Affection of multiple feeding water supply network on the concentration of trihalomethane

تأثير تعدد مصادر التغذية بشبكة مياه الشرب علي تركيز ملوث التراي هالوميثان

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الملخص العربي

اهتمت الدراسات السابقة بدراسة مركب التراي هالوميثان (THMs) في شبكات مياه الشرب ذات مصدر التغذية الواحد ، بينما تمت هذه الدراسة علي شبكة مياه شرب تتغذي عن طريق عدة مصادر للمياه لتوضيح أثر ذلك علي(THMs) .تم اختيار شبكة مياه الشرب بمحافظة الفيوم حيث تمتازبأنها خليط من النوع الشجري والنوع الشطرنجى ويوجد أكثر من مصدر تغذية للخط الواحد. وتم قياس تركيز (THMs) والمركبات الاخري المساعدة علي تكوينة وذلك في عشرة أماكن مختلفة. وقد تبين أن تركيز (THMs) في جميع العينات لا يزيد عن الحد الأقصي (100 µg/L) ،وان مركب الكلوروفورم ($CHCL_3$) هو العنصر الأساسي في تكوين THM وعدم تواجد أي أثر لمركب البروموفورم ($CHBr_3$). و نتيجة لتواجد بعض المحطات علي أطراف الشبكة والتي تستمد المياه الخام لها من ترع ثانوية (تصب بها بعض المصارف) يزداد تركيز THMs الخارج منها ولكن لصغر تصرف المحطات و لقرب المناطق المخدومة بها فلا يزيد تركيز (THMs) عن الحد الأقصى. وقد لوحظ أن كلما أستهلك الكلور الحر المتبقي في الشبكة بمقدار 0.1 mg\L يزداد تركيز(THMs) بمقدار يتراوح بين 2 الى 2.5 µg/L. وكذلك كلما أرتفعت درجة الحرارة بمقدار 5 درجات منوية أدي ذلك إلي زيادة تركيز(THMs) بمقدار يتراوح بين 27% الى 32% . وقد تبين ايضا أن كلما زاد تركيزTHMs في بداية الشبكة كلما قل معدل الزيادة لتركيز THMs في شبكة التوزيع وبالتالي يفضل الشبكات المفتوحة مع تعدد مصادر التغذية حيث يكون لها تأثير في تقليل تركيزات THMs في الشبكة.

Abstract

The previous researches studied the concentration of (THMs) in water networks having only one feeding source. This research illustration the effect of multiple feeding source for water supply network on the concentration of (THMs). This research focuses on the evaluation and assessment of THMs contamination in Fayoum Water Supply Network. To investigate the influence of multiple feeding source for a distribution water network on the THMs contaminant, an intensive 5-months sampling programmed was undertaken. pH, Free Chlorine, Bromine, Temperature, Travel Time, TOC and THMs were all measured. Results showed that the concentration of THMs in all the selected points in the distribution network were less than the maximum acceptable concentration for THMs, and the chloroform is the predominant THMs compound (it represents an average of 50% of total THMs). It was noticed that an average chlorine consumption of 0.1 mg/L leads to the increase of THMs concentration by 2.0 to 2.5 µg/L . An increase in temperature by $5^{o}C$ leads to the increase of THMs concentration by 27% to 32% . The higher the initial THMs formation after post-chlorination, the lower the relative increase in THMs in the distribution system. 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 and the concentration of THMs at point of mixing between conventional treatment plant & small plant is less than the concentration of THMs at point in distribution network for small plant only.

Key Words

Disinfection by-Products, THMs, Chlorine, Fayoum Water Distribution System

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Introduction

Disinfection is usually a chemical process used in water system which chemicals are added to or kill pathogens found in the water source, and/or to ensure residual concentrations in distribution systems, thus protecting water from microorg- anism regrowth (Bridie, G. S. and Bridie, J.S., 2004). Chlorine is a common practice used in Egypt. Chlorine has traditionally been a preferred disinfection agent because of its proven effectiveness and being relatively inexpensive. Total organic material (TOC) (such as the decaying vegetation) ,and/or bromide found in rivers and canals, reacts with chlorine used to treat the water. This reaction produces "disinfection by-products," the most common of which are Trihalomethanes (Stevens, Alan A. and Symons, James M.,1980 , Crittenden, John C. and Trussell, R. Rhodes, 2005).

