

# **Bridging the GAPS: Approaches for Treating Water On-Farm**

## Implementing Agricultural Water Treatments on the Farm

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# Bridging the GAPs: Approaches for Treating Irrigation Water On-Farm

The goal of this series of modules on water treatment is to equip growers with the knowledge to successfully implement water treatment systems on their farms. Fruit and vegetable growers are continually assessing their operations to determine where they can limit risk and increase productivity. As a result, many have expressed interest in learning more about how on-farm preharvest water treatment systems work and how they may fit within their current setup.



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These four modules help growers to: 1) understand the background for water treatment; 2) learn about different approaches to treating water on-farm; 3) how to implement these systems to meet requirements of the Produce Safety Rule; and 4) how to verify that the system is operating as intended.

W 920-A, Agricultural Water Treatment and FSMA

W 920-B, Agricultural Water Treatment Tools

W 920-C, Developing On-farm Agricultural Water Treatment Programs

W 920-D, Implementing Agricultural Water Treatments on the Farm





# **Implementing Agricultural Water Treatments on the Farm**

## **Module 4**



## Learning Objectives

1. Assess if a system is working properly based upon monitoring data
2. Recommend appropriate corrective actions based upon a given scenario

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In this module, we will focus on both system evaluation as well as troubleshooting if problems arise. We will cover basic components, methods for monitoring chemical as well as UV light treatment systems and approaches for correcting issues as they arise.



# Components of Water Treatment Systems



## Components of an Agricultural Water Treatment System

### Calcium Hypochlorite Chlorinator

- 68% calcium hypochlorite
  - Tablet
  - Hypochlorous acid active ingredient
- Similar to pool chlorination
- Assure that tablets are compatible with chlorinator system
  - Various sizes



Image: Faith Critzer

The first system we will discuss is the tablet chlorinator system.

This system utilized calcium hypochlorite tablets that come in many dimensions. Each manufacturer will specify the types of tablets which their systems are optimized to use.

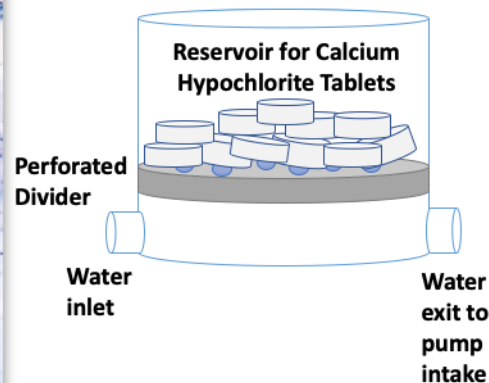
The active antimicrobial compound produced in these systems is hypochlorous acid, which was discussed in module 2.

This is a similar type of system utilized for pool chlorination.



## Components of an Agricultural Water Treatment System

### Calcium Hypochlorite Chlorinator



- System size based upon flow rates
- Small amount of water flow diverts through the system delivering concentrated dose of hypochlorous acid to the intake side of the pump
- Configurations with pump also available

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A tablet chlorination system should be sized based upon flow rates (gallons per minute) a farm would expect to use. If higher flow rates are used for special circumstances, such as frost protection, this should be considered when sizing units.

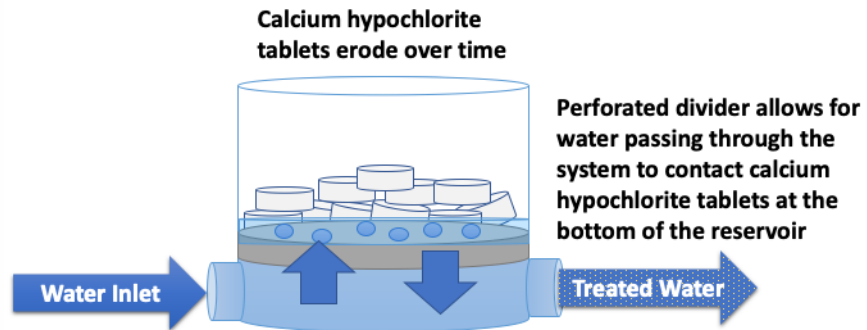
In these systems, a portion of the water being pulled out for irrigation or other field applications is diverted to the chlorination system. The flow into the system will be monitored with a flow meter.

