
Bibliography. Figures. Tables.


Boustany, Z.

PER L1049 / FA193886P
ASSESSMENT OF THE PRESENCE OF TRIHALOMETHANES IN THE PUBLIC DRINKING WATER OF THE KESROUAN REGION IN LEBANON

Z. BOUSTANY
Holy Spirit University of Kaslik
Faculty of Agricultural Sciences
P. O. Box 446 Jounieh, Lebanon

Under the supervision of Prof. G. AYOUB
American University of Beirut
Faculty of Agricultural and Food Sciences
P. O. Box 11-0236/Riad El-Solh, Lebanon

ABSTRACT

This study, undertaken in the Kesrouan region, has shown that trihalomethanes (THMs) are present in chlorinated drinking water. Samples from different wells and springs at different locations, before chlorination, directly after chlorination and at the end of the distribution network, were taken and analyzed for THMs presence. Analysis have been performed by Purge-and-Trap (PAT) Gas Chromatography (GC) Mass Spectrometry (MS) and Liquid-Liquid (LL) Gas Chromatography (GC) Electron Capture Detector (ECD) techniques. Water samples have been collected in springtime, and have shown the occurrence of bromoform (TBM), dichlorobromomethane (DCBM) and dibromochloromethane (DBCM) as a result of the chlorination of raw water. In all samples, the concentrations were far below the Maximum Acceptable Concentration (MAC) of 80 µg/l for Total Trihalomethanes (TTHMs) as presently set by the US Environmental Protection Agency.

Keywords: trihalomethanes, chlorinated drinking water, Purge-and-Trap GC/MS, Liquid-Liquid GC-ECD, Kesrouan, Lebanon.
RÉSUMÉ

Cette étude a été réalisée dans le but de déterminer la présence des Trihalométhanes (THMs) dans l’eau potable chlorée de la région de Kesrouan. Les analyses ont été faites avec les techniques du PAT-GC/MS et du LL/GC-ECD. Les échantillons ont été prélévés, à la fin du printemps, de différents puits et sources d’eau, à trois emplacements, respectivement avant chloration, directement après chloration et à la fin du réseau de distribution. Les résultats ont mis en évidence la présence du bromoforme (TBM), du dichlorobromométhane (DCBM) et du dibromochlorométhane (DBCM) suite à l’addition du chlore à l’eau potable. Ces composés ont été détectés à des concentrations très inférieures à la concentration maximale admise (MAC) de 80 µg/l établie par l’Agence Américaine de Protection de l’Environnement.

Mots-clés: trihalométhanes, eau potable chlorée, PAT-GC/MS, LL GC-ECD, Kesrouan, Liban.

INTRODUCTION

Water is the most important part of every living organism. It comprises 76% of all human tissues and is vital to every biological function. Drinking water is not an option. Under normal conditions, the human body loses and therefore must replace 2-3 liters of water every day. Water acts like a liquid sponge, it soaks up chemicals, absorbs them and carries them along with it. It is therefore essential to ingest water that is pure, free of contaminants in order to maintain good health.

One of the primary goals in providing potable water is to reduce the risk of microbial contamination in drinking water supplies. For decades, water systems have used disinfectants, such as chlorine and ozone, to effectively inactivate and control many microbes as well as to provide a disinfectant residual in distribution systems. However the same disinfectants that are used to protect the public from microbial outbreaks have been found to form by-products that might cause potential health risks. As the level of disinfectant increases, the relative microbial risk decreases and the Disinfection By-Products (DBPs) risk increases. The use of chlorine in water treatment, to reduce the risk of disease, may account for a substantial portion of the cancer risks associated with drinking water.

Of these by-products, trihalomethane (THM) is known to be a carcinogenic compound. Little, if any, is known about the levels of THMs in the drinking
water of Lebanon compared to other countries. What is definitely known is that the addition of chlorine to our water supplies, in most cases, is practiced in an erratic and uncontrolled manner. Such a practice and in the presence of precursors could lead to the formation of THM in our water supplies. To the best of our knowledge, no studies have been conducted or reported on THMs in drinking water in Lebanon.

The aim of this study is to detect and quantify the levels of THMs in our drinking water. The Kesrouan Region was selected to cover the study area as it engulfs many sources from which water is supplied after a simple process of disinfection with chlorine.

Furthermore, preliminary studies conducted during the late summer of 2002 have indicated the presence of THM’s in some of these sources.

**MATERIALS AND METHODS**

Samples of water were collected from seven different sources (wells and springs) of public drinking water that serve the Kesrouan region in the summer period. The only water treatment process applied to these sources is disinfection using chlorine. The collected samples were analyzed on-site for some physical characteristics, pH with a pH-meter, temperature with a digital thermometer, TDS with a conductivity-meter, conductivity with a conductivity-meter, and then taken to the laboratory to be tested for the presence of trihalomethanes.

