# Potable water system
# Municipality of Casselman

# Report on
# Roots of aesthetic (color)
# Problems and
# Proposed water treatment adjustment

AUGUST 16th, 2023

Our ref: JOB200723-001


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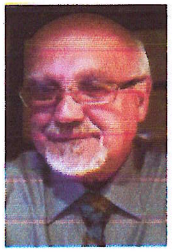

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To M. Pierre-Paul Beauchamp
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REF: REPORT JOB 200723-001

Montreal August 16, 2023

**Subject:**
Consulting report on Aesthetic (Color) problems in the potable water distribution system of the municipality of Casselman

M. Beauchamp

I am pleased to present to you this report with key findings results and recommendations. The report is based on a comprehensive assessment of the Casselmam municipality potable water distribution Plant.

## Water Aesthetic (Color) problems

Iron and manganese are common in rivers supplies used by many water utilities. Exceeding the suggested maximum contaminant levels (MCL) usually results in discolored water, laundry, and plumbing fixtures. This, in turn, results in consumer complaints and a general dissatisfaction with the water utility company.

Water can be safe to drink but its aesthetic aspects such taste, color, odor, turbidity, salinity, hardness, softness and temperature can play a major role in consumer satisfactions

We know that heath Canada set a limit of heath issue for manganese not exceeding 0.12 mg/L (120 µg/L) but there are secondary standards set for iron and manganese. These secondary standards are not health related and are not enforceable. The secondary (aesthetic) for manganese is set for a max of **0.02 mg/L (20 µg/L)** and for iron is set for a max of **0.30 mg/l (30 µg/L)**

It looks, according to data available to me (refer to the monthly operation report MAY 2023- appendix A shows levels on manganese from January to March 2023 between **0.06 and 0.34 mg / L** with no indication of iron levels.

June and July 2023, a sudden increase in the total manganese reading was recorded **0.04 to 0.950 mg/L**. Those data give us a clear indication of the inability of the actual treatment plant to achieve the required aesthetic goal (clear crystal water)

Add to that, the biggest challenges that encounter Casselamn water utility plant is that when the raw river water quality is unpredictable during the course of a year and subject to variation due to heavy rain or drought for a prolonged period. Casselmam water plant resources and equipments are not enough practicable to deal with these fluctuations.

## Scope of my work

As part of my task, to target this priority problematic, I conducted an in-depth analysis to identify the causes of the water color issue and propose effective solutions to address it. Analysis includes assessment of your actual treatment operations to deal with the inconsistent raw water intake quality during drought conditions seasons.

I kept in mind that suggested improvements are realistic, feasible and tailored to existing equipments and treatment protocol.

## Methodology

### Site visits of infrastructures and field investigations

I organize for several site visits for in-depth assessment of water treatment processes and taking pictures for documentations an future examination

### Interviewing personnel

I interview Mme Lamarche (process and compliance technician) and Mr. Payne (operator / mechanic)

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**Laboratory reagent production for testing purposes**
After a thorough examination of your case and considering other solutions such as air bubbling raw water reservoir or/and introducing a green sand filtration. I concluded that your best option is to use the chlorine dioxide technology

Because $ClO_2$ (chlorine dioxide) liquid solution cannot be transport. On site production was necessary for testing purpose. There are two reagents (A) and (B) that was prepared in the Lab and a protocol was written to follow during field testing.

**On site water sampling and onsite testing with $ClO_2$ liquid solution**
During a complete day, we intentionally stop the addition of potassium permanganate and recorded results with or without bench lab filtration. We also, add a simulated chlorine dioxide solution at different concentration on existing water at different stage of production and recorded the water quality of each stage.

**Finally - conducting a research on each chemical in use during the production of potable water and to explore the pros and cons**

The chemicals in target are

Potassium permanganate
Coagulant type
Flocculent type
Micro sand filtration type
G.A.C type - granulated activated carbon
Caustic soda
Ammonium sulfate
Chlorine gas

**Key Findings of the roots of problems**

After I assess the historical and current treatment processes, I concluded

1. The current infrastructure and equipments are suitable and do not need any additional investment.

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2. On the contrary, I identify three major issue that need to be modernized

**The potassium permanganate (KPP) has to be discontinue * and be replace by the chlorine dioxide oxidative property**
** In some cases the addition of permanganate in conjunction with ClO2 may be effective for higher DOC waters (DOC = dissolve organic carbon)*

<u>Reasons:</u>
This chemical @ 2.0 % solution is use for oxidation of manganese and iron. But there are situations that force this reaction not to be completed (High production demand of water or sudden spike of manganese levels) according to operators they have to guess estimate the spike but an excess of this chemicals that do not see any excess manganese will jeopardized the water quality production.

