

Assessment date	1993
Principal reference	WHO (2003) <i>Chlorine in drinking-water</i>

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).

Chlorine dioxide, chlorite and chlorate

Chlorite and chlorate are DBPs resulting from the use of chlorine dioxide as a disinfectant and for odour and taste control in water. Sodium chlorite and sodium chlorate are both used in the production of chlorine dioxide as well as for other commercial purposes. Chlorite and chlorate are also formed during the decomposition of hypochlorite solutions that are stored for long periods, particularly at warm temperatures. Where hypochlorite or chlorine dioxide is used as a disinfectant, the major route of environmental exposure to chlorite and chlorate is expected to be through drinking-water.

Provisional guideline values	<i>Chlorite</i> : 0.7 mg/l (700 µg/l)
	<i>Chlorate</i> : 0.7 mg/l (700 µg/l)
	The guideline values for chlorite and chlorate are designated as provisional because use of aged hypochlorite or of chlorine dioxide as disinfectants may result in the chlorite and chlorate guideline values being exceeded, and difficulties in meeting the guideline values must never be a reason for compromising adequate disinfection
Occurrence	When chlorine dioxide is used as the final disinfectant at typical doses, the resulting chlorite concentration would normally be less than 0.2 mg/l. Chlorate concentrations above 1 mg/l have been reported when hypochlorite was used, but such high concentrations would be unusual unless hypochlorite is stored under adverse conditions.
ADIs	<i>Chlorite</i> : 0–0.03 mg/kg bw based on a NOAEL of 3 mg/kg bw per day for reduced liver weight of F ₀ females and F ₁ males and females in a two-generation reproductive toxicity study in rats and using a safety factor of 100 (10 each for interspecies and intraspecies variability)
	<i>Chlorate</i> : 0–0.01 mg/kg bw based on a BMDL ₁₀ of 1.1 mg/kg bw per day for non-neoplastic effects on the thyroid of male rats in a carcinogenicity study and using a safety factor of 100 (10 to allow for intraspecies variability and an additional factor of 10 to allow for the deficiencies in the database; a safety factor for interspecies variation was not considered necessary because humans are likely to be less sensitive than rats to these effects)
Limit of detection	MDLs as low as 0.45 µg/l for chlorite and 0.78 µg/l for chlorate (IC with conductivity detection) and 78 µg/l for chlorine dioxide (UV/visible spectrophotometric method)

Prevention and treatment	When using hypochlorite, the following control approach is recommended to minimize formation of chlorite and chlorate: purchase fresh solutions that are of an appropriate quality, store them in a cool place and out of direct sunlight, and use the hypochlorite as soon as possible after purchase (e.g. within a month, if possible). Further, new hypochlorite solutions should not be added to containers containing old hypochlorite solutions, as this will accelerate chlorate formation. It is possible to reduce the concentration of chlorine dioxide and chlorite 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 provide some protection against microbial regrowth during distribution. With chlorine dioxide disinfection, the concentrations of chlorate and chlorite depend on process conditions (in both the chlorine dioxide generator and the water treatment plant) and applied dose of chlorine dioxide. As there is no low-cost option for reducing concentrations of chlorate once it is formed, control of chlorate concentration must rely on preventing its addition (from sodium hypochlorite) or formation (from chlorine dioxide). If chlorine dioxide is used as a pre-oxidant, the resulting chlorite concentration may need to be reduced using ferrous iron, sulfur reducing agents or activated carbon.
Guideline value derivation	
• allocation to water	80% of ADI
• weight	60 kg adult
• consumption	2 litres/day
Additional comments	Concentrations should be maintained as low as reasonably practical, without compromising adequate disinfection. Although a health-based value of 0.3 mg/l could be derived from the ADI for chlorate, in some circumstances, it may not be possible to adequately disinfect potable water and maintain chlorate concentrations at or below the health-based value as chlorate is a byproduct of hypochlorite. Therefore, the previous provisional guideline value is retained. Moreover, even this provisional guideline value may be exceeded when aged hypochlorite is used and difficulties in meeting the guideline value must never be a reason for compromising adequate disinfection.
Assessment date	2016
Principal references	IPCS (2000). <i>Disinfectants and disinfectant by-products</i> WHO (2008). <i>Acidified sodium chlorite</i> WHO (2016). <i>Chlorine dioxide, chlorate and chlorite in drinking-water</i>

Chlorine dioxide

Any chlorine dioxide remaining at the consumer's tap will be reduced to chlorite and chloride upon ingestion. Consequently, a guideline value for chlorine dioxide has not been established. The provisional guideline values for chlorite and chlorate are adequately protective for potential toxicity from chlorine dioxide. The taste and odour threshold for chlorine dioxide is 0.2–0.4 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 in a

number of species was oxidative stress resulting in changes in the red blood cells. This observation was supported by a number of biochemical studies conducted in vitro. 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 bw per day.

Chlorate

Although chlorate has also been reported to have effects on red blood cells, the most sensitive effects observed in rats administered sodium chlorate in drinking-water for 21 or 90 days were changes in thyroid histology (e.g. colloid depletion, hypertrophy, incidence and severity of hyperplasia) and in thyroid hormones. As with chlorite, a chlorate dose of 36 µg/kg bw per day for 12 weeks did not result in any adverse effects in human volunteers.