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Assessment of Potential risks from Trihalomethanes in Water Supply at Wasit Province, Iraq

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ABSTRACT

Chlorination is used worldwide in produce drinking water in the most developing world. Frequently, lack of proper sanitation and pollution control increases the organic content in water sources, thereby increasing the potential for trihalomethanes (THMs) formation. This paper evaluates the lifetime cancer risk and the hazard index caused by THMs contained in drinking water from four areas of Wasit province, middle of Iraq. Oral exposure and the health risk were estimated using a probabilistic approach. This was done by monitoring the free residual chlorine and the THMs content in drinking water and by obtaining the actual population characteristics. Population characteristics considered, among other variables, the water intake rate, the body weight and the exposure time, and were expressed as empirical frequency distribution curves. Results showed that the 95% of the carcinogenic risk estimated for bromodichloromethane (BDCM) and dibromochloromethane (DBCM) were above the acceptable level. Until proper sanitation is implemented and water is managed integrally (in quantity and quality), the Iraq government may be need to consider alternate disinfection systems or may be need to review integrally its water supply policy in these areas.

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INTRODUCTION

A water service is currently supplied to 90% of the Iraq population. It is estimated that 99% of the distributed water is chlorinated. Chlorination of water has certainly contributed to reducing the incidence of gastrointestinal diseases such as cholera, typhoid fever, hepatitis, etc. and, disinfection with chlorine has been recognized as one of the major public health achievements. However, appropriate levels of free residual chlorine in supply systems are needed to protect health and increasingly amount of chlorine is added to sources that are becoming polluted. The addition of chlorine reduces microbial risk but poses chemical risks when disinfection by-products (DBPs) are formed. DBPs occur when chlorine reacts with natural (e.g., humic and fulvic) organic matter present naturally in water (Gallard and Gunten, 2002).

Natural organic matter, commonly measured as total organic carbon (TOC) is the organic precursor, while bromide ion is the inorganic one.

DBPs; may be found in chlorinated water, trihalomethanes (THMs), which include chloroform ($CHCl_3$), bromodichloromethane ($CHCl_2Br$), dibromochloromethane ($CHClBr_2$) and bromoform ($CHBr_3$), have been widely studied because they are considered potentially carcinogenic (McGeehin *et al*., 1993). In addition, recent studies suggest that they also produce reproductive disorders (Graves *et al*., 2002) if ingested during pregnancy (Bove *et al*., 1995, King and Marret, 1996, Dodds *et al*., 1999). Therefore, water utility managers try to reduce their formation while maintaining a free residual chlorine content that should be enough to inactivate microorganisms and prevent their re-growth in the distribution system. To control health risks caused by THMs, several countries have established a maximum content in drinking water. In the USA, the US EPA (2006) has set a value of 0.08 mg/l, in the United Kingdom (2000) and Canada (Health Canada, 2001) the limit is 0.10 mg/l, and in Egypt (Ali M. Abdullah, 2008) it is 0.10 mg/l. However, in Iraq, it is evidence that; water sources are becoming increasingly polluted due to a lack of sanitation raises concerns about the possible presence of DBPs in drinking water, so the risks are bigger because most of the population consumes tap water instead of bottled water.

The aims of this research is to evaluate the life cancer risk and the hazard index caused by THMs contained in drinking water from four areas

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communities of Wasit province using field data to characterize the local population and the quality of the drinking water.

MATERIALS AND METHOD

In this research, four communities located in the Wasit province were considered: Zahraa, Shohadaa, Damouk and Maymoun with less than 200,000 total residents. Each community has its own source to supply water where chlorine is automatically added before water enters the distribution pipes.

The field study was divided into two parts. In the first one, an environmental study was performed to determine the quality of drinking water. In the second part, data to characterize the population of each community was gathered to use it for the human health risk assessment. Field data was gathered during a 4-week sampling program in May 2013.

Water samples were taken in each area from household water intake points and from tap water inside the houses, after passage through individual storage tanks. Sampling sites were selected considering: (a) the population size; (b) the direct supply from the municipal network and (c) the household's agreement to participate in the monitoring of their water and in the survey to gather information for the risk assessment analysis.