Trihalomethanes are chlorinated organic compounds. The four most common THMs typically found in water are chloroform ($CHCl_3$), Bromoform ($CHBr_3$) ,Bromo-dichloro-methane ($CHCl_2Br$) and Dibromo-chloromethane ($CHBr_2Cl$). 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 (Singer, 1993, L. Attias,et. al. 1993).100 µg/L is maximum acceptable concentration for total THMs in drinking water in Egypt (According to the decision of the Ministry of Health No.458, 2007). Several investigations have been carried out to improve the understanding of the relation between water-quality parameters, WTP managing, and concentrations of THMs in drinking water. Total organic carbon (TOC) in surface waters is a heterogeneous mixture of substances, such as humic acids, fulvic acids and others 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 (Manuel J. Rodriguez and Jean-B. Sérodes,2001, Paolo Roccaro,2007, Sergio Navalon, Mercedes Alvaro, and Hermenegildo Garcia,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 (C. J. Nokes, Fenton and C. J. Randall, 1998).

The aim of this paper is to study the spatial and temporal 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 THM 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 distribution 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 300 mm).

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 treatment plants.
- 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 5 months sampling programmed was undertaken between January and May 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 six sample 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), 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.

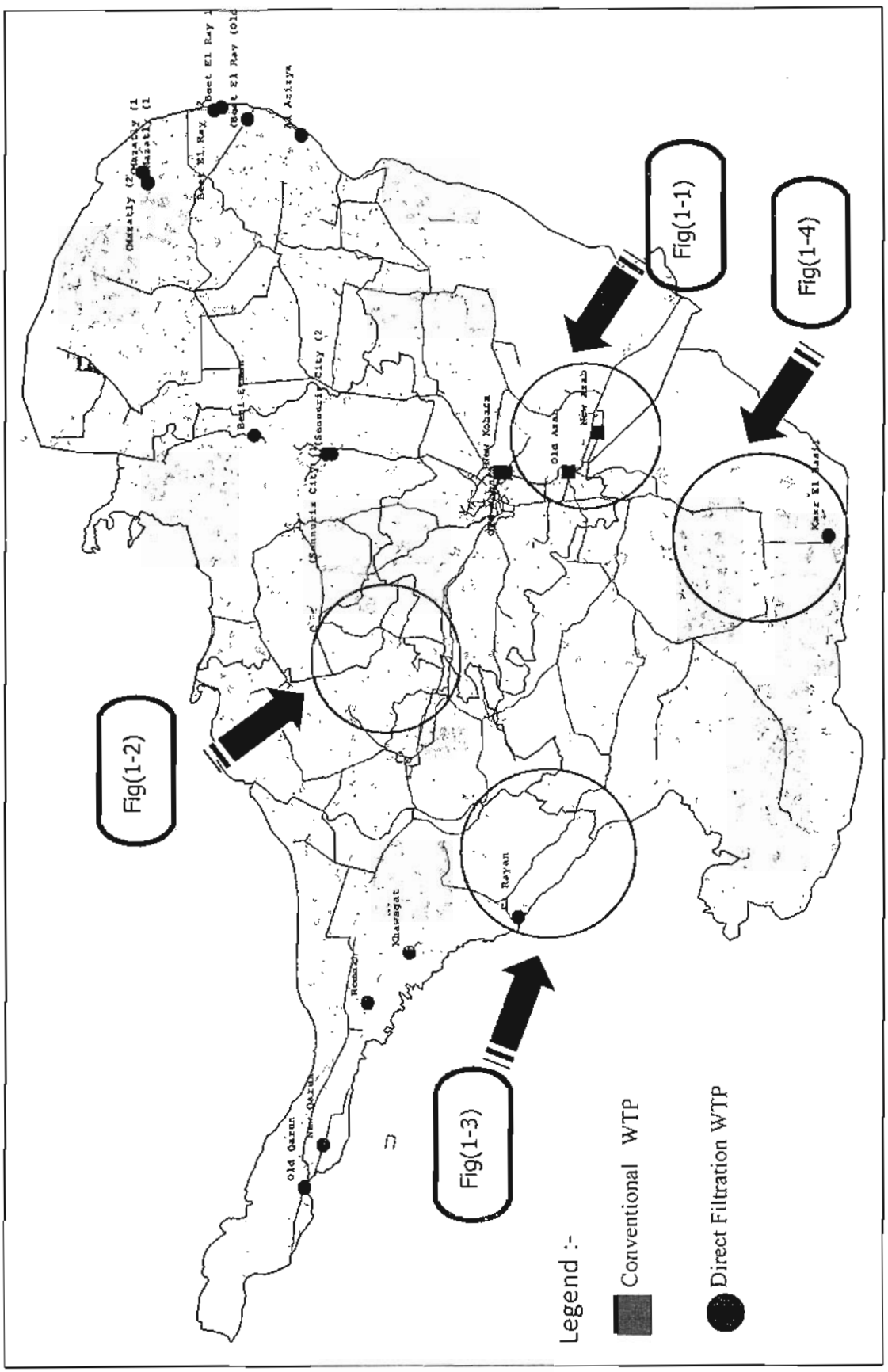


Fig.(1) The Fayoum water distribution network and The location of treatment plants

