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Trihalomethanes (THMs) in Malaysian Drinking Water

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Abstract : Municipal water treatment plants in Malaysia use chlorination for drinking water disinfection due to its cost effectiveness and efficiency. Although, chlorination has worked well, the use of chlorine posed potential health risks due to formation of carcinogenic or mutagenic halo-organic compounds as disinfection by-products such as trihalomethanes (THMs). A study was carried out to assess the THMs level in drinking water supply from Selangor, West Pahang, Negeri Sembilan and Federal Territory-Kuala Lumpur for the years 1999, 2000 and 2001. The results of the study indicate that chloroform constituted the principal fraction of the THMs in all samples analyzed. For the year 1999, THMs were present in the range of 2 - 245 of µg/L (mean of 71 µg/L) for Selangor, 1 - 186 µg/L (mean of 39 µg/L) for West Pahang, 3 - 301 µg/L (mean of 82 µg/L) for Negeri Sembilan and 6 - 176 µg/L (mean of 48 µg/L) for Federal Territory -Kuala Lumpur. As for the year 2000, THMs were present in the range of 1 - 224 µg/L (mean of 59 µg/L) for Selangor, 2 - 264 µg/L (mean of 60 µg/L) for West Pahang, 1 - 239 µg/L (mean of 53 µg/L) for Negeri Sembilan and 2 - 280 µg/L (mean of 51 µg/L) for Federal Territory-Kuala Lumpur. For the year 2001, THM was present in the range of 2 - 221 µg/L (mean of 42 µg/L) for Selangor, 2 - 145 µg/L (mean of 38 µg/L) for West Pahang, 2 - 289 µg/L (mean of 53 µg/L) for Negeri Sembilan and 8 - 147 µg/L (mean of 35 µg/L) for Federal Territory -Kuala Lumpur. Comparison of the levels with the maximum permissible level (MPL) of 100 µg/L for total trihalomethanes (TTHMs), shows general compliance.

Key words : Trihalomethanes, Chlorination, Drinking water quality

Abstrak : Loji-loji rawatan air di Malaysia menggunakan proses penklorinan sebagai langkah disinfeksi kerana ianya cekap, murah dan berkesan. Walaupun proses disinfeksi efektif tetapi ianya didapati membahayakan kesihatan manusia atas pembentukan sebatian sampingan haloorganik yang karsinogenik dan mutagenik seperti trihalometana (THMs). Satu kajian telah dijalankan untuk memantau paras THMs dalam bekalan air minum di Selangor, Pahang Barat, Negeri Sembilan dan Wilayah Persekutuan-Kuala Lumpur untuk tahun 1999, 2000 dan 2001. Hasil kajian menunjukkan klorofom merupakan komponen utama dalam THMs untuk sampel yang dianalisis. Bagi tahun 1999, THMs wujud dalam julat 2 - 245 µg/L (min 71 µg/L) untuk Selangor, 1 - 186 µg/L (min 39 µg/L) untuk Pahang Barat, 3 - 301 µg/L (min 82 µg/L) bagi Negeri Sembilan dan of 6 - 176 µg/L (min 48 µg/L) bagi Wilayah Persekutuan-Kuala Lumpur. Untuk tahun 2000 pula, THMs wujud dalam julat 1 - 224 µg/L (min 59 µg/L) bagi Selangor, 2 - 264 µg/L (min 60 µg/L) bagi Pahang Barat, 1 - 239 µg/L (min 53 µg/L) bagi Negeri Sembilan dan 2 - 280 µg/L (min 51 µg/L) bagi Wilayah Persekutuan-Kuala Lumpur. Bagi tahun 2001, THMs wujud dalam julat 2 - 221 µg/L (min 42 µg/L) untuk Selangor, 2 - 145 µg/L (min 38 µg/L) untuk Pahang Barat, 2 - 289 µg/L (min 53 µg/L) bagi Negeri Sembilan dan 8 - 147 µg/L (min 35 µg/L) bagi Wilayah Persekutuan-Kuala Lumpur. Perbandingan aras THMs dengan aras maksimum yang dibenarkan (MPL) iaitu 100 µg/L untuk jumlah THMs, hasil analisis menunjukkan ianya mematuhi MPL yang ditetapkan.

