Bull. Environ. Contam. Toxicol. (1992) 48:157–162

Environmental Contamination and Toxicology

Trihalomethane in Drinking Water Supplies and Reused Water

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Potable water for drinking purposes and other domestic needs in Muscat Area (Capital area of Sultanate of Oman) is obtained from desalination plant and wells. The desalination plant supplies water to 90% of the population based in the area. The water quality is generally maintained in accordance with the specification laid down in "Omani standard for drinking water".

Chlorine is used in water and wastewater treatment primarily as a disinfectant. Trihalomethane (THMs) in water occurs principally as a product of the reaction of chlorine and the naturally occuring organic materials in water. The four most frequently occuring THMs are chloroform ($CHCl_3$), bromodichloromethane ($CHBrCl_2$), dibromochloromethane ($CHBr_2Cl$) and bromoform ($CHBr_3$). The total concentration of these four THMs in drinking water may vary up to 1000 ug/L but it must not exceed 100 ug/L (WHO 1984). Toxicological studies suggest that chloroform and other THMs have detrimental effect on human health (National Cancer Institute 1976; Hogan 1979). THMs in water supplies should be monitored closely so that measures may be taken to minimize or eliminate them whenever concentration approaches levels of concern. Therefore, the aim of this study is to know the levels of THMs in drinking water supplies and reused water in Muscat area.

MATERIALS AND METHODS

Water samples were collected into 20mL headspace vials. The vials were completely filled so that no headspace was left in the bottles. About 100 uL sodium thiosulfate solution (one normal) was added, then they were capped with a teflon septa faced silicone and sealed by crimping the aluminium septum retainer over the lip of the vial. The samples were transferred into the laboratory in ice box. The analysis were carried out immediately after sampling.

The residue levels were determined by the headspace method which was recommended by the Japan Ministry of Health and Welfare (1981). Hewlett Packard 1939 SA Headspace sampler was used at equilibration time of 20 min. The bath and valveloop temperatures were 50 °C, 60 °C, respectively. Helium was used as a purge gas at a flow rate of 20 mL/min. Hewlett Packard gas chromatograph with an electrolytical conductivity detector and stainless steel column of 60/80 carbopack BSP-800, 8'x1/8" O.D. was used to determine the residues. Column temperature was 60 °C for 2 min, then increased to 160 °C at 3°C/min and held for 10 min. the injector and detector temperatures were 100°C and 850 °C respectively.

Standard THMs solutions (1 mL=20ug) already prepared were obtained from Supelco Company. Working standard solutions were prepared by diluting 1 mL to 20 mL with methanol. Calibration standards at a minimum of five concentration levels were prepared by adding different amounts of standard solutions to headspace vials containing 15 mL double distilled water. Those amounts were equivalent to 2,4,6, 8 and 10 ug/L. To varify the calibration standard curve 50 uL of THMs mixture of working standard solutions was daily injected into headspace vial containing 15 mL double distilled water and analysed.

Total organic carbon (TOC) and ammonia (NH_3) were determined by using total carbon analyser (Beckman 915B) and auto kjeldahl analyser (Tecator 1030), respectively, while total suspended solids were examined gravimetrically at 105 °C (APHA 1985).

