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Evaluation of Trihalomethanes in Water Treatment Plants' Outputs in Cairo, Egypt During 1991 to 1993

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Chlorination of raw surface water containing natural organic substances produces a number of by-products including the trihalomethanes (THMs) chloroform, dichlorobromomethane, chlorodibromomethane and tribromomethane (bromoform) (Symons et al. 1975, Allgeir et al. 1980; Stevens and Symons 1980). Chloroform has been shown to cause cancer in two species of laboratory animal (Bull 1981) and is regarded as a potential cancer risk in man, although the mechanism of carcinogenesis has not yet to be discovered (Dunnick and Melnick 1993).

Chlorine is used in water treatment as a disinfectant. The formation of trihalomethanes (THMs) is largely dependent upon the interaction of chlorine and certain organic substances in the water (e.g. fulvic and humic acids) (Trussell et al. 1978).

Several studies have shown that the formation of THMs depends on several parameters, including the concentrations of total organic carbon (TOC) , bromide ions , water temperature, P^H and chlorine dosage (Stevens and Symons 1980, Rook 1973). The total concentration of the trihalomethanes ($CHCI_3$, $CHCI_2Br$, $CHCl_2Br$ and $CHBr_3$) in drinking water may vary up to 1000 µg/l but it must not exceed 100 µg/l (WHO 1984) .

The aim of this study is to evaluate the concentration levels of chloroform, dichlorobromomethane, chlorodibromomethane, bromoform and total trihalomethanes in water treatment plants outputs in Cairo during 1991 - 1993.

MATERIALS AND METHODS

Drinking water samples were collected every month during 1991 - 1993 from the outputs of 3 water treatment plants in Cairo, including : Mostorod, Tebbin and Rod El - Farag. Drinking water sample collection, preservation, dechlorination by sodium thiosulfate and liquid - liquid extraction with n-hexane were carried out according to standard methods (USEPA 1985). A 20 ml aliquot of sample was placed in a 40 ml bottle. 4 ml of n-hexane were added. The bottle was shake for 25 minutes and the phases were allowed to separate. The extract Was analyzed by injecting 2 ml of the organic phase into a gas chromatograph (GC). Analyses were performed using a Hewlett - Packard GC, Model 5890 A, equipped with Ni 63 electron capture detector, split / splitless injector and HP 763A Autosampler.
A computerized integrator, HP 3396 B Series II. is used for measuring and

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calculating peak areas. The GC was fitted with (25m length and 0.32 mm I.D.) a fused - silica capillary column coated with 0.25 mm film of the stationary phase. The injector and detector temperatures were 180° C and 270° C, respectively, The column temperature was 40° C for 4 min., then increased to 100° C at 10° C / min. and held for 2 minuets. The helium was the carrier gas at a flow rate of 2.5 ml/mm. and the nitrogen was the make up gas at a flow rate of 60 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 $CHCI_3$, $CHCI_2Br$, $CHCl_2Br$ and $CHBr_3$ amounted to 93, 90, 92 and 98, resepctively.

RESULTS AND DISCUSSION

The mean values of the chloroform, dichlorobromomethane, chlorodibromomethane, bromoform and the total trihalomethanes concentrations in the outputs of 3 water treatment plants in Cairo during 1991 - 1993 are given in Tables (1 - 3). Chloroform and dichlorobromomethane constituted the major fraction of the total trihalomethanes (TTHMs). Other THMs were found in small amounts. Bromoform was even not detectable in most of the water samples collected (Tables 1 - 3), 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 permissible level of 30 µg/l for chloroform in drinking water. The known carcinogenic effects of THMs other than chloroform are limited (Cantor and Mc Cabe 1978). However, they are known to be more active than chloroform in the Ames Salmonella test for mutagenis (WHO 1984). Available results (Tables 1-3) reveal that the mean values of chloroform concentrations amounted to 4-25 µg/l. Meanwhile, dichlorobromomethane conc. in drinking water was amounted to 4-21 µg/l in samples collected during 1991-1993. Results of the water samples collected during 1991-1993 revealed that the concs. of TTHMs and chloroform were within the permissible levels.

