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STUDY THE CONCENTRATION OF TRIHALOMETHANES (THMs) FORMED IN WATER SUPPLY NETWORK WITH MULTI FEEDING SOURCE

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ABSTRACT

The problem of the Trihalomethanes (THMs) compounds in drinking water systems is the major problem that actuate the world nowadays because of their harmful effect that can result from drinking water containing it. So there are a lot of previous researches studied the concentration of (THMs) in water networks having only one feeding source, but this research focuses on the evaluation and assessment of THMs contamination in Fayoum Water Supply Network which have multi-source of water feeding .THMs and other parameters effecting on its formation were measured at raw and treated water for four treatment plants and at ten location in the water networks to investigate the influence of multiple feeding source for a distribution water network on the THMs concentration. Results showed that THMs at raw water hasn't been formed, and the concentration of THMs in all the selected locations were less than the maximum acceptable concentration for THMs, and the chloroform is the predominant THMs compound. It was noticed that an average chlorine consumption of 0.1 mg/L leads to the increase of THMs concentration by 0.8 to 1.5 μg/L . An increase in temperature by 10C leads to increase of THMs concentration by 27% to 32% μg/L. The mixing between two feeding sources is better for the distribution network not only for flexibility in operation, but also for the quality of the water. Finally it was found that the main factors affecting THMs formation at the end of the treatment are the chlorine dose and the TOC concentration at raw water. and the main parameters affecting THMs concentration at point having more than one source are the present of mixing between sources at this point and the water quality at each source before mixing.

Key Words : *Disinfection by-products, THMs, Chlorine, Water Quality, Water Supply Network and Fayoum Water Distribution System.*

INTRODUCTION

Many of the most common diseases found in traumatized communities after a disaster or emergency are related to drinking contaminated water, the contamination can be from micro-organisms or natural and man made chemicals. that problems can be reduced by using disinfection [Bridie, 2004].

Chlorine has been the most widely used chemical for disinfecting drinking water since the turn of the century. Although chlorine has

proved very effective in disinfecting water and hence protecting humans from water born diseases, chlorine is a strong oxidizing agent that reacts with many organics that may be present in water to produce harmful by-products. With the development of new analytical methods, it was found that water contains hundreds of natural and man-made organic compounds[Al-Omari; et al..,2004], some of which can react with free chlorine to form harmful by-products such as Trihalomethanes [Alan and James,1980, Bridie, 2004].

THMs are chlorinated organic compounds. The four most common THMs typically found in water are chloroform ($CHCl_3$), Bromoform ($CHBr_3$), Bromo-dichloromethane (CHCl2Br) and Dibromo-chloromethane ($CHBr_2Cl$). [Dumitru; et al.., 2008].

Prolonged consumption of drinking water containing high levels of THMs has been linked with diseases of the liver, kidneys, bladder, or central nervous system, and may result in an increased likelihood of cancer[Attias; et al.., 1993]. An article in the Washington Post Health showed that a 10 minute shower produced more absorption of THMs through the skin than drinking 5 glasses of water.[Attias; et al..,1993, Singer, 1993].

The previous reasons make EPA organization reduce the limit of THMs concentrations from 100μg/L to be 80μg/L [EPA, 1997] and make maximum acceptable concentration for THMs in drinking water in Egypt to be 100 μg/L. (according to the decision of the Ministry of Health No.458 of 2007.

Several investigations have been carried out to improve the understanding of the relation between water-quality parameters, WTP managing, and con-centrations of THMs in drinking water. Total organic carbon (TOC) in surface waters is a heterogeneous mixture of substances, have been considered as the main precursors of THMs. Other parameters that influence the formation of THMs are chlorine residual concentrations, reaction time, pH and temperature [Rodriguez and Sérodes, 2001, Roccaro; et al., 2007, Navalon; et al., 2008]. Brominated THMs are also formed especially in water containing bromide ion. The presence and concentration of bromide ion affects the overall formation of halogenated THMs [Nokes and Randall, 1998].

The aim of this paper is to monitoring and evolution of THMs in the treated water of Fayoum water distribution system (FWDS) which have multi-water sources (main canals and secondary canals) and multi-treatment processes (Conventional and Direct filtration treatment plant) feeding the distribution network and to investigate the effects of water quality and operational parameters on THMs occurrence.

MATERIAL AND METHODS

The water utilities taken as a case study are those supplying the province of Fayoum. The area presents an interesting profile for research purposes because it counts several types of feeding sources. The distribu-tion networks is a mixing of tree and grid types and it has more than one source for the feeding the same pipe line. The lengths of the carrier and distribution networks about 4180 km

with diameters from 100 mm to 1000 mm (17% carrier lines with diameter from 300 mm to 1000 mm and 83% distribution line with diameter from 100 mm to 300mm).

The network consists of more than one type of pipes such as (PVC - DI - AC - CI - PRC - HDPE) and it had been constructed 1926 until now.