<u>Why this issue leads to color water</u>?
In the raw water tank where (KPP) is added according to manual testing the manganese levels, any non oxidized manganese will find its way out to the transfer Well ( before UV units) , the fact that we add the KOH before the UV units it initiate a new settling condition of manganese then the complete new oxidized manganese is initiated by adding chlorine gas and ammonium chloride chemicals). These particles escape the plant and find their way to the distribution line.

**The chlorine gas and the ammonium sulfate has to discontinue and be replace by the chlorine dioxide as a powerful disinfectant. In other term abandon completely the chloramination technology**

<u>Reasons:</u>
As mentioned above, chlorine gas contributes for the formation of trihalomethane and its disinfecting properties are weaken at pH higher than ph=7.5. On the contrary chlorine dioxide do not produce any THM and is not sensitive to pH variation.

**A complete automation of oxidation of manganese and iron is the final key for success much needed in actual river conditions**
Auto control oxidation process with chlorine dioxide dosage 24/24 using online reliable analyzer which will counter attack instantly any manganese or iron spike rely on manual sampling and manual adjustment

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**Minimum investment for maximum results**

As I mentioned before, I kept in mind that suggested improvements are realistic, feasible and tailored to existing equipments and treatment protocol.

You need the following add/on

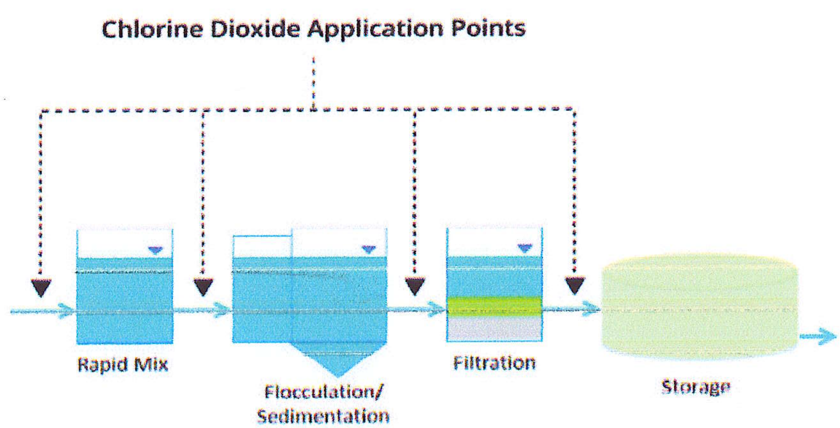
Chlorine dioxide generators (based on two chemicals)

- Sodium chlorite solution
  Will replace the following chemicals
  - Potassium permanganate
  - Caustic soda
  - Ammonium sulfate

- Chlorine gas ( already exist )

**Dosing Systems**

The appropriate chlorine dioxide dosing system is dependent upon the desired reaction chemistry. There are five main chemical reactions used to safely generate chlorine dioxide for municipal water treatment. Each chemical reaction produces different efficiencies and byproducts.



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**Opinion of health Canada about the use of chlorine dioxide technology**
Cat.: H144-39/2017E-PDF ISBN: 978-0-660-07496-2 Pub.: 160316 7.2.2.2

Chlorine dioxide (ClO2) can effectively oxidize dissolved Mn(II) to Mn(IV), although it is best suited for source waters that do not have a high oxidant demand from organic matter (Tobiason et al., 2008). Reaction rates between ClO2 and dissolved Mn(II) are rapid, with typical reaction times of 1–2 min or less, depending on the dosage of ClO2 and the initial dissolved Mn(II) concentration (Brandhuber et al., 2013). As with permanganate, a significant decrease in oxidant efficiency was observed at low temperatures (5°C) and low pH (5.5) (Knocke et al.,1990a).

The stoichiometric dosage of ClO2 required for oxidation of Mn(II) is 2.45 mg ClO2 per mg Mn(II). However, in the presence of Mn(II), ClO2 is not completely reduced to a chloride ion (Cl-); instead it is reduced only to chlorite (ClO2-) (Knocke et al., 1990a). In addition, it should be noted that if ClO2 and Cl- are not removed prior to secondary disinfection with chlorine, they will react with free chlorine to form chlorate ion. Once Cl- is present in water, it is very persistent and very difficult to remove. In Canada, chlorite and chlorate have health-based drinking water guidelines of 1 mg/L. However, to ensure that the chlorite and chlorate guidelines can be met, it is recommended that treatment plants using ClO2 as a primary disinfectant not exceed a feed dose of 1.2 mg/L (Health Canada, 2008).
Knocke et al. (1987) demonstrated that a dosage of 1–1.5 mg/L effectively oxidized initial Mn(II) concentrations of approximately 0.25 mg/L over a wide pH range when the DOC was below 2.5 mg/L. By contrast, water with DOC of 8–10 mg/L required more than 3 mg/L of ClO2. Gregory and Carlson (2003) compared oxidation of Mn(II) with ClO2, KMnO4 and ozone at lower initial Mn(II) concentrations (60 µg/L) and found that ClO2 was the most effective for achieving treated water concentrations <10 µg/L.

