Online Help Centre
for BC Small Water Systems

Chlorine & UV Disinfection Applications for Small Water Systems

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Agenda:

How do UV and chlorination work?

Advantages, disadvantages, and limitations

Common equipment and accessories

Installation, operation and maintenance best practices

Dealing with common problems / challenges

What is our objective?

- 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**

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

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

  Interpretation of this objective varies slightly among the HA's

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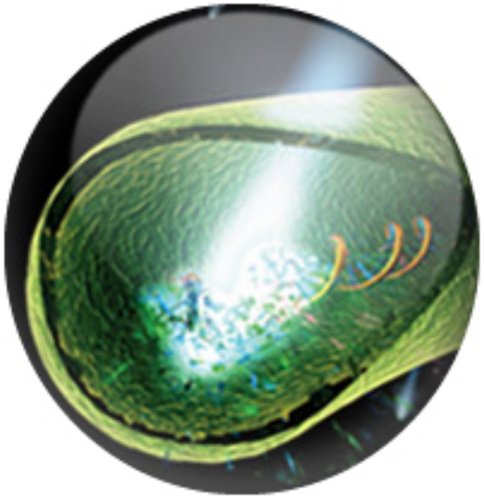
What is UV?

• 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, **<u>Cryptosporidium, and Giardia</u>**
- 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)

• not as effective as chlorination at inactivating certain resistant viruses

• no residual downstream treatment

• may have increased risk of reactivation after long-term storage

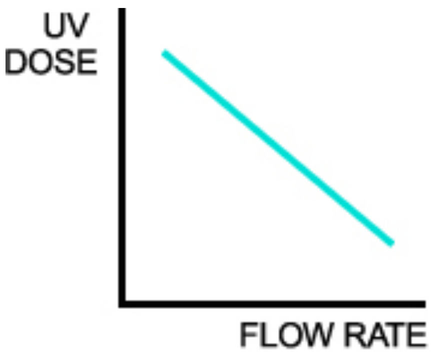
UV Dose is a function of UV Intensity and Exposure Time

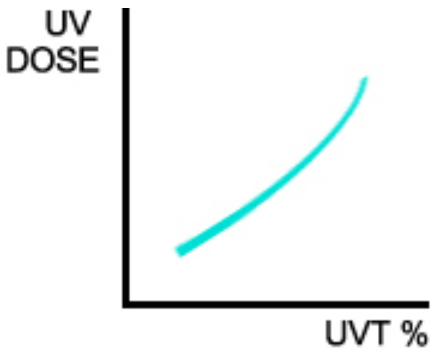
Unit of Measure:

mJ/cm^2
or
$\mu Ws/cm^2$

$1\ mJ/cm^2 = 1{,}000\ \mu Ws/cm^2$

- 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 a 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

Microorganism	Approx. UV Dose Required for 3-Log Inactivation (99.9%) – mJ/cm^2	Approx. UV Dose Required for 4-Log Inactivation (99.99%) -mJ/cm^2
Cryptosporidium parvum oocysts	6.4	7.9
Giardia lamblia cysts	10	16
E.coli (O157:H7)	4.1	5.6
Hepatitis A Virus	22	30
Poliovirus Type 1	23	30
Rotavirus SA11	26	36
Shigella dysenteriae (Dysentery)	2.0	3.0
Shigella sonnei	6.5	8.2
Legionella pneumophila (Legionnaires' disease)	6.9	9.4
Salmonella enteritidis	9	10
Salmonella typhi (Typhoid fever)	6.4	8.2
Coxsackie B5 Virus	22	30
Vibrio cholerae (Cholera)	2.2	2.9
Campylobacter	4.0	4.6

Most resistant: Adenovirus 186 mJ/cm2 for 4 log inactivation

Dosage from Typical Validated UV Sterilizer is > 40 mJ/cm2

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!)


VIQUA
VIQUA
VIQUA

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
- <u>Never</u> 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
- take spare parts to the job site / have spares 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
- never leave the site without serial numbers and water sample
- 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?