The source of water for Fayoum Water Supply Network are :-

- Four conventional water treatmentplants.
- Seventeen direct filtration water treatment plant.
- Two compact units water treatment plant.

Fig (1) illustrates the FWDS and The location of feeding stations .

To investigate the occurrence of THMs within the water distribution systems of the concerned utilities, and the influence of multiple water feeding on the THMs contamination levels, an intensive sampling programmed was undertaken between January and November 2009. Samples were collected monthly at representative points for each utility, from treated water to the extremities of the distribution systems. Samples were taken at the treatment plant from raw water and after final chlorination (two samples from conventional plants and two samples from direct filtration plants), these samples were taken to characterize the quality of treated water leaving the plant as well as initial formation of THMs, and ten samples were taken at the distribution systems for each feeding before any mixing and in the distribution systems after mixing at different distance from the origin in order to represent water with moderate and high residence time within the distribution system.

Sampling points were selected on the basis of the hydraulic calculation from (WaterCad V8 program) [EPA, 2007], and the technicians responsible for maintenance the Fayoum networks. It was determined that all points were accessible for sampling at the same day of month. For the utilities, the selected sampling points are supplied directly from the treatment plants.

Table (1) represents the nomenclature, the location of the sampling points and the distance from the plant to the sampling points along the distribution network. Figures (1-1, 1-2, 1-3, 1-4) showing the location of Samples.

*** Measured parameters**

The parameters measured were pH, Free Chlorine, Bromine, Temperature, Travel Time, TOC and THMs (and its component).

1- pH

The pH was measured using (HANNA - HI83200 Multiparameter Ion Specific Meter) at the site. This was done by adoption of the Phenol Red method with the reagent causes a yellow to red tint in the sample.

2- Free Chlorine

Free Chlorine was measured using (HANNA -HI83200 Multi-parameter Ion Specific Meter) for concentration range between 0.00 to 2.50 mg/L and using Pool tester for range between 2.50 to 6.0 mg/L at the site. The Method of measured is Adoption of the EPA DPD method 330.5. The reaction between