At a relative stoichiometric ClO2 dose of 200%, oxidation of 60 µg/L down to less than 10 µg/L occurred within 300 sec in water with T = 9°C, pH = 7.0, and TOC = 3.4 mg/L. This was reduced to less than 75 sec when the initial Mn(II) concentration was 200 µg/L.

Given that ClO2 dosing needs to be controlled to below 1.2 mg/L, several authors have noted that the application of only ClO2 for Mn(II) oxidation is limited to waters with low DOC and relatively low dissolved Mn(II) levels that require oxidation for treatment. In some cases the addition of permanganate in conjunction with ClO2 may be effective for higher DOC waters (Knocke et al., 1987; Casale et al., 2002; Brandhuber et al., 2013). An additional consideration is that on-site generation of ClO2 is required due to its high degree of reactivity.

Despite these limitations, several full-scale treatment plants have reported using ClO2 followed by physical separation for manganese removal. Kohl and Medlar (2006) reported data from several plants using ClO2 followed by conventional filtration that were capable of 81–95% removal of manganese, to achieve average treated water concentrations as low as 0.001 mg/L. In a case study

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reported by Brandhuber et al. (2013), a full-scale treatment plant that was experiencing coloured water complaints successfully switched from using KMnO4 to using ClO2 for oxidizing raw water Mn(II) concentrations of 0.07–0.2 mg/L. The utility found that ClO2 was more effective at controlling Mn(II) concentrations to below 0.02 mg/L. Similarly, studies to determine the most effective oxidant for Mn(II) removal found that ClO2 was more effective than KMnO4 and ozone for achieving low levels of Mn(II). ClO2 doses of 0.44–1.5 mg/L effectively oxidized Mn(II) to 0.005 mg/L without creating unacceptable levels of chlorite (Carlson and Gregory, 2003).

The combination of oxidation using ClO2 and microfiltration is also effective at removing manganese from drinking water. Tobiason et al. (2008) reported that a pilot-scale system using 0.5 mg/L of ClO2 as the pre-filter oxidant and microfiltration was capable of reducing an influent manganese concentration of 0.094 mg/L down to 0.001 mg/L.

Here after some useful data collected from different research

Effect of pH and alkalinity on the rate of manganese solubility

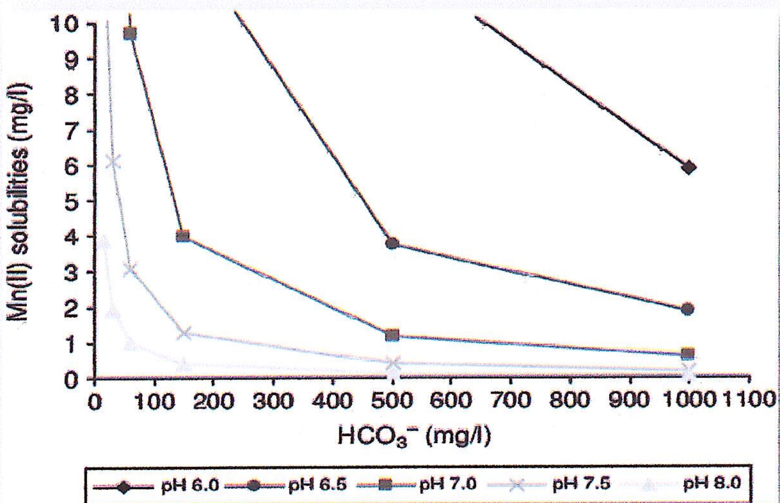
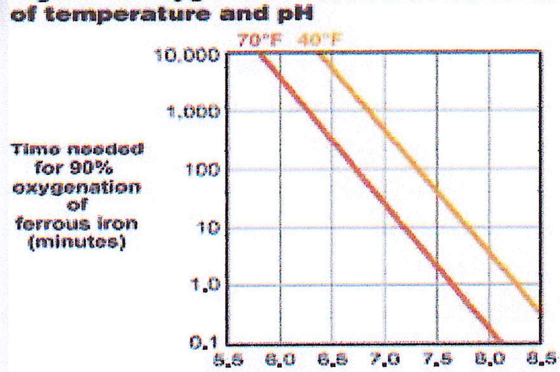



