Manganese Treatment & Pressure Filter Optimization

IL RWA
Rockford, IL
Wednesday, October 12, 2022

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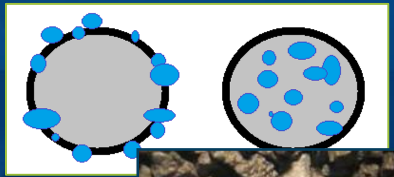
WATER SURPLUS®

Manganese (Mn)

Health & Aesthetic Issues

Limits and Regulation



Removal Mechanisms

Treatment Technologies

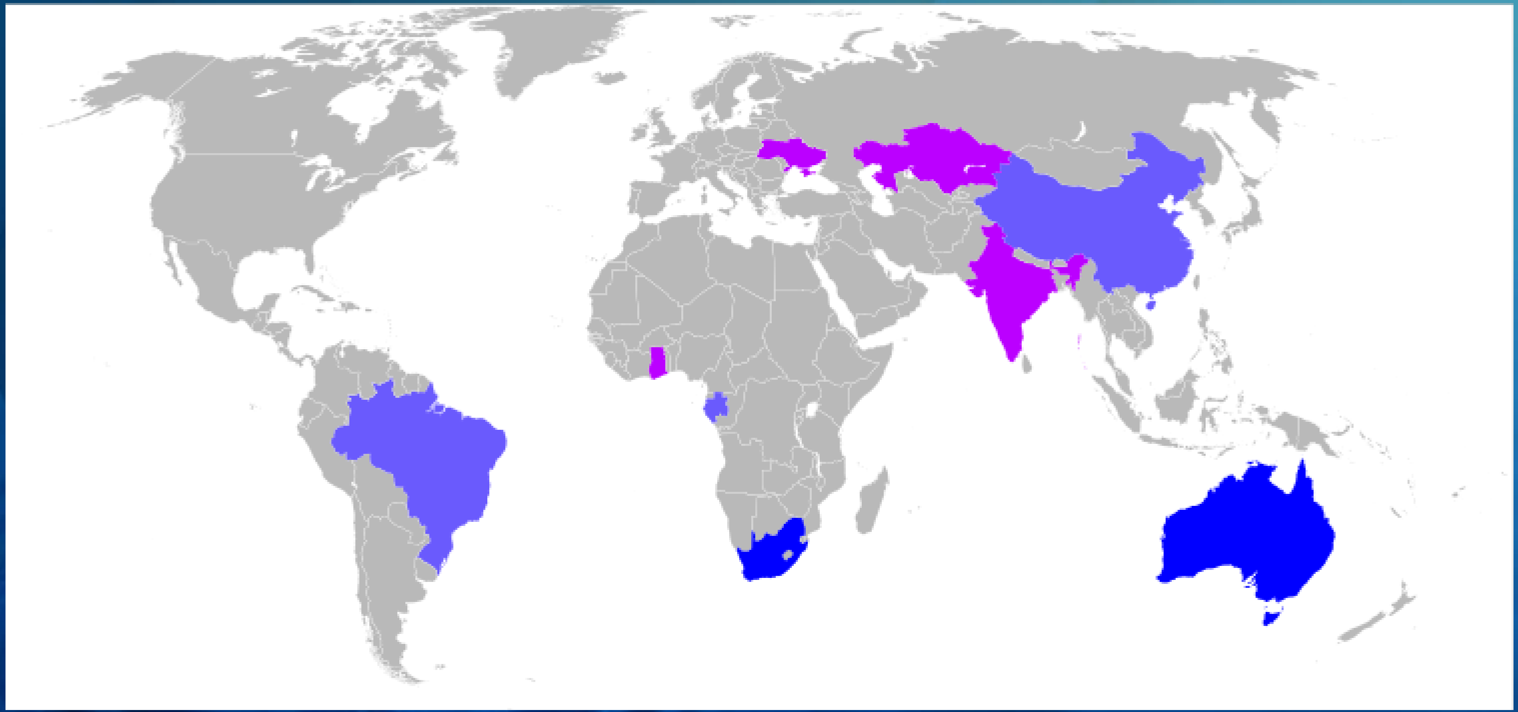
Filter Operation & Maintenance

Manganese (Mn) is a naturally occurring element

- Ranked 12th in earths crust (0.1%)
- 100+ minerals- Sulfides, oxides, carbonates, silicates, phosphates, borates

18.5 million tons of Mn are mined annually

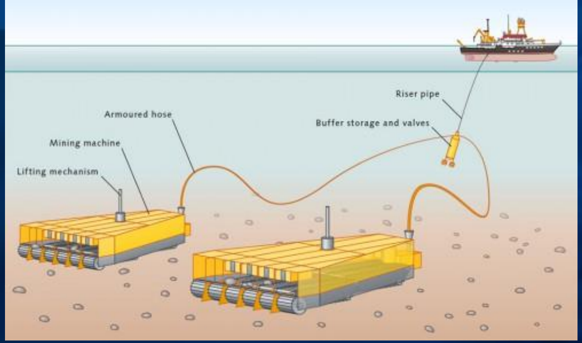
1. South Africa- 33.5%
2. Australia 15%
3. China
4. Gabon
5. Brazil
6. India
7. Malaysia
8. Ukraine
9. Kazakistan
10. Ghana