These systems can be installed using gravity to feed a stream of hypochlorous acid back into the intake of the pump efficiently chlorinating the system. In systems where this setup is not possible, a skid with a pump will be necessary to inject the treated water. In these systems a reservoir at the base of the unit will hold the concentrated hypochlorous acid solution.



# Components of an Agricultural Water Treatment System

## Calcium Hypochlorite Chlorinator



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As water flows into the system, it comes up through a perforated divider, many times referred to as a sieve plate, where it will contact the bottom layer of tablets. Water will then flow out where it rejoins the primary line carrying with it hypochlorous acid.





## Components of an Agricultural Water Treatment System

### Liquid Hypochlorite or Peroxyacetic Acid Injection

- Any liquid that is recognized by EPA as a registered pesticide product can be injected
- Most common targets will be sodium hypochlorite or peroxyacetic acid, therefore, we have focused on them
- Other targets
  - Chlorine dioxide, hydrogen peroxide

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As with any EPA registered pesticide products, the label is the law, so make sure that any products you are injecting have a label for treating agricultural water in the field.



# Components of an Agricultural Water Treatment System

## Liquid Hypochlorite or Peroxyacetic Acid Injection

- **Delivery Systems**
  - Water (hydraulic) powered
    - Venturi
    - Positive displacement piston
  - Electric powered
    - Metering pump
      - Diaphragm pump
      - Peristaltic pump

We will discuss each of these systems in greater detail in the coming slides.



## Components of an Agricultural Water Treatment System

### Liquid Hypochlorite or Peroxyacetic Acid Injection

- Venturi System
  - System differential creates a vacuum
  - Vacuum draws chemical into water flow
  - Flow rates dictate injection
    - Injectors will be sized for minimum and maximum gallons per minute (GPM)
    - With fluctuations in pressure, you will have variation in injection rates

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Venturi systems are nice because they do not require electricity to inject a liquid. Within fruit and vegetable production, they are most commonly used for fertilizer injection.

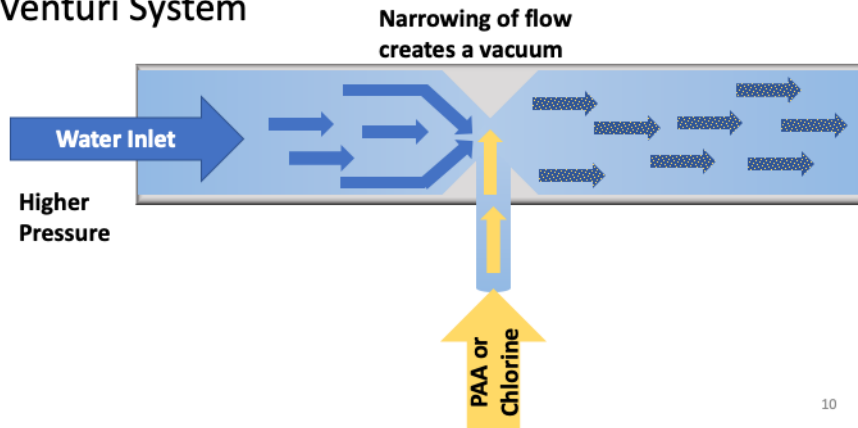
Venturi systems work by narrowing the the flow of water just prior to the injection point, this negative pressure will draw a compound into the water stream. Inevitably, these systems can have greater variation when evaluating the injected compound compared to systems which are driven by electric pumps. This is due to fluctuations in pressure at the inlet and outlet sides of the system (shown further in the next slide). Regulators can be used to help compensate for some of these fluctuations.



