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Carcinogenic Risk Assessment of Trihalomethanes in Major Drinking Water Sources of Baghdad City[1]

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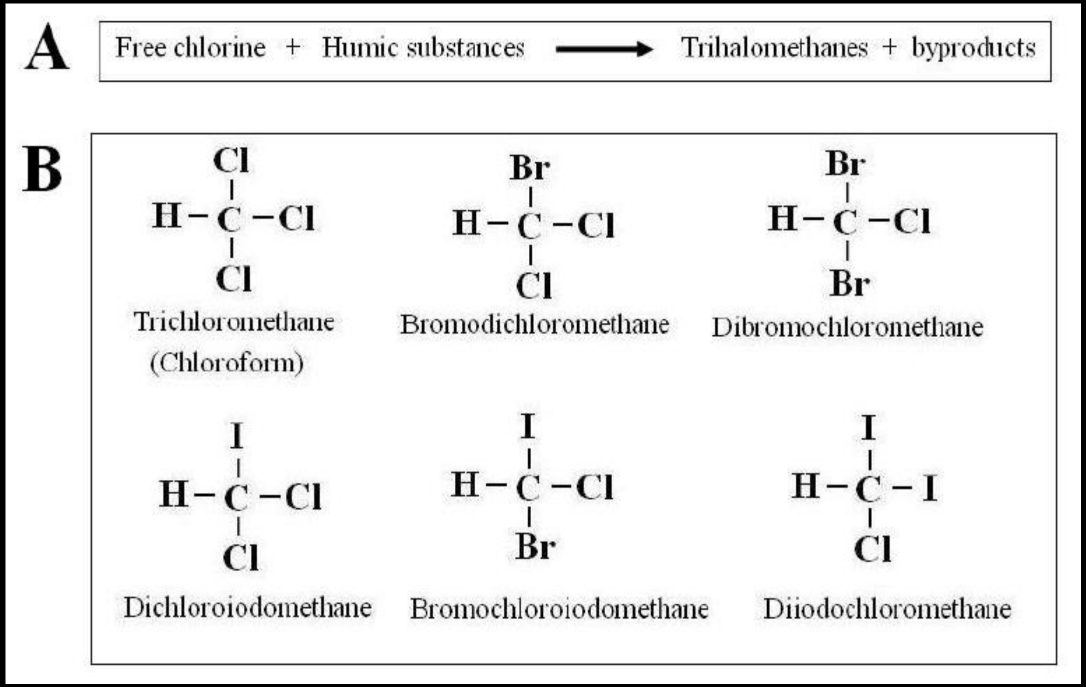
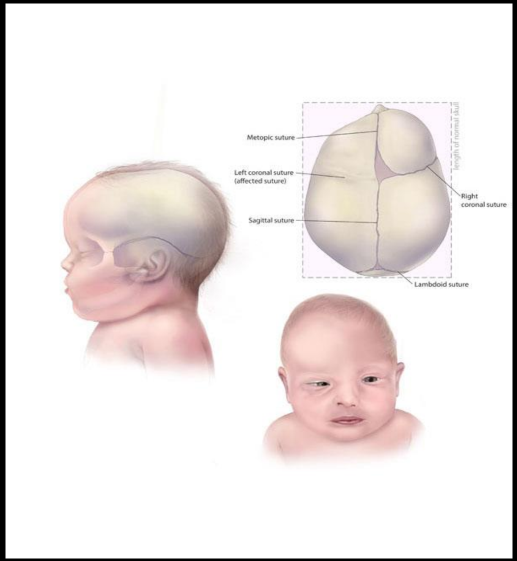




