Manganese Revisited
Beyond the Secondary Limit

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Overview

Background

Existing and Pending Regulations

Health Effect Research

Treatment Alternatives

Background on Manganese

- Naturally occurring metal (soil and rock)

- Commercial uses of Inorganic Mn
  - Production of Iron and Steel
  - Production of Aluminum Alloys
  - Production of Lithium Ion Batteries

- Commercial uses of Organic Mn
  - Fertilizers
  - Pesticides

Background (cont.)

- Prevalent throughout the US
  - 68% of PWS had Mn at detectable levels
  - 11% of PWS had Mn greater than 0.3 mg/L
  - High concentrations in Northeastern US

  (EPA Regulatory Support Document, 2003)

- Dissolved, Particulate, Colloidal (sometimes organically complexed)

- Divalent form (Mn^{2+}) predominates pH 4-7

- Essential human nutrient (food and water)
  - 2.3 mg/day for average male
  - 1.8 mg/day for average female
  - Adults consume 0.7 and 10.9 mg/day (food)

Existing Regulations

- SMCL of 0.05 mg/L
- EPA Health Advisory Level of 0.3 mg/L (2004)
  (acute exposure limit of 1.0 mg/L for adults)
  (acute exposure limit of 0.3 mg/L for infants)
- WHO Health Based Guideline of 0.5 mg/L
- NH Health Based Guideline of 0.84 mg/L
  ME Health Based Guideline of 0.8 mg/L
  CT Action Level of 0.5 mg/L

SMCL Concerns

- Dark Brown to Black Stains
- Stained Laundry / Fixtures
- Unpleasant Taste
- Discolored Water

Health Concerns

- Neurological Impacts
- Hyperactivity (2007)
- Intellectual Impairment (2011)
- Sensitive Population – Children/Infants

Recent Studies by Boucher et al. (Quebec and Boston)

2007 Study (Bouchard et al.)

- 46 children, one PWS
  (two sources Mn 0.50 mg/L and 0.16 mg/L)
- Higher Mn levels in drinking water associated with Higher Mn levels in hair, subsequently associated with increased hyperactivity
- Study Limitations
  - Small sample pool
  - Participants volunteered (self-selected)
  - Other potential factors not evaluated

2011 Study (Bouchard et al.)

- 362 children, eight PWS
  - Median Mn 0.034 mg/L
  - Range Mn 0.001 mg/L to 2.7 mg/L
- Higher Mn levels in drinking water associated with Higher Mn levels in hair, subsequently associated with lower IQ
- Results indicate Mn in water metabolized differently than Mn in food

Research | Children's Health

Intellectual Impairment in School-Age Children Exposed to Manganese from Drinking Water

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"The findings from our study support the hypothesis that low-level, chronic exposure to manganese from drinking water is associated with significant intellectual impairments in children."

BACKGROUND: Manganese is an e
Despite the common occurrence o
of exposure are largely unknown.

OBJECTIVES: Our first aim was to
ing water and children's intellige
manganese exposures from water
concentration.

METHODS: This cross-sectional stu
supplied by groundwater. Manganese concentration was measured in home tap water (MnW) and children's hair (MnH). We estimated manganese intake from water ingestion and the diet using a food frequency questionnaire and assessed IQ with the Wechsler Abbreviated Scale of Intelligence.

RESULTS: The median MnW in children's home tap water was 34 µg/L (range, 1–2,700 µg/L). MnH increased with manganese intake from water consumption, but not with dietary manganese intake. Higher MnW and MnH were significantly associated with lower IQ scores. A 10-fold increase in MnW was associated with a decrease of 2.4 IQ points (95% confidence interval: –3.9 to –0.9; $p < 0.01$), adjusting for maternal intelligence, family income, and other potential confounders. There was a 6.2-point difference in IQ between children in the lowest and highest MnW quintiles. MnW was more strongly associated with Performance IQ than Verbal IQ.