# Components of an Agricultural Water Treatment System

## Liquid Hypochlorite or Peroxyacetic Acid Injection

- Venturi System



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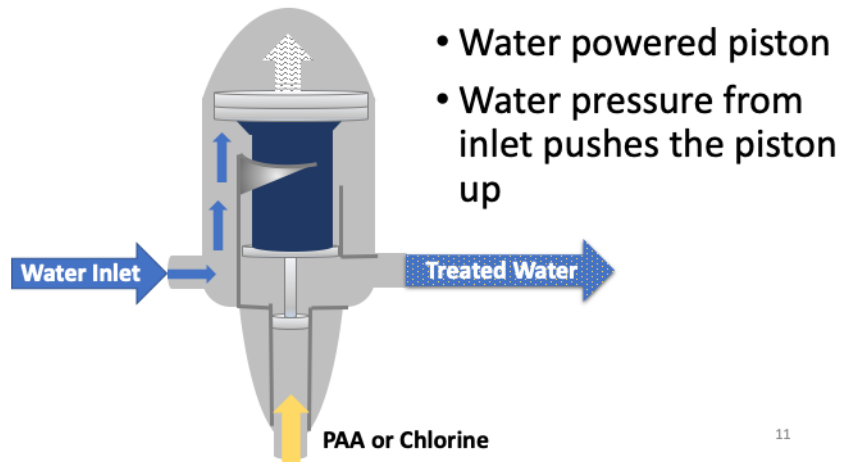
This diagram shows the basic principle of the Venturi system and the means by which a compound will be incorporated on the outlet side. To reiterate, you have narrowing of the flow, which creates a vacuum allowing for incorporation of your injected compound (shown in yellow) through formed suction.

The pressure on the inlet side will be higher than that of the outlet side. The larger the pressure differential, measured in PSI. To learn more about these types of systems you can refer to this webinar produced by Mazzei®, which is a commercial manufacturer of Venturi style injectors:  
<https://www.youtube.com/watch?v=GECrGkLEffo>.



# Components of an Agricultural Water Treatment System

## Liquid Hypochlorite or Peroxyacetic Acid Injection



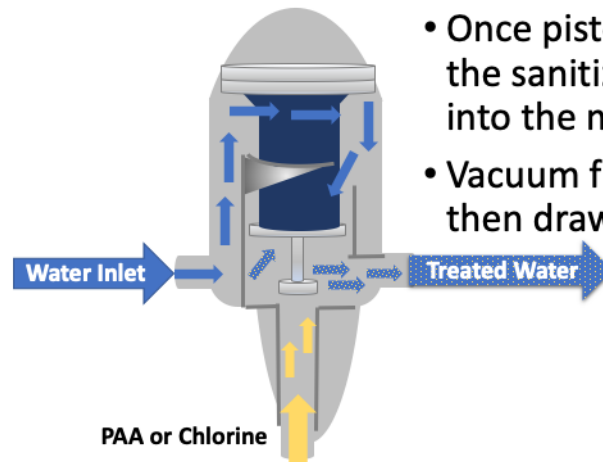
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The next water powered injection system we will discuss will be the water powered piston.

As water flows in under high pressure the piston will be pushed up, eventually opening the valve to the injected compound (shown in yellow)

# Components of an Agricultural Water Treatment System

## Liquid Hypochlorite or Peroxyacetic Acid Injection



- Once piston is displaced, the sanitizer can flow into the mixing chamber
- Vacuum from outlet will then draw piston closed

Once the piston is displaced, the valve will open and allow mixing of your injected compound, as the water exits the system.

# Components of an Agricultural Water Treatment System

## Liquid Hypochlorite or Peroxyacetic Acid Injection



Image: Faith Critzer



- Water powered diaphragm
- Water pressure from inlet triggers hydraulic motor
- On the upstroke, the sanitizer is drawn into the mixing chamber

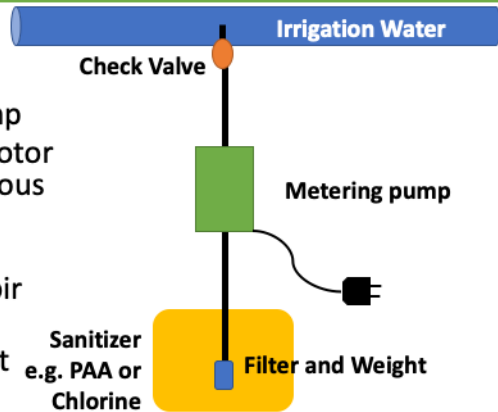
Video from: <http://www.dosatronusa.com/how-it-works/>



