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Trihalomethanes in Chlorinated Drinking Water of Cairo, Egypt

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Chlorination of surface water containing organic compounds results in the formation of trihalomethanes (THMs) as indicated by several investigators (Symons et al. 1975; Stevens and Symons 1980; Allgeir et al. 1980). THMs adversely affect human health (Cantor and McCabe 1978; WHO 1984). Chloroform was reported to cause cancer in experimental animals (Bull 1981). Other THMs, based on the structural similarity to chloroform, may be also classified as health hazard compounds (WHO 1984, Parra et al 1986).

Very little is known about the levels of chloroform and THMs in drinking water in Egypt compared to other countries (Trussel et al. 1979).

Drinking water in Cairo is produced by twelve conventional treatments plants which derive raw water from Nile River to yield about 4 millions m^3/day. Chlorination is applied for disnifection. It is added to raw water at a dose of 5 mg/l (pre chlorination) and to the filtered water to reach a concentration of 1.5 mg/l (post chlorination).

The present study aimed to reveal the nature and concentration levels of THMs in drinking water in Cairo and to evaluate the role of chlorination in the formation of THMs.

MATERIALS AND METHODS

Drinking water samples were collected so as to represent the various districts served by the distribution system. Samples collection, preservation, dechlorination by sodium thiosulfate and liquid liquid extraction with n-pentane were carried out according to Standard Methods (1985). Extraction of THMs was

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achieved by transferring a ten-ml portion of the water sample to a clean extraction flask and extracted with 2 ml of n-pentane. The flask was shaked vigorously for one minute and the phases were allowed to separate. The extract was analyzed by injecting 3 ul of the organic phase. Analyses were run using a Perkin Elmer GLC, model 8320, equipped with Ni63 electron capture detector and a data station. The GLC was fitted with a conventional stainless steel column (2 m length and 3.2 mm I.D.) packed with 4% OV-101 and 6% 0V-210 on 80/100 Chromosorp W. The injector and detector temperatures were 230°C and 250°C, respectively. The column temperature was 60°C (isothermal) and nitrogen was the carriergas at a flow rate of 30 ml/min.

Standard reference solutions of chloroform, dichlorobromomethane, chlorodibromomethane and bromoform were prepared in organic free distilled water, and were used for the identification and calculation of their specific concentrations in water samples. Percentage recoveries of standard aqueous solutions of $CHCl_3$, $CHCl_2Br$, $CHClBr_2$ and $CHBr_3$ amounted to 92.9, 88.2, 88.1 and 97.7, respectively.

RESULTS AND DISCUSSION

The mean values of THMs and their distribution in Cairo drinking water are given in Tables 1 to 5. Chloroform ($CHCl_3$), dichlorobromomethane ($CHCl_2Br$), chlorodibromomethane ($CHCl\ Br_2$) and bromoform ($CHBr_3$) constitute the total trihalomethanes (TTHMs). Results obtained reflect the wide variation in the levels of such compounds in water. Chloroform and dichlorobromomethane constituted the major fraction of TTHMs. Such findings are in agreement with that reported by Otson et al (1982). Other THMs were found in trace amounts (Tables 1 and 2). Bromoform was even not detectable in water samples collected during August and September 1989, (Tables 3 and 4).

The maximum contamination level (MCL) proposed by US. Environmental Protection Agency (EPA 1985) for TTHMs is 100 µg/l. The World Health Organization (WHO 1984) recommended a maximum permessible level of 30 µg/l for chloroform in drinking water. The known carcinogenic effects of THMs other than chloroform are limited (Cantor and McCabe 1978). However, they are known to be more active than chloroform in the Ames Salmonella test for mutagenis (WHO 1984). Based on structural similarity of dichlorobromomethane to chloroform, a MCL of 30 µg/l will be arbitary assumed for that THM species in this study. There is strong indication that EPA standards for TTHMs will be lowered (Amy et al. 1991).

Table 1. Mean values of THMs in drinking water during February, 1989.