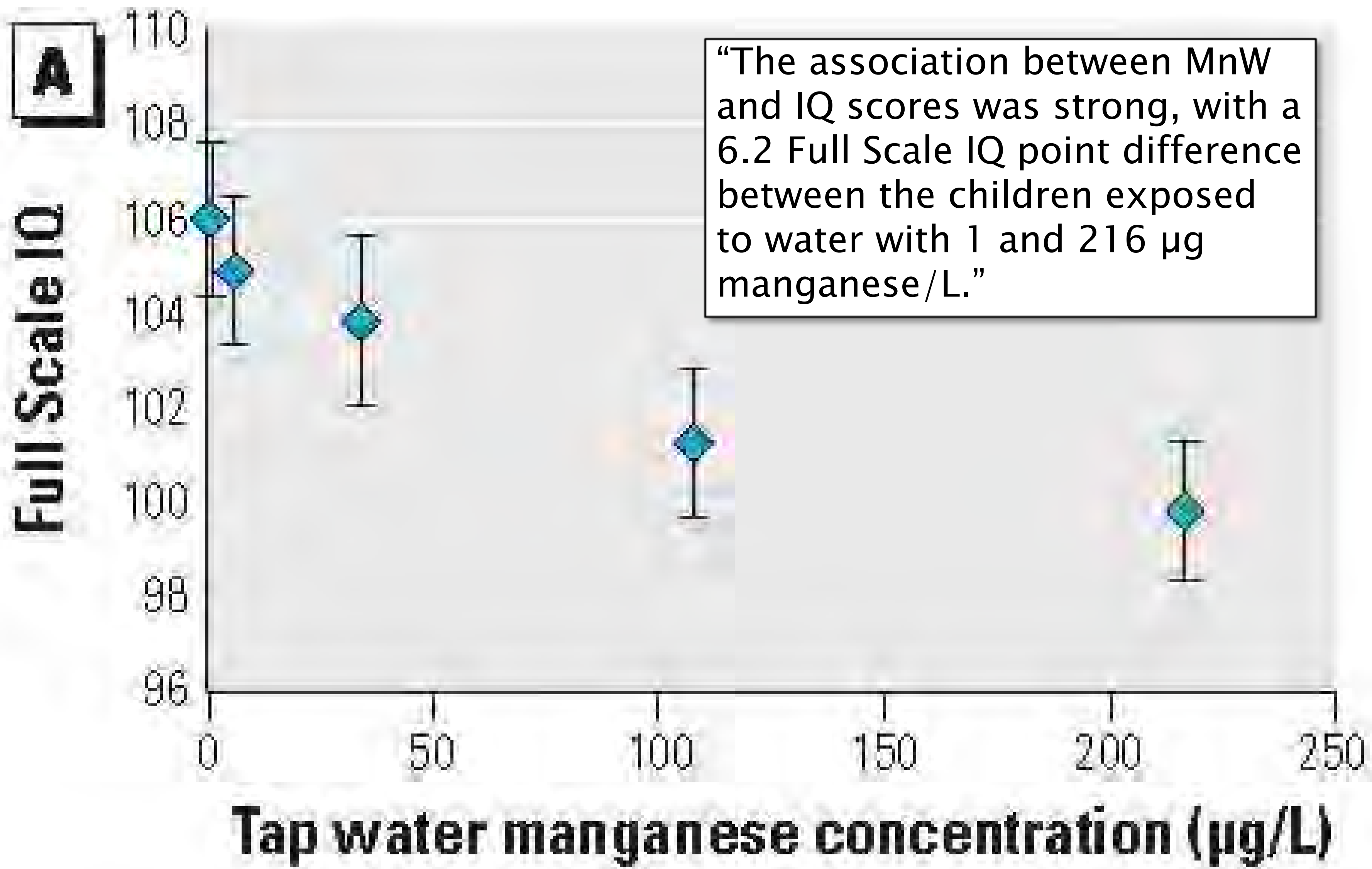
CONCLUSIONS: The findings of this cross-sectional study suggest that exposure to manganese at levels common in groundwater is associated with intellectual impairment in children.

KEYWORDS: children, intellectual quotient, manganese, neurotoxicity, water. *Environ Health Perspect* 119:138–143 (2011). doi:10.1289/ehp.1002321 [Online 20 September 2010]

ation from water containing
nese/L, one presenting with
mory impairments (Woolf
the other with neurologic
ing a repetitive stuttered
nce, coordination, and fine
et al. 2007).
oncentration in drinking
lated in the United States
or Canada. Health-based guidelines for the maximum level of manganese in drinking water are set at 300 µg/L by the U.S. Environmental Protection Agency (EPA) (2004) and at 400 µg/L by the World Health Organization (WHO) (2008).

To date, no epidemiologic study has examined possible neurotoxic effects at manganese concentrations common in North American aquifers. In the present study, we assessed the relationship between exposure to manganese from drinking water and IQ of school-age children living in communities relying on groundwater. In addition, we

2011 Study (Bouchard et al.)



"The association between MnW and IQ scores was strong, with a 6.2 Full Scale IQ point difference between the children exposed to water with 1 and 216 µg manganese/L."

Current Guidance

MassDEP **CCR Guide** – Suggested Language (use if Mn detected at any level)

EPA has established a lifetime health advisory (HA) of 300 ppb for manganese to protect against concerns of potential neurological effects, and a one-day and 10-day HA of 1000 ppb for acute exposure.

Current Guidance

- MassDEP **CCR Template** – Suggested Language (use if Mn levels detected above 0.3 mg/L)

EPA has established a lifetime health advisory (HA) value of 0.3 ppm for manganese to protect against concerns of potential neurological effects, and a One-day and 10-day HA of 1 ppm for acute exposure. However, it is advised that for infants younger than 6 months, the lifetime HA of 0.3 ppm be used even for an acute exposure of 10 days.