Kata kunci: Trihalometana, Pengklorinan, Kualiti air minum

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Introduction

Disinfection is the most important stage in the treatment of drinking water supplies because it removes or inactivates pathogenic organisms responsible for waterborne diseases such as cholera, typhoid fever, and dysentery [1]. Most municipal water supply system in Malaysia use chlorination for water disinfections [2,3]. Chlorination is a widely used method of disinfections because it is extremely efficient and cost effective. Although, chlorination works well, it was discovered that the use of chlorine posed potential health risks due to the formation of carcinogenic halo-organic compound as disinfections by-products [4,5,6].

Due to the health risks pose by these substances, various limits for trihalomethanes (THMs) in drinking water were set by different countries. The United States Environmental Protection Agency (US EPA) has set a limit of 100 µg/L on acceptable total trihalomethanes (TTHMs) concentration in finished drinking water [7]. The Commission of the European Communities has proposed the values of 40 µg/L for chloroform

Parameter	Maximum Permissible Level (μg/L)
Trihalomethanes	The sum of the ratio of the concentration of each to its respective guideline value should not exceed 1.
Chloroform	200
Dichlorobromomethane	60
Dibromochloromethane	100
Bromoform	100

Table 1. Guidelines for National Drinking Water Quality Standard (2001) for THMs

($CHCl_3$) and 15 μg/L for bromodichloromethane [8]. The Swedish regulation of total THMs is set at 50 μg/L [9]. In Malaysia, the level of $CHCl_3$ permitted in drinking water is 30 μg/L in accordance with the National Drinking Water Quality Standards (1990). However, the Ministry of Health of Malaysia has adopted the WHO Guidelines [10] in preparing the guidelines for National Drinking Water Quality Standard (2001) [11], as shown in Table 1.

A number of analytical methods have been published for the determination of THMs in drinking water. These include liquid-liquid extraction method prior to GC analysis [12, 13, 14]; headspace techniques [15, 16]; purge and trap method [17] and solid phase microextraction method [18]. The analysis of volatile organic compounds (VOC) by purge and trap method is perhaps the most widely employed method of trace analysis in environmental organic chemistry. The main reason is that it is applicable to a wide range of analytes in practically any sample matrix and is, to date, still unsurpassed in method sensitivity.

The aim of this work is to assess the THMs level in the municipal drinking water supply in Selangor, Federal Territory-Kuala Lumpur, West Pahang, and Negeri Sembilan. A simple and rapid method for THMs analysis by Purge and Trap coupled with capillary column gas chromatograph with electron capture detector was used to determine the THMs level in drinking water.

Experimental

Sampling

The samples were collected in 40 mL amber glass vials equipped with teflon-faced septa supplied by the Ministry of Health. The areas under study included the State of Selangor, Federal Territory-Kuala Lumpur, West Pahang and Negeri Sembilan. Water samples were collected from various sampling points in each district for the four states for the years 1999, 2000 and 2001. The sampling points were located at the pipelines of the Treatment Plant Operation (TPO), Service Reservoir Outlet (SRO) and Auxiliary Outlet Point (AOP). The frequency of sampling at each sampling point depends on the nature and types of stations involved. Generally for TPO station, the frequency of sampling was about three times per year. As for the SRO station, the frequency of sampling was about two times per year. The frequency for AOP station was either once or twice a year. A total of 1163, 1562 and 1315 samples were collected and analysed from the 23 districts in Selangor, Federal Territory-Kuala Lumpur, West Pahang and Negeri Sembilan for the years 1999, 2000 and 2001, respectively.

Analysis of THMs

A Hewlett-Packard HP 5690 series II gas chromatograph equipped with electron capture detector and HP chemstation was used in this study. The injector had a straight split/splitless liner with silanized glasswool in the middle. The separation was achieved using Supelco Vocol capillary column: 60 m x 0.75 mm i.d. with 1.5 μm film thickness. Purge and Trap technique (Model HP 7695, No. G 1905A) was used for sampling. The GC conditions used were:-

Carrier gas : Nitrogen set at 60 psi to the GC. Column flow was set to 12.0 mL/min, split flow to 20 mL/min and septum purge flow to 3.0 mL/min.

