulation could be employed as a controlled technique for THMFP.

First of all, it was considered useful to give some general knowledge on the coagulation and THMFP. Braaten and Flaherty (2000) reported that a 22-44% settlement of suspended solids could be achieved and there was no significant difference between setting times of 1, 2 and 3 hours. This implied that the use of settling ponds for removal of this fraction was somewhat ineffective unless enhanced sedimentation was to be practiced (e.g. flocculation). Therefore this simple experiment was set up to determine the effect of coagulation on shrimp farm effluents and four shrimp farms (farm No. 13 – 16) were selected as a case study.

It should be noted that this experiment was conducted without controlling both an initial and a final pH, so the initial pH of the coagulation varied from batch to batch depending on an initial pH of the water samples and a coagulant doses. As shown in Figure 5-1, variation of coagulant doses from 40 to 120 mg/L resulted in slight reduction of TOC of the samples. Adding high coagulant doses meant that a large amount of charged metals and metal hydroxide, Al $(OH)_3$, could be in contact and form complex with organic matters resulting in TOC reduction.

TOC reductions of farm No. 15 and No. 16 were 47 % and 27 %, respectively. The reductions of organic precursors contributed to the decline in THMFP of 26 and 33 % of farm No. 15 and farm No 16, respectively (see Table 5-3). Theoretically, percentage of THMFP removal of Farm No.15 should be higher than that of Farm No.16 because Farm No. 15 had higher percentage of TOC reduction (47 %) in comparison to that of Farm No.16 (27%). However, opposite results were observed. This means that there must be other important factors promoting the THMFP of Farm No.15. One of those factors might be salinity. Salinity could enhance formation reaction of THMs in farm No.15 as higher salinity was detected in the farm No.15 than in the farm No 16.

The preliminary results discussed in the pervious paragraph are in good agreement with the experimental results in Chapter 4 where hydrophilic fraction was the dominant fraction in the shrimp farm effluents. Coagulation is generally effective in removal of the hydrophobic fraction but the hydrophilic. Consequently, less than 50% of the total organic content in the shrimp farm effluents could be removed. This led to a small removal percentage of THMFP as observed from the coagulation experiment here in this section.

Surprisingly, THMFP of farm No. 13 and No. 14 were found to slightly increase with the additional of alum (see Figure 5-2). This could be explained by these following reasons. Firstly, it was due to a long retention time (unavoidable as the lab was closed for a long holiday period) which allowed bromine ions to form THMs as stated by Miltner (1994). Secondly, these two samples had relatively high salinity which might also enhance the formation of THMs (see Figure 5-3). However, these are only preliminary observation. It is recommended at this stage that more investigation on this subject be carried out.

Last but not least, it should be noted that, according to this preliminary study, although coagulation was found to significantly reduce turbidity of all the samples (92-98 % reduction), it did not mean that DBPs precursors were also reduced. For this reason, the reduction in turbidity could not be used to indicate the reduction in DBPs precursors. Operators, therefore, should be well aware of this fact as the ignorance of this situation might cause a long term health effect.

Table 5-1 The number of cancer patients in Chachoengsao Province

	The total number of cancer cases, Chachoengsao Province 1998-2002											
	Bangkla				Ban-Pho				Chachoengsao Province		Thailand[c]	
year	Health center	Hospital	Total	Rate[a]	Health center	Hospital	Total	Rate[a]	Total	Rate[a]	Total	Rate[b]
1998	0	57	57	122.85	1	20	21	46.11	2,576	410.77		
1999	0	85	85	182.37	10	26	36	79.03	2,562	402.63		
2000	0	88	88	189.49	0	32	32	70.39	2,507	393.15	296,169	527.94
2001	0	216	216	465.55	3	177	180	393.98	3,749	586.01	327,787	581.28
2002	6	311	317	677.22	8	340	348	754.64	5,936	918.11	465,795	820.06

[a] The number of people in province and amphur on December 31 1997-2001 were used to calculate the ratio (1:100000)

[b] The number of people in country on the middle year 1998- 2001 were used to calculate the ratio (1:100000)