# Components of an Agricultural Water Treatment System

## Liquid Hypochlorite or Peroxyacetic Acid Injection

- Displacement-style metering pumps
  - Peristaltic or diaphragm pump
  - Requires electricity to run motor as opposed to water in previous examples
    - 120 V
  - Sanitizer pulled from reservoir
    - Filter and weight
  - Check valve at injection point
    - Prevent siphoning



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We will now transition to electric powered pumps that inject compounds by displacing the compound, thus providing the energy to incorporate it into the system. These systems will inject compounds with less variation compared to the Venturi and hydraulic powered piston that were just discussed, which is important for any chemicals that may be used for ag water treatment as their concentrations are likely to be very low.

We will discuss two basic pump styles, peristaltic and diaphragm pumps, although others may also be appropriate.

These pumps require electricity in order to operate, most will run on 120 volts.

In these systems, once the pump is on and operating, it will physically draw the sanitizer from a reservoir and introduce it into the irrigation line. Typically a filter and weight are installed on the end of the line to assure constant flow as the container empties. As with all connections to an irrigation line, even previously discussed hydraulic pistons or Venturi systems, a check valve will be installed. This valve will only allow flow into the irrigation line. If a check valve was not installed, once the system was turned off, water would siphon into the sanitizer container.





# Components of an Agricultural Water Treatment System

## Liquid Hypochlorite or Peroxyacetic Acid Injection

- Peristaltic pump
  - Motor drives circular rotor assembly
  - Draws sanitizer from reservoir to injection point
  - Variable speeds or fixed speeds
  - Setting based upon percent time pump is operating
    - 50%= 30 seconds on and 30 seconds off

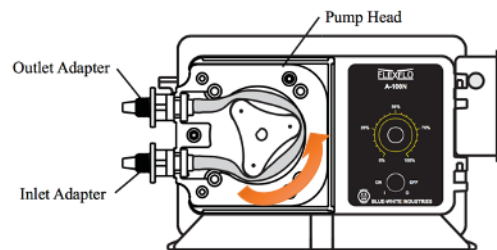


Image: <https://blue-white.com/pumps/peristaltic-pumps/>

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In peristaltic pumps the liquid which is being injected flows through a tube that is compressed by a motor-driven rotor assembly. In this system, the liquid (in our case a sanitizer) being injected doesn't actually come in contact with the components of the pump.

These pumps can be variable speed or fixed speed. A variable speed pump will allow greater flexibility in delivery volumes, but should always be checked to make sure the proper speed is set at startup.

The speeds for a variable speed pump is based upon the percent time the pump is operating. For instance, a 50% setting equates to 30 seconds on and 30 seconds off.

# Components of an Agricultural Water Treatment System

## Liquid Hypochlorite or Peroxyacetic Acid Injection



- Chemical is injected inline

Image: Faith Critzer

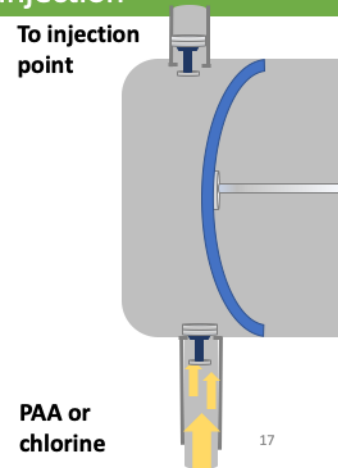
This is an example of a peristaltic pump shown drawing the liquid from the reservoir below and injecting it inline to an irrigation system.

# Components of an Agricultural Water Treatment System

## Liquid Hypochlorite or Peroxyacetic Acid Injection



- Diaphragm pump
  - Motor moves diaphragm
  - Draws sanitizer from reservoir to injection point
  - Variable speeds or fixed speeds



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Diaphragm pumps work through a motor moving a diaphragm that will move back and forth creating a vacuum to draw the liquid from the reservoir below. Similar to peristaltic pumps, these systems also come in fixed and variable speeds.

