CHAPTER IV

RESULTS AND DISCUSSIONS

The Study of Swimming Pool Primary Data

The swimming pool primary data were obtained by questionnaires. One hundred and four pool staffs were interviewed. The sampling sites were randomly selected from every district in Bangkok area. The details of data are described in Appendix C and the summary of the obtained data is presented below:

1. Location of Swimming Pools

Nearly all of the swimming pools were outdoor pools. There was only one indoor pool. The indoor and outdoor swimming pools would be exposed to sunlight differently. Since the occurrence of halogenated hydrocrbons in swimming pool resulted from photochemical reaction and therefore, the amounts of halogenated hydrocarbons in indoor and outdoor swimming pools may be difference. However, the results from this study showed that the amounts of halogenated hydrocarbon found in indoor swimming pool was not difference due to there was only one registered indoor swimming pool in this study.

2. Size and Shape of Swimming pools

Size and shape of the pools were varied. Most of the pools were rectangular with few were round or oval. The standard size was 12.5×25 metres. Width of walkway around swimming pool is between 0.5-5 metres. Refering to the standard rule of swimming pool described in Appendix C, it was indicated that 1.92% of the swimming pools were below the standard criteria, since the criteria of width of walkway is 1 metre.

3. Source of Water Used in Swimming Pools

Most of the pools were filled with tap water which was treated by chlorination before filled in the pool.

4. Type of Water Circulation System

Water circulation system was classified into five types as described in Appendix B. The most popular one was the fourth type that the water flows into the pool through the pipes setting around the bottom of a pool and flows out through the overflow channel around a pool. The water should be replaced by clean water derived from the pool's bottom. Meanwhile, the wastewater, mostly at the water surface will be eliminated within a short time and should not be mixed with most of the pool's water. The frequency distribution of each types are shown in Figure 4.1.

5. Type of Water Filter

Generally, there were two types of filter used; sand filter and diatomaceous earth filter. Twenty eight of pools used the sand filter and seventy one pools used diatomaceous earth filter. Two of the pool samples used both types. Both of water filter types were used to remove turbidity of water. Selection of water filter type depends on many factors such as area of setting filter, budget, cost of maintenance etc.

6. Cleaning of Swimming Pools

The frequency of swimming pool cleaning and water filter cleaning were varied. Most of them was one time per day. Summary of the obtained data are presented in Table 4.1.

The frequency of filter cleaning depended on the accumulation of insoluble deposit on the prepared mat which has produced a pressure drop across the filter of sufficient magnitude to prevent the proper distribution of the filtered water to the various pool inlets. When this occurs the filter must be cleaned by backwash to flush the accumulated deposits to drain out. Data obtained from questionnaires were different. They are described in Table 4.2.

Table 4.1 Frequency of swimming pool cleaning.

Frequency of swimming pool cleaning	Number of pools
1 time/day	91
2 times/day	3
1time/2 days	6
1-2 times/week	2
not indicated	2

7. Duration of Water Circulation

Water is circulated by using the filter plant and circulation pump. Circulation rates are proportioned to the sanitation load of the various pools. Data of water recirculation are shown in Table 4.3.

Table 4.2 Duration between each water filter cleaning

Frequency of water filter cleaning	Number of pool
1-7 days/time	77
8-20 days/time	8
1 month/time	8
3-6 months/time	2
uncertain	2
not indicated	7

Table 4.3 Period of water circulation in swimming pools

Period of water circulation (hours)	Number. of pools
1-6	4
>6-12	12
>12-18	1
>18-24	42
not indicated	45

It should be noted that 43.27% of all swimming pools did not provide data about the period of water circulation. The staff of these swimming pools did not indicate the period of water circulation. This showed that these pools may have or may have not circulated water in the period according to the standard set by Bangkok Metropolitan Administration.

8. Period of Drainage of Swimming Pools

As shown in Table 4.4, 36.54 % of pools were drained every year and57.69% indicated that period of drainage was uncertain, depending on the water quality.

Table 4.4 Period of drainage of swimming pools.

Period of drainage of water	Number of pools
1-6 months	13
> 6-12 months	26
>12-18 months	1
>18-24 months	2
>24-36 months	3
uncertain	59

9. Physical Check for swimming users

Physical check up of all users before using swimming pools is one of the many ways to introducing prevent the water disease into the pools. From the obtained data, eighty eight pools did not have a regulation for physical check up or endorsed by doctors before using swimming pool. There were only sixteen pools that have the regulation for physical check up before using the swimming pools.

10. Disinfection Methods

From the data obtained, there were many kinds of chemical used as disinfection such as chlorine, phosphoric acid and ozone. Disinfection by chlorine was most often used in the following forms;

1) Calcium hypochlorite available as a granular powder and in tablet forms contains 70 percent available chlorine.

2) Sodium hypochlorite available as colorless, clear solution contains10-15 percent available chlorine.

3) Sodium dichloroisocyanurate contains 60 percent available chlorine.

4) Chlorine gas and

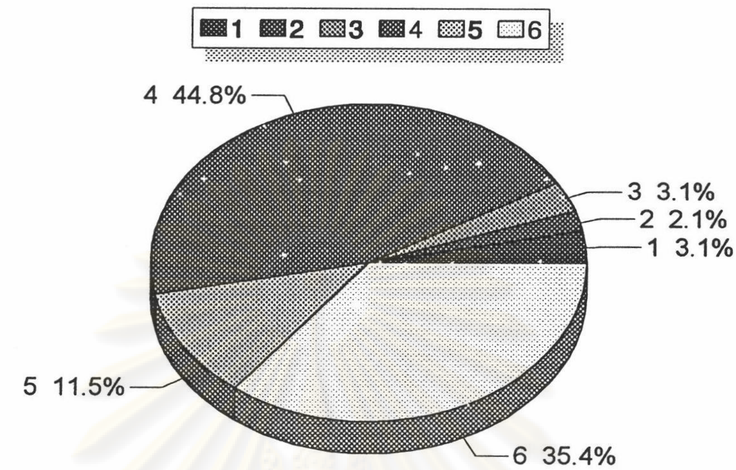
5) Trichloroisocyanuric acid contains 90 percent available chlorine.

It was found that trichloroisocyanuric acid was the most widely used chemical in disinfection. Some swimming pools used only one type of chlorine and some swimming pools used more than one type. Figure 4.2 summarizes the disinfection methods used by the swimming pools in this study.

The frequency of chlorine used was varied, depending on the water quality. Most of them always used chlorine everyday and added chlorine after closing the pool each day. Dosages used for each pool varied from pool to pool in different sampling sites due to many factors influencing chemicals demand. There were two methods in applying chlorine, One was manual operation by scattering chlorine by hand over the water or placing it in the skimmer. The other was using an automatic feeder. In this study it was found that 14.42 percent of the pools used the automatic feeders and 85.58 percent used the manual operation.

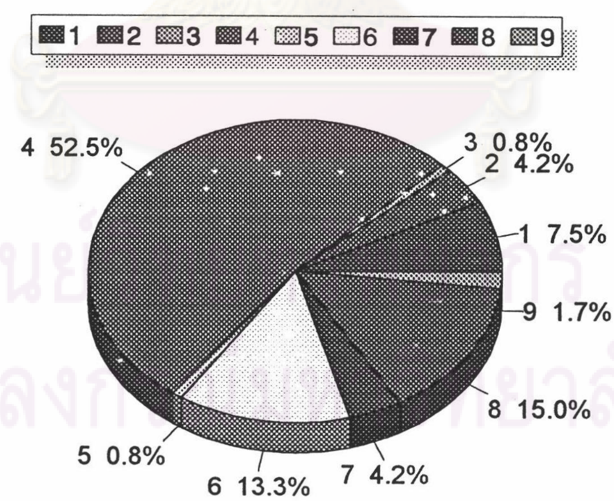
11Chemical used in Algae and pH Control

From the data obtained, chemicals were widely used in algae and pH control. Caustic soda or soda ash was used to rise up the pH in pool water and hydrochloric acid or sodium acid sulfate was used to decrease pH. If algae growth occurs, Algaes generally destroyed by applying an over dose of chlorine, or using algaecide or copper sulfate. Types of algalcide were varied by trade name such as Swim chem Algae-rid, Swimtrin Plus, black Algetrine etc.



1=Type1, 2=Type2, 3=Type3, 4=Type4, 5=Type5, 6=unclassified

Figure 4.1 Types of water circulation system used by the swimming pools in this study.



1=chlorine 10%, 2=chlorine gas, 3=phosphoric acid, 4= chlorine 90%, 5=ozone, 6=uncertain, 7= chlorine60%, 8=chlorine70%, 9=chlorine98%

Figure 4.2 Types of chemical used in disinfection by the swimming pools in this study.

sulfate. Types of algalcide were varied by trade name such as Swim chem Algae-rid, Swimtrin Plus, black Algetrine etc.

In general, pH of the swimming pool water is affected by ; 1) the source of water; 2) the body secretions of the swimmer; 3) the application of chlorination agent to destroy pollution; 4) the application of coagulation agent. The optimum pH range for a swimming pool water is 7.2 to 7.8. The change of pH value always due to the use of chlorine agent. When the disinfection is used with chlorine gas, the pH will be fallen below 7.2.On the contrary, if the disinfection used is sodium hypochlorite or calcium hypochlorite the pH will rise up above 7.8.

Algae problem in swimming pools caused by spores and seeds of algae from the air. Algae flourish in the absence of sunlight, growths can develop rapidly on cloudy or rainy days or at night if the chlorine residual is allowed to fall off.(Swimming pool Annual Data&Reference, 1964)

12. Water Quality Determination

The standard of water quality determination determined by Bangkok Metropolitan Administration is at least 1 time/week and every day for biological check, chlorine residual and pH respectively. As shown in Table 4.5, there was only one pool that upto the standard of biological check. For chlorine residual and pH check, there were 70 pools that meet standard regulation.

This finding was conformed with the previous study of Matana *et al.*(1988) showed that the pools within criteria was only 27 percent. In this case, most of the swimming pools had not done biological check weekly. It is speculated that chlorination dose must be increase to guarantee disinfection. So, the trend of number of pools that over standard of chlorine residual should be increased

Table 4.5 Water quality check in the swimming pools in this study.

