Bromate in Drinking Water

The bromate ion (BrO₃⁻) may exist in a number of salts, the most common of which are potassium and sodium bromate.

### Identity

<table>
<thead>
<tr>
<th>Compound</th>
<th>CAS No.</th>
<th>Molecular formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>Potassium bromate</td>
<td>7758-01-2</td>
<td>KBrO₃</td>
</tr>
<tr>
<td>Sodium bromate</td>
<td>7789-38-0</td>
<td>NaBrO₃</td>
</tr>
</tbody>
</table>

### Physicochemical properties (Weast, 1986)

<table>
<thead>
<tr>
<th>Property</th>
<th>Potassium bromate</th>
<th>Sodium bromate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boiling point (°C)</td>
<td>370 (decomposes)</td>
<td>-</td>
</tr>
<tr>
<td>Melting point (°C)</td>
<td>350</td>
<td>3.81</td>
</tr>
<tr>
<td>Density at 20 °C</td>
<td>3.27</td>
<td>3.34</td>
</tr>
<tr>
<td>Water solubility (g/litre)</td>
<td>133 (40 °C)</td>
<td>498 (100 °C)</td>
</tr>
<tr>
<td></td>
<td>275 (8 °C)</td>
<td>909 (100 °C)</td>
</tr>
</tbody>
</table>

### Major uses and sources in drinking-water

Bromate may be formed in water during ozonation when the bromide ion is present (Haag & Hoigné, 1983). Under certain conditions, bromate may also be formed in concentrated hypochlorite solutions used to disinfect drinking-water (IPCS, 2000). This reaction is due to the presence of bromide in the raw materials (chlorine and sodium hydroxide) used in the manufacture of sodium hypochlorite. Bromide is not oxidized by chlorine dioxide, so the use of chlorine dioxide will not generate hypobromous acid, hypobromite ion or bromate (Hoigné & Bader, 1994). (Although bromate can be formed on simultaneous exposure to chlorine dioxide and light [Rice & Gomez-Taylor, 1986; Gordon & Emmert, 1996], the reaction is thermodynamically unfavourable, and bromate is unlikely to be formed under water treatment conditions.) Bromate can also be formed in electrolytically generated hypochlorous acid solutions when bromide is present in the brine (Fielding & Hutchison, 1993).

Sodium and potassium bromate are powerful oxidizers used mainly in permanent wave neutralizing solutions and the dying of textiles using sulfur dyes (Mack, 1988). Potassium bromate is also used as a chemical reagent and as an oxidizer to mature flour during milling and to condition dough during baking (US FDA, 1994; IARC, 1999). As well, it is used in treating barley in beer making and has been used for the improvement of the quality of fish paste products in Japan (Ministry of Health and Welfare, 1979; JECFA, 1995). However, JECFA (1995) concluded that the use of potassium bromate in food processing was not appropriate and that, as a general principle, bromate should not be present in food as consumed.

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1 Extracted from "Bromate in Drinking-water: Background document for development of WHO Guidelines for Drinking-water Quality, WHO/SDE/WSH/05.08/78, World Health Organization 2005."
**Environmental fate**

No information is available on the taste or odour threshold of bromate. Bromate does not volatilize and is only slightly adsorbed onto soil or sediment. Because it is a strong oxidant, its most likely fate is reaction with organic matter, leading to the formation of bromide ion.

**Bromate in Water**

Bromate is not normally found in water. Conversion of bromide to bromate upon ozonation may be affected by natural organic matter, pH and temperature, among other factors. The relative increase of bromate depends on measures used for comparison (over time or as a function of concentration x time, or CT). The use of CT has been suggested as a more useful indicator to describe the relative rate of bromate formation because it also gives a simultaneous descriptor for disinfection efficiency (von Gunten et al., 2001). The rate of formation of bromate ion may increase with temperature (AWWARF, 1991; Siddiqui & Amy, 1993). In addition, many studies on the effect of alkalinity on the formation of bromate during ozonation indicate that increased alkalinity increases bromate formation (Siddiqui et al., 1995). However, the rate of formation of bromate during ozonation is also affected by ozone characteristics. Thus, a smaller CT might result because ozone becomes less stable with increasing temperature and/or alkalinity. All factors being equal, bromide concentration and ozone dose are the best predictors of bromate formation during ozonation (IPCS, 2000).