Trussell et al. (1979) reported a mean value of 15.8 µg/l of TTHMs in several international drinking waters. In Japan (Kagino and Yagi 1978) TTHMs ranged between 12.5 and 37.5 µg/l. In Thailand (Onodera et al. 1984) the mean values was 44.90 µg/l whereas in sweeden a much lower range between 0.2 and 25 µg/l was recorded for TTHMs (Norin and Lars 1980). Such variations in TTHMs levels reflects the effects of different factors controlling the formation of THMs on chlorination of drinking water (Jonson and Jensen 1986). 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 temperature 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). In our study, the results (Tables 1-3) show that no correlation between water temperature (15 - 40° C) and THMs content of water samples. This behaviour is in agreement with the study done by (Fayed and Iqbal 1985).

Table 1. Mean values of THMs in water treatment plants outputs in Cairo during (Sept. 1991 - Dec. 1991).

Date	Sampling Site	THMs Species µg/1				
		$CHC1_3$	$CHC1_2Br$	$CHC1Br_2$	$CHBr_3$	TTHMs
Sept. 1991	Mostord	16.10	15.60	6.60	ND	38.30
	Tebbin	16.70	22.00	8.40	2.9	49.00
	Rod El - Frag	20.40	18.30	7.10	ND	45.80
Oct. 1991	Mostord	15.50	28.80	8.20	ND	52.50
	Tebbin	25.50	24.40	9.70	1.80	61.41
	Rod El - Frag	35.20	17.80	8.30	ND	61.30
Nov. 1991	Mostord	14.00	12.70	5.60	ND	32.30
	Tebbin	16.01	15.95	7.79	ND	39.75
	Rod El - Frag	13.70	10.70	7.30	ND	31.70
Dec. 1991	Mostord	21.10	20.50	7.40	ND	51.00
	Tebbin	18.40	14.80	7.15	ND	40.35
	Rod El - Frag	16.40	16.90	6.90	ND	40.20

Table 2. Mean values of THMs in water treatment plants outputs in Cairo during (Jan. 1992 - August. 1992).

Date	Sampling Site	THMs Species µg/1				
		$CHC1_3$	$CHC1_2Br$	$CHC1Br_2$	$CHBr_3$	TTHMs
Jan. 1992	Mostord	24.50	5.10	2.80	ND	32.40
	Tebbin	16.76	5.12	3.23	ND	25.11
	Rod El - Frag	17.00	6.00	2.50	ND	25.50
Feb. 1992	Mostord	21.20	5.00	2.60	ND	28.80
	Tebbin	16.70	4.80	2.50	ND	24.00
	Rod El - Frag	21.10	4.40	2.40	ND	27.90
March 1992	Mostord	14.40	13.60	5.60	ND	33.60
	Tebbin	17.44	11.20	4.50	ND	33.14
	Rod El - Frag	17.00	12.80	5.20	ND	35.00
April 1992	Mostord	16.39	11.00	2.70	ND	30.09
	Tebbin	16.70	9.70	3.20	ND	29.60
	Rod El - Frag	17.30	11.20	3.30	ND	31.80
May 1992	Mostord	31.70	6.70	2.20	ND	40.60
	Tebbin	33.30	6.70	2.30	ND	42.30
	Rod El - Frag	28.40	7.30	1.50	ND	37.20
August 1992	Mostord	8.55	10.65	1.93	ND	21.13
	Tebbin	8.11	11.50	1.75	ND	21.36
	Rod El - Frag	8.80	9.25	1.35	ND	19.19

Table 3. Mean values of THMs in water treatment plants outputs in Cairo during (Sept. 1992 - Feb. 1993).

