UV Technology Overview

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- Disinfection History
- Disinfection Techniques
- The UV Process
- UV Dose
- Various Types of Microorganisms
- Drinking Water Regulations
- Advantages of UV Disinfection
- Water Quality Effects
- Installation Tips
- UV System Design

Disinfection History

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- After the turn of the century, chlorine started to be used as a disinfectant in water supplies to combat the 3 most common water borne bacterial diseases
  - Typhoid Fever
  - Asiatic cholera
  - Bacillary dysentary
- UV disinfection was first applied in early 1900's for disinfection of industrial process waters
- By mid 1980's UV became the BAT for wastewater
- By the 1990's the USEPA begin to consider UV disinfection as a primary disinfectant for municipal drinking water
- Late 1990's UV was considered BAT for both Cryptosporidium & Giardia

2003 UV disinfection was written into both USEPA drinking water regulations & Health Canada guidelines

Disinfection Techniques

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- There are two types of disinfection, physical & chemical
- Chemical disinfection is when a chemical agent must be added to the water for disinfection and the water undergoes chemical changes (ie. Chlorine, iodine, ozone)
- Physical disinfection is a physical means of inactivating or removing bacteria (ie boiling, filtration, UV light)
- UV disinfection does not change the water – it smells the same, it tastes the same, the pH has not changed – it's only target is the bacteria
- It is important to remember the definition of disinfection:

  To cleanse so as to destroy or prevent the growth of disease carrying microorganisms

Disinfection Techniques

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SANITIZATION

defined as a 2-log reduction or 50 - 99% reduction

DISINFECTION

defined as a 4-log reduction or 99.99% reduction

STERILIZATION

defined as a 6-log reduction or 99.9999% reduction

REDUCTION LEVELS:

3 log = 1 in 1,000
4 log = 1 in 10,000
6 log = 1 in 1,000,000

UV Process

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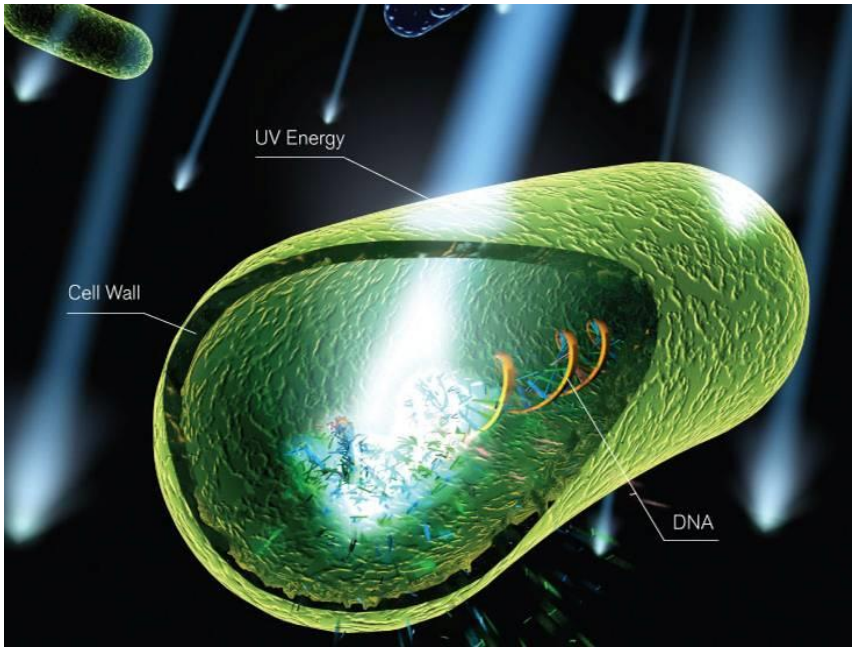
- The UV treatment process is an extremely rapid physical process, that causes a molecular rearrangement of the genetic material, known as the DNA, of the microorganism
- **DNA** is the main constituent of all chromosomes of all organisms, known as deoxyribonucleic acid, and is self replicating
- This blocks the microorganism's ability to replicate itself, and consequently its ability to breed colonies
- Due to individual cell makeup, different microorganisms require different levels of UV energy for their destruction
- This energy level is known as dosage