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

Sample Code	Location	The Source Of Water	Distance From The Origin
NAT_w	Treated water (before distribution) At New Azab plant	Hassan Wassef canal	0.00m From New Azab plant
NAd1	**(Mosque in Alquases-Algindy)** Sample1 at New Azab distribution network	New Azab plant	3760m From New Azab plant
NAd2	**(Nawara)** Sample2 at New Azab distribution network	New Azab plant	24500m From New Azab plant
OAT_w	Treated water (before distribution) At Old Azab plant	Hassan Wassef canal	0.0 From Old Azab plant
NOAd1	**(Rstom Dala)** Sample1 at New Azab& Old Azab distribution network	New Azab & Old Azab plant	3664 m From Old Azab plant 7140m From New Azab plant
NOAd2	**(Ebshwaye)** Sample2 at New Azab& Old Azab distribution network	New Azab & Old Azab plant	46805 m From Old Azab plant 50165m From New Azab plant
RT_w	Treated water (before distribution) At EL-Rayan plant	El-Banat canal	0.0 From EL-Rayan plant
Rd1	**(AL-Hosynia)** Sample1 at EL-Rayan distribution network	EL-Rayan plant	11960 From EL-Rayan plant
KBT_w	Treated water (before distribution) At Kasr El Basil plant	Algaraque canal	0.0 From Kasr El Basil plant
NAKBd1	**(Kasr El Basil)** Sample1 at New Azab& Kasr El Basil distribution network	New Azab & Kasr El Basil plant	23000 m From New Azab plant 400 m From Kasr El Basil plant