Frequency	Biological check	Cl residual and pH.check
1-6 times/week	1	17
7-14 times/week	-	53
15-21 times/week	-	6
22-28 times/week	-	1
1-2 times/month	18	2
1-2 times/year	4	-
uncertain	3	2
not check	78	-
no data	-	23

The Study of Standard Calibration Curve

The calibration curves of methylene chloride, chloroform, 1,1,1-trichloroethane, carbon tetrachloride and trichloroethylene, are shown in Figure 4.3-4.8. The chromatogram of the standard mixture .in methanol is shown in Figure 4.9.

The Study of Water Quality in the Swimming Pools

1. The Study of Water Quality

The subjects of this study were thirty six swimming pools. They were classified into four groups as follow:

group A : hotel swimming pools

group B : academic swimming pools

group C : club swimming pools

group D : public swimming pools

The results of water quality analysis in this study are shown in Table 4.6 -4.9.

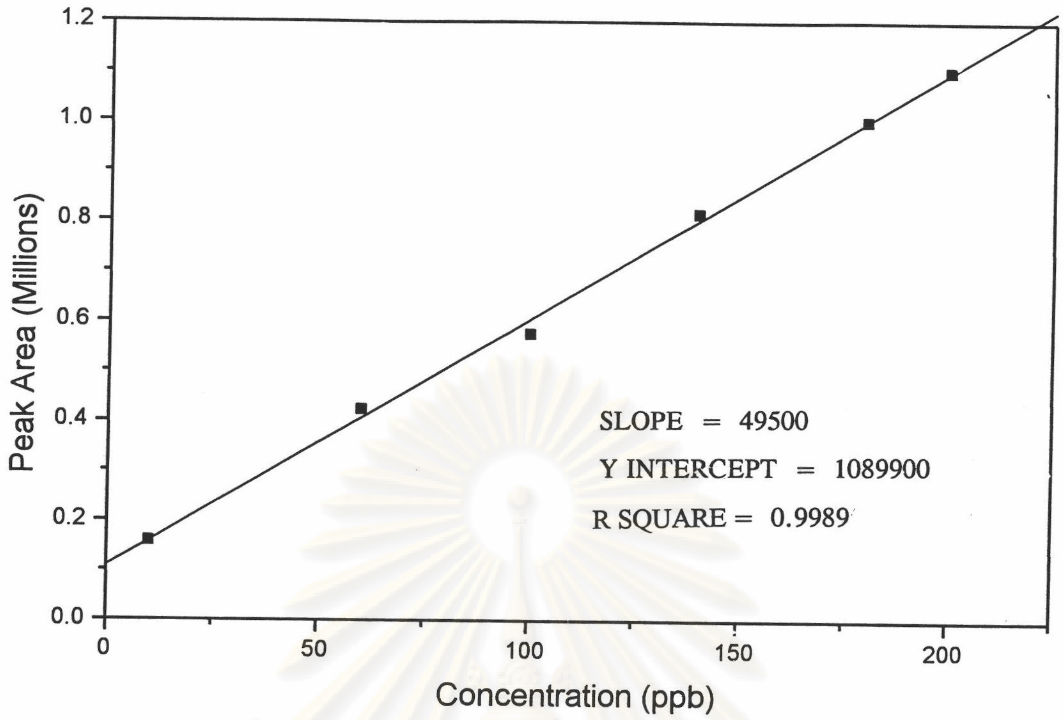


Figure 4.3 The calibration curve of methylene chloride in methanol using HP-5 capillary column with ECD as a detector.

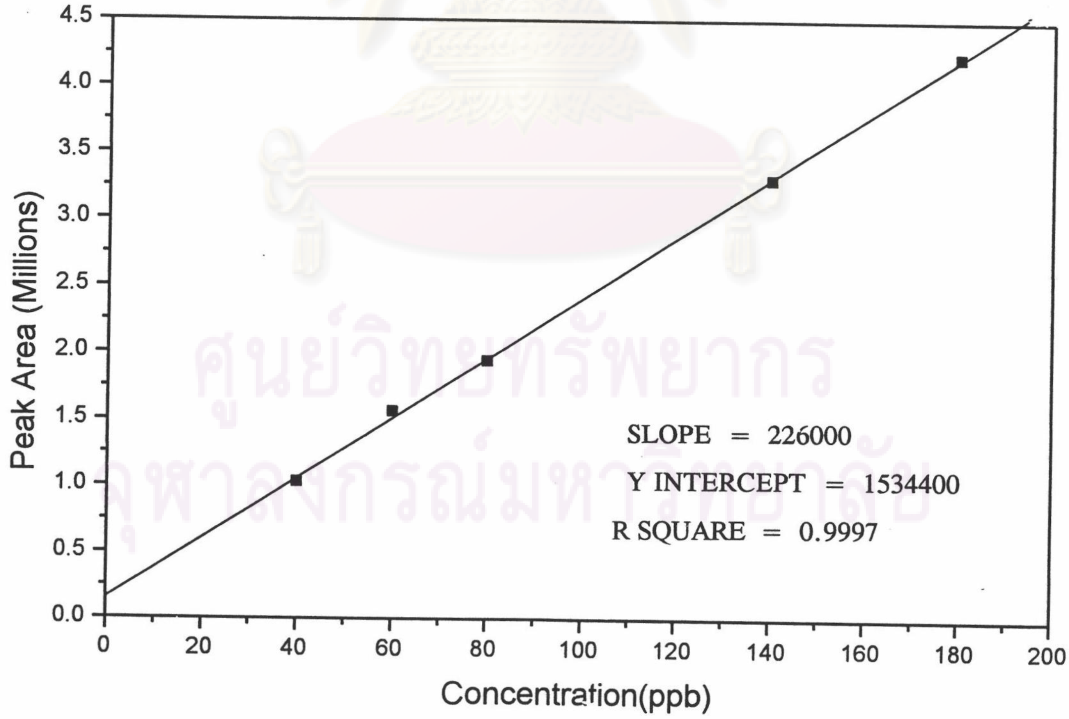


Figure 4.4 The calibration curve of chloroform (low concentration) in methanol using HP-5 capillary column with ECD as a detector.

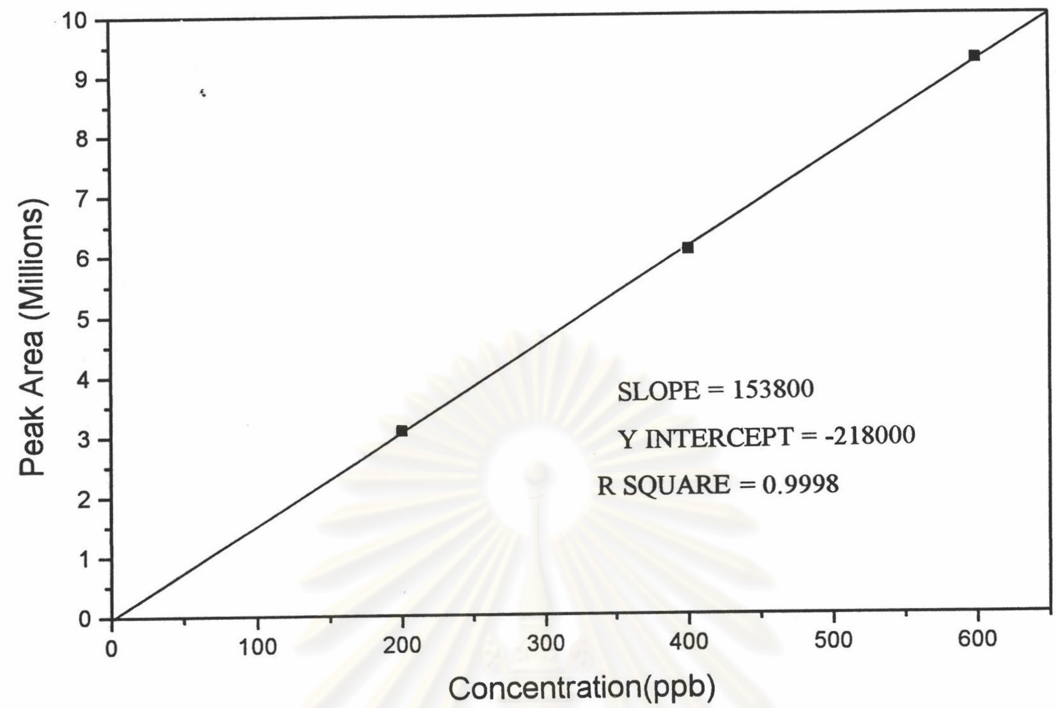


Figure 4.5 The calibration curve of chloroform (high concentration) in methanol using HP-5 capillary column with ECD as a detector.

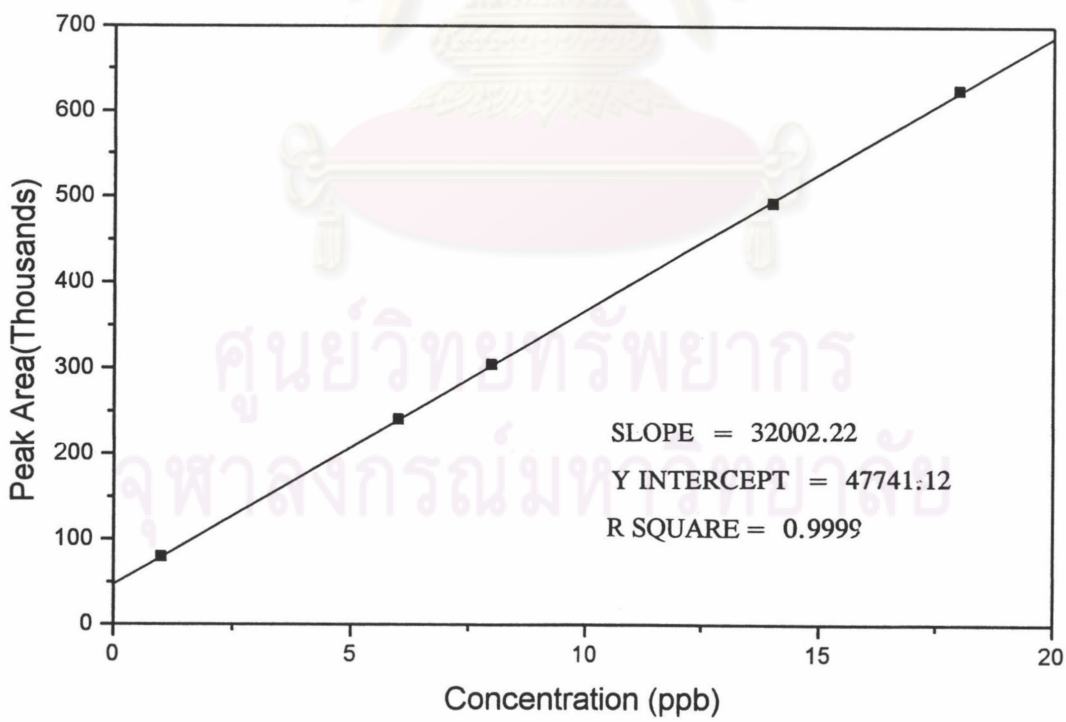


Figure 4.6 The calibration curve of 1,1,1-trichloroethane in methanol using HP-5 capillary column with ECD as a detector.