RESULTS AND DISCUSSION

The residue levels of THMs have been investigated in drinking water samples collected from the main reservoir of Desalination Plant and four distribution reservoirs. $CHCl_3$, $CHBrCl_2$, $CHBr_2Cl$ and $CHBr_3$ were identified and quantified in all samples. Results in Table 1 showed that the concentrations of brominated THMs were much higher than $CHCl_3$. Generally, the residue levels of THMs followed the order $CHBr_3$ > $CHBr_2Cl$ > $CHCl_3$. This order indicates that the concentration of THMs is proportional with bromine content. This finding is related to the presence of bromide in all samples collected during the period of study and ranged between 1.36 and 1.85 mg/L. The relation between the brominated (THMs) and Br-content was investigated and the same finding was observed (Rook 1975; Lahl et al. 1981). The source of bromide in desalinated water was from the chlorination of seawater prior to entry into flush distillation unit. Also bromine itself is carried over in steam and condensed into distillate. Available results (Table 1) revealed slight variations, at given sampling sites, in residue levels of THMs in drinking water samples during the period of investigation. However, considerable variation in concentration do exist according to sampling sites. The highest concentration was found in the samples collected from the main reservoir at Desalination Plant (11.09 ug/L). However, the lowest concentration was detected in the samples collected from Muscat holding reservoir at the end of the drinking water distribution system. Generally, it was noticed that the level of THMs decreased with increase of the distance between the sampling site and the Desalination Plant location.

Table 2 shows the residues of $CHCl_3$, $CHBrCl_2$, $CHBr_2Cl$ and $CHBr_3$ identified in all groundwater samples except in samples collected from well No. 4 where $CHBr_3$ was not detected. In general, residue levels of THMs in groundwater sample followed the order: $CHBr_2Cl > CHBrCl_2 > CHBr_3 > CHCl_3$. The mean concentration of total THMs in groundwater samples ranged between 33.7 and 43.6 ug/L with an average of 39.2 ug/L, while the mean concentration of THMs in desalinated water was 8.5 ug/L and ranged between 6.36 and 10.9 ug/L. It appeared that the residue levels of THMs in groundwater were much higher than those detected in desalinated water. This finding was related to the humic substances which are naturally found in groundwater (CEQ 1980).

The residue levels of total THMs in reused water are represented in Table 3. It was found that the total (THMs) ranged between 10.2 to 99.0 ug/L with mean of 38.4 ug/L. The concentration of THMs increased at higher TOC and pH values. However, it decreased as the ammonia concentration increased. Previous study indicated that the reaction of ammonia with chlorine is of particular importance in the water chlorination treatment processes and the production of chloroamines proceeds very fast compared to other chlorination reactions, (Lietzkel 1978). Urano et al. (1981) found that (THMs) increased linearly with TOC values. However, lower concentration of THMs was detected at higher ammonia concentration (Lahl et al. 1981).

The residue levels of THMs in drinking water are much lower compared with the permissible limits for drinking water (WHO 1984). On the other hand, we found that the level of THMs in Omani drinking water is within the range reported in West Germany (WHO 1984). However, it was much lower than the concentration detected in Australian, Brazilian and USA drinking water (Jolley 1978; WHO 1984).

Table 1. Levels of THMs in desalinated water (ug/L).

Site	Date	CHCl3	CHBrCl2	CHBr2Cl	CHBr3	Total
*		<0.03	<0.05	<0.05	<0.1	<0.1
Main Reservoir	07/01/90	1.20	1.69	1.49	6.59	10.92
	04/02/90	1.30	1.64	1.42	5.17	9.53
	12/03/90	1.48	2.09	2.79	4.46	11.09
Al Qurum Reservoir	07/01/90	1.20	1.69	1.36	4.75	9.00
	04/02/90	1.52	1.62	1.41	4.00	8.55
	12/03/90	1.32	1.85	2.15	3.21	8.36
Wattayah Reservoir	07/01/90	1.20	1.04	1.24	4.32	8.53
	04/02/90	1.36	1.42	1.23	3.40	7.41
	12/03/90	1.13	1.76	1.92	3.14	7.95
Muscat Reservoir	07/01/90	0.42	1.22	1.28	4.06	6.98
	04/02/90	0.50	1.35	1.37	3.14	6.36
	12/03/90	0.50	1.58	1.85	3.90	7.83

*   Double distilled water

Table 2. Levels of THMs in chlorinated groundwater (ug/L).