Sampling Site	No. of samples	THMs species, µg/l					Range of TTHMs µg/l.
		$CHCl_3$	$CHCl_2Br$	$CHClBr_2$	$CHBr_3$	TTHMs	
Al-Dokki	4	51.42	56.29	1.98	5.19	114.9	65.9 - 143.4
El-Mohandsine	2	16.65	23.17	0.38	0.50	40.7	21.6 - 50.8
Boulac Al-Dakrour	7	47.45	32.62	0.86	0.51	81.4	37.9 - 129.6
Embaba	5	40.56	53.22	1.43	0.13	95.3	57.1 - 140.9
Shobra	5	22.04	37.24	1.84	1.60	62.7	22.2 - 112.8
Al-Sayda-Zaynab	8	55.17	65.11	2.43	1.42	124.1	36.4 - 281.6
Al-Abbassia	3	50.98	62.50	2.50	0.74	116.7	89.2 - 161.3
Nassry City	3	30.99	24.70	1.38	3.63	60.7	51.1 - 75.2
Al-Maadi	3	62.81	65.01	2.21	0.59	130.6	126.2 - 134.8
Al-Giza	2	32.11	39.42	1.15	1.35	74.0	46.8 - 101.27
Mean of all samples	42	41.19	45.93	1.60	1.56	90.3	
% of TTHMs		45.60	50.90	1.80	1.70	100.0	

Table 2. Mean values of THMs in drinking water during March 1989.

Sampling Site	No. of samples	THMs species, ug/l.					Range of TTHMs µg/l
		$CHCl_3$	$CHCl_2Br$	$CHClBr_2$	$CHBr_3$	TTHMs	
Al-Dokki	2	44.92	72.45	2.31	0.0	119.6	100.8-138.5
El-Mohandsine	2	21.06	31.59	0.11	0.0	52.7	4.4-101.1
Boulac Al-Dakrour	3	36.22	31.80	0.84	0.61	69.4	37.1- 94.3
Embaba	5	29.93	62.09	1.79	0.37	94.1	57.1-140.9
Shobra	2	22.02	55.88	2.25	0.92	81.1	49.4-112.8
Al-Sayda-Zaynab	2	15.93	48.62	2.18	0.81	67.5	67.0- 68.0
Al-Abbassia	2	47.35	54.13	2.73	2.97	107.1	85.2-129.1
Nassry City	4	31.03	57.65	1.97	0.45	91.1	55.6-174.1
Al-Maadi	2	21.26	42.17	1.10	0.00	64.5	59.9- 69.1
Al-Giza	4	63.14	54.80	1.76	1.04	120.7	71.9-193.1
Mean of all samples	28	33.28	51.12	1.70	0.71	86.8	
% of TTHMs		38.30	58.90	2.00	0.80	100.0	

Table 3. Mean values of THMs in drinking water during August, 1989.

Sampling Site	No. of samples	THMs species, ug/l.				Range of TTHMs µg/l
		$CHCl_3$	$CHCl_2Br$	$CHClBr_2$	TTHMs	
Al-Dokki	3	12.95	11.77	2.87	27.6	18.7-37.6
El-Mohandsine	3	9.32	9.55	2.45	21.3	17.9-25.4
Boulac Al-Dakrour	3	9.89	10.71	2.16	22.7	20.0-27.1
Embaba	9	10.65	9.96	2.44	23.0	15.9-32.2
Shobra	3	5.25	8.20	4.11	17.5	12.9-19.9
Al-Sayda-Zaynab	4	8.33	9.17	3.16	20.6	18.9-21.9
Al-Abbassia	5	11.21	9.56	3.33	24.1	18.3-30.3
Nassry City	3	6.23	8.37	3.38	17.9	11.7-26.4
Al-Maadi	5	9.58	10.91	3.22	23.7	20.3-25.6
Al-Giza	6	10.02	11.33	4.10	25.4	21.4-29.1
Al-Tounsi	2	7.70	9.78	3.20	20.6	19.2-22.1
Mean of all samples	46	9.19	9.98	3.13	22.3	
% of TTHMs		41.2	44.7	14.1	100.0	

Table 4. Mean values of THMs in dirnking water during September, 1989.