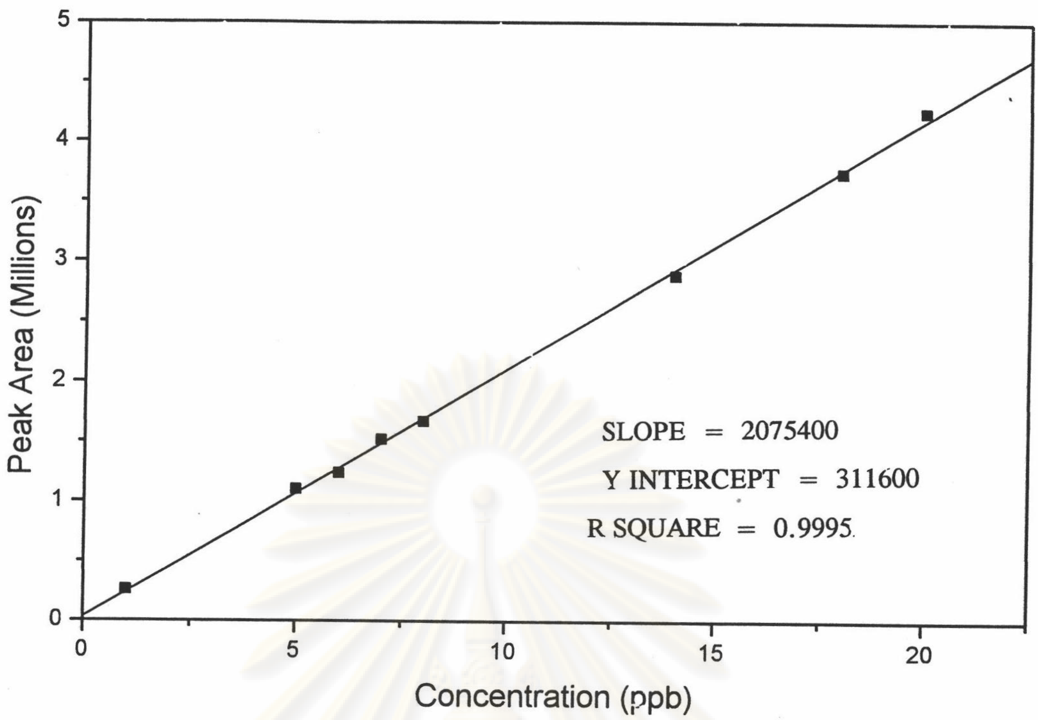


Figure 4.7 The calibration curve of carbon tetrachloride in methanol using HP-5 capillary column with ECD as a detector.

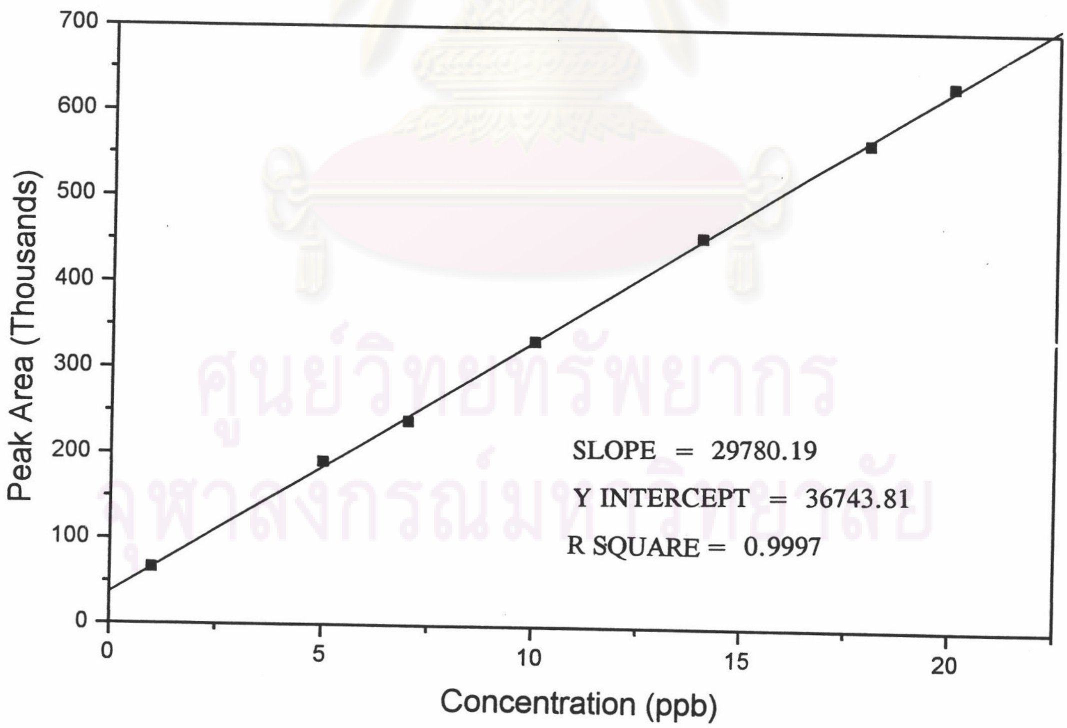


Figure 4.8 The calibration curve of trichloroethylene in methanol using HP-5 capillary column with ECD as a detector.

1.1 Chlorine Residual

According to the water quality standard of Bangkok Metropolitan Administration, chlorine residual in swimming pool is between 0.6-1.0 mg/l. In this study, it was found that only 8.33 percent (n=3) of total samples was upto the standard. Fifty percent(n=18) and 41.67 percent(n=15) were under the standard and over the standard respectively. As in previous study carried out by the Environmental Health Division(1988), percent of the pools upto the standard was lower than the ones out of standard. The present results are shown in Table 4.10.The hotel swimming pool was the only one type that water quality was up to the standard. The others were out of the standard.

1.2 pH

The pH of most swimming pools in this study were in the standard range of 7.2-8.4. It was found that 69.44%(n=25) were upto standard and 30.56 % (n=11) were under the standard. The result are showed in Table 4.10. The over standard pool was not found in any type of the pools.

From the data obtained, there was a small variation in the range of pH because of the direct effect that pH has upon the quality of swimming pool water. When the pH drops below 7.0, the water irritates to swimmers, may corrode metals and may damage other pool materials. At pH above 8.0, the water is likely to appear cloudy and to cause formation of scale in the pool plumbing system. Of even great importance, the alkaline water sharply reduces the effectiveness of chlorine as a disinfecting and oxidizing agent, so, pH must be controled up to the standard (Schuler, 1974)

1.3 Temperature

The temperature of all water samples were between 29-37°C . The fluctuated value depended on many factors such as being outdoor or indoor pool, light intensity, time of the day, the weather etc.

