

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Physical and Chemical Characteristics of Shrimp Farm Effluents

The physical and chemical characteristics of the shrimp farm effluents and river are summarized in Tables 3-4 and 3-5 where detail for each of the parameters is given below:

Temperature

All experiments were performed in the normal rainfall season. The fluctuating water temperature of both shrimp farm effluents and river were in a range from 23 to 34 and 27 to 31°C, respectively. It is generally accepted that water temperature and the presence of organic precursors are related to seasonal variation (Etsu, 1998 and Michael, 2000). High temperature was more likely to activate the growth of algae in shrimp ponds and led to the increase of both decay and reactivity rate with chlorine dose. However, such relationship is not obvious in this study. This may be due to several reasons: (1) other contributory parameters such as salinity, shrimp feeds, uneaten food, and fertilizer in effluents besides temperature had stronger influence than the presence of organic precursors, (2) the experiment did not cover a full one year period so that the correlation between temperature and organic could not be discussed, (3) there was no significant difference between temperature in winter and summer in Thailand.

pH

pH of shrimp farm effluents ranged from 7 to 10 and pH of river water ranged from 6 to 7. Higher level of pH in shrimp farm effluents was due to the concentration of ammonia and phytoplankton (Funge-Smith, 1998). Farmers usually maintain pH between 7 and 8. If pH rises too high during the day time, farmers need to reduce the large amount of phytoplankton. Besides, lime and dolomite are also used for the purpose of increasing buffering capacity, neutralization the acidity of the soil and water, and increasing the total alkalinity and total hardness (Sara, 2001).

Salinity

Salinity in river water varied from near zero at upstream locations to 6 ppt (part per trillion). downstream. Downstream samples tended to have higher salinity level than those of upstream. This could be a result from the high salinity contamination from either shrimp farm effluents (0 to 15 ppt) or sea water intrusion (20-30 ppt) or both.

Alkalinity

Adding food additive, chemical substances, fertilizers, etc. for growing shrimp might elevate alkalinity values to shrimp effluents. Alkalinity is found ranging from 40 to 180 mg/L as CaCO₃. These results were relatively high when compared to alkalinity in river of 28 -78 mg/L as CaCO₃.

Conductivity

Conductivity of river at upstream (50-184 $\mu\text{s}/\text{cm}$) was lower than that at downstream (233 -10,380 $\mu\text{s}/\text{cm}$). The higher conductivity in downstream river was due to the fact that (1) sea water intrusion (2) contamination from several substances released from the shrimp farms, e.g. inorganic dissolved solids from additive substances such as chloride, nitrate, sulfate, and phosphate anions or sodium,

magnesium, calcium, iron, and aluminum cations; (3) clay soil run offs both from clay ponds and terrain. According to the geology of the studied areas, it was found that clay soil was the most outstanding character surrounding the areas (pollution control, 2002). Clay soil could significantly influence conductivity because it could be ionized when washed into water.

Conductivity of shrimp farm effluents ranged from 680 to 31,700 $\mu\text{s}/\text{cm}$. This was in a much higher scale than the conductivity of upstream river. Similar reasons as described above were applied here only in this case there was no effect of water dilution.

In order to find the linkage between conductivity and salinity, Pearson correlation was used. In statistical results, there was an almost linear relationship between conductivity and salinity in all samples collected from shrimp farm effluents with correlation 0.984 at the 0.1 level (Table 4-3). The supporting reason was that water samples with higher level of salinity contained more highly electrically conductive potential such as Br and Cl ions and this resulted in an apparent high level of conductivity.

Turbidity

Turbidity of shrimp farm effluents and river ranged from 16 to 160 and from 12 to 286 NTU. Surprisingly, turbidity in river at the point No. 2 and 3 showed slightly higher than those in shrimp farm effluents. This was possible because at those collecting points, the two main rivers, Nakornayok and Prajinburii Rivers, join and cause high turbulent flow. This leads to a higher distribution of particulate matters and high turbidity was observed.



4.2 Surrogate parameters for predicting THMFP

Due to the difficulties in analyzing THMs, some researchers investigated surrogate parameters for a rapid estimate of THMFP. Common indicators are total organic carbon and UV absorbance at a wavelength of 254 nm.

Organic carbon

Organic carbon both in river and shrimp effluents was analyzed by TOC analyzer. In general, DOC (filtrated water) is often used rather than TOC (non-filtrated sample) because TOC analyzers are more effective measurement for DOC than TOC. In this work, however, samples were analyzed for both TOC and DOC.

TOC and DOC of shrimp farm effluents ranged from 3 to 18 mg/L and from 4 to 15 mg/L, respectively (Table 4-1). The higher level of organic matters existed in the ponds was a result from the fact that the farmers daily added feed and fertilizer which were full of organic contents as shown in Table 2-6. Moreover, pond soil erosion might be a significant factor which increases organic levels. The relationships between TOC and DOC from different shrimp farms were analyzed in order to find the correlation in statistics. It was found that TOC and DOC showed pearson correlation 0.941 and sig. = .000 this means that these two parameters have strongly and linearly correlated.

TOC and DOC of river samples ranged from 2 to 5 and from 2 to 8 mg/L, respectively (Table 4-2). Upstream samples tended to have lower level of DOC than downstream, except for the last point of downstream river. At that point, downstream river sample No 6 was supposed to have a relatively large amount of DOC, but a contrary to the expected results was observed. It was possible that the intrusion of low DOC in sea water leads to low DOC concentration in the sample.

The correlation of physical-chemical parameters can be seen from data presented in Tables 4-3 and 4-4.

Figure 4-1 illustrated that TOC and DOC were strongly related (correlation > 0.80) and have a linear correlation with salinity and conductivity (sig = 0.00) (Tables 4-3 and 4-4). The negative pearson coefficient demonstrated that TOC and DOC were found to decrease with an increase in salinity and conductivity. In other

words, TOC and DOC were inverse linear function of these parameters. This agreed with the finding of Kavanaugh (1987) who reported that DOC in sea water samples was often lower than DOC in the fresh water samples as shown in Table 2-2. Moreover, the low conductivity in these low salinity samples may also occur due to the presence of high level of organic compounds like oil, phenol, alcohol, and sugar which did not carry high conductivity electrical potential. On the contrary, sample with low salinity would potentially carry higher level of DOC.

Specific ultraviolet absorption

SUVA is defined as a surrogate parameter used to estimate hydrophobic NOM; the higher SUVA means that the water is enriched in hydrophobic such as humic substance. River and shrimp farm effluents had the SUVA values ranged from 2 - 5 L/mg-m and 1 – 22 L/mg-m (see Tables 4-1 and 4-2).

The statistic showed the linkage between SUVA and conductivity, salinity, and DOC. SUVA values increased as salinity and conductivity values increased and the contrary was true for DOC. The correlation between these parameters was summarized in Tables 4-3 and 4-4 or graphically in Figures 4-2 and 4-3.

High SUVA was found in samples from farm No. 4, 5, 6, 13, 14 and river No 6. Placing a special concern on this observation, a close link between salinity and SUVA values can be observed as shown in Figure 4-2. The important link between these was assisted by the studies of Williams (1975) and Wong and Oatts (1984) who noted that the DOC in seawater was dominated by polymeric high molecular weight compounds. This humic material had a range of molecular weights of 2,000-300,000 a.m.u. (Stevenson and Bulter, 1969) which meant that it contained high molecular weight or hydrophobic NOM. The samples which had high salinity tend to have high SUVA values as well.

4.3 Hydrophobic and Hydrophilic Fractionation

Shrimp farm effluents from farm No. 7- No 16 were fractionated into hydrophobic and hydrophilic fraction. Mass balance of each fraction was calculated in

terms of % surplus to confirm the effectiveness of the fraction procedure and the results are shown in Table 4-5.

$$\% \text{ surplus} = ((\text{sum of fraction (mg)} - \text{DOC (mg)}) * 100) / \text{DOC (mg)} \quad (4-1)$$

The loss of DOC ranged from -1 to -7 % and the excess of DOC ranged from 8 to 38 %. The excessive of DOM could be the results of inorganic, acid (H_2SO_4 and HCl) and base (NaOH), adding in sample to adjust pH and back elution (Marhaba *et al.*, 1999) and these might interfere the measurement of TOC analyzer. The loss of DOM would be from the limitation of fractionation because the small humic acid molecules could not be completely desorbed from the resin (Raewyn *et al.*, 1993). In addition, hydrophobic neutral fraction was not desorbed by NaOH (Leenheer, 1981).

Table 4-6 illustrates that hydrophilic fraction was a dominant species in shrimp farm effluents (56-77%), while hydrophobic fractions ranged from 23 to 44 %. This result was consistent with previous study of Owen *et al.*, (1995) who found that the non-humic fraction (hydrophilic fraction) accounted for about half of the DOC or about 44 to 58 % (42 to 56% humic). Marhaba and Van (2000) also found that hydrophilic acid was a dominant fraction in the water treatment plant in Northern New Jersey, USA. On the contrary, there were some researchers whose works showed different results. Thurman (1985) stated that humic species (hydrophobic fraction) typically dominated in NOM contributing from 50 to 90 % of the DOC in most natural waters. Martin-Mousset *et al.*, (1997) also reported that the hydrophobic fraction was generally slightly more abundant in reservoir water (51 to 62 % for four water sources) than in river water (41 to 50 % for four water sources).

To amplify the characteristics of each fraction, hydrophilic fractions mainly consist of carboxylic acids, carbohydrates, amino acids and amino sugars, and proteins (Dilling and Kaiser, 2002). On a case by case basis, the abundant of hydrophilic fractions perhaps came from shrimp activity such as feed, fertilizer, and excretion. Hydrophobic fractions contained the acidic products which came from the degradation of lignin, more aromatic moieties and low in organically bound nutrients such as P, N, S. (Jorg Dilling, 2002).

The causes of seasonal cycles, biological activities, sources of materials, geography, geology, landscape etc. were due to the variation of components

or properties of NOM in shrimp farm effluents which significantly vary from location to location. Similarly, the variation of hydrophobic and hydrophilic materials in different water may diverge depending on sources of materials, biological process etc. However, in the same water sources, its composition (structure, functional group) should be the same, except for the amounts of the components. In these studied areas, all farmers used the same source water, Bangplakong River, so that all have hydrophilic characteristic as a major fraction came as no surprise. The variation factors which made % composition of hydrophobic and hydrophilic fractions differently among farms were the types of palletized feeds, fertilizers and chemo-therapeutants.

It has been well known by several researchers that SUVA and the aromatic carbon contented in natural waters were directly correlated (Leenheer *et al.*, 2003). Consequently, the hydrophobic fraction which usually contained more aromatic carbon and higher-molecular-weight material than corresponding hydrophilic fraction showed the consistently higher SUVA values than those of the hydrophilic fractions (see Table 4-6).

Typically, SUVA values less than 3 L/mg-m were due to the presence of abundantly non-humic material (hydrophilic), whereas SUVA values in the range of 4-5 L/mg-m represented mainly humic material (hydrophobic) (Edzwald and Van Benschoten, 1990). Coordinating to previous work (Edzwald and Van Benschoten, 1990), shrimp effluents which had SUVA values of hydrophilic fraction less than 3 L/mg-m were the farms which had hydrophilic more than 60 % in DOC while the farms which had % hydrophilic fraction lower than 60 %, SUVA values were over 3 L/mg-m.

It should be noted that there were limitation on the usage of XAD-8 adsorption resin. Firstly, XAD-8 cannot insolate molecule of hydrophobic (humic) and hydrophilic (non-humic) fractions which could form complex or associate with one another in solution (Lytle and Perdue, 1981; Leenheer *et al.*, 1989; Boerschke *et al.*, 1996; Cook and Langford, 1998; Volk *et al.*, 1997; Jahnel and Frimmel, 1996). Secondly, XAD-8 could not adsorb large humic molecules (MW > 30,000) (Raewyn *et al.*, 1993). It was evident that seawater was dominated with polymeric high molecular weight compounds which had a range of molecular weights of 2,000-300,000 a.m.u. (Stevenson and Bulter, 1969) and, hence, these might not have been well adsorbed by this resin. Another reason was that chlorine and bromide ions in salinity water might interfere the sorption of hydrophobic substances on a column (Yamada *et al.*, 1998).

Hence, the results from the fractionation of samples No. 13-15 might not be of great accuracy.

