The Investigation of Total Trihalomethanes Concentration in Drinking Water in Al-Dora and Al-Rasheed plants in Baghdad

Nasma M. Asaad*, Muhamad N. Al-Azzawi, Ahmad J. Mohammed
Department of Biology, College of Science, University of Baghdad, Baghdad, Iraq.

Abstract
During period from September 2012 to August 2013, concentration of total Trihalomethanes (TTHMs) was assessed in drinking water in Al-Dora and Al-Rasheed purification plants. 216 samples were collected from final basins of chlorination in purification plants and from sites that distributed among residential areas fed by the project. TTHMs concentration did not exceed (0.15 ppm) which is the maximum limits according to Iraqi standard specification for drinking water. The highest value was in July (0.12 ppm) and the lowest value was in November (0.01 ppm).

Keywords: Total Trihalomethanes (TTHMs), disinfection by-products (DBPs), Drinking water.

التحري عن تراكيز ثلاثي الهالوميثانات الكلية في مياه الشرب في محطتي الدورة والرشيد في بغداد

نسمة مهران أسعد*، محمد نافع العزاوي، احمد جاسم محمد
[1] قسم علوم الحياة، كلية العلوم، جامعة بغداد، بغداد، العراق.

الخلاصة
أجريت الدراسة للتحري عن ثلاثي الهالوميثانات الكلية في الفترة الممتدة من أيلول 2012 ولغاية آب 2013 والتي شملت كل من محطتي تصفية الدورة والرشيد 216 عينة جمعت من الخزانات النهائية للمياه المعقمة بعد اضافة الكلور في محطات التصفية وكذلك من مواقع تُغذى من المحطة توزعت على مسافات مختلفة. لم تتجاوز النتائج الـ 0.15 جزء من المليون وهوالحد الأعلى المسموح به وفقاً للمواصفة العراقية لمياه الشرب ، إذ كانت أعلى قيمة قد سجلت في تموز 0.12 جزء من المليون وأقل قيمة سجلت في تشرين الثاني 0.01 جزء من المليون.

Introduction

Drinking water disinfection is one of the most significant public health advances of the 21st century. Methods have been used for drinking water disinfection varied (e.g. chloramination, ozonation, chlorine dioxide, and ultraviolet irradiation) [1]. Although disinfection by chlorine eliminates waterborne pathogens, it has the ability to interact with natural organic matter (NOM) and form halogenated and non-halogenated disinfection by-products (DBPs) [2- 5]. The trihalomethanes (THMs) and halo acetic acids (HAAs) are the most abundant classes of DBPs present in treated water [6, 7]. Chloroform is the most common THM and the principal disinfection by-product in chlorinated drinking water. It is assumed that most THMs present in water are ultimately transferred to air as a result of their volatility. Individuals may be exposed to chloroform during showering to elevated concentrations from chlorinated tap water. For the volatile THMs, approximately equal contributions

*Email:nasma_sn@yahoo.com

to total exposure come from four areas: ingestion of drinking water, inhalation of indoor air largely due to volatilization from drinking water, inhalation and dermal exposure during showering or bathing and ingestion of food, with all but food exposure arising primarily from drinking water. Indoor air exposure to the volatile THMs is particularly important in countries with low rates of ventilation in houses and high rates of showering and bathing [5, 8, 9]. Chloroform has been classified by International Agency for Research on Cancer (IARC) as possibly carcinogenic to humans based on limited evidence of carcinogenicity in humans but sufficient evidence of carcinogenicity in experimental animals [10-13].

IARC has classified Bromodichloromethane BDCM as possibly carcinogenic to humans. BDCM gave both positive and negative results in a variety of in vitro and in vivo genotoxicity assays. In an NTP bioassay, BDCM induced renal adenomas and adenocarcinomas in both sexes of rats and male mice, rare tumors of the large intestine in both sexes of rats and hepatocellular adenomas and adenocarcinomas in female mice. However, BDCM was negative for carcinogenicity in a recent NTP bioassay in which it was dosed in drinking water. Exposure to BDCM has also been linked to a possible increase in reproductive effects increased risk for spontaneous abortion or stillbirth [5, 7, 9].

Many factors affecting THMs formation, including: dissolved organic nitrogen DON, Bromide level Br^-, Chlorine dose, Reaction time or contact time, Temperature/ season, pH [14-17].

There are many studies that dealt with this paper subject such as Kutty *et al.*, 1995; Hong *et al.*, 2007; Colman *et al*., 2011; Parvez *et al*., 2011; Xu *et al.,* 2011; Yamamoto, 2011,and Lyon *et al*., 2012.