[c] The cancer cases in Thailand not included the cancer cases in Bangkok

Source Public health Chachoengsao Province

Table 5-2 Population in the areas used to calculate in table 5-1

Years	Bangkla	Ban-Pho	Chachoengsao Province	Thailand	Middle years	Thailand	Bangkok	Except Bangkok
1997	46,397	45,548	627,119	55,529,602	1998	61,155,888	5,626,286	55,529,602
1998	46,609	45,554	636,323	55,908,830	1999	61,563,980	5,655,150	55,908,830
1999	46,440	45,458	637,665	56,098,819	2000	61,770,259	5,671,440	56,098,819
2000	46,397	45,688	639,751	56,390,563	2001	62,093,855	5,703,292	56,390,563
2001	46,809	46,115	646,548	56,800,199	2002	62,554,380	5,754,181	56,800,199

Table 5-3 TOC, SUVA, and THMFP pre and post coagulation

Shrimp farms	Optimum dose(mg/L)	Pre-coagulation			Post-coagulation			%TOC removal	% SUVA reduction	%THMFP removal
		TOC(mg/L)	SUVA(L/mg.m)	THMFP(ug/L)	TOC(mg/L)	SUVA(L/mg.m)	THMFP(ug/L)			
No. 13	60	8.026	15.487	2475.990	6.812	3.876	5605.000	15.126	74.976	
No. 14	100	4.742	9.279	3105.012	3.243	5.982	5659.498	31.611	35.531	
No. 15	100	8.491	4.063	2228.216	4.507	3.195	1648.775	46.920	21.365	26.005
No. 16	100	7.787	2.722	1103.236	5.681	1.831	743.010	27.045	32.746	32.652

