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Assessment of disinfection by-products levels in Aga surface water plant and its distribution system, Dakhlia, Egypt

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Abstract

Chlorine is the most common disinfectant used in drinking water that can reacts with naturally occurring organic matter to form a number of chemical byproducts as trihalomethanes (THMs). The aims of the present study are to investigate the levels of THMs in Aga surface water plant (ASWP) and its distribution system (DS)during the period between spring 2015 and winter 2016 as well as its levels in tanks in August 2015. Drinking water samples were collected from ASWP, in addition to4 sites away from the plant at different distances. Other parameters as temperature and residual chlorine were measured. The maximum concentrations of THMs in ASWP were detected during summer, 2015 while the minimum concentrations were recorded during autumn 2015. While in DS, the maximum value recorded atsite 4. Generally, all values of THMs during the study lies within the limits of the Egyptian standards 458 decreed in 2007.

Keywords: Water quality, THMs, organic matter, Aga, water plant.

Introduction

The main consideration in ensuring the safety of public water supplies is the elimination of the agent of waterborne infectious disease. To get rid of drinking water harmful bacteria, viruses and parasites, purification with an oxidizing agent is necessary **(Baird, 1997).**The goal of disinfection in current water treatment practice is to maximize protection from bacterial contamination while minimizing the formation of disinfection by- products. Disinfection methods may be physical or chemical methods. Physical methods include heat treatment and ultraviolet (UV) irradiation. While chemical methods include the addition of ozone, or most commonly chlorine and its derivatives **(WHO, 1998).**Therefore, chlorine is one of the most important disinfectants that can be used in drinking water systems for both primary and secondary disinfections. Chlorine is an oxidizing agent that reacts rapidly with organic and inorganic matter present in water**(WHO, 1996).** Unfortunately, natural organic matter (NOM) in water reacts with chlorine to form THMs as disinfection by-products (D-BPs) (**Zimoch, 2014**). However, the presence of THMs in chlorinated drinking water and their lifetime exposure on humans have raised a great concern due to its carcinogenicity and recognition as potential risk to human health (**Zimoch, 2010**).These compounds are consumed during drinking, showering, bathing, and swimming through three routes: ingestion, contact with skin, and inhalation(**Iszatt, 2011**).

Chloroform ($CHCl_3$), bromoform ($CHBr_3$), bromodichloromethane ($CHCl_2Br$), and dibromochloromethane ($CHClBr_2$) are the four compounds belonging to the group of THMs **Crittenden *et al.*, 2012).** However, the kinetics of the formation of THMs depends on many factors. The most well-known of them are water pH and temperature, contact time, residual chlorine, seasonal fluctuations, NOM concentration, flow rate, and construction and management of the drinking water supply system (**Edzwald *et al.*, 2011).**

So the main objective of the present study aims to investigate the concentration of THMs and its groups in ASWP and its distribution systems and comparing it seasonally and also investigate some microbiological activities that have a direct effects on water quality, and consequently the human health.

Materials and Methods

1- Study area:

Aga surface water Plant (ASWP), distribution system and associated tanks:

ASWP (Fig. 1) locates in Aga City, Dakahlia Governorate. The plant was constructed in March2015 to meet the requirements of Aga City population from drinking water. Water samples were collected monthly from ASWP between spring 2015 and winter 2016. Additional samples were collected from different 5 sites that depend on Aga water plant for drinking and other daily needs. The selected sites were away from the plant at different distances located at 500m, 1.2Km, 3.5 Km, 5km from the plant for the 4 chosen sites, respectively. Moreover, water samples from associated tanks used for storage purpose of drinking water were also taken. Samples of tanks collected in Agust,2015 from the same areas in distribution system.

2- Chemical analyses:

For THMs detection, GC Varian Cp- 3800 with ECD and column Cp- sil 19 were used to determine the concentrations of THMs groups comprised $CHCl_3$, $CHCl_2Br$, $CHClBr_2$ and $CHBr_3$ according to **USEPA (1998).** Other parameters as temperature and residual chlorine were measured in the field by using a mercury thermometer of the range (0 – 100 °C) and DPD Lovibond MD-100, respectively (APHA, 2012)

Fig (1): Aga surface water plant.

Results

The data presented in (Table 1) show the seasonal variations in concentrations of disinfection by-products (THMs) and TOC levels as well as total and initial chlorine doses applied and residual chlorine in ASWP.

Table (1): Seasonal variation of D-BP, TOC, THMs and Chlorine dose in ASWP during spring, 2015 to winter, and 2016.