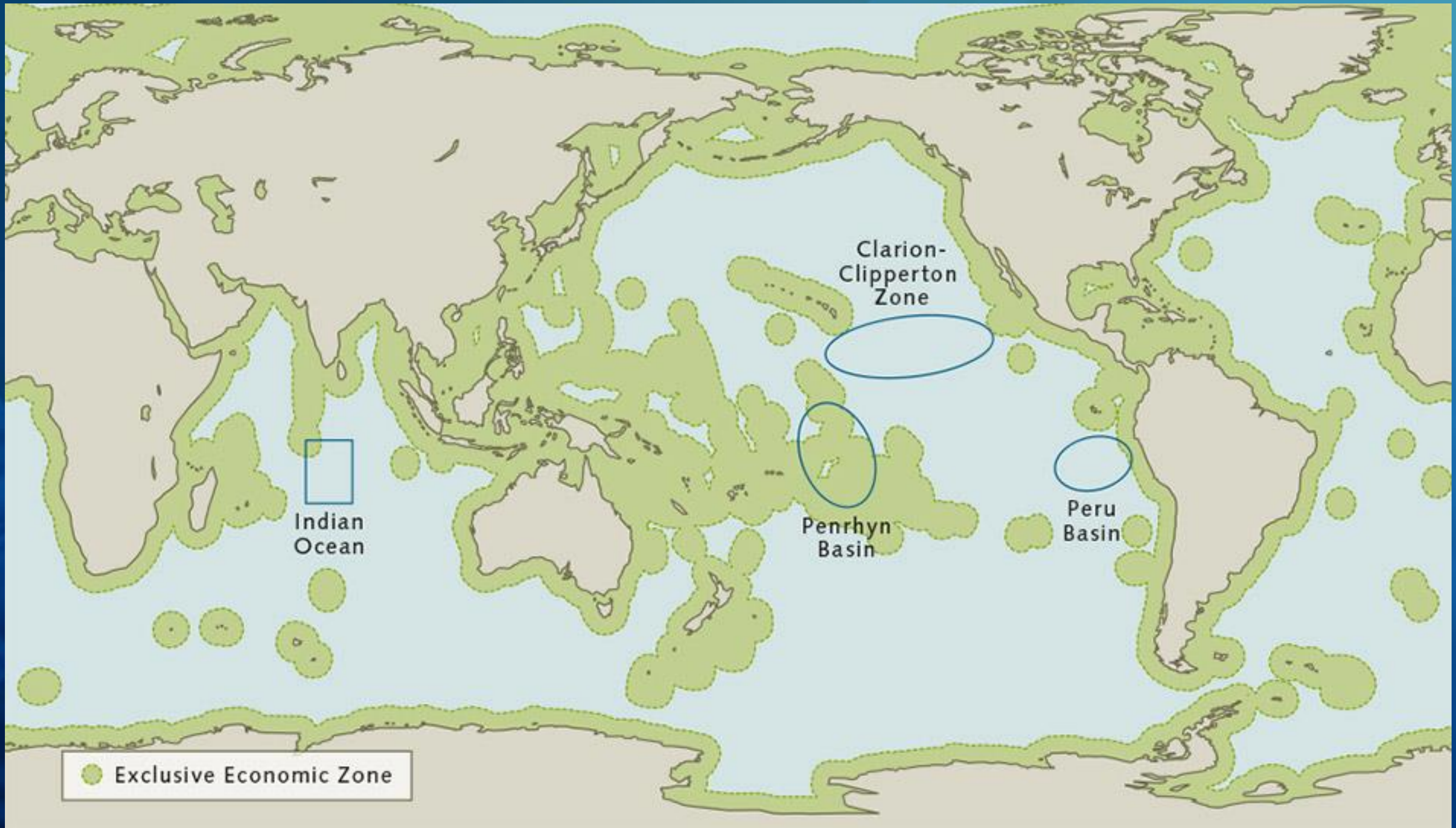


(List from 2020 article in NS Energy)

Nodules on the sea floor can contain up to ~30% Mn

- Approx. 5,000 m deep





https://worldoceanreview.com/en/wor-3/mineral-resources/manganese-nodules/

Almost 90% of Mn mined is used in production of steel

- Other uses
  - Batteries
  - Drink cans
  - Rubber additive
  - Glass
  - Fungicide
  - Fertilizers
  - Ceramics
  - Fireworks
  - Food supplement

Manganese (Mn) is an essential nutrient

3 oz = 5.8 mg

1 cup = 2.5 mg 2 mg
1.5 mg

Manganese (Mn) is an essential nutrient

- Recommended Adequate Intake (AI) values (mg/day)*
  - Infants, <1 year: 0.003-0.06
  - Children: 1.2-1.5
  - Preteens/teens: 1.9-2.2 (boys), 1.6 (girls)
  - Adults: 1.8-2.3
    - Tolerable upper intake level = 11

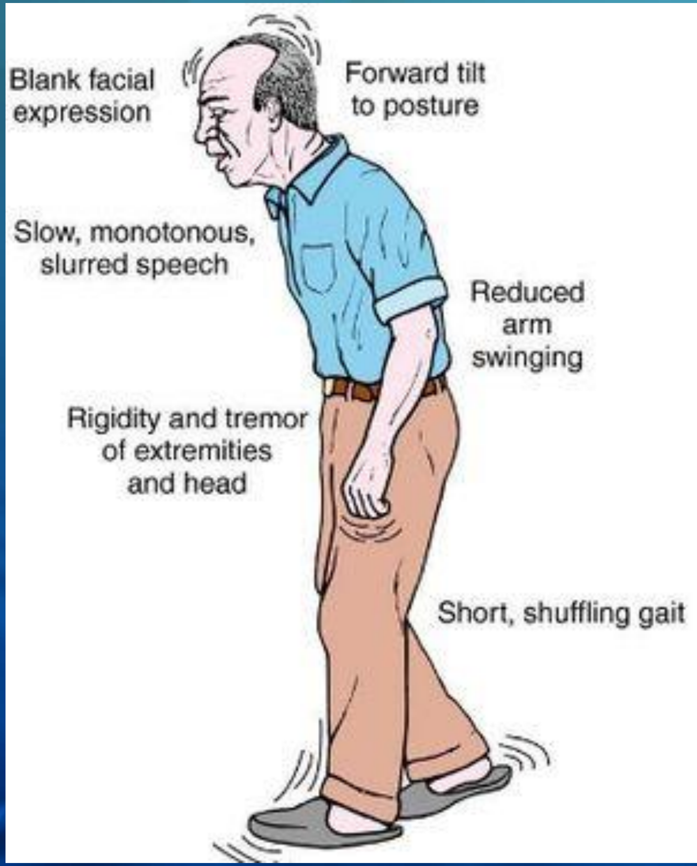
3 oz = 5.8 mg

1 cup = 2.5 mg 2 mg
1.5 mg

*determined by the Food & Nutrition Board of the Institute of Medicine (IOM)