Materials and methods

The test was conducted depending on USEPA method 551.1 [18], for determination of four THMs, chloroform ($CHCl_3$), bromodichloromethane ($CHBrCl_2$), dibrochloromomethane ($CHBr_2Cl$), bromoform ($CHBr_3$) as total trihalomethanes (TTHMs).

Gas chromatography with electron capture detector, headspace techniques HS/GC/ECD, N_2 carrier gas 30 ml/min, column with 0.25 mm diameter and 60 m in length, was used for this test. 216 samples were collected by glass bottles 25 ml with plastic screw caps and Teflon rubber, by filling the bottle completely without any bobbles, cooled at 4°C. In the laboratory, 10 ml of each sample was filled into 20 ml headspace vials and closed with a screw cap with Polytetrafluoroethylene PTFE/silicone septa, headspace supplied with heating auto sampler which provide high temperature for evaporate THMs compounds reach to 200°C. TTHMs calculated in part per billion ppb unite and converted to ppm unit.

The samples were collected from the study areas from September 2012 until August 2013 where coverage Al-Dora and Al-Rasheed plants. The samples were collected from sites were distributed among residential areas fed by the plants. Distribution based on the division of the area equipped with water to equal-dimensional squares as far as possible and as the number of samples possible withdrawn to cover plants, the alleys covered al-Dora plant is: S_1 Final basins of after chlorination within the plant, S_2 804, S_3 812, S_4 818, S_5 820, S_6 826, S_7 842, S_8 848, S_9 834, S_{10} 846 and S_{11} 850.
Alleys covered al-Rasheed plant is: S_1 Final basins of after chlorination within the plant S_2 949, S_3 953, S_4 957, S_5 977, S_6 961 and S_7 965 figure-1.

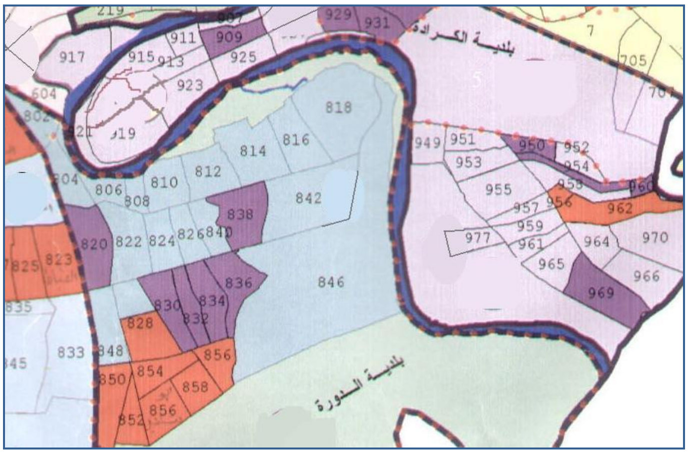

Figure 1- The covered alleys that fed from al-Dora and al-Rasheed plants.

Results and Discussions

Results showed an increase in the values of THMs which ranged between (0.01 – 0.12 ppm) with high summer temperatures which ranged between (15 – 28°C) for water temperature at sampling time and between (12 - 21°C) in the laboratory at examination time, and also increase high proportion of TOC in winter which ranged between (0.32 – 3.9 ppm), but the biggest rise significantly was in summer figure-2, 3, table-1, 2.

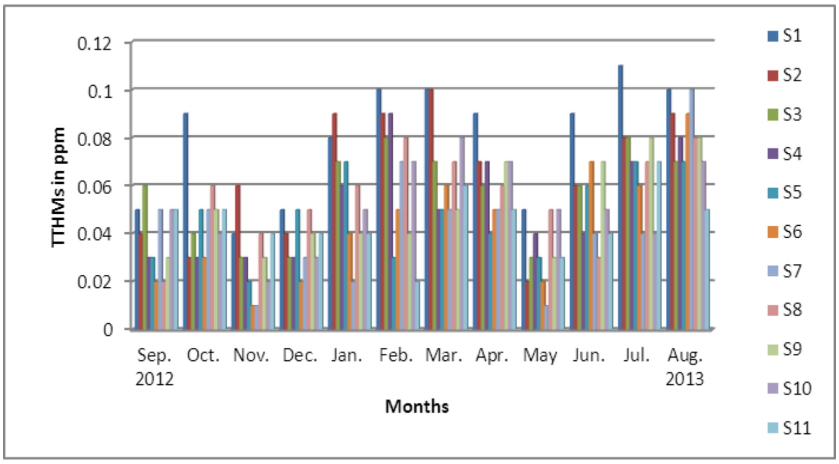

Figure 2- shows monthly variations of TTHMs values in ppm of Al-Dora drinking water in study area from Sep. 2012 – Aug. 2013