UV Process

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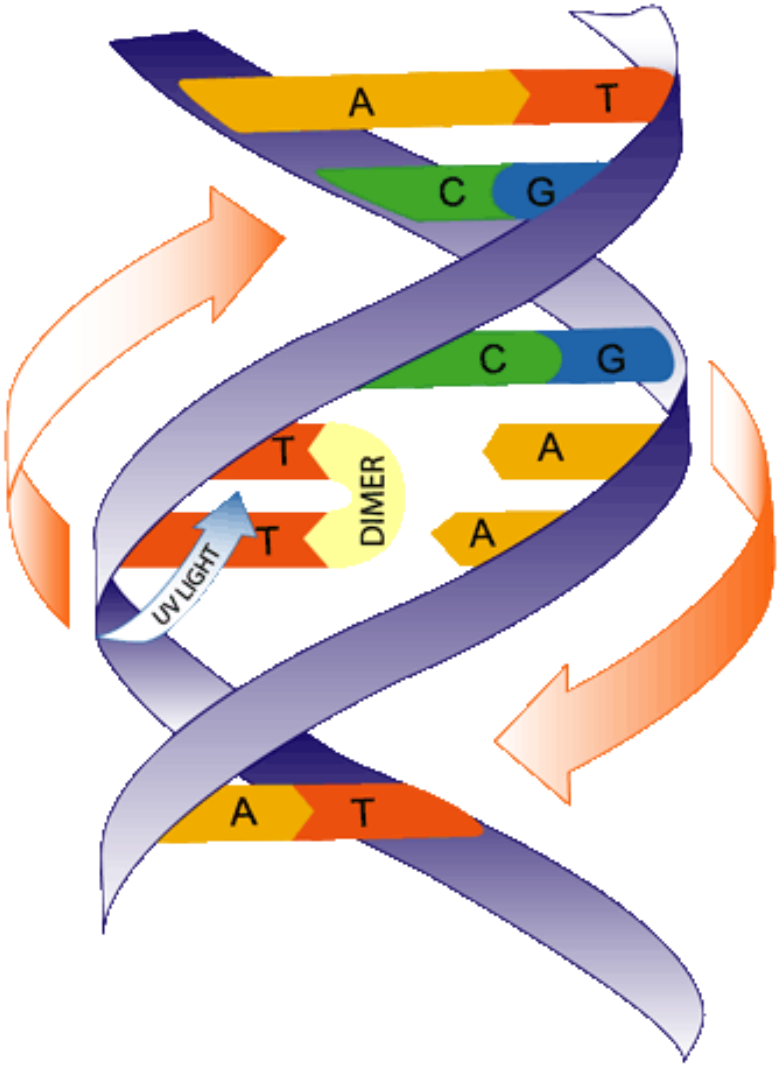

UV Process

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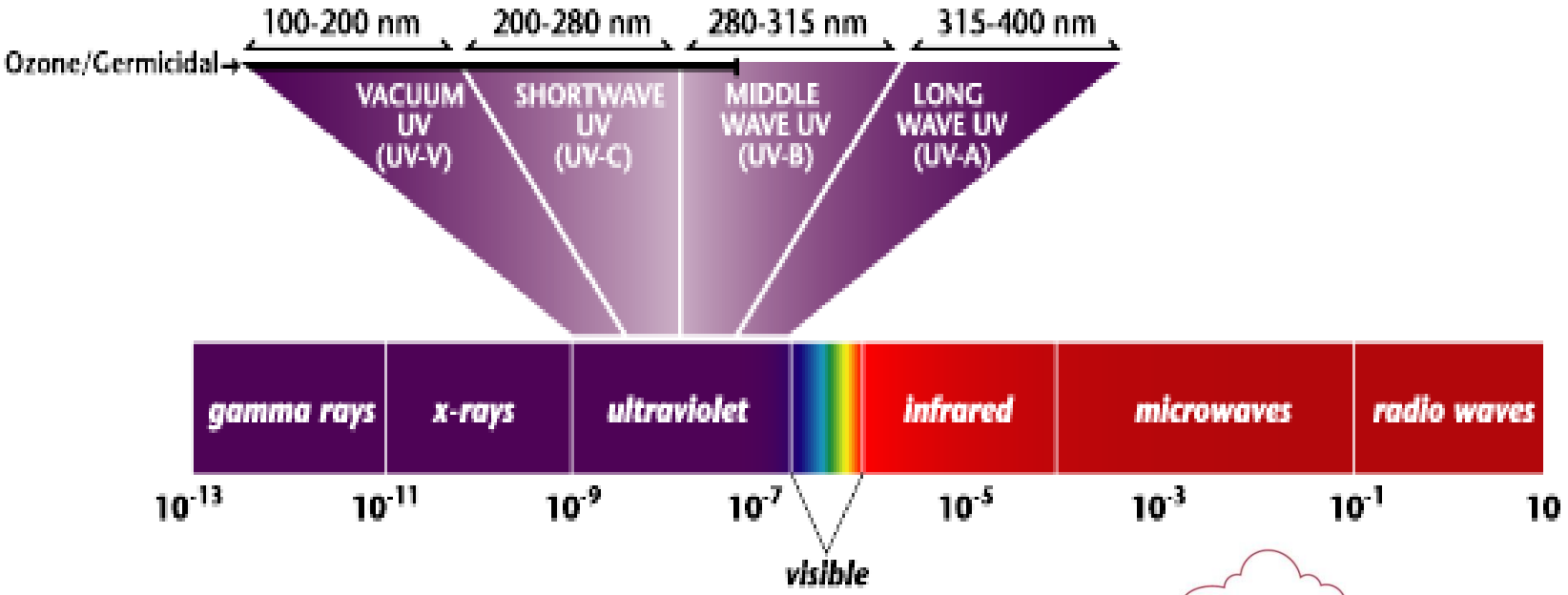
ELECTROMAGNETIC SPECTRUM:



UV Process

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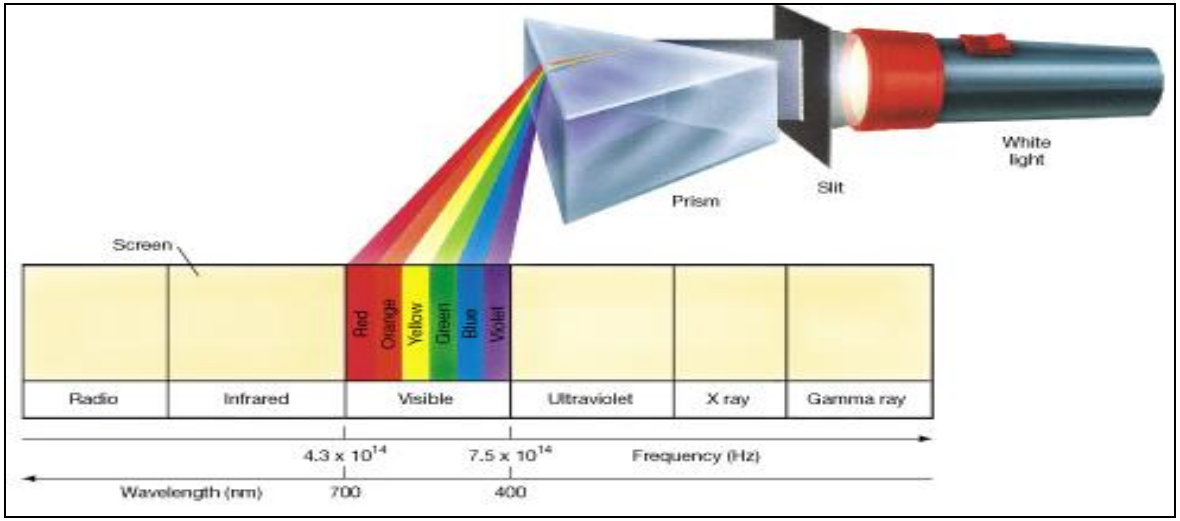
WAVELENGTHS OF LIGHT:



- UVC light is not visible light; therefore you cannot see UVC light with the naked eye (254 nm)
- Exposing skin &/or eyes to UVC light can cause damage
- UV lamps will glow a nice blue-violet color for much longer than the recommended life of the lamp but THIS DOES NOT MEAN that lamp is still giving off UVC germicidal light

UV Dose

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- UV Dose is the product of UV light intensity and time

Dose is sometimes referred to as fluence

DOSE = INTENSITY x TIME
= millijoules/(sec)(cm^2) x time
= mJ/cm^2

NOTE: 10 J/m^2 = 1,000 microWsec/cm^2 = 1 mJ/cm^2

UV Dose

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What Dose is Required?

30 mJ/cm^2	Industry Standard
40 mJ/cm^2	NSF 55 Class A Requirement

Is a Specific Dose Required?

- The drinking water regulations layout the disinfection requirements in log reductions of specific pathogenic microorganisms
- Some regulators and environmental consultants are more familiar with UV dose levels or feel more comfortable specifying a more conservative approach to disinfection but this is not required by the regulations in either Canada or the US

UV Dose

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Microorganism Destruction Chart:

PATHOGENIC BACTERIA (to achieve 4-log inactivation)	
Cholera	6.5 mJ/cm^2 (6,500 microWs/cm^2)
Dysentary	4.2 mJ/cm^2 (4,200 microWs/cm^2)
E. coli	6.6 mJ/cm^2 (6,600 microWs/cm^2)
Legionella	3.8 mJ/cm^2 (3,800 microWs/cm^2)
Salmonella	10 mJ/cm^2 (10,000 microWs/cm^2)

PATHOGENIC VIRUSES (to achieve 4-log inactivation)	
Poliovirus	7 mJ/cm^2 (7,000 microWs/cm^2)
Hepatitis A	8 mJ/cm^2 (8,000 microWs/cm^2)

PROTOZOAN CYSTS (to achieve 4-log inactivation)	
Giardia lamblia	10 mJ/cm^2 (10,000 microWs/cm^2)
Cryptosporidium	<10 mJ/cm^2 (<10,000 microWs/cm^2)

Microorganisms

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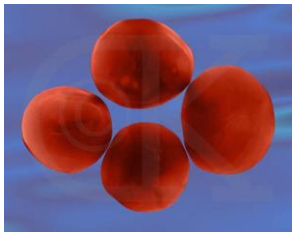
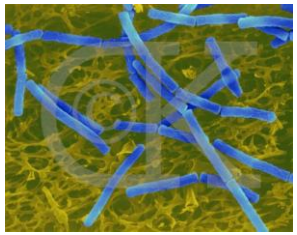
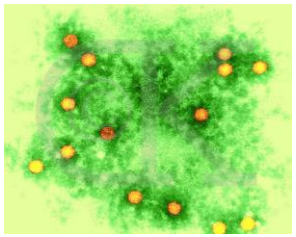


