Treatment of Manganese in Drinking Water

Ted Molyneux
Vancouver, BC
Indigenous Services Canada
22 November 2022

Acknowledgements

- Dave Tambyln,
  Public Health Engineer, FNHA
- Kimberly Brown,
  Public Health Engineer, FNHA
- Grant Robertson,
  Certified Water Technician, HomePlus Products Inc.
- Satwinder Paul,
  Assistant Teaching Professor & Program Coordinator, Thompson Rivers University
- Sanjana Akella,
  Project Engineer, ISC

First Nations Health Authority
Health through wellness

Manganese as a drinking water problem

- Aesthetic concerns:
  - **tasteless, odorless**
  - black/brown color → staining, turbidity
  - aesthetic objective (AO) **20 µg/L** (down from 50)

    → consumer confidence

Manganese as a drinking water problem

- Health concerns
  - essential element; deficiency rare 
  - excessive Mn causes disease: *manganism*
    - **severe**: bradykinesia, widespread rigidity, gait disturbances, falling, dystonia, difficulty walking backwards, and speech difficulties
    - **mild**: impaired fine motor skills, eye-hand coordination and reaction time
  - epidemiological *association* with neurological effects in *children*
    - behavioral (memory, attention, motor function, hyperactivity)
    - intellectual impairment (5-10 IQ points) **
  -  maximum acceptable concentration (MAC) **120 µg/L** derived for bottle-fed infants based on rat studies showing similar endpoints

What is the risk for everyone who is not an infant?

- *BC Drinking Water Officers' Guide – Part B*
- Manganese in Drinking Water – Health Link BC

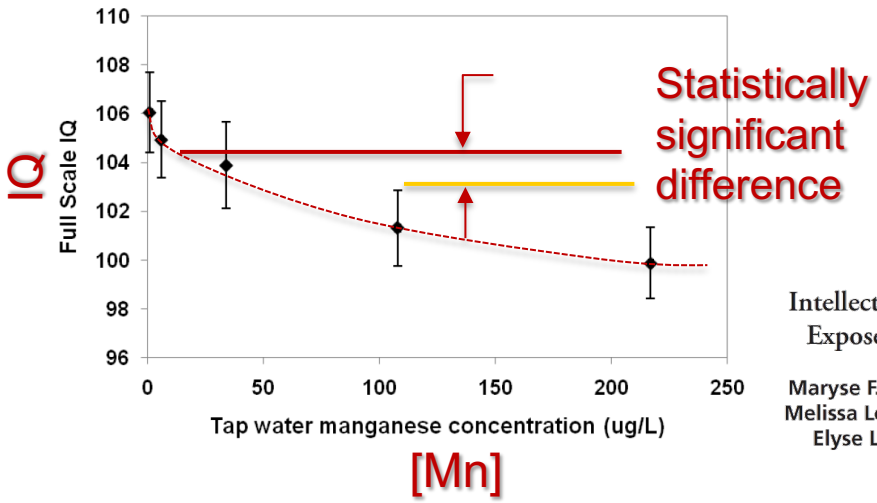
GUIDANCE ON MANGANESE IN DRINKING WATER

How FNHA evaluates risk…

- The *magnitude of the exceedance* above the MAC
  - 120<Mn<300 … short-term ⇨ further evaluation ≠ immediate action
  - 120<Mn<300 … long-term ⇨
    - notification that infants should not consume formula made with tap water
    - options for mitigation (⇨ bottled water, new well, *treatment*)
  - **Mn>300** µg/L ⇨
    - > US EPA, WHO ⇨health risks to general population (especially children)
    - consider risks to a broader population
    - short-term mitigation (DNC ⇨ bottled water)

www2.gov.bc.ca/assets/gov/environment/air-land-water/water/waterquality/how-drinking-water-is-protected-in-bc/manganese.pdf

Studies on IQ of School-Aged Children



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

Maryse F. Bouchard, Sébastien Sauvé, Benoit Barbeau, Melissa Legrand, Marie-Ève Brodeur, Thérèse Bouffard, Elyse Limoges, David C. Bellinger, Donna Mergler

Online 20 September 2010

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.