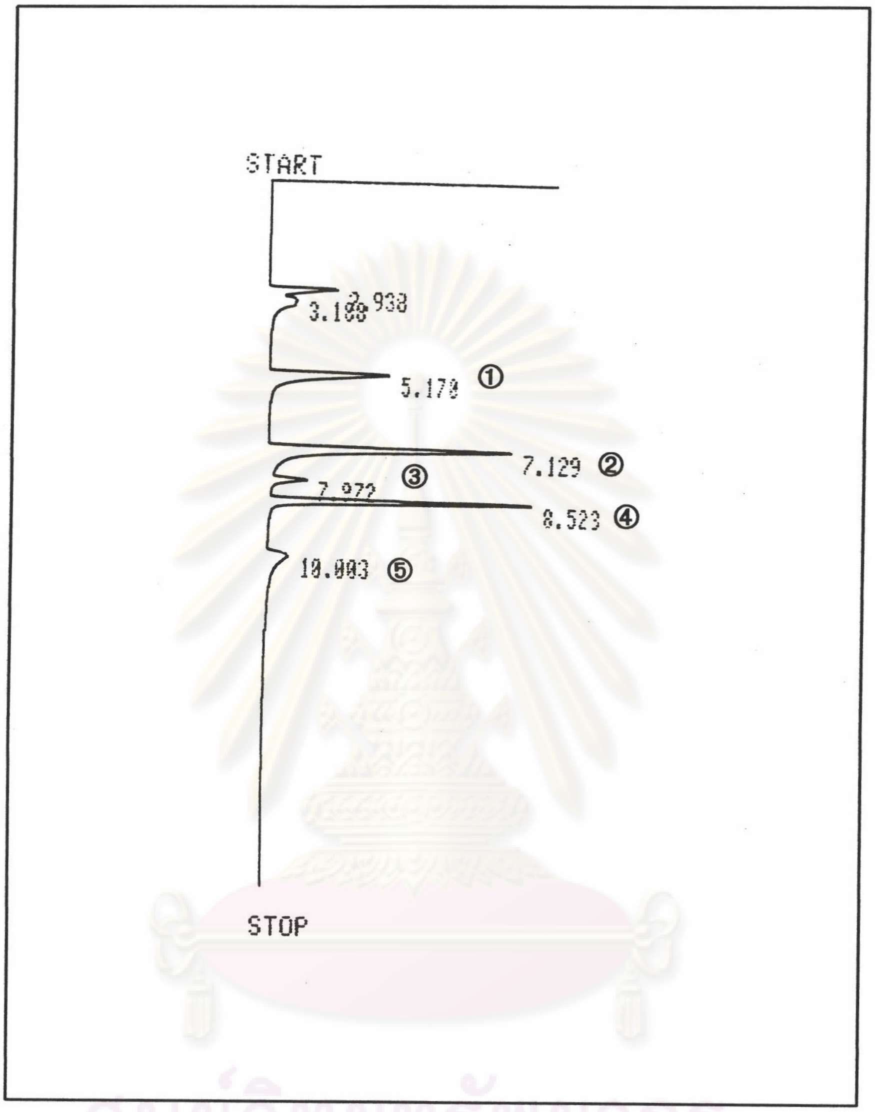


Figure 4.9 The gas chromatogram of the standard mixture in methanol

Condition : GC described in Table 3.4

Headspace described in Table 3.5

① = Methylene chloride : concentration 100.02 ppb

② = Chloroform : concentration 100.16 ppb

③ = 1,1,1,-trichloroethane : concentration 5.04 ppb

④ = Carbontetrachloride : concentration 5.09 ppb

⑤ = Trichloroethylene : concentration 4.97 ppb

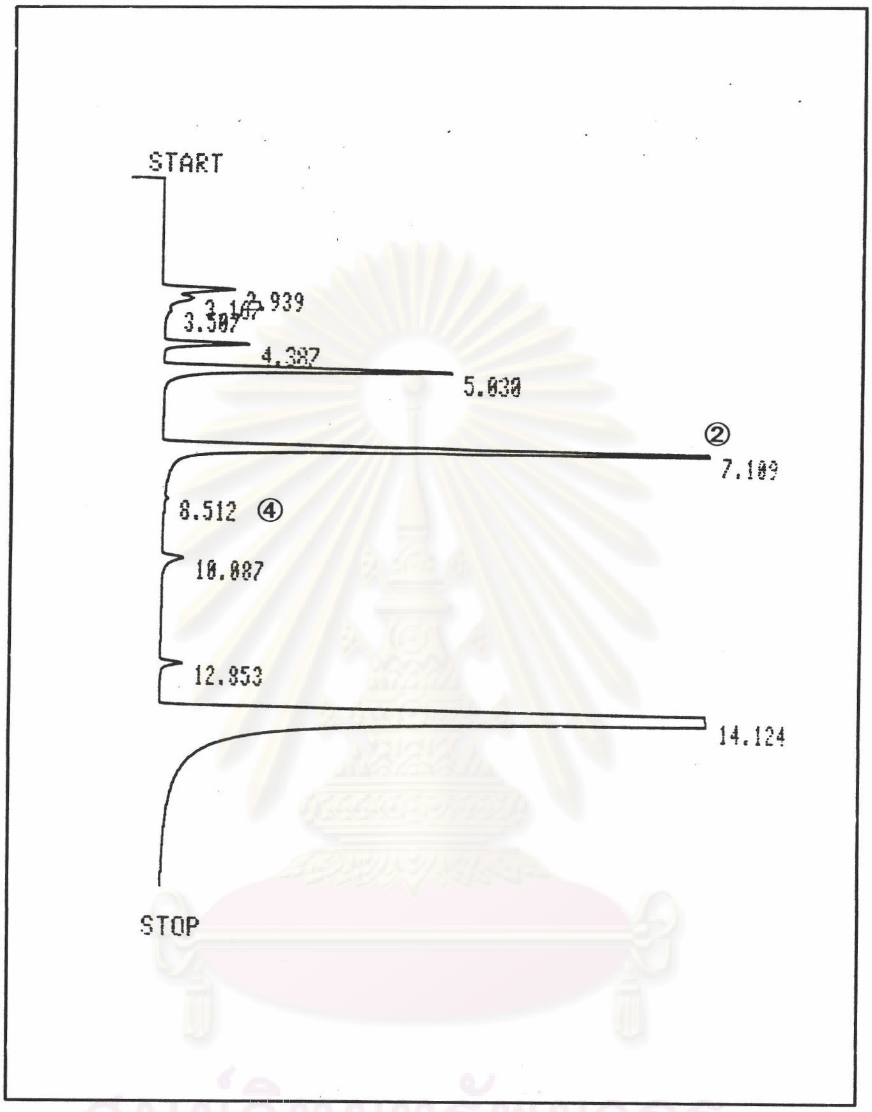


Figure 4.10 The gas chromatogram of sample1
Condition : GC described in Table 3.4
Headspace described in Table 3.5
② = Chloroform
④ = Carbontetrachloride

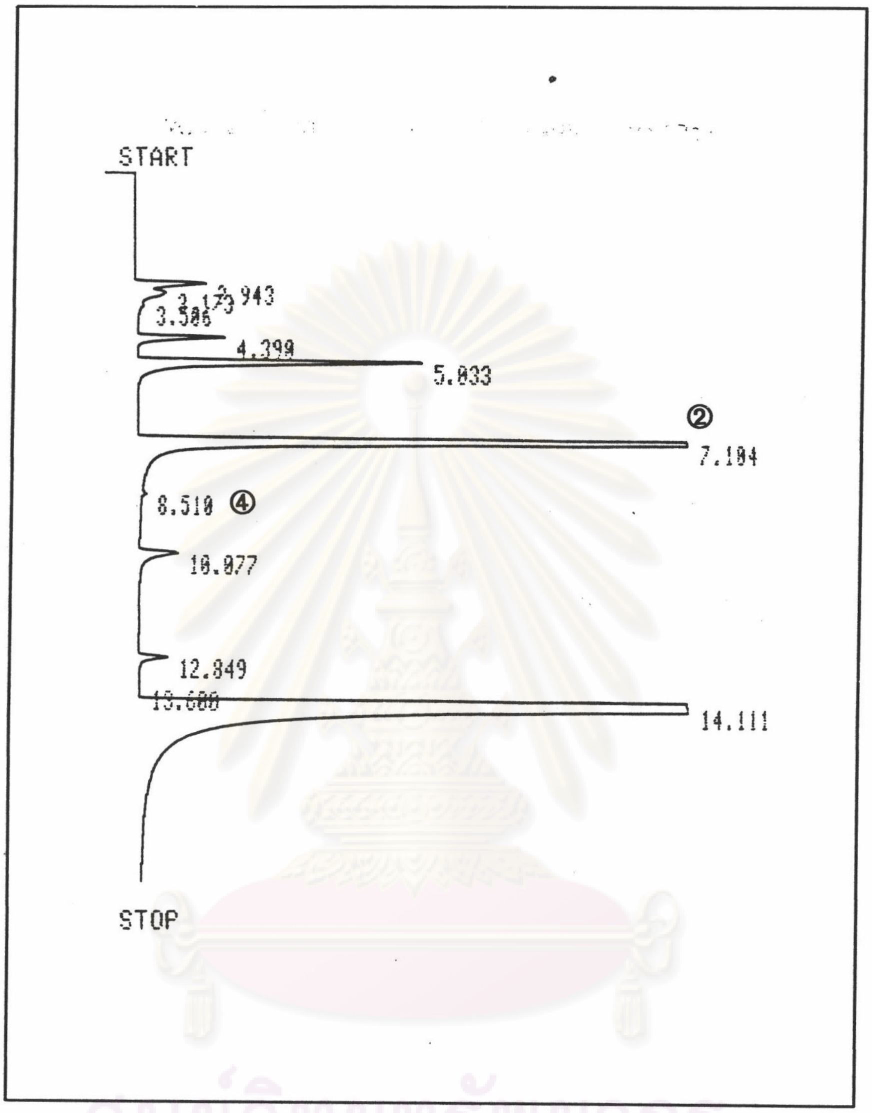


Figure 4.11 The gas chromatogram of sample2
Condition : GC described in Table 3.4
Headspace described in Table 3.5
② = Chloroform
④ = Carbontetrachloride

Table 4.6 Water quality in the Hotel swimming pools in this study.

Sampling Site	parameter				Concentration(ppb)									
					shallow					deep				
	Cl residual (mg/l)	pH	Temp. (°C)	Light Intensity (Lux)	CH_2Cl_2	$CHCl_3$	CH_3CCl_3	CCl_4	$CHCCl_3$	CH_2Cl_2	$CHCl_3$	CH_3CCl_3	CCl_4	$CHCCl_3$
A1	2.5	7.8	31	56000	ND	96	ND	0.2	ND	ND	88	ND	0.2	ND
A2	0.2	7.8	37	26500	ND	72	ND	0.19	ND	ND	72	ND	0.21	ND
A3	3	7.8	31	18500	ND	60	ND	0.24	ND	ND	74	ND	0.23	ND
A4	3	7	34	19400	ND	113	ND	ND	ND	ND	119	ND	ND	ND
A5	0.2	7.6	34	15300	ND	67	ND	ND	ND	ND	59	ND	ND	ND
A6	1	7.8	27	8860	ND	35	ND	ND	ND	ND	25	ND	ND	ND
A7	1	7.8	30	78700	ND	25	ND	ND	ND	ND	54	ND	ND	ND
A8	0	7.8	29.5	32700	ND	19	ND	0.45	ND	ND	75	ND	0.4	ND
A9	1	7.8	30.5	27500	ND	17	ND	0.42	ND	ND	25	ND	0.44	ND
A10	2	7.8	31	31000	ND	30	ND	0.4	ND	ND	25	ND	0.43	ND
AVERAGE	1.39	7.7	31.5	31446		53.4		0.3167			61.6		0.3183	
SD (±)	1.15	0.25	2.8	20979.28		33.57		0.12			30.76		0.11	

Table 4.7 Water quality in the academic swimming pools in this study.

