Physical and Chemical Control Options of Pathogens in Water Recycling Systems

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OVERVIEW
Water Storage
Debris Removal
Clarification
Disinfection


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Water Storage

Collection Basin Size

~nursery runoff

~greenhouse roofs

~parking lots

~first storm event (required in some regions)

~Follow local guidelines and regulations

Basin Location

~topography - gravity

~space available

~different production sites

Multiple Collection Basins

~backup – when other basins are cleaned. i.e. Slow Sand Filtration Beds


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Debris Removal

Problem:

*Floating debris will clog filters and pipes, and increase water treatment requirements.

*Dirtier water requires more chemicals or treatment to disinfect effectively

Treatment Options:

*Baffle system or filters.


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CLARIFICATION

Problem: suspended solids and dissolved organics reduce efficacy of sanitation processes, clog pipes, clog emitters, stain foliage, etc.

Treatment Options:

*Water retention facilities - sedimentation through time and gravity. - dredging of canals.

*Flocculation- use of ferric sulfate/alum and polymer to flocculate suspended clay (5 minutes).

*Sand/charcoal filters- to filter out remaining particles

Pathogen Control

Treatment Options:

Chemical (oxidizers)

*Chlorination

*Copper Ionization

*Ultraviolet Light

*Ozonation

Physical

*Sand Filtration

*Heat

*Ultrafiltration

Test: Test fresh water for pathogen populations.

City water - no pathogens

Well or surface waters - test.

Treated recycled waters – test.

Install a small pilot system: to ensure system works for your nursery.

Chemical Control
Oxidizing, Agents

(1) Most compounds are stable at an electrical charge of 0

(2) Electrons are only stable as pairs. –

***Oxidant** = chemical that takes electrons away from another chemical. Originally termed 'oxidation' because it was believed that oxygen was the only chemical to do this.

Ability of a specific chemical environment to cause oxidation is measured as 'redox potential' (REDOX) or 'oxidation reduction potential' (ORP). ORP values of 700 mv should provide complete disinfection. = monitored only in ozonation systems

*ORP values less than 300 mv are usually considered safe for most aquatic life.

Chemical Control
Oxidizing Agents

***Free radical** = atom or molecule that has an unpaired electron, but overall 0 charge (it is a particle that is neither positively or negatively charged).

*Even though a free radical has a charge of 0, still needs to have the unpaired electron teamed up with another electron.

*All are oxidants since they have the ability to take electrons from other molecules.

Ozone is <u>not</u> a free radical because all of its electrons are paired together. However, when ozone breaks down during oxidation reactions, oxygen free radicals (O·) and hydroxyl free radicals (HO·) can be produced. – specified to ozonation treatment.

Chemical Control
Antioxidants

***Antioxidant** = any chemical that protects an organism from being oxidized or any chemical that inhibits the ability of oxidants to oxidize.

Blueberries are good for you because they have a lot of antioxidants!

Chlorination

Mode of Action: Oxidizing agent

Effectiveness of Treatment:

1. Chlorine concentration - higher concentrations will disinfect water more quickly. Residual chlorine of <100 ppm (3meq/L).
2. Exposure Duration – effective exposure - 1 minute to 24 hours.
3. Initial Cleanliness of Water – dirty water ties up chlorine.
4. Water pH – more stable at neutral pH.
5. Water Temperature – relatively high (>20C) or low (10C) may reduce effectiveness.

Chlorination

Mode of Action: Oxidation

$Cl_2 + H_2O = HOCl + H^+ + OCl^-$

Chlorine + water = hypochlorous acid + hydrogen + hypochlorite

Methods:

1. Sodium hypochlorite - commercial bleach – 100,000 – 140,000 mg chlroine/L. Most commonly used in industry.
2. Calcium hypochlorite– 350,000 mg chlorine/L. Occasionally used if sodium is a problem in production.
3. Chlorine gas– least expensive of the methods, but dangerous and more regulations.

Chlorination

Disadvantages:

1. Chemicals - high residual chlorine may injure plants.
2. Herbicide and pesticide removal– does not breakdown or remove most pesticides or herbicides.
3. Floating debris removal– debris needs to be removed.
4. Dissolved organic matter – organic matter will bind free chlorine, making it inactive. Coloration due to organic acids not removed with chlorination

Chlorination

Caution:

Pathogen populations and residual chlorine concentrations should be routinely monitored to ensure disinfection is sufficient and residual chlorine concentrations are not too high for plants.

Chlorination

Advantages:

1. Operation costs low- injection required limited energy.
2. Capital costs low– most cost is for chlorine.
3. Exposure time fast– most pathogens killed within seconds to minutes of exposure time.
4. Adaptability – used in small or large production systems.

Copper Ionization

Mode of Action: Oxidizing agent

- Method: Inserting copper-coated ceramic electrodes and pass an electric current through these electrodes, releasing copper ions (Cu^{2+}).
- An essential plant nutrient, which is required at relatively low concentrations (0.002-0.003%) (20-30 ppm plant dry weight). Because of such relatively low requirements, any additional copper that is added to a plant system, either as a pesticide or fertilizer, should be monitored so that copper toxicity is avoided.

Copper Ionization

Advantages

+<u>Operation costs</u> -- Moderate. Electrode replacement ($10,000), electricity.

+<u>Installation costs</u> -- low. installation of electrodes and electrical source.

+<u>Chemicals</u> no additional chemicals are required. Others indicate oxidizers such as chlorine will still be needed, but at lower concentrations.