< Home

CTV NEWS

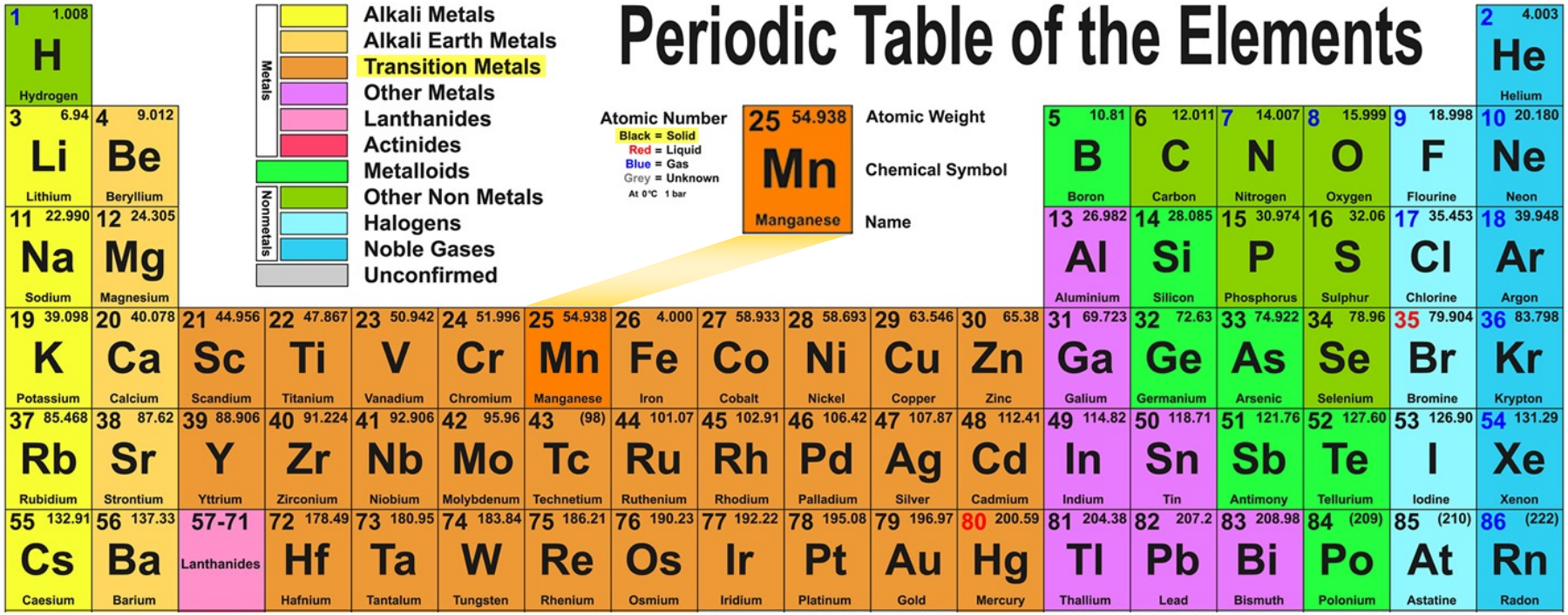
CTVNEWS

Manganese in well water linked to lower IQ scores

6

(Just enough) chemistry … 1

- heavy (transition) metal
- atomic number 25, molar mass 55 g
- neighbour of iron