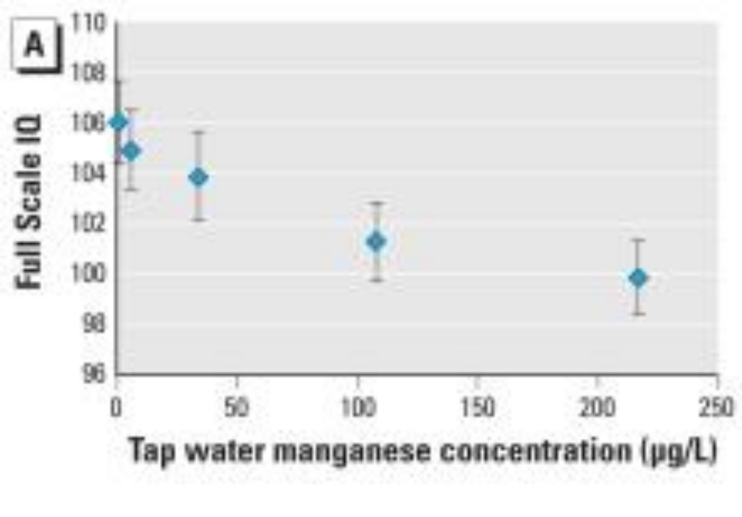
High levels of Mn can cause health issues

- Manganism
  - From inhalation
  - Similar to Parkinson's
    - Motor skill decline
    - Gait disturbances
    - Speech impairment



University of British Columbia: https://wiki.ubc.ca/SPPH381B/TermProject/Alkaline_battery-_Samin/Granulation/Neurobehavioral_dysfunctions,_called_Chronic_manganese_poisonin

Exposure to Mn in drinking water can cause more subtle effects




Research | Children's Health

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

Maryse F. Bouchard,[1,2] Sébastien Sauvé,[3] Benoit Barbeau,[4] Melissa Legrand,[5] Marie-Ève Brodeur,[1] Thérèse Bouffard,[6] Elyse Limoges,[7] David C. Bellinger,[8] and Donna Mergler[1]

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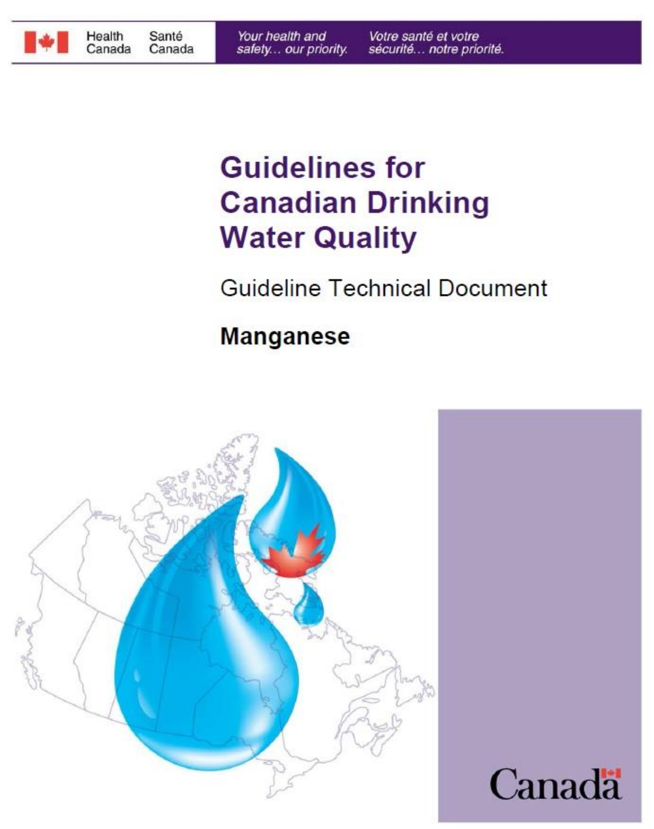
BACKGROUND: Manganese is an essential nutrient, but in excess it can be a potent neurotoxicant. Despite the common occurrence of manganese in groundwater, the risks associated with this source

manganese intoxication from water containing > 1,000 µg manganese/L, one presenting with attention and memory impairments (Woolf

- Over 6 pt difference in IQ (Bouchard et al. 2011)
- Decrease memory, attention, and motor skills (Olhote et al. 2014)
- High blood and high hair Mn conc. associated with lower IQ scores (Haynes et al. 2015)

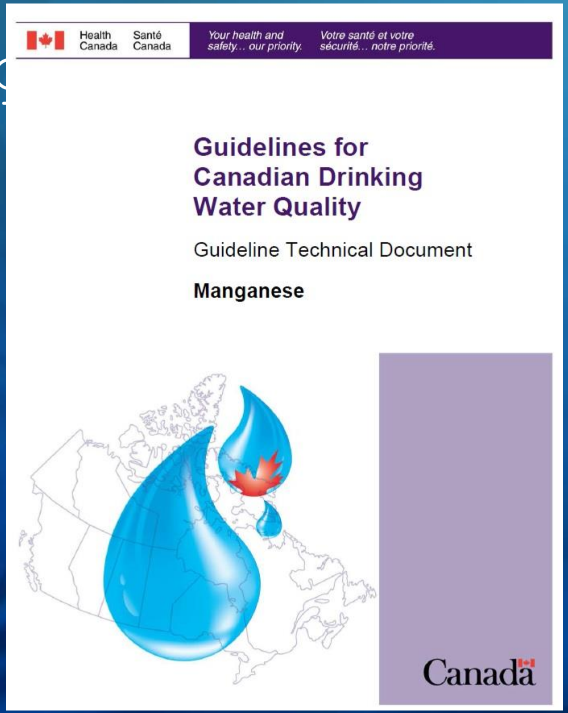
General conclusions about high Mn levels from Canada Health:

- The CNS is the primary target of Mn toxicity
- Elderly and children most susceptible
- Infants and children may experience:
  - Changes in behavior
  - lower IQ and test scores
  - Impaired reading ability
  - Speech and memory difficulties
  - Lack of coordination



In 2019, Canada set more strict limits on Mn

- Maximum Acceptable Concentration (MAC) = 0.12 mg/L
- Aesthetic Objective (AO) = 0.02 mg


Health Canada Santé Canada
Your health and safety... our priority. Votre santé et votre sécurité... notre priorité.