**Figure 3. Oxygenation time as a function of temperature and pH**



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Summary of my research for comparison consideration (available technologies)

**SOURCE OF SUPPLY**
- Well
- Reservoir
- Creek/River

**OXIDATION**
Aeration
Chlorine (gas chlorine, sodium hypochlorite, calcium hypochlorite, on- site generation of sodium hypochlorite)
Potassium Permanganate
Sodium Permanganate
Chlorine Dioxide
Ozone

**CLARIFICATION**
Conventional Sedimentation
Plate Settlers
Tube Settlers
Ballasted Flocculation

**FILTRATION**
Biological filtration
Dual Media
Greensand
Ion Exchange
MnO2 Coated Media
MnO2 Ore
Hollow-Fiber Membranes
Spiral Membranes
Ceramic membranes

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**Hereafter the name of some manufacturers of chlorine dioxide generators**

Evoqua water technologies, International dioxcide, Osomo enterprises
Ecolab, Prominent fluid controls Ltd

**Hereafter the name of manufacturers of online integrated analyser**

ABB , HACH , WIF

**<u>In summary</u>**

The chlorine dioxide generator will use the existing chlorine gas plus chemicals called sodium chlorite (liquid form 15 to 35 %) to produce on site chlorine dioxide at a % yield higher than 95 avoiding to the maximum the formation of chlorite and chlorate ions . The chlorine gas produced will act as an oxidizer with or without the permanganate and also as a final disinfectant before the distribution lines . The most powerful advantages of chlorine dioxide is that it is much faster to oxidized the manganese or the iron and also reduce the turbidity levels in the water and finally does not react with carbon to generate THM like chlorine.

This report is considered as a primarily assessment of successful transition to a more efficient treatment for removing manganese at very low levels.

The final calculations of the chlorine dioxide generator sizing and the type of on line analyser should be explored further more. The choice of any analyser must communicate with the existing PLC (programmable logical controllers). The PLC will be responsible to command the flow of chlorine dioxide which will be related to the outcome of the online analysers 24/7

The writer has the knowledge and the expertise to coordinate between manufacturers and online analysers manufacture and PLC manufacturer to advise the automated company about the required additional binary or analogical input and output needed for communications and execution the command. Plus, the need to assist technicians for the extra logic that is needed to be implemented in the existing PLC.

I believe that the implementation of the proposed solutions will significantly improve the water quality and address the coloration issues in the potable water distribution system of Casselamn. I am available to provide further clarification and

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support as needed to ensure the successful execution of these recommendations.

Thank you for entrusting me with this important assignment. I am confident that my comprehensive analysis and recommendations will contribute to the enhancement of Casselamn water distribution system.

Sincerely,

Bill Dallala, P.chemical Eng.MBA1
Senior chemical engineer
Water treatment expert

Nabil F. Dallala
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Acknowledgments
Recognition of the collaboration and support received from
Pierre-Paul Beauchamp - Director - public work
Caroline Lamarche - Process & Compliance Technician
Brandon Payne- Operator/Mechanic

Appendices

Flow chart - Casselman water treatment - actual process treatment
Flow chart - Casselman water treatment - proposed modification process treatment
Results of primarily field experiments and testing
Two years averages results compilations by Caroline Lamarche
Technical explanation about - discomfort at the level of end user of municipal water