As shown here the diaphragm has ceased flow of the sanitizer from below causing the valve to block flow through positive pressure created.

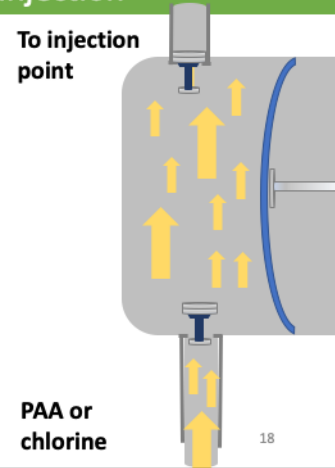
# Components of an Agricultural Water Treatment System

## Liquid Hypochlorite or Peroxyacetic Acid Injection

- Diaphragm pump



Image: Faith Critzer



As the diaphragm begins to move back, the valve is displaced allowing for the compound to flow freely from the reservoir below finishing once cycle of the pump.



## Components of an Agricultural Water Treatment System

### Liquid Hypochlorite or Peroxyacetic Acid Injection

- **Setup considerations**
  - **Makeup of sanitizer**
    - Highly corrosive- materials need to be able to withstand extended exposure
    - Off-gassing - hydrogen peroxide, PAA may cause certain pumps to seize, e.g. diaphragm pumps
  - **Pump location**
    - Positioned next to power supply
    - Protected in a cabinet or housing to maximize working life
      - Limit exposure to rain, wind, dust to the extent possible

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When you are deciding what type of system you should invest in there are several factors that should be considered.

The first is the makeup of the sanitizers. By nature, these compounds tend to be corrosive and the materials that will be handling concentrated sanitizers will need to be built to withstand this corrosivity. There are pumps and tubing that are designed to withstand more corrosive compounds.

Additionally, some compounds such as PAA will have hydrogen peroxide that can evolve during normal use creating a fair amount of gas. In some systems, like the diaphragm pump, this can create pressure and cause the pump to seize. Therefore, when gas is anticipated during normal operation, a peristaltic pump would be preferred.

With these pumps, they must be located near power supplies and it would be preferred to protect them from the elements in order to get the longest life. If it is anticipated that these pumps will be exposed to all or some of the elements, this should be communicated to your supplier.



## Components of an Agricultural Water Treatment System

### Ultraviolet Light

- Any EPA pesticide device can be used that is effective for in-line treatment of agricultural water
- Other devices include
  - Ozone generator
  - Filters
- Ozone generators are similar to UV, in that they will require power
  - Initial equipment investment should be considered
- Filters must be sized so they are small enough to remove microorganisms

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We'll now segue from injection systems to UV lights.

As previously discussed, ultraviolet (UV) lights are considered an EPA pesticide device, which is different from an EPA registered pesticide product (like chlorine or PAA). These systems will not have an EPA approved label, but the device manufacturer will be registered with the EPA.

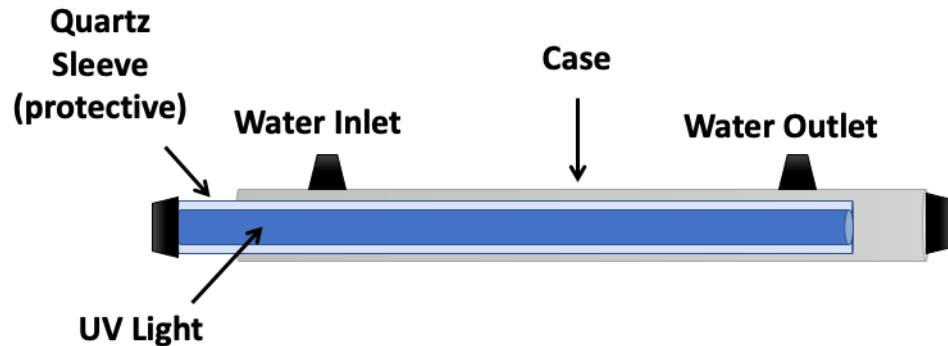
Beyond UV lights, water filters that have pores small enough to catch target organisms such as bacteria and parasites or ozone generators are also considered EPA pesticide devices.

