and well below the upper limit of the ADI. As the chemical occurs in drinking-water at concentrations much lower than the health-based value, the presence of malathion in drinking-water under usual conditions is unlikely to represent a hazard to human health. For this reason, it is considered unnecessary to derive a formal guideline value for malathion in drinking-water.

Manganese[1]

Manganese is one of the most abundant metals in Earth's crust, usually occurring with iron. It can exist in 11 oxidation states, often as chloride, oxides and sulfates. The most common oxidation states for manganese in natural water are manganese(II) and manganese(IV). Manganese is used principally in the manufacture of iron and steel alloys, and manganese compounds such as potassium and sodium permanganate are ingredients in various products used for cleaning, bleaching and disinfection. Manganese compounds are additionally used in some locations for potable water treatment and can also be an impurity in coagulants used during water treatment. Manganese occurs naturally in many surface water and groundwater sources; although naturally occurring manganese is usually the most important source for drinking-water, anthropogenic activities can also contribute to high levels of manganese in water. Manganese also occurs naturally in many food sources, and the greatest exposure to manganese is usually from food.

Provisional guideline value	*Total manganese*: 0.08 mg/l (80 µg/l), to be protective against neurological effects in the most sensitive subpopulation—bottle-fed infants—and consequently the general population
	This guideline value is provisional because of the high level of uncertainty, as reflected in the composite uncertainty factor of 1000
Occurrence	Levels in fresh waters vary widely. They are typically in the range 1–200 µg/l. Higher levels are usually associated with groundwater, lakes and reservoirs under acidic or reducing conditions, or in aerobic waters with industrial pollution. Very high concentrations (up to 10 mg/l) have been reported in acidic groundwater. In treated drinking-water, concentrations are typically less than 50 µg/l.
TDI	0.025 mg/kg bw, derived by applying an uncertainty factor of 1000 to a LOAEL of 25 mg/kg bw per day identified from studies that reported neurological effects in rats exposed to manganese from birth to postnatal day 21. The uncertainty factor takes into account interpecies variation (10), intraspecies variation (10) and database uncertainties (10, including use of a LOAEL).
Limit of detection	0.002 µg/l by ICP-MS; 0.005–50 µg/l by ICP-AES and GFAA spectrometry; and 10–70 µg/l by colorimetric methods. None of these methods distinguish between the different oxidation states of manganese.

[1] As naturally occurring manganese in drinking-water is a chemical of concern in many areas, its chemical fact sheet has been expanded.

Treatment performance	Manganese concentrations in drinking-water can be easily lowered to less than 0.05 mg/l using several treatment methods, including oxidation/filtration, adsorption/oxidation, softening/ion exchange and biological filtration. Selection of the appropriate treatment system for manganese removal depends on the form of manganese (dissolved or particulate) in the source water.
Guideline value derivation	
• allocation to water	50% of TDI
• weight	5 kg body weight for a bottle-fed infant
• consumption	0.75 litres per day for a bottle-fed infant
Additional comments	Risks to infants arising from exceedance of the provisional guideline value may be mitigated by following the WHO recommendation for exclusive breastfeeding, or by using an alternative safe source of drinking-water (e.g. bottled water that is certified by the responsible authorities) to prepare formula.
	The presence of particulate manganese in drinking-water systems can cause acceptability problems; concentrations above 0.02 mg/l have caused complaints about discoloured water and staining of plumbing fixtures and laundry. Therefore, aesthetic as well as health aspects should be considered in the management of manganese in drinking-water, and when setting regulations and standards for drinking-water quality.
Assessment date	2020
Principal references	WHO (2021) *Manganese in drinking-water*

Manganese is an essential trace element. It is a necessary component of a number of enzymes and activates several others. The central nervous system is the primary concern for manganese toxicity in mammals, including humans. Neurodevelopmental toxicity studies in manganese-exposed juvenile rats revealed behavioural and sensorimotor effects, and corresponding neurostructural and neurochemical changes. Several epidemiological studies have also reported neurological effects (including reduced cognitive ability) in adult populations and children following ingestion of manganese-contaminated water. The epidemiological studies have limited utility in risk assessment due to uncertain manganese exposure levels, unclear temporality of effects and other potential confounding factors. However, collectively, they provide qualitative support that the neurological effects reported in animal studies are relevant in humans. Existing studies and reports do not provide adequate evidence to assess potential carcinogenicity from oral exposure to manganese in humans.

Absorption of manganese from the gastrointestinal (GI) tract has been suggested to take place through both an active transport mechanism and passive diffusion. GI absorption is influenced by several factors, including dietary factors: absorption is negatively correlated with intake of dietary fibre, oxalic acids and phytic acids. Some studies and reports have suggested that absorption and bioavailability of manganese are greater from drinking-water than from food, although other studies have reported no differences. However, absorption from drinking-water may be influenced by fasting conditions and the chemical form of manganese.