Cryptosporidium

cyanobacteria

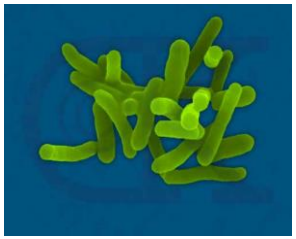


bacillus



Polio

E. coli



Shigella

Microorganisms

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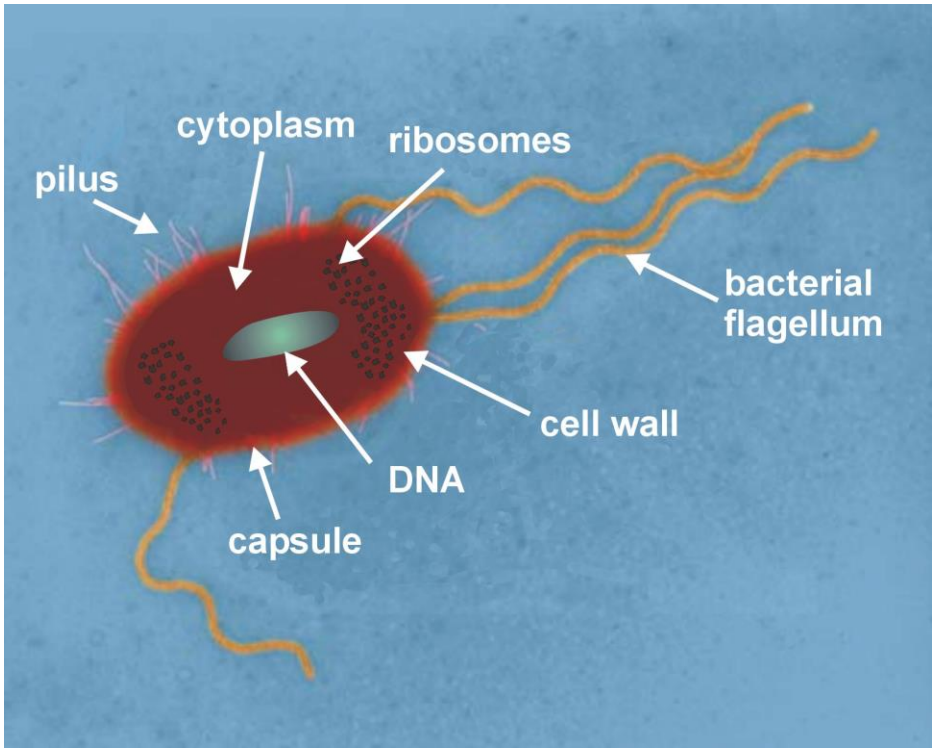
BACTERIA STRUCTURE:



Microorganisms

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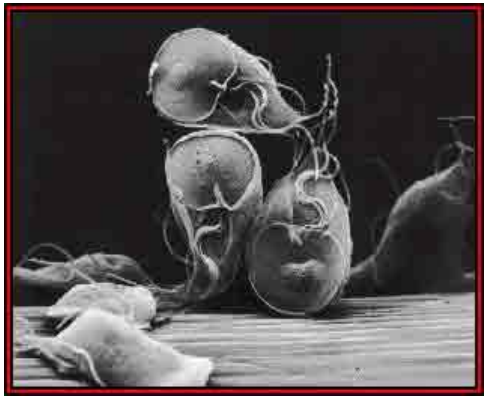
Protozoan Cysts:

- Both Cryptosporidium & Giardia are very sensitive to UV
- UV has been deemed the BAT for inactivation of these cysts
- When UV was first proposed for Crypto & Giardia research showed that UV was ineffective against both cysts
- However original excystation tests merely determined the response to external stimuli & not the ability to cause an infection in a susceptible host
- New tests used live animal infectivity tests to prove new findings

Cryptosporidium parvum
Dose required for 4-log inactivation: < 10 mJ/cm^2



Giardia lamblia
Dose required for 4-log inactivation: 6-10 mJ/cm^2

Microorganisms

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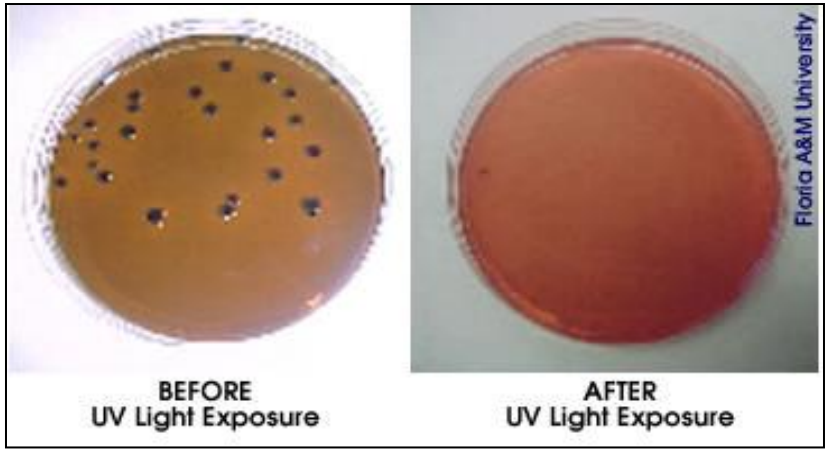
Effects of UV on Microorganisms:



Once microorganisms are exposed to UV light they are rendered ‘inactive’ and can no longer replicate – meaning they can no longer produce colonies

In the above picture on the left an agar plate is smeared with an untreated water sample, incubated & analyzed for colony growth

The agar plate on the right has been smeared with a water sample that has been exposed to UV treatment – no colony growth occurred

following incubation

Microorganisms

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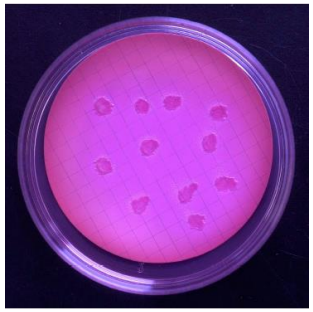
Microbiological Analyses:

1. Sample Collection

2. Plating of sample using membrane filter technique

3. Membrane filter is removed from apparatus & placed on agar plate for incubation



4. Total coliform growth following incubation period

Drinking Water Regulations

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- UV disinfection is accepted by the Canada Health drinking water guidelines as well as the USEPA drinking water regulations (as of 2003) however the equipment must have proof of performance (ie NSF 55)
- Private homes do not fall under either of the regulations/guidelines therefore do not require validated systems

Specific markets that do require validated UV equipment are ones that serve water to the public

- Schools
- Hospitals
- Apartment complexes
- Churches

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Advantages of UV Disinfection

- No need to handle dangerous toxic or corrosive chemicals
- No chemicals being added to the water
- Cost effective
- Simple maintenance
- No moving parts to wear out or break
- Immediate disinfection
- Proven & trusted

Water Quality Effects

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- A common misconception is the following ‘I have bacteria so I’ll install a UV system and my problem is resolved’ – not true
- Water quality is the most important aspect when considering a UV disinfection system
- UV can only be effective if it is absorbed by it’s target, the microorganism
- The main concerns are:

  Hardness

  Iron

  Tannins

  Turbidity

Water Quality Effects

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UV APPLICATION GUIDELINES:

- Iron: < 0.3 ppm (0.3 mg/L)
- Manganese: < 0.05 ppm (0.05 mg/L)
- Turbidity: < 1 NTU
- Hardness: < 7 gpg (120 mg/L)
- Tannins: < 0.1 ppm (0.1 mg/L)
- UV Transmittance: > 75% (call factory for applications where UVT < 75%)

Water Quality Effects

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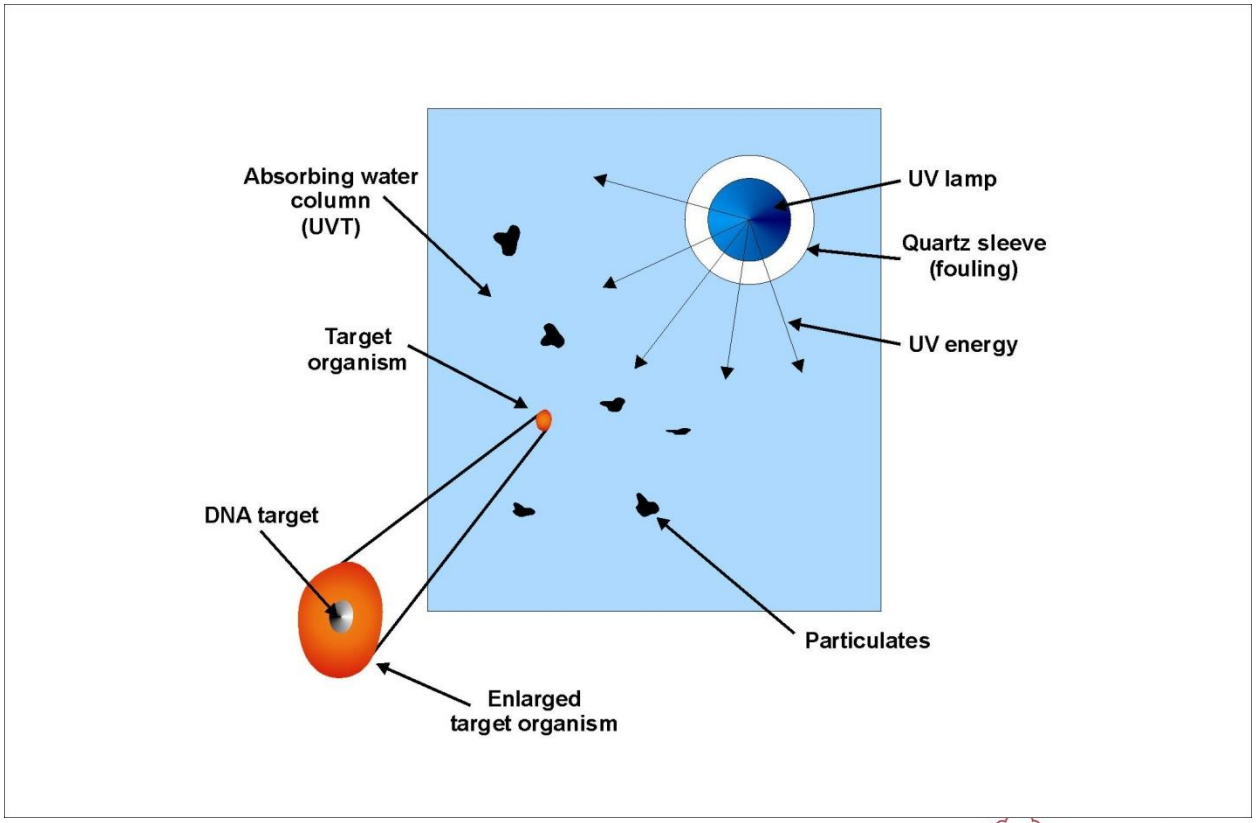
FATE OF UV LIGHT IN WATER:



Installation Tips

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- Never undersize a UV system
- Install UV as the last piece of treatment equipment
- Test water first (UVT as well as other recommended parameters)
- Shock system & check for for ‘dead spots’
- Install system vertically with connector at top of reactor or horizontally with ports pointing up

Shocking the lines:

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- Upon installation of the POE system the water lines must be disinfected using chlorine
- The first step is to ensure that the UV system is ON
- Add household bleach to one of the filter sumps (after removing the filter cartridge) and turn the water ON
- Ensure that chlorine can be detected (by smell) at each faucet in order to ensure that ll lines are being exposed to the chlorine
- Leave sit for approximately 30 minutes & then flush all chlorine out of the water lines until it can no longer be detected

Example of a POE Installation

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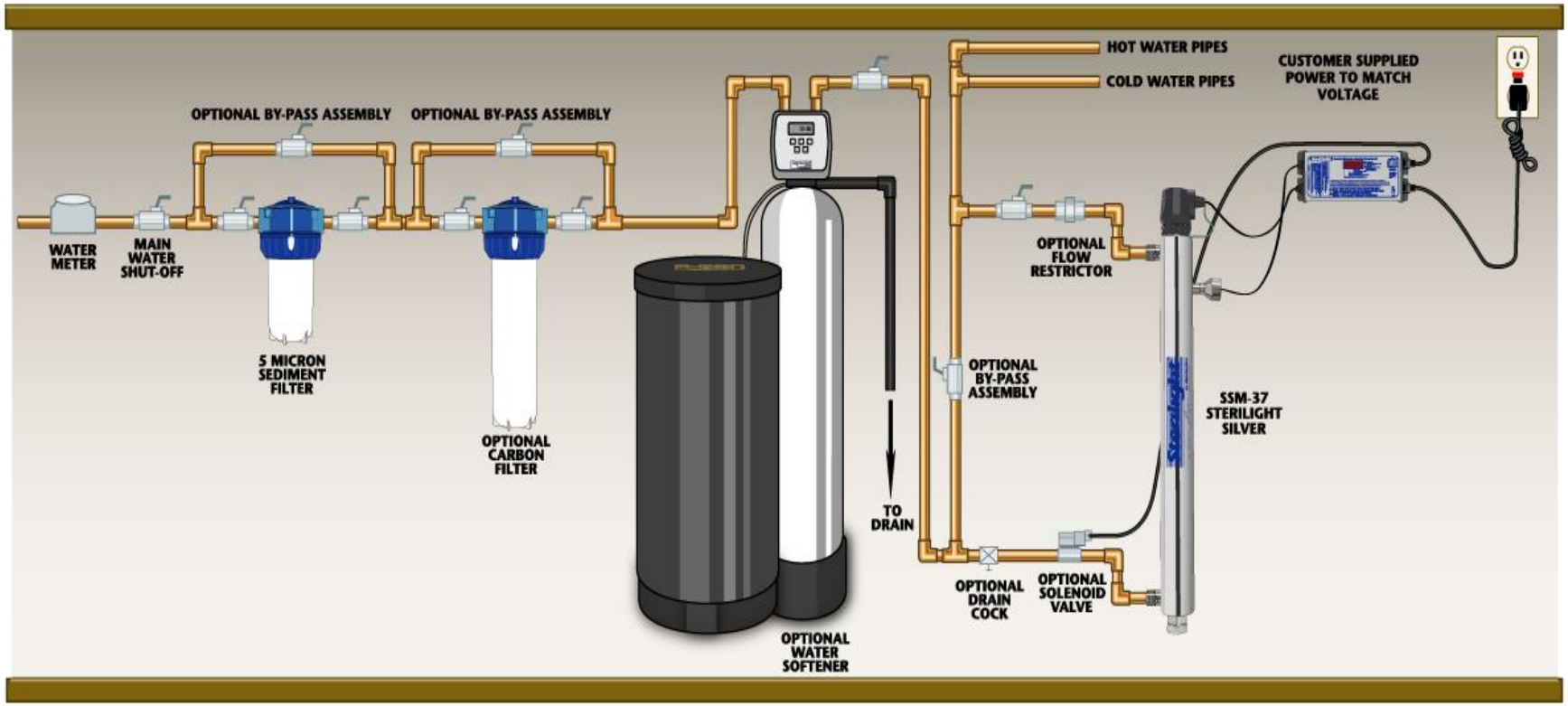