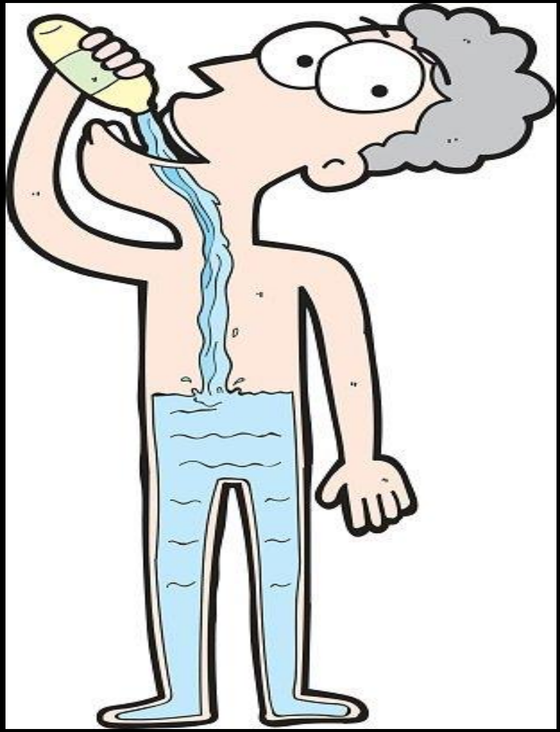
INTRODUCTION

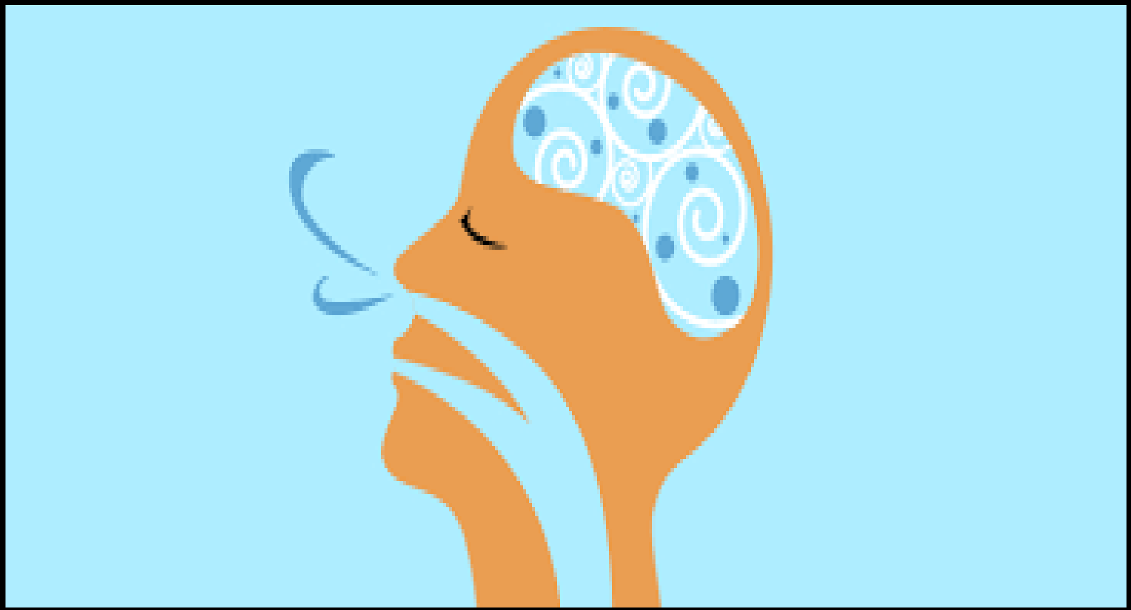
Chlorination is one of the most widely applied disinfection treatment due to its higher oxidizing potential, low cost, ease of operation and effectiveness to improve the quality of drinking water [11]. Chlorine reacts with natural organic matter (NOM) in raw water and produce disinfection byproducts (DBPs) such as chloroform (CF), bromodichloromethane (BDCM), chlorodibromomethane (DBCM) and bromoform (BF). These DBPs pose harmful health effects even at very low concentrations. These health risks may include various cancers, reproductive disorders, birth defects and miscarriage [19, 24]. DBPs formation varies greatly with quality of source water, such as concentrations and properties of NOM (as organic precursors) and levels of bromide (as inorganic precursor), chlorine dose, contact time between chlorine and water, temperature and pH of the reaction solution [8, 18, 26]. Traditional risk assessments of water often consider only ingestion exposure to toxic chemicals, but scientists have proposed that inhalation and dermal absorption should be considered [33]. Thus, the purpose of this study is to conduct a multi-pathway exposure assessment of selected seven water treatment plants in Baghdad City based on the concentrations of THMs within water distribution system.