Sampling Site	parameter				Concentration(ppb)									
	Cl residual (mg/l)	pH	Temp. (°C)	Light Intensity (Lux)	shallow					deep				
					CH_2Cl_2	$CHCl_3$	CH_3CCl_3	CCl_4	$CHCCl_3$	CH_2Cl_2	$CHCl_3$	CH_3CCl_3	CCl_4	$CHCCl_3$
B1	3	7.8	32.5	12960	ND	15	ND	ND	ND	ND	17	ND	ND	ND
B2	0.2	7.8	29	7060	ND	6	ND	ND	ND	ND	40	ND	ND	ND
B3	1.5	7.8	31	3210	ND	6	ND	0.49	ND	ND	8	ND	0.5	ND
B4	3	7.8	29	55200	ND	9	ND	0.45	ND	ND	12	ND	0.45	ND
B5	0.2	7.8	31	31300	ND	12	ND	0.48	ND	ND	17	ND	0.4	ND
B6	3	6.8	29.5	14,080	ND	2	ND	0.47	ND	ND	24	ND	0.45	ND
B7	0.2	6.8	29.5	17700	ND	7	ND	0.48	ND	ND	13	ND	0.32	ND
B8	0	6.8	30	68500	ND	30	ND	0.3	ND	ND	14	ND	0.43	ND
B9	0.1	7.5	29	6970	ND	155	ND	0.29	ND	ND	135	ND	0.28	ND
B10	0	7.8	29	100000	ND	12	ND	0.39	ND	ND	16	ND	0.37	ND
AVERAGE	1.12	7.34	29.95	31698		25.4		0.419			29.6		0.4	
SD (±)	1.37	0.47	1.19	32420.11		46.18		0.083			38.07		0.07	

Table 4.8 Water quality in the club swimming pools in this study.

Sampling Site	parameter				Concentration(ppb)									
					shallow					deep				
	Cl residual (mg/l)	pH	Temp. (°C)	Light Intensity (Lux)	CH_2Cl_2	$CHCl_3$	CH_3CCl_3	CCl_4	$CHCCl_3$	CH_2Cl_2	$CHCl_3$	CH_3CCl_3	CCl_4	$CHCCl_3$
C1	0.2	7.2	30	8500	ND	26	ND	ND	ND	ND	26	ND	ND	ND
C2	0.2	7	30.5	15400	ND	65	ND	ND	ND	ND	68	ND	ND	ND
C3	0.2	7	30.5	4450	ND	46	ND	ND	ND	ND	37	ND	ND	ND
C4	0	8.2	31.5	3530	ND	33	ND	ND	ND	ND	33	ND	ND	ND
C5	0.2	6.8	30.5	108600	ND	79	ND	ND	ND	ND	49	ND	ND	ND
C6	3	7.8	32	45000	ND	132	ND	ND	ND	ND	147	ND	ND	ND
C7	3	7	33	29400	ND	44	ND	ND	ND	ND	15	ND	ND	ND
C8	3	7.8	31.5	84500	ND	254	ND	ND	ND	ND	220	ND	ND	ND
AVERAGE	1.23	7.35	31.2	37422.5		84.88					74.38			
SD (±)	1.47	0.51	0.99	39572.17		76.15					71.85			

Table 4.9 Water quality in the public swimming pools in this study.

Sampling Sit	parameter				Concentration(ppb)									
	Cl residual (mg/l)	pH	Temp. (°C)	Light Intensity (Lux)	shallow					deep				
					CH_2Cl_2	$CHCl_3$	CH_3CCl_3	CCl_4	$CHCCl_3$	CH_2Cl_2	$CHCl_3$	CH_3CCl_3	CCl_4	$CHCCl_3$
D1	1.5	6.8	35	5650	ND	16	ND	ND	ND	ND	16	ND	ND	ND
D2	2	7	31.5	7560	ND	55	ND	ND	ND	ND	75	ND	ND	ND
D3	0.2	7.8	31	4090	ND	35	ND	ND	ND	ND	27	ND	ND	ND
D4	0.2	7.8	31	3320	ND	50	ND	ND	ND	ND	47	ND	ND	ND
D5	0	7	30	22000	ND	15	ND	ND	ND	ND	19	ND	ND	ND
D6	3	6.8	31.5	28000	ND	106	ND	ND	ND	ND	136	ND	ND	ND
D7	3	6.8	29	22700	ND	15	ND	0.42	ND	ND	13	ND	0.4	ND
D8	0.2	7	31	73000	ND	126	ND	ND	ND	ND	114	ND	ND	ND
AVERAGE	1.26	7.13	31.25	20790		52.25		0.42			55.88		0.4	
SD (±)	1.28	0.42	1.73	23211.22		42.64					47.61			

1.4 Concentration of Halogenated Hydrocarbons in Swimming Pools

Thirty-six samples of swimming pool water were studied for halogenated hydrocarbons. All samples produced a chromatogram of chloroform and fifteen samples also produced a chromatogram of carbon tetrachloride, but methylene chloride, 1,1,1-trichloroethane and trichloroethylene were not detected in any samples. The chromatogram of some samples are shown in the Figure 4.10 and Figure 4.11 and the results of the analyses are shown in Table 4.6-4.9.

Table 4.10 summarizes the average amount of chloroform and carbon tetrachloride found in the four groups of the swimming pools and graphic representation of chloroform levels in all types of the swimming pools can be seen in Figure 4.12-4.15.

1.5 Chloroform Levels in the Swimming Pools

In support to the previous research (Beech *et al.*, 1980; Aggazzotti, 1986; Chambon *et al.*, 1983; Coast, 1991; etc.), this study found that chloroform concentrations were presented in all of the samples. The concentrations varied among all types of the swimming pools.

As shown in Table 4.6, the concentrations of chloroform in the hotel swimming pool water in shallow area(the depth of surface of water to the bottom of swimming pool $\leq$1.5 m) were between 17-113 ppb and the mean value was 53.4 ppb. In deep area(the depth of surface of water to the bottom of swimming pool > 1.5m) chloroform levels were in the range of 25-119 ppb and the mean value was 61.6 ppb.

For the academic pools, chloroform concentrations were detected between 2-155 ppb with the mean value of 25.4 ppb in shallow area, while in deep area, chloroform level was between 8-135 ppb with a mean value of 29.6 ppb.

Table 4.8 displays chloroform levels in the club pools. The concentration of chloroform fluctuated between 26-254 ppb with a mean value of 84.88 ppb in the shallow area and found in the range of 15-220 ppb with a mean value of 74.38 ppb in the deep area.