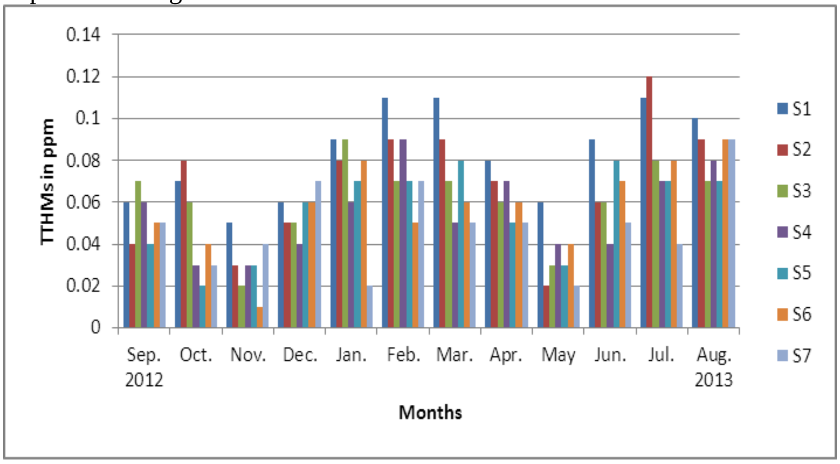

Figure 3- shows monthly variation of TTHMs values in ppm of Al-Rasheed drinking water in study area from Sep. 2012 – Aug. 2013

Table 1- Monthly variation of TTHMs concentration in ppm of Al-Dora plant drinking water

	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr	May	Jun.	Jul.	Aug.
S1	0.05	0.09	0.04	0.05	0.08	0.1	0.1	0.09	0.05	0.09	0.11	0.1
S2	0.04	0.03	0.06	0.04	0.09	0.09	0.1	0.07	0.02	0.06	0.08	0.09
S3	0.06	0.04	0.03	0.03	0.07	0.08	0.07	0.06	0.03	0.06	0.08	0.07
S4	0.03	0.03	0.03	0.03	0.06	0.09	0.05	0.07	0.04	0.04	0.07	0.08
S5	0.03	0.05	0.02	0.05	0.07	0.03	0.05	0.04	0.03	0.06	0.07	0.07
S6	0.02	0.03	0.01	0.02	0.04	0.05	0.06	0.05	0.02	0.07	0.06	0.09
S7	0.05	0.05	0.01	0.03	0.02	0.07	0.05	0.05	0.01	0.04	0.04	0.10
S8	0.02	0.06	0.04	0.05	0.06	0.08	0.07	0.06	0.05	0.03	0.07	0.08
S9	0.03	0.05	0.03	0.04	0.04	0.04	0.05	0.07	0.03	0.07	0.08	0.08
S10	0.05	0.04	0.02	0.03	0.05	0.07	0.08	0.07	0.05	0.05	0.04	0.07
S11	0.05	0.05	0.04	0.04	0.04	0.02	0.06	0.05	0.03	0.04	0.07	0.05

Table 2- Monthly variation of TTHMs concentration in ppm of Al-Rasheed plant drinking water

	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr	May	Jun.	Jul.	Aug.
S1	0.06	0.07	0.05	0.06	0.09	0.11	0.11	0.08	0.06	0.09	0.11	0.1
S2	0.04	0.08	0.03	0.05	0.08	0.09	0.09	0.07	0.02	0.06	0.12	0.09
S3	0.07	0.06	0.02	0.05	0.09	0.07	0.07	0.06	0.03	0.06	0.08	0.07
S4	0.06	0.03	0.03	0.04	0.06	0.09	0.05	0.07	0.04	0.04	0.07	0.08
S5	0.04	0.02	0.03	0.06	0.07	0.07	0.08	0.05	0.03	0.08	0.07	0.07
S6	0.05	0.04	0.01	0.06	0.08	0.05	0.06	0.06	0.04	0.07	0.08	0.09
S7	0.05	0.03	0.04	0.07	0.02	0.07	0.05	0.05	0.02	0.05	0.04	0.09

Table-4 Contains TTHMs means values ± SD of both Al-Dora and Al-Rasheed plant drinking water samples examined, the highest mean values ± SD was in August with 0.08 ± 0.014832 ppm and 0.084286 ± 0.011339 ppm respectively and the lowest mean value was in November with 0.03 ± 0.014832 ppm and 0.03 ± 0.01291 ppm respectively.

