



# Understanding Disinfection for Small Water Systems

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## Agenda:

Disinfection requirements in B.C.

How do filtration, UV, and chlorination work?

Advantages, disadvantages, and limitations

Common equipment and accessories

Installation, operation and maintenance best practices

Dealing with common problems / challenges

What's new in disinfection?



## **Purpose and objectives of disinfection**

- provide the public with consistently safe drinking water
- required for small water systems under the Drinking Water Protection Act and Regulations
- exact disinfection requirements vary depending on risk assessment of the water source, generally performed by a Drinking Water Officer from one of the 5 provincial health authorities
  - proximity to potential contamination sources
  - vulnerability of aquifer / water source
  - sensitivity of population
  - water test history

## 4-3-2-1-0 Drinking Water Objective

- Minimum acceptable treatment standard

**4** = 4-log (99.99%) inactivation of viruses

**3** = 3-log (99.9%) inactivation of Cryptosporidium and Giardia

**2** = minimum 2 barriers / methods of treatment for all surface water or unprotected ground water

**1** = turbidity must be  $< 1$  NTU (target level = 0.1 NTU)

**0** = zero total / fecal coliform / e.coli in microbiological testing

Interpretation of this objective varies slightly among the HA's



## **Core Technologies**

- Very Fine Filtration
- Ultraviolet (UV) Light
- High-Dose Ultraviolet (UV) Light
- Chlorination

## **Some Key Principles**

- Primary vs. Secondary Disinfection
- Disinfection processes works as part of a “System,” not as a standalone function – the multi-barrier approach
- Ability to monitor / validate key to technology approvals



## Very Fine Filtration

- effective physical barrier against protozoa and cysts that cause common waterborne illnesses (eg. cryptosporidium and giardia)
- relatively low cost, easy to operate
- 1 micron absolute generally required in B.C. (note differences between absolute and nominally rated filters)
- cartridges require independent / third-party cyst removal validations to be accepted (eg. NSF/ANSI 53) in addition to material safety certifications like NSF/ANSI 61.
- real-time performance monitoring is generally limited to monitoring pressure loss.



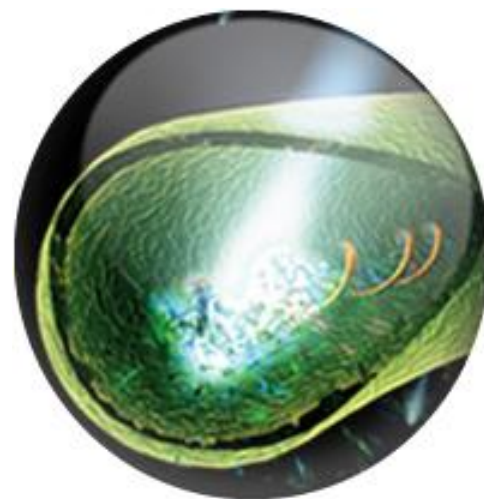
## **Fine Filtration – Successful Operation & Keeping Cartridge Costs Manageable**

- staged filtration – protect the absolute rated filter!
- for severe sediment loads, protect with backwashable media filter and/or spin down filters
- pressure gauges before and after each stage to monitor pressure drop
- bigger is generally better!
- new non-metallic filter housings are replacing stainless steel housings at far lower price points



## What is UV?

- UV-C spectrum light of much greater intensity than sunlight
- concentrated at the 254 nm "germicidal" wavelength
- destroys DNA of bacteria, viruses, and other microorganisms, rendering them sterile and unable to reproduce and cause illness (inactivated)
- proven technology used for residential, commercial, and municipal water and wastewater treatment
- effectiveness is largely determined by "dosage" which is a function of the UV intensity and the length of exposure (time)



## Why Use UV?

- highly effective at inactivating microorganisms, particularly bacteria, **Cryptosporidium, and Giardia**
- does not alter any other mineral or physical attributes of the treated water (taste, odour, pH)
- no formation of disinfection by-products (THMs)
- relatively simply installation and operation
- energy efficient and cost effective
- small physical footprint
- no chemical handling requirements



## Some Important Considerations / Limitations

- pre-treatment required to ensure adequate dose is maintained and to prevent frequent maintenance (depending on water conditions)
- standard UV is not as effective as chlorination at inactivating certain resistant viruses
- no residual downstream treatment
- may have increased risk of reactivation after long-term storage