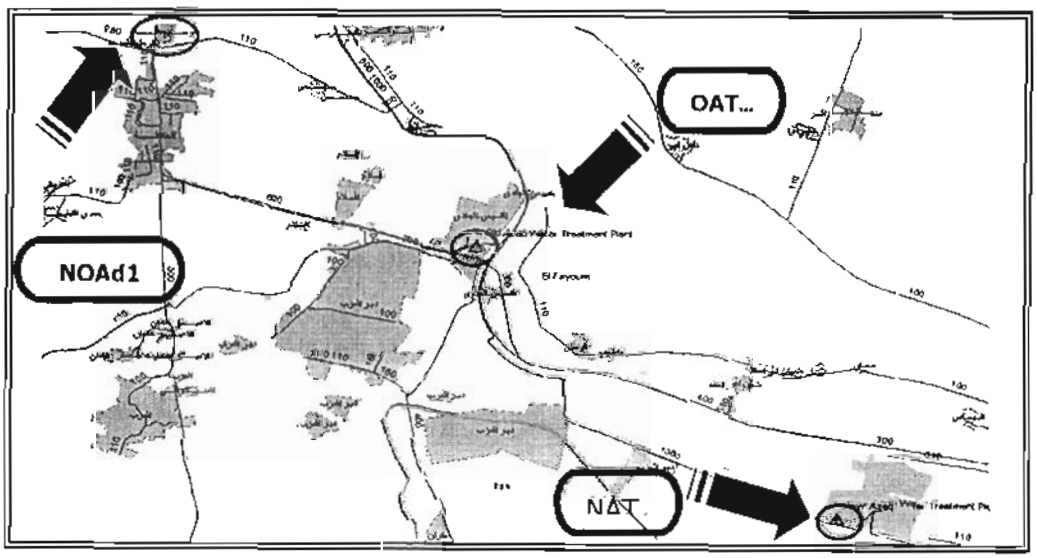


Fig. (1-1) The location of samples NAT_w, OAT_w and NOAd1

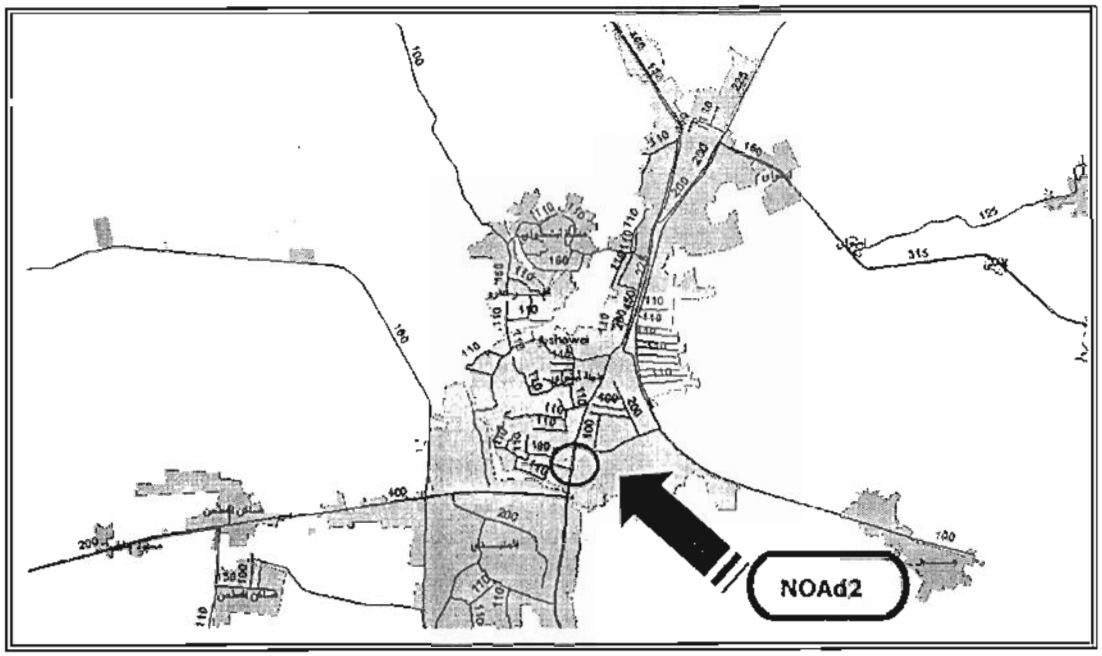


Fig. (1-2) The location of sample NOAd2

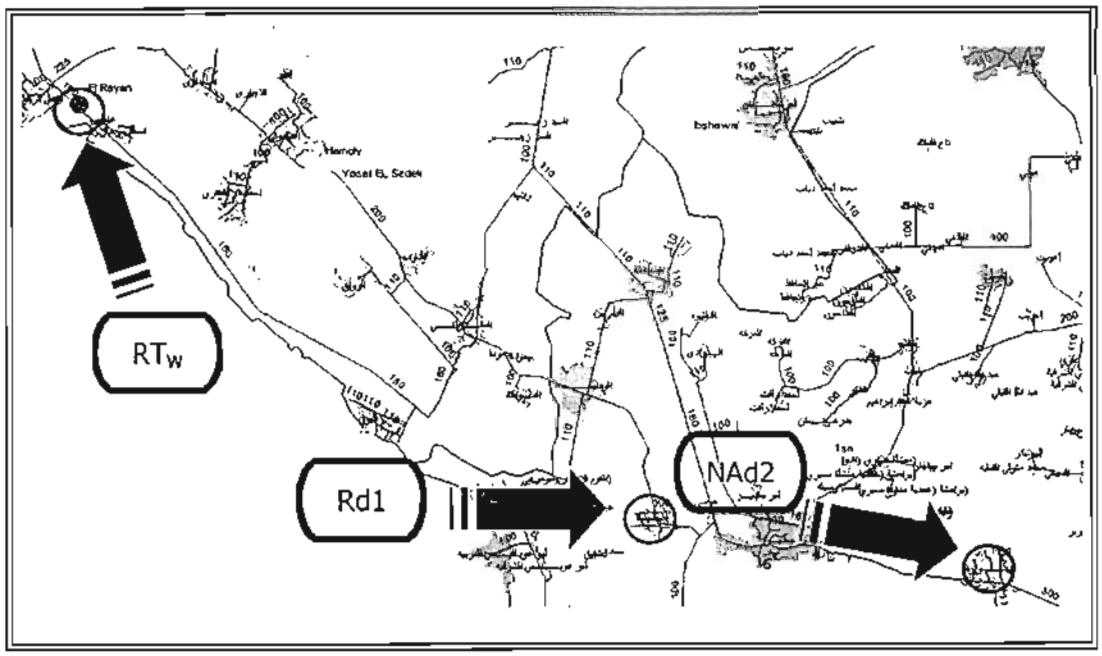


Fig. (1-3) The location of samples RT_w , Rd1 and Nad2

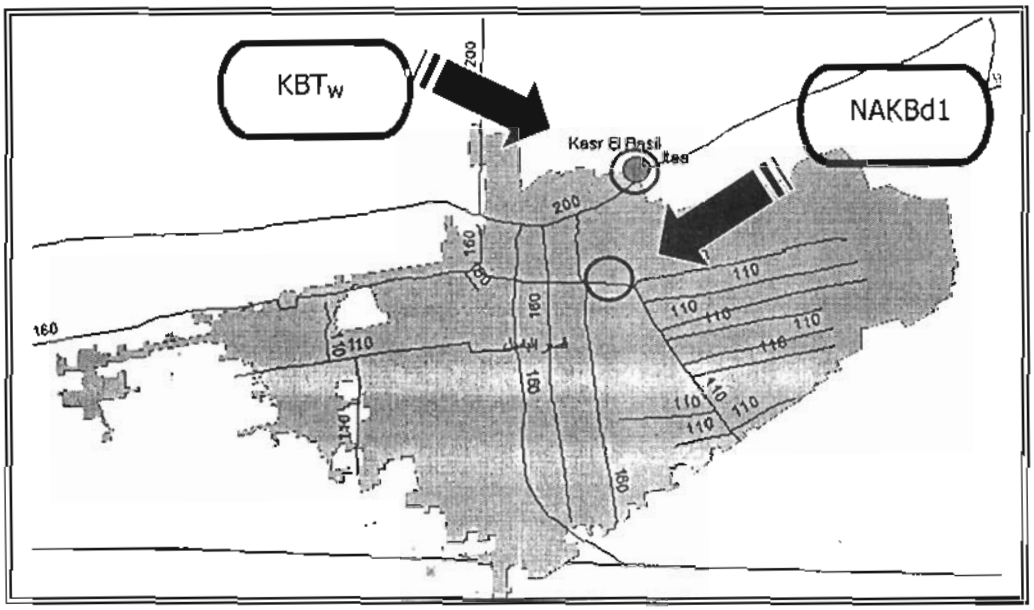


Fig. (1-4) The location of samples KBT_w and NAKBd1

- **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 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, 18th 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. Samples were transported in Icebox from site to the library.