Initial temperature : 35 °C
Rate : 6 °C/min
Final temperature : 180 °C
Injector temperature : 200 °C
Detector temperature : 250 °C

THMs and other volatile compounds were extracted (purged) from the sample matrix by bubbling nitrogen though the aqueous sample. Purged volatile components were trapped in a tube (trap) containing suitable sorbent materials. When purging was complete, the sorbent tube (or trap) was heated and backflushed with an inert gas to desorb trapped sample components onto a gas chromatography (GC) column. The gas chromatograph was temperature-programmed to separate the method analytes which were then detected with electron capture detector.

State	District	1999		2000		2001	
		Mean (μg/L)	Range (μg/L)	Mean (μg/L)	Range (μg/L)	Mean (μg/L)	Range (μg/L)
Selangor	Gombak	48	4 - 196	52	2 - 204	33	4-94
	Hulu Langat	13	2 - 56	47	1 - 213	23	3-148
	Hulu Selangor	54	4 - 162	52	3 - 224	51	2-200
	Klang	92	3 - 173	48	3 - 163	50	10-221
	Kuala Langat	64	5 - 137	53	3 - 209	31	4-56
	Kuala Selangor	70	29 - 187	57	3 - 178	43	12-81
	Petaling Jaya	91	2 - 118	62	2 - 180	56	2-151
	Sabak Bernam	156	108 - 245	98	2 - 172	60	5-136
	Sepang	52	20 - 147	60	2 -150	34	8-75
Average (State)		71	2 - 245	59	1 - 224	42	2-221
Total (State)	9						
Federal Territory	Kuala Lumpur	48	6 - 176	51	2 - 280	35	8-147
West Pahang	Bentong	41	3 - 116	47	2 – 220	32	3-143
	Kuala Lipis	43	8 - 150	74	3 – 264	25	2-108
	Raub	17	1 - 80	43	2 – 110	35	3-145
	Jerantut	25	1 - 162	45	3 – 169	28	3-140
	Temerloh	70	2 - 186	51	3 – 168	68	3-115
	Bera	38	2 - 83	51	2 - 113	42	3-131
Average (State)		39	1 - 186	60	2 - 264	38	2-145
Total (State)	6						
Negeri Sembilan	Jelebu	71	17 - 169	53	2 – 146	26	4-92
	Jempol	53	3 - 98	78	5 – 185	56	10-116
	Kuala Pilah	67	5 - 133	53	9 – 222	69	2-242
	Port Dickson	53	7 - 182	51	8 – 133	38	5-55
	Rembau	121	57 - 202	54	4 – 239	106	24-289
	Seremban	66	5 - 147	42	3 - 132	26	3-62
	Tampin	145	74 - 301	41	1 - 161	50	4-189
Average (State)		82	3 - 301	53	1 - 239	53	2-289
Total (State)	7						

Table 2. Mean and Range of THMs concentration (μg/L) in drinking water of Selangor, Federal Territory-Kuala Lumpur, West Pahang and Negeri Sembilan for Years 1999, 2000 and 2001.

Results and Discussion

Comparison of THMs level for years 1999, 2000 and 2001

Tables 2 and 3 show that THMs and $CHCl_3$ were detected in all water samples collected from the water distribution system of the four areas. Comparison of the levels with the maximum permissible level (MPL) of 30 μg/L for $CHCl_3$ and 100 μg/L for total trihalomethanes (TTHMs) shows general compliance for TTHMs. In the State of Selangor, it was noted that the district of Sabak Bernam has the highest average level of THMs, namely 156, 98 and 60 μg/L respectively, for the years 1999, 2000 and 2001. The fact that THMs level of the district had decreased from 156 to 60 μg/L over a period of 3 years progressively may indicate an improvement in the water quality and treatment process over the years. Similar trend was observed for total organic carbon (TOC) level which has also decreased from 5 to 3 μg/mL.

It is also noted from the record of Malaysian Meteorological Department that the rainfall for the month of October in 1999, 2000 and 2001 were relatively high in Selangor. The THMs level in Sabak Bernam was at the highest during this month for these three years. The lowest THMs level was in the months of April and May for 1999, 2000 and 2001 when the rainfall was relatively low. This may be due to some of the natural organic matters present in the raw water at Sg. Bernam, which resulted in the high level of THMs formation during disinfection process. This phenomenon is common especially during high rainfall season when the organic matters on land were washed into the river, thus resulting in high TOC value.