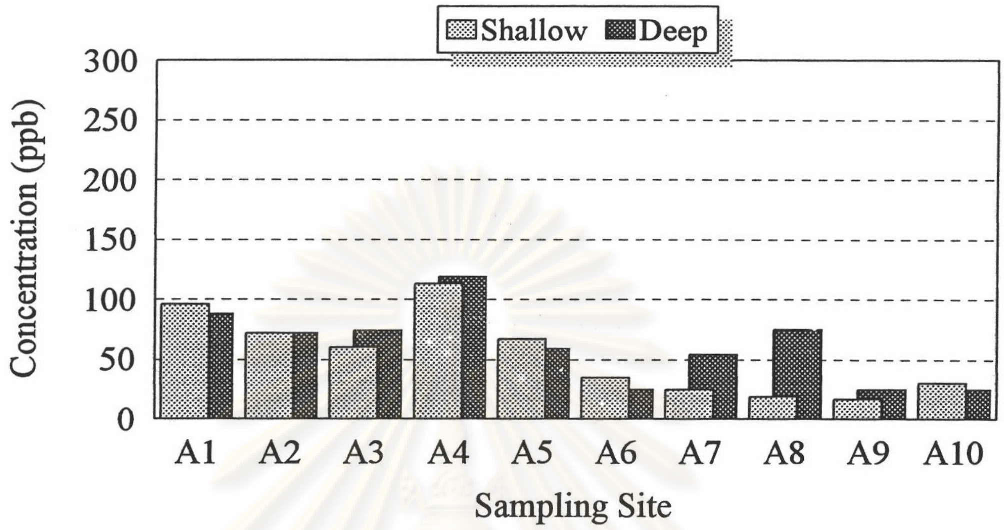


Figure 4.12 Chloroform levels in the hotel swimming pools

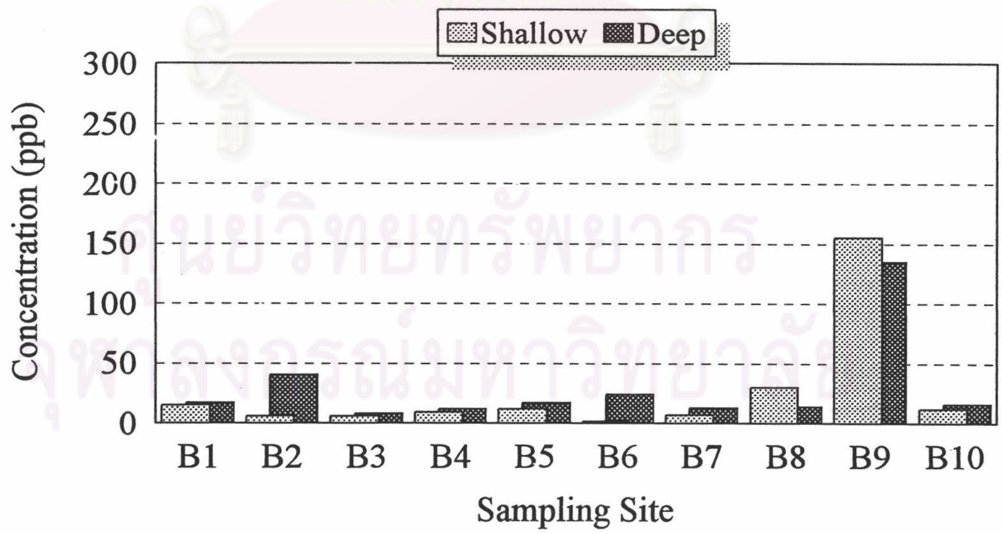


Figure 4.13 Chloroform levels in the academic swimming pools

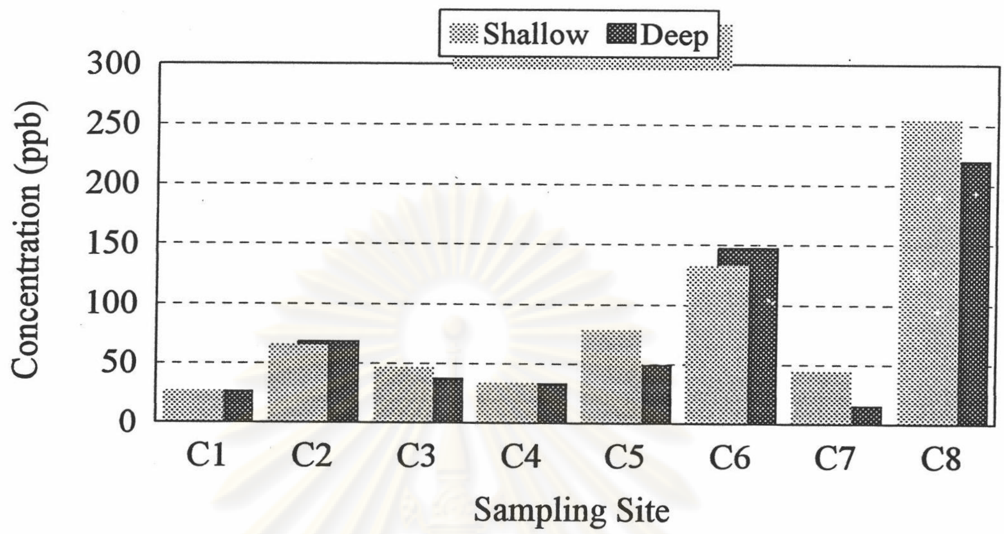


Figure 4.14 Chloroform levels in the club swimming pools

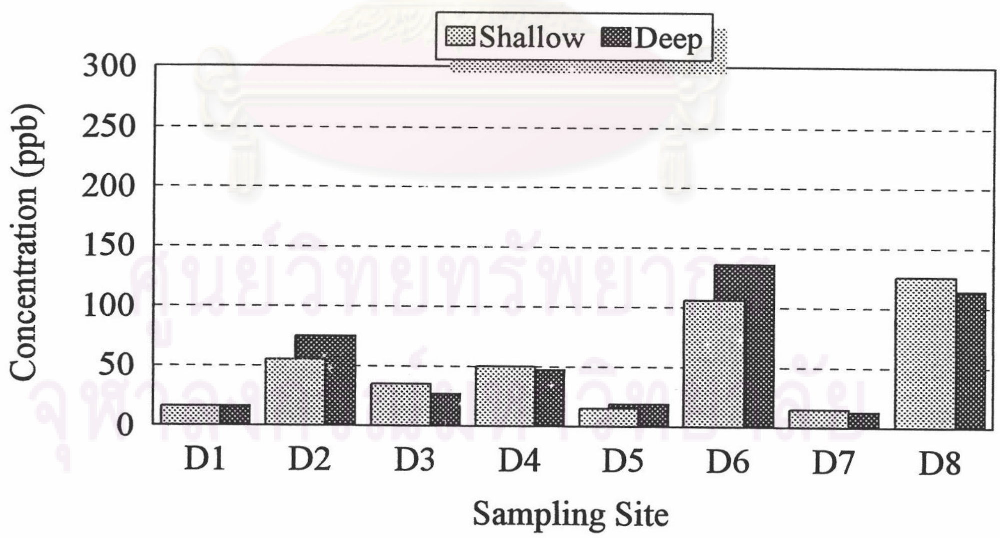


Figure 4.15 Chloroform levels in the public swimming pools

Table 4.10 Summary of water quality in the swimminng pools in this study.

Group	Chlorine residual			pH			Mean of $CHCl_3$ (ppb)		Mean of CCl_4 (ppb)	
	In std.	Over std.	Under std.	In std.	Over std.	Under std.	Shallow	Deep	Shallow	Deep
A	3	3	4	9	1	-	53.40	61.60	0.32	0.32
B	0	6	4	7	3	-	25.40	29.60	0.42	0.40
C	0	5	3	4	4	-	84.88	74.38	-	-
D	0	4	4	2	6	-	52.25	55.88	0.42	0.40

A = Hotel swimming pool B = Academic swimming pool

C = Club swimming pool D = Public swimming pool

The chloroform levels found in the public pools were in the range of 15-126 ppb(mean=52.25) and 13-136 ppb (mean=55.88) in the shallow and the deep area, respectively. The details are shown in Table 4.9.The water source used in swimming pools could be one of the factors affecting the concentrations of chloroform in the samples. Since all swimming pools in this study were supplied with tap water, which already contained chloroform from chlorination in the plant,(29.58-31.86 ppb of chloroform in tap water.Wutichai, 1992 and 16.8-100 ppb of THM. NEB, 1984) the chloroform levels in the swimming pool water were usualy high because of rechlorination.

The high concentration of chloroform found in water samples might resulted from the follow reasons

1) The water in swimming pool was reused several times, it was treated and then chlorine was add every time.

2) The more people in the swimming pools would lead to increase more organic matters in it and

3) The high content of chlorine in swimming pool is to make sure it would kill all the germ.

Statistical analysis was carried out on the data obtained and it was found that there was no significant differences in the chloroform levels of all types of the swimming pools studied.(F=0.11).

1.6 Carbon tetrachloride Level in Swimming Pools

Fifteen samples were found to contain carbon tetrachloride in the range of 0.19-0.42 ppb in the shallow area and 0.20-0.45 ppb in the deep area.

As shown in Table 4.6, carbon tetrachloride levels in the hotel swimming pool water were in the range of 0.19-0.45 ppb in shallow area and in the range of 0.20-0.44 ppb in the deep area.

Table 4.7 shows carbon tetrachloride level in the academic swimming pools. The level were between 0.29-0.49 ppb in the shallow area and 0.28-0.45 ppb in the deep area.

In the club swimming pools, it was not found carbon tetrachloride in all samples and there was only one public swimming pool that carbon tetrachloride was detected.

1.7 Unexpected Peak

It should be noted that a peak at the retention time 14.12 minutes was found in the chromatograms of all samples. The representative chromatograms are shown in Figure 4.10 and Figure 4.11. This peak was not in the scope of this study, but it's peak area is the highest. Confirmation with GC-MS technique was carried out and it was found to be tetrachloroethane. Mass spectrum was matched with the standard library Wiley138 at 95% confidence level. The details are shown in Appendix D

Concentration of tetrachloroethane in drinking water is recommended by EPA and WHO not to exceed 0.8 μg/L and 10 μg/L, respectively. WHO report showed that tetrachloroethane is remarkable persistent in water. Survey of drinking water in 100 cities in the Federal Republic of Germany,1977, found that the maximum of tetrachloroethane was 35.3 μg/L and the average was 0.6 μg/L. Tetrachloroethane was found to be carcinogen for mice but not for rats. Evidence from epidemiological studies is insufficient for a conclusion that exposure to tetrachloroethane causes cancer in human being(WHO, 1984).

Since this peak was found in all samples, it could be concluded that tetrachloroethane is the most stable form in water. The peak abundance of tetrachloroethane shows intensively high. It might not be related to its concentration but due to the nature of the compound. Since tetrachloroethane has four chlorine atoms so its detector response should be high. Therefore, it is interesting to study concentration of tetrachloroethane in chlorinated water in the future.

2 The Study of Factor Affecting the Occurrence of Halogenated Hydrocarbons in swimming Pools

The samples in this study were four swimming pools selected from four types of swimming pools. The study was carried out by collecting water samples every three hours. The results are shown in Table 4.11-4.14. Graphic representation of chloroform levels are shown in Figure 4.16-4.23.

1. Comparison between Chloroform Level in Shallow and Deep Area

Comparison of chloroform levels have no significant difference between the shallow and the deep area at 95% confidence. The detail are shown in Table 4.15.

2. Comparison between chloroform levels in 20 cm and 60 cm depth

Statistical analysis was carried out. The data obtained (Table 4.16) showed that there was a significant difference in the 20 cm and 60 cm water depth in chloroform levels.

Table 4.15 Mean comparison tested by analysis of t-test on chloroform levels in shallow and deep area.

sample	number of data	mean of $CHCl_3$	t-value	p-value
shallow area	36	52.36a	0.63	0.53
deep area	36	54.28a	0.63	0.53

The difference alphabet on the mean of $CHCl_3$ means there is significant difference at 95% confidence.

Table 4.16 Mean comparison tested by analysis of t-test on chloroform levels in 20 cm and 60 cm depth.

depth	number of data	mean of $CHCl_3$	t-value	p-value
20 cm	40	219.53a	-2.54	0.015
60 cm	40	195.68b	-2.54	0.015

The difference alphabet on the mean of $CHCl_3$ means there is significant difference at 95% confidence.

Table 4.11 Water quality in sampling site A(Hotel swimming pool)

Sampling Site	parameter				Concentration(ppb)									
					20 cm.					60 cm.				
	Cl residual (mg/l)	pH	Temp. (°C)	Light Intensity (Lux)	CH_2Cl_2	$CHCl_3$	CH_3CCl_3	CCl_4	$CHCCl_3$	CH_2Cl_2	$CHCl_3$	CH_3CCl_3	CCl_4	$CHCCl_3$
Site A-Day1														
6.00	3	7.8	28	4450	ND	139	ND	0.33	ND	ND	50	ND	0.32	ND
9.00	3	7.8	28	8780	ND	88	ND	0.37	ND	ND	73	ND	0.37	ND
12.00	3	7.8	29	43400	ND	100	ND	0.39	ND	ND	56	ND	0.44	ND
15.00	2.5	7.8	29	44700	ND	124	ND	0.37	ND	ND	156	ND	0.36	ND
18.00	2.5	7.8	28.5	3400	ND	66	ND	0.47	ND	ND	84	ND	0.47	ND
Site A-Day2					average	103.4		0.386		average	83.8		0.392	
6.00	3	8.2	29	7300	ND	480	ND	ND	ND	ND	350	ND	ND	ND
9.00	3	8.2	29	16640	ND	340	ND	ND	ND	ND	305	ND	ND	ND
12.00	3	8.2	29.5	7580	ND	350	ND	ND	ND	ND	315	ND	ND	ND
15.00	3	8.2	29	2280	ND	350	ND	ND	ND	ND	255	ND	ND	ND
18.00	3	8.2	29	7010	ND	430	ND	ND	ND	ND	350	ND	ND	ND
					average	390				average	315			

Table 4.12 Water quality in sampling site B(Academic swimming pool)