6- Temperature

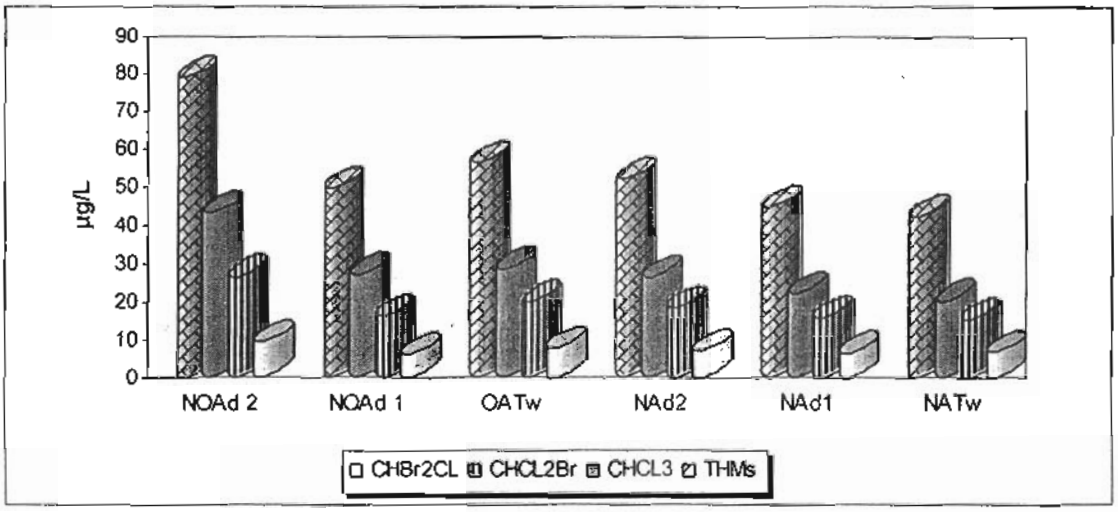
Temperature was measured using the Thermometer Mercurial at the site.

7- Travel Time

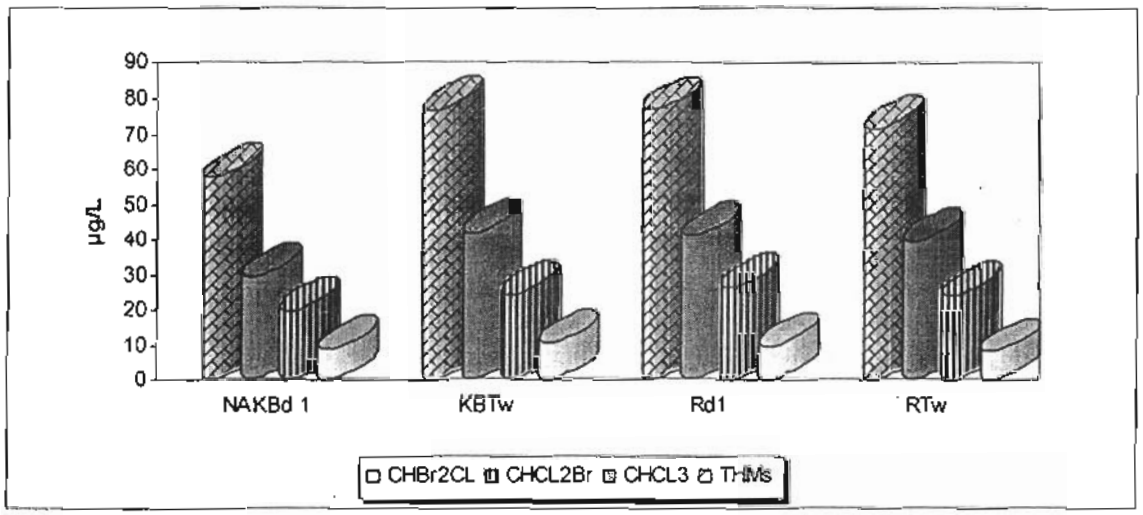
Using the water cad V8 program, The length, diameter, and C-coefficient were introduced for each pipe, as well as the flow for each treatment plant, the head of the pumps, the location of the elevated tanks, the demand pattern, chlorine dose for each and the poster pump heads.