Hulu Langat district has the lowest mean THMs level, namely 13, 47 and 23 μg/L, respectively, for the years 1999, 2000 and 2001. It appears that the THMs level of the district had increased from 13 to 47 μg/L and subsequently decreased to 23 μg/L for the year 2001. This

State	District	1999		2000		2001	
		Mean (µg/L)	Range (µg/L)	Mean (µg/L)	Range (µg/L)	Mean (µg/L)	Range (µg/L)
Selangor	Gombak	40	4 - 172	47	2 – 187	27	4-64
	Hulu Langat	10	2 - 148	39	1 – 205	19	3-148
	Hulu Selangor	48	4 - 154	47	3 – 206	46	2-48
	Klang	75	3 - 150	42	3 - 153	43	8-158
	Kuala Langat	44	5 - 98	38	3 – 195	22	3-58
	Kuala Selangor	57	24 - 165	46	3 – 164	34	8-67
	Petaling Jaya	48	2 - 95	51	2 – 160	46	2-131
	Sabak Bernam	141	91 - 233	86	2 – 161	53	4-125
	Sepang	33	8 - 105	41	2 –100	23	6-55
Average (State)		55	2 - 233	51	1 - 206	35	2-158
Total (State)	9						
Federal Territory	Kuala Lumpur	38	5 - 159	41	2 – 264	28	5-131
West Pahang	Bentong	33	3 - 94	41	2 – 215	28	2-138
	Kuala Lipis	37	3 - 138	68	3 – 250	23	3-107
	Raub	14	1 - 60	39	2 – 100	32	2-141
	Jerantut	23	1 - 152	40	3 – 161	25	3-133
	Temerloh	59	2 - 167	47	3 – 160	63	3-108
	Bera	31	2 - 75	45	2 – 108	37	3-125
Average (State)		33	1 - 167	47	2 – 250	34	2-141
Total (State)	6						
Negeri Sembilan	Jelebu	55	16 - 157	42	2 – 137	21	3-83
	Jempol	40	2 - 92	65	5 – 166	47	7-105
	Kuala Pilah	65	4 - 103	47	9 – 205	61	2-225
	Port Dickson	33	3 - 149	34	8 – 107	25	4-39
	Rembau	114	51 - 190	50	4 – 227	98	16-227
	Seremban	53	2 - 127	34	3 – 114	21	2-51
	Tampin	121	54 - 272	34	1 – 147	43	3-175
Average (State)		69	2 - 272	44	2 – 227	45	2-277
Total (State)	7						

Table 3. Mean and Range of $CHCl_3$ concentration (µg/L) in drinking water of Selangor, Federal Territory-Kuala Lumpur, West Pahang and Negeri Sembilan for Years 1999, 2000 and 2001

indicates the variation of water quality during the period under review.

The average THMs level in Selangor, namely 71, 59 and 42 µg/L, for the years 1999, 2000 and 2001, respectively, is still within the permissible levels. It appears that the water quality in this State has improved resulting in the reduction of THMs level over this period.

In the Federal Territory-Kuala Lumpur, the average THMs level of 48, 51 and 35 µg/L, respectively, for the years 1999, 2000 and 2001 is within the permissible level. It would appear that the water quality in this state has improved resulting in the reduction of THMs level over this period.

The average levels of THMs in the state of West Pahang for the years 1999, 2000 and 2001 were relatively low compared to the other areas under survey. The THMs level had increased from 39 to 60 µg/L and subsequently decreased to 38 µg/L in 2001. It is also noted that, in 2001, there was an increase of about 17 µg/L of mean THMs level in the district of Temerloh compared with the level in 2000. The increase of the mean THMs level may be due to the deterioration of water quality as a result of some human development in this catchment area. In other districts, the THMs level has generally decreased from year 2000 to year 2001 as can be seen in Table 2.