Sampling Site	No. of samples	THMs species, ug/l.				Range of TTHMs µg/l
		$CHCl_3$	$CHCl_2Br$	$CHClBr_2$	TTHMs	
Al-Dokki	3	8.30	13.80	4.07	26.2	19.1-36.8
El-Mohandsine	4	10.46	11.33	2.79	24.6	16.8-33.9
Boulac Al-Dakrour	2	6.00	9.69	2.40	18.1	14.8-21.4
Embaba	3	11.73	13.92	3.72	29.4	23.3-34.0
Shobra	7	5.72	9.72	2.80	18.2	10.3-24.1
Al-Sayda-Zaynab	2	7.67	13.37	4.61	25.6	23.5-27.7
Al-Abbassia	7	5.92	9.35	3.78	19.0	15.9-21.8
Nassry City	7	4.20	9.27	4.31	17.8	11.8-25.9
Al-Maadi	3	10.74	13.40	5.11	29.2	22.1-36.3
Al-Giza	4	5.83	11.96	3.99	21.8	13.1-25.6
Al-Tounsi	3	6.30	7.64	2.61	16.5	12.9-21.4
Mean of all samples		7.53	11.22	3.65	22.4	
% of TTHMs		33.60	50.10	16.30	100.0	

Table 5. Distribution of water samples showing THMs species exceeding the MCL during Feb. and March, 1989.

Sampling site	No. of samples tested	No. of samples exceeding MCL of THMs species		
		$CHCl_3$	$CHCl_2Br$	TTHMs
Al-Dokki	6	5	6	4
El-Mohandsine	4	1	2	1
Boulac	10	7	6	3
Al-Dakrour				
Embaba	10	6	8	4
Shobra	7	0	5	1
Al-Sayda-Zaynab	10	6	8	4
Al-Abbassia	5	5	5	2
Nassry City	7	4	5	1
Al-Maadi	5	3	5	3
Al-Giza	6	5	4	3
Total No. of samples	70	42	54	26
% Exceeding MCL		60	77	37

Available results (Tables 1 and 2) reveal that the mean values of chloroform concentrations amounted to 41 and 33 µg/l during February and March 1989, respectively. Meanwhile, $CHCl_2Br$ concentration in drinking water was represented by 45.9 and 51.0 µg/l in samples collected during the same months, respectively. In addition, results given in Table 5 showed that out of 70 samples, the MCL of 100 µg/l for TTHMs was exceeded in 26 water samples during February and March. Chloroform was also present at concentrations exceeding 30 µg/l in case of 42 samples of those collected in the same period. With respect to $CHCl_2Br$ 54 water samples showed concentrations exceeding the arbitary level of 30 µg/l. Results of water samples collected in summer revealed that the concentrations of TTHMs and chloroform were within the permissible levels. Values of TTHMs revealed by the present study approaches those to be found in drinking water in kentucky, USA (Allgeier et al., 1978). However, other investigators recorded much lower values. Trussell et al. (1979) reported a mean value of 15.8 µg/l for TTHMs in several international dirnking waters. In Japan (Kagino and Yagi, 1978), TTHMs ranged between 12.5 and 37.5 µg/l, in Thailand

(Onodera et al., 1980) the mean values was 44.9 µg/l whereas in Sweden a much lower range between 0.2 and 25 µg/l was recorded for TTHMs (Norin and lars 1980). Such variations in THMs levels reflect the effects of different factors controlling the formation of THMs on chlorination of dirnking water (Johnson and Jensen 1986) and the performance of treatment facilities.

Previous studies have shown a relative increase in THMs during summer due to the increase of temperature (Otson et al. 1982) and that THMs formation is temperature dependant (Allgeier et al. 1980). The elevated temeprature may increase the rate of THMs production, although this may be confounded with the increase in partition of THMs from water to air (Lahi et al. 1981). Fayed and Igbal (1985) found no correlation between water temperature (22°C - 35°C) and THMs content of water. In Egypt, water temperature in winter ranges between 15 and 22°C which is 10 times that prevails for mid winter conditions in Europe, which may account for such variation in THMs.

Due to the complexity of the water distribution system which contains 3200 km of pipliens and presence of several by passes connecting the main piplines, it was not possible to relate the water quality to a specific treatment plant in Cairo. Meanwhile, if the THMs standards for dirnking water proposed by EPA, (1983) and WH0 (1984) are implemented in Egypt, it would be necessary to take measures to remove organic precursors or chlorinated organics formed by chlorination.

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