Sampling Site	parameter				Concentration(ppb)									
	Cl residual (mg/l)	pH	Temp. (°C)	Light Intensity (Lux)	20 cm.					60 cm.				
					CH_2Cl_2	$CHCl_3$	CH_3CCl_3	CCl_4	$CHCCl_3$	CH_2Cl_2	$CHCl_3$	CH_3CCl_3	CCl_4	$CHCCl_3$
Site B-Day 1														
6.00	3	7.8	30	550	ND	107	ND	ND	ND	ND	131	ND	ND	ND
9.00	0.3	7.8	30	62400	ND	205	ND	ND	ND	ND	81	ND	ND	ND
12.00	0.2	7.8	30.5	107600	ND	128	ND	ND	ND	ND	118	ND	ND	ND
15.00	0	7.8	31	6450	ND	142	ND	ND	ND	ND	88	ND	ND	ND
18.00	0	7.8	30.5	418	ND	141	ND	ND	ND	ND	81	ND	ND	ND
Site B-Day 2					average	144.6				average	99.8			
6.00	3	7.8	29	3910	ND	190	ND	ND	ND	ND	220	ND	ND	ND
9.00	2.5	7.8	29	47900	ND	190	ND	ND	ND	ND	189	ND	ND	ND
12.00	0.1	7.7	29.5	6200	ND	140	ND	ND	ND	ND	140	ND	ND	ND
15.00	0.1	7.5	29	6970	ND	160	ND	ND	ND	ND	150	ND	ND	ND
18.00	0.05	7.5	29.5	3040	ND	105	ND	ND	ND	ND	145	ND	ND	ND
					average	157				average	168.8			

Table 4.13 Water quality in sampling site C (Club swimming pool)

Sampling Site	parameter				Concentration(ppb)									
	Cl residual (mg/l)	pH	Temp. (°C)	Light Intensity (Lux)	20 cm.					20 cm.				
					CH_2Cl_2	$CHCl_3$	CH_3CCl_3	CCl_4	$CHCCl_3$	CH_2Cl_2	$CHCl_3$	CH_3CCl_3	CCl_4	$CHCCl_3$
Site C-Day1														
6.00	3	7.8	30	4840	ND	520	ND	ND	ND	ND	424	ND	ND	ND
9.00	3	7.8	31	65300	ND	530	ND	ND	ND	ND	405	ND	ND	ND
12.00	3	7.8	32	113900	ND	330	ND	ND	ND	ND	300	ND	ND	ND
15.00	3	7.8	32	65100	ND	455	ND	ND	ND	ND	287	ND	ND	ND
18.00	3	7.8	32	3240	ND	308	ND	ND	ND	ND	426	ND	ND	ND
Site C-Day2					average	428.6				average	368.4			
6.00	3	7.8	29.5	5600	ND	275	ND	ND	ND	ND	207	ND	ND	ND
9.00	3	7.8	30	12680	ND	243	ND	ND	ND	ND	220	ND	ND	ND
12.00	3	7.8	30.5	116900	ND	207	ND	ND	ND	ND	211	ND	ND	ND
15.00	3	7.8	31.5	84500	ND	254	ND	ND	ND	ND	220	ND	ND	ND
18.00	3	7.8	31	1300	ND	222	ND	ND	ND	ND	187	ND	ND	ND
					average	240.2				average	209			

Table 4.14 Water quality in sampling site D(Public swimming pool)

Sampling Site	parameter				Concentration(ppb)									
					20 cm.					60 cm.				
	Cl residual (mg/l)	pH	Temp. (°C)	Light Intensity (Lux)	CH_2Cl_2	$CHCl_3$	CH_3CCl_3	CCl_4	$CHCCl_3$	CH_2Cl_2	$CHCl_3$	CH_3CCl_3	CCl_4	$CHCCl_3$
Site D-Day 1														
6.00	3	7.8	29	16000	ND	157	ND	ND	ND	ND	198	ND	ND	ND
9.00	0.5	7.8	30	89800	ND	159	ND	ND	ND	ND	205	ND	ND	ND
12.00	0.2	7.8	31	61200	ND	220	ND	ND	ND	ND	189	ND	ND	ND
15.00	0	7.8	30.5	28900	ND	152	ND	ND	ND	ND	240	ND	ND	ND
18.00	0	7.8	30	2620	ND	157	ND	ND	ND	ND	172	ND	ND	ND
Site D-Day 2					average	169				average	200.8			
6.00	2.5	7	29	12100	ND	139	ND	ND	ND	ND	135	ND	ND	ND
9.00	0.5	7	30	71300	ND	113	ND	ND	ND	ND	118	ND	ND	ND
12.00	0.2	7	30	109000	ND	92	ND	ND	ND	ND	98	ND	ND	ND
15.00	0.1	7	31	73000	ND	126	ND	ND	ND	ND	114	ND	ND	ND
18.00	0.1	7	31	4590	ND	147	ND	ND	ND	ND	136	ND	ND	ND
					average	123.4				average	120.2			