The average THMs level in Negeri Sembilan for the years 1999, 2000 and 2001 were relatively high compared to the other areas under survey. The level of THMs in this State had decreased from 82 to 53 µg/L. This indicates the variation of water quality during the period under review. It was observed that the THMs level of Tampin district had decreased from 145 to 40 µg/L and increased to 50 µg/L over a period of 3 years. The increase of THMs level, from year 2000 to 2001 may be due to the increase of natural organic matter present in the raw water. The variation of THMs level is generally due to the variation of water quality particularly the TOC content in raw water and also the high dosage of chlorine used during low rainfall season in this district.

State	District	THM					
		Guidelines for Drinking Water Quality Standard (2001) / WHO (1993) *			USEPA 1993 (100 µg/L)		
		A	B	C	A	B	C
Selangor	Gombak	67	0	0.0	67	6	9.0
	Hulu Langat	63	1	1.5	63	1	1.6
	Hulu Selangor	88	0	0.0	88	10	11.4
	Klang	59	0	0.0	59	28	47.5
	Kuala Langat	37	0	0.0	37	9	24.3
	Kuala Selangor	20	1	5.0	20	16	80.0
	Petaling Jaya	41	0	0.0	41	7	17.1
	Sabak Bernam	20	3	15.0	20	20	100.0
	Sepang	20	0	0.0	20	1	5.0
Average (State)				1.2			23.6
Total (State)	9	415	5		415	98	
Federal Territory	Kuala Lumpur	94	0	0.0	94	9	9.6
West Pahang	Bentong	90	0	0.0	90	3	3.3
	Kuala Lipis	51	0	0.0	51	1	2.0
	Raub	124	0	0.0	124	0	0.0
	Jerantut	59	0	0.0	59	2	3.4
	Temerloh	23	1	4.3	23	5	21.7
	Bera	54	0	0.0	54	10	18.5
Average (State)				0.2			5.2
Total (State)	6	401	1		401	21	
Negeri Sembilan	Jelebu	54	2	3.7	54	7	13.0
	Jempol	34	0	0.0	34	0	0.0
	Kuala Pilah	22	0	0.0	22	4	18.2
	Port Dickson	31	0	0.0	31	1	3.2
	Rembau	16	1	6.3	16	11	68.8
	Seremban	66	0	0.0	66	8	12.1
	Tampin	30	3	10.0	30	23	76.7
Average (State)				2.4			29.6
Total (State)	7	253	6		253	75	

Note : * Trihalomethanes : The sum of the ratio of the concentration of each to its respective guidelines value should not exceed 1; Bromoform: 100 µg/L; Chloroform: 200 µg/L; Dibromochloromethane: 100 µg/L; Bromodichloromethane: 60 µg/L

A = Number of samples analyze
B = Number of samples violated
C = Percentage of sample violated

Table 4. Summary of THMs compliance in drinking water for Selangor, Federal Territory-Kuala Lumpur, West Pahang and Negeri Sembilan for Year 1999

State	District	THM					
		Guidelines for Drinking Water Quality Standard (2001) / WHO (1993) *			USEPA 1993 (100 µg/L)		
		A	B	C	A	B	C
Selangor	Gombak	98	1	1.0	98	12	12.2
	Hulu Langat	117	1	0.9	117	12	10.3
	Hulu Selangor	111	1	0.9	111	12	10.8
	Klang	55	0	0.0	55	5	9.0
	Kuala Langat	66	1	1.5	66	5	7.6
	Kuala Selangor	69	0	0.0	69	4	5.8
	Petaling Jaya	66	0	0.0	66	6	9.0
	Sabak Bernam	32	0	0.0	32	18	56.3
	Sepang	43	0	0.0	43	7	16.3
Average (State)				0.5			26.7
Total (State)	9	657	3		657	81	
Federal Territory	Kuala Lumpur	108	2	1.9	108	11	10.2
West Pahang	Bentong	95	2	2.1	95	7	7.4
	Kuala Lipis	51	4	7.8	51	9	17.6
	Raub	126	0	0.0	126	11	8.7
	Jerantut	67	0	0.0	67	9	13.4
	Temerloh	43	0	0.0	43	6	14.0
	Bera	53	0	0.0	53	1	1.9
Average (State)				1.4			19.9
Total (State)	6	432	6		432	43	
Negeri Sembilan	Jelebu	38	0	0.0	38	3	7.9
	Jempol	70	0	0.0	70	14	20.0
	Kuala Pilah	57	1		57	5	8.8
	Port Dickson	38	0	0.0	38	4	10.5
	Rembau	23	1	4.3	23	4	17.4
	Seremban	88	0	0.0	88	6	6.8
	Tampin	51	0	0.0	51	1	2.0
Average (State)				0.5			20.3
Total (State)	7	365	2		365	37	