(Just enough) chemistry … 2

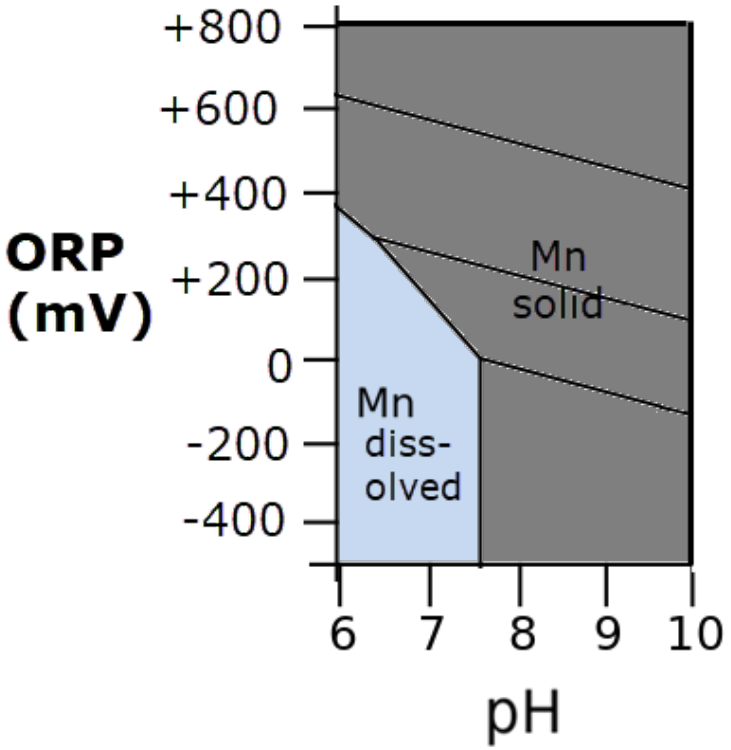
- Key factor is *oxidation state*
  - Mn^0 = metal (doesn't occur naturally)
  - Mn^{2+} = Mn(II) = most soluble (clear)
  - Mn^{3+} = Mn(III) = low solubility (dark brown)
  - **Mn^{4+} = Mn(IV) = low solubility (black)**
  - Mn^{7+} = Mn(VII) = soluble (pink)

Increasing oxidation

- Similar to iron:
  - Fe^{2+} = Fe(II) = most soluble (clear)
  - Fe^{3+} = Fe(III) = low solubility (yellow, red)

Too much chemistry! Pourbaix (equilibrium)

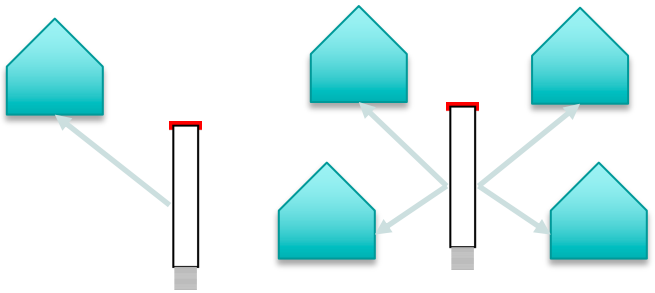
We start with *dissolved* Mn^{2+} in groundwater



- Mn solids (MnO_x) may be:
  - small (colloidal; < 0.1 micron)
  - large (particulate; > 1 micron)
- Treatment to reduce Mn
  - want all solid, or all dissolved; not a mix
- **Ion exchange, RO** goals:
  - keep Mn dissolved
  - ↓ pH or ↓ ORP (E_H)
  - ⇨ no chlorination
- **Filtration** goals:
  - shift to Mn solid
  - ↑ pH or ↑ ORP (E_H)
  - ⇨ chlorine ok

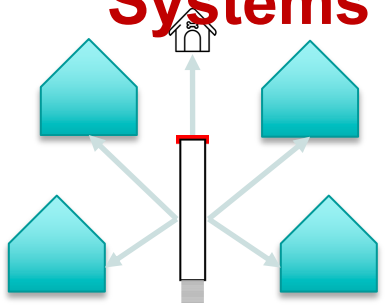
Level of Service Standards (LOSS)