Site	Date	CHCl3	CHBrCl2	CHBr2Cl	CHBr3	Total
*	07/01/90	<0.03	<0.05	<0.05	<0.1	<0.1
	12/03/90	<0.03	<0.05	<0.05	<0.1	<0.1
Well 1	07/01/90	2.6	10.9	16.2	5.3	35.1
	12/03/90	2.6	14.4	11.7	5.0	33.7
Well 2	07/01/90	3.9	16.6	16.2	4.2	40.9
	12/03/90	4.3	16.4	10.4	3.7	35.0
Well 3	07/01/90	1.3	9.2	16.2	13.3	39.9
	12/03/90	2.6	16.5	13.9	10.6	43.6
Well 4	07/01/90	2.6	16.6	22.0	<0.1	41.6
	12/03/90	3.6	16.7	23.0	<0.1	43.6

*   Unchlorinated sample.

Table 3. The average composition of secondary effluent (mg/L) and the levels of THMs in chlorinated secondary effluent (ug/L).

Site	Date	*TOC mg/L	NH3 mg/L	pH	** T.S.S. mg/L	THMs ug/L
Darsait	12/12/89	25.0	0.3	8.1	14.5	28.9
	03/01/90	18.4	0.2	6.4	14.5	27.8
	06/02/90	25.4	<0.1	8.9	8.2	99.0
	17/03/90	2.1	0.4	7.0	3.0	10.6
Royal Hospital	12/12/89	96.0	23.1	6.8	11.0	65.7
	03/01/90	43.7	31.8	8.2	12.0	41.7
	06/02/90	56.4	26.0	7.5	24.0	52.6
	17/03/90	36.8	15.6	8.4	56.0	17.1
Al Ansab	12/12/89	40.0	5.0	6.4	16.0	44.0
	03/01/90	56.4	26.0	7.5	24.0	52.0
	06/02/90	15.4	11.7	7.1	8.0	10.2
	17/03/90	6.8	2.0	6.4	9.5	8.5

* Total Organic Carbon
** Total Suspended Solids

Acknowledgements. The author expresses his thanks and appreciation to the authorities of the Ministry of Environment in the Sultanate of Oman, for their cooperation. Special thanks are also extended to the staff of Laboratories Department for their support through all stages of the chemical analysis and sampling.

REFERENCES

American Public Health Association (1985) Standard methods for examination of water and wastewater, 16 ed. APHA, Washington, DC

Council of Environmental Quality (1981) Contamination of groundwater by toxic organic chemicals. U.S.Government Printing Office, Washington DC

Hogan MD (1979) Association between chloroform levels in finished drinking water supplies and various site specific cancer mortality rates. J. Environ Pathol Toxicol 2:873-883

Japan Ministry of Health and Welfare (1981) Counterplan for total trihalomethanes in drinking water. Jap J Water Works Assoc 561:76-85

Jolley RL (1978) Water Chlorination environmental impact and health effects Vol 1. Ann Arbor Science, Ann Arbor, Michigan

Lahl U, Batjer K, Duszeln JV, Gabel B, Stachel B and Thelman W (1981) Distribution and balance of volatile halogenated hydrocarbons in water and air covered swimming pools using chlorine for water disinfection. Water Res 15:804-814

Lietzle HM (1978) A Kinetic model for predicting the composition of chlorinated water discharge from power plant cooling systems. In: Jolley RL (ed) Water Chlorination environmental impact and health effect Vol 1. Ann Arbor Science, Ann Arbor, Michigan

National Cancer Institute (1976) Carcinogenesis bioassay of Chloroform. National Cancer Institute, Bethesda, Maryland

Rook JJ (1975) Bromerung Organischer Wassernhaltsotoffe als nabenteaktion der chlrung. Vam Wasser 49:44-46

Urano K, Wada H and Takemasa T (1983) Emperical rate equation for trihalomethane formation with chlorination of humic substances in water. Water Res 17:1797-1802

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

Received August 8, 1990; accepted April 4, 1991.