4.4 Trihalomethanes Formation Potential

Initially, THMs in shrimp ponds were supposed to be higher than zero owing to the fact that farmers usually used calcium hypochlorite (60% w/w applied at 300 kg ha^{-1}) to kill disease such as mysid shrimp, white shrimp, swimming crabs and to reduce the problem of over-blooming phytoplankton (Funge-Smith *et al.*, 1998; Sara, 2001). However, treatment of shrimp ponds that contain a considerably large amount of organic substances and ions such as bromide with large amount of calcium hypochlorite can form DBPs. However, THMs₀ (THM₀) or THMs concentration at the time zero could not be detected (THM₀ = 0). It might be the causes of the aerators used in all shrimp farms to increase the oxygen in the pond water disperse residual chlorine and DBPs which are volatile organic carbon. After adding excess chlorine in the samples to find the maximum formation potential of THMs, it was found that THMs₇ or THMFP of shrimp farm effluents ranged from 810 to 3,350 $\mu\text{g/L}$. This leads to the conclusion that shrimp farm effluents had considerably high THMFP compared with other studies (see Table 2-8). The possible effect of directly discharging shrimp farm effluents were presented by studying THMFP of Bangpakong River from upstream to downstream. Upstream river THMFP ranged from 30 to 280 $\mu\text{g/L}$ whereas downstream river THMFP ranged from 580 to 1,100 $\mu\text{g/L}$. River samples at downstream location were observed to have higher THMFP than upstream samples. This was due to the increasing number of shrimp farms from upstream to downstream. In other words, river which acted as a reservoir for shrimp farm effluents was more contaminated at downstream location as there receives a larger quantity of discharges from shrimp farms.

4.4.1 THMFP and salinity

The correlations between THMFP, standardized THMs (THMFP/organic matter) and salinity for all fractions (raw, filtrated, hydrophobic, and hydrophilic) were summarized in Tables 4-7 to 4-10. In a word, standardized THMs of raw and standardized THMs of filtrated waters showed significant correlations with

salinity with Pearson correlation > 0.900 at the 0.01 level which meant that the increase in the salinity was found to have a positive effect on the formation of standardized THMs. Additionally, the values of Sig. (2-tailed) were both lower than 0.05 which meant that the relationship of these two was a linear. Figures 4-4 and 4-5 showed the relationships between THMFP, standardized THMs and salinity for all fractions.

In shrimp farm effluents, the farms which had high salinity also had higher potential to form THMFP than the farms which had low salinity. Figures 4-6 and 4-7 illustrate the relationship between standardized THMs and salinity in each shrimp farm. River salinity gradually increased from upstream to downstream. At the point No.1, upstream River (no inland shrimp farms around the areas) had the lowest THMFP, while the highest THMFP was at the No.6, downstream river.

The dominant trihalomethane species was chloroform which was found to be present in most of the samples. Previous work suggested that organic chemicals such as aliphatic carboxylic acids, hydroxybenzoic acids (Rockwell and Larson, 1978), phenols and pyrrole derivatives e.g. tryptophan (Morris and Baum, 1978), are reactive substances for CHCl_3 (Ritchelita *et al.*, 1998) and they could be presented in large quantities in the samples from this work. On the other hand, bromoform was the least species commonly detected. However, in the case which the samples are salinity waters for example shrimp farms No 4, 5, 6, 13, 14, 15, chloroform was present very small amount in contrast to bromoform (Figure 4-8). Accordingly, river downstream No 6, the salinity water, also reported the same trend (Figure 4-9). Bromide ions from seawater were also an important contributor to THMs formation and increasing brominated species of THMs. This was due to the fact that during chlorination of the saline water, bromide ion is oxidized to bromine. Bromine seems to be more effective as a halogen-substituting agent and if bromine acts as an oxidant it will be reduced to bromide ion, which may then be re-oxidized by chlorine. Additionally, Figure 4-10 showed that THMFP-hydrophobic had low brominated trihalomethane comparing with others fractions. The most reasonable for these results is that bromine is more reactive with aliphatic precursors (hydrophilic) than with aromatic precursors (hydrophobic). This is consistent with the hypothesis proposed above in connection that aliphatic structures may play a relatively more important role in THMs formation.

4.4.2 THMFP and turbidity

Turbidity is a representative of how the water sample was contaminated with visible impurities. If turbidity is directly a function of organic constituents in the water sample, then it may be possible that a well defined relationship between turbidity and THMFP be observed. According to the statistic correlation summarized in Table 4-7 and Figure 4-6, filtrated waters were formed to have higher potential to form THMs than raw waters. This is attributed to the fact that turbidity interfered the interaction between chlorine and substances in water and led to inefficiency in forming THMs. In most cases, the increasing in turbidity contributed to the decreasing of THMFP. The amount of impurities in water samples did not directly represent the quantity of organic matters.

4.4.3 THMFP and organic carbon

According to Equation 2-1, DOM plays a crucial role in the formation of THMs. THMs formation was found to increase proportionally to the amount of DOM in the source water. The examples of THMs precursors were the degradation products of humic and fulvic acids such as resoreinol, phloroglucinol, pyrogallol, catechol, orcinol, 2, 6-duhydroxytoluene, o- and m – phthalic acids, and 3, 5-dihydroxybenzoic acids etc (Samuel and Osman, 1998). Additionally, green and blue-green algae abundantly found in shrimp ponds are also THMs precursors. The large amount of precursors (organic matter) provides a high potential in the formation of THMs.

Statistical analysis was used to make a better understanding about the relation between THMFP and organic matter. THMFP and organic matter for all fractions showed an invert correlation with negative coefficient and low significant correlation except for filtrated water. The correlations of THMFP and TOC and THMFP and DOC were -0.412 and -0.676, respectively which the latter was considered as a good correlation at the 0.01 level (2-tailed) and indicated a linear relation with Sig. < 0.05 (see Tables 4-7 and 4-8 and Figure 4-15).

According to Tables 4-9 and 4-10, the correlations of THMFP and humic organic carbon (hydrophobic) and THMFP and non-humic acid (hydrophilic) were -0.225 and -0.545, respectively and Sig.(2-tailed) > 0.05 which means that the

correlations are not significant and not linearly related. Figure 4-7 showed that hydrophilic fraction was abundantly contained in shrimp effluents rather than hydrophobic fraction and the hydrophilic fraction was found to be more reactive precursor for THMs. However, this result did not agree with the finding of some previous studies listed in Table 2-7 and Leenheer (2003) who summarized that hydrophobic fraction has been generally accepted as the major source of DBP precursor sites (Leenheer, 2003). The difference between the reporting data and the experimental results in this work might be due to the nature of water sources. In this work, samples were obtained from shrimp farms which were contaminated with chemicals. On the other hand, most reported data were for natural water sources which were usually more enriched with hydrophobic organic than hydrophilic fraction.

TOC or DOC alone, however, is not a good indicator for THMFP because the nature of the material differs considerably from source to source. Nevertheless, a precise predict the effects of numerous parameters influencing the kinetics of THMs formation is difficult to conclude because of the unknown structure of mixed precursors which could be reacting with free chlorine.

4.4.4 THMFP and UV

The difference of absorbance illustrates that NOM characteristics in waters had been changed. According to this work, the differential absorbance between before and after chlorinating water was negative (Table 4-11) which entirely agreed with the results of Korshin *et al.*, (2002). In other words, water chlorination decreases the absorbance of the NOM. The most rational reason can be explained herein was that chlorine broke the aromatic rings and thus absorbance decreased (Li, 2000.)

A small significance in statistical correlation as reported in Tables 4-7 and 4-10 indicated that UV-light absorbance could not be used for an accurate prediction of specific trihalomethane formation potential.

4.4.5 THMFP and SUVA

To demonstrate whether SUVA was a good estimator for THMFP, Pearson correlation was used again as a tool. According to Tables 4-7 and 4-10, SUVA and standardized THMs which are THMFP/TOC, THMFP/DOC, and

THMFP/hydrophilic reported strongly correlations of 0.762, 0.971, and 0.938, respectively. There was no relationship between SUVA and other non-standardized THMFP except for that of filtrated water which had a significant correlation (0.724). Figures 4-16 and 4-18 show the relationships between THMFP, standardized THMs and SUVA for all fractions.

In order to find the parameters which related the formation of THMs from different shrimp farm effluents, multiple regression models both linear and non-linear regression were used. In the model THMFP was fixed as dependent variable and related parameters in the formation of THMs salinity and DOC were fixed as independent variable. Salinity was formed to have higher influence in the formation of THMFP than organic carbon with R^2_{adjust} of 0.582 for linear and 0.790 for non-linear regressions. The results were summarized in Table 4-12.

Table 4-1 Surrogate parameters for raw and filtrated shrimp farm effluents

Water Sources	Organic carbon (mg/L)	UV (1/cm)	SUVA (L/mg.m)
Farm No 1			
raw water	13.459	0.338	2.511
filtrated water	12.694	0.242	1.906
Farm No 2			
raw water	14.397	0.404	2.806
filtrated water	13.616	0.264	1.939
Farm No 3			
raw water	12.800	0.284	2.219
filtrated water	12.642	0.235	1.859
Farm No 4			
raw water	3.190	0.352	11.028
filtrated water	3.680	0.184	5.005
Farm No 5			
raw water	4.318	0.947	21.931
filtrated water	3.884	0.218	5.613
Farm No 6			
raw water	3.880	0.508	13.086
filtrated water	4.180	0.217	5.194
Farm No 7			
raw water	14.811	0.227	1.532
filtrated	10.354	0.172	1.663
Farm No 8			
raw water	15.034	0.428	2.845
filtrated	13.948	0.189	1.358
Farm No 9			
raw water	13.782	0.279	2.022
filtrated	13.278	0.222	1.673
Farm No 10			
raw water	18.267	0.707	3.868
filtrated	13.263	0.267	2.015
Farm No 11			
raw water	14.209	0.388	2.730
filtrated	12.340	0.183	1.483
Farm No 12			
raw water	15.783	0.358	2.268
filtrated	15.461	0.282	1.824
Farm No 13			
raw water	8.026	1.2430	15.487
filtrated	8.871	0.2930	3.303
Farm No 14			
raw water	6.742	0.440	9.279
filtrated	5.410	0.244	5.533
Farm No 15			
raw water	8.491	0.345	4.063
filtrated	10.236	0.195	1.905
Farm No 16			
raw water	7.787	0.212	2.722
filtrated	8.300	0.146	1.759

Table 4-2 Surrogate parameters for River water

Water Sources	Organic carbon (mg/L)	UV (1/cm)	SUVA (L/mg.m)
	Upstream 1 (No 1)		
raw water	2.007	0.104	5.157
filtrated	2.351	0.057	2.403
	Upstream 2 (No 2)		
raw water	4.498	0.386	8.570
filtrated	5.464	0.149	2.718
	Upstream 3 (No 3)		
raw water	4.969	0.549	11.038
filtrated	5.576	0.177	3.174
	Downstream 1 (No 4)		
raw water	5.15	0.507	9.839
filtrated	4.47	0.158	3.532
	Downstream 2 (No 5)		
raw water	4.574	0.268	5.859
filtrated	7.696	0.192	2.495
	Downstream 3 (No 6)		
raw water	1.936	0.219	11.312
filtrated	2.33	0.121	5.193

Table 4-3 The correlation of TOC and physical-chemical parameters

		SUVA (L/mg.m)	Salinity (ppt)	Conductivity (µs/cm)	Turbidity (NTU)
TOC (mg/L)	Pearson Correlation	-.754**	-.831**	-.805**	.378
	Sig. (2-tailed)	.001	.000	.000	.149
	N	16	16	16	16

		Salinity (ppt)	Conductivity (µs/cm)	Turbidity (NTU)
SUVA (L/mg.m)	Pearson Correlation	.877	.915**	-.154
	Sig. (2-tailed)	.000	.000	.570
	N	16	16	16

		Conductivity (µs/cm)	Turbidity (NTU)
Salinity (ppt)	Pearson Correlation	.984**	-.166
	Sig. (2-tailed)	.000	.540
	N	16	16

		Turbidity (NTU)
Conductivity (µs/cm)	Pearson Correlation	-.165
	Sig. (2-tailed)	.542
	N	16