We have elected to focus on UV lights as they have the greatest promise of treating agricultural water that commonly has sediment which would easily clog many filters. Ozone generators has been shown to have efficacy in treating agricultural water, but are much more expensive than UV systems and therefore, not as practical unless treating large quantities of water.



## Components of an Agricultural Water Treatment System

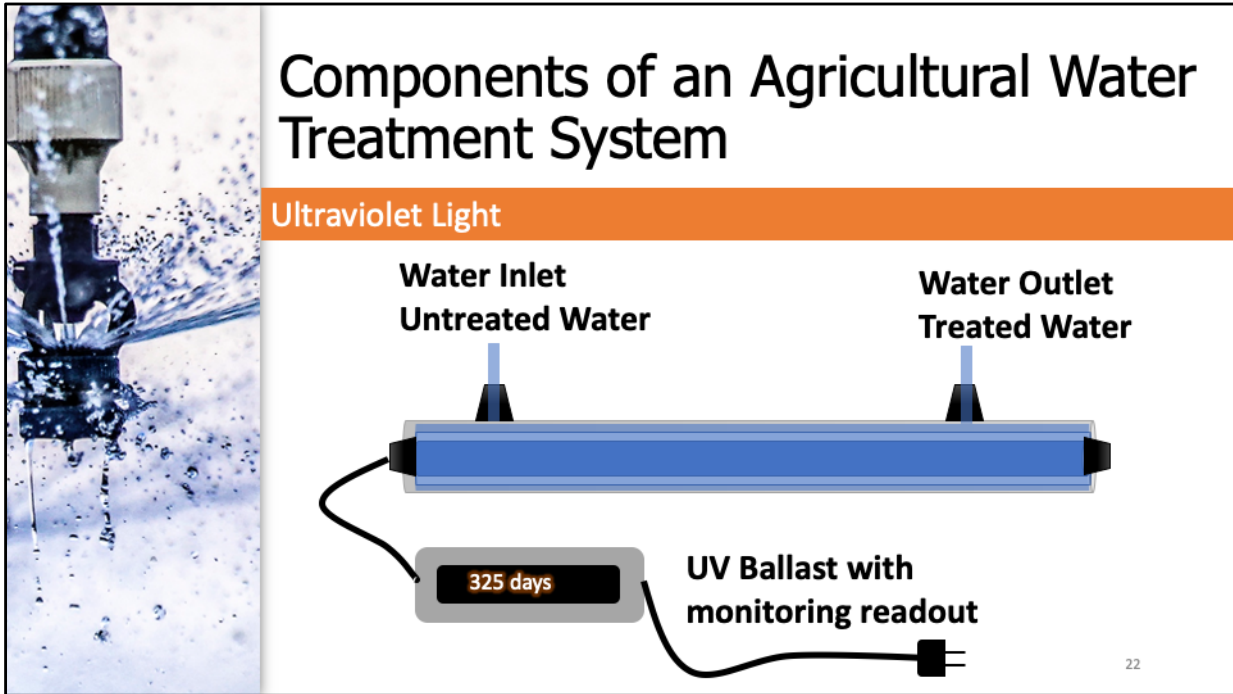
### Ultraviolet Light



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The basic components of a UV water treatment system are shown here. They are:

- 1) Outer case that will keep UV light from escaping the unit- most UV lights have a stainless steel case.
- 2) Inside the case is the UV light. This light will generate UV light in the correct wavelength to inactivate microorganisms.
- 3) The UV light will have a protective quartz glass that will keep the light from getting dirty. This glass should be regularly cleaned as algae can grow and sediment attach, decreasing the penetration of the UV light to the water you are treating. The UV light and quartz glass can be unscrewed from the unit and be removed as shown here.
- 4) There will also be a water inlet and water outlet. It is imperative that you understand if your unit has a mandated orientation (vertical or horizontal) that should be adhered to when installing.



