



Improvement of Water Quality to Reduce the Formation of Hazardous Disinfection By- Products Compounds

**A Thesis Submitted for the degree of Master of Science as
a partial fulfilment for requirements of the Master of Science**

By

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(B.Sc. in Chemistry)**

**Department of Chemistry
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Cairo, Egypt
2015**



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LIST OF ABBREVIATION

No.	Abbreviations	Meaning
1	DBPs	Disinfectant By-Products
2	THMs	Trihalomethanes
3	HAAs	Haloacetic Acids
4	TOC	Total Organic Carbon
5	WHO	World Health Organization
6	km	Kilometer
7	TDS	Total Dissolved Solids
8	NOM	Natural Organic Material
9	HAAs	Haloacetic Acids
10	WTPs	Water Treatment Plants
11	NOM	Natural Organic Material
12	DOC	Dissolved Organic Carbon
13	UV	Ultraviolet Irradiation
14	HANs	Haloacetonitriles
15	EPA	Environmental Protection Agency
16	OSE	On-Site Electrochlorination
17	DCAA	Dichloro-Acetic Acid
18	TCAA	Trichloro-Acetic Acid
19	mm	Millimeter
20	µm	Micrometer
21	MTBE	Methyl-Tert-Butyl-Ether
22	min	Minute

List of Abbreviation

23	μL	Micro Litre
24	$\mu\text{g/l}$	Microgram per Litre
25	mg/l	Milligram per Litre
26	IC	Ion Chromatography
27	BDCM	Bromodichloromethane
28	CHCl_3	Chloroform
29	CHBr_3	Bromoform
30	DBCM	Dibromochloromethane
31	ppm	Part per Million
32	GC	Gas Chromatography

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Research Article

Open Access

Seasonal Variation of Trihalomethanes Levels in Greater Cairo Drinking Water

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Abstract

The formation of carcinogenic Trihalomethanes (THMs) in the process of water disinfection by chlorine has raised concerns in the scientific community. This study aims to determine the levels of THMs in Greater Cairo drinking water over year of the study and compare it with the regulation in the Egypt law (458/2007), and the World Health Organization. The THMs concentration was measured in five different locations during 2014. The results indicate that the seasonal variation is below the critical values stipulated in the state, WHO and Egyptian regulations (seasonal average $45.14 \pm 9.23 \mu\text{g/l}$). In conclusion, it can be inferred that the concentration of THMs in the drinking water of Greater Cairo is not hazardous to human health.

Keywords: Drinking water; Greater Cairo; Trihalomethanes

Introduction

Chlorine disinfection processes and other oxidation processes to inactivate harmful microorganisms are questioned by the potentially toxic by-products formed during disinfection. Chloroform, a Trihalomethane produced during chlorination, was shown to be a carcinogen for mice and rats [1]. THMs are the most commonly occurring and toxic DBPs found in chlorinated waters [2]. There is a variety of disinfection methods being use worldwide for treatment, but chlorination is the most common method among these methods. Water disinfection with chlorine improves the hygienic quality of water by eliminating waterborne bacterial pathogens such as dysentery and diarrhea diseases, cholera, typhoid fever, hepatitis A, etc. Residual chlorine can protect water from secondary pollution in the water network; also Chlorine application is simpler than other disinfectants. The usage of chlorine consequences a wide range of organic compounds (DBPs), which occur due to the reaction between chlorine with natural organic compounds, mainly humic substances [3]. One of the main groups of DBPs is THMS compounds. Clark et al. suggested that; more than 500 DBPs have been identified in tap water [4,5]. Chloroform, a DBP was first identified in the finished drinking water in 1974 in the Netherlands by Rook and in the United States by Bellar et al. [6].

A statistical correlation was developed to predict the concentration of chloroform formation as function of pH, temperature and distance (near or far) between a reservoir and a point of interest in the distribution system. This correlation is qualitative in the sense that distance and time are not included implicitly in it [6].

Many studies cited that the generated a multiple regression model for predicting THMs level in the finished water leaving a treatment plant. The correlation implies that THMs formation is higher in summer through autumn and lower in winter through spring.