<u>Ballast Failure</u>

• 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 (Adenoviruses) and most bacteria

•Residual provides ongoing disinfection after point of treatment

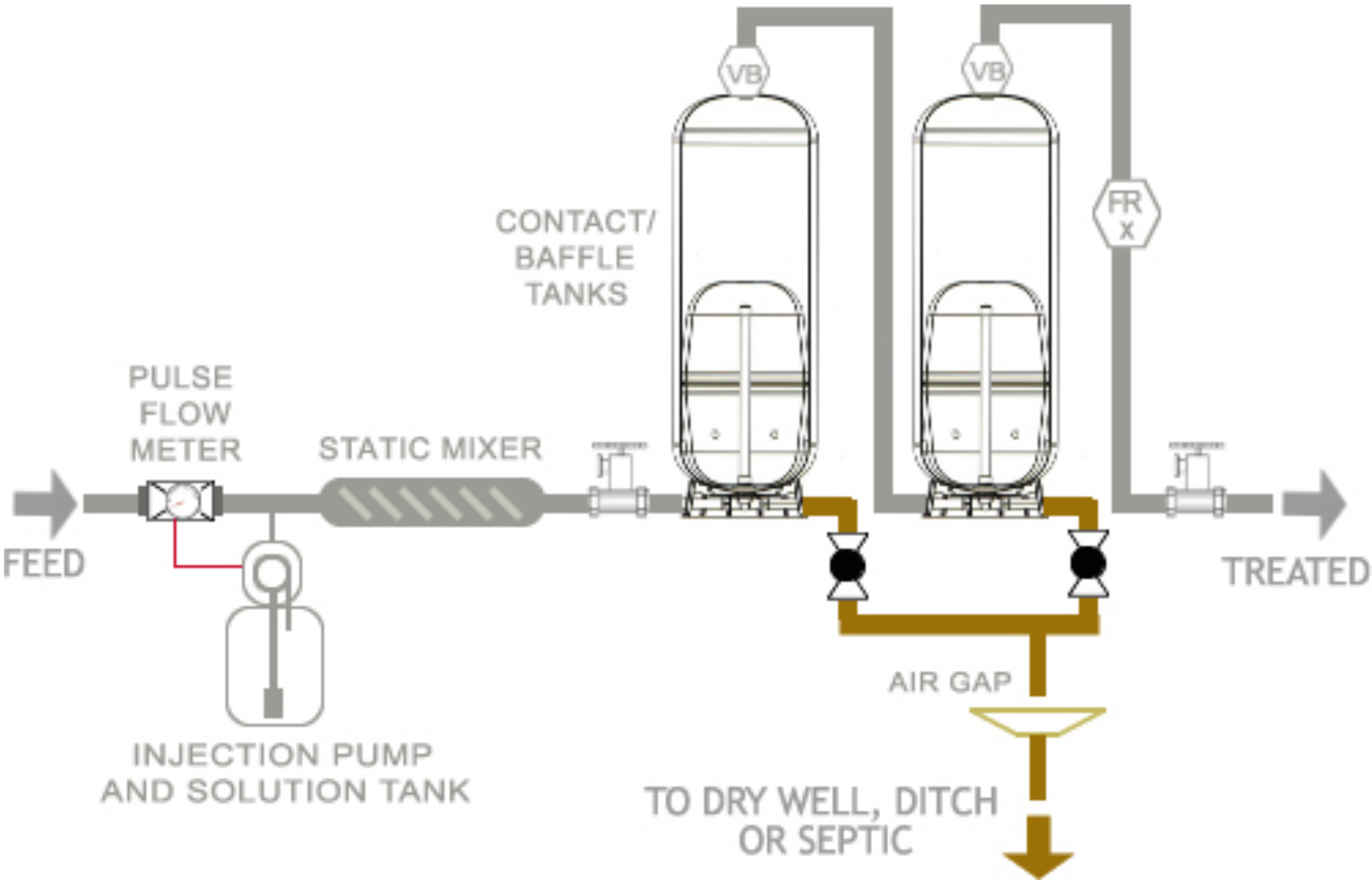
•Relatively simple to monitor

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


VB
VB
FR
X
CONTACT/
BAFFLE
TANKS
PULSE
FLOW
METER
STATIC MIXER
FEED
TREATED
AIR GAP
INJECTION PUMP
AND SOLUTION TANK
TO DRY WELL, DITCH
OR SEPTIC

