are mostly a consequence of the presence of cyanogen chloride, it is not considered necessary to develop a guideline value for long-term exposure to cyanide.

Cyanobacterial toxins: Microcystin-LR

Among the cyanobacterial toxins, microcystins are the best-researched group and probably occur most frequently in fresh waters. Many practical considerations for the abatement of microcystins apply similarly to the other cyanotoxins (i.e. cylindrospermopsins, saxitoxins, anatoxin-a and anatoxin-a(s)), with one key difference that is relevant to the efficacy of their removal in drinking-water treatment: microcystins are usually cell-bound, and substantial amounts are released to the surrounding water only in situations of cell rupture (i.e. lysis), whereas the other cyanotoxins may occur to a larger extent dissolved in water.

Although microcystins may occur in fish, molluscs and shellfish from water bodies with cyanobacterial proliferation, human exposure to microcystins is largely through drinking-water or recreational use of water bodies with cyanobacterial blooms.

Among the more than 80 microcystins identified to date, only a few occur frequently and in high concentrations. Microcystin-LR is among the most frequently occurring and most toxic microcystin congeners. It is the only one for which enough toxicological data are available with which to derive a provisional guideline value. Frequently occurring cyanobacterial genera that may contain microcystins are *Microcystis*, *Planktothrix* and *Anabaena* (see also section 11.5).

Provisional guideline value	*Total microcystin-LR (free plus cell-bound):* 0.001 mg/l (1 µg/l)
	The guideline value is provisional, as it covers only microcystin-LR, the database is limited and new data for the toxicity of cyanobacterial toxins are being generated.
TDI	0.04 µg/kg body weight, based on liver pathology observed in a 13-week study in mice and applying an uncertainty factor of 1000, taking into consideration limitations in the database, in particular lack of data on chronic toxicity and carcinogenicity
Limit of detection	0.1–1 µg/l by HPLC following extraction of cells with 75% aqueous methanol or following concentration of microcystins from liquid samples on C-18; will allow differentiation between variants where standards are available
	0.1–0.5 µg/l by commercially available immunoassay kits (enzyme-linked immunosorbent assay) for microcystins dissolved in water or in aqueous extracts of cells; will detect most microcystins; these are less precise in quantification than HPLC, but useful for screening
	0.5–1.5 µg/l by protein phosphatase assay for microcystins dissolved in water or in aqueous extracts of cells; will detect all microcystins; this assay is less precise in quantification and identification than HPLC, but useful for screening
Monitoring	The preferred approach is visual monitoring (including microscopy for potentially microcystin-containing genera) of source water for evidence of increasing cyanobacterial cell density (blooms) or bloom-forming potential and increased vigilance where such events occur

Prevention and treatment	Actions to decrease the probability of bloom occurrence include catchment and source water management, such as reducing nutrient loading or changing reservoir stratification and mixing. Treatment effective for the removal of cyanobacteria includes filtration to remove intact cells. Treatment effective against free microcystins in water (as well as most other free cyanotoxins) includes oxidation through ozone or chlorine at sufficient concentrations and contact times, as well as GAC and some PAC applications (see the supporting document *Management of cyanobacteria in drinking-water supplies*; Annex 1).
Guideline value derivation	
• allocation to water	80% of TDI
• weight	60 kg adult
• consumption	2 litres/day
Assessment date	2003
Principal references	Chorus & Bartram (1999) *Toxic cyanobacteria in water* WHO (2003) *Cyanobacterial toxins: Microcystin-LR in drinking-water*

Microcystin-LR is a potent inhibitor of eukaryotic protein serine/threonine phosphatases 1 and 2A. The primary target for microcystin toxicity is the liver, as microcystins cross cell membranes chiefly through the bile acid transporter. Guideline value derivation was based on an oral 13-week study with mice, supported by an oral 44-day study with pigs. A large number of poisonings of livestock and wildlife have been recorded. Evidence of tumour promotion has been published. In 2006, IARC classified microcystin-LR as a possible carcinogen (Group 2B).