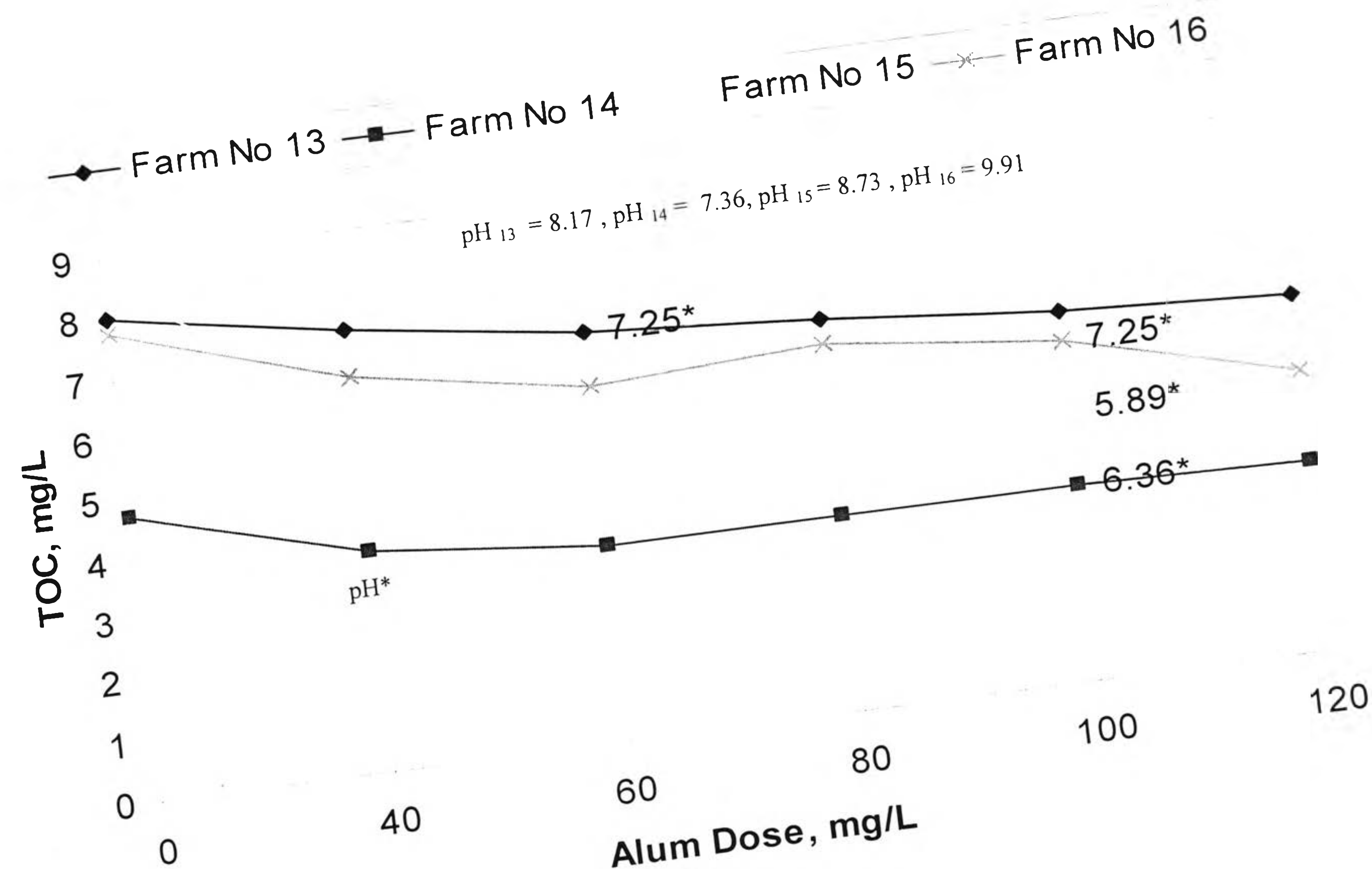

Figure 5-1 Relationship between alum dose and TOC

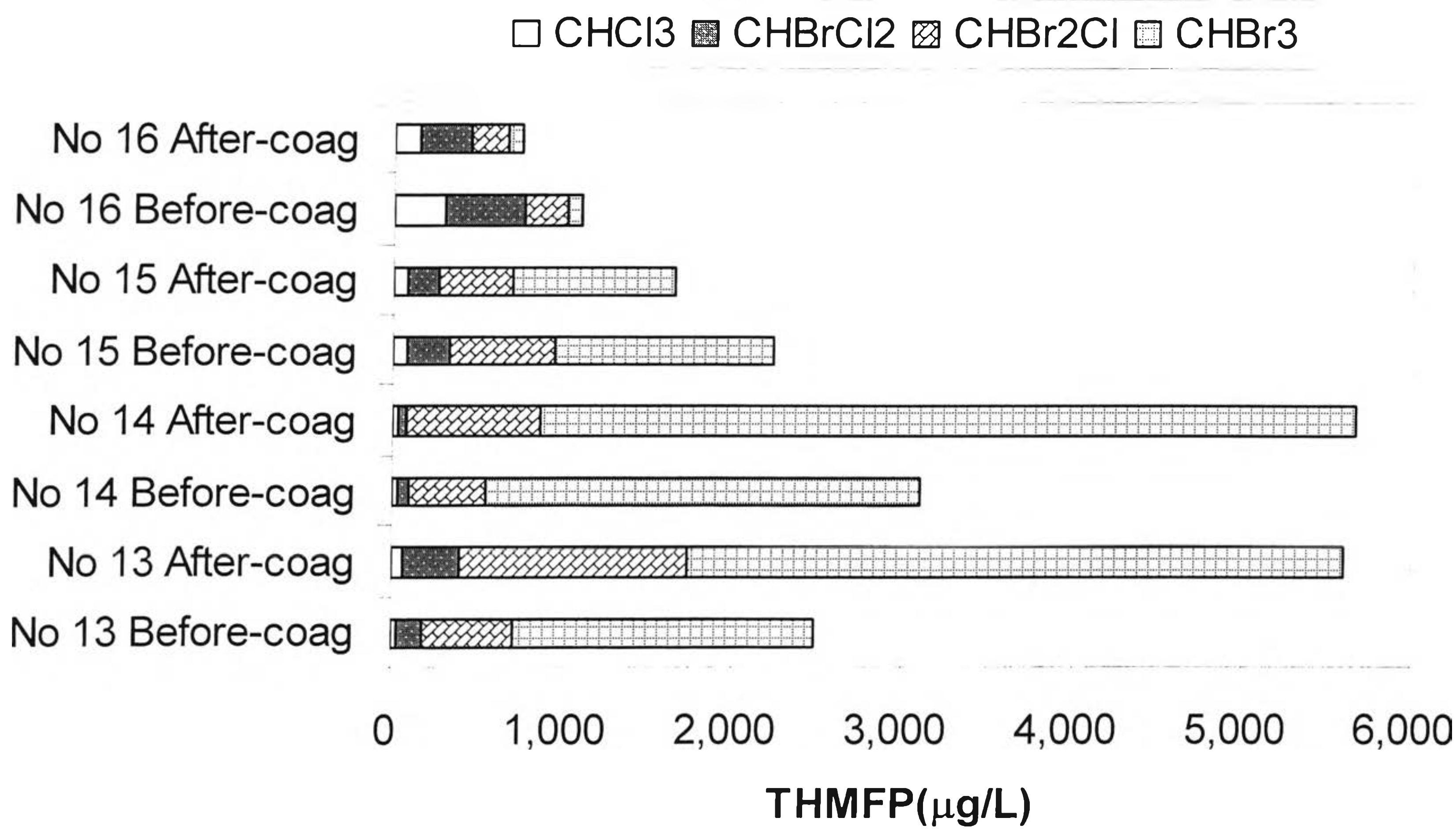