** Correlation is significant at the 0.01 level (2-tailed).

Table 4-4 The correlation of DOC and physical-chemical parameters

		SUVA (L/mg.m)	Salinity (ppt)	Conductivity (µs/cm)
DOC (mg/L)	Pearson Correlation	-.905	-.847	-.829
	Sig. (2-tailed)	.000	.000	.000
	N	16	16	16

		Salinity (ppt)	Conductivity (µs/cm)
SUVA (L/mg.m)	Pearson Correlation	.934	.919
	Sig. (2-tailed)	.000	.000
	N	16	16

		Conductivity (µs/cm)
Salinity (ppt)	Pearson Correlation	.984
	Sig. (2-tailed)	.000
	N	16

** Correlation is significant at the 0.01 level (2-tailed).

Table 4-5 Mass balance for all fractionations

Shrimp farms	DOC (mg/L)	TOC (mg/L)	Mass (mg)				% Surplus
			DOC	Sum of fractions	Hydrophobic	Hydrophilic	
No. 7	10.354	14.811	31.062	30.372	8.937	21.435	-2.221
No. 8	13.948	15.034	41.844	39.183	9.027	30.156	-6.359
No. 9	13.278	13.782	39.834	39.393	13.887	25.506	-1.107
No. 10	13.263	18.267	35.810	34.636	10.203	24.434	-3.278
No. 11	12.340	14.209	24.680	22.976	6.120	16.856	-6.904
No. 12	15.461	15.783	30.922	29.680	9.910	19.770	-4.017
No. 13	8.871	8.026	17.742	22.026	7.548	14.478	24.146
No. 14	4.410	4.742	8.820	12.146	5.292	6.854	37.710
No. 15	10.236	8.491	20.472	22.228	6.454	15.774	8.578
No. 16	8.300	7.787	16.600	15.796	5.546	10.250	-4.843

Table 4-6 Surrogate parameters for hydrophobic and hydrophilic fraction

Water Sources	Organic carbon (mg/L)	UV (1/cm)	SUVA (L/mg.m)
No 7 (19-Jun-03)			
raw water	14.811	0.227	1.532
filtrated	10.354	0.172	1.663
hydrophobic (29%)	2.979	0.053	1.762
hydrophilic (71%)	7.145	0.083	1.160
No 8 (12-Jul-03)			
raw water	15.034	0.428	2.845
filtrated	13.948	0.189	1.358
hydrophobic (23%)	3.009	0.050	1.665
hydrophilic (77%)	10.052	0.108	1.078
No 9 (22- Jul- 03)			
raw water	13.782	0.279	2.022
filtrated	13.278	0.222	1.673
hydrophobic (35%)	4.629	0.082	1.778
hydrophilic(65%)	8.502	0.091	1.066
No 10 (29-Jul-03)			
raw water	18.267	0.707	3.868
filtrated	13.263	0.267	2.015
hydrophobic (29.5%)	3.710	0.084	2.259
hydrophilic(70.5%)	8.885	0.117	1.314
No 11 (6-Aug-03)			
raw water	14.209	0.388	2.730
filtrated	12.340	0.183	1.483
hydrophobic (27%)	3.060	0.071	2.327
hydrophilic(73%)	8.428	0.096	1.142
No 12 (6-Aug-03)			
raw water	15.783	0.358	2.268
filtrated	15.461	0.282	1.824
hydrophobic(33%)	4.955	0.142	2.866
hydrophilic (67%)	9.885	0.121	1.220
No 13 (6-Aug-03)			
raw water	8.026	1.243	15.487
filtrated	8.871	0.293	3.303
hydrophobic(34%)	3.774	0.158	4.187
hydrophilic(66%)	7.239	0.175	2.417
No 14 (6-Aug-03)			
raw water	4.742	0.440	9.279
filtrated	4.410	0.244	5.533
hydrophobic (44%)	2.646	0.265	10.015
hydrophilic(56%)	3.427	0.131	3.823
No 15 (6-Aug-03)			
raw water	8.491	0.345	4.063
filtrated	10.236	0.195	1.905
hydrophobic (29%)	3.227	0.071	2.200
hydrophilic (71%)	7.887	0.101	1.281
No 16 (6-Aug-03)			
raw water	7.787	0.212	2.722
filtrated	8.300	0.146	1.759
hydrophobic (35%)	2.773	0.067	2.416
hydrophilic(65%)	5.125	0.061	1.190

Table 4-7 Correlation of THMFP of raw water, filtrated water and surrogated parameters

	THMs/TOC ($\mu\text{g}/\text{mg C}$)	Salinity (ppt)	TOC (mg/L)	UV (1/cm)	SUVA (L/mg.m)	Turbidity (NTU)
THMFP ($\mu\text{g}/\text{L}$) Pearson Correlation	.626	.533	-.412	.569	.460	-.064
Sig. (2-tailed)	.009	.033	.113	.022	.073	.813
N	16	16	16	16	16	16

	Salinity (ppt)	TOC (mg/L)	UV (1/cm)	SUVA (L/mg.m)	Turbidity (NTU)
THMs/TOC ($\mu\text{g}/\text{mg C}$) Pearson Correlation	.909	-.894	.362	.762	-.178
Sig. (2-tailed)	.000	.000	.168	.001	.510
N	16	16	16	16	16

** Correlation is significant at the 0.01 level (2-tailed).

* Correlation is significant at the 0.05 level (2-tailed).

Table 4-8 Correlation of THMFP of filtrated water and surrogated parameters

		THM/DOC ($\mu\text{g}/\text{mg C}$)	Salinity (ppt)	DOC (mg/L)	UV (1/cm)	SUVA (L/mg.m)
THMFP ($\mu\text{g}/\text{L}$)	Pearson Correlation	.793	.781	-.676	.120	.724
	Sig. (2-tailed)	.000	.000	.004	.659	.002
	N	16	16	16	16	16

		Salinity (ppt)	DOC (mg/L)	UV (1/cm)	SUVA (L/mg.m)
THM/DOC ($\mu\text{g}/\text{mg C}$)	Pearson Correlation	.917	-.937	-.086	.971
	Sig. (2-tailed)	.000	.000	.751	.000
	N	16	16	16	16

** Correlation is significant at the 0.01 level (2-tailed).

Table 4-9 Correlation of THMFPP of hydrophobic and surrogated parameters

		THMs/DOC-hydrophobic (µg/mg C)	THMs/hydrophobic (µg/mg C)	Salinity (ppt)	Hydrophobic (mg/L)	UV (1/cm)	SUVA (L/mg.m)
THMFPP (µg/L)	Pearson Correlation	.836	.910	.462	-.225	.310	.410
	Sig. (2-tailed)	.003	.000	.179	.533	.383	.240
	N	10	10	10	10	10	10

		THMs/hydrophobic (µg/mg C)	Salinity (ppt)	Hydrophobic (mg/L)	UV (1/cm)	SUVA (L/mg.m)
THMs/DOC-hydrophobic (µg/mg C)	Pearson Correlation	.927	.433	-.474	.649	.798
	Sig. (2-tailed)	.000	.211	.166	.042	.006
	N	10	10	10	10	10

		Salinity (ppt)	Hydrophobic (mg/L)	UV (1/cm)	SUVA (L/mg.m)
THMs/hydrophobic (µg/mg C)	Pearson Correlation	.544	-.580	.346	.541
	Sig. (2-tailed)	.104	.079	.327	.106
	N	10	10	10	10

		Salinity (ppt)	UV (1/cm)	SUVA (L/mg.m)
Hydrophobic (mg/L)	Pearson Correlation	-.457	.016	-.288
	Sig. (2-tailed)	.184	.965	.420
	N	10	10	10

** Correlation is significant at the 0.01 level (2-tailed).

* Correlation is significant at the 0.05 level (2-tailed).

Table 4-10 Correlation of THMFP of hydrophilic and surrogated parameters

		THMs/hydrophilic ($\mu\text{g}/\text{mg C}$)	THMs/DOC- hydrophilic ($\mu\text{g}/\text{mg C}$)	Salinity (ppt)	Hydrophilic (mg/L)	UV (1/cm)	SUVA (L/mg.m)
THMFP ($\mu\text{g}/\text{L}$)	Pearson Correlation	.845	.897	-.337	-.545	.543	.759
	Sig. (2-tailed)	.002	.000	.341	.104	.105	.011
	N	10	10	10	10	10	10

		THMs/DOC- hydrophilic ($\mu\text{g}/\text{mg C}$)	Salinity (ppt)	Hydrophilic (mg/L)	UV (1/cm)	SUVA (L/mg.m)
THMs/hydrophilic ($\mu\text{g}/\text{mg C}$)	Pearson Correlation	.994	-.327	-.807	.369	.938
	Sig. (2-tailed)	.000	.356	.005	.294	.000
	N	10	10	10	10	10

		Salinity (ppt)	Hydrophilic (mg/L)	UV (1/cm)	SUVA (L/mg.m)
THMs/DOC- hydrophilic ($\mu\text{g}/\text{mg C}$)	Pearson Correlation	-.353	-.779	.405	.923
	Sig. (2-tailed)	.317	.008	.245	.000
	N	10	10	10	10

		Salinity (ppt)	UV (1/cm)	SUVA (L/mg.m)
Hydrophilic (mg/L)	Pearson Correlation	.435	.037	-.718
	Sig. (2-tailed)	.209	.919	.019
	N	10	10	10

** Correlation is significant at the 0.01 level (2-tailed).

* Correlation is significant at the 0.05 level (2-tailed).

Table 4-11 UV absorbance at day 0 and 7

Water Sources	UV 1	UV 7	ΔA				
					Farm No 13		
	Farm No 1			raw water	1.243	0.15	-1.098
raw water	0.338	0.117	-0.221	filtrated	0.293	0.13	-0.167
filtrated water	0.242	0.105	-0.137	hydrophobic	0.158	0.08	-0.078
	Farm No 2			hydrophilic	0.175	0.07	-0.104
raw water	0.404	0.149	-0.255		Farm No 14		
filtrated water	0.264	0.102	-0.162	raw water	0.44	0.2125	-0.228
	Farm No 3			filtrated	0.244	0.091	-0.153
raw water	0.284	0.107	-0.177	hydrophobic	0.265	0.0955	-0.170
filtrated water	0.235	0.095	-0.140	hydrophilic	0.131	0.047	-0.084
	Farm No 4				Farm No 15		
raw water	0.352	0.119	-0.233	raw water	0.345	0.139	-0.206
filtrated water	0.184	0.0975	-0.087	filtrated	0.195	0.081	-0.114
	Farm No 5			hydrophobic	0.071	0.034	-0.037
raw water	0.947	0.261	-0.686	hydrophilic	0.101	0.041	-0.060
filtrated water	0.218	0.102	-0.116		Farm No 16		
	Farm No 6			raw water	0.212	0.074	-0.138
raw water	0.508	0.116	-0.392	filtrated	0.146	0.062	-0.085
filtrated water	0.217	0.096	-0.121	hydrophobic	0.067	0.037	-0.030
	Farm No 7			hydrophilic	0.061	0.029	-0.033
raw water	0.22695	0.12015	-0.107				
filtrated	0.17215	0.062875	-0.109				
hydrophobic	0.0525	0.02503	-0.027				
hydrophilic	0.0829	0.04355	-0.039				
	Farm No 8						
raw water	0.4277	ND.					
filtrated	0.18935	ND.					
hydrophobic	0.0501	ND.					
hydrophilic	0.1084	ND.					
	Farm No 9						
raw water	0.27865	ND.					
filtrated	0.2221	ND.					
hydrophobic	0.0823	ND.					
hydrophilic	0.0906	ND.					
	Farm No 10						
raw water	0.70665	ND.					
filtrated	0.2672	ND.					
hydrophobic	0.0838	ND.					
hydrophilic	0.11675	ND.					
	Farm No 11						
raw water	0.38785	ND.					
filtrated	0.183	ND.					
hydrophobic	0.0712	ND.					
hydrophilic	0.09625	ND.					
	Farm No 12						
raw water	0.358	0.143	-0.215				
filtrated	0.282	0.142	-0.140				
hydrophobic	0.142	0.058	-0.084				
hydrophilic	0.121	0.062	-0.059				

Table 4-12 Regression models for predicting THMFP

Fraction	regression	Dependent variable	Independent variable	R	R ²	R ² adjust	Equations
Filtrated water	Linear regression	THMFP	Salinity	0.781	0.610	0.582	THMFP = 1246.438 + 97.049 salinity
		THMFP	SUVA	0.724	0.524	0.490	THMFP= 846.518 + 289.025 SUVA
		THMFP	Conductivity	0.731	0.535	0.502	THMFP = 1278.786 + 4.788E-02 Conductivity
	Non-linear regression	THMFP	Salinity	0.901	0.811	0.790	ln THMFP = 7.207 + 0.241 ln Salinity