Guidelines for Canadian Drinking Water Quality

Guideline Technical Document

Manganese

Canada

The Secondary Maximum Contaminant Level (SMCL) for Mn is 0.05 mg/L

- Basically our “Aesthetic Objective”
  - Unpleasant taste and color
  - Costly problems to water distribution systems

https://www.wateronline.com/doc/the-hidden-dangers-of-manganese-in-drinking-water-0001

https://tataandhoward.com/2017/01/importance-treating-manganese-drinking-water/

https://www.safewater.org/operation-water-drop-listings/2016/11/13/manganese-analysis-for-high-school-operation-water-drop

Is regulation coming to US?

- Long, slow process
  - CCL → RD → MCL
- On list for potential regulation

IL-EPA Manganese Requirements

Drinking Water Illinois State MCL

Requiries Treatment if Mn>0.15 mg/L
Because of Health Concerns

Removal Mechanisms vs Treatment Technologies

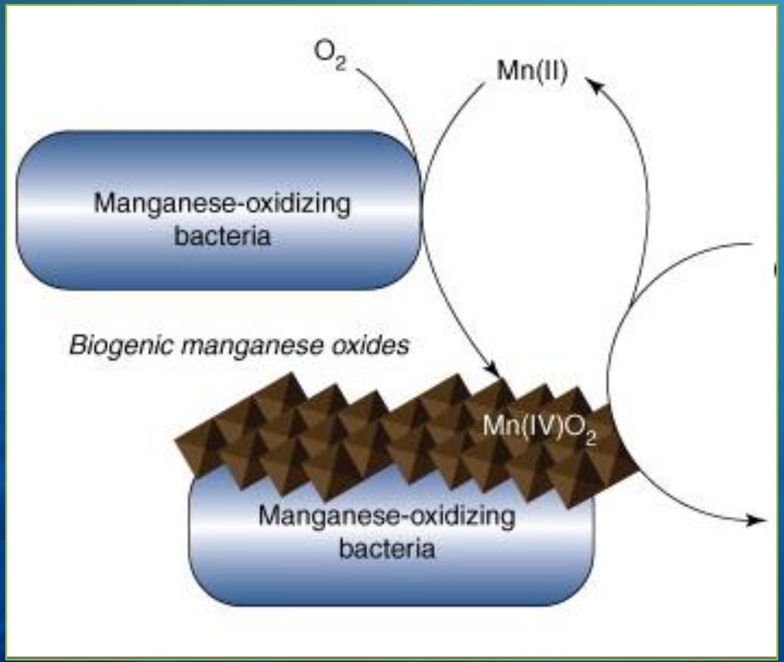
Removal Mechanisms vs Treatment Technologies

- Biological uptake
- Ion exchange
- Precipitation
- Adsorption

- Coagulation-filtration
- Membrane filtration
- Lime softening
- Biological filtration
- Ion exchange
- Oxidation/precipitation/filtration
- Adsorptive treatment
  - GAC and catalytic oxide media

Biological uptake/filtration

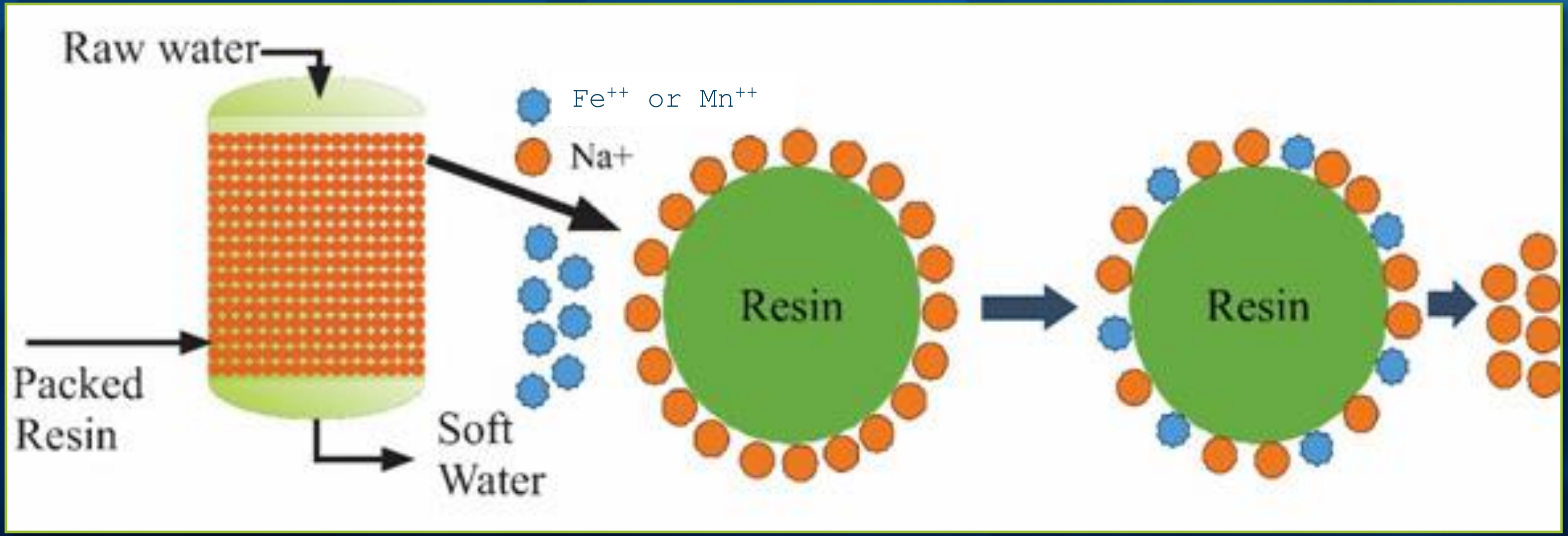
- Promote growth of certain bacteria
  - Sand, gravel, anthracite, GAC
- No or very little chemical addition required
  - Nutrient feed may be needed
- Specific conditions are required
  - Start up period
  - Living things are picky
  - Fe & Mn removed in two separate stages



https://www.cell.com/trends/biotechnology/fulltext/S0167-7799(08)00286-2?code=cell-site