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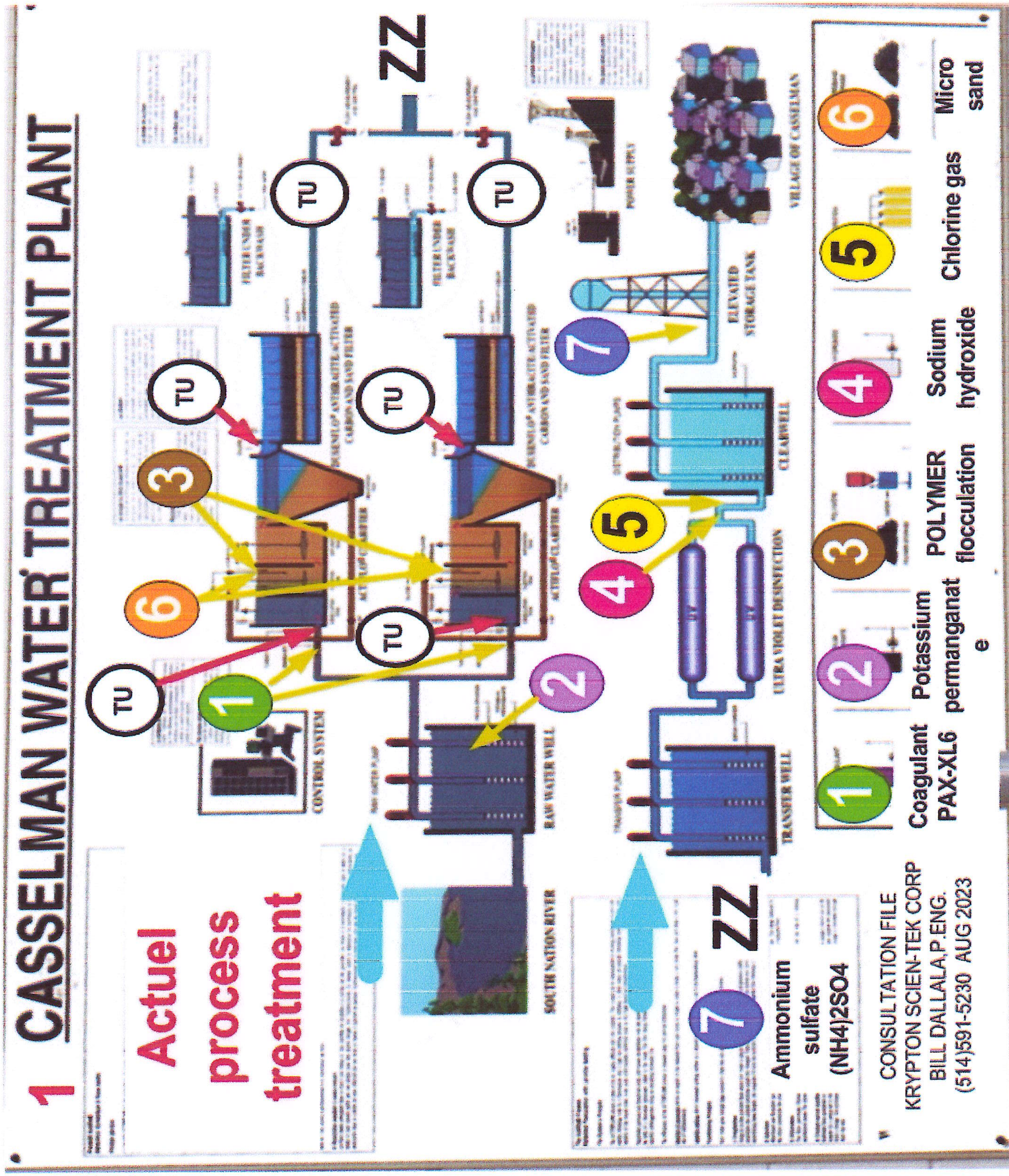

