Water Research Australia

Fact Sheet

Manganese in drinking water

WHY IS MANGANESE IN DRINKING WATER AN ISSUE?

Manganese (Mn) is an element that can impart undesirable taste and odour in drinking water. Mn also contributes to discoloured water that may result in dirty or stained clothes during washing. Recently, evidence of neurological, cognitive, and neuropsychological effects of manganese exposure from drinking water in children has generated widespread public health concern in some countries.

WHAT IS MANGANESE?

Mn is an element that is found in air, soil, and water. It is one of the most abundant metals in the Earth's crust and is a component of over 100 minerals, including various sulfides, oxides, carbonates, silicates, phosphates, and borates. Mn can exist in eleven oxidative states ranging from –3 to +7 but the most environmentally and biologically important states are +2 (e.g., $MnCl_2$), +4 (e.g., MnO_2), and +7 (e.g., $KMnO_4$).[1] Mn and its compounds can exist as solids in the soil and as solutes or small particles in water. Most Mn salts are readily soluble in water, with only the phosphate and the carbonate having low solubility. The Mn oxides are also poorly soluble in water.[1]

ENVIRONMENTAL SOURCES OF MANGANESE

Mn occurs naturally in many surface water and groundwater sources and in soils that may erode into these waters. The Earth's crust is a major source of Mn to the atmosphere, soil and water. In surface waters, Mn occurs in both dissolved and suspended forms, depending on factors such as pH, anions present and oxidation–reduction potential. High concentrations may occur in polluted rivers or under low oxygen conditions such as at the bottom of deep reservoirs or lakes, or in groundwater.[2]

HUMAN GENERATED SOURCES OF MANGANESE

Mn is used principally in the manufacture of iron and steel alloys. It is also used as Mn compounds and as an ingredient in various products.[3] Mn dioxide and other Mn-based compounds are used in products such as batteries, glass and fireworks. Potassium permanganate is used as an oxidant for cleaning, bleaching and disinfection purposes.[3] Mn greensands are used in some locations for potable water treatment.[3] Other Mn compounds are used in fertilisers, varnish and fungicides and as livestock feeding supplements. The major anthropogenic sources of environmental Mn include municipal wastewater discharges, sewage sludge, mining and mineral processing (particularly nickel), emissions from alloy, steel, and iron production and the combustion of fossil fuels.[1] Human activities can be responsible for much of the Mn contamination in water in some areas.[2]

CONCENTRATIONS OF MANGANESE IN WATER

Concentrations of dissolved Mn in natural waters that are essentially free of anthropogenic inputs can range from 0.01 to > 10 mg/L. Higher levels in aerobic waters are usually associated with industrial pollution and the low oxygen environments found in groundwater and some lakes and reservoirs favour high Mn levels.[2] In Australian drinking water supplies, Mn concentrations can range up to 1.41 mg/L, but are typically less than 0.01 mg/L. For example, the median Mn concentration at a regional NSW treatment plant was 0.005 mg/L over a nine-year period.[4]

HUMAN HEALTH EFFECTS OF MANGANESE EXPOSURE

Mn is an essential element that is required by humans for normal growth. Mn deficiency affects bone, the brain and reproduction. The greatest source of Mn is usually from food and intake from drinking water is substantially lower.[4] The health effects from over-exposure of Mn are dependent on the route of exposure, the chemical form, the age at exposure, and an individual's nutritional status. Toxicity has occurred mainly as a result of inhalation of Mn dust over long periods in occupational settings. The nervous system has been determined to be the primary target with neurological effects generally observed. In contrast to inhalation exposure, Mn is regarded as one of the least toxic elements via the oral route. In one case involving heavy consumption of highly contaminated well water that contained Mn concentrations > 14 mg/L the symptoms included lethargy, increased muscle tone, tremor and mental disturbances, however, concentrations of other metals were also high and the reported effects may not have been due solely to Mn.[5] Evidence of neurological, cognitive, and neuropsychological effects of Mn exposure from drinking water in children has generated widespread public health concern.[6]

MANAGING DRINKING WATER FOR MANGANESE

Australian Drinking Water Guidelines recommend an aesthetic guideline of 0.1 mg/L at the customer's tap that is based on practical experience by utilities as being acceptable to customers. At concentrations exceeding 0.1 mg/L, Mn imparts an undesirable taste to water and stains plumbing fixtures and laundry. Even at concentrations of 0.02 mg/L, Mn will form a coating on pipes that can come off as a black-ooze. Some nuisance microorganisms can concentrate Mn and give rise to taste, odour and turbidity problems in distribution systems. To avoid these problems Australian Drinking Water Guidelines recommend a discretionary target of 0.01 mg/L at the treatment plant. This target is also based on experience; that although Mn accumulates in distribution systems, a plant producing 0.01 mg/L generally does not generate customer complaints, while a concentration of 0.02 mg/L or more tends to lead to various problems. Similarly, the USEPA recommends reducing Mn concentrations <0.050 mg/L based on staining and taste considerations, which will enhance consumer acceptance of the water.

An Australian health-based guideline value for Mn is set at 0.5 mg/L and at this concentration it is considered that Mn will not impact negatively upon human health for a lifetime of exposure through drinking water. Even though the assumptions applied by the USEPA and the WHO are slightly different, their recommended health based limits are similar; 0.3 mg/L and 0.4 mg/L respectively. The health-based guideline values are above concentrations of Mn normally found in drinking-water and the concentration at which taste and odor issues occur, therefore each organisation has considered it unnecessary to issue a formal guideline value.[2]

TREATMENT OPTIONS FOR REDUCING MANGANESE

Mn concentrations in drinking water are easily lowered using common treatment methods; typically by converting soluble forms to insoluble precipitates and then removing via filtration. Mn levels below 0.02 mg/L can be achieved with a well operated and optimised potassium permanganate system. Achieving <0.01 mg/L Mn in treated water is not possible with potassium permanganate alone, so high pH coagulation processes or a two-stage filtration process is recommended; however, this process is not suitable for all waters. Pre-filtration chlorination can also help to achieve a target of 0.01 mg/L.

REFERENCES

[1] WHO, Concise International Chemical Assessment Document 63. Manganese and its compounds: Environmental Aspects In World Health Organisation, International Programme on Chemical Safety (IPCS), Inter-Organization Programme for the Sound Management of Chemicals (IOMC): Geneva, (2004).

[2] WHO, Manganese in Drinking-water - Background document for development of WHO Guidelines for Drinking-water Quality, In World Health Organisation: Geneva, (2011).

[3] ATSDR, Toxicological Profile for Manganese, In US Department of Health and Human Services Ed. Agency for Toxic Substances and Disease Registry: Atlanta, (2008).

[4] NHMRC, National Water Quality Management Strategy: Australian Drinking Water Guidelines 6, In Australian Government - National Health and Medical Research Council and Natural Resource Management Ministerial Council: Canberra, (2011).

[5] US EPA, Drinking Water Health Advisory for Manganese, In US Environmental Protection Agency, Office of Water: Washington, (2004).

[6] Khan, K; Factor-Litvak, P; Wasserman, GA; Liu, X; Ahmed, E; Parvez, F; Slavkovich, V; Levy, D; Mey, J; van Geen, A; Graziano, JH, Environ Health Persp, (2011) 119, 1501.

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