Ion Exchange

- Performance based on raw water quality and target effluent concentrations
- High TDS residuals
- 7 gpm/ft^2 with 6-8 gpm/ft^2 backwash

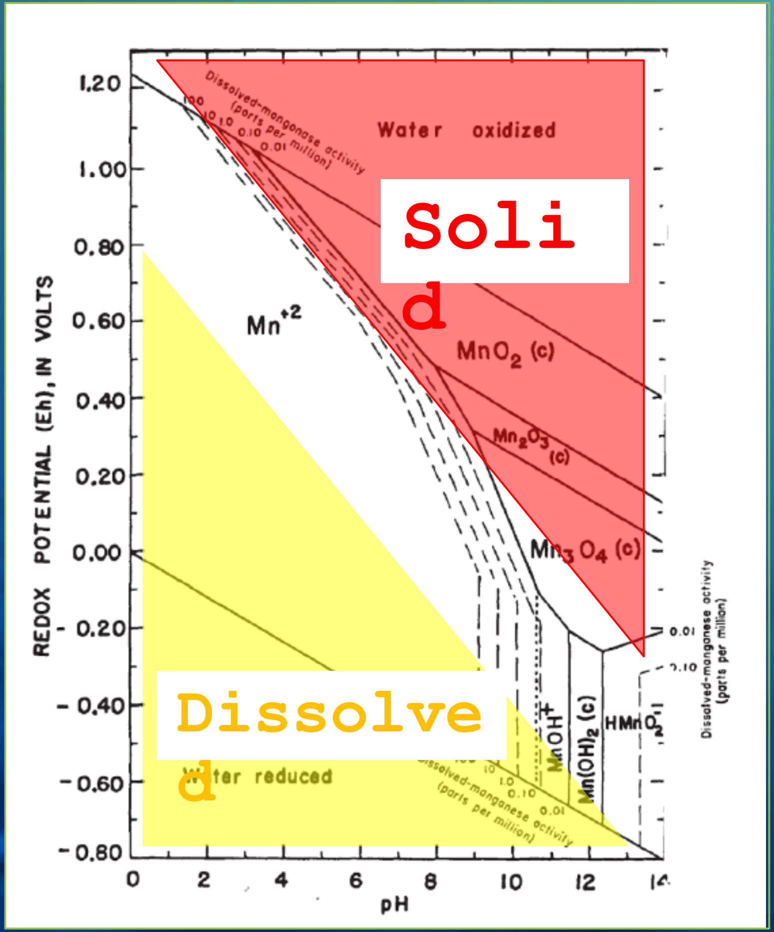


Precipitation (via supersaturation or oxidation)

High redox, high pH = water **oxidized**

Low redox, low pH = water **reduced**

This is traditional treatment!
Oxidation → precipitation → filtration



Eh-pH diagram describing the stability of solid ("c") and aqueous phases of Mn as a function of redox potential and pH, at 25 C and 1atm

Comparing oxidants for Traditional Mn removal:

Oxygen (aeration)
Ozone
Chlorine
Potassium permanganate
Chlorine dioxide

Comparing oxidants for Traditional Mn removal:

	Oxidant Required ***per mg/L Mn***	**Oxidation Reaction Time** ***per mg/L Mn***	**Benefits & Drawbacks**
Oxygen (aeration)	0.29	80 minutes to days	No chemical use/easy to use, weak, may require detention, $$, low loading rates
Ozone	0.67	< 5 min	Strong, tricky to operate, $$$
Chlorine	1.28	15 minutes to 12 hrs	Easy, safe, common disinfectant, weak, may require detention
Potassium permanganate	1.92	<7 min	Strong, messy, undesirable to work with
Chlorine dioxide	2.4	<5 min	Strong, requires additional safety considerations, $$

Compare Mn to Fe oxidation

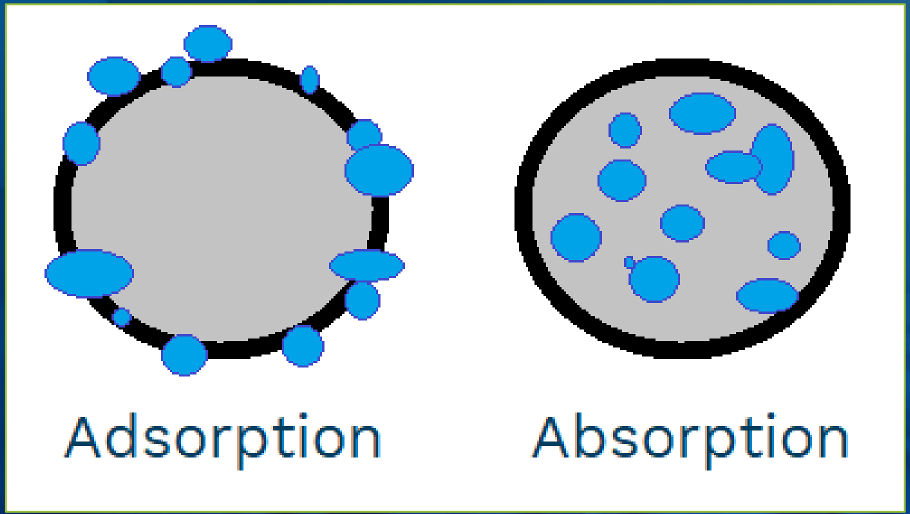
	Oxidant Required		Oxidation Reaction Time	
	per mg/L Fe	*per mg/L Mn*	per mg/L Fe	*per mg/L Mn*
Oxygen (aeration)	0.14	*0.29*	<10 min to 4 hr	*80 minutes to days*
Ozone	0.43	*0.67*	< 1 min	*< 5 min*
Chlorine	0.63	*1.28*	Instantaneous to 1 hr	*15 minutes to 12 hrs*
Potassium permanganate	0.94	*1.92*	<5 min	*<7 min*
Chlorine dioxide	1.2	*2.4*	<5 min	*<5 min*