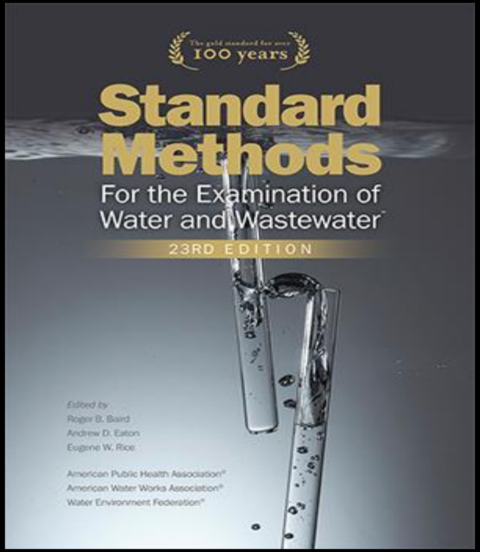
MATERIALS AND METHODS

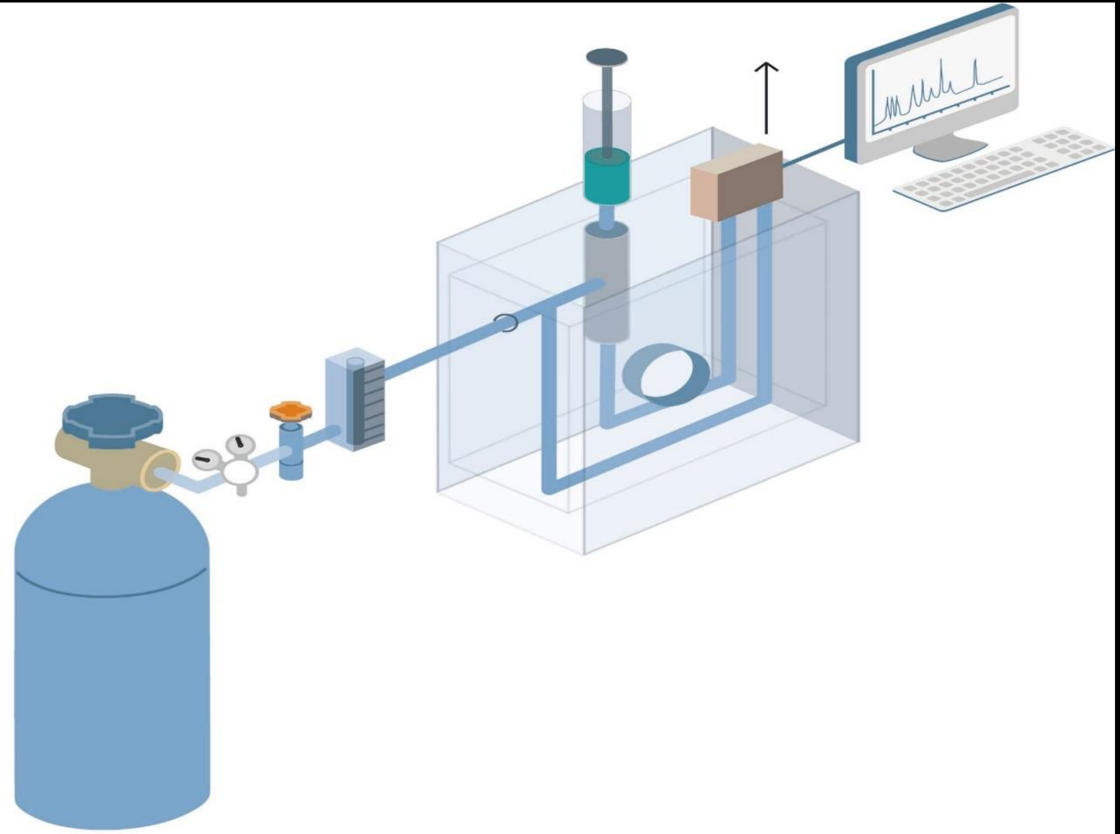
Drinking Water Treatment Plants in Baghdad

There are 10 water treatment plants (WTPs) in Baghdad City which take water from the Tigris River. These plants use chlorine to maintain a certain level of residual chlorine in the distribution system to prevent bacterial growth [2]. All data for this study were obtained from seven WTPs (Sh. Dijla, Wathba, Karama, Qadisyah, Dura, Wahda and Rasheed) and from distribution networks nearby for each of them. Baghdad City had 7.5 million inhabitants [10], and the area of the city is 1000 km^2. The design capacities of the 7 WTPs in Baghdad are 3120000 m^3/day and the actual production is 2504000 m^3/day.









Water samples collected for ten months starting in January 2014 to October 2014. Sample volume of 250 mL was collected into clean glass bottles filled completely to avoid air bubbles and loss of THM, and sodium thiosulfate (10 mg for 10 mL of sample) was added as a dechlorination agent. All glass bottles sealed with TFE-lined screw caps and placed in a cooler box, stored at 4°C and analyzed within 2−3 h.