The environmental study consisted of 24 sampling points in different households (tap water). The parameters measured were free-residual chlorine (Cl_2) and THMs.

The THM extraction and analysis was carried out according to EPA 551 method (APHA, 1995). Free residual chlorine was analyzed using a friendly colorimetric kit (DPD4).

The monitoring of residual chlorine in water was carrying out in the morning and in the afternoon, at the household's water intake point and tap water.

To characterize population exposure scenarios, questionnaires were applied to 100 adults from the four areas to determine their: tap water ingestion habits, time of residence at the site and body weight, and were expressed as empiric distribution functions (EDFs) to describe the variability of those parameters. To evaluate the lifetime cancer risk (R_{ci}) caused by the exposure to halogen compounds in drinking water, a risk assessment model was applied (equation 1) based on United States Environmental Protection Agency guidelines (US EPA, 1989). The non-cancer hazard quotient (HI_i) was used (equation 2) to estimate the risk caused by chloroform as a secondary carcinogen.

$$R_{ci} \equiv \frac{EF \times ED}{BW \times AT} \times C_{ai} \times IR_a \times Sf_i \quad (1)$$

$$HI_i \equiv \frac{EF \times ED}{BW \times AT} \times \frac{C_{ai} \times IR_a}{RfD_i} \quad (2)$$

Where Cai is the concentration of the trihalomethanes measured (mg/l) in drinking water for each community, IRa is the water ingestion rate (l/d), Sfi is the specific cancer slope factor $(mg/kg.d)^{-1}$ for bromide compounds and RfDi is the reference dose for chloroform (mg/kg.d). The other exposure variables are EF, exposure frequency (d/y); ED, exposure duration (y); BW, body weight (kg) and AT, average exposure time (d).

RESULTS AND DISCUSSION

- ***Free residual chlorine:***

A total of 288 measurements were done at households' in tap water after passing through the individual storing tanks. Only 73.6% of the measurements (Table 1) in tap water fulfilled the free residual chlorine content established by the Iraq drinking water standard of 0.35 (Ali M. Abdullah, 2008). This is a serious concern about the safeness of water, particularly from a microbial point of view.

According to Table 1, *Maymoun* area has the worse water quality supply and the major impact on water quality due to storage, followed by *Damouk*, where all the values were less than or equal to the minimum enough level free residual chlorine of 0.35 mg/l. Less adverse conditions were observed in *Zahraa* and *Shohadaa*.

- ***THMs Exposure levels:***

The total THMs concentration varied from 12 to 74 µg/l, always meeting the WHO drinking water standard of 100 µg/l (Ali M. Abdullah, 2008). THMs concentration ranges for the different chemical species were as follows: $CHCl_3$, 8 – 46.5 µg/l; $CHCl_2Br$, 4 – 21.3 µg/l; $CHClBr_2$, 0.0 – 6.9 µg/l and $CHBr_3$ 0.0 – 2.0 µg/l (Tables 2-5 and Figures 1-4). Chloroform ($CHCl_3$) was then the major specie, and was notably present in *Damouk* and *Maymoun*. $CHCl_2Br$ was the most important brominates compound, $CHBr_3$ being the least one. This is consistent with other studies (Ali M. Abdullah, 2008).

- ***Risk estimation:***

The probabilistic health risk estimation (US EPA, 2001) was estimated for drinking water ingestion. The cancer risk equation (1) was used for bromide compounds while the chloroform hazard quotient was estimated using equation (2). The empirical distribution functions developed for the ED, BW, Cai and IRa variables were used as inputs to the risk equations in order to obtain the risks as probabilistic functions. The hazard quotient for chloroform was estimated using the reference dose value given by IRIS (2005), which is considered as protective to carcinogenic effects.

The 95% of the probabilistic distribution functions (Table 6) calculated for the four areas communities showed in all cases that risk caused by

chloroform and bromoform are acceptable (< than 1 for the first compound and < than 10^{-6} for the second one). However, the 95% for bromodichloromethane and dibromochloromethane for tap water was greater than 10^{-6} for all communities. These results show that oral exposure to these compounds is higher than internationally acceptable levels, although content in water fulfill the Iraq regulation.