Sokeng et al. described a mathematical model that applies second order kinetics to predict the chlorine residuals and demonstrates that THMs formation can be characterized as a function of chlorine demand [7]. The parameters of this model are correlated as a function of pH, TOC, temperature and chlorine residual. The formation of THMs in drinking water has been shown to be a function of various water quality parameters and chlorination conditions. THMs formation is one of the slowest known reactions in water treatment and a number of important factors influence this reaction. These include residence time, pH, temperature, bromide ion concentration, chlorine dosage, type of

organic precursor and the Total Organic Carbon (TOC).

In the present paper, the overall objective is to monitoring and understanding of the effect of water parameters on THMs formation in Greater Cairo region drinking water.

Materials and Methods

The city of Cairo is capital of Egypt and has about 15000000 inhabitants. Even though it has sufficient water resources and permanent water flows (river Nile). The statistics show that the average amount of water per inhabitant is about 200-250 liters per day. The drinking water in Cairo is disinfected with gaseous chlorine without any kind of special treatment.

The experimental part of the research was done in the laboratories of the Holding Company for Water and Wastewater. Five sample points were selected in the city of Cairo and during the study 2014 the drinking water samples were analyzed.

The water samples were collected from five water treatment plants and its distribution systems, Water samples at the specified locations were collected in 60 ml glass bottles (amber glass), which were filled without passing air bubbles through the sample. Before sampling, a solution of sodium thiosulfate was added to the amber bottles to eliminate any remaining residual chlorine and to stop further THM formation. Each glassware used was previously washed with phosphate-free detergent, rinsed with ultrapure water (Milli-Q) and acetone (HPLC grade). Then, it was placed in an oven at 150°C for two hour and cooled at room temperature.

Samples were prepared by extracting 10 ml of water with 2 ml of pentane by shaking for 2 min in a separation funnel of 25 ml. Phase separation occurred within 3 min and the upper phase was collected into 2 ml vials having screw caps with PTFE septa. THM measurements

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were made using a gas chromatograph equipped with electron capture detector (GC-ECD, Varian, Model CP-3800). Chromatographic separation was accomplished with a capillary column DB-5 (J and W Scientific Inc./Agilent Technologies, 30 m × 0.25 mm × 0.25 μm). The GC oven temperature program was as follow: initial temperature in 40°C for 2 min and then ramped 10°C per min until 150°C. Carrier gas (N₂) at a flow rate of 0.8 ml min⁻¹ and split ratio of 1:10 was used in each experiment. It was injected 2 μl of each sample in the capillary column. For the calibration curve, standard solutions of CHCl₃ (Supelco Inc., 98.8%), CHBrCl₂ (Supelco Inc., 99.9%), CHBr₂Cl (Supelco Inc., 99.0%), and CHBr₃ (Supelco Inc., 99.9%) in concentrations ranging from 0.05 to 100 μg/l in ultrapure water (Table 1).

Result and Discussion

The experimental results have been presented in Figures 1-6. The concentration of THMs on the sample points vary from one month to another at a low rate. Therefore, the average values of THM concentrations during the present study in Fustat district (South of Cairo) were 45.14 μg/l, respectively, the minimum value observed during December 2014 and the maximum value observed during July 2014 as shown in Figure 1. The average values of THM concentrations during the present study in Rod El-Farag district (middle of Cairo) were 46.28 μg/l, respectively, the minimum value observed during March 2014 and the maximum value observed during October 2014 as shown in Figure 2. The average values of THM concentrations during the present study in Shoubra district (North of Cairo) were 51.40 μg/l, respectively, the minimum value observed during May 2014 and the maximum value observed during October 2014 as shown in Figure 3.

The average values of THM concentrations during the present study in El-Obour district (East of Cairo) were 44.32 μg/l, respectively, the minimum value observed during May 2014 and the maximum value observed during October 2014 as shown in Figure 4. The average values of THM concentrations during the present study in El- Roda district (East of Cairo) were 49.95 μg/l, respectively, the minimum value observed during March 2014 and the maximum value observed during June 2014 as shown in Figure 5.

All samples collected from five districts had THM less than the Egyptian regulation limits (100 μg/l).

In 1988, Ali et al. found that THM in drinking water of Kuwait (from rooftop tanks) averaged 25.6 ± 9.1 μg/l with a maximum recorded value of 50.5 μg/l. the THM formation generally favored by high temperature, chlorine residue and source natural organic matters composition (NOMs) [8-10].

The observed seasonal variation of THMs was consistent with earlier studies reported maximum THM formation in summer [11]. CHCl₂ Br and CHClBr₂ exhibit inconsistent higher mean seasonal variations in winter than summer as indicated in Figures 1-5.