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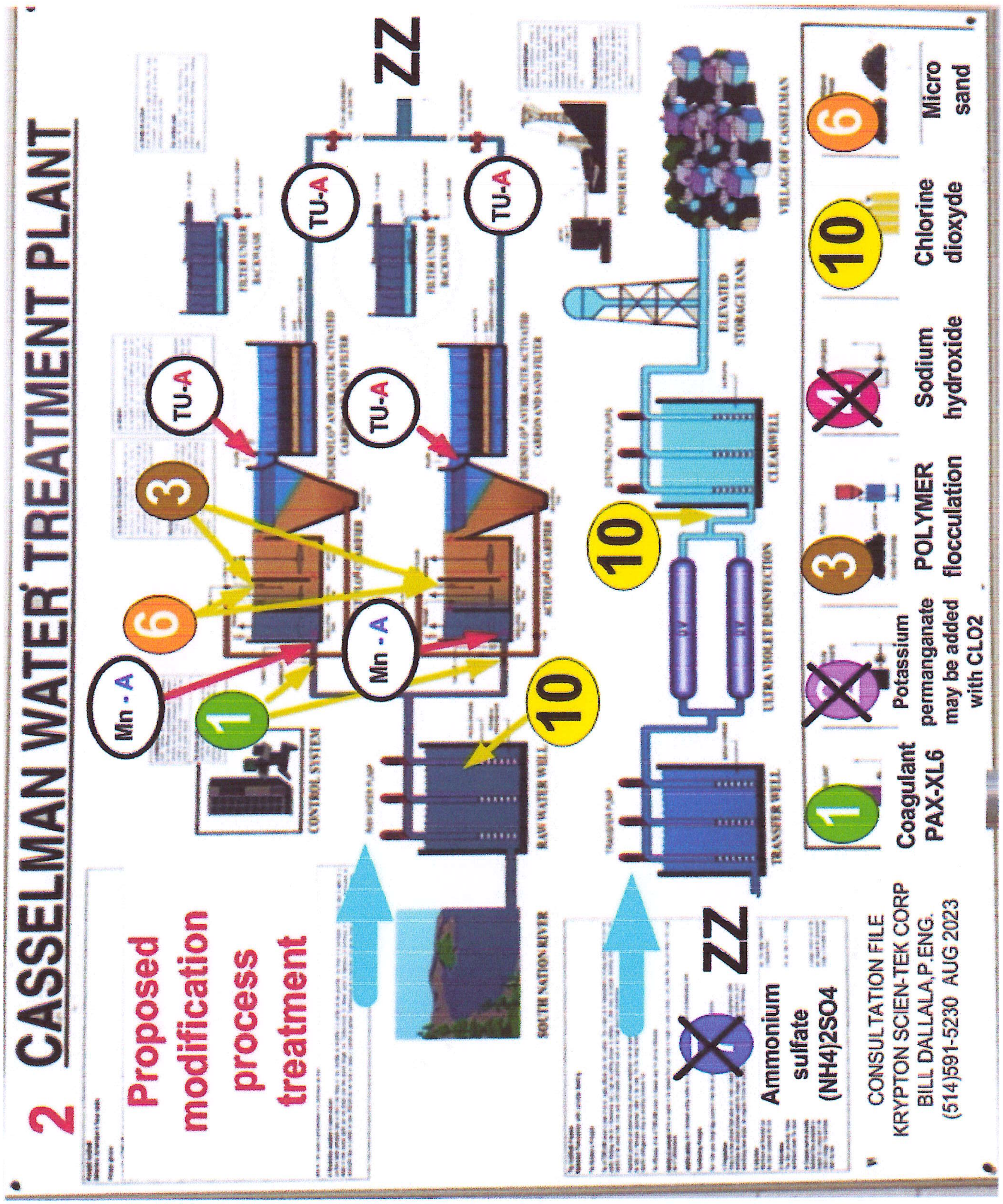

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Hereafter results of primarily field experiments and testing and my personal notes
Note chlorine dioxide enhance the turbidity levels

JOB#2 Field testing – Casselman
TUESDAY 01 AUG 2023

| Water type | Manganese PPM | Turbidity NTU | Comments |
|---|---|---|---|
| **Demineralized water(D.I) blank test** | 0.00 | | Water bought from Canadian Tire " Casselamn "<br>D.I = Demineralised or deionised are OK |
| **Before GAC Activated carbon bed And sand** | 0.040 | 0.411 | Water production was " OFF" for 6 hours + The potassium permanganate was in contact for long time. it helps reduce the manganese level<br>No lab 0.45 micron filtration of the sample yet |
| **Addition of 3 Drops A 3 Drops B 25 ml same above water sample** | 0.051 | 0.385 | No lab 0.45 micron filtration of the sample yet<br>Notes:<br>Theoretically we added 1.75 PPM ClO2 to the sample<br>Turbidity went down |
| **Addition of 6 Drops A 6 Drops B 25 ml same above water sample** | No filtration 0.031<br>After filtration 0.036 | No filtration 0.118<br>After filtration 0.179 | Vacuum 0.45 micron filtration of the sample (Yes)<br>Notes:<br>Theoretically we added 3.50 PPM ClO2 to the sample<br>Manganese & Turbidity went down |
| Below results are after running the water production normally for 45 minutes.<br>Hereafter the K permanganate has a 20 min. contact time during production | | | |
| **Raw river water** | 0.126 | 0.268 | No K permanganate yet |
| **Raw river water with K permanganate 20 m.** | 0.038 | 0.132 | The sample is filtered with 0.45 micron |

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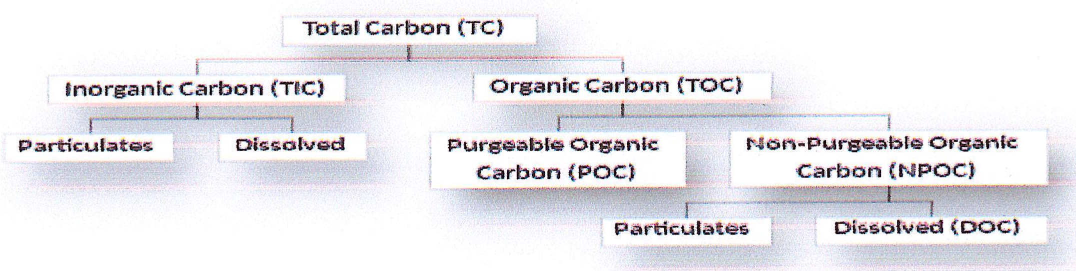
| | | | |
|---|---|---|---|
| **Raw river water with K permanganate 20 m. Plus add 10 Drops A 10 Drops B 25 ml same as above water sample** | No filtration 0.049 After filtration 0.031 | No filtration 0.300 After filtration 0.123 | Theoretically 7.00 PPM ClO2<br>Oxidation of manganese achieved<br>Higher turbidity because excess sodium chlorite<br>As CLO2 yield reaction at 65 % only<br>Effect of 0.45 Micron filtration<br>When filtered , manganese & turbidity down |