Individual Water Systems



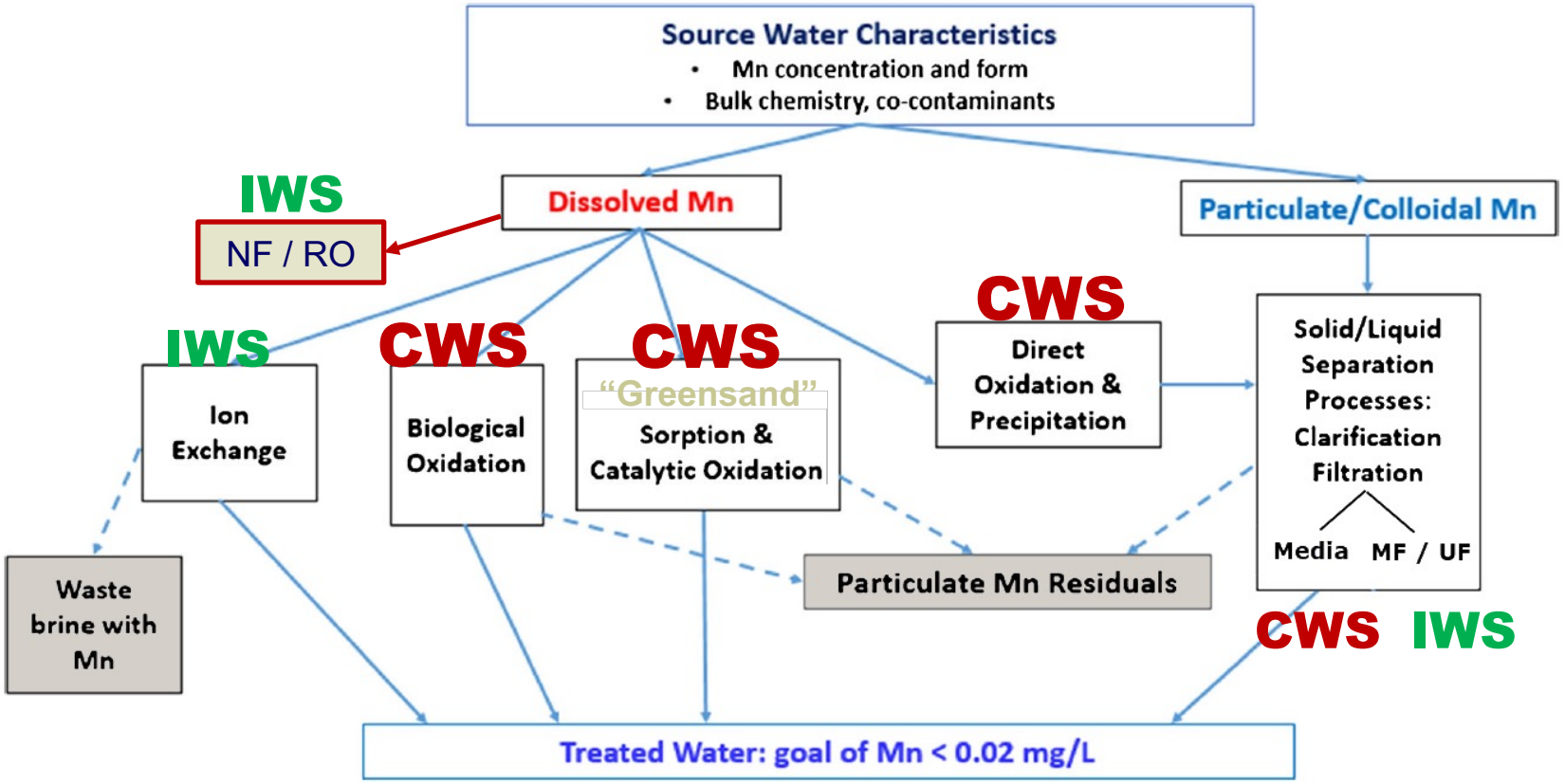
1 - 4 connections ⇨ IWS ≠ $$$

Community Water Systems



≥ 5 connections ⇨ CWS = $$$

Treatment overview

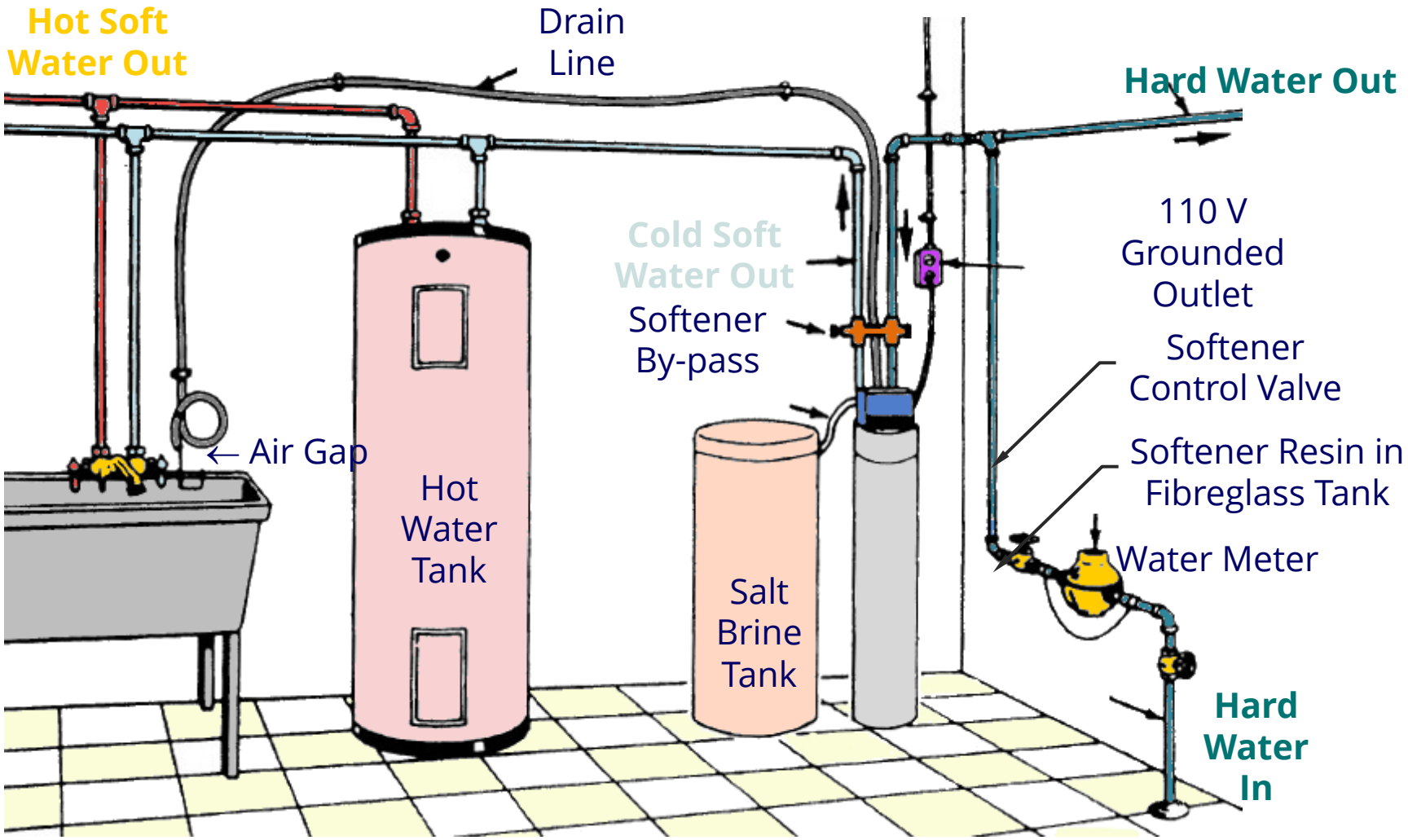


Reference: Tobiason et al., 2016

Main Treatment Options for IWS Manganese Treatment

- Dissolved Mn (II)
  - NF/RO membrane filtration (POU)
  - Ion exchange (POE)
- Particulate $MnO_x(s)$
  - MF/UF membrane filtration (POE or POU)
- Both Dissolved and Particulate
  - MF/UF membrane ➔ NF/RO membrane filtration train

IWS - Typical POE NSF 44 Water Softener Setup



IWS - Typical POE NSF 44 Water Softener Setup

HOW IT WORKS

01 Softening

02 Regeneration

03 Backwashing

04 Rinse

05 Controller

Pentair Water Softening System,
1-2 bath (11.6 USGPM), 3-4 bath (11.9 USGPM),
4+ bath (13.2 USGPM) options available