THMs / Seasons	TOC (ppm)	THMs (ppb)				Total THMs (ppb)	Chlorine dose		R. chlorine (ppm)
		$CHCl_3$	DCBM	DBCM	$CHBr_3$		Initial	Total	
Spring	**4.26**	**40.08**	**11.41**	**N.D**	**N.D**	**51.49**	**7.4**	**8.63**	**2**
Summer	**5.13**	**45.67**	**18.93**	**N.D**	**N.D**	**64.6**	**7.4**	**8.94**	**1.8**
Autumn	**4.08**	**22.13**	**12.61**	**N.D**	**N.D**	**34.74**	**4.93**	**6.16**	**2**
Winter	**4.13**	**26.75**	**12.23**	**N.D**	**N.D**	**38.98**	**6.78**	**7.62**	**2.1**
Average ± SD	**4.4 ± 0.49**	**33.6 ± 11.4**	**13.8 ± 3.45**	**-**	**-**	**47.45 ± 13.46**	**6.6 ± 1.16**	**7.83 ± 1.25**	**1.97 ± 0.12**

THMs levels averaged during study period 66 ±1.16, with a mean maximum value of 64.6ppb recorded in summer 2015, declined sharply to the minimum level of34.74ppb measured in autumn 2015. While the highest level of TOC was 5.13 ppm detected in summer and the lowest one was 4.08 ppm, recorded in autumn of the same year, with an average 4.4 ± 0.49 throughout the year. While as, chloroform ranged from 22.13 to 45.67 ppb, showing the minimum value in autumn 2015 and the maximum one in summer 2015. These values showed remarkable decline in Dichlorobromomethane (DCBM) which ranged from 11.41 – 18.93 ppb, with minimum values in spring and the maximum one in the following summer 2015.In contrast, DBCM (Dibromochloromethane) and Bromoform were N.D**.**

On the other hand**,** the maximum dose of Chlorine applied in summer 2015 and the minimum dose was applied in the following autumn 2015. These doses ranged between 6.16 and 8.94 mg/L. Noteworthy, residual chlorine ranged between 1.8 and 2.1 ppm in the outlet of ASWP.

Statistical analysis showed that there was positive correlations between both of temperature and THMs (r= 0.85) and also between THMs and chlorine dose (r= 0.89). Also the regression analysis has a strong relationship between THMs and chlorine dose (R^2 = 0.8). (Fig. 2)

On the other hand, data mentioned in (Tables 2, 3) exhibited seasonal variations in levels of disinfection by-products (THMs), TOC levels and residual chlorine recorded at Aga distribution systems (DS). These data showed that, THMs levels were slightly higher than those recorded at ASWP, and ranged between 37.59 – 72.76, 38.98 – 79.52, 45.78 – 81.69 and 57.77 – 86.79 ppb at the four chosen sites (1-4), respectively. The maximum value recorded in summer at site 4, while the minimum value recorded in autumn at site 1. On the other hand, the values of TOC were similar to that recorded at ASWP, and were nearly stable at the selected sites, ranged between 4.1 – 5.11, 4.08 – 5.13, 4.09 – 5.18 and 4.08 – 5.16 ppm at these sites (1-4), respectively, with the maximum value in summer at site 4(3) and minimum one in winter and autumn at sites 2 and 4, respectively. Generally, the maximum average of THMs throughout the year recorded at site 4 (69.69 ± 12.4), while the minimum average recorded at site 1 (50.9 ± 16.36).

Table (2): Seasonal variation of D-BP, TOC, THMs and residual chlorine in DS during spring, 2015 to winter, and 2016.(Area1 and 2).

Sites	Site 1							Site 2						
THMs / Seasons	TOC (ppm)	THMs (ppb)				Total THMs	R.Chlorine (ppm)	TOC (ppm)	THMs (ppb)				Total THMs	R. chlorine (ppm)
		$CHCl_3$	DCBM	DBCM	$CHBr_3$				$CHCl_3$	DCBM	DBCM	$CHBr_3$		
Spring	4.25	41.12	12.9	N.D	N.D	54.1	1.6	4.28	41.57	14.57	N.D	N.D	55.62	1.4
Summer	5.11	43.14	19.87	N.D	9.75	72.76	1.5	5.13	71.29	8.23	N.D	N.D	79.52	1.5
Autumn	4.1	24.14	13.45	N.D	N.D	37.59	1.5	4.08	26.28	12.7	N.D	N.D	38.98	1.4
Winter	4.1	25.63	13.8	N.D	N.D	39.16	1.5	4.08	50.76	N.D	N.D	N.D	50.76	1.4
Average ± SD	4.39 ± 0.48	33.5 ± 10	15 ± 3.26	-	2.4 ± 4.8	50.9 ± 16.36	1.52 ± 0.05	4.39 ± 0.5	47.47 ± 18.8	11.8 ± 3.25	-	-	56.22 ± 17	1.42 ± 0.05

Table (3): Seasonal variation of D-BP, TOC, THMs and residual chlorine in DS during spring, 2015 to winter, and 2016.(Area3 and 4).