For each well or spring, samples were collected, in duplicates, at three different points (before chlorination, after chlorination, and at the end of the distribution network) when possible.

Upon collection, the sample vials were stored in the dark at temperatures below 4 °C, and later carried to the Environmental Engineering Research Center (EERC) at the American University of Beirut (AUB) and to the Water Quality Laboratory at the Dbayeh Treatment Plant, which is affiliated to the Beirut Water Office, for testing for THMs.

At the laboratories, the following THMs were studied: chloroform, dibromo-methane, bromodichloromethane and bromoform. These compounds were analyzed according to two different approved analytical methods: (1) Purge and Trap coupled to Gas Chromatography/ Mass spectrometry (PAT-GC/MS) (US EPA, 2000) in Dbayeh Treatment plant, and (2) Liquid-Liquid Extraction and Gas Chromatography with Electron Capture detection (LL/GC-ECD) (US EPA, 1995) at the EERC/AUB.
RESULTS AND DISCUSSION

Water samples were examined before any treatment, after the disinfection process and at the end of the distribution network when possible. Some of the parameters that impact the formation of THMS in the water were analyzed such as pH and temperature. As these parameters increased, the formation potential of THMs increased (Amy et al., 1987). Figures 1 and 2 show the evolution of the temperature and pH respectively of the waters originating from some of the wells and springs in use. In general, these parameters increased marginally for the same water source, with the point of sampling (before Chlorination< after Chlorination< end of the distribution network). Results of analysis of water samples were summarized in Table 1.
Table 1: Results of analysis of the different wells and springs.

<table>
<thead>
<tr>
<th>Date</th>
<th>Source</th>
<th>Background info</th>
<th>pH</th>
<th>Temperature (°C)</th>
<th>Conductivity (μS/cm at 25°C)</th>
<th>TDS (mg/L at 25°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>23-4-2003</td>
<td>Ainoura Well (400 m depth)</td>
<td>Before Cl</td>
<td>NA*</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td></td>
<td></td>
<td>After Cl</td>
<td>Aintoura</td>
<td>6.84</td>
<td>18.5</td>
<td>593</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Network</td>
<td>Aintoura</td>
<td>6.81</td>
<td>22</td>
<td>635</td>
</tr>
<tr>
<td>23-4-2003</td>
<td>Jeita Well (100 m depth)</td>
<td>Before Cl</td>
<td>Jeita</td>
<td>6.94</td>
<td>19.9</td>
<td>500</td>
</tr>
<tr>
<td></td>
<td></td>
<td>After Cl</td>
<td>Jeita</td>
<td>6.97</td>
<td>20</td>
<td>506</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Network</td>
<td>Aintoura</td>
<td>7.15</td>
<td>20.6</td>
<td>522</td>
</tr>
<tr>
<td>5-5-2003</td>
<td>Chnaniir Well (400 m depth)</td>
<td>Before Cl</td>
<td>Chnaniir</td>
<td>6.81</td>
<td>22</td>
<td>635</td>
</tr>
<tr>
<td></td>
<td></td>
<td>After Cl</td>
<td>Chnaniir</td>
<td>7.04</td>
<td>21.1</td>
<td>648</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Network</td>
<td>Aintoura</td>
<td>7.53</td>
<td>35</td>
<td>859</td>
</tr>
<tr>
<td>8-5-2003</td>
<td>Al Moundik Spring</td>
<td>Before Cl</td>
<td>El Zeyir</td>
<td>7.23</td>
<td>17.8</td>
<td>298</td>
</tr>
<tr>
<td></td>
<td></td>
<td>After Cl</td>
<td>El Zeyir</td>
<td>7.35</td>
<td>21</td>
<td>334</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Network</td>
<td>Jounieh</td>
<td>7.35</td>
<td>19</td>
<td>313</td>
</tr>
<tr>
<td>21-5-2003</td>
<td>Al Assal Spring</td>
<td>Before Cl</td>
<td>Faraya</td>
<td>7.63</td>
<td>13.4</td>
<td>163.9</td>
</tr>
<tr>
<td>19-5-2003</td>
<td>Chahtoul Well (375 m depth)</td>
<td>Before Cl</td>
<td>Chahtoul</td>
<td>7.39</td>
<td>18.3</td>
<td>415</td>
</tr>
<tr>
<td>9-5-2003</td>
<td>Harissa Well</td>
<td>Before Cl</td>
<td>Harissa</td>
<td>7.16</td>
<td>19.6</td>
<td>623</td>
</tr>
</tbody>
</table>

*NA: Not available for sampling
Figure 1 shows a modest variation in temperature for the different sources except for the Chnaniir source, where a marked increase in temperature in the network measurement was recorded. This increase could partly be attributed to the fact that the sample was taken from a home at the end of the distribution network where the water is stored and supplied from a roof tank that is exposed to sun heat.