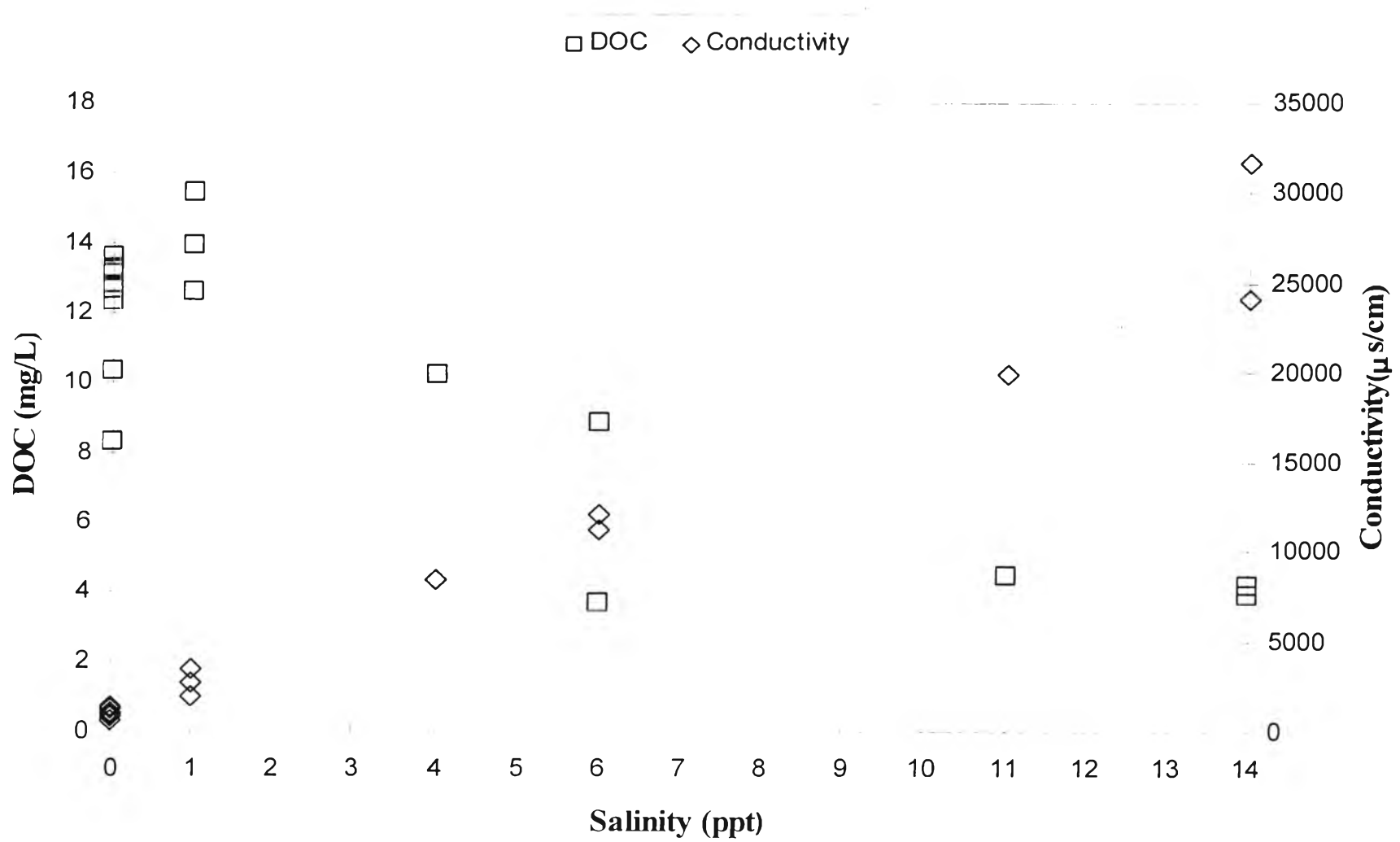


Figure 4-1 Relationships between Salinity, DOC, and Conductivity in the different shrimp farm effluents

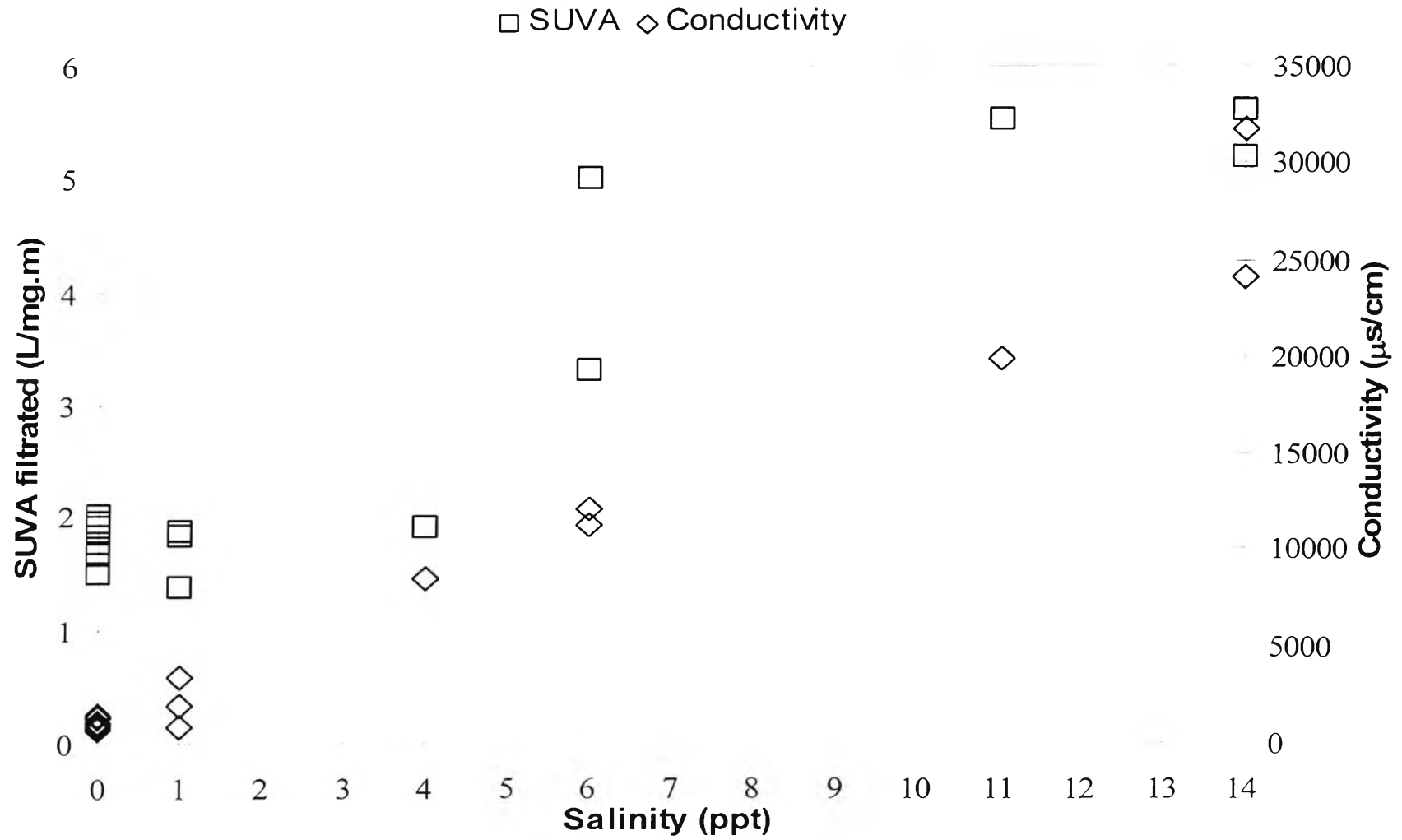


Figure 4-2 Relationship among DOC, salinity, conductivity, and SUVA in the different shrimp farm effluents

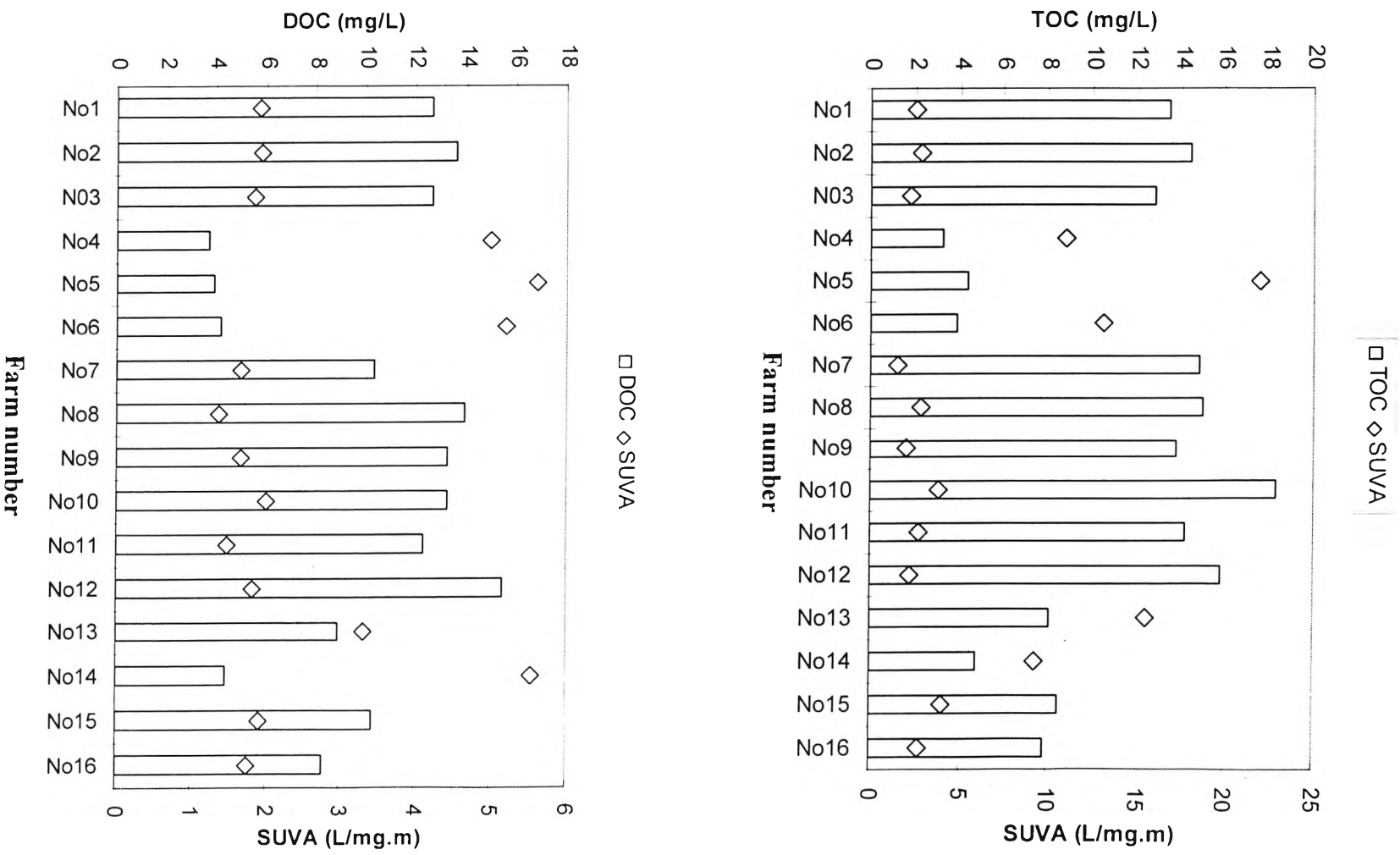


Figure 4-3 Relationship between organic matter and SUVA in the different shrimp farm effluents.