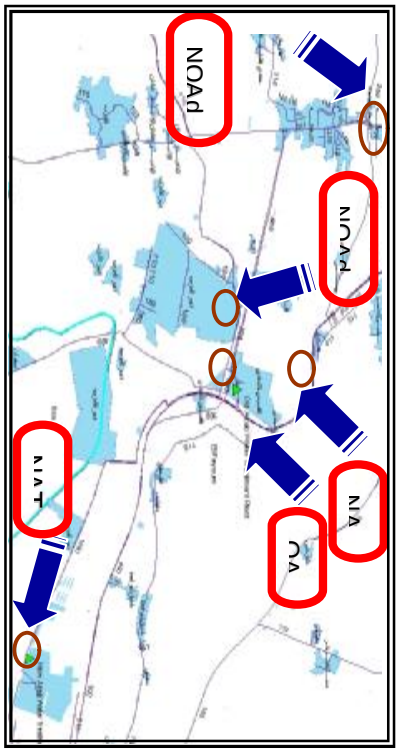

Fig. (1-1) The location of samples NAT_w , OAT_w , NAd1,NOAd1 and NOAd2

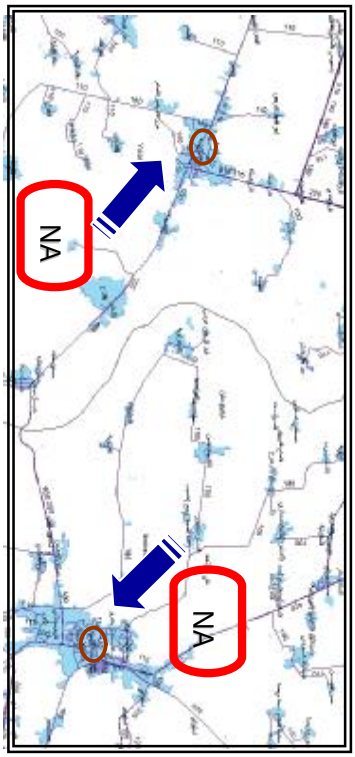

Fig. (1-2) The location of samples NAd2 and NAd3

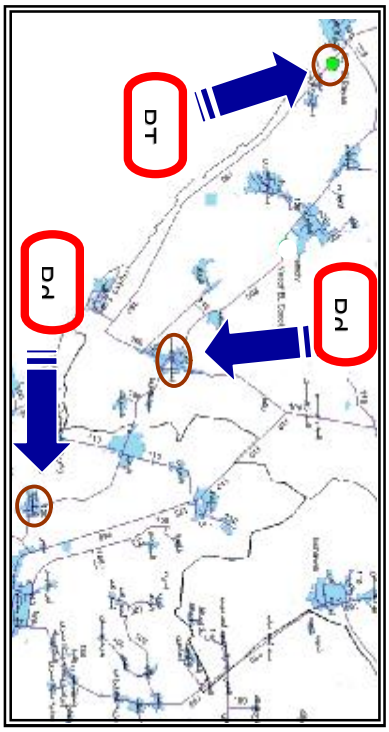

Fig. (1-3) The location of samples RT_w , Rd1 and Rd2

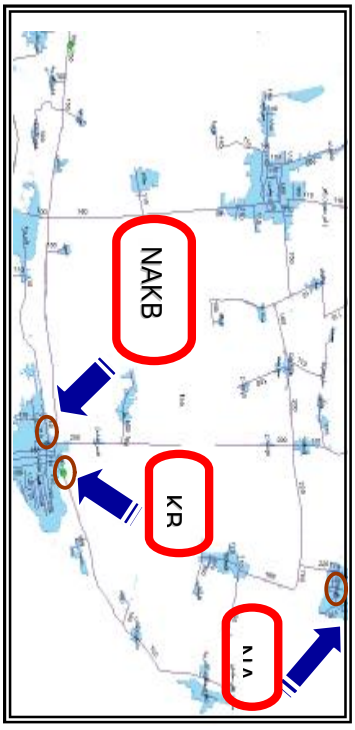

Fig. (1-4) The location of samples KBT_w , NAd4 and NAKBd1

Table (1) : Represents the nomenclature and the location of the sampling points.

SAMPLE CODE	LOCATION	THE SOURCE OF WATER
NAR_w	Raw water (before treatment) At New Azab plant	Hassan Wassef canal
NAT_w	Treated water (before distribution) At New Azab plant	Hassan Wassef canal
NAd1	**(Mosque in Alquases-Algindy)** Sample1 at New Azab distribution network	New Azab plant
NAd2	**(Ebshwaye)** Sample2 at New Azab distribution network	New Azab plant
NAd3	**(Alshawashna)** Sample3 at New Azab distribution network	New Azab plant
NAd4	**(Klamchah)** Sample4 at New Azab distribution network	New Azab plant
OAR_w	Raw water (before treatment) At Old Azab plant	Hassan Wassef canal
OAT_w	Treated water (before distribution) At Old Azab plant	Hassan Wassef canal
NOAd1	**(Army stores)** Sample1 at New Azab& Old Azab distribution network	New Azab & Old Azab plant
NOAd2	**(Rstom-Dala)** Sample2 at New Azab& Old Azab distribution network	New Azab & Old Azab plant
KBR_w	Raw water (before treatment) At Kasr El Basil plant	Algaraque canal
KBT_w	Treated water (before distribution) At Kasr El Basil plant	Algaraque canal
NAKBd1	**(Kasr El Basil)** Sample1 at New Azab& Kasr El Basil distribution network	New Azab & Kasr El Basil plant
RR_w	Raw water (before treatment) At EL-Rayan plant	El-Banat canal
RT_w	Treated water (before distribution) At EL-Rayan plant	El-Banat canal
Rd1	**(AL-Hosynia)** Sample2 at EL-Rayan distribution network	EL-Rayan plant
Rd2	**(AL-Moqurany)** Sample1 at EL-Rayan distribution network	EL-Rayan plant

Free chlorine and The DPD reagent causes a pink tint in the sample.

3- Bromine

Bromine was measured using (HANNA - HI83200 Multi- parameter Ion Specific Meter) at the site. The measurements were carried out according to the standard method for the Examination of water & wastewater, 18^{th} Edition, DPD method.

4- Total Organic Carbon

TOC was measured using the TOC analyzer at the Central Laboratory of Fayoum.

5- THMs

THMs was measured using the Gas Chromatography at the Central Laboratory of Fayoum. Sample were taken in brown bottle (40 ml) with screw cap Lined with (PTF) preservated by Sodium Thiosulfate 110μL [APHA, 1992]. Samples were transported in Icebox from site to the laboratory.

6- Temperature

Temperature was measured using the Thermometer Mercurial at the site.

7- Travel Time

Using the water cad V8 program [EPA, 2007], The length, diameter, and C-coefficient were introduced for each pipe, as well as the flow for each treatment plant, the head of the pumps, the location of the elevated tanks, the demand pattern, chlorine dose for each and the poster pump heads.

RESULTS AND DISCUSSION

Figs. (2, 3 & 4) illustrates the concentrations of THMs in the sampling program. Results showed that the concentration of THMs in all points in the distribution network is less than the maximum acceptable concentration. The results obtained illustrated that for all the location under study, chloroform ($CHCL_3$) is the predominant THMs compound. It represents an average of 52.6% of total THMs, whereas CHCl2Br represents an average of 33.4% of total THMs, and the rest is $CHBr_2Cl$. The $CHBr_3$ wasn't shown at any location, and THMs at raw water hasn't been formed.