![Temperature Graph](image)

**Figure 1.** Temperature of different wells and springs related to location.

![pH Graph](image)

**Figure 2.** pH of different wells and springs related to location.
A marked increase in pH values with sampling locations is noted as shown in figure 2 for most of the sources. Also, the highest measured increase was recorded for the Chnaniir source, which varied from a value of 6.81 (before adding chlorine) to 7.04 (after adding chlorine) to 7.53 (at the end of the network).

The other two physical parameters analyzed on-site, conductivity and TDS (Fig. 3 and 4) show relatively stable concentrations for the different sources except for the Chnaniir source, which demonstrated appreciable increases in TDS concentration and hence conductivity in the network as compared to the other sampling locations. This may be due to the mixing of water from another source in the main network supplied from the Chnaniir well.

![Conductivity Graph](image)

**Figure 3.** Conductivity of some wells and springs related to location.

![TDS Graph](image)

**Figure 4.** TDS of some wells and springs related to location.
The analytical results of the samples revealed the presence of THMs in water directly after the chlorination point. No THMs were detected in the raw water samples. The analysis of samples indicated that the formed volatile organic compounds upon chlorination of water were bromoform (TBM), dibromochloromethane (DBCM) and bromodichloromethane (BDCM).

The increase in THMs in the distribution system especially at the end of the distribution system is likely due to the larger contact time of chlorine with water. Bromoform was the most frequently detected compound among all the THMs present.

Analysis with the PAT-GC/MS showed no presence of THMs in all wells and spring analyzed.

1- Jeita well

Analysis with the LL/GC-ECD, showed that Bromoform and dibromochloroform do exist but only upon chlorination of the well water (Fig. 5). Bromoform appears in the samples directly after chlorination and at the end of the distribution network but at different concentrations, 1.48433e-1μg/L and 9.14489e-1μg/L, respectively. The increase in TBM concentration is a result, most probably, of the prolonged residence time in the distribution network. DBCM appears only at the end of the distribution network at a concentration of 2.36349e1μg/L. These concentrations are far below the MAC of 80μg/L for TTHM adopted by the USEPA in 1989. The two other THMs compound, TCM and BDCM are absent in all three sampling locations.

![Figure 5. Evolution of THMs concentration with sampling location for Jeita well.](image-url)
2- Nabeh El Madik spring

The LL/GC-ECD detected the presence of TBM directly after chlorination and at the end of the distribution network (Fig. 6). DBCM on the other hand appeared only directly after chlorination and is not detected at the end of the distribution network. The absence of DBCM and the decrease in the TBM could be a consequence of the intrusion of other sources of water along the distribution network. The other THMs were not detected in all three samples.

![Graph showing concentration of TBM and DBCM in Nabeh Al Madik](image)

**Figure 6.** Evolution of THMs concentration with sampling location for Nabeh Al Madik.

3- Aintoura well

TBM was detected in both locations with the LL/GC-ECD (Fig. 7). The three other THMs did not appear in the chromatograms.

![Graph showing concentration of TBM in Aintoura Well](image)

**Figure 7.** Evolution of THMs concentration with sampling location for Aintoura well.
4- Chaanniir well

TBM, DBCM and BDCM were detected with the LL/GC-ECD at the end of the distribution network at concentrations of 3.01474 µg/L, 1.49625 and 0.957909 µg/L respectively (Fig. 8).

![Chnaniir Well](image)

**Figure 8.** Evolution of THMs concentration with sampling location for Chnaniir Well.

5- Harissa well, Chahtoul well and Nabeel El Aassal spring

These sources of water were analyzed before chlorination. All three were free from THMs. Both the Chahtoul and Harissa wells are usually not chlorinated because their citizens stand against any disinfection process that could induce a tasty and smelly drinking water.

As for the Nabeel El Aassal spring, at the time of sampling the station was out of chlorine.

CONCLUSION

Trihalomethane formation resulting from chlorination of drinking water was studied in different wells and springs of the Kesrouan region in Lebanon. The detected THMs were Bromoform, Dibromochloromethane and Dichlorobromomethane. The concentrations of the THMs were depicted in the following order: end of distribution network> directly after chlorination. However, the difference between the two locations was relatively low. The mean concentrations found in chlorinated samples were between 0.16 µg/l and 3.01µg/l for
bromoform, 0.23 µg/l and 1.49 µg/l for DBCM and of 0.958 µg/l for BDCM. Bromoform was the mostly detected compound among the other THMs. This may be due to the presence of Bromide in these waters.

Based on the data of this survey, it appears that Kesrouan public drinking water is within the acceptable standards set by the US EPA THM limit of 80 µg/L. Even with more stringent standards that are being contemplated by EPA, the THM values recorded for the Kesrouan region will remain to be acceptable.

It is recommended that further studies be conducted to assess the presence of THMs in all drinking waters of Lebanon to extend over the four seasons and to extend for several years. This will provide Lebanon with some reliable statistics concerning THMs and their occurrence in the Lebanese public drinking water supplies.
BIBLIOGRAPHY