Practical considerations

Cyanobacteria occur widely in lakes, reservoirs, ponds and slow-flowing rivers. Where their excessive growth leads to high cell numbers, sometimes termed "bloom" events, their toxins can reach concentrations in raw water that are potentially hazardous to human health. Blooms occur if concentrations of nutrients (phosphorus and nitrogen) are elevated, particularly in stagnant or very slowly flowing water bodies. Blooms tend to recur in the same water bodies. Cells of some cyanobacterial species may accumulate at the surface as scums or at the thermocline of thermally stratified reservoirs. Such accumulations may develop rapidly, and they may be of very variable duration (hours to weeks). In many circumstances, blooms and accumulations are seasonal.

A variety of resource protection and source management actions are available to decrease the probability of bloom occurrence. Among these, the most sustainable and effective measure is to reduce nutrient (particularly phosphorus) concentrations in the water body to levels sufficiently low to substantially limit the amount of cyanobacterial biomass that can grow. This is achieved by controlling nutrient loads from sewage effluents and from land areas. The latter involves controlling erosion as well as the amount of manure and fertilizers spread in the catchment. Further, hydrological management actions such as water body mixing and flushing can render hydrophysical conditions less suitable for cyanobacteria and thus shift plankton species from cyanobacteria to others (i.e. planktonic algae such as diatoms) that are less relevant to human health.

As microcystins almost always occur largely cell-bound, any drinking-water treatment that removes particles—i.e. soil or riverbank filtration, flocculation and filtration or dissolved air filtration—controls them effectively if the process is optimized to target their removal. This also applies to the cell-bound fraction of other cyanotoxins. Process operation should avoid cell rupture and toxin release. Hazardously high concentrations of dissolved cyanotoxins appear to occur less frequently. They are well removed by most types of activated carbon. Chlorination and ozonation are effective for the removal of many cyanotoxins at sufficiently high doses and contact times, but not very effective for saxitoxins. Potassium permanganate is effective for microcystins, whereas limited or no data are available at present for other toxins. Chlorine dioxide and chloramine are ineffective for removing cyanotoxins.

Cyanotoxin monitoring is most effectively based on surveillance of source water for evidence of cyanobacterial blooms or bloom-forming potential (i.e. nutrient levels and phytoplankton species composition), with vigilance increased where such events occur. In contrast, monitoring finished water against target cyanotoxin concentrations is unsatisfactory for determining whether or not it is safe, because of the large variety of toxins (particularly of microcystins), the lack of guideline values for all but one (i.e. microcystin-LR) against which to monitor and the lack of analytical standards for many. Analysis of cyanotoxins is particularly useful for validating and optimizing the efficacy of control measures such as riverbank filtration or treatment. A caveat in cyanotoxin analysis is the need for extraction of the cell-bound fraction from the cells; although this is easy to do, particularly for microcystins, neglecting extraction from cells will lead to dramatic underestimation of concentrations.

Cyanogen chloride

Cyanogen chloride may be formed as a by-product of chloramination or chlorination of water. It is also formed by the chlorination of cyanide ion present in raw water.

Reason for not establishing a guideline value	Occurs in drinking-water at concentrations well below those of health concern
Assessment date	2009
Principal references	IPCS (2004) *Hydrogen cyanide and cyanides* WHO (2009) *Cyanogen chloride in drinking-water*

Cyanogen chloride is rapidly metabolized to cyanide in the body. There are few data available on the oral toxicity of cyanogen chloride.

As cyanogen chloride is unlikely to be found in drinking-water at concentrations that are of health concern, it is considered unnecessary to develop a formal guideline value for cyanogen chloride. Instead, for guidance purposes, a health-based value is derived based on cyanide.

Using a NOAEL for cyanide of 4.5 mg/kg body weight per day for minor changes in the testis in a subchronic study in which rats were exposed through their drinking-water and an uncertainty factor of 100, a TDI for cyanide of 0.045 mg/kg body weight (corresponding to a cyanogen chloride dose of 0.11 mg/kg body weight) can be