In humans and experimental animals exposed to chlorine in drinking-water, no specific adverse treatment-related effects have been observed. IARC has classified hypochlorite in Group 3 (not classifiable as to its carcinogenicity to humans).

**Chlorite and chlorate**

Chlorite and chlorate are disinfection by-products resulting from the use of chlorine dioxide as a disinfectant and for odour and taste control in water. Chlorine dioxide is also used as a bleaching agent for cellulose, paper pulp, flour and oils. Sodium chlorite and sodium chlorate are both used in the production of chlorine dioxide as well as for other commercial purposes. Chlorine dioxide rapidly decomposes into chlorite, chlorate and chloride ions in treated water, chlorite being the predominant species; this reaction is favoured by alkaline conditions. The major route of environmental exposure to chlorine dioxide, sodium chlorite and sodium chlorate is through drinking-water. Chlorate is also formed in sodium hypochlorite solution that is stored for long periods, particularly at high ambient temperatures.

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Provisional guideline values

<table>
<thead>
<tr>
<th>Compound</th>
<th>Guideline Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chlorite</td>
<td>0.7 mg/l (700 µg/l)</td>
</tr>
<tr>
<td>Chlorate</td>
<td>0.7 mg/l (700 µg/l)</td>
</tr>
</tbody>
</table>

The guideline values for chlorite and chlorate are designated as provisional because use of chlorine dioxide as a disinfectant may result in the chlorite and chlorate guideline values being exceeded, and difficulties in meeting the guideline value must never be a reason for compromising adequate disinfection.

Occurrence

Levels of chlorite in water reported in one study ranged from 3.2 to 7.0 mg/l; however, the combined levels will not exceed the dose of chlorine dioxide applied. Chlorate can also form in hypochlorite solutions on storage.

TDIs

<table>
<thead>
<tr>
<th>Compound</th>
<th>TD Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chlorite</td>
<td>30 µg/kg body weight based on a NOAEL of 2.9 mg/kg body weight per day identified in a two-generation study in rats, based on lower startle amplitude, decreased absolute brain weights in two generations and altered liver weights in two generations, using an uncertainty factor of 100 (10 each for interspecies and intraspecies variation)</td>
</tr>
<tr>
<td>Chlorate</td>
<td>30 µg/kg body weight based on a NOAEL of 30 mg/kg body weight per day in a well-conducted 90-day study in rats, based on thyroid gland colloid depletion at the next higher dose, and using an uncertainty factor of 1000 (10 each for interspecies and intraspecies variation and 10 for the short duration of the study)</td>
</tr>
</tbody>
</table>

Limit of detection

5 µg/l by ion chromatography with suppressed conductivity detection for chlorate
Treatment performance

It is possible to reduce the concentration of chlorine dioxide effectively to zero (< 0.1 mg/l) by reduction; however, it is normal practice to supply water with a chlorine dioxide residual of a few tenths of a milligram per litre to act as a preservative during distribution. Chlorate concentrations arising from the use of sodium hypochlorite are generally around 0.1 mg/l, although concentrations above 1 mg/l have been reported. With chlorine dioxide disinfection, the concentration of chlorate depends heavily on process conditions (in both the chlorine dioxide generator and the water treatment plant) and applied dose of chlorine dioxide. As there is no viable option for reducing chlorate concentrations, control of chlorate concentration must rely on preventing its addition (from sodium hypochlorite) or formation (from chlorine dioxide). Chlorite ion is an inevitable by-product arising from the use of chlorine dioxide. When chlorine dioxide is used as the final disinfectant at typical doses, the resulting chlorite concentration should be less than 0.2 mg/l. If chlorine dioxide is used as a pre-oxidant, the resulting chlorite concentration may need to be reduced using ferrous iron or activated carbon.

Guideline value derivation

- allocation to water 80% of TDI
- weight 60 kg adult
- consumption 2 litres/day

Assessment date 2003

Principal references

IPCS (2000) Disinfectants and disinfectant by-products
WHO (2005) Chlorite and chlorate in drinking-water

Chlorine dioxide

Chlorine dioxide has been shown to impair neurobehavioural and neurological development in rats exposed perinatally. Significant depression of thyroid hormones has also been observed in rats and monkeys exposed to it in drinking-water studies. A guideline value has not been established for chlorine dioxide because of its rapid hydrolysis to chlorite and because the provisional guideline value for chlorite is adequately protective for potential toxicity from chlorine dioxide. The taste and odour threshold for this compound is 0.4 mg/l.

Chlorite

IARC has concluded that chlorite is not classifiable as to its carcinogenicity to humans. The primary and most consistent finding arising from exposure to chlorite is oxidative stress resulting in changes in the red blood cells. This end-point is seen in laboratory animals and, by analogy with chlorate, in humans exposed to high doses in poisoning incidents. Studies with human volunteers for up to 12 weeks did not identify any effect on blood parameters at the highest dose tested, 36 µg/kg body weight per day.

Chlorate

Like chlorite, the primary concern with chlorate is oxidative damage to red blood cells. Also like chlorite, a chlorate dose of 36 µg/kg body weight per day for 12 weeks did not result in any adverse effects in human volunteers. Although the database for chlorate is less extensive than that for chlorite, a well-conducted 90-day study in rats is available. High doses of chlorate can also interfere with thyroid function.