At (NOAd1) in the distribution network, the concentration of THMs was less than that at (OAT_w) after chlorinated in Old Azab treatment plant. This is because the mixing before those location between effluent of the New and Old Azab treatment plant and the quality of treated water from New Azab treatment plant is better than water that at the Old Azab treatment plant (as shown in Figs 2, 3). The concentration of THMs at ($NOAd_2$) was more than that at (NOAd1). This is because Old Azab Treatment plant was the main source of water at location $NOAd_2$ (80% of flow at this location from OATP), but at NOAd1 only 60% of flow from OATP. Also, at location (NAKBd1) in the distribution network, the concentration of THMs was less than that at NAd_4.

This is because the mixing before those location between effluent of the New Azab [represented by NAd4] and Kasr EL-Basil treatment plant (50% of flow at this location from KBTP)

The TOC concentration at raw water appears to be associated with the TTHM

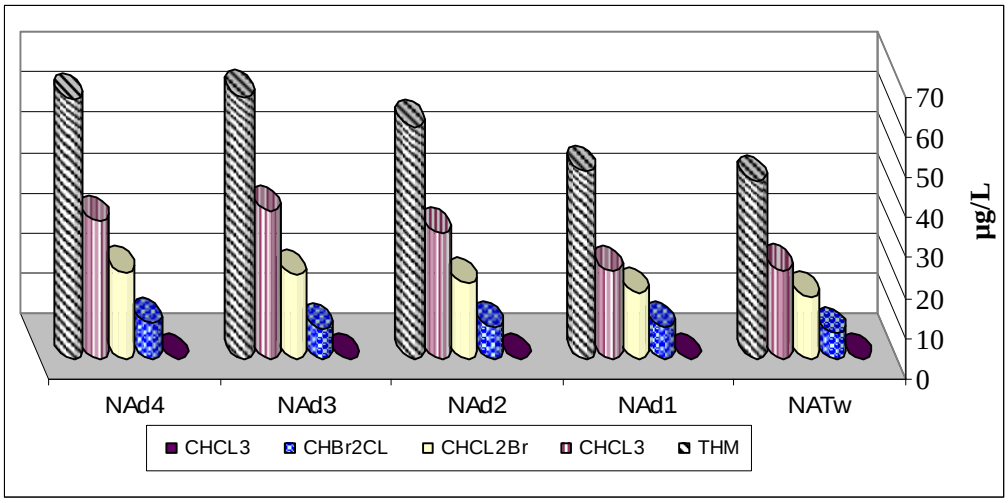

Fig. (2) : The average of THMs,$CHCL_3$,$CHCL_2Br$ and $CHBr_2CL$ concentrations for five sample locations.

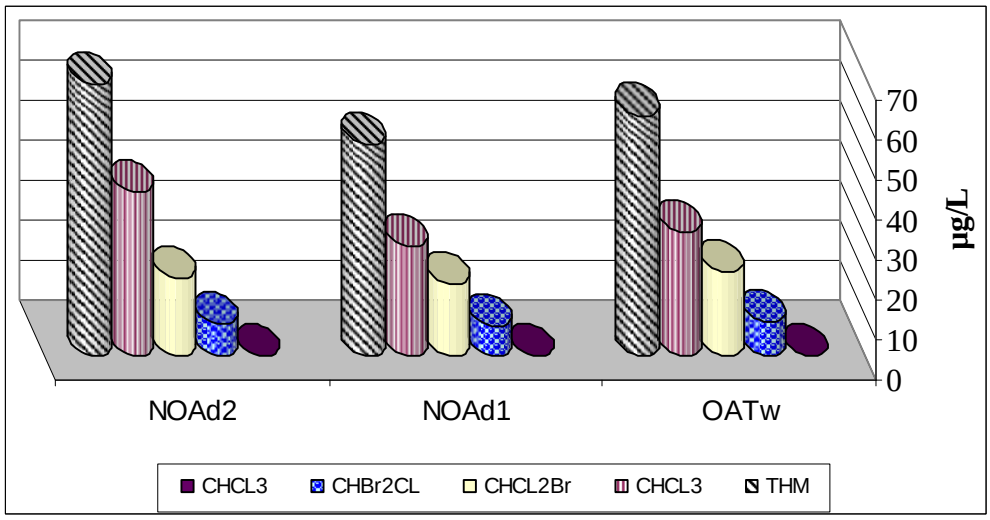

Fig. (3) : The average of THMs,$CHCL_3$,$CHCL_2Br$ and $CHBr_2CL$ concentrations for four sample locations.