IWS - Typical POE NSF 44 Water Softener Setup

HOW IT WORKS

01 5 Micron Prefilter System

02 Carbon Filtration

03 Softening

04 Regeneration

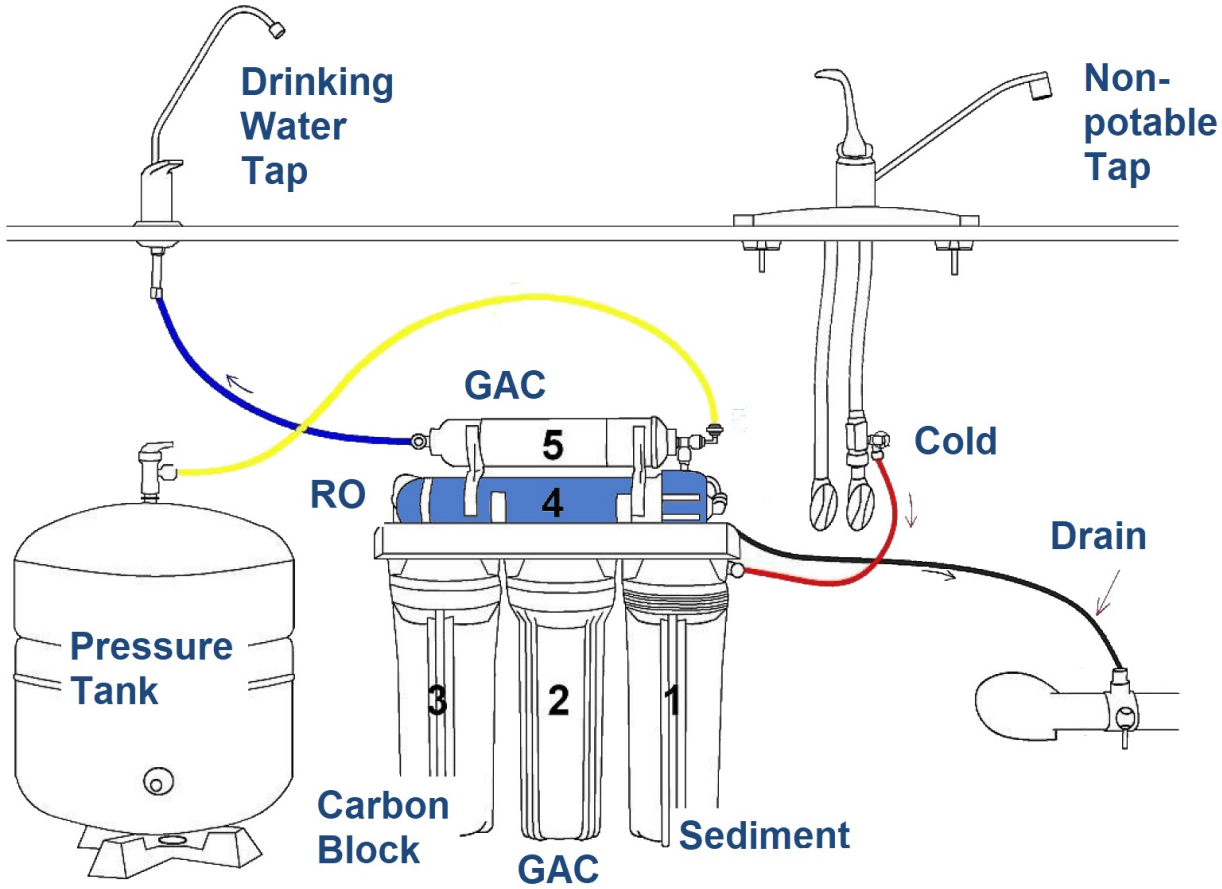
05 Backwashing

06 Rinse

07 Controller

Pentair Salt Softener & Carbon Combo System,
PAC4: 1-3 bath; PAC7: 4-6 bath

IWS - Typical POU NSF 58 Reverse Osmosis Setup



TDS meter
$20 to $40

IWS - Typical POU NSF 58 Reverse Osmosis Setup

WQA CERTIFIED — **WQA Std 58 Gold Seal Certified System**
Certified for material and parts safety, structural integrity, and contaminant rejection performance.

1st STAGE — **Super Capacity Sediment Filter**
Removes dust, particles, and rust.

2nd STAGE — **Super Capacity Carbon Block**
Removes chlorine, tastes, odors, cloudiness, colors, VOCs and other chemicals.

3rd STAGE — **Super Capacity Carbon Block**
Further removes residual chemicals, tastes and odors, guarantee purity.

4th STAGE — **Top Tier FILMTEC RO Membrane**
Removes up to 99% of contaminants including arsenic, lead, fluoride, heavy metals, and much more...

5th STAGE — **Refining Coconut Carbon Filter**
Removes any possible residual taste & impurity from the tank.