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 a 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?

$$CT = Cl_2 \text{ Concentration} \times SCF \times \frac{\text{Minimum Water Volume}}{\text{Maximum Outlet Flow Rate}}$$

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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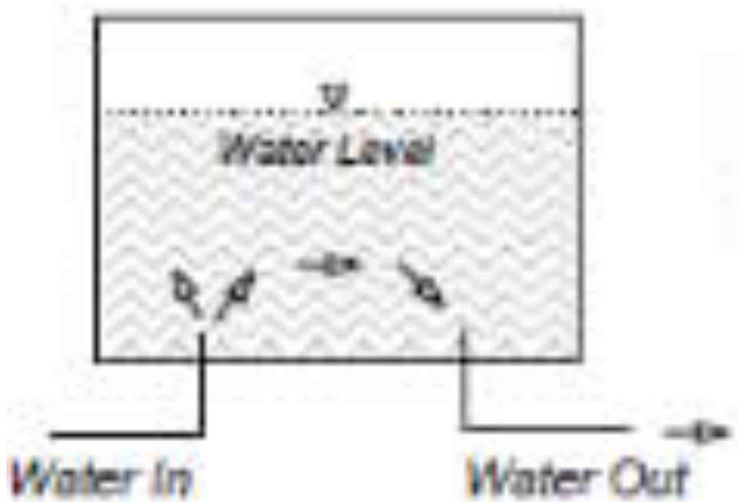
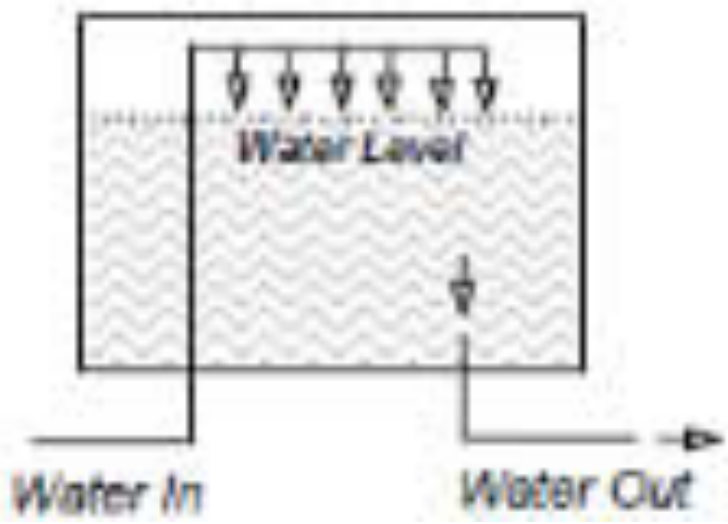
What is the Short-Circuiting Factor?



Poor
5-10% SCF

What is the Short-Circuiting Factor?



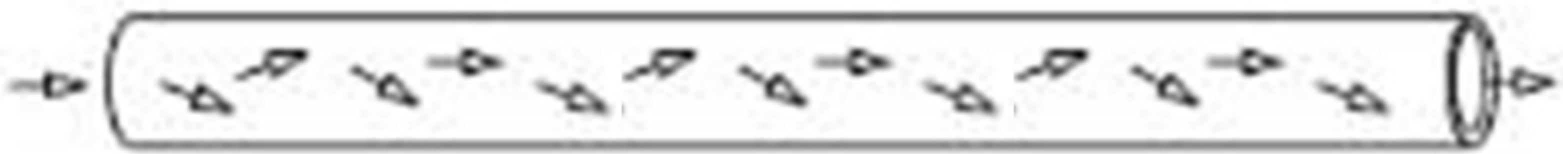
Good
20-30% SCF

What is the Short-Circuiting Factor?

Superior
50-70% SCF

What is the Short-Circuiting Factor?

Perfect
100% SCF



What is the Short-Circuiting Factor?

0% 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 6mo.)
- 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

• where 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
- 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?