UV Dose is a function of UV Intensity and Exposure Time



**Units of Measure:**  
 $\text{mJ}/\text{cm}^2$  or  $\mu\text{Ws}/\text{cm}^2$

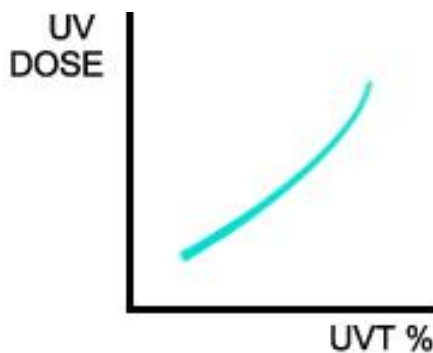
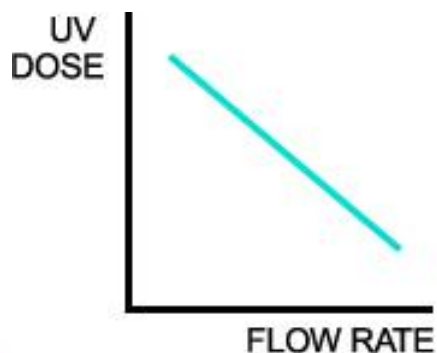
**Standard Dose UV:**

40  $\text{mJ}/\text{cm}^2$

**High Dose UV:**

186  $\text{mJ}/\text{cm}^2$

- water flow rate has a direct linear relationship to UV dose – almost...
  - reduce flow rate by 50%, roughly double the UV dose
  - this is strictly a function of exposure time
- UV intensity (UV transmittance or UVT – expressed as a percentage) has an exponential relationship to UV dose
  - a relatively small increase in UVT can dramatically increase UV dose



## UV intensity is a function of:

- lamp UV output / spectrum (lamp type, age, etc.)
- clarity of the UV sleeve
- UV transmittance properties (UVT) of the water being treated





## Feed Water Quality

Water testing is vital to determine if there are contaminants in the water that may reduce UV intensity

- turbidity – minimum 5 micron pre-filtration (1 micron rec.)
- hardness (indirect – sleeve fouling) < 7 GPG or 120 mg/l
- iron (indirect – sleeve fouling) <0.3 mg/l
- manganese (indirect – sleeve fouling) <0.05 mg/l
- tannins / colour / organics (direct – UVT reduction) varies, <0.3 mg/l
- total organic carbon (direct – UVT reduction) – varies, <4 mg/l
- UVT min 75%



## Common Components

- sterilization chamber (reactor)
- ballast / controller
- lamp (pressure, output, mercury vs. amalgam)
- sleeve
- UV intensity monitor



## Common Features and Accessories

- validation (NSF Class A / B, US EPA, other) - differences
- emergency solenoid shut-off valves
- flow restrictors
- cooling systems (thermal valves, fans, convection)
- data collection / logging systems, diagnostics
- voltage compensation
- true dose monitoring





## Installation Best Practice Considerations

- GFCI outlet or outlet protected by GFCI breaker
- surge protector, power back-up
- chamber & sensor orientation
- drainage, sample ports, shut-offs, bypass?
- location of solenoid & flow restrictors
- location of electronics
- plumbing materials
- accessibility for maintenance (don't forget lamp removal!)







## Maintenance Best Practices – Quartz Sleeves and Sensors

Clean quartz sleeve and sensor window regularly to maintain UV intensity and maximize UV dose

- CLR or Lime Away are recommended cleaners
- Never use glass cleaners like Windex
- Use a soft white cotton cloth and Q-Tips
- Do not handle lamps and sleeves with bare hands
- Do not use lubricants on sleeve o-rings
- Sleeves should be replaced if etching or clouding is visible and cannot be removed by cleaning (most manufacturers recommend replacement every 3 years)



## **Maintenance Best Practices Lamps**

- Follow manufacturer's recommended replacement schedule
- Disinfect system after each lamp replacement
- Use genuine OEM lamps/parts (validation, safety certifications)

## **Other Maintenance Best Practices**

- Keep a log book documenting all maintenance



## General Troubleshooting Suggestions

- do not assume anything
- sensor and lamps failures are not very common
- have spare parts on hand
- test the water (UVT) – consider recent events that could have changed feed water conditions
- consider timing of alarm(s) – temp mgmt, regen,, recent lamp change
- consider environmental conditions
- document everything you do – be specific and do one thing at a time – be methodical



## Lamp Failure

- what is the age of the lamp – is it due for replacement?
- inspect lamp for physical damage
- install a new lamp – is problem resolved?
- DOA or pre-mature lamp failures are rare
- possible other causes of non-firing lamp: ballast failure, power service failure (breaker, outlet, UPS, surge protector, fuse), reed switch/safety switch failed or not engaged



## UV Intensity Alarm

- make sure sensor is still connected to controller
- **clean UV sleeve and sensor window\*\*\*\*\***
- dry test / test UVT if possible
- consider over-heating issues, air in system?
- investigate lamp age – is it due for replacement?
- considering installation new lamp then re-test, if still fails, install new sleeve and re-test – dry test
- have water conditions changed? Spring freshet? Heavy rain? / Has the pre-treatment failed? Correlation to pre-treatment backwash or regeneration?