Results And Discussion

Figs. 3 & 4 illustrates the concentrateions 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 .



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



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

The results obtained illustrated that for all the location under study, chloroform ($CHCL_3$) is the predominant THMs compound. It represents an average of 50% of total THMs, whereas $CHCl_2Br$ represents an average of 34 % of total THMs , and the Rest is $CHBr_2Cl$. The $CHBr_3$ wasn't shown at any location. At (NOAd1) in the distribution network ,the concentration of THMs is 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. The quality of treated water from New Azab treatment plant is better than water that at the Old Azab treatment plant (as shown in Fig.3). Also, at location (NAKBd1) in the distribution network, the concentration of THMs is less than that at (KBT_w) after chlorinated in Kasr El Basil treatment plant. This is because the mixing before those location between effluent of the New Azab and Kasr EL-Basil treatment plant. The quality of treated water from New Azab treatment plant is better than water that at the Kasr EL-Basil treatment plant (as shown in Fig. 4). During the period of study, although the parameter (pH, Temp., TOC, Br^-) are nearly equal for location (OAT_w, NAT_w, KBT_w), the THMs concentration at KBT_w is higher than other location, that is because Kasr EL-Basil treatment plant is a small plant located at the end of network. Its raw water comes from small secondary canal called Algaraque canal (the concentration of TOC & Br^- before intake are too high). This is because its sources of collect water from some drain such as Altuor-Alwestany (800m before the intake). The concentrations of Initial THMs appears to be associated with the THMs concentration from location to another in the distribution network as shown in (Figs.3,4). The higher the initial THMs formation after post chlorination, the lower the relative increase in THMs in the distribution network. There was 23.6% increase of THMs concentration for 5.416hr travel time difference between the locations NAd1 and NAT_w and 7.15% increase of THMs concentration for 4.861 hr travel time difference between the locations Rd1 and RT_w. 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. 5,6). There was an average chlorine consumption of 0.512 mg with an 8 μg/L increase of THMs concentration between the locations NAd1 and NAd2, but between the locations NAT_w and NAd1, 0.1 mg chlorine consumption lead to 2.5 μg/L increase of THMs concentration.

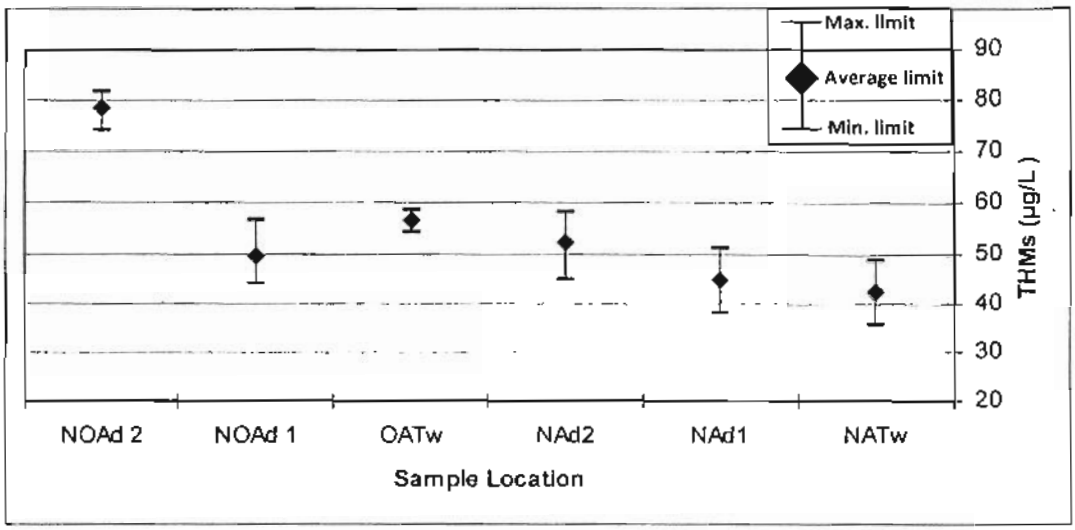


Fig.(5) The THMs concentration for six sample locations.