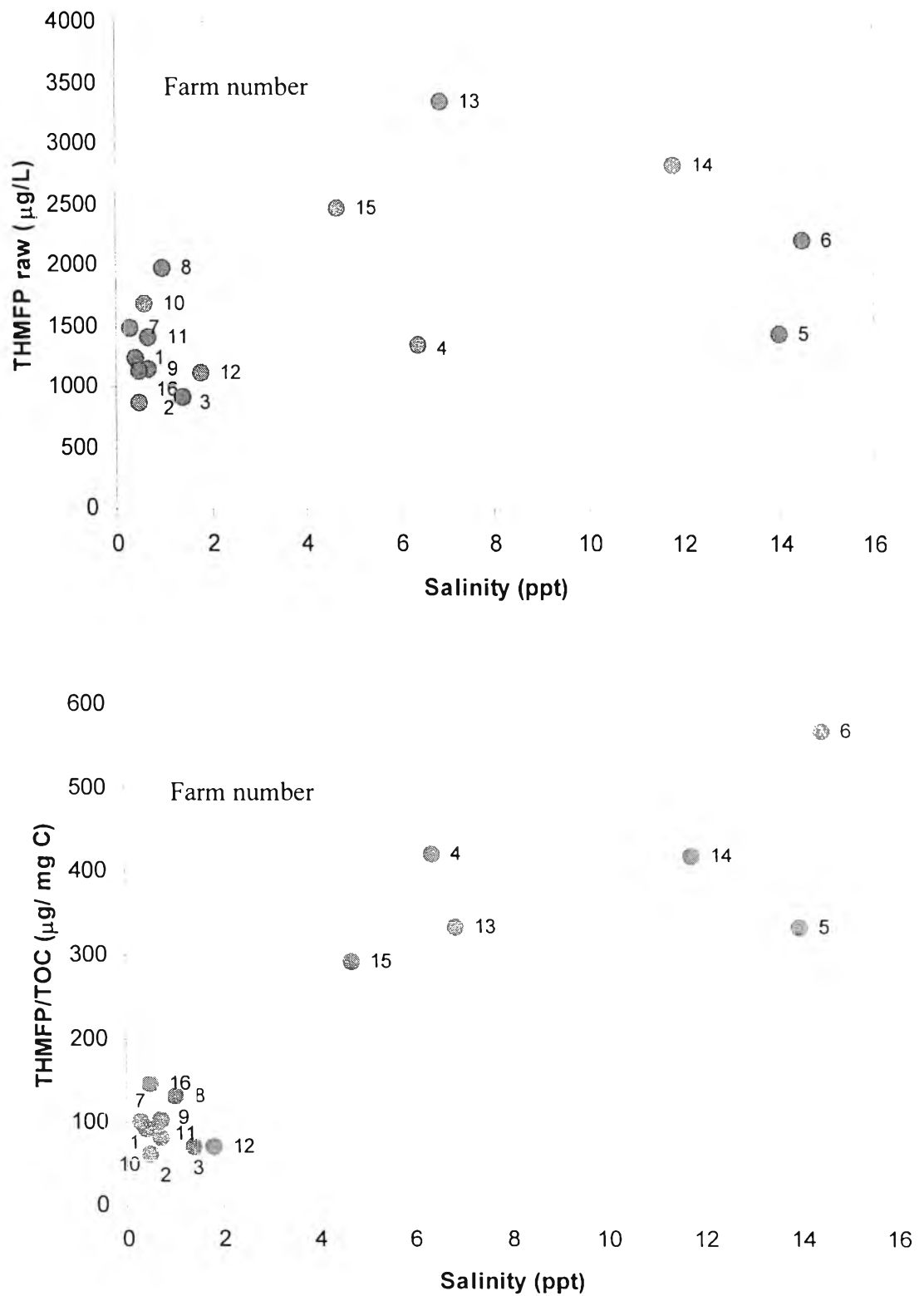


Figure 4-4 Relationship between THMFP_{raw}, THMs/TOC and Salinity in the different shrimp farm effluents.

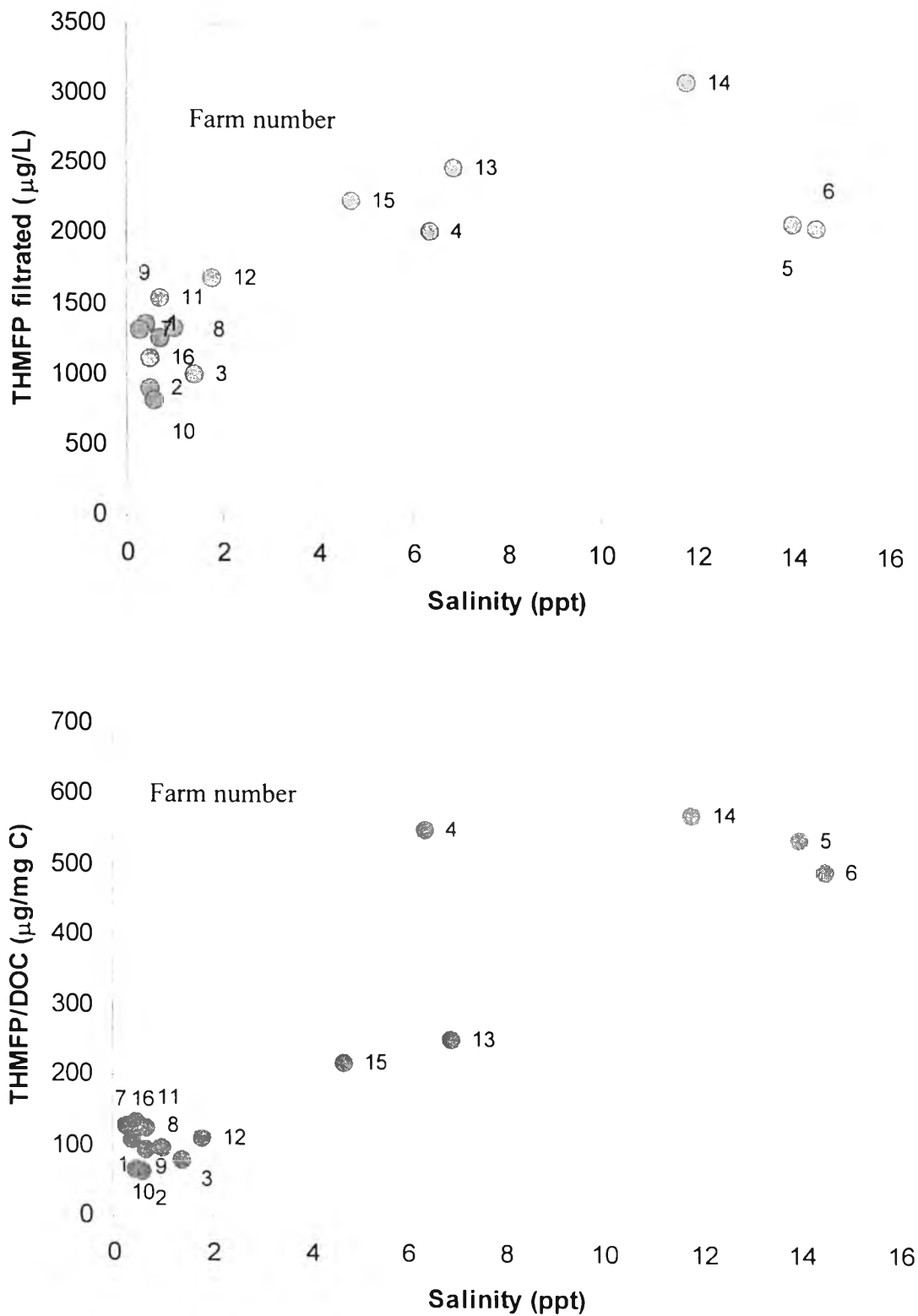


Figure 4-5 Relationship between THMFP_{filtrated}, THMs/DOC and Salinity in the different shrimp farm effluents.