Sites	Area 3							Area 4						
THMs / Seasons	TOC (ppm)	THMs (ppb)				Total THMs	R. Chlorine (ppm)	TOC (ppm)	THMs (ppb)				Total THMs	R. Chlorine (ppm)
		CHCl3	DCBM	DBCM	CHBr3				CHCl3	DCBM	DBCM	CHBr3		
Spring	4.26	43.08	15.41	N.D	N.D	58.49	1.2	4.26	49.78	19.97	N.D	N.D	69.75	1.2
Summer	5.18	59.3	22.39	N.D	N.D	81.69	1.3	5.16	65.43	21.36	N.D	N.D	86.79	1.1
Autumn	4.09	37.82	19.95	N.D	N.D	45.78	1.3	4.08	37.82	19.95	N.D	N.D	57.77	1.2
Winter	4.09	39.61	17.1	N.D	N.D	56.71	1.3	4.08	64.45	N.D	N.D	N.D	64.45	1.2
Average ± SD	4.4 ± 0.52	44.9 ± 9.8	18.71 ± 3.08	-	-	60.66 ± 15	1.2 ± 0.05	4.39 ± 0.51	54.37 ± 13.15	20.42 ±0.8	-	-	69.69 ± 12.4	1.17 ± 0.05

The present results showed that, chloroform recorded the highest levels of D-BPs, and ranged from 24.14 – 43.14, 26.28 – 71.29, 39.61 – 59.3 and 37.82 – 65.43 ppb at sites 1-4, respectively, with the maximum value at site 2 in summer, and the minimum value at area1 in autumn. For dichlorobromomethane (DCBM), the data ranged between 13.45 – 19.87, N.D – 14.57, 15.41 – 22.39 and N.D – 21.3 ppb atsites 1-4, respectively, and the maximum value recorded in summer at site 3. It reached to non detected (N.D.) in winter at sites 2 and 4. The values of DBCM and Bromoform were N.D in all areas except at site 1 while it recorded 9.75ppb.

Generally, the highest mean level of THMs averaged 69.69 ppb recorded at site 4, while it has minimum level (50.9 ppb) recorded at site 1. But the values of residual chlorine measured averaged 000+000 and ranged between 1.1 – 1.6 ppm at all sites.

According to data presented in table (4) show that the levels of THMs at 4 tanks used for water storage for human purpose. These results indicated to high levels of THMs higher than that recorded at plant and distribution systems. These data ranged from 89.62 – 149.8 ppb as total THMs. During these study, the mean value of THMs from the three (3)tanks, exceed permissible limits set by EMH/20117 and WHO (100 ppb).

Table (4): Seasonal variation of D-BP, TOC, THMs and residual chlorine in tanks during spring, 2015 to winter, and 2016.

Items / Tanks	TOC (ppm)	THMs					Risedual chlorine (ppm)
		Chloroform (ppb)	DCBM ppb	DBCM (ppb)	Bromoform (ppb)	Total THMs (ppb)	
Tank 1	**4.54**	**58.32**	**31.1**	N.D	N.D	89.62	**0.5**
Tank 2	**5.04**	**63.25**	**38.75**	N.D	**9.79**	**111.79**	**0.4**
Tank 3	**5.08**	**72.4**	**39.81**	N.D	N.D	**112.21**	**0.4**
Tank 4	**5.18**	**83.98**	**55.38**	**9.72**	N.D	**149.8**	**0.3**

On the other hand, levels of chloroform ranged between 58.32 – 10.34 ppm, 31.3 – 55.38 and. For DCBM, it varied for non detected (N.D.) and varied from N.D – 9.72 ppb for DBCM and N.D – 9.79 for Bromoform. While the mean values of TOC fluctuated between 4.54 – 5.18 ppm. The residual chlorine was very low and ranged between (0.3 – 0.7) ppm.

Regression analysis confirmed the presence of strong relation between THMs and its contact time in distribution system (R_2 = 0.93) (Fig.2).