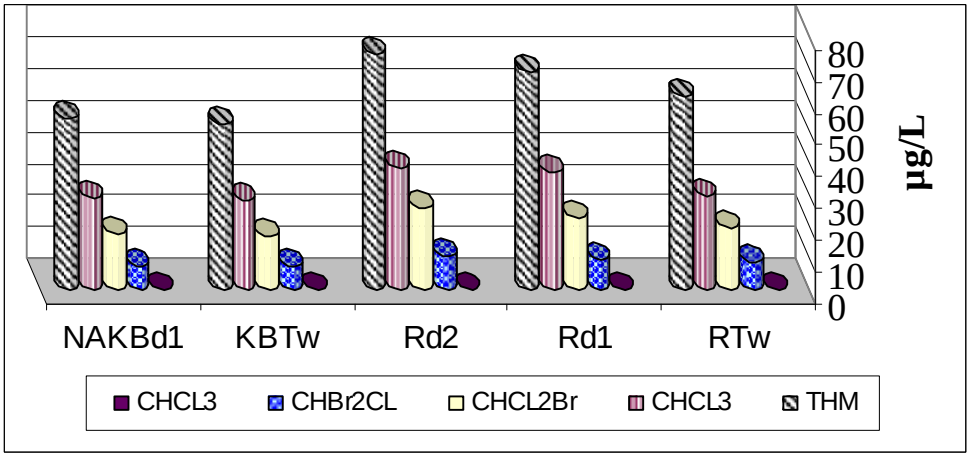

Fig. (4) : The average of THMs,$CHCL_3$,$CHCL_2Br$ and $CHBr_2CL$ concentrations for four sample locations.

concentration after chlorination as shown in (Figs. 5). The higher TOC concentration, the higher initial THMs concentrations formed. Although the TOC concentration at NATw and RTw was nearly the same but the THMs concentration at RTw was more than NATw, this is because Br- concentration at RTw was more than that at NAT_w.

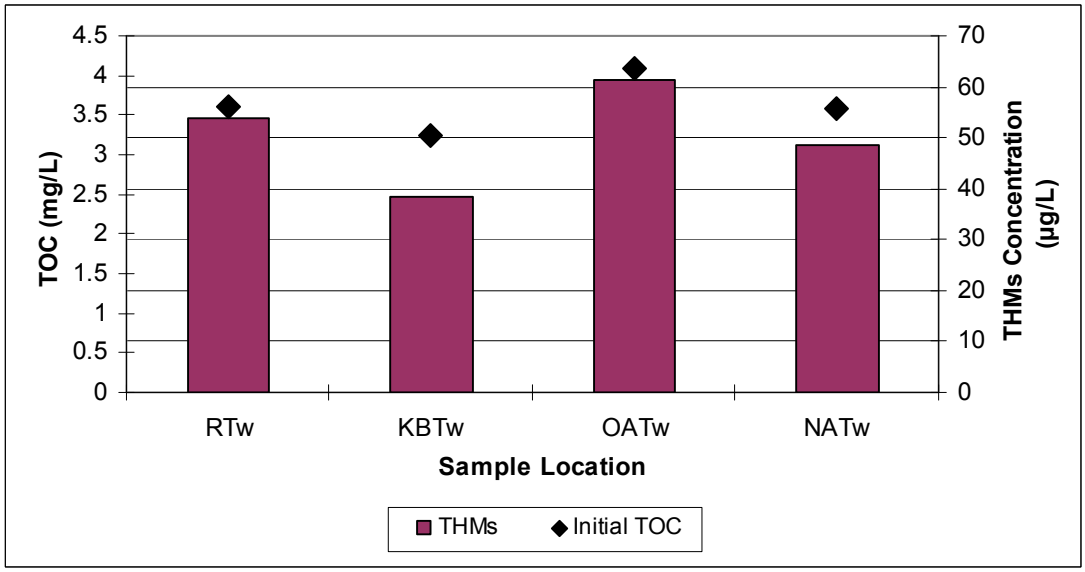

Fig. (5) : The relation between the concentration of THMs after chlorination and raw water TOC at (same temperature).

The chlorine dose concentration appears to be associated with the initial THMs concentration before distribution as shown in (Fig. 6). The higher of chlorine dose the higher for THMs concentration in most cases. At NATw, samples No. 1,2,3,5 have the same chlorine dose but the THMs concentration at sample No.1 was the smallest that because it has the less degree of temperature. THMs concentra-tion at sample 4 is less than THMs concentration at samples 3 and 5 although chlorine dose at sample 4 was more than that at samples 3 and 5, this is because TOC concentration at sample 4 was less than that at samples 3 and 4.

At RTw, THMs concentration at sample 3 was more than that at sample 2 although chlorine dose at sample 3 was less than sample 2 that because TOC, Free Chlorine at sample 3 were more and less respectively than that at sample 2. At KBw, THMs concentration at sample 1 was more than that at samples 2,3 although chlorine dose at sample 1 was less than samples 2,3 that because TOC concentration at sample 1 equal 6.9 mg/L but at samples 2, 3 TOC concentration equal 3.21 and 3.56 mg/L respectively.

