Summary

Aims

Manganese (Mn) is a transition element which can exist in a number of oxidation states. The main states in water are Mn(II), which is soluble and bioavailable, and Mn(IV), which is essentially insoluble. The World Health Organization (WHO) has established a health based value of 400 µg/l, based on an upper tolerable intake, while the standard set in the UK is 50 µg/l, based on avoidance of water discolouration and deposition in mains, rather than human health.

Although Mn is an essential mineral, neurotoxicity by inhalation has been widely described, particularly in workers and miners, where exposure is relatively high. Recently, there has been concern over a number of studies that have suggested that exposure to Mn in drinking water may have neurological adverse effects in terms of intellectual and cognitive development. A recent Canadian study indicated these effects below the WHO health based values but above the UK standard.

With these concerns in mind, this project reviewed the recent data on the potential neurotoxicity of Mn relating to oral intake via drinking water, both in experimental animals and humans, including the bioavailability of different states of Mn. The literature on the behaviour of Mn in water and its possible removal was also reviewed.

Four seasonal monitoring surveys were conducted on final drinking water at up to 20 sites in England and Wales that had been identified as being at potential risk of high Mn concentrations. 18 of these were public supplies and a further two were private supplies. The water samples were analysed for the presence of total Mn and soluble Mn. The soluble Mn was reported as the Mn(II) concentration and Mn(IV) concentration was calculated as the difference between total and soluble Mn.

Results

In summary, the review of the literature on studies that have been conducted in experimental animals, suggests that there is a biologically plausible hypothesis for an adverse effect on neurological development of Mn taken in orally via drinking water. There is an accumulation of Mn in those same areas of the brain which accompanies neurotoxicity, caused by inhalation of Mn, together with some behavioural and locomotor effects.

The human epidemiological studies, particularly on children, are suggestive of an effect on intellectual and cognitive development. However, the types of studies conducted are not the most appropriate for measuring the longer-term effects such as those which may occur after
accumulation of Mn in the brain. There are also problems in the accurate estimation of exposure via drinking water, and the detection of Mn in the body (through the measurement of blood or hair). Therefore, these experimental animal and human studies do not, at present, provide conclusive evidence that exposure to Mn in drinking water causes adverse neurological effects in humans; however, additional studies are currently in progress that may yield further information. It should be clearly stated that this is not a review of all the toxicological data on Mn but only considers the recent studies on possible neurological effects (mainly in children) of Mn in drinking water together with neurological studies in experimental animals. It does not consider toxicological effects on other target organs or the regulatory studies on Mn exposure by the oral route.

In the recent Canadian studies, populations were exposed to borehole drinking water with variable, but with some groups, naturally high levels of Mn, mainly in the bioavailable Mn(II) form (95%). In the other epidemiological studies in Bangladesh and China where drinking water Mn was measured, the concentrations were very high, with the cut-off for high and low exposure in several studies being 400-500 µg/l and concentrations up to 6000 µg/l detected. However, the Mn speciation in these waters was unknown. A monitoring survey was conducted in England and Wales to ascertain whether these final drinking waters were similar to those in the Quebec region of Canada. The four seasonal sampling exercises indicated that public water supplies had low levels of Mn (the great majority below 5 µg/l), and levels of Mn(II) were on average approximately 50% of total Mn. Therefore, the Quebec studies do not represent the typical situation in the public supplies of England and Wales, as the concentrations of Mn are low with a smaller proportion in the bioavailable Mn(II) form. The maximum level of Mn in public supplies (11.04 µg/l) represents a small proportion of an adequate dietary intake. The exception to these findings in England and Wales was in two private borehole supplies, which had high concentrations of Mn nearly all in the Mn(II) form, i.e. similar to the water in the Quebec boreholes. The British Geological Survey indicates that these boreholes are in a geological area which may have high deposits of Mn, although the final drinking water from a nearby public supply does not have an increased concentration of Mn.