Note : * Trihalomethanes : The sum of the ratio of the concentration of each to its respective guidelines value should not exceed 1; Bromoform: 100 µg/L; Chloroform: 200 µg/L; Dibromochloromethane: 100 µg/L; Bromodichloromethane: 60 µg/L.

A = Number of samples analyze
B = Number of samples violated
C = Percentage of sample violated

Table 5. Summary of THMs compliance in drinking water for Selangor, Federal Territory-Kuala Lumpur, West Pahang and Negeri Sembilan for Year 2000.

State	District	THM					
		Guidelines for Drinking Water Quality Standard (2001) / WHO (1993) *			USEPA 1993 (100 µg/L)		
		A	B	C	A	B	C
Selangor	Gombak	56	0	0	56	0	0
	Hulu Langat	82	0	0	82	1	1.2
	Hulu Selangor	53	1	1.9	53	8	15.1
	Klang	41	1	2.4	41	3	7.3
	Kuala Langat	36	0	0	36	0	0
	Kuala Selangor	46	0	0	46	0	0
	Petaling Jaya	86	0	0	86	3	3.5
	Sabak Bernam	150	0	0	150	20	13.3
	Sepang	28	0	0	28	0	0
Average (State)				0.5			6.1
Total (District)	9	578	2		578	35	
Federal Territory	Kuala Lumpur	55	0	0	55	4	7.3
West Pahang	Bentong	70	0	0	70	1	1.4
	Kuala Lipis	69	0	0	69	1	1.5
	Raub	86	0	0	86	4	4.7
	Jerantut	50	0	0	50	2	4.0
	Temerloh	38	0	0	38	2	5.3
	Bera	46	0	0	46	2	2.2
Average (State)				0			4.4
Total (District)	6	359	0		359	12	
Negeri Sembilan	Jelebu	20	0	0	20	0	0
	Jempol	47	0	0	47	5	10.6
	Kuala Pilah	26	1	3.9	26	8	30.8
	Port Dickson	38	0	0	38	0	0
	Rembau	16	3	18.8	16	4	25.0
	Seremban	47	0	0	47	0	0
	Tampin	129	0	0	129	13	10.1
Average (State)				3.2			9.3
Total (District)	7	323	4		323	30	

Note : * Trihalomethanes : The sum of the ratio of the concentration of each to its respective guidelines value should not exceed 1; Bromoform: 100 µg/L; Chloroform: 200 µg/L; Dibromochloromethane: 100 µg/L; Bromodichloromethane: 60 µg/L

A = Number of samples analyze
B = Number of samples violated
C = Percentage of sample violated

Table 6. Summary of THMs compliance in drinking water for Selangor, Federal Territory-Kuala Lumpur, West Pahang and Negeri Sembilan for Year 2001.

Review of non-compliances based on US EPA Standard (1993) and Draft Drinking Water Quality Standard 2001/ WHO (1993)

Tables 4, 5 and 6 show a summary of THMs compliances for Selangor, Federal Territory-Kuala Lumpur, West Pahang and Negeri Sembilan for the years 1999, 2000 and 2001, respectively. If the maximum permissible level of 100 µg/L for THMs as suggested by USEPA (1993) were to be adopted, non-compliance was about 17% in 1999, 19% in 2000 and 7% in 2001.