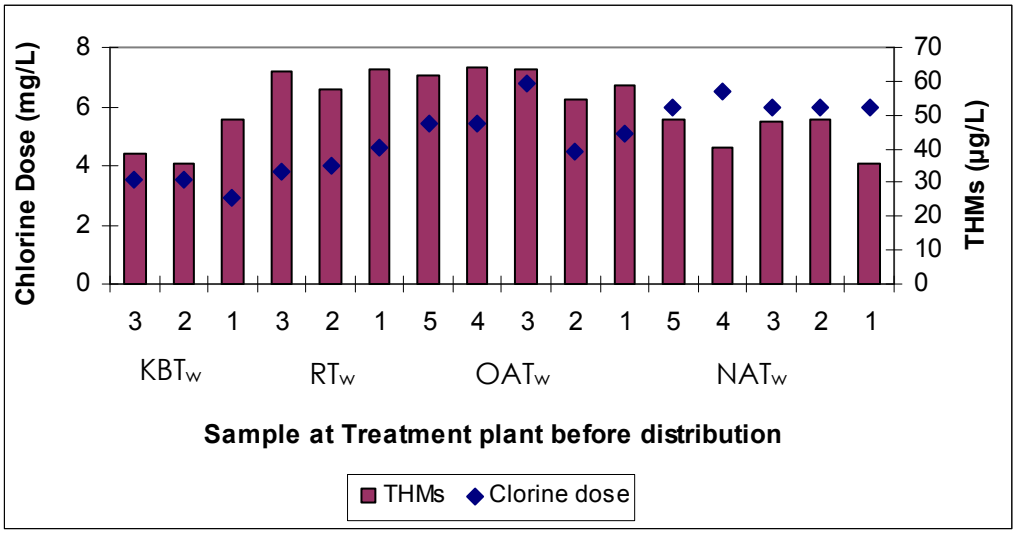

Fig. (6) : The relation between the concentration of THMs and Chlorine dose.

The results obtained illustrated that the higher in temperature, the higher in the $CHCL_3$ concentration. (5°C increase in temp. leads to the increase of $CHCL_3$ concentration by 27% to 32) as shown in (Fig. 7).

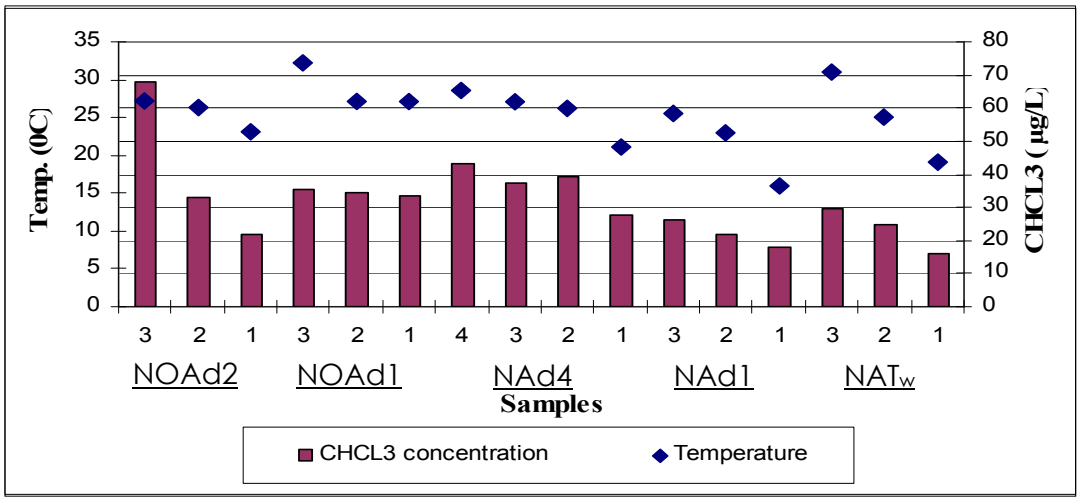

Fig. (7) : The relation between Temperature and $CHCL_3$ concentration .

The concentrations of Br- appears to be associated with the THMs concentration at the same location. The higher in Br-concentration the higher in concentration of $CHCL_2Br$ and $CHBr_2CL$. The rate of increase is very small especially for $CHCL_2Br$ as shown in (Fig. 8).