## Ballast Failure

- often a default diagnosis after all other items are confirmed to be operational
- best way to confirm is to install new ballast to see if the problem is resolved
- repeat ballast failures often due to power supply surges – install a suitable surge protector or UPS



## Troubleshooting Redundant Systems

- if both units in alarm, STRONGLY suspect a water quality problem
- if only one unit is in alarm, you have all the parts available to determine the faulty part or fouled part



QUESTIONS?



## **Chlorination Advantages**

- Highly effective at inactivating resistant viruses (including Adenoviruses) and most bacteria
- Residual provides ongoing disinfection after point of treatment
- Relatively simple to monitor – monitor residual free chlorine level



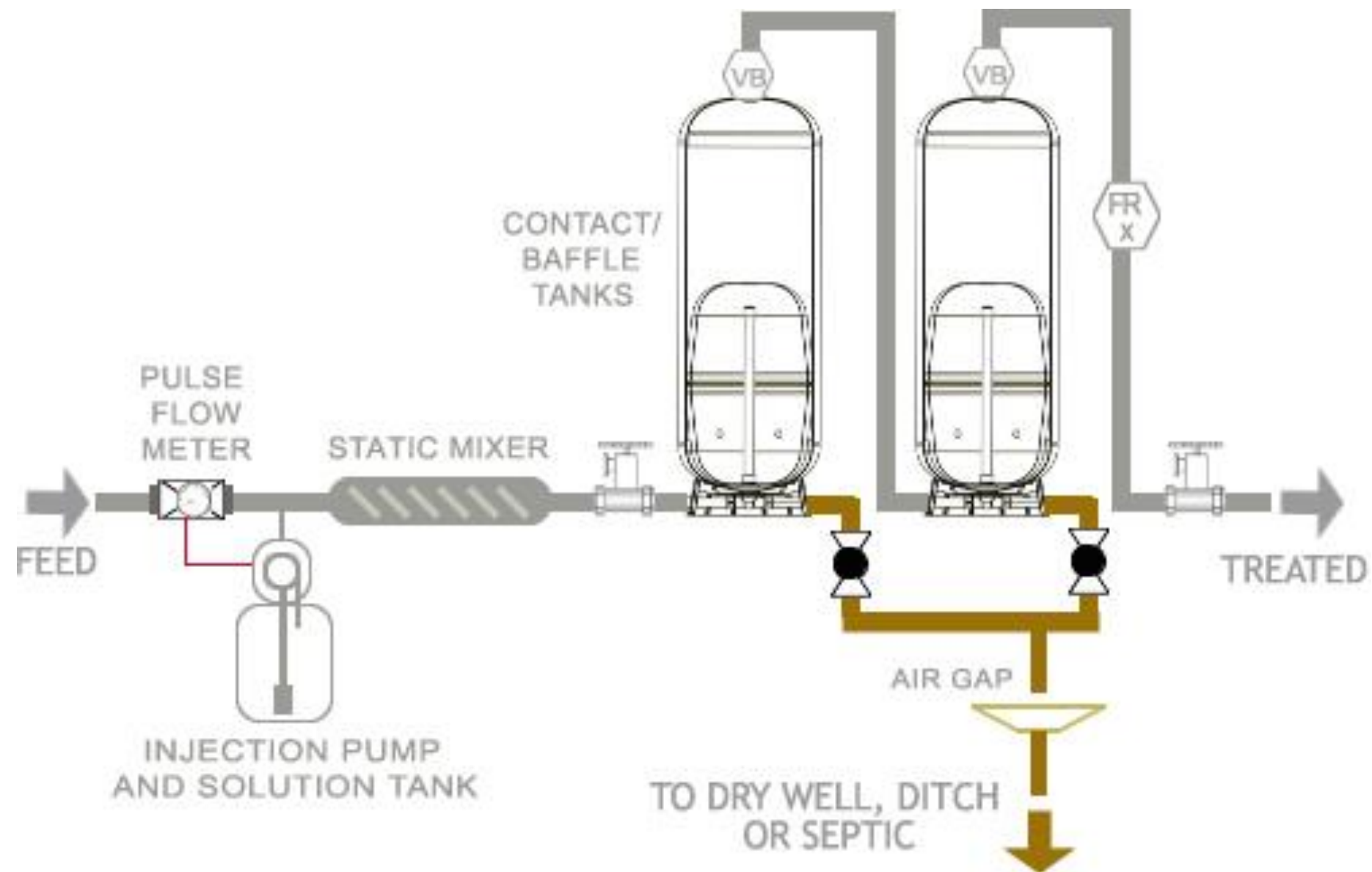
## **Chlorination Disadvantages**

- Chemical handling
- Operator training requirements
- Public perception of “chemicals” and taste / odour
- Potential formation of disinfection byproducts when organics are present
- Less effective at inactivating cryptosporidium and giardia
- Contact time requirements can often be difficult or costly to meet

## Typical Chlorination System for a Small Water System Consists of:

- Chemical feed pump (peristaltic / diaphragm)
- Injection point / quill
- Solution tank with/without spill containment
- Foot valve with check valve and potentially level switch / alert
- Probes / analyzers and/or flow meter
- Water storage / retention
- Static or active mixer
- Safety equipment – PPE, eyewash station







## Contact / Retention Time Options:

- Reservoir / holding tanks
- Contact tanks / specialized baffle tanks
- Coiled Pipe
- Large diameter buried pipe
- Distribution pipe (based on distance to closest point of use)
- Other treatment equipment



## **CT = Concentration x Time**

**To use CT to demonstrate that you have sufficient water treatment, you need to do the following three things.**

1. Determine how much CT you need.