State	District	$CHCl_3$					
		Guidelines for Drinking Water Quality Standard (2001) / WHO (1993) *			Drinking Water Quality Standard (1990) (30 µg/L)		
		A	B	C	A	B	C
Selangor	Gombak	67	0	0.0	67	35	52.2
	Hulu Langat	63	0	0.0	63	5	7.9
	Hulu Selangor	88	0	0.0	88	50	56.8
	Klang	59	0	0.0	59	49	83.1
	Kuala Langat	37	0	0.0	37	23	62.2
	Kuala Selangor	20	0	0.0	20	12	60.0
	Petaling Jaya	41	0	0.0	41	29	70.7
	Sabak Bernam	20	2	10.0	20	20	100.0
	Sepang	20	0	0.0	20	7	35.0
Average (State)				0.5			55.4
Total (District)	9	415	2		415	230	
Federal Territory	Kuala Lumpur	94	0	0.0	94	56	59.6
West Pahang	Bentong	90	0	0.0	90	41	45.6
	Kuala Lipis	51	0	0.0	51	28	54.9
	Raub	124	0	0.0	124	13	10.5
	Jerantut	59	0	0.0	59	15	25.4
	Temerloh	23	0	0.0	23	15	65.2
	Bera	54	0	0.0	54	24	44.4
Average (State)				0.0			67.8
Total (District)	6	401	0		401	136	
Negeri Sembilan	Jelebu	54	0	0.0	54	39	72.2
	Jempol	34	0	0.0	34	18	52.9
	Kuala Pilah	22	0	0.0	22	21	95.5
	Port Dickson	31	0	0.0	31	13	41.9
	Rembau	16	0	0.0	16	16	100.0
	Seremban	66	0	0.0	66	52	78.1
	Tampin	30	1	3.3	30	30	100.0
Average (State)				0.4			74.7
Total (District)	7	253	1		253	189	

Note : * Trihalomethanes : The sum of the ratio of the concentration of each to its respective guidelines value should not exceed 1; Bromoform: 100 µg/L; Chloroform: 200 µg/L; Dibromochloromethane: 100 µg/L; Bromodichloromethane: 60 µg/L.

A = Number of samples analyze
B = Number of samples violated
C = Percentage of sample violated

Table 7. Summary of Chloroform compliance in drinking water for Selangor, Federal Territory-Kuala Lumpur, West Pahang and Negeri Sembilan for Year 1999

State	District	$CHCl_3$					
		Guidelines for Drinking Water Quality Standard (2001) / WHO (1993) *			Drinking Water Quality Standard (1990) (30 µg/L)		
		A	B	C	A	B	C
Selangor	Gombak	98	0	0.0	98	50	50.5
	Hulu Langat	117	1	0.9	117	52	44.4
	Hulu Selangor	111	1	0.9	111	58	52.3
	Klang	55	0	0.0	55	31	56.4
	Kuala Langat	66	0	0.0	66	39	59.1
	Kuala Selangor	69	0	0.0	69	39	56.5
	Petaling Jaya	66	0	0.0	66	44	66.7
	Sabak Bernam	32	0	0.0	32	23	71.9
	Sepang	43	0	0.0	43	27	62.8
Average (State)				0.4			55.3
Total (State)	9	657	3		657	363	
Federal Territory	Kuala Lumpur	108	2	1.9	108	51	47.2
West Pahang	Bentong	95	2	2.1	95	36	37.9
	Kuala Lipis	51	4	7.8	51	22	43.1
	Raub	126	0	0.0	126	56	44.4
	Jerantut	67	0	0.0	67	28	41.8
	Temerloh	43	0	0.0	43	22	51.2
	Bera	53	0	0.0	53	24	45.3
Average (State)				1.4			43.5
Total (State)	6	432	6		432	188	
Negeri Sembilan	Jelebu	38	0	0.0	38	21	55.3
	Jempol	70	0	0.0	70	56	80.0
	Kuala Pilah	57	1	1.7	57	28	49.1
	Port Dickson	38	0	0.0	38	23	60.5
	Rembau	23	1	4.3	23	8	34.8
	Seremban	88	0	0.0	88	35	39.8
	Tampin	51	0	0.0	51	22	43.1
Average (State)				0.5			52.9
Total (State)	7	365	2		365	193	

Note : * Trihalomethanes : The sum of the ratio of the concentration of each to its respective guidelines value should not exceed 1; Bromoform: 100 µg/L; Chloroform: 200 µg/L; Dibromochloromethane: 100 µg/L; Bromodichloromethane: 60 µg/L.