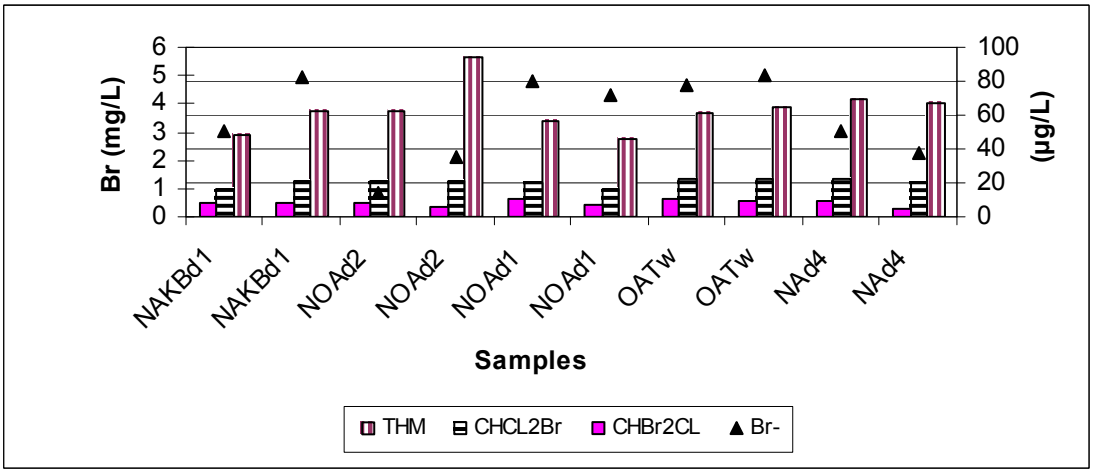

Fig. (8) : The relation between the concentration of TTHM and Br-

The concentration of free residual chlorine appears to be associated with the THMs concentration from location to another in the distribution network as shown in (Figs. 9,10). There was an average chlorine consumption of 0.78 mg with an 11 µg/L increase of THMs concentration between the locations NAd_1 and NAd_2, but between the locations RTw and Rd1, 0.95 mg chlorine consumption lead to 7.8 µg/L increase of THMs concentration.

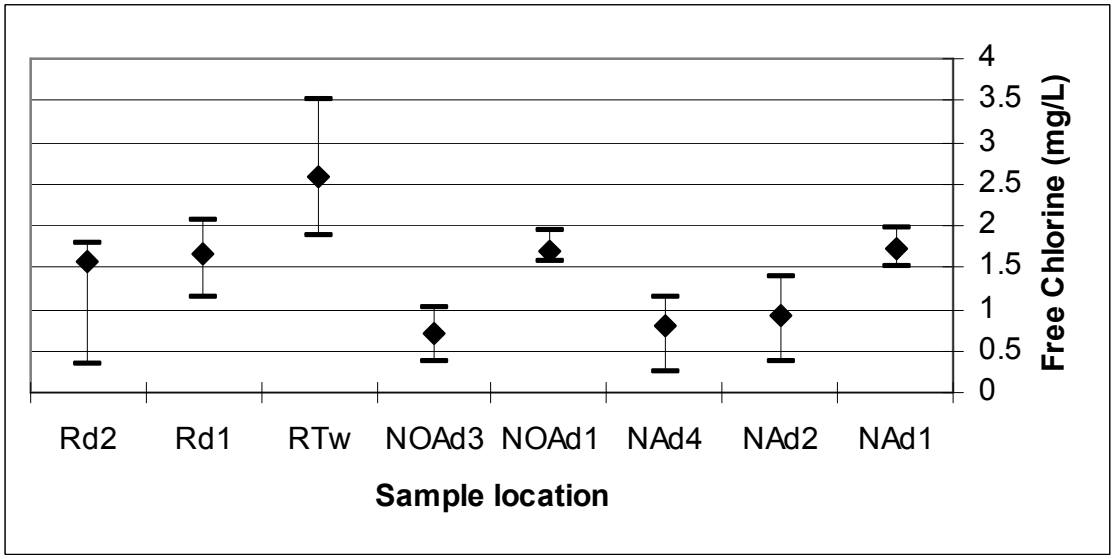

Fig. (9) : The free residual chlorine concentration for eight sample locations.

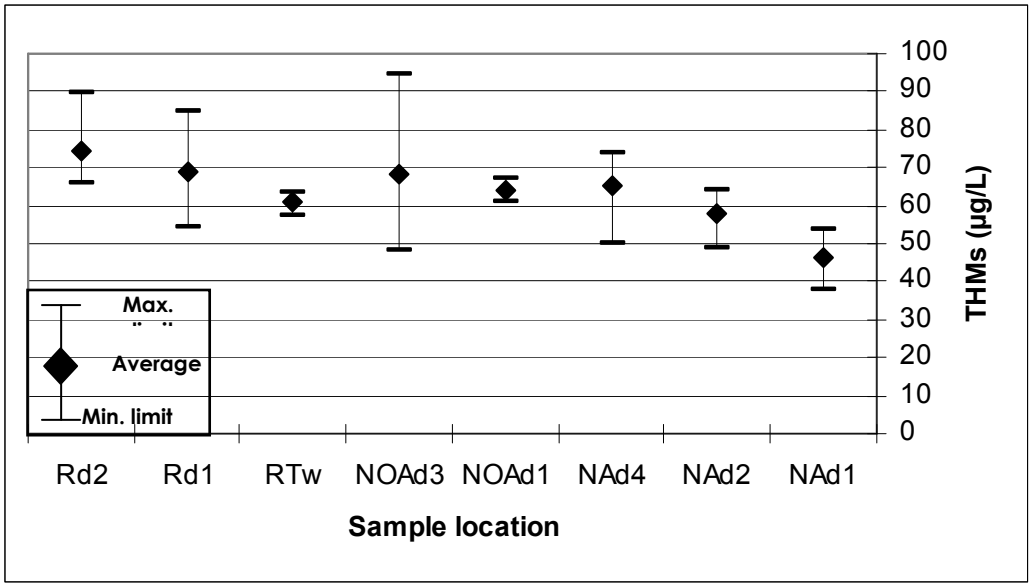

Fig. (10) : The THMs concentration for eight sample locations.