Table 4- TTHMs means values ± SD in ppm of al-Dora and Al-Rasheed drinking water in study area from Sep. 2012 – Aug. 2013

Stations / months	Al-Dora drinking water	Al-Rasheed drinking water
Sep. 2012	0.039091 ± 0.013751	0.052857 ± 0.011127
Oct.	0.047273 ± 0.017373	0.047143 ± 0.022887
Nov.	0.03 ± 0.014832	0.03 ± 0.01291
Dec.	0.037273 ± 0.01009	0.055714 ± 0.009759
Jan.	0.056364 ± 0.020627	0.07 ± 0.024495
Feb.	0.065455 ± 0.026595	0.078571 ± 0.019518
Mar.	0.067273 ± 0.019022	0.072857 ± 0.022147
Apr.	0.061818 ± 0.014013	0.062857 ± 0.011127
May	0.032727 ± 0.013484	0.034286 ± 0.013973
Jun.	0.055455 ± 0.017529	0.064286 ± 0.017182
Jul.	0.07 ± 0.019494	0.081429 ± 0.026726
Aug. 2013	0.08 ± 0.014832	0.084286 ± 0.011339

The statistical analysis of TTHMs of Al-Dora plant drinking water show high significant differences found at (LSD = 0.014608 at $P \geq 0.05$) between the year months table-5.

While the statistical analysis of TTHMs means of drinking water shown high significant differences found at (LSD = 0.019062 at $P \geq 0.05$) between the year months table-6.

Table 5- The differences test between the means of TTHMs of Al-Dora plant drinking water in study area from Sep. 2012 – Aug. 2013.

	Nov.	May	Dec.	Sep. 2012	Oct.	Jun.	Jan.	Apr.	Feb.	Mar.	Jul
Aug. 2013	**0.05**	**0.047273**	**0.042727**	**0.040909**	**0.032727**	**0.024545**	**0.023636**	**0.018182**	0.014545	0.012727	0.01
Jul.	**0.04**	**0.037273**	**0.032727**	**0.030909**	**0.022727**	0.014545	0.013636	0.008182	0.004545	0.002727	
Mar.	**0.037273**	**0.034545**	**0.03**	**0.028182**	**0.02**	0.011818	0.010909	0.005455	0.001818		
Feb.	**0.035455**	**0.032727**	**0.028182**	**0.026364**	**0.018182**	0.01	0.009091	0.003636			
Apr.	**0.031818**	**0.029091**	**0.024545**	**0.022727**	0.014545	0.006364	0.005455				
Jan.	**0.026364**	**0.023636**	**0.019091**	**0.017273**	0.009091	0.000909					
Jun.	**0.025455**	**0.022727**	**0.018182**	**0.016364**	0.008182						
Oct.	**0.017273**	0.014545	0.01	0.008182							
Sep. 2012	0.009091	0.006364	0.001818								
Dec.	0.007273	0.004545									
May	0.002727										

Table 6- The differences test between the means of TTHMs of Al-Rasheed plant drinking water in study area from Sep. 2012 – Aug. 2013.

	Nov.	May	Oct.	Sep. 2012	Dec.	Apr.	Jun.	Jan.	Mar.	Feb.	Jul.
Aug. 2013	**0.054286**	**0.05**	**0.037143**	**0.031429**	**0.028571**	**0.021429**	**0.02**	0.014286	0.011429	0.005714	0.002857
Jul.	**0.051429**	**0.047143**	**0.034286**	**0.028571**	**0.025714**	0.018571	0.017143	0.011429	0.008571	0.002857	
Feb.	**0.048571**	**0.044286**	**0.031429**	**0.025714**	**0.022857**	0.015714	0.014286	0.008571	0.005714		
Mar.	**0.042857**	**0.038571**	**0.025714**	**0.02**	0.017143	0.01	0.008571	0.002857			
Jan.	**0.04**	**0.035714**	**0.022857**	0.017143	0.014286	0.007143	0.005714				
Jun.	**0.034286**	**0.03**	0.017143	0.011429	0.008571	0.001429					
Apr.	**0.032857**	**0.028571**	0.015714	0.01	0.007143						
Dec.	**0.025714**	**0.021429**	0.008571	0.002857							
Sep. 2012	**0.022857**	0.018571	0.005714								
Oct.	0.017143	0.012857									
May	0.004286										

The existence of DBPs in drinking water may lead to potential human health risks and many of the DBPs have been classified as carcinogens, its formation varies greatly with quality of source water, such as concentrations and properties of TOC as well as the chlorination conditions including chlorine dose, contact time, temperature and pH [19- 25]

TTHMs concentrations did not exceed (0.15 ppm), the maximum limits according to Iraqi standard specification for drinking water's [26]. High values of TTHMs in summer rather than winter despite the convergence of the TOC values due to the larger amount of chlorine that added in summer which increases the probability of DBPs and accordingly TTHMs formation, because higher temperatures

may promote chlorination reaction rates and longer reaction time may lead to complete and higher production of TTHMs. Generally, types of organic material in water such as humic and fulvic acids played an important role in determining THMs formation [27- 30].
The results of this study agree with [1, 3, 21, 31-33].

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