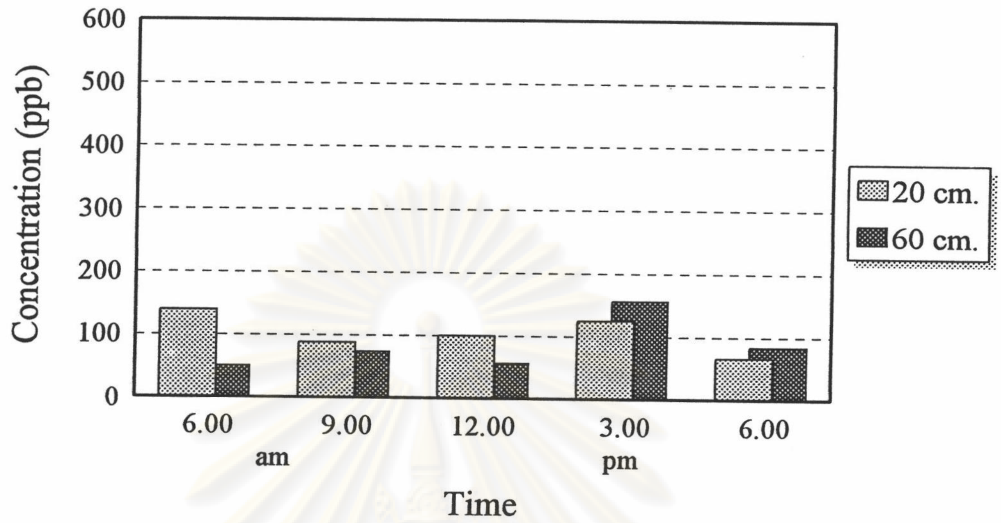


Figure 4.16 Chloroform levels in sampling site A-Day1

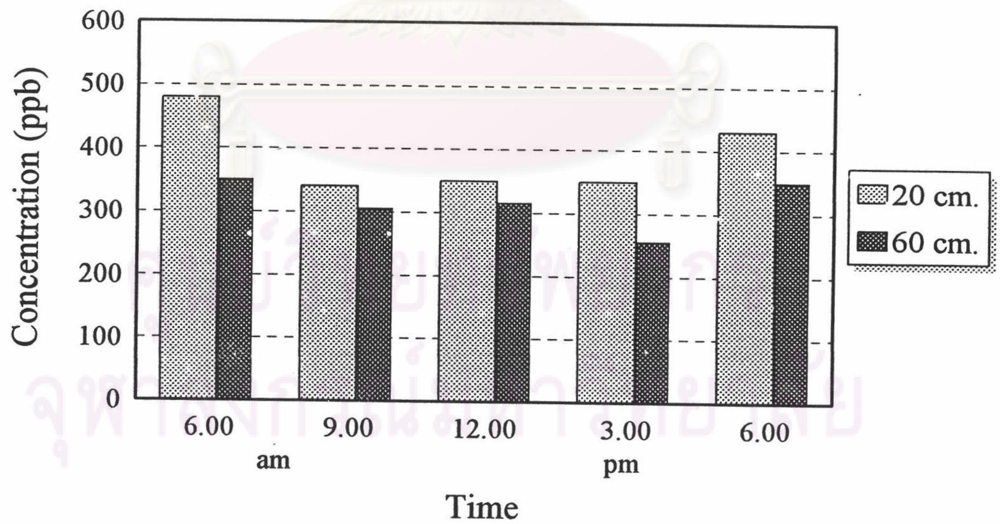


Figure 4.17 Chloroform levels in sampling site A-Day2

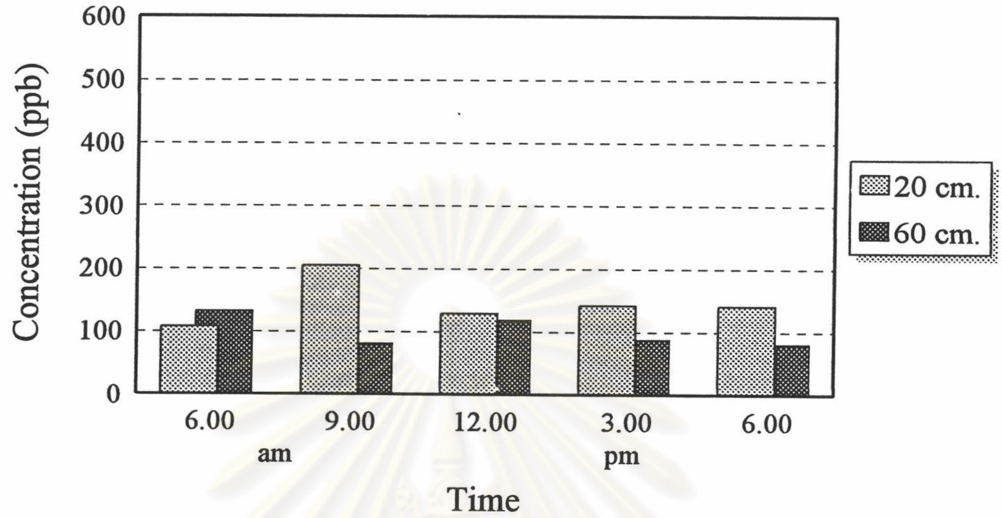


Figure 4.18 Chloroform levels in sampling site B-Day1

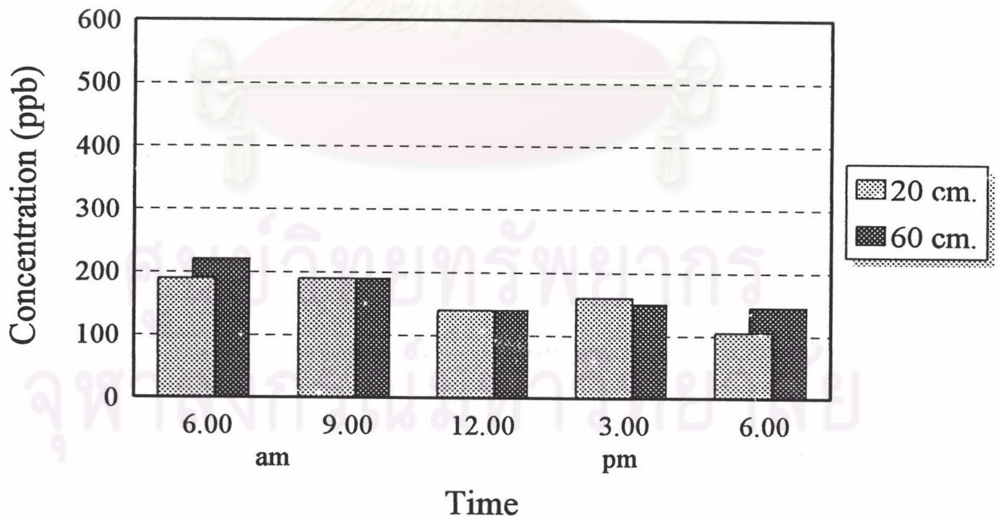


Figure 4.19 Chloroform levels in sampling site B-Day2

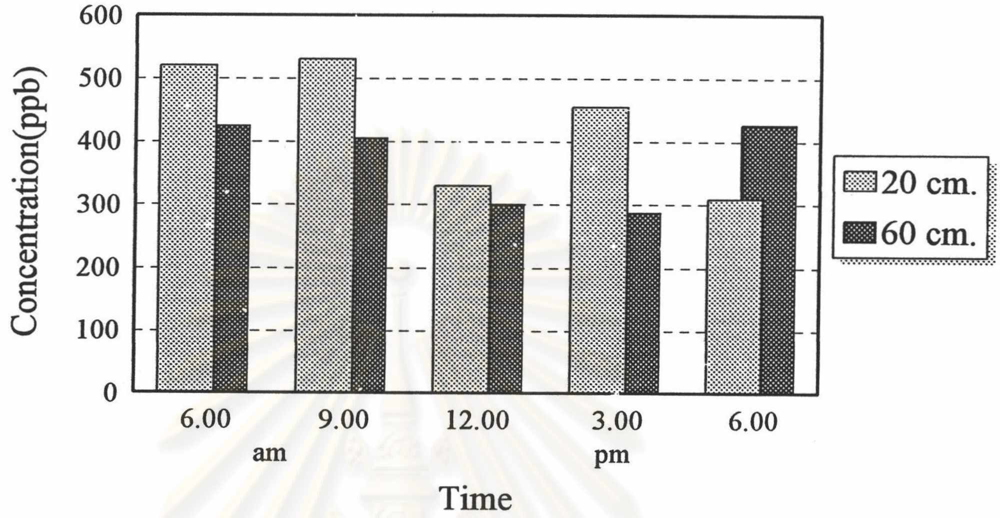


Figure 4.20 Chloroform levels in sampling site C-Day1

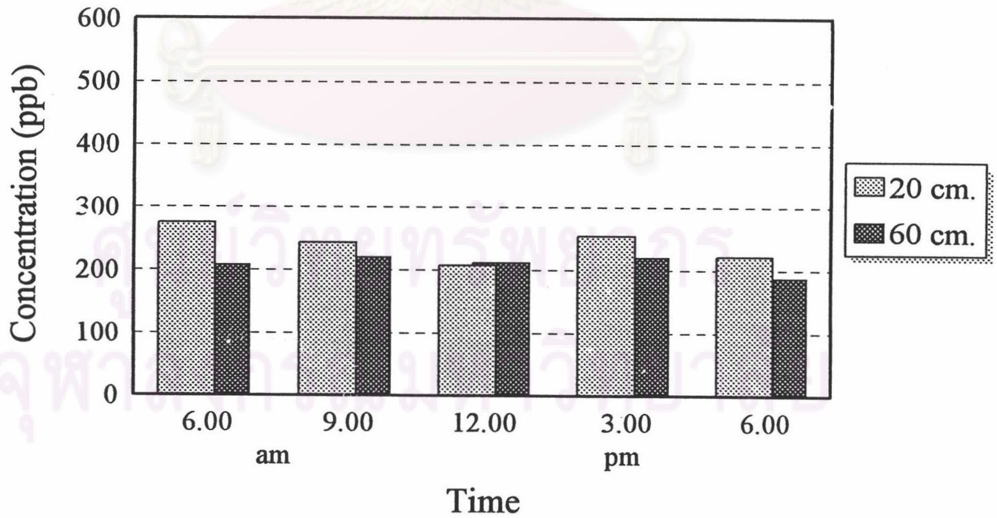


Figure 4.21 Chloroform levels in sampling site C-Day2

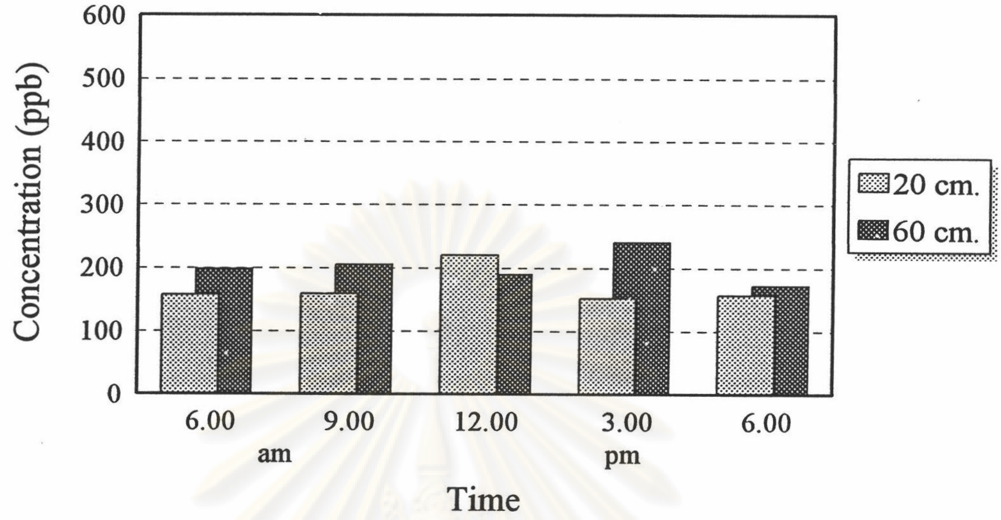


Figure 4.22 Chloroform level in sampling site D-day1

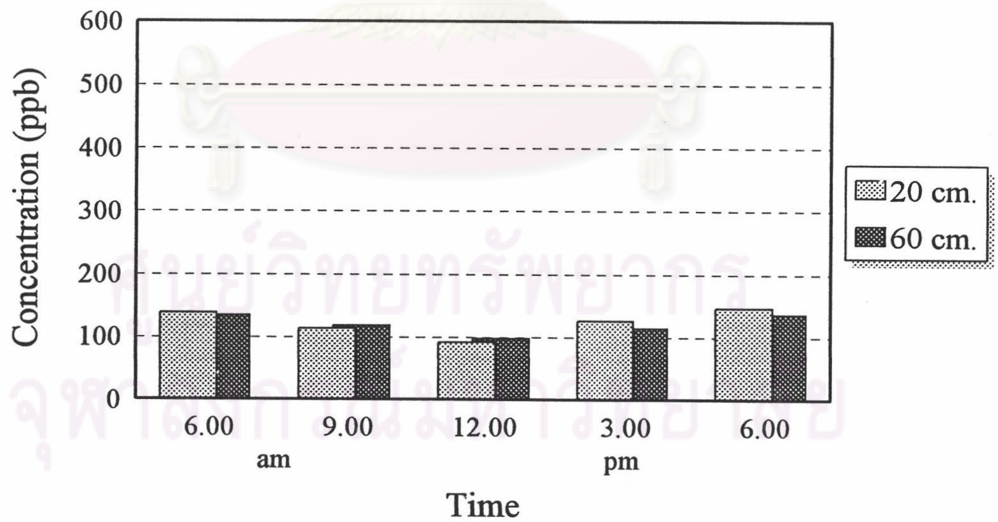


Figure 4.23 Chloroform levels in sampling site D-Day2

3. Comparison by the time

The result showed that the chloroform levels in the swimming pools during 6.00 a.m. to 9.00 p.m. fluctuated. Most of the sampling sites were found to have chloroform level dropped at noon and increased in the afternoon until the evening. It was speculated that because there were less swimmers and more sun ray than the afternoon. This result is conformed with the previous study by Lalh (1981) which indicated that contamination with organics as precursors of THM (chloroform is in THM group) production and increase by the number of swimmers.

The differences in chloroform levels at various time of the day may be related to the formation and evaporation of chloroform. The chloroform values are the results from continuous formation and continuous surface evaporation. Continuous formation of chloroform would be expected from interaction of the chlorine added regularly, and organic material that enter the pool via user, the environment and make-up water. (Beech, 1980)

4. Chlorine residual, pH, temperature and light intensity

After the statistical analysis using correlation, the results showed that p-value of all correlation coefficients among factors are more than 0.05($p>0.05$). The result was not conformed with the previous study of Reiches and Wilkins(1983) in term of positive correlation among THM entities and raw water, temperature and free chlorine residual. It might be related to some factors such as water circulation system and duration of water circulating. Generally, if water in the swimming pool is not circulated through filter, organic matter from swimmers may accumulate and interact with chlorine residual quite easier than in the properly circulated water. Therefore, the correlation of the factors affecting chloroform concentration in the swimming pool were not correlated.