In these systems the inlet will be connected so that all the water moving through the system will come through. For higher flow rates multiple systems are joined together for greater throughput. The pump that the system is hooked up to will drive the flow of water through this system.

One end will be connected to a UV ballast that will provide power to the system. Increasingly, these systems will also display the number of days the unit has been in operation to give you an idea of bulb life. The bulb manufacturer will tell you what the expected life of your bulb is. Most are rated for approximately 10,000 hours, which is slightly longer than one year.





## Components of an Agricultural Water Treatment System

### Ultraviolet Light

- Systems can be designed to meet your requirements
  - Sensors for monitoring treatment
    - % UV transmittance through the water
    - Alarm sounds if drops below 50%
    - Solenoid to stop water flow
    - Recorder to document delivery of treatment (not common)
  - Self-cleaning systems

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Sensors should be installed within UV water treatment systems. These sensors will increase the cost of the unit, but they are the only means to monitor UV transmittance and the efficacy of the treatment.

The sensor is designed to measure the UV light which is passing through the water, the system has been designed by the manufacturer to sound an alarm if the %UV transmittance falls below 50%, in which case the target microbial inactivation will not be achieved. These alarm systems can also be installed with a solenoid to stop the system if this occurs as well as a recorder to document %UV transmittance during treatment.

Another additional cost will be associated with self-cleaning systems (as opposed to manual cleaning). These systems wipe the quartz glass sleeve to assure it remains clear for optimal water treatment.



## Components of an Agricultural Water Treatment System

### Ultraviolet Light

- Sensor with % transmittance is recommended
- This will allow you to monitor and record the treatment
- This will help account for variations in turbidity which may impact activity

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It is imperative that a system be purchased with the UV sensor to monitor transmittance. This is because UV transmittance will vary along with incoming water quality. If the capacity of the system is surpassed, target microbial inactivation will not be achieved. There are many uses for UV water treatment. When selecting a supplier, target one which has experience treating agricultural water as opposed to potable water.

	<b>Chemical Injection</b>	<b>Treatment with a Pesticide Device</b>
<b>Antimicrobial Activity</b>	Downstream activity past the point of injection <ul style="list-style-type: none"> <li>• Helps control biofilm formation in irrigation delivery systems</li> </ul>	UV light or filter- no downstream activity <ul style="list-style-type: none"> <li>• Only inactivating microorganisms at the point of treatment</li> </ul> Ozonation- downstream activity
<b>EPA Approval</b>	Must be EPA labeled for treating agricultural water <ul style="list-style-type: none"> <li>• Will need supporting scientific studies that validate the activity of the system as you intend to operate it</li> </ul>	No EPA approval needed <ul style="list-style-type: none"> <li>• Will need supporting scientific studies that validate the activity of the system as you intend to operate it</li> </ul>
<b>Implementation</b>	Must demonstrate agricultural water is of adequate sanitary quality <ul style="list-style-type: none"> <li>• Monitoring</li> <li>• Corrective actions</li> </ul>	Must demonstrate agricultural water is of adequate sanitary quality <ul style="list-style-type: none"> <li>• Monitoring</li> <li>• Corrective actions</li> </ul>
<b>Interaction with Other Compounds</b>	Most will oxidize organic and inorganic materials <ul style="list-style-type: none"> <li>• Fertilizers</li> <li>• Pesticides</li> <li>• Herbicides</li> </ul>	UV light and ozone will interact with <ul style="list-style-type: none"> <li>• Fertilizers</li> <li>• Pesticides</li> <li>• Herbicides</li> </ul> Filters should not influence these compounds

This chart is a nice summary of material we have covered and compares various aspects of chemical injection vs. treatment with pesticide devices.



## Multi-hurdle Approach May Work Best

- By injecting a chemical at startup and the end of irrigation, you can sanitize the line to keep likelihood of biofilm formation down
- Treat all water with UV light or filter
  - Inject fertilizer or incorporate foliar sprays post treatment
- All water receives a uniform treatment
- But this will result in more systems to install and monitor

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For some operations a combination of water treatments may work the best given cost associated with certain pesticide products, water volume, and their interaction with fertilizers, pesticides, and herbicides. Additionally pesticide devices without downstream activity may allow for growth of microorganisms within the irrigation system.