CONCLUSIONS

- The concentrations of THMs in all locations at the distribution network are less than the allowable limit (100µg/L) stated by the decision of the Ministry of Health No.458 of 2007.
- Chloroform is the predominant THMs compound. It represents an average of 52.6% of total THMs whereas the $CHBr_3$ wasn't shown at any location .
- The mixing between two feeding sources is better for the distribution network not only for flexibility in operation, but also for the properties of the water.
- The main parameters affecting on THMs concentration at point having more than one source are the present of mixing between sources at this point and the water quality at each source before mixing.
- The higher TOC concentration at raw water, the higher initial THMs concentrations formed .
- The higher the chlorine dose , the higher concentrations of initial THMs formed .
- The higher the chlorine consumption between two points, the higher concentrations of THMs formed. (an average chlorine consumption of 0.1mg leads to the increase of THMs concentration by 0.8 to 1.5 µg/L).
- The higher in the temperature of water, the higher the concentrations of THMs formed, (5°C increase in temperature for water leads to the increase of $CHCL_3$ concentration by 27% to 32%).
- The higher in concentration in Br-, the higher in the concentration of the $CHCL_2Br$ and $CHBr_2CL$ (with small rate of increase) but not necessarily the concentration of THMs .

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الملخص العربى

دراسة تركيزات ملوث التراى هالوميثان خلال شبكة مياه الشرب متعـددة مصـادر التغذيـة

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إن مشكلة تكون مركبات التراى هالوميثان (THMs) فى شبكات مياه الشرب من أهم المشكلات التى تشغل العالم بأثرة فى هذه الأيام، ونظراً للأمراض التى يتعرض لها الإنسان التى يمكن أن تنجم عن شرب المياه التى تحتوى على مركب التراى هالوميثان(THMs) أصبحت الأبحاث المتعلقة بهذا الموضوع تأتى فى مقدمة الأولويات لدراسة أسباب تكون مركب (THMs) ولإيجاد الحلول الفعالة والاقتصادية للحفاظ على صحة الإنسان.

لذلك هناك عديد من الدراسات السابقة التى اهتمت بدراسة (THMs) والعوامل المؤثرة على تكوينه فى شبكات مياه الشرب ذات مصدر التغذية الواحد، بينما تمت هذه الدراسة على شبكة مياه شرب تتغذى عن طريق عدة مصادر للمياه للخط الواحد لتوضيح أثر ذلك على (THMs)، ولتحقيق ذلك تم قياس مركب (THMs) والعناصر المساعدة على تكوينه عند مدخل ومخرج أربع مصادر للتغذية وكذلك عشرة أماكن مختلفة فى الشبكة (سبعة أماكن ذات مصدر واحد - ثلاثة أماكن ذات مصدرين للتغذية) على مسافات مختلفة من المصدر.

وقد تبين أن تركيز (THMs)فى جميع العينات لايزيد عن الحد الأقصى المسموح به (100 µg/L)، وأن مركب الكلوروفورم ($CHCL_3$)هو العنصر الأساسى فى تكوين (THMs)، وقد تبين أيضاً أن جودة المياه الخام كلما زاد تركيز(THMs). ومن أهم العناصر التى تؤثر على تركيز مركب (THMs) عند مخرج المحطة هو كمية الكلور المضافة حيث وجد أن كلما زاد تركيز الكلور المضاف زاد تركيز (THMs) مهما اختلف نوع المحطة، وقد لوحظ أنه كلما زاد استهلاك الكلور الحر المتبقى فى الشبكة بمقدار 0.1 mg/L يزداد تركيز (THMs)بمقدار يتراوح بين 0.8 إلى 1.5 µg/L وكذلك كلما ارتفعت درجة الحرارة بمقدار 1 درجات مئوية أدى ذلك إلى زيادة تركيز (THMs) بمقدار يتراوح بين 27% إلى 32%، وقد أثبتت النتائج أن تركيز (THMs)يقل عند نقاط الخلط حيث أنه يعتمد على تركيز THMs لكل مصدر قبل الخلط مباشرة ونسبة الخلط بين المصادر المختلفة، لذلك فإنه يفضل الشبكات المفتوحة مع تعدد مصادر التغذية مما لها من تأثير فى تقليل تركيزات THMs فى الشبكة.

JOESE 5

STUDY THE CONCENTRATION OF TRIHALOMETHANES (THMs) FORMED IN WATER SUPPLY NETWORK WITH MULTI FEEDING SOURCE

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