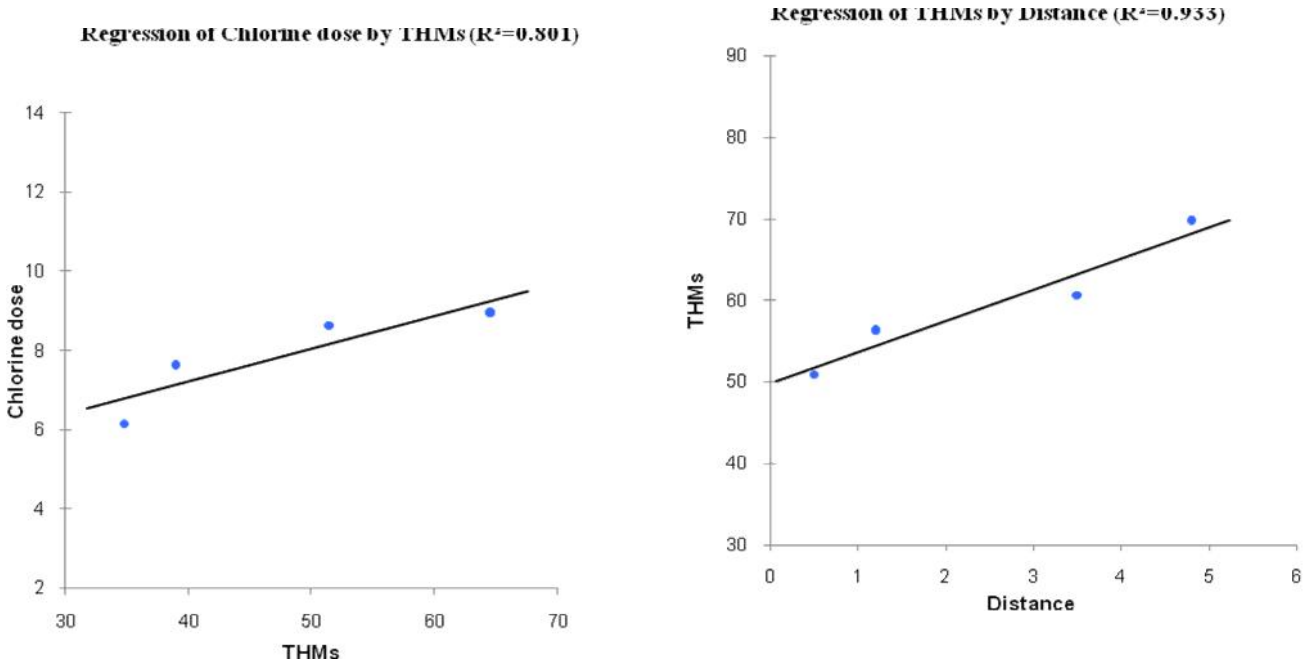

Fig (2): Effect of Chlorine dose and Distances(Contact time) on THMs formation

Discussion

THMs is one of the disinfection by-products that produces from the reaction between chlorine and natural organic matter. The kinetics of formation of THMs depends on many factors. The most well known of them are water temperature, contact time, residual chlorine, seasonal fluctuation, NOM concentration, flow rate, and construction and management of the drinking water supply system (**Edzwald *et al*., 2011).**

According to the permissible limits of WHO and the Egyptian Ministry of Health Standards (458/2007), the limits of THMs must not be exceed 100ppb. Consequently all values that measured in ASWP and DS are within the permissible limits. The maximum value recorded in summer and this agrees with a lot of studies as **Rizzo *et al*. (2005), Parvez *et al*.,(2011), and Hassan *et al*.,(2015).** While the minimum value recorded in autumn but this is different from the results obtained by **Hassan *et al*. (2015** who recorded the lowest value in winter. This may be related to cleansing process of water plant that measured in November, 2015 where was the plant discharged completely from water.

It was observed that concentrations of THMs had increased in DS than ASWP and with increasing the distance form the water plant. The concentration of THMs increased to the maximum value recorded in the farthest point. This is due to an increasing in contact time between chlorine and organic compounds as reported **by Hassouna, *et al.* (2013)**who referred the increasing of THMs concentration to the long contact between the free chlorine and natural organic matter in the distribution system. This is the reason for decreasing of residual chlorine in DS specially in the last point in the network as a result of interaction between chlorine and any contaminants in the sources of water supply. The regression analysis showed a strong relation between THMs and its contact time.

For tanks, the values of THMs exceed the permissible limit in tanks 2-4, while these values lay within the limits in tank 1. These may be attributed to some factors as increasing in contact time and also lack of cleanliness of tanks. Consequently, residual chlorine decreased to range between 0.3 – 0.5 ppm which means consumption of chlorine dose in the elimination of pollutants. This lead to increasing of THMs levels so much so overcome the permissible limits. This is identical to that mentioned by **Hassouna, *et al*., (2013).**

Also Statistical analyses showed that a positive correlation between temperature and THMs (0.85) and this is confirmed by **Edzwald *et al*.,(2011)** who concluded in their paper the presence of strong relation between THMs and temperature.

Conclusion

Present study showed significance variations in THMs concentrations between the four seasons. All measured samples were complying with the Egyptian standard (Ministerial Decree No.458/2007) and WHO (2012) standards and for drinking water samples, except collected from tanks. It is recommended to clean thanks from time to time and also continuation of follow up the levels of THMs in distribution systems.

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