Below we are testing raw water without any potassium permanganate . Plant is running since 60 minute
Reasons: How efficient is the oxidation behavior of ClO2

| Conditions > | Raw water | Raw with sand & G.A.C filtration | Raw + Lab - filtration 0.45 Microns | Raw water with (3xA+3xB) ClO2 1.7 PPM No Lab - filtration | Raw water with (3xA+3xB) CLO2 1.7 PPM with Lab- filtration |
|---|---|---|---|---|---|
| Results Manganese PPM | 0.11 | 0.014 | 0.053 | 0.082 | 0.039 |
| Results Turbidity | 7.13 | 0.239 | 0.350 | 6.580 | 0.168 |

Comments: The actual sand + G.A.C. filter better than the 0.45 disk vacuum lab filtration
The ClO2 has good effect on lowering the turbidity & manganese. The results are with experimental produc
on site of 65 to 75 % yield of ClO2. But with $Cl_2$ gas and sodium chlorite the yield is 100 %

<u>Question GAC is used by operators to identify what? 2 possibilities</u>
G.A.C means granulated activated Carbone (is that the anthracite activated carbon? )
G.A.C is the manufacturer of " ammonium sulfate used for chloramination

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## Casselman Drinking Water System

Data from January 1, 2022 - December 31, 2022

| Parameters | Raw Water | | | Treated Water | | |
|---|---|---|---|---|---|---|
| | Min | Max | Avg | Min | Max | Avg |
| Total Managanese (mg/L) | 0.01 | 0.90 | 0.14 | 0.00 | 0.72 | 0.06 |
| Colour (PtCo) | 6 | 1,267 | 182 | - | - | - |
| Turbidity (NTU) | 2.55 | 121 | 12.7 | 0.22 | 2 | 0.5 |
| Alkalinity ($CaCO_3$) | 80 | 480 | 251 | 120 | 520 | 233 |
| Hardness (mg/L as $CaCO_3$) | 138 | 478 | 318 | 264 | 480 | 329 |
| DOC (mg/L) | 3.6 | 11.3 | 6.9 | 2.0 | 5.6 | 3.1 |
| TOC (mg/L) | 4.1 | 11.3 | 7.1 | 1.8 | 5.6 | 3.2 |
| pH | 7.26 | 8.40 | 7.74 | 7.15 | 8.57 | 7.71 |
| Temperature (°C) | 1.3 | 26.0 | 10.4 | - | - | - |

Data from January 1, 2023 - July 31, 2023

| Parameters | Raw Water | | | Treated Water | | |
|---|---|---|---|---|---|---|
| | Min | Max | Avg | Min | Max | Avg |
| Total Managanese (mg/L) | 0.04 | 1.22 | 0.34 | 0.00 | 1.00 | 0.19 |
| Colour (PtCo) | 39 | 794 | 164 | 0 | 246 | 29 |
| Turbidity (NTU) | 2.36 | 188 | 15.2 | 0.13 | 13.2 | 1.18 |
| Alkalinity ($CaCO_3$) | 140 | 320 | 251 | 140 | 300 | 242 |
| Hardness (mg/L as $CaCO_3$) | 169 | 372 | 269 | 161 | 361 | 264 |
| DOC (mg/L) | 3.3 | 8.3 | 5.1 | 1.0 | 3.0 | 1.8 |
| TOC (mg/L) | 3.3 | 8.4 | 5.4 | 1.0 | 3.2 | 1.9 |
| pH | 7.13 | 8.14 | 7.62 | 7.19 | 8.20 | 7.60 |
| Temperature (°C) | 1.8 | 22.4 | 11.2 | 2.0 | 23.4 | 12.5 |

DOC = dissolved organic carbon TOC = total organic carbon *hereafter from my investigation*