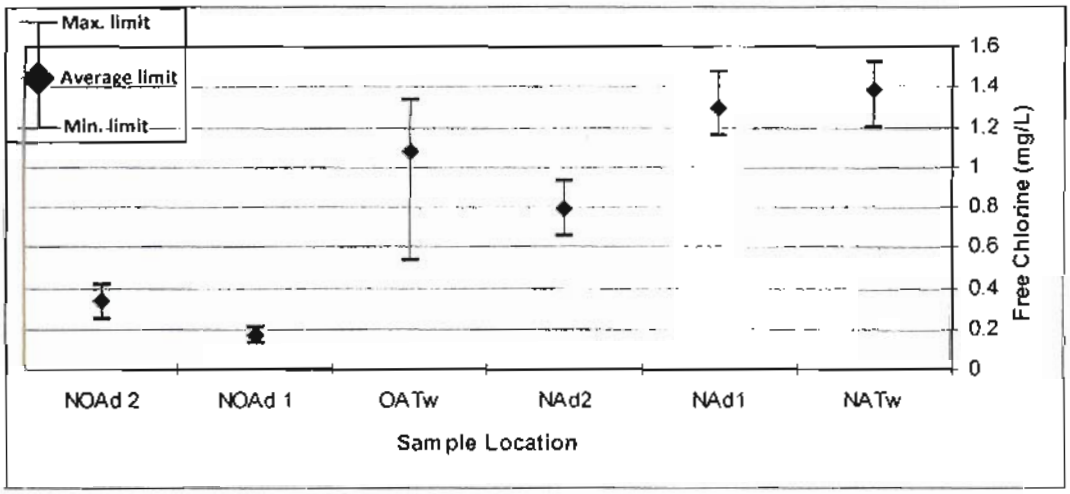


Fig.(6) The free residual chlorine concentration for six sample locations.

The residual free chlorine at location NOAd2 is higher than that at NOAd1, but the THMs concentration at location NOAd2 is higher than that at location NOAd1 as shown in (Figs. 5, 6) because the different of water quantity mixed from New and Old Azab treatment plants before the two locations since most water at locations NOAd1 and NOAd2 effluent from Old Azab treatment plant and New Azab treatment plant respectively. The concentrations of TOC appears to be associated with the THMs concentration at the location of chlorination before being distributed in the network, as shown in (Fig.7). The higher TOC concentration, the higher THMs concentrations formed .

TOC concentration at location RT_w is

less than that at location OAT_w, but the THMs concentration is higher because the chlorine dose at RT_w is equal 2 times than at OAT_w.

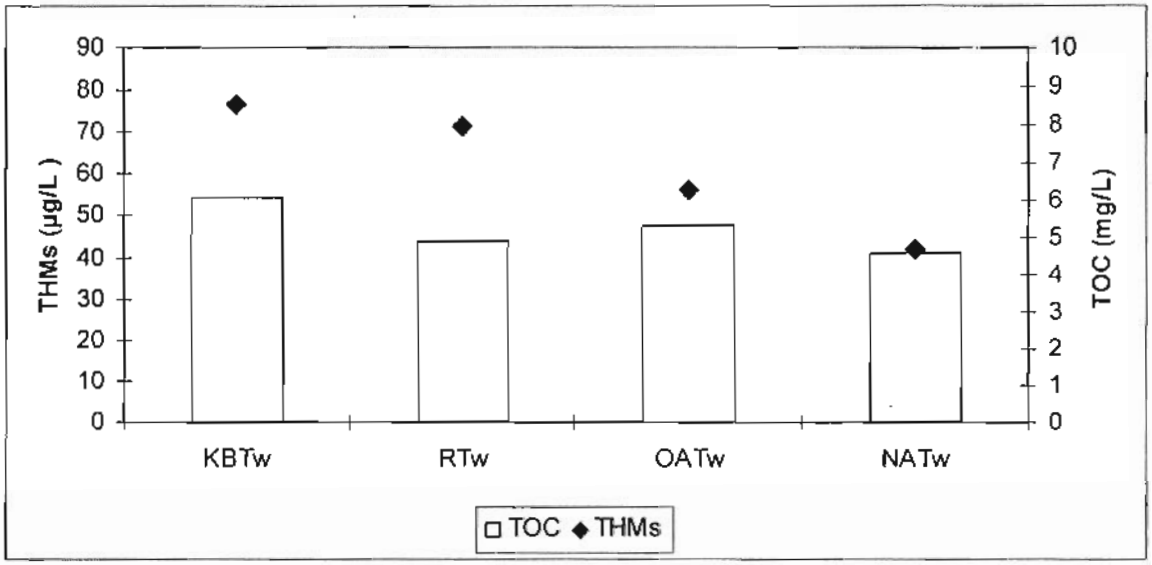


Fig.(7) The relation between TOC and THMs concentration at the effluent of treatment plants

The results obtained illustrated that the higher in temperature , the higher in the THMs concentration. (5°C increase in temp. leads to the increase of THMs concentration by 27% to 32%) as shown in (Fig. 8).