Pending Guidelines

- MassDEP **CCR Guide**, March 2012 included draft Mn reporting language

- Mn concentrations greater than 50 ug/L but less than or equal to 300 ug/L, report levels similar to current CCR Template

- Mn concentrations greater than 300 ug/L, report and include educational statement

Pending Guidelines

MassDEP **CCR Guide** (2012) – Draft Language (use if Mn levels detected above 0.3 mg/L)

Manganese is a naturally occurring mineral found in rocks, soil and groundwater. The United States Environmental Protection Agency (US EPA) and MassDEP have set an aesthetics-based Secondary Maximum Contaminant Level (SMCL) for manganese of 50 micrograms per liter (ug/L) or 50 parts per billion (ppb)). At levels, greater than 50 ug/L, the water may appear brown, taste unpleasant and may leave black stains on bathroom fixtures and laundry. While manganese is part of a healthy diet, it can be harmful if consumed in large concentrations. ***Manganese is a nutrient that is part of a healthy diet. Drinking water may naturally have manganese, and when concentrations are greater than 50 µg/L, the water may be discolored and taste bad. Over a lifetime, the US EPA recommends that people drink water with manganese levels less than 300 µg/L and over the short term, US EPA recommends that people limit their consumption of water with levels over 1000 ug/L, primarily due to concerns about possible neurological effects. Children up to 3 years of age should not be given water with manganese over 300 ug/L, nor should formula for infants be made with that water.*** This recommendation is based on concerns about effects to the nervous system that are more likely to occur in younger children, and because formula-fed infants/children already receive adequate manganese as an added essential nutrient in their formula. Formula fed infants or children may consume more manganese than the rest of the family if the manganese fortified formula is prepared with water that also contains manganese. In addition, young children appear to absorb more but excrete less manganese than older children.

Treatment Options

- Sequestering
- Oxidation and Filtration
- Membrane Filtration
- Biological Filtration
- Ion Exchange Process

Sequestering

- Common approach for managing Mn
- Binds Mn in solution to prevent oxidizing by air or chlorine, preventing color/staining
- Limitations
  - Only effective for Mn up to approx 0.1 mg/L
  - Ineffective at higher temps (hot water heaters)
  - <u>Mn is not removed</u> (potential health impacts)

Pressure Filtration

- Greensand Filtration
  - Manganese Greensand
  - GreensandPlus
- Absorptive Media
  - Proprietary media
- Contact Clarifier/Filter
  - Upflow clarifier with media
  - Traditional filtration

Pressure Filtration (cont.)

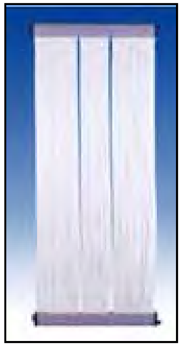
- Design can be "pump-thru" to avoid double pumping and associated inefficiencies
- Chlorine can be used for oxidation only, not needed for disinfection
- Greensand Filtration (and Adsorptive Media)
  - Established conventional process
  - Treats effectively up to 2 mg/L (combined Fe and Mn)
- Contact Clarifier/Filter
  - Treats higher levels of combined Fe and Mn

Membrane Filtration

- Treats higher levels of Fe and Mn
- Requires clearwell & finished water pumps
- Disinfection residual needed
- Minimal (or none) virus log credit removal (some states allow 0.5 log) relative to GWR

Membrane Filtration

- Immersed
  - Low energy
  - “Open to atmosphere”



- Pressure Cartridges
  - Smaller footprint
  - Outside In or Inside Out

Biological Filtration

- Treats higher levels of Fe and Mn (smaller process footprint)

- New Technology (Ferazur/Magnazur by IDI)
- Only needs chemical for pH adjustment
- Limitations
  - Need post-filter UV disinfection or chlorination
  - Requires constant operation for biological life
  - Cleaning waste neutralization/disposal

Ion Exchange

- Treats low levels of Fe and Mn
- Water softeners commonly used for Mn removal for private wells
- Resin can be fouled by high levels of Fe
- Regenerant/waste disposal issues

Treatment Issues

- High Levels of Fe and Mn
- Organic Complexing
- Life Cycle Costs
  - Capital Equipment (anticipated life)
  - Chemical (impacts on Building Footprint)
  - Energy Requirements
- Waste Treatment and Disposal

Treatment Goal

Final Thought

"These findings should be replicated in another population. Because of the common occurrence of this metal in drinking water and the observed effects at low MnW, we believe that national and international guidelines for safe manganese in water should be revisited."

(Boucher et al., 2011)

Questions?

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