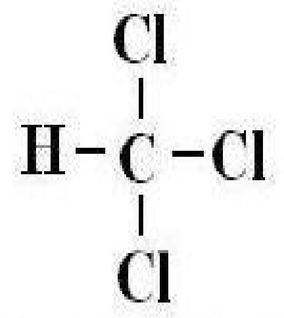
Free residual chlorine ($R.Cl_2$), pH and temperature (Tem) were measured in situ, while the other parameters like alkalinity (Alk), turbidity (Tur), total suspended solids (TSS), chlorine dose and electrical conductivity (EC) were measured in a laboratory according to the respective procedure described in standard methods of APHA [6]. THMs were measured using Gas chromatography model (DANI GC 1000, Dani Instrument SPA, Italy) with electron capture detector (GC-ECD). The TOC determination procedure followed that outlined in standard method No. 5310 C of APHA [6] using (multi N/C 3100 total organic carbon analyzer, Analyticjena, Italy).

limit (150 µg/L). However, many samples exceeded the maximum contaminant level of USEPA (80 µg/L) in summer. The results of TTHMs and components formed in the treated water at the seven WTPs indicated that the seasonal concentration of TTHMs ranged between 13.78 and 63.1 µg/L in winter and summer, respectively (Table 5). Seasonal variation in surface water quality is mainly related to changes in climatic parameters like temperature and rainfall. During warm months of the year, organic matter content increases due to rapid decay of vegetation. The rains also increase the organic matter content by leaching of organic matter into the watersheds [1].

In samplescollected from treated water, the DBCM was the major constituent (40%) of the THMs ranged between 5.5 and 25.27 µg/L in winter and summer, respectively. The general trend of THMs species followed this order: DBCM (36%) > BDCM (27%) > CF (25%) > BF (12%). The present study suggests that the treated water produced by the 7 WTPs are within the WHO and Iraqi standards limits with respect to THMs.

In this study, a multi-pathways (oral, dermal, and inhalation) exposures were considered in the cancer risk assessment of THM in Baghdad population and were estimated based on the exposure factors in Tables 1 and 2.

The calculation of the cancer risks of THM through inhalation is only carried out for chloroform. In inhalation risk calculations, the daily dose was calculated by assuming 20 m^3 aspiratedair per day [16]. The chloroform concentration in air used for the estimation of risk through inhalation was calculated using a volatilization factor of 0.5 L/m^3 as suggested by USEPA [28]. The following relationships were used to



Trichloromethane
(Chloroform)