Figure 5-2 THMs species before and after coagulation

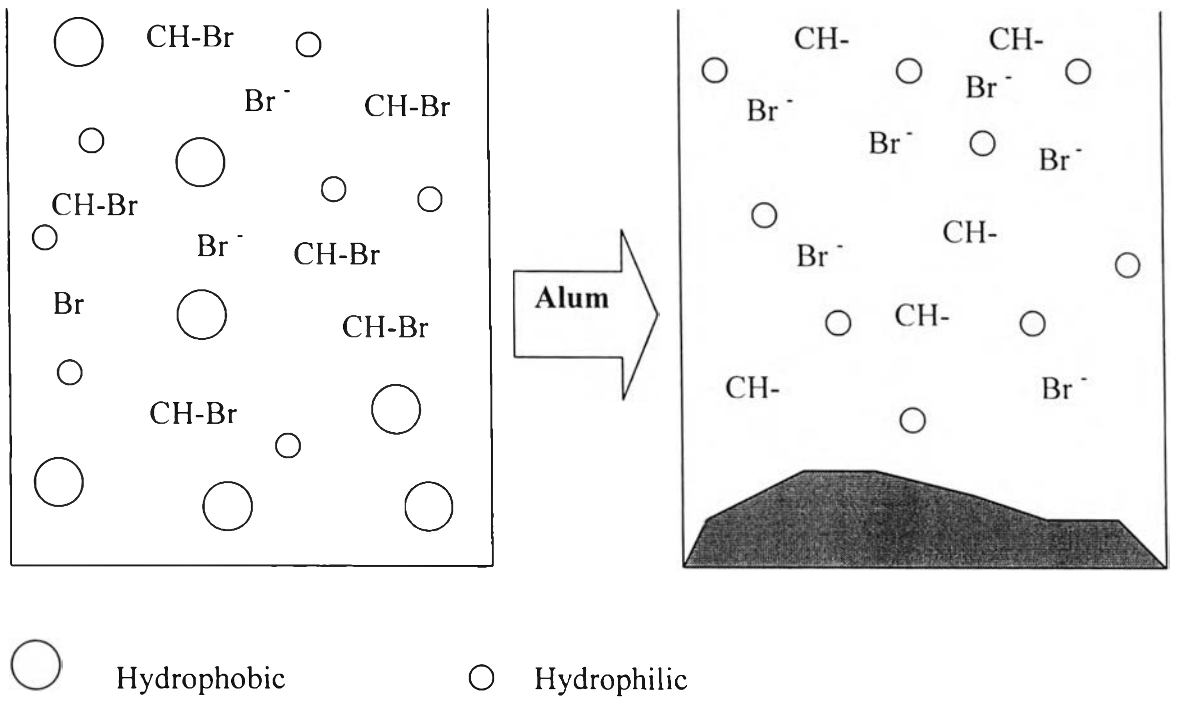

Figure 5-3 Mechanism of pre and post coagulation