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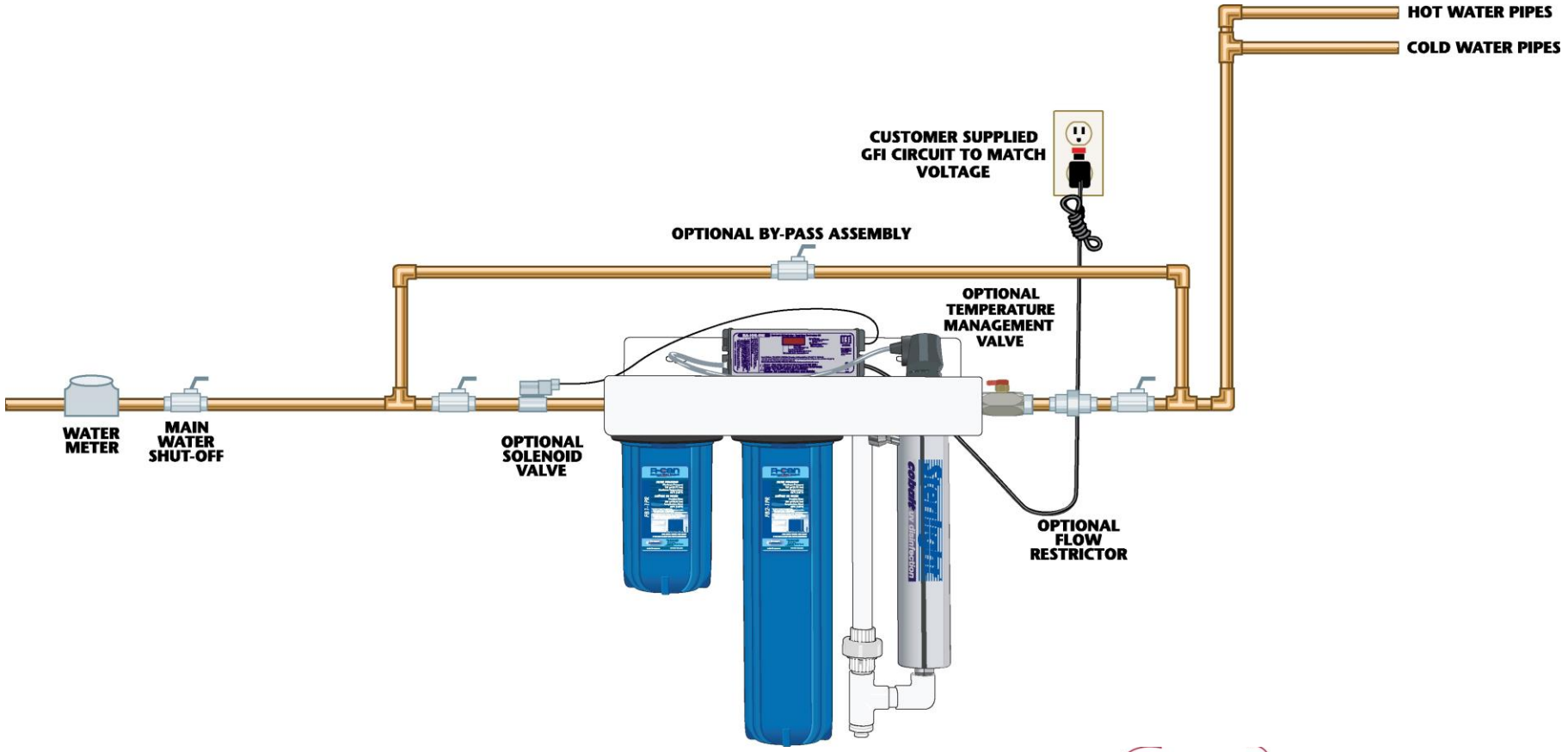

UV Design

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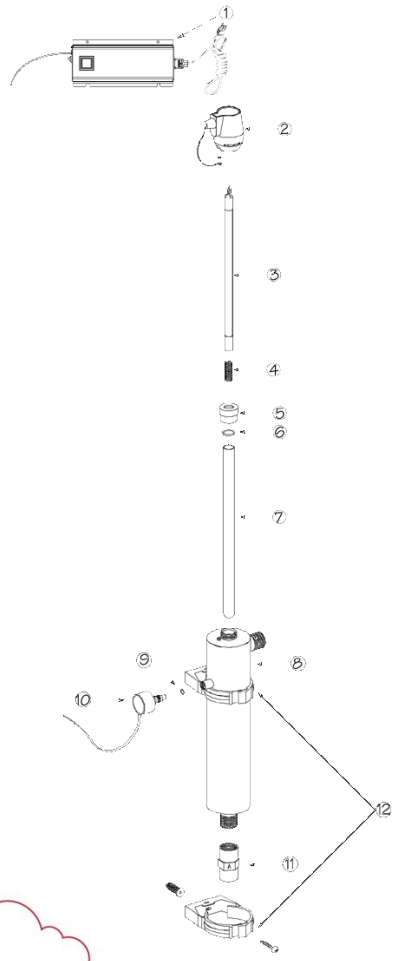
What makes up a UV system?