One example is applying a pesticide product at startup and shutdown with all water receiving a UV light treatment.

This of course will result in increased startup costs and complexity connected to operation and monitoring.



## Monitoring Requirements- Produce Safety Rule

- Monitoring
  - *You must monitor any treatment of agricultural water at a frequency adequate to ensure that the treated water is consistently safe and of adequate sanitary quality for its intended use and/or consistently meets the relevant microbial quality § 112.43*



## Monitoring Chemical Injection

- Any chemical should be monitored to assure proper use rates
  - Too little indicates less compound being injected
    - Potential for untreated water
  - Too much indicates over treatment
    - May be over maximum concentration indicated on product label
- Verify settings for any injection system
  - Variable speed adds flexibility, but can be easily changed resulting in insufficient treatment
- Verify pumps are on and operating
  - Liquids that can form gas (hydrogen peroxide, chlorine) can create a lock or seize the pump



## Monitoring Calcium Hypochlorite

- Verifying Concentration
  - Titration or test strips
    - Free chlorine
      - **NOT** total chlorine
  - pH
    - Target 6.5-7.5
    - If >7.5 another compound may be better
  - Oxidation Reduction Potential (ORP)
    - Continuous measurement
    - Controller/recorders



Image:  
Faith Critzer





## Monitoring Peroxyacetic Acid

- Verifying concentration
  - Titration solutions
  - Test strips
- ORP not appropriate
  - Specialized sensors for PAA
- Compound specific electrodes

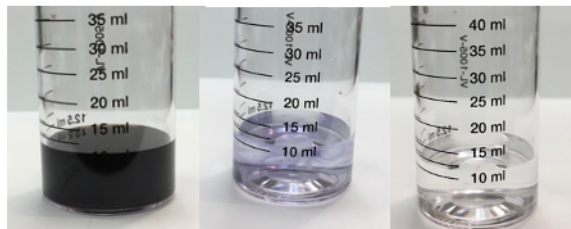


Image: Faith Critzer





## Monitoring UV Light

- Unit is powered on
- Sensor is operating
  - Remove sensor from port to make sure alarm sounds
- Verify UV dose through sensor output reading
- Preventive maintenance
  - Quartz glass should be cleaned on a regular basis due to fouling
    - Algae, soil can buildup, blocking UV light
  - Recommended to replace light after 10,000 hr of use



## Monitoring Frequency

- Each operation will have to determine their approach for monitoring water treatment
- Monitoring should *at least* occur at startup
- Monitoring at other times during treatment would also be recommended, especially if the system has had previous failures in delivery



## Water Testing

- Microbial water testing is recommended to verify the effectiveness of any treatment
  - Demonstrate adequate sanitary quality
- Target: generic *E. coli* and coliforms per 100 ml
- There is no regulatory requirement to test any agricultural water when you treat water in accordance with the requirements of §112.43
  - Do not need to establish a Microbial Water Quality Profile
- Again, water testing at an interval determined by the operation will help verify treatment effectiveness and may still be required by auditing or buyer requirements

## Corrective Actions

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As discussed in the third module, correct the issue that caused non-compliance

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Take a water sample

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Determine what produce has been exposed to water that was not adequately treated

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Conduct an assessment based upon factors such as time until harvest, microbial quality of water when deviation was identified, and determine what to do with crops that came in contact with untreated agricultural water

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Always maintain records documenting all corrective actions



## Summary

- Select the approach that works best for your operation
- Monitoring will be key to demonstrate compliance
- Systems will malfunction, it is imperative that employees are trained in how to respond with corrective actions



# Questions?

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United States Department of Agriculture  
National Institute of Food and Agriculture

This work was supported by Food Safety Outreach  
Program grant no. 2016-70020-25803 from the USDA National  
Institute of Food and Agriculture.



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