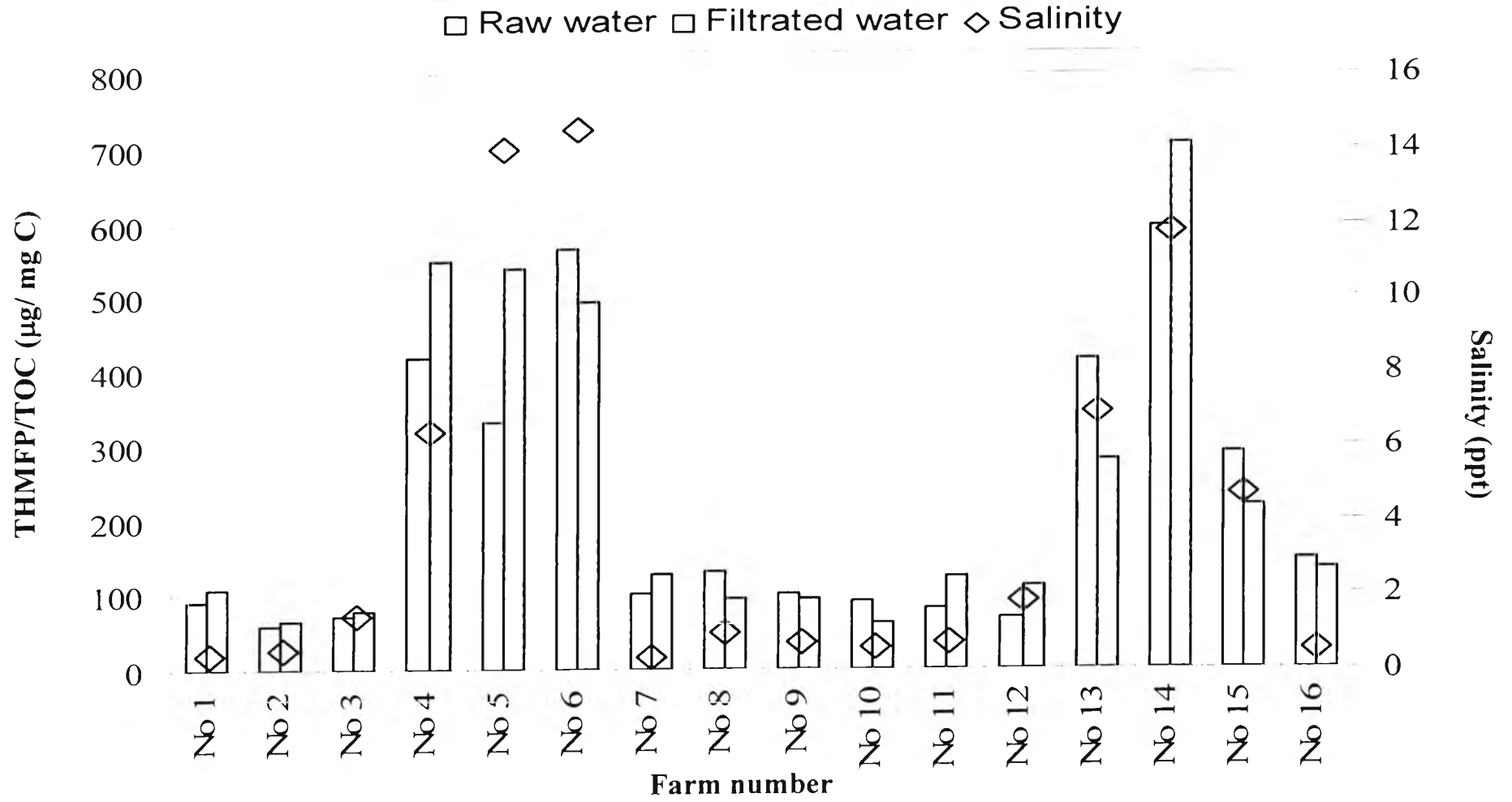


Figure 4-6 THMF/TOC of Raw water and Filtrated water

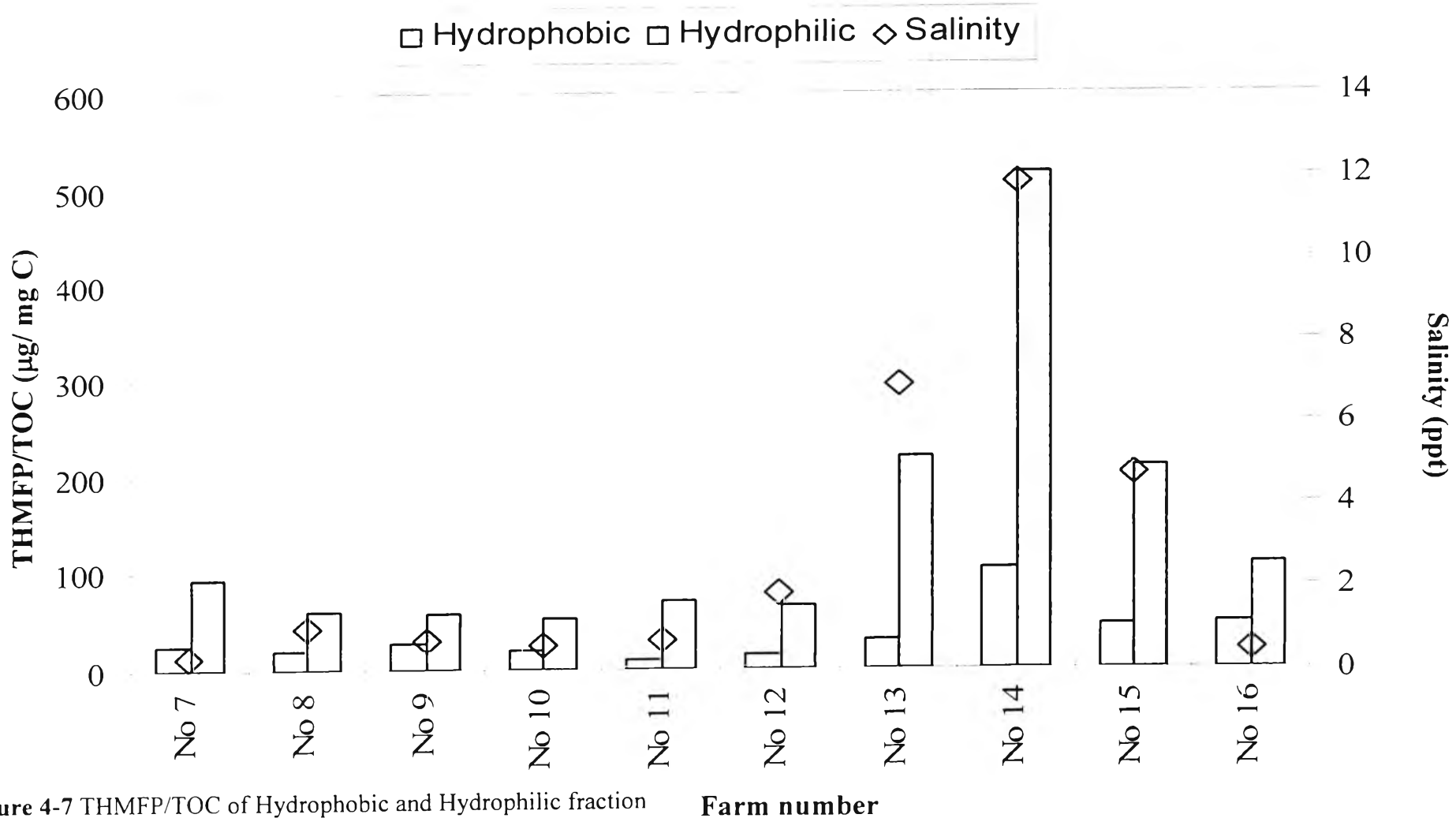


Figure 4-7 THMF/TOC of Hydrophobic and Hydrophilic fraction Farm number

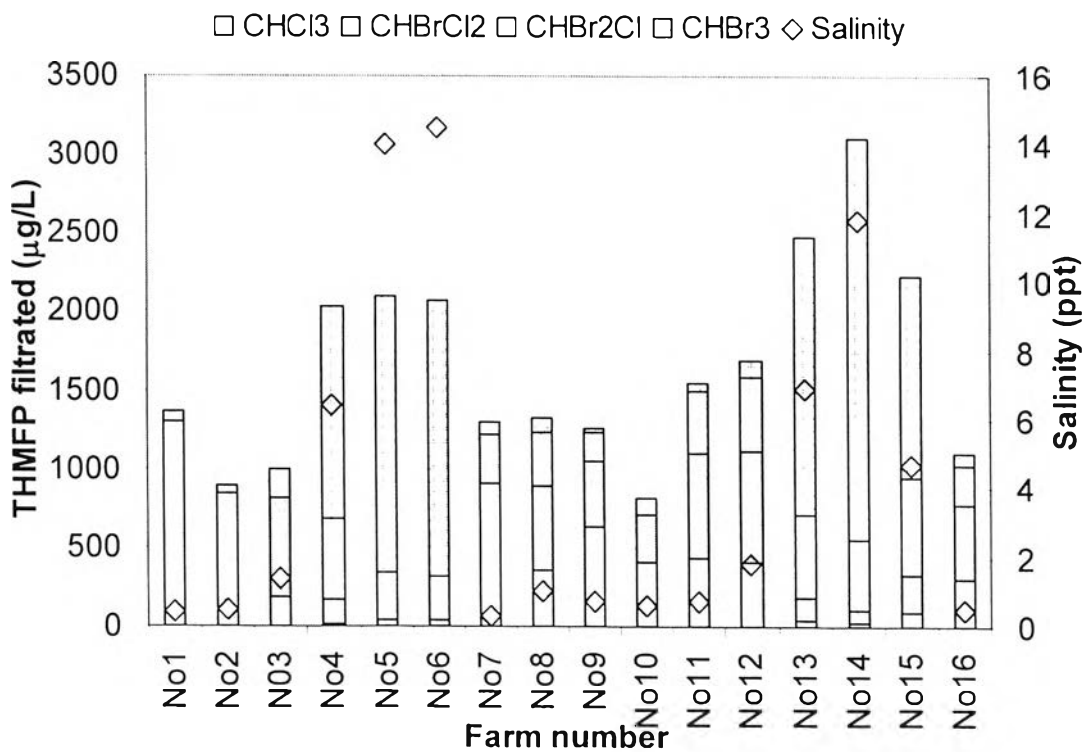
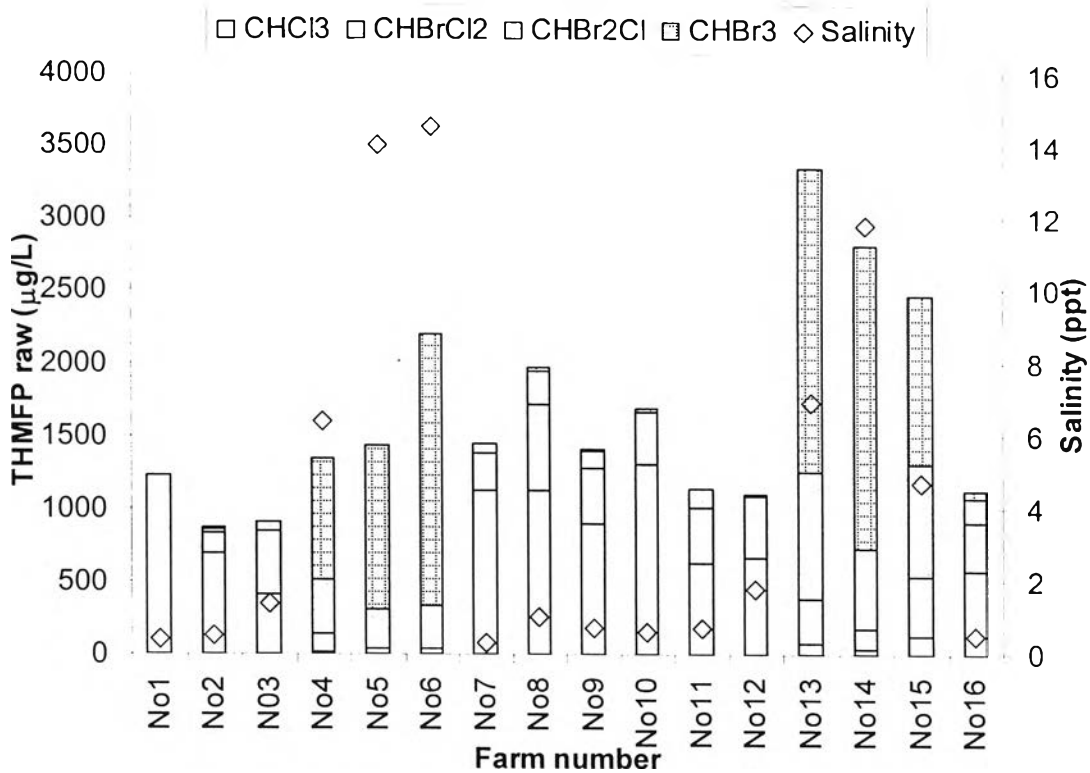


Figure 4-8 Relationship between THMs species and salinity in shrimp farm effluents



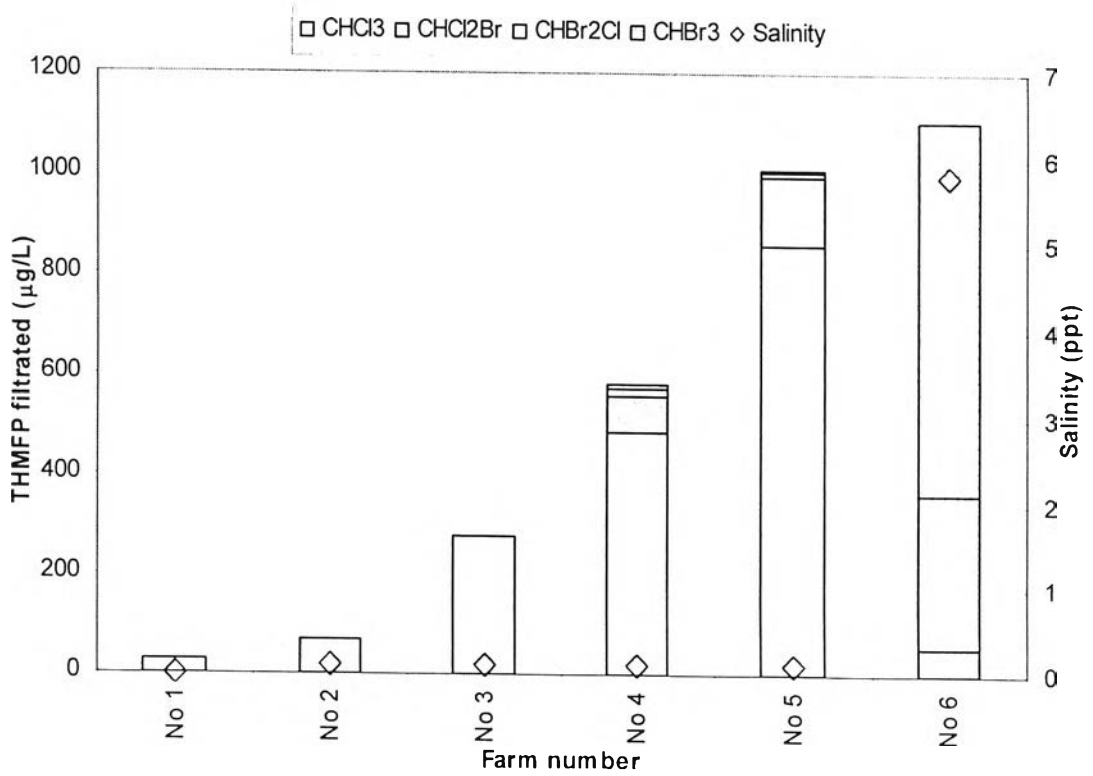
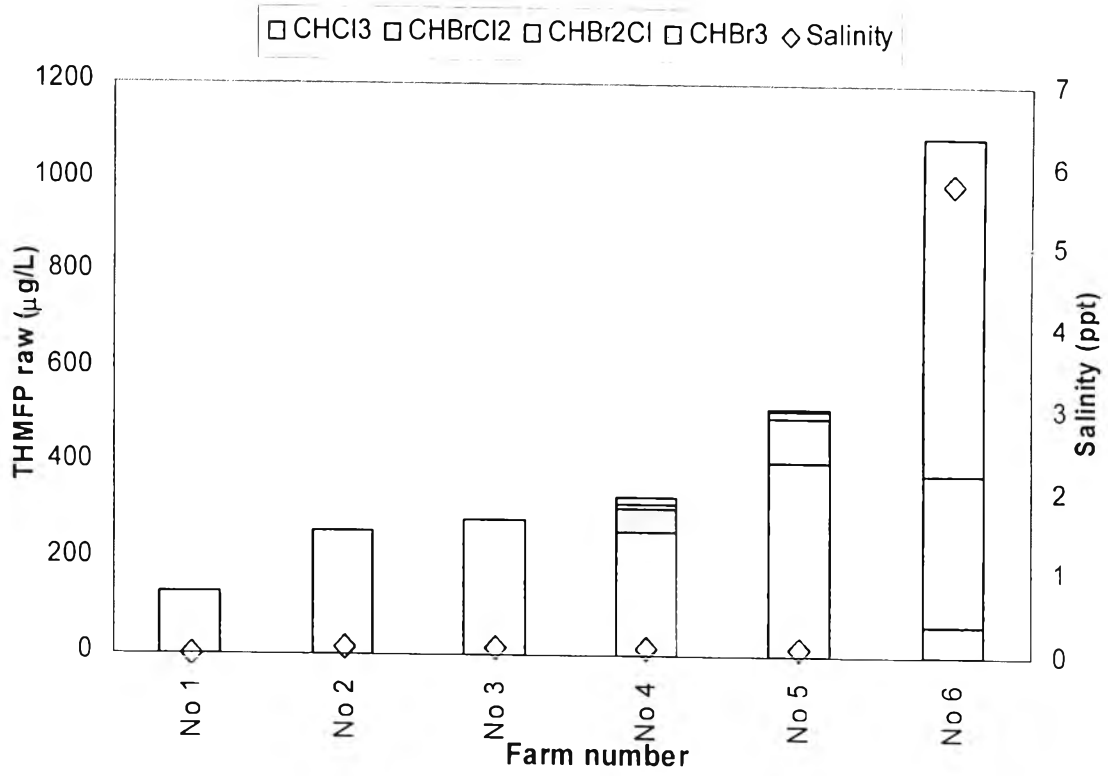