**Notes on site**

Maximum flow (as per operators) = 2000 m3 / day
Raw tank pH river water : 7.40 - 7.70 T-Alkalinity : 270 - 300 PPM
K permanganate is injected before coagulant (At raw water)
By preparing 2 % solution (Stocking as powder ) preparation by operators
Manganese 0.9 goes down to 0.53
Injection is very sensitive for K permanganate for color issue
Coagulant Kemira PAX XL6
Floculant : Polyacrylate
Mixed Bed: Sand + G.A.C = granular activated carbon (Dusenflo anthracite)

G A C generally is an organic carbon filtration media — wood, coconut shells, coal or peat — used for water purification, typically applied in a fixed bed application. A filter with GAC can remove certain chemicals, particularly organic contaminants, from water, as well as chemicals that produce odors or tastes to water such as hydrogen sulfide or chlorine. Granular activated carbon notably assists with the removal of per- and polyfluoroalkyl substances (PFAS), which have become an increasing contaminant of concern for regulators. Other chemicals, specifically iron and nitrate, can not be removed with GAC. GAC should be changed based on contaminant levels and water use, as higher levels or use may require more frequent change-outs.

Then after G A C
inject NaOH (50%) + Cl2 gaz + Amonia ( Granular diluted ) Chloramination to hit: 2.18 PPM chlormines .
Levels during WINTER period :
Mn 0.03 PPM but JULY Mn 0.57 - 0.88 PPM ( reasons: River stagnant no rain )

<u>Summary of observation</u>
The water production is not chemically automated.
All the chemicals are dosed flow paced.
The dosage is controlled by a pump speed multiplier.
<u>For example</u>
NaOH dosing is not controlled on the pH levels and
Coagulant/polymer dosing is not controlled by turbidity readings.

The PLC is an Allen-Bradley Panel View 1000. Our contact for design is Capital Controls. Jean-Louis is the technician that usually comes on site for programming

**PLC** is an Allen-Bradley Panel View 1000
Capital Controls & Instrumentation
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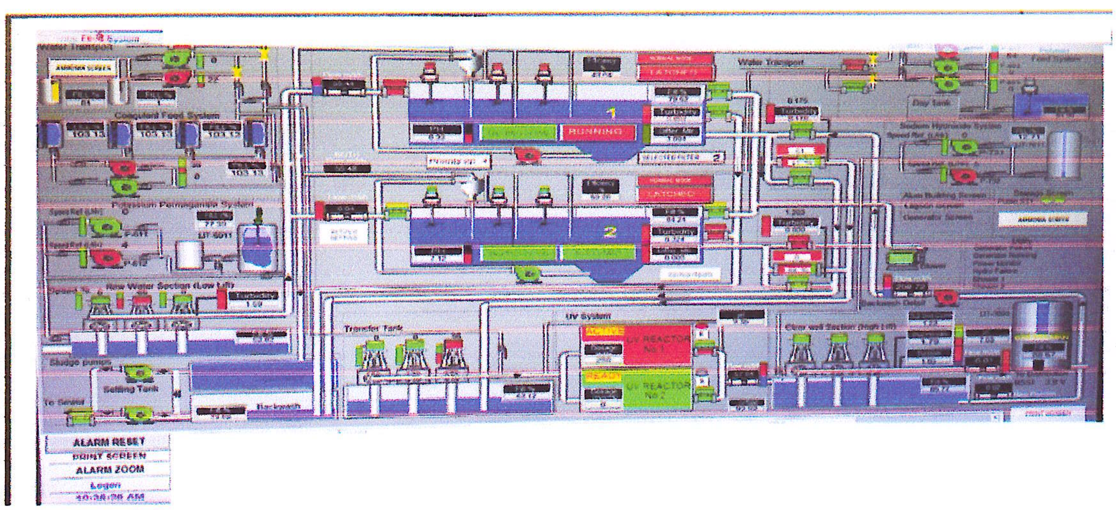

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Technical explanation about
**Discomfort at the level of end user of municipal water**

Why end users react to a non health issue. As I said, Iron and manganese are both known to stain the water supply. They can make water appear red or yellow, create brown or black stains in the sink, and give off an easily detectable metallic taste. Although these can all be aesthetically displeasing, iron and manganese are not considered health risks. First though, the type of iron that is contaminating the water supply must be determined.

1. *Ferrous iron* - The water appears to be clear, but after standing, black or rust colored particles settle to the bottom.

2. *Ferric iron* - Water straight from the faucet has a red, yellow, or rusty color to it. This type will also easily settle to the bottom.

3. *Iron bacteria* - Plumbing fixtures have a slimy brown, red or green film, or there is a gelatinous sludge in the pipes. Occasionally chunks of this slime can be dislodged from pipes yielding colored water. These bacteria feed on iron found in pipes or fittings.

End of appendices
End of the primarily report