Following GI tract absorption, manganese is distributed via the systemic circulation to all tissues. Levels of manganese can increase in several tissues following oral exposure, including some regions of the brain in infants and adults. The main route of elimination of manganese from the body is faecal elimination via hepatobiliary excretion.

Manganese absorption from the GI tract may be higher in infants than in adults. Infants also retain higher levels of manganese than adults during the early neonatal period, possibly because of the incomplete development of the biliary excretion system. Along with the important neurodevelopmental processes occurring in neonates, this may render them particularly susceptible to toxicity from exposure to manganese. Further, there is potential for increased exposure to manganese in bottle-fed infants compared with breastfed infants—from the concentrated or powdered formula itself as well as the tap water used to prepare the formula.

Practical considerations

Manganese levels in drinking-water can be an issue in both high- and low-income countries, and should be considered in establishing national standards and local guidance. Resource-limited suppliers, in particular, may have difficulty in achieving the provisional guideline value; in such cases, incremental improvements towards meeting the provisional guideline value are encouraged. This is a particular problem for groundwater, for which treatment may be minimal and prohibitively expensive. In such instances, benefits from a reliable, microbiologically safe groundwater source should be assessed against the risks posed by an alternative source that may be subject to faecal contamination. Issues of acceptability of the drinking-water (which varies between different populations) should also be considered, since reduced acceptability may lead consumers to turn to more aesthetically acceptable but less microbiologically safe water supplies. It is vital that a sufficient supply of acceptable, microbiologically safe water is always available, even if some guidelines or standards for chemicals such as manganese cannot be immediately met.

Manganese should be evaluated and managed in the context of developing a WSP (see chapter 4). Surface waters prone to high and variable concentrations of manganese may require more frequent and targeted monitoring than groundwater. Where manganese is present at concentrations close to the provisional guideline value or the water is treated to remove manganese, routine monitoring should be conducted after treatment. If manganese is detected at the point of collection or use, or aesthetic issues related to manganese are reported by consumers, this indicates that treatment for manganese removal is not optimized or that the distribution system is not appropriately managed.

Options for controlling levels in groundwater include drilling a new well or blending water from different wells. For lake and reservoir sources where there is a thermocline and lower water levels become anoxic, management of the sources to prevent release of manganese from sediment is important.

Selection of the appropriate treatment system for manganese removal depends on the form of manganese (dissolved or particulate) in the source water. Dissolved manganese(II) is most often the predominant form present in anoxic and acidic

groundwater or lakes. However, depending on the pH and the dissolved oxygen content of the water, a combination of dissolved and particulate manganese can be present. In general, treatment methods used for manganese rely on a combination of processes (e.g. oxidation, adsorption, filtration) to remove both the dissolved and particulate forms. At the point of use, reverse osmosis is the most effective and reliable treatment technology; however, point-of-use units using ion exchange media are also moderately effective. To reduce water discoloration and staining of laundry and fixtures, ion exchange and greensand filtration with careful operation and maintenance can be used at the point of entry.

Low levels of manganese in source or treated water can accumulate in the distribution system. Periodic release of manganese can then occur, resulting in high levels at the tap. Releases can occur as a result of physical or hydraulic disturbances to the system (e.g. mains breaks, hydrant flushing) or changes in water chemistry (e.g. changes in pH, temperature, chlorine residual, source water type/blending). Physical and hydraulic disturbances most often release particulate manganese and can cause discoloured water and consumer complaints. Chemical releases can go unnoticed if manganese occurs predominantly in the dissolved form. Other contaminants (e.g. arsenic, barium, chromium, lead, uranium) that deposit with manganese oxides in the distribution system may also be released into the water and reach consumers' taps. Control measures to minimize manganese release events include maintaining stable water chemistry and minimizing manganese levels entering the distribution system, the amount of manganese oxide deposits in the distribution system (through best practices for water mains cleaning), and physical or hydraulic disturbances.

MCPA

MCPA is a phenoxyacetic acid herbicide that is found in various formulations: as the free acid (CAS No. 94-74-6), as a dimethylamine salt (CAS No. 2039-46-5), as a sodium salt (CAS No. 3653-48-3) and as a 2-ethylhexyl ester (CAS No. 29450-45-1). It is a post-emergence herbicide that is widely used against broadleaf weeds in agriculture and horticulture and on grassland and lawns. All forms of MCPA will dissociate in water to the acid (anion) form. MCPA is highly soluble in water. Biological degradation is an important process in determining MCPA's environmental fate. Chlorophenols and chlorocresols are potential soil metabolites and may, if present in water, give rise to unacceptable tastes. Surface water may be contaminated via spray drift and runoff, whereas groundwater may be contaminated via leaching from soil. Exposure from food is likely to be low.

Reason for not establishing a guideline value	Occurs in drinking-water or drinking-water sources at concentrations well below those of health concern
Health-based value*	0.7 mg/l
Acute health-based value**	20 mg/l
Occurrence	Concentrations in surface water usually less than 1 µg/l; concentrations in drinking-water usually below 0.1 µg/l