Figure 4-9 Relationship between THMs species and salinity in River

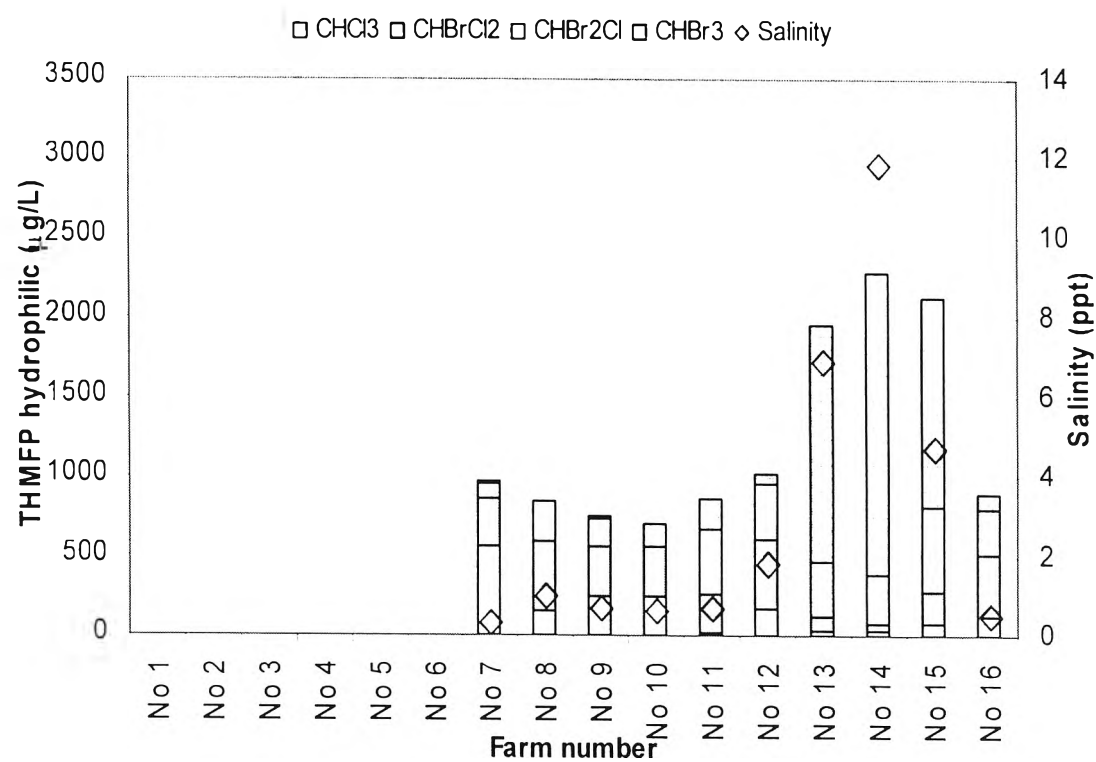
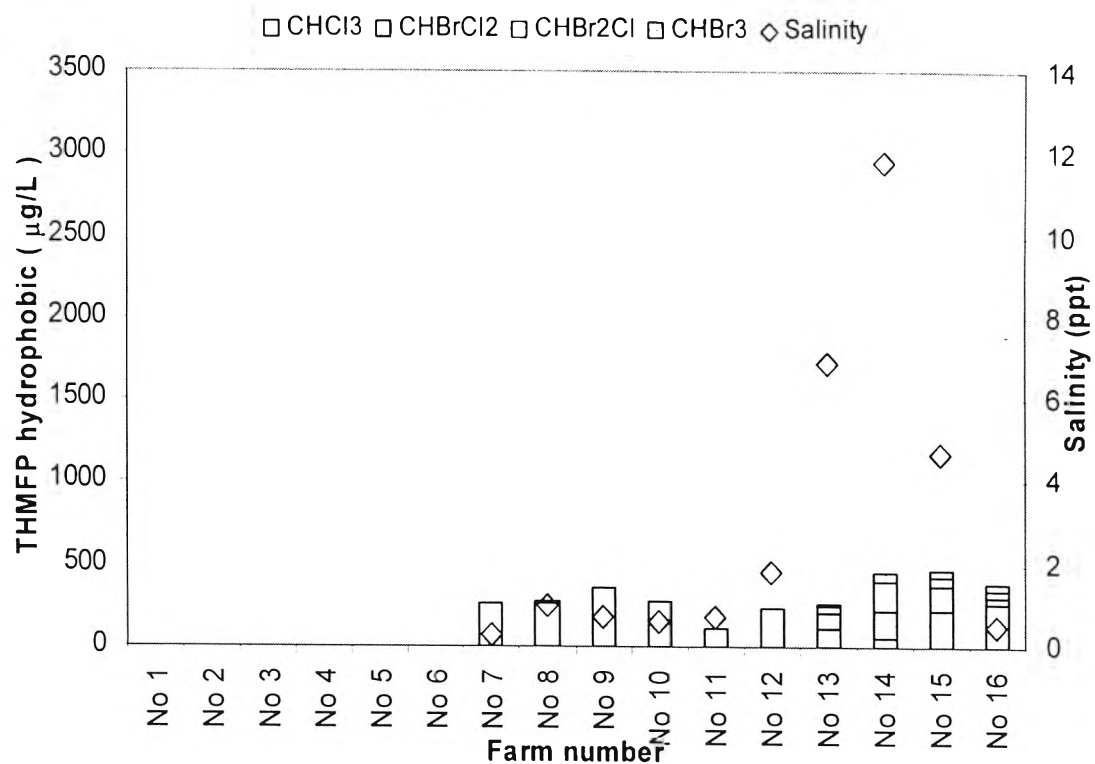