RO-Hi – Ultimate 5-Stage 90 GPD High Output Fast Flow Reverse Osmosis Water Systems for Drinking Water, WQA Certified

Main Treatment Options for CWS Manganese Treatment

- Dissolved Mn (II)
  - Manganese oxide based media catalytic oxidation and filtration
  - Direct oxidation and filtration ➔ using chlorine, potassium permanganate, ozone
  - Biological oxidation and filtration ➔ Suez Mangazur
- Particulate $MnO_x(s)$
  - Media filtration
- Both Dissolved and Particulate
  - Pre-filtration using media/membranes➔ Greensand media filtration train

Oxidation Filtration

- Robust (wide? pH and temperature range, particulate and dissolved)

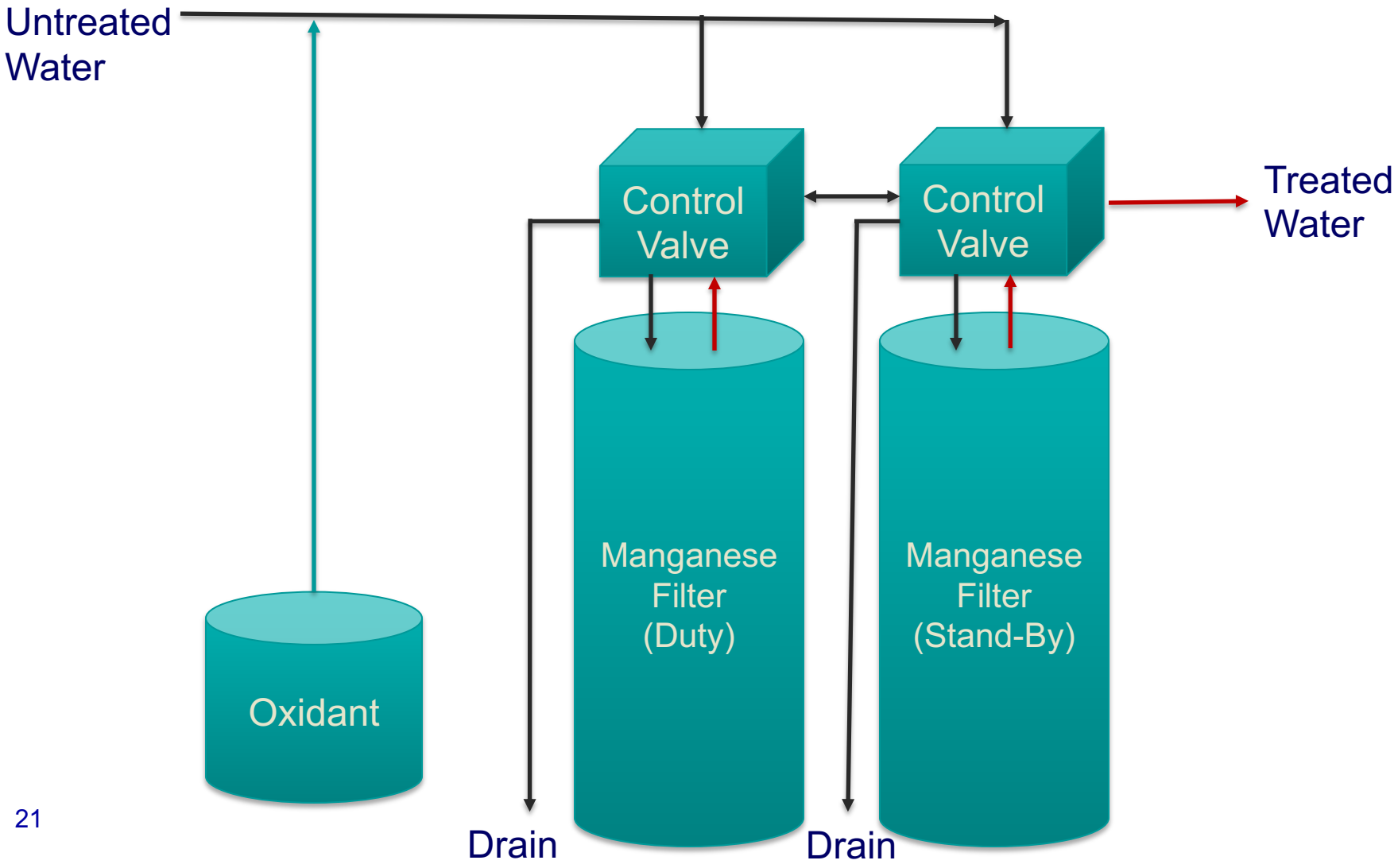
- With or with out chemical pretreatment
  - Generally, chlorine is preferred over potassium permanganate
  - Also, Ozone and hydrogen peroxide

