public health purposes by the WHO Pesticide Evaluation Scheme (WHOPES), it may be used in some countries as an aquatic larvicide for the control of mosquito larvae. Chlorpyrifos is strongly absorbed by soil and does not readily leach from it, degrading slowly by microbial action. It has a low solubility in water and great tendency to partition from aqueous phases into organic phases in the environment.

Guideline value	0.03 mg/l (30 µg/l)
Occurrence	Detected in surface waters in the USA, usually at concentrations below 0.1 µg/l; also detected in groundwater in less than 1% of the wells tested, usually at concentrations below 0.01 µg/l
ADI	0–0.01 mg/kg body weight on the basis of a NOAEL of 1 mg/kg body weight per day for inhibition of brain acetylcholinesterase activity in studies in mice, rats and dogs, using a 100-fold uncertainty factor, and on the basis of a NOAEL of 0.1 mg/kg body weight per day for inhibition of erythrocyte acetylcholinesterase activity in a study of human subjects exposed for 9 days, using a 10-fold uncertainty factor
Limit of detection	1 µg/l by GC using ECD or flame photometric detection
Treatment performance	No data available; should be amenable to treatment by coagulation (10–20% removal), activated carbon adsorption and ozonation
Guideline value derivation	
• allocation to water	10% of upper limit of ADI
• weight	60 kg adult
• consumption	2 litres/day
Assessment date	2003
Principal references	FAO/WHO (2000) *Pesticide residues in food—1999 evaluations* WHO (2003) *Chlorpyrifos in drinking-water*

JMPR concluded that chlorpyrifos is unlikely to pose a carcinogenic risk to humans. Chlorpyrifos was not genotoxic in an adequate range of studies in vitro and in vivo. In long-term studies, inhibition of cholinesterase activity was the main toxicological finding in all species.

Chromium

Chromium is widely distributed in Earth's crust. It can exist in valences of −2 to +6 but is primarily in its trivalent (III) and hexavalent (VI) forms. In general, with the exception of individuals living close to a point source of contamination, food appears to be the major source of intake.

Guideline value	*Total chromium*: 0.05 mg/l (50 µg/l)
Occurrence	Total chromium concentrations in drinking-water are usually low (<5 µg/l), although there may be elevated concentrations in areas containing natural sources or as a result of anthropogenic contamination. Few data are available on the speciation of chromium in drinking-water.

Basis of guideline value derivation	The guideline value is based on achievability by available treatment technologies, measurability by analytical methods, and toxicology. The guideline value is for total chromium because of limitations in currently available analytical methods that preclude reliable speciation of chromium in water. Hyperplasia in the small intestine was considered the most sensitive end-point of tumour formation, and is protective of both noncancer (in the case of chromium(III) and chromium(VI)) and cancer (in the case of chromium(VI)) effects.
Limit of detection	0.08–7 µg/l for total chromium by ICP-AES, ICP-MS, AES or graphite furnace AAS; 0.5 mg/ for total chromium by FAAS. FAAS and electrothermal atomization AAS methods are recommended when concentrations are 0.5–20 mg/l and <0.1 mg/ml, respectively.
	0.0044–0.015 µg/l for chromium(VI) by IC with post-column derivatization and UV-visible spectroscopy; 0.5 µg/l for chromium (III) and chromium(VI) using ion chromatography followed by ICP-MS.
	Determination of chromium species remains difficult; reliable and validated methods to separate analysis of chromium(III) and chromium(VI) are still required.
Treatment performance	Effective central treatment technologies for chromium(III) and chromium(VI) include conventional water treatment (coagulation, sedimentation, filtration—requires chromium(VI) reduction to chromium(III)), adsorption by iron oxides, ion exchange, reverse osmosis and nanofiltration.
Additional comments	As chromium is usually found in drinking-water below the guideline value, in general, monitoring and inclusion in drinking-water standards would only be necessary if there were indications that a problem might exist. Monitoring can usually be limited to treatment works; however, specific pollution events may need to be considered on a case-by-case basis.
Assessment date	2020
Principal reference	WHO (2020) *Chromium in drinking-water*

Chromium toxicity is dependent on its valence state; chromium(VI) is known to be more toxic than chromium(III). Following oral exposure, chromium(VI) is rapidly and efficiently reduced in the gastrointestinal tract to chromium(III), although a proportion of chromium(VI) may remain available for absorption. IARC has classified chromium(VI) compounds as “carcinogenic to humans” (Group 1) by the inhalation route of exposure; however, data on human carcinogenicity via the oral route are lacking. In a 2-year chronic drinking-water study, increased incidence of tumours of the oral cavity squamous epithelium and of the small intestinal epithelium were reported in rats and mice (respectively) exposed to chromium(VI), at doses of 0.77 mg/kg bw per day in rats and 0.38 mg/kg bw/day in mice. These tumours have been attributed to a threshold mode of action, recognizing an absence of mutagenicity in highly proliferative intestinal tissue following drinking-water exposure, lack of concordance of mutagenicity and tumour development, and early onset of crypt cell proliferation, which is unlikely to result from a fixed mutation. Concentrations in drinking-water rarely approach the guideline value, and evaluation of drinking-water carcinogenicity studies indicate that most environmental concentrations of chromium(VI) are orders of magnitude below the lowest concentrations tested in the rodent cancer bioassays; therefore, it was determined that the existing guideline value continues to be adequately health-protective.

Copper

Copper is both an essential nutrient and a drinking-water contaminant. It is used to make pipes, valves and fittings and is present in alloys and coatings. Copper sulfate pentahydrate is sometimes added to surface water for the control of algae. Copper concentrations in drinking-water vary widely, with the primary source most often being the corrosion of interior copper plumbing. Levels in running or fully flushed water tend to be low, whereas those in standing or partially flushed water samples are more variable and can be substantially higher (frequently above 1 mg/l). Copper concentrations in treated water often increase during distribution, especially in systems with an acid pH or high-carbonate waters with an alkaline pH. Food and water are the primary sources of copper exposure in developed countries. Consumption of standing or partially flushed water from a distribution system that includes copper pipes or fittings can considerably increase total daily copper exposure, especially for infants fed formula reconstituted with tap water.

Guideline value	2 mg/l (2000 µg/l)
Occurrence	Concentrations in drinking-water range from ≤ 0.005 to > 30 mg/l, primarily as a result of the corrosion of interior copper plumbing
Basis of guideline value derivation	To be protective against acute gastrointestinal effects of copper and provide an adequate margin of safety in populations with normal copper homeostasis
Limit of detection	0.02–0.1 µg/l by ICP-MS; 0.3 µg/l by ICP–optical emission spectroscopy; 0.5 µg/l by flame AAS
Treatment performance	Copper is not removed by conventional treatment processes. However, copper is not normally a raw water contaminant.
Additional comments	For adults with normal copper homeostasis, the guideline value should permit consumption of 2 or 3 litres of water per day, use of a nutritional supplement and copper from foods without exceeding the tolerable upper intake level of 10 mg/day or eliciting an adverse gastrointestinal response.
	Staining of laundry and sanitary ware occurs at copper concentrations above 1 mg/l. At levels above 2.5 mg/l, copper imparts an undesirable bitter taste to water; at higher levels, the colour of water is also impacted.
	In most instances where copper tubing is used as a plumbing material, concentrations of copper will be below the guideline value. However, there are some conditions, such as highly acidic or aggressive waters, that will give rise to much higher copper concentrations, and the use of copper tubing may not be appropriate in such circumstances.
Assessment date	2003
Principal references	IPCS (1998) *Copper* WHO (2004) *Copper in drinking-water*