Conclusions:

This research showed that risks produced by THMs in four areas are not negligible and are present even though the free residual chlorine content is low or equal to zero and the drinking water limit in the norm is met. Based on these results, Iraqi policy to provide water to these areas should be reviewed integrally not only in terms of water supply but also to protect water sources, to enhance the operation of water distribution systems and, eventually, to consider alternative disinfection methods such as UV-light. Even though at the present time health risks caused by disinfection byproducts remain small compared to those caused by microbes, they might become important in the future, hence the importance of planning future water supply more carefully. This recommendation as well as the methodology approach used for the risk analysis might also be applied to other communities from developing countries in similar conditions where it is important to use actual data describing the specific local population characteristics and behavior.

Table 1: Free residual chlorine at household water in tap water samples.

Chlorine Residual (mg/l)	*Zahraa*	*Shohadaa*	*Damouk*	*Maymoun*
<0.1	3	0	9	14
0.1-0.3	6	3	23	18
0.35-0.6	12	9	22	16
0.65-1.0	30	16	10	10
>1.0	21	44	8	14

Table 2: Chloroform at household water in tap water samples.

Chloroform (µg/l)	*Zahraa*	*Shohadaa*	*Damouk*	*Maymoun*
<5	2	0	0	0
5-15	42	36	6	8
16-40	20	26	31	34
>40	8	10	35	30

Table 3: Dichlorobromomethane at household water in tap water samples.

Dichlorobromomethane (µg/l)	*Zahraa*	*Shohadaa*	*Damouk*	*Maymoun*
<5	48	44	0	0
5-15	16	18	44	52
16-40	8	10	28	20
>40	0	0	0	0

Table 4: Dibromochloromethane at household water in tap water samples.

Dibromochloromethane (µg/l)	*Zahraa*	*Shohadaa*	*Damouk*	*Maymoun*
<5	62	58	47	51
5-15	10	14	14	8
16-40	0	0	11	13
>40	0	0	0	0

Table 5: Bromoform at household water in tap water samples.

Bromoform (µg/l)	*Zahraa*	*Shohadaa*	*Damouk*	*Maymoun*
<5	72	72	66	65
5-15	0	0	6	7
16-40	0	0	0	0
>40	0	0	0	0

Table 6: The 95% from the risk distribution function.

Bromoform (µg/l)	*Zahraa*	*Shohadaa*	*Damouk*	*Maymoun*
Chloroform	*6.82E-07*	*6.08E-07*	*6.07E-07*	*5.89E-07*
Bromodichloromethane	*1.27E-05*	*1.18E-05*	*1.22E-05*	*1.39E-05*
Chlorodibromomethane	*1.59E-05*	*1.51E-05*	*1.24E-05*	*1.33E-05*
Bromoform	*1.80E-05*	*1.80E-05*	*1.68E-05*	*1.65E-05*

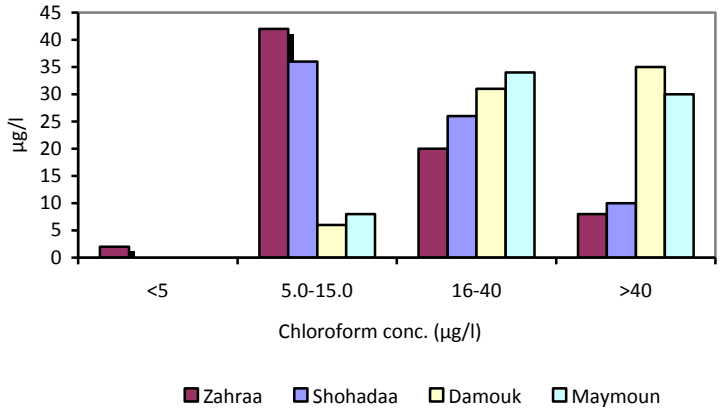

Fig. 1: Chloroform at household water in tap water samples.