2. Determine how much CT you have achieved.
3. Ensure CT achieved is more than CT required.

**Must calculate for each storage / retention vessel and add together.**





## Contact Time – Chlorination – How Much Do I Need?

It depends!

**Must consider water temperature and pH.**

**Temperature** - disinfection ability of chlorine decreases as temperature declines so we need to consider the minimum water temperature.

**pH** - the disinfection effectiveness of chlorine decreases as the pH increases.

The CT required for 4-log inactivation of viruses by free chlorine, at pH 6.0 to 9.0, and at a water temperature of 2C is 10.7

(Source: EPA Guidance Manual: Disinfection Profiling and Benchmarking)



## Disinfection Effectiveness (Chlorine)

**Chlorine Concentration** should be measured at the outlet of storage (at the end of the contact time).

**The trade-off:** If we increase the chlorine concentration, we reduce the time required for contact. BUT.... Increasing it too much will negatively impact taste/odour.

**Residual and the end of the line is important too!** We generally require at least 0.2 mg/l free chlorine residual at the end of our distribution system, so you may have to aim higher than this at the outlet of your storage to ensure the minimum residual at the end of the longest distribution line.

Typical values for small water systems range from min 0.4 mg/l to 1.0 mg/l at the outlet of the contact tank(s).



OK, so how do I calculate it?

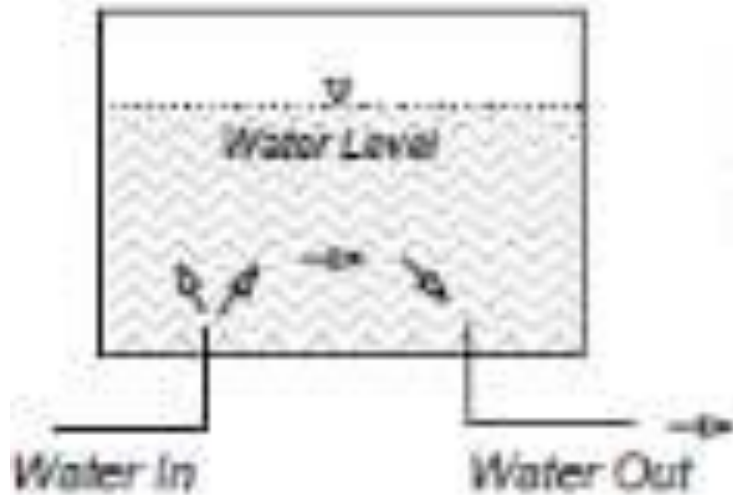
$$CT = \text{Cl}_2 \text{ Concentration} \times \text{SCF} \times \frac{\text{Minimum Water Volume}}{\text{Maximum Outlet Flow Rate}}$$

**SCF = Short Circuiting Factor (a.k.a. Baffle Factor)**

The short-circuiting factor is determined either by tracer tests of the actual reservoir/storage vessel, or it will be assigned, based on tracer tests for similarly configured reservoirs/vessels. It is expressed as a %. 100% means no short-circuiting and 0% means potential for complete short-circuiting or bypass of storage exists,