Date	Sampling Site	THMs Species µg/l				
		$CHCl_3$	$CHCl_2Br$	$CHClBr_2$	$CHBr_3$	TTHMs
Sept. 1992	Mostord	8.80	9.00	2.44	ND	20.24
	Tebbin	13.30	6.30	2.40	ND	23.00
	Rod El - Frag	8.30	7.90	2.30	ND	19.05
Oct. 1992	Mostord	9.50	7.16	3.69	ND	20.35
	Tebbin	10.12	12.70	6.90	ND	29.72
	Rod El - Frag	15.40	7.00	3.90	ND	26.30
Nov. 1992	Mostord	10.80	10.70	2.80	ND	24.30
	Tebbin	10.60	9.00	3.30	ND	22.90
	Rod El - Frag	10.40	11.30	2.20	ND	23.90
Jan. 1993	Mostord	10.90	12.00	4.80	ND	27.70
	Tebbin	13.30	15.40	6.00	ND	34.70
	Rod El - Frag	14.75	10.80	4.50	ND	30.00
Feb. 1993	Mostord	11.54	7.83	3.88	ND	23.25
	Tebbin	12.80	9.10	4.30	3.30	29.50
	Rod El - Frag	12.20	10.10	3.60	3.20	32.10

ND : not detected.

REFERENCES

Symons JM, Belllar TA, Carswell JK, Marce J, Kroop KL, Robck GG, Stevens AA (1975) National organics reconnaissance survey for halogenated organics . JAWWA, 67:634 - 640

Allgeier GD, Mullins J, Wilding DA, Zogorski JS, Hubbs SA (1980) Trihalomethane levels at selected water utilities in Kentucky, USA. International symposium on the analysis of hydrocarbons and halogenated hydrocarbons. (B.K. Afghan and D. Mackays, editors), Plenum Press, New York, 473 - 490

Stevens AA, Symons JM (1980) Formation and measurment of trihalomethanes in drinking water, control of organic chemical contaminants in drinking Water, USEPA, Cincinnati,Ohio

Bull RJ (1981) Health effects of drinking water disinfectants and disinfectants by-products. Enivron Sci Technol 16:554 - 560

Dunnick J, Meknick R (1993) Assessment of the carcinogenic potential of chlorinated water. J Nat Cancer Inst, 85:817 - 825

Trussell AR, Umphres MD (Nov 1978) The formation of trihalomethanes. J AWWA 70: 604 - 612

Rook JJ (1978) Bromide oxidation and organic substitution in water treatment. J Environ Sci H 13 : 91 - 95

World Health Organisation , WHO (1984) Guidelines for drinking water quality vol 2, WHO Geneva, Switzerland

Standard methods for the examination of water and waste water (1985) 15th ed APHA, New York

Cantor K, Mc Cabe L (1978) The epidemiologic approach to the evaluation of chemicals in drinking water. Proceedings of the Annual Amer Water Works Meeting, Atlantic City, New Jersey USA

Trussell AR, Cromer JL, Umphres MD, Kelly PE, Moncur JM (1979) Monitoring of volatile halogenated organics : A survey of twelve drinking waters from various parts of the world water chlornation : Environmental impact and health effects, vol. 3 Ann Arbor Sci Pupl Ann Arbor Mich

Kagino M, Yagi M (1978) International symposium on the analysis of hydrocarbons and halogenated hydrocarbons. (B.K.Afghan and D. Mackay, editors) Plenum Press, New York, P491 - 502

Onodera S, Schiwong C, Tabucanon M (1984) Comparison of methods for determination of trihalomethanes in drinking water. J Sci Soc Thailand 10:221 - 237

Norin H, Lars R (1980) Determination of trihalomethanes in water using high efficiency solvent extraction. Water Res 14:1397 - 1405

Johnson J, Jensen J (1986) THM and TOX formation, routes, rates and precursors. J AWWA 78 : 156 - 162

Otson R, Willians DT, Bigg DC (1982) Relationship between raw water quality, treatment and occurrence of organics in Canadian potable water . Bull Environ Contam Toxicol 28 : 396 - 403

Lahi U, Batjerk K, Duszelen JV, Gabel B, Stache B, Thieman W(1981) Distribution and balance of volatile halogenated hydrocarbons in the water and air of covered swimming pools using chlorine for water disinfection. Water Res 15: 903-910

Fayed NM, and lqbal S (1985) Analysis of drinking water for the detection of trihalomethanes. Bull Environ Contam Toxicol 35:576 - 583