Comparing oxidants:

Treatment Technology	Benefits	Drawbacks
Aeration, Filtration	•No chemical use •Easy to operate	•Entrained air can interfere with filtration if not broken •May require breaking head and repumping •Not effective for complexes with organic material •Low filter loading rates for effective removal •High capital cost
Chlorination, Filtration	•Chlorine often used for disinfection and present at treatment plant, Easy to operate	•May require pH adjustment •Low filter loading rates for effective removal •High capital cost
Ozone, Filtration	•Strong oxidant, requires little reaction time	•May oxidize manganese to permanganate •May oxidize manganese dioxide-containing media to permanganate •Difficult to operate •High capital and operations and maintenance costs
Chlorine Dioxide, Filtration	•Effective for iron complexed with organic material •No trihalomethane formation	•Generated on site with variety of chemicals •Requires careful operation and maintenance •Chlorite is a by-product •High capital cost
Potassium permanganate, Filtration	•Strong oxidant, requires short reaction times •Can reform manganese dioxide coating on media	•Causes staining if spilled •May be overfed, resulting in pink or purple water

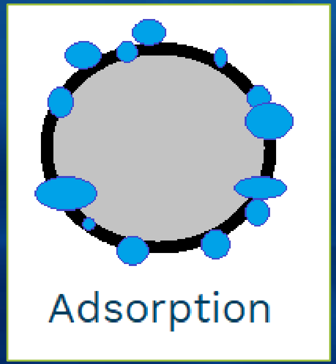
AWWA Publication: Treatment Technologies for

Adsorption: contaminants removed by sorption onto media surfaces



Adsorption: contaminants removed by sorption onto media surfaces

- **Iron oxides**- arsenic
- **GAC**- inorganic metals, organic compounds, radionuclides
- **Manganese oxides**- iron, manganese, arsenic, radium, H_2S
  - Oxides (negatively charged) adsorb ions to surface of particle
  - Evolution: Greensand → fusion-bonded coating → Pyrolusite (MnO_2)
  - Reaction is very fast! Key for Mn

Adsorptive (Catalytic) Filtration Allows for High Loading Rates

- >2x the typical 3-4 gpm/ft^2 (sand/anthracite)
- Smaller filters, smaller building
- Eliminate $KMnO_4$, detention basin, booster pump(s)
- Uses sodium hypochlorite –current common disinfectant
- Longer media life - 20+ years for pyrolusite
- Less backwash waste

Compare These 400 gpm Plants

a) Traditional media system, 3.14 gpm/ft^2

- Eight (8) 54” diameter tanks
- 19,120 gallons bw waste (@ 15 gpm/ft^2 for 10 minutes)

b) Pyrolusite media system, 6.29 gpm/ft^2

- Four (4) 54” diameter tanks
- 7,960 gallons bw waste (@ 25 gpm/ft^2 for 5 minutes)


WATERPLUS™

Raw Water

Backwash

Rinse/filter to waste

Finished water → Storage/Distribution

Chemical feed(s)

Raw Water

Chemistry
Flow Rate

Backwash

Rate
Duration
Frequency

Rinse/filter to waste

Duration

Finished water → Storage/Distribution

Chemistry
Quality target

Chemical feed(s)

dose

Raw Water

Chemistry
Rate

Backwash

Rate
Duration
Frequency

Rinse/filter to waste

Duration

Finished water → Storage/Distribution

Chemistry

Chemical feed(s)

dose

Monitor & adjust!

Backwash

Rate
Duration
Frequency

Raw Water

Chemistry
Rate

Rinse/filter to waste

Duration

Finished water → Storage/Distribution

Chemistry

Chemical feed(s)

dose

Keep a filter log

3.3 Filter Log Sheet

FILTER MODEL NO: NAME OF COMPANY:

SERIAL NO: PERIOD OF THIS SHEET:

NOTE: Please record all calibrations of instruments or other occurrences related to this system.

DATE									
TIME									
UNIT IN SERVICE									
INLET PRESSURE (*psi or bar*)									
OUTLET PRESSURE *(psi or bar)*									
DIFFERENTIAL PRESSURE (*psi or bar*)									
FLOW RATE *(gpm or lpm)*									
WATER TEMP (deg F or C)									
INLET CHLORINE (*ORP in mV*)									
OUTLET CHLORINE (*OPR in mV*)									
INLET IRON (*Fe in mg/l*)									
OUTLET IRON (*Fe in mg/l*)									
TOTALIZED (*gallons or liters*)									
*BACKWASH INITIATED									
OPERATOR'S INITIALS									

Reference the Troubleshooting Guide where trends or differences are noted. This is a template; make copies as necessary.