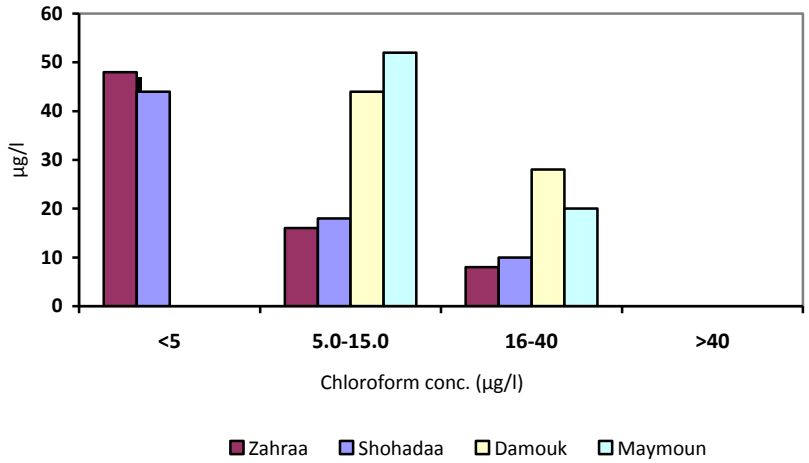

Fig. 2: Dichlorobromomethane at household water in tap water samples.

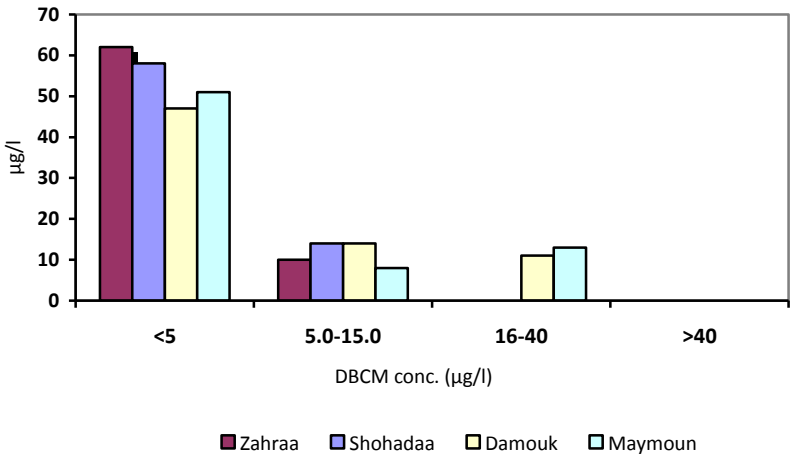

Fig. 3: Dibromochloromethane at household water in tap water samples.

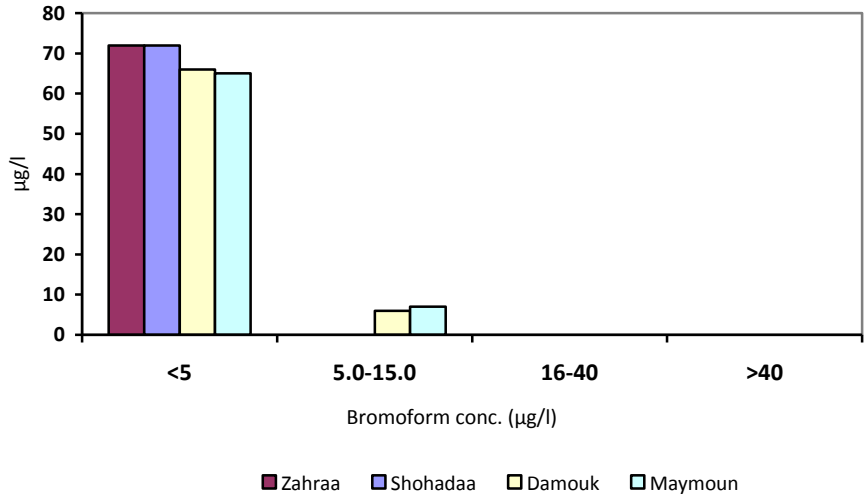

Fig. 4: Bromoform at household water in tap water samples.

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