Figure 4-10 Relationship between THMs species of two fractions and salinity

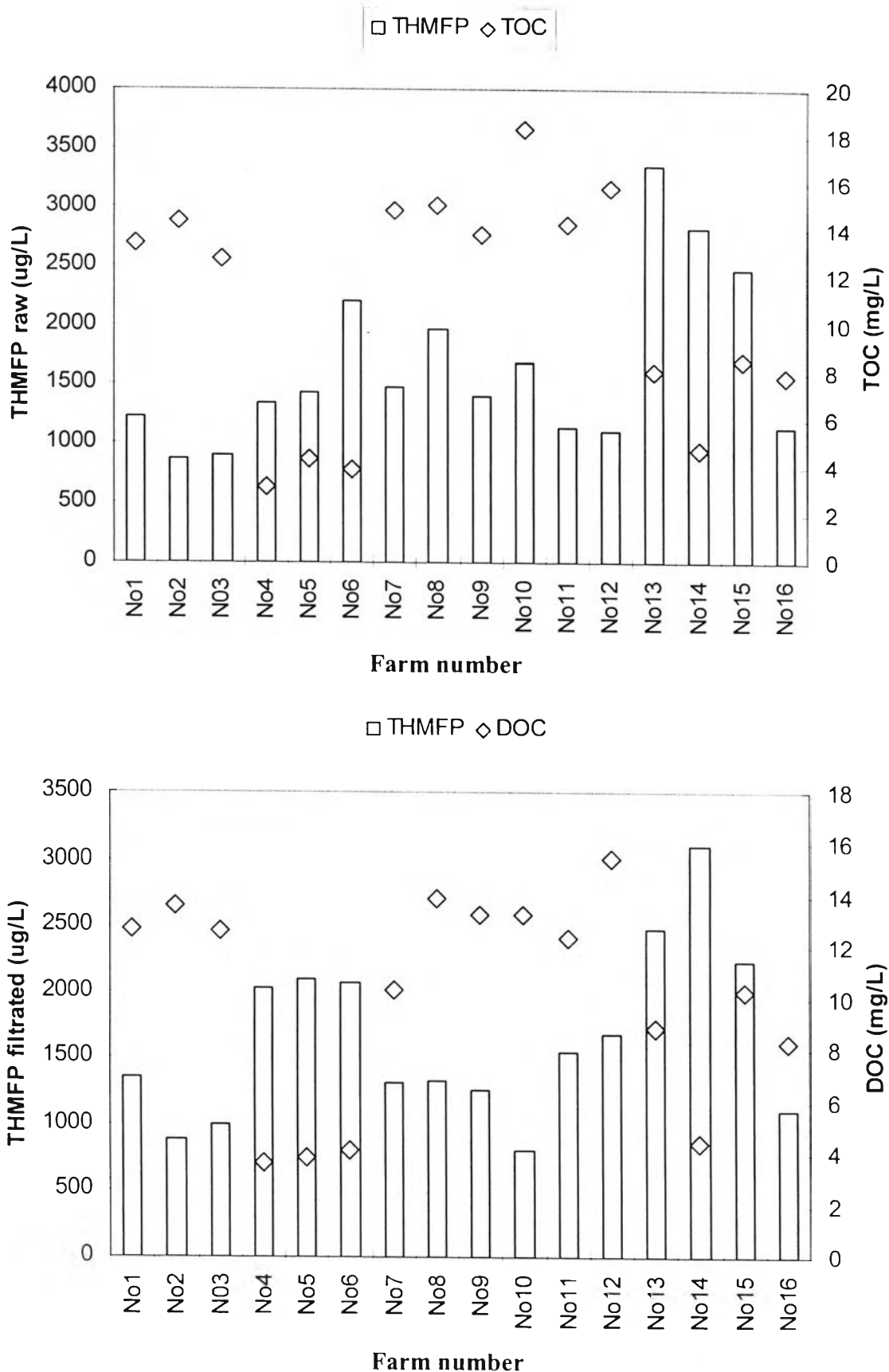


Figure 4-11 Relationship between THMFP, TOC , and DOC

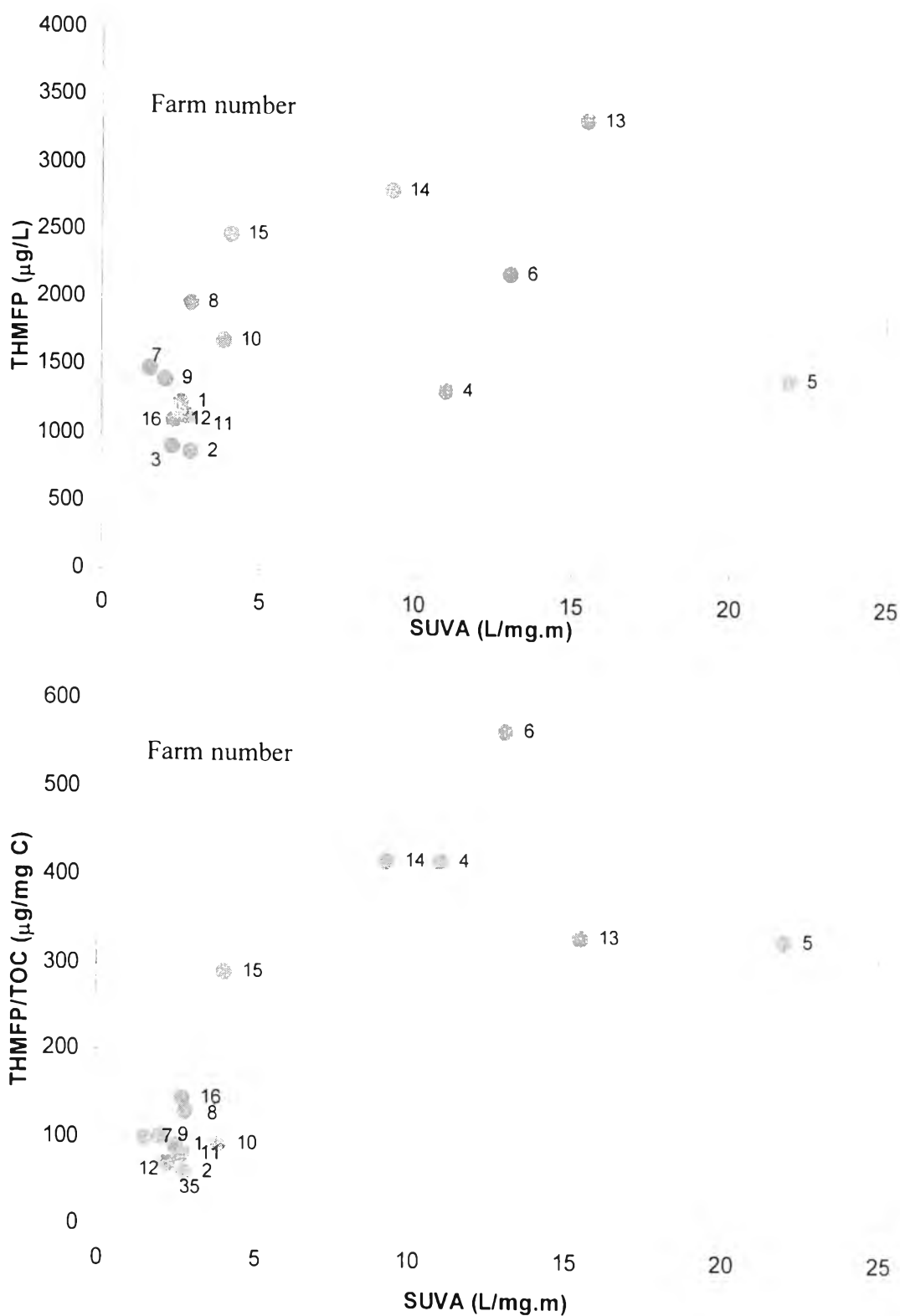


Figure 4-12 Relationship between THMFP, THMs/ TOC and SUVA

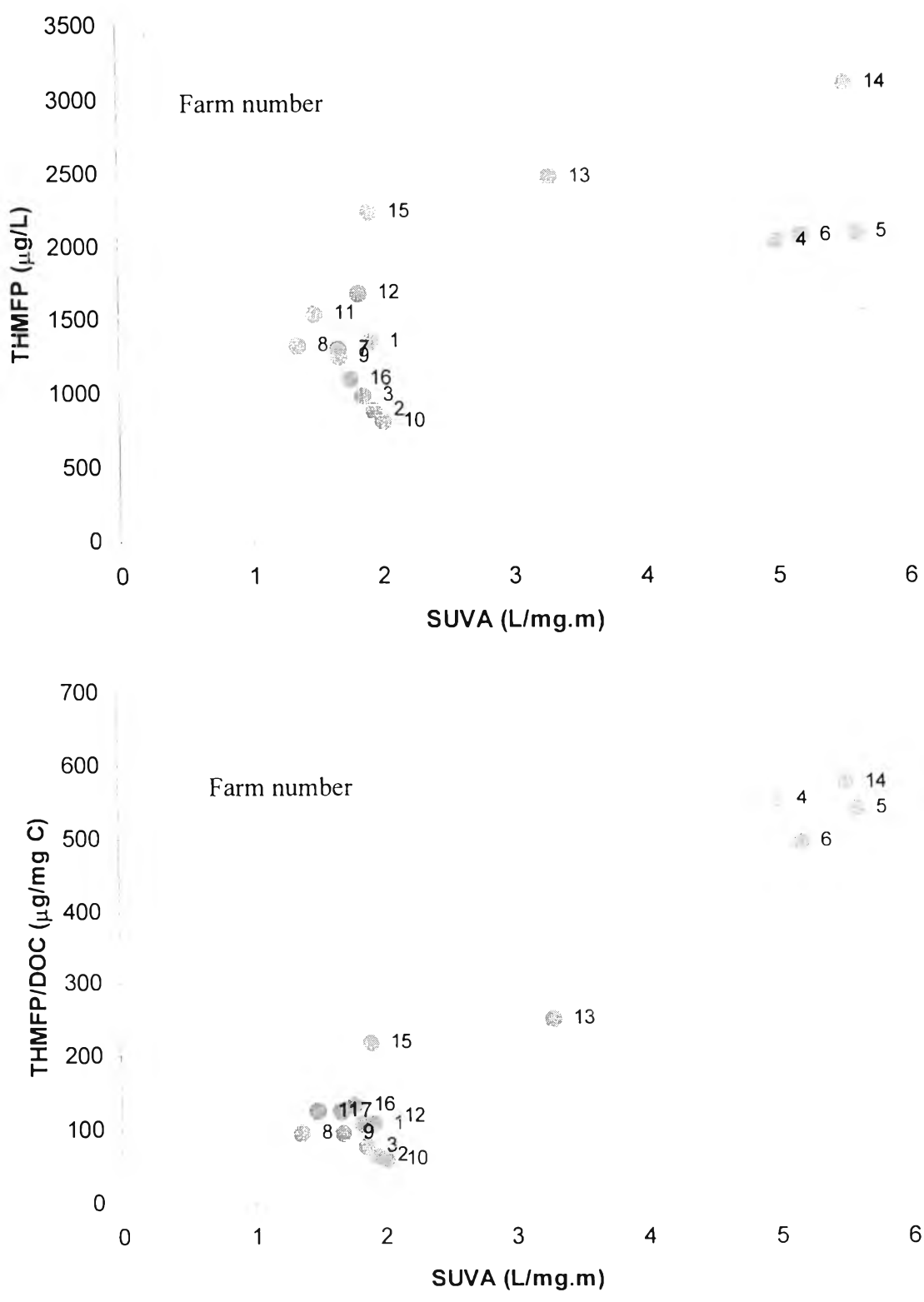


Figure 4-13 Relationship between THMFP, THMs/ DOC and SUVA

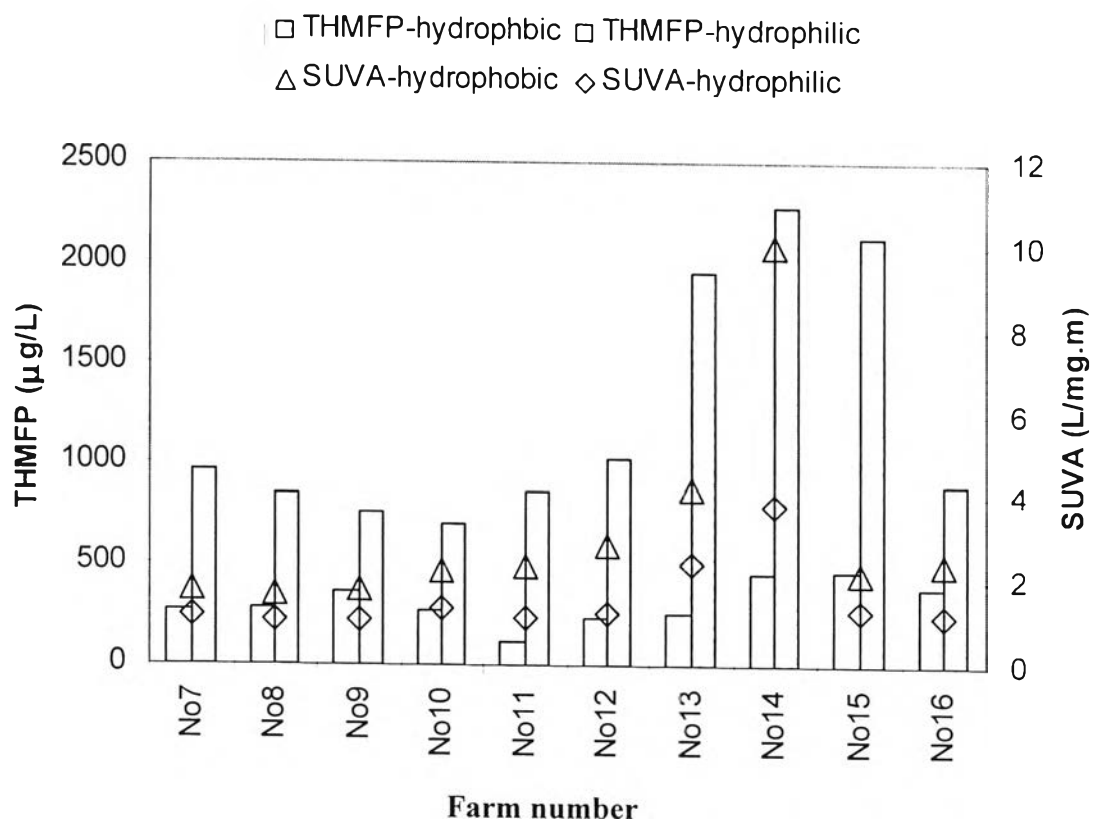
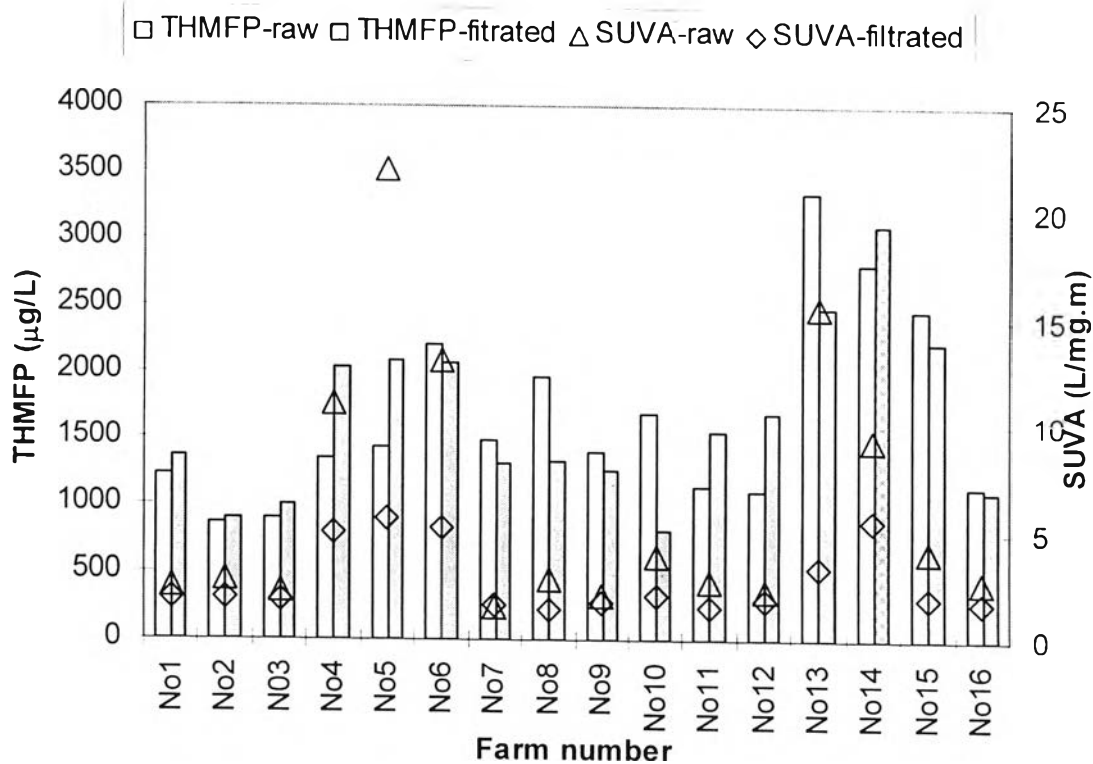


Figure 4-14 The relationship between THMs/DOC hydrophobic, hydrophilic and SUVA