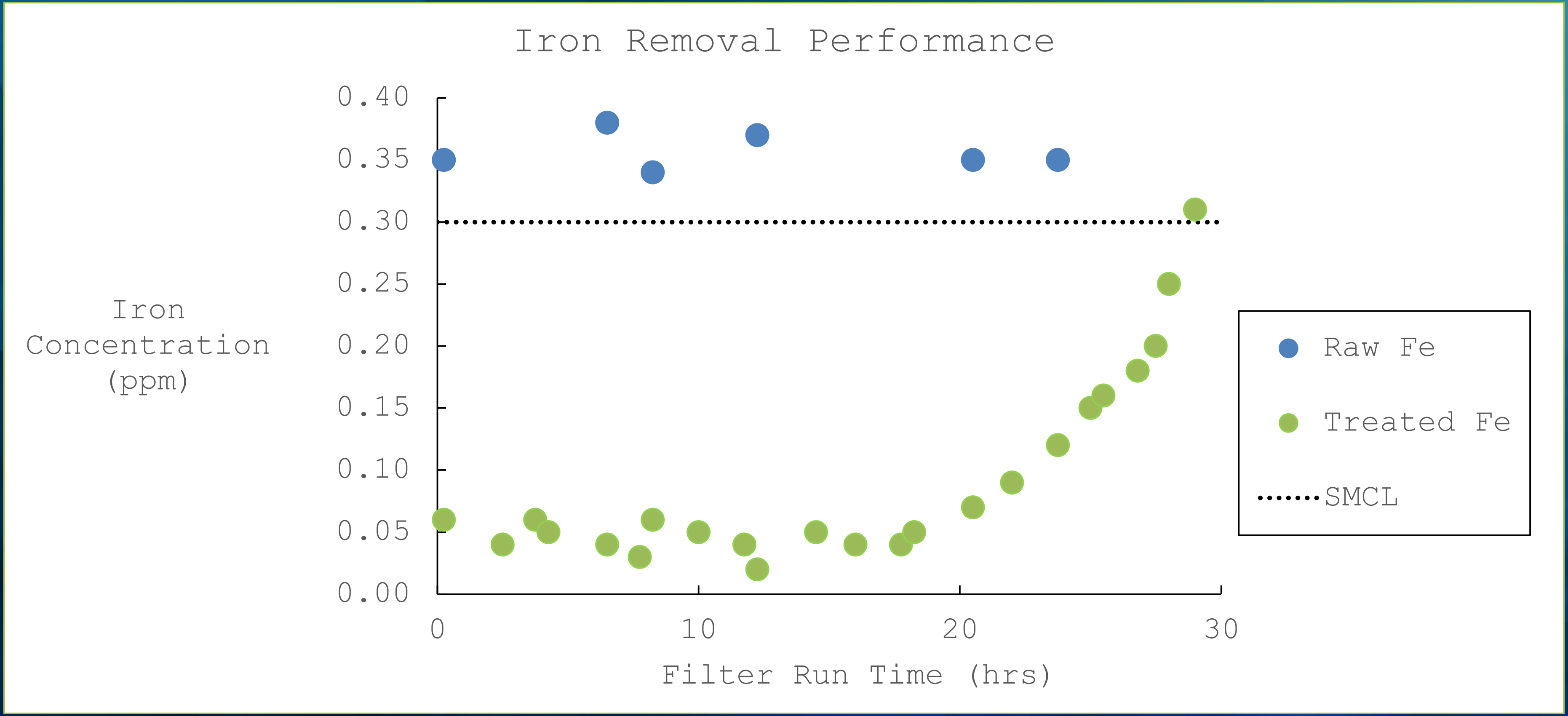
NOTES: * BACKWASH REQUIRED- MANUAL if 10-15 psi or .7-1BAR DP increase, TIME OR VOLUME (TOTALIZED)

Optimize your backwash procedure

- Most backwash based on time, pressure differential, or gallons throughput
  - Consider duration, frequency, rate, bed expansion, rinse to waste
  - Air scour