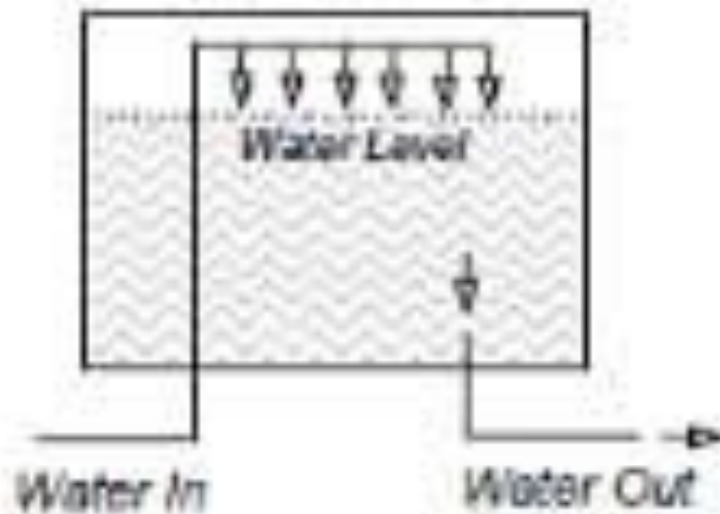
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**What is the Short-Circuiting Factor?**



**Poor  
5-10% SCF**

**What is the Short-Circuiting Factor?**



**Good  
20-30% SCF**

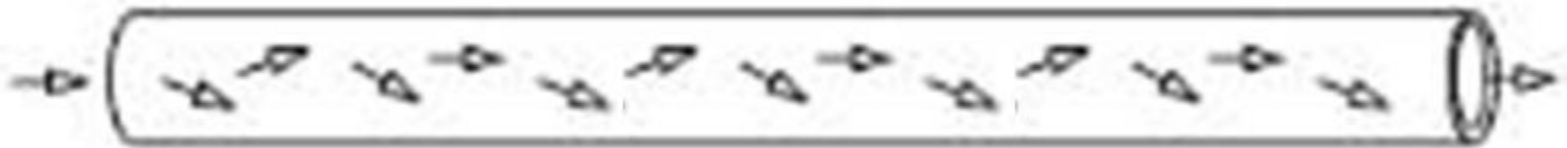
**What is the Short-Circuiting Factor?**



**Superior  
50-70% SCF**

**What is the Short-Circuiting Factor?**

**Perfect  
100% SCF**





## About the Chlorine (Sodium Hypochlorite) Itself

- make sure it is NSF validated (NSF/ANSI Standard 60)
- make sure it is fresh (<1 month old)! Chlorine degrades over time (about 50% in 6 mo.)
- DILUTE IT! For most small systems, we recommend diluting the approx. 12% sodium hypochlorite from the supplier by a ratio of between 10 and 30 parts water to 1 part chlorine
- use CLEAN water to dilute





## Chlorination System Maintenance

- follow safe chemical handling, storage, and ventilation requirements
- wear personal protective equipment (PPE) – eye protection + gloves
- ensure chlorine solution is fresh, accurately diluted, and keep solution tank topped up
- inspect and clean injection points and foot valves regularly
- replace peristaltic tubes per manufacturer recommendations
- monitor chlorine residuals very often and keep a log book



## **Common Problem – Low Residual Chlorine Level**

- increase in chlorine demand (change in feed water conditions)
- weak / old chlorine solution
- pump capacity cannot keep up with high flow rates at current rate of dilution
- too much contact time or reduced storage turnover may be causing chlorine loss through dissipation? This can be common with seasonal operations. Consider secondary chlorine injection loop or adjusting storage levels.
- clogged injection point, foot valve, or tubing or worn peristaltic tube



## **Common Problem – Difficult to Maintain Steady Residuals**

- high or fluctuating chlorine demand – consider additional pre-treatment for iron/manganese/organics, source protection measures
- make sure chlorine analyzer probes/sensors are clean and calibrated
- are you diluting enough? (long pauses between injections of high concentrations)?
- consider a static or active mixer
- pump capacity cannot keep up with periodic high flow
- too much contact time? (dissipation) – secondary chlorine injection loop



## **Common Problem – Loss of Prime**

- off-gassing – reduce concentration, reduce tube length
- foot valve failure – clean screen and inspect check valve
- solution tank running empty / low

## **Common Problem – Disinfection Byproducts**

- add pre-treatment to remove organics, consider chloramine?

## **Common Problem – Complaints about Taste/Smell**

- residuals too high? Often we compensate for fluctuating chlorine demand by raising levels instead of increasing pre-treatment to ensure consistency in our feed water.



QUESTIONS?