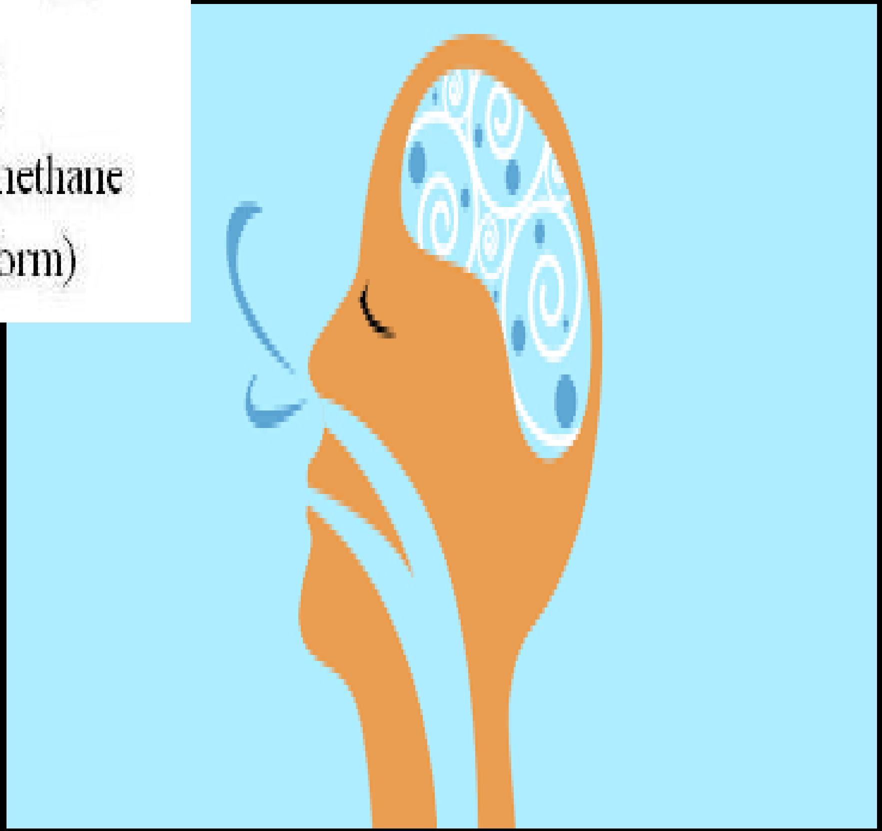


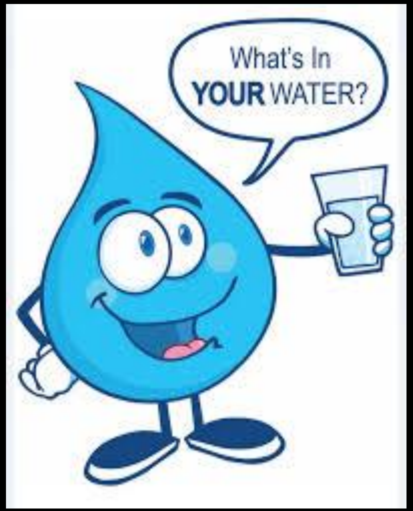
Table 4. Seasonal variations of TTHM in raw water, treated water and tap water (μg/L)

Water treatment plants	SharqDijla	Wathba	Karama	Qadysia	Dura	Wahda	Rasheed
Representative winter months (January and February)							
Raw	3.5 ± 2.1	4 ± 1.4	4 ± 1.4	4 ± 2.8	5.5 ± 0.7	9 ± 1.4	6 ± 0
Treated	8.5 ± 3.5	10.5 ± 2.1	9.5 ± 4.9	9.5 ± 7.7	17 ± 2.9	24 ± 4.2	17.5 ± 2.1
Tap water	12 ± 5.6	14 ± 3.5	15 ± 4.2	13.5 ± 10.6	22.5 ± 2.1	33 ± 5.6	23.5 ± 2.1
Spring months (March, April, and May)							
Raw	10.3 ± 5	12 ± 7	31.3 ± 33.5	12 ± 2.6	9.3 ± 4	14 ± 1.5	13.6 ± 3.2
Treated	25.6 ± 10	28.6 ± 16.7	40 ± 19.7	28.3 ± 5.8	25 ± 8.1	39.3 ± 13	38 ± 5.2
Tap water	36 ± 16.3	40.6 ± 23.7	33.3 ± 15	40.3 ± 8.3	24.3 ± 12.2	53.3 ± 18.5	51.6 ± 8
Summer months (June, July and August)							
Raw	25 ± 3	28 ± 6	28 ± 2.6	22.6 ± 4	25.6 ± 8.9	30.3 ± 2.5	23.6 ± 2
Treated	58 ± 8.1	64.6 ± 2	62.6 ± 13	62.6 ± 12.2	56.6 ± 3.7	67 ± 1.7	70.3 ± 8.5
Tap water	83 ± 11	89.6 ± 4.7	90.6 ± 15.6	86 ± 16.5	79 ± 16.3	97.3 ± 4	94 ± 6.9
Representative Autumn months (September and October)							
Raw	21.5 ± 6	20.5 ± 0.2	20.5 ± 0.7	25 ± 7	21.5 ± 9.2	20 ± 12.7	16.5 ± 4.9
Treated	53.5 ± 7	54.5 ± 0.1	51.5 ± 16.2	51.5 ± 17	50 ± 18.3	53 ± 32.5	61 ± 24
Tap water	75 ± 14.4	75 ± 0.3	72 ± 15.5	76.5 ± 26.1	71.5 ± 27.5	73 ± 45.2	77.5 ± 29

CONCLUSIONS

The concentration of THMs in drinking water samples collected from seven WTPs and distribution systems of Baghdad City is generally within the allowable concentration recommended by the WHO and the Iraqi standards, and the seasonal variation of TTHMs concentrations followed the order: summer > autumn > spring > winter. The results revealed that the Bromotrihalomethanes (BrTHMs) was found at highest level compared to other bromine compounds (dibromochloromethane and bromodichloromethane). Non-carcinogenicrisksinduced by ingestion of THMs were below the tolerable level (10^{-6}). The highest lifetime cancer risk comes from oral ingestion followed by dermal absorption and inhalation exposure, respectively.

Data obtained in this research demonstrate that exposure to drinking water contaminants and associated risks were higher than the acceptable level. Therefore, the optimized use and practice of chlorination should be controlled in order to reduce of THMs formation at acceptable risk, in order to provide the safe water to Baghdad people. A method for decision-makers in formulating a modus operandi considering the economy and reasonable technology to reduce the national standard value limits is necessary.

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