- Reactor chamber
- UV lamp
- Quartz sleeve
- Ballast
- Optional components include the following:
  - •UV sensor
  - •Solenoid valve
  - •Flow restrictor



UV Design

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UV Reactor:

- Physically houses UV lamps & sleeves
- Constructed from stainless steel (depending on the model will determine whether it is 304 SS or 316 SS)
- Different types of reactors are available (axial or boot shape)
- Variety of port sizes for different models & flow rates

UV Design

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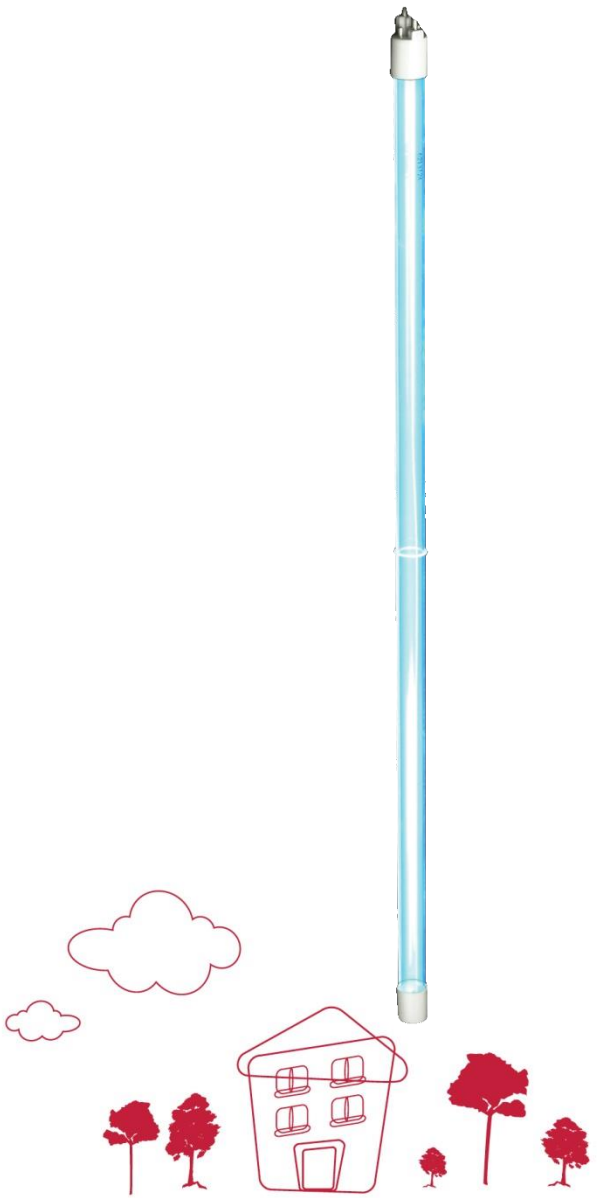
UV Lamp:

- UV lamps provide the energy required for disinfection
- Typical residential UV lamps are low pressure mercury vapour lamps
- Different types of UV lamps are available depending on the model of system
- It is imperative that lamp has the correct power source (ballast)
- Typical life of lamp is one year (9000 hours)
- Not all lamps operate the same even though they physically look the same * VERY IMPORTANT TO REMEMBER
- Never look directly at a UV lamp!!



UV Design

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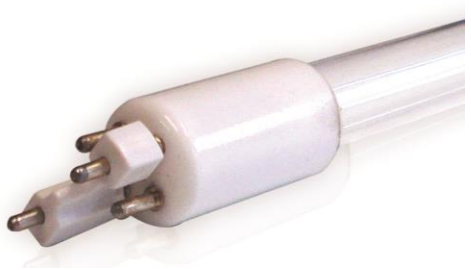
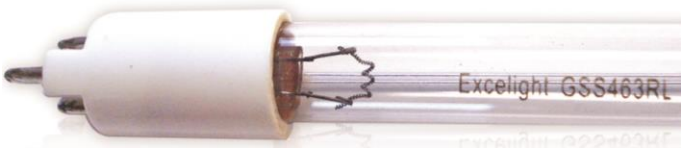
Knock Off Lamps:

- Be very cautious when approached about ‘cheaper’ lamps that will ‘fit’ in your system
- These are most likely ‘knock-off’ lamps & can cause major problems with your UV system
    - False lamp ON indication
    - Poor wiring of lamp has the potential to cause a fire
    - Voids any electrical certification of UV system





UV Design

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Quartz Sleeve:

- Quartz sleeves provide thermal protection for the lamp
- Constructed from 100% fused silica
- Quartz is used due to its high transmittance rate
- Quartz sleeves can be either open or domed, depending on the reactor design

UV Design

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Ballast:

- Provides power to drive UV lamps
- Needs to supply constant output current to lamps
- Protects system from electrical transients
- Visually & audibly displays faults & system status
- Requires electrical certification from recognized third party (ie. CSA)