A = Number of samples analyze
B = Number of samples violated
C = Percentage of sample violated

Table 8. Summary of Chloroform compliance in drinking water for Selangor, Federal Territory-Kuala Lumpur, West Pahang and Negeri Sembilan for Year 2000

State	District	$CHCl_3$					
		Guidelines for Drinking Water Quality Standard (2001) / WHO (1993) *			Drinking Water Quality Standard (1990) (30 µg/L)		
		A	B	C	A	B	C
Selangor	Gombak	56	0	0	56	20	35.7
	Hulu Langat	82	0	0	82	11	13.4
	Hulu Selangor	53	0	0	53	30	56.6
	Klang	41	1	2.4	41	26	63.4
	Kuala Langat	36	0	0	36	8	22.2
	Kuala Selangor	46	0	0	46	24	52.2
	Petaling Jaya	86	0	0	86	75	87.2
	Sabak Bernam	150	0	0	150	114	76.0
	Sepang	28	0	0	28	7	25.0
Average (State)				0.2			55
Total (District)	9	578	1		578	315	
Federal Territory	Kuala Lumpur	55	0	0	55	17	30.9
West Pahang	Bentong	70	0	0	70	22	31.4
	Kuala Lipis	69	0	0	69	16	23.2
	Raub	86	0	0	86	34	40.0
	Jerantut	50	0	0	50	17	34.0
	Temerloh	38	0	0	38	31	81.6
	Bera	46	0	0	46	22	47.8
Average (State)				0			40.0
Total (District)	6	359	0		359	142	
Negeri Sembilan	Jelebu	20	0	0	20	4	20.0
	Jempol	47	0	0	47	33	70.2
	Kuala Pilah	26	1	3.9	26	15	57.7
	Port Dickson	38	0	0	38	8	21.1
	Rembau	16	3	18.8	16	13	81.3
	Seremban	47	0	0	47	12	25.5
	Tampin	129	0	0	129	78	60.5
Average (State)				1.2			50.5
Total (District)	7	323	4		323	163	

Note : * Trihalomethanes : The sum of the ratio of the concentration of each to its respective guidelines value should not exceed 1; Bromoform: 100 µg/L; Chloroform: 200 µg/L; Dibromochloromethane: 100 µg/L; Bromodichloromethane: 60 µg/L.

A = Number of samples analyze
B = Number of samples violated
C = Percentage of sample violated

Table 9. Summary of Chloroform compliance in drinking water for Selangor, Federal Territory-Kuala Lumpur, West Pahang and Negeri Sembilan for Year 2001.

Tables 7, 8 and 9 show a summary of $CHCl_3$ compliance in drinking water for Selangor, Federal Territory-Kuala Lumpur, West Pahang and Negeri Sembilan for the years 1999, 2000 and 2001, respectively. Based on the present National Standards (1990) of 30 µg/L $CHCl_3$ in the drinking water, non-compliance was about 64% in 1999, 50% in 2000 and 44% in 2001. However, if the guidelines on National Drinking Water Quality Standard (2001) of 200 µg/L $CHCl_3$ in the drinking water were to be adopted, non-compliance for THMs was 0.9% in 1999, 1% in 2000 and 0.9% in

2001. In the case of $CHCl_3$, the percentage of non-compliances was 0.2%, 1% and 0.4%, respectively, in 1999, 2000 and 2001. These values are almost negligible.

Conclusion

The presence of THMs in the nation's drinking water is of concern from a health-related aspect since these compounds have been linked to the occurrence of human cancer in many instances. THMs are not altered or removed by coagulation, sedimentation, or filtration but can be removed by aeration or adsorption processes. Thus, reduction in THMs formation is important to ensure that the drinking water is safe for consumption. Although action to reduce THMs is encouraged, disinfection must not be compromised.

The variations in THMs levels indicate the effect of different factors controlling the formation of these compounds during the chlorination of drinking water and also the performance of treatment facilities. Depending on various water quality and operation conditions, the contribution that an individual THMs makes to the total concentration can vary from a few per cent to over 90 per cent of the total.

In addition to the above, economic and health factors should be considered before revision on the National Standards on THMs level in drinking water. This is to ensure that all factors are considered when comprehensive National Drinking Water Quality Standard is implemented.

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