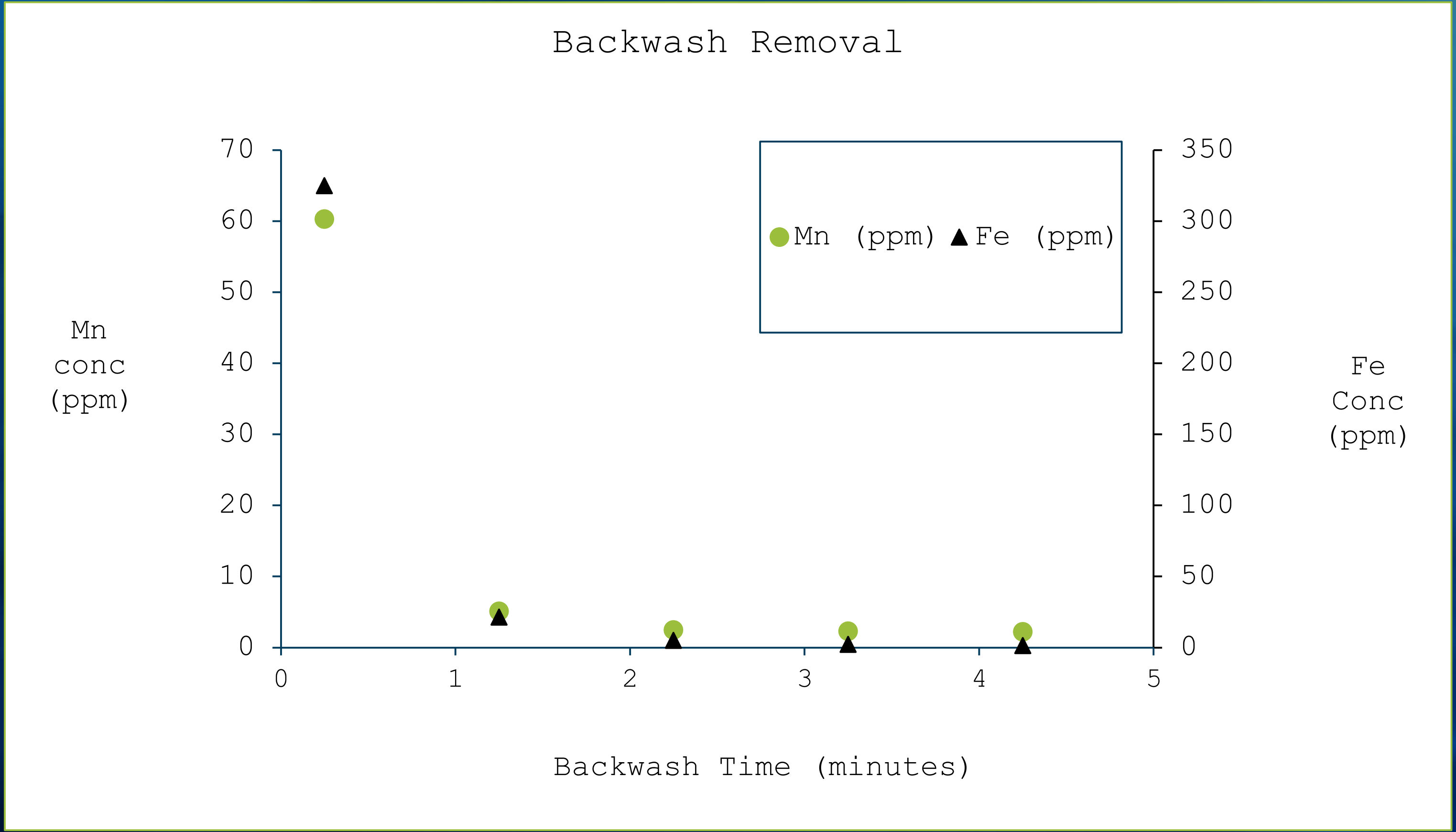
Optimize your backwash procedure

- When do you backwash?



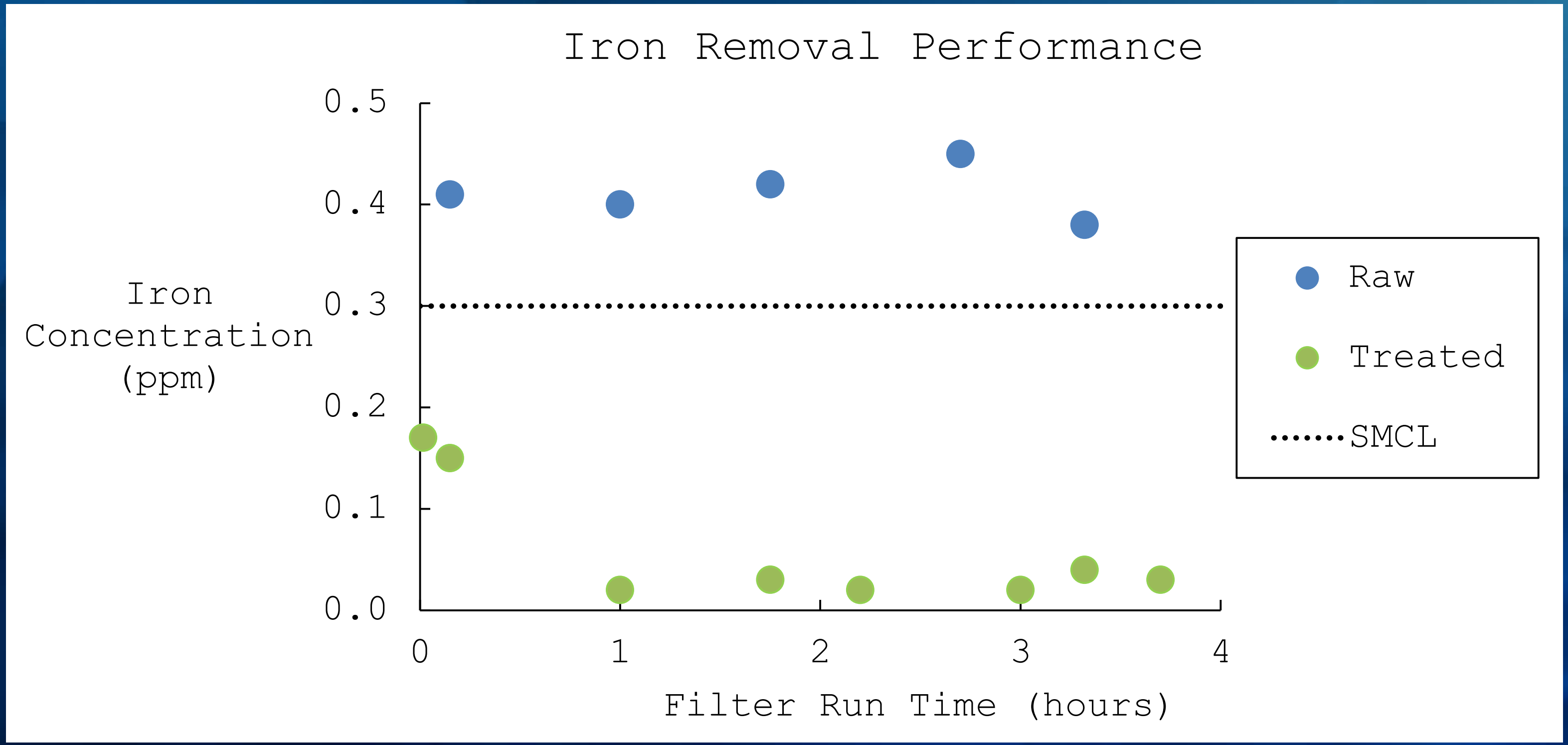
Optimize your backwash procedure

- How effective is your backwash?



Optimize your backwash procedure

- Do you include a rinse/filter-to-waste step?



Monitor Measurables:

- Raw and effluent water quality
- Chem feed systems

Inspection Focus:

- Measure freeboard, replace gaskets
- Calibrate Chem feeds, instruments, analyzers
- Photograph media surface, collect sample for lab analysis
- Review BW duration, frequency, rate set points
- Monitor complete backwash monthly, listen
- Drain and inspect tank underdrains

- Inspect filters every 3-5 years… or as needed.

In summary

- Mn is difficult to remove, catalytic media technology of choice
- Understand your system and removal mechanism(s)
- Monitor your system and make adjustments
- The more data you have the better
- Questions?

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