A study of European water utilities found bromate levels ranging from less than the detection limit (2 µg/litre) to 16 µg/litre in finished water (IPCS, 2000). Health Canada (1999) reported an average level of 1.71 µg/litre, with a range of 0.55–4.42 µg/litre; in another survey, it reported an average concentration of 3.17 µg/litre, with a range of 0.73–8.00 µg/litre. In ozonated bottled water, the average level of bromate was 18 µg/litre, with a range of 4.3–37.3 µg/litre (Health Canada, 1999). Haag & Hoigné (1983) and McGuire et al. (1990) reported a range of 60–90 µg/litre in ozonated water. In IPCS (2000), the range of bromate concentrations reported in drinking-water with a variety of source water characteristics after ozonation was <2–293 µg/litre, depending on bromide ion concentration, ozone dosage, pH, alkalinity and dissolved organic carbon. AWWA (2000) reported a mean level of bromate in finished waters of 3.06 µg/litre and a median level of 3.64 µg/litre. The mean level in the distribution system was 2.5 µg/litre, and the median level was 0.05 µg/litre. It should be noted that some of the studies demonstrating high rates of conversion of bromide to bromate are pure laboratory studies with very high bromide levels and thus may not be representative of conversion rates at environmentally relevant doses.

In the USA, the annual mean bromate concentration in finished surface water determined using the EPA methods was 2.9 µg/litre, with a range of <0.2–25 µg/litre; the annual mean concentration of bromate in the same waters determined using the utility method was 2.1 µg/litre, with a range of <5–50 µg/litre. It is difficult to compare values obtained by the EPA and utility methods because the minimum reporting level using the utility method is 5 µg/litre, while for the EPA method it is 0.2 µg/litre. At this time, there are no data for groundwater plants (US EPA, 2001a).
Analytical methods and analytical achievability

Bromate in drinking-water may be measured by ion chromatography using conductivity detection (EPA Method 300.1), ultraviolet/visible absorbance detection (EPA Method 317.0) or detection by inductively coupled plasma–mass spectrometry (EPA Method 321.8). For samples with high chloride ion content, a silver cartridge can be used to remove chloride prior to ion chromatographic analysis to minimize its interference with bromate measurement (IPCS, 2000). However, it should be noted that for natural sources and waters with high total organic carbon levels, detection limits will be slightly different because of the masking effect of natural organic matter and high concentrations of carbonate/bicarbonate ions that may interfere with bromate measurement (IPCS, 2000). The method detection limit (MDL) for bromate in EPA Method 300.1 is ≈1.5 μg/litre, and the practical quantification level (PQL) is approximately 5 μg/litre. The MDLs for bromate in EPA Methods 317.0 and 328.1 are <0.2 μg/litre and 0.3 μg/litre, respectively, and the PQL for both methods is as low as 1 μg/litre.

Treatment and control methods and technical achievability

There are no practical methods currently available to remove bromate from water. Advanced treatment processes that have been suggested as warranting further evaluation include ion exchange and membrane filtration (Kruithof et al., 1992). Bromate in ozonated drinking-water supplies is best controlled by limiting its formation, which is influenced by the bromide concentration (≥0.18 mg/litre) (Krasner et al., 1993), the source and concentration of organic precursors, pH, temperature, alkalinity and ozone dose (AWWA, 1993). For example, reductions in bromate formation can be achieved by lowering the pH to less than 8, adding ammonia or controlling the ozone reaction time and the ozone/dissolved organic carbon ratio (Kruithof et al., 1992; von Gunten & Hoigné, 1992; Siddiqui & Amy, 1993). These and other measures have both advantages and disadvantages; a low pH, while reducing bromate formation, increases the formation of bromoform and other brominated organic by-products, in addition to being undesirable from the point of view of corrosion control; addition of ammonia results in the conversion of hypobromous acid to monobromamine, which in turn may be oxidized to nitrate (Siddiqui & Amy, 1993). Because of the large number of factors that influence bromate production, it will be necessary to optimize treatment by balancing the advantages and disadvantages of various measures on an individual basis for each water supply.

REFERENCES


**Methods of Measurement of Bromate in Drinking-Water**

**EPA Method 300.1**: Determination of Inorganic Anions in Drinking Water by Ion Chromatography;  
http://water.epa.gov/scitech/drinkingwater/labcert/upload/met300.pdf

The U.S.EPA Method 300.1 employs conductivity as the means of detection which works well for most anions. However, the method is nonspecific and coeluting interferences cannot be identified. The more recent U.S.EPA Method 317.0 utilizes a Bromate specific reagent in a post-column reaction. This allows for a very specific and sensitive assay for Bromate in complex matrices.

**EPA Method 317.0**: Determination Of Inorganic Oxyhalide Disinfection By-Products In Drinking Water Using Ion Chromatography With The Addition Of A Postcolumn Reagent For Trace Bromate Analysis  

**EPA Method 321.8**: Determination of Bromate in Drinking Waters by Ion Chromatography Inductively Coupled Plasma Mass Spectrometry.  
http://www.epa.gov/microbes/m_321_8.pdf

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**Published paper shows low concentration of bromate in municipal waters as compared to bottled drinking waters:**


Chlorination has been commonly used for more than a century to disinfect public drinking waters. However, chlorination of drinking water can produce trihalomethanes and other suspected carcinogenic DBPs that can endanger human health.

The data in these tables demonstrate acceptable levels for most inorganic DBP anions and bromide using either EPA methods.