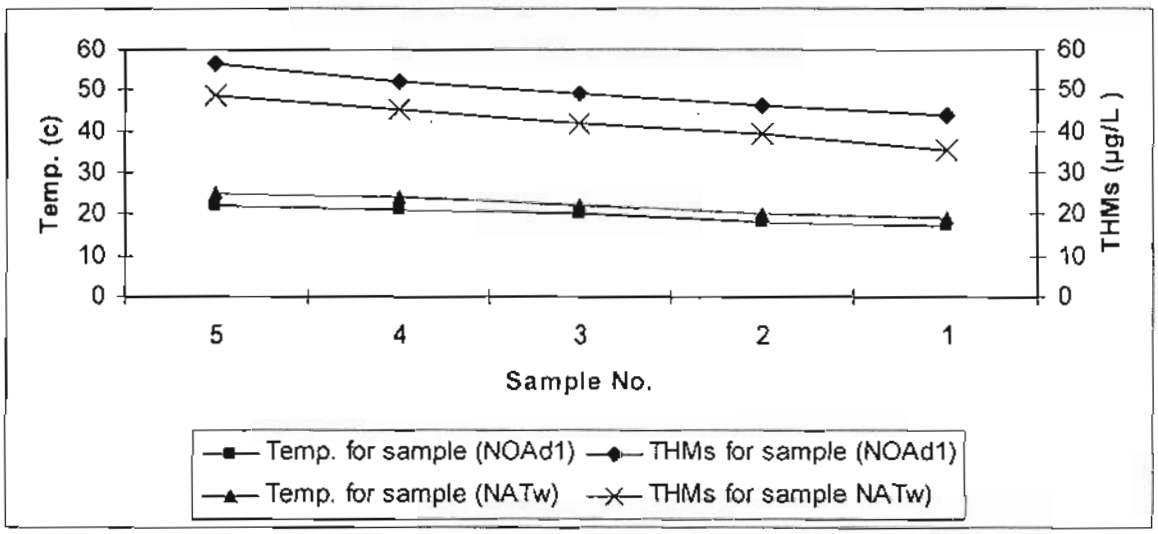


Fig.(8) The relation between Temperature and THMs concentration at (NAT_w – NOAd1)

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. 9).

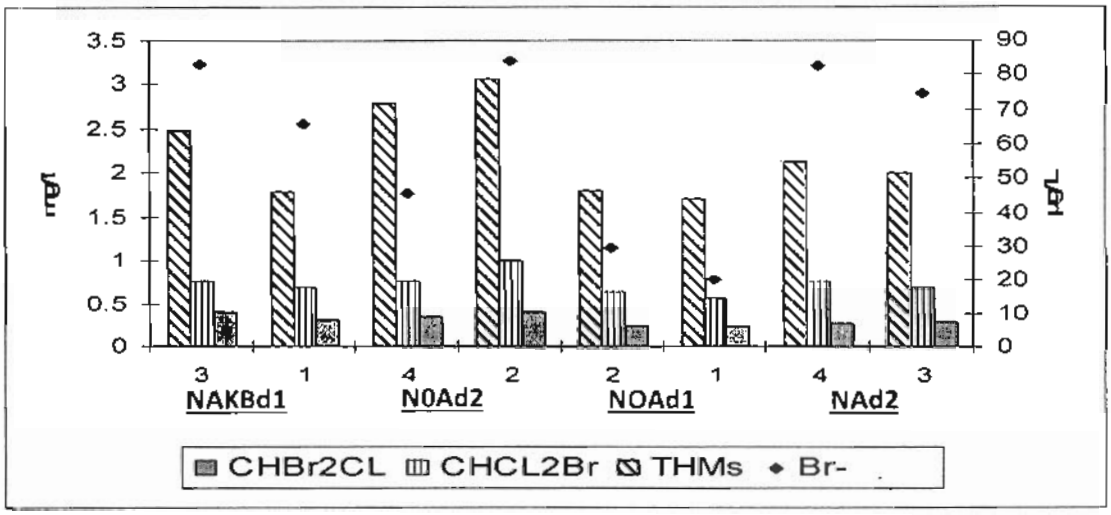


Fig.(9) The relation between Br^- and THMs concentration (TOC &Free Chlorine constant at the same location)

CONCLUSIONS

- The concentrations of THMs in all locations at the distribution network are less than the allowable limit (100 µg/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 50% 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 higher the initial THMs formation after post-chlorination, the lower the relative increase in THMs in the distribution system.
- The higher the chlorine consumption between two points, the higher concentrations of THMs formed . (an average chlorine consumption of 0.1 mg leads to the increase of THMs concentration by 2.0 to 2.5 µg/L).
- The higher in the temperature of water, the higher the concentrations of THMs formed , (5^oC increase in temperature for water leads to the increase of THMs 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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