These higher mean values in winter can be attributed to characteristics of natural organic matter and changes in the nature of THM precursors in the source water [12-15].

Compound	WHO (2012)	Egypt (2007)
Chloroform	0.300	0.300
Bromodichloromethane	0.100	0.100
Dibromochloromethane	0.60	-
Bromoform	0.100	0.100
Total Trihalomethanes	0.100	0.100

The maximum permissible limits

Table 1: Standards/recommending guidelines for THMs (mg/l) in the world jurisdictions.

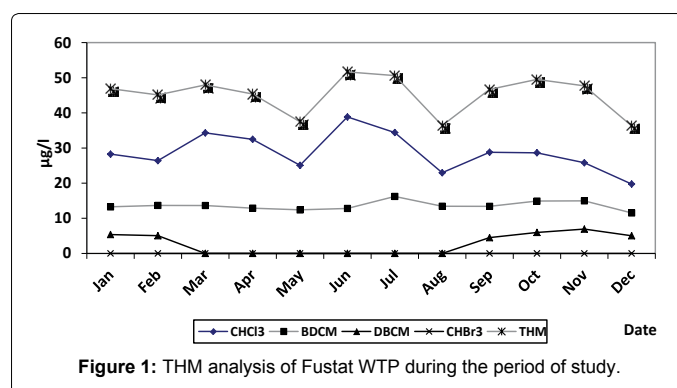


Figure 1: THM analysis of Fustat WTP during the period of study.

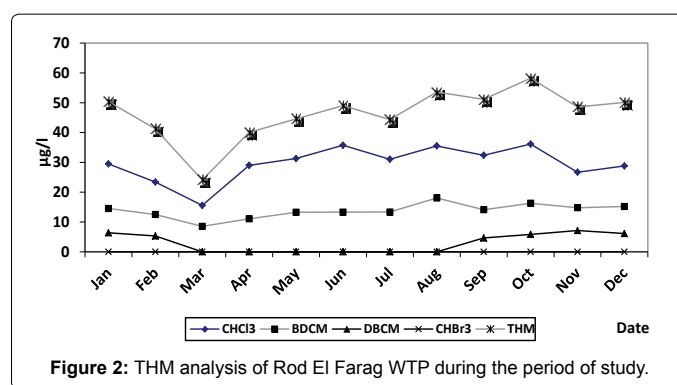


Figure 2: THM analysis of Rod El Farag WTP during the period of study.

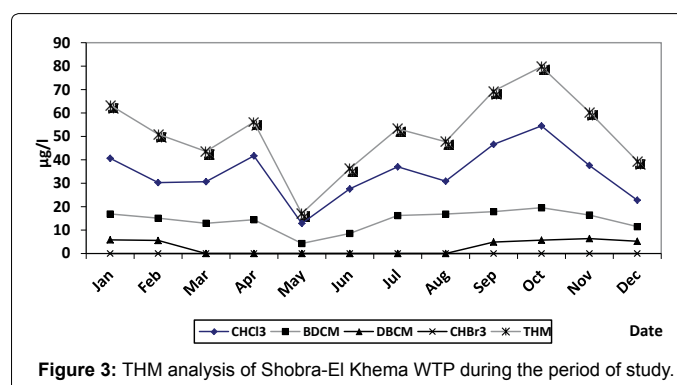


Figure 3: THM analysis of Shobra-EI Khema WTP during the period of study.

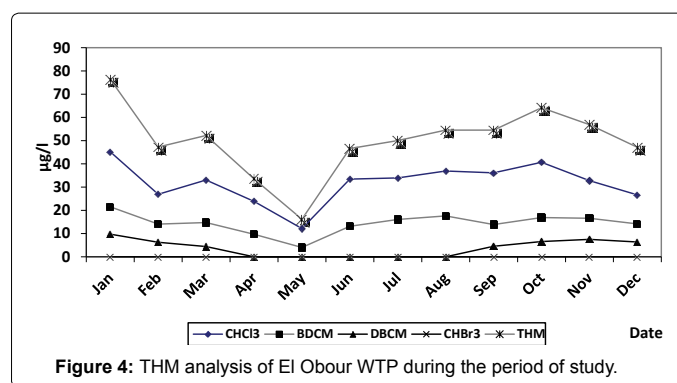


Figure 4: THM analysis of EI Obour WTP during the period of study.