- But pretreatment can even just be
  - …..air
  - Oxygen is not as strong as chlorine
  - but is the oldest known to people
  - Air Injected Oxidation (AIO)

Oxidation Filtration Continued

- Two types of Manganese Oxide media:
  - Coated
    - Manganese Greensand, now GreensandPlus, Birm
  - Solid
    - Originally just called pyrolusite
    - Filox, Mang-Ox, Pyrolox, or Katalox-Light
  - Others
    - Catalytic Carbon (Centaur)
    - Specialty cation exchange resins (Purolite)

CWS – Typical Oxidation Filtration Setup



CWS – Typical Oxidation Filtration Setup

Complications with Oxidation Filtration

- Manganese reacts far more slowly than Iron
  - And creates smaller particles that are harder to filter

- Other common problems in BC

1. Arsenic
2. Organics
3. Ammonia
4. Hydrogen Sulfide
5. Hardness

Summary and steps …

- Need complete chemical test(s) to characterise source well water
- Test for total and dissolved metals to see if Mn is:
    a) dissolved
    b) particulate (total – dissolved)
    c) both

- If Mn > MAC (120 µg/L), then *recommend* treatment (infants)
- If Mn > USEPA Health-based guideline (300 µg/L), then *urge* treatment

Summary and steps …

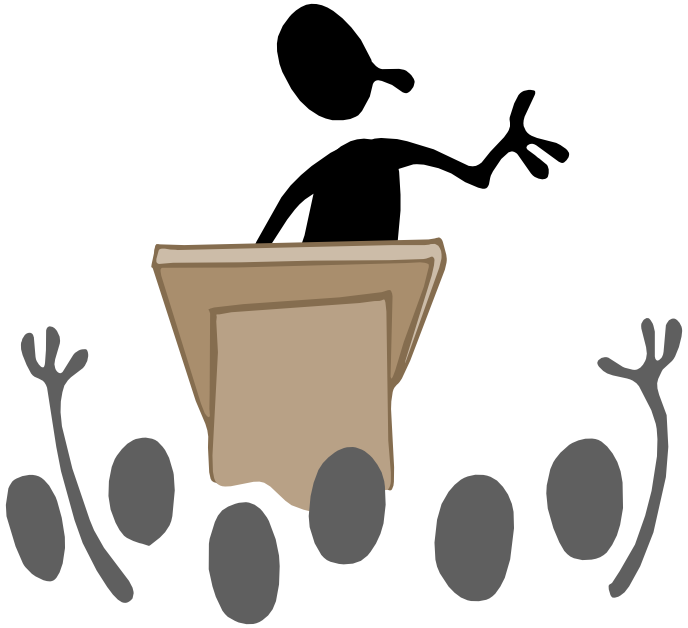
- Recommend some combination of:
  - microfiltration or ultrafiltration for IWS
  - POE NSF 44 softening or POU NSF 58 RO for IWS
  - Greensand filtration for CWS
- Validation sampling required to confirm
  - efficacy (Mn < 20 µg/L)
  - breakthrough (time until Mn > 120 µg/L)
- Steps to lift advisories for IWS and CWS:
  - IWS – sampling after installation at POU
  - CWS – sampling after installation and after first backwash event

References

- Review paper: Tobiason, J. E., Bazilio, A., Goodwill, J., Mai, X., & Nguyen, C. (2016). Manganese removal from drinking water sources. *Current Pollution Reports*, *2*(3), 168-177. 10pp.
- Section 7 in Guideline Technical Document (HC 2019) pp 17-33
- Brandhuber, P., Clark, S., Knocke, W., Tobiason, J. (2013). *Guidance for the Treatment of Manganese*. Project #4373. Water Research Foundation. 160pp.
- Webinar: www.youtube.com/watch?v=3jo6tALw7BI&feature=youtu.be
- Webinar: https://www.youtube.com/watch?v=rXNx1RF9mSs

- TRU Online Help Centre for BC Small Water Systems: https://smallwatersystemsbc.ca/
- BCWWA Small Water Network: https://www.bcwwa.org/site/resources/systems?nav=sidebar

Questions?



For any questions or comments, call or email …
Ted Molyneux 604-817-1253
Ted.molyneux@sac-isc.gc.ca