+<u>Technical components</u> -- few technical components or control systems.

+<u>Maintenance</u> -- low (occasional replacement of copper electrodes.)

+<u>Pathogen removal</u> -- Pathogens such as bacteria and fungi will be killed.

+<u>Chemical effects</u> -- Will not alter pH of water.

+<u>Space</u> -- No additional land for large treatment facilities.

+<u>Algae control</u> -- Will kill algae on water and on coolant pads.

Copper Ionization

Disadvantages

- Toxicity -- Some crops sensitive to Cu (0.5-1.5 ppm). No data is available on Cu accumulation with long-term usage.

-Effectiveness reduced with dirty water – Binds to negatively charged particles of organic matter and clay, making the Cu ions inactive. Greater injection rates will be needed.

-Herbicide and Pesticide removal -- Does not remove other chemicals.

-Floating debris removal -- Does not break down floating debris.

-Dissolved organic matter -- Coloration due to dissolved organic matter and acids is not removed.

-Clay and silt removal -- Clays and other soil particles not removed.

-Cu in closed recycling systems -- If sludge recycled into media, Cu concentrations in sludge could be toxic to some crops.

Ultraviolet Light

Mode of Action: **Oxidizing Agent**

Effectiveness of treatment:

1. Wavelength- 100-400 nanometers.
2. Exposure Duration – effective exposure times range from 1 minute to 24 hours.

UV Sources.

(1) low pressure mercury vapor lamps. emit a wavelength of 254 nm. The use of 'high' pressure mercury lamps may also be used, but they also emit wavelengths of 190 nm, which results in the formation of ozone in the water. This ozone can also sanitize the water to a certain degree.

(2) Xenon flashlamps emit pulses of light that is a higher power source of emission. However, Xenon lamps also emit wavelengths over a larger spectrum, some of which are not UV, making less energy efficient.

(3) Excimer lasers emits pulses of light (248 nm).

Ultraviolet Light

- ***Advantages**

+Operation costs – Low if the water source is already clarified.
+Installation costs – Relatively lower for cleaner water supplies such as those of hydroponic systems.

+Chemicals – No chemicals.

+Technical components -- Few technical components

+Maintenance -- low

+Pathogen extermination -- Pathogens will be killed.

+Chemical effects – No effect on water pH.

+Space – Relatively small space required.

+Algae control -- Will kill algae suspended in the water source.

+Nontoxic to plants – no toxic effect.

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Ultraviolet Light

*Disadvantages

-Chemical effects – Chemically denature chelates that may be used to keep micronutrients such as iron in a soluble form.

-Effectiveness reduced with dirty water – Since UV light must pass through the water column, dissolved or suspended substances, organic acids, clay will reduce efficacy.

-Herbicide and Pesticide removal -- Not removed. May break down light-sensitive herbicides and pesticides. Consult manufacturer for specific chemical questions.

-Dissolved organic matter -- Coloration due to dissolved organic matter and acids is not removed from the water.

-Exposure time –UV light may require an exposure time of 30 seconds or longer, depending on the clarity of the water. Slower flow rates will be required, but lower flow rates will also reduce water turbulence and efficiency of treatment.

Ozonation

Mode of Action: **Oxidizing Agent**

Effectiveness of treatment:

1. Pure oxygen - Provide pure oxygen source through corona discharge or plasma discharge units. Electrically charged oxygen (O_2) form ozone (O_3).
2. Exposure Duration – injection rate of 1 oz per 1,000 gallons of water with an exposure time of 1 hour.
3. Holding Time – treated water should be maintained in a closed pressurized system to prevent off-gassing of the ozone.
4. Ultraviolet light – can be used to increase rate of ozone breakdown, which causes free radical hydroxyl groups (OH). This acts as a better disinfectant. This technique is called ‘Advanced Photoxidation’.

Ozonation

***Advantages**

+No chemical residues – Ozone breaks down to oxygen.

+No additional chemicals

+No chemical storage – since ozone is made on-site

+Easy monitoring – efficacy of system easily monitored by measuring the ORP (redox potential).

+Maintenance –low maintenance unless oxygen source is not clean, then electrodes must be cleaned.

+Pesticide breakdown – many pesticides will be oxidized.

Ozonation

*Disadvantages

+-Lengthy treatment period – May require up to 20 minutes to 1 hour to achieve 100% mortality of pathogens.

-Space allocation – Collection tanks for treated ozone water will be needed so that ozonated water can be stored long enough for effective disinfection.

-High operation cost – for electrical source, much is wasted in heat production.

- Increased water pH – Ozone will increase water pH, so water acidification may be necessary.

-Effectiveness reduced with dirty water – organic matter will react with ozone, decreasing the amount of ozone available to kill pathogens.

-Pathogen resistance – the chlamydospores and microsclerotia of some pathogens are more difficult to kill with ozone.

- Chelates destroyed – May react with the chelates, precipitating the nutrient out of solution.

-Element precipitation – ozone may oxidize and precipitate out of solution some essential nutrients such as iron, even if chelates are not being used.

-Plant toxicity – Toxic to plants, so ozone levels should below toxicity levels before applying to water.

Heat Treatment

Mode of Action: Viruses are killed at temperatures as low as 130F (55C) if that temperature is maintained for a period of 1.5 hours. At higher temperatures, the required heat duration for organism death decreases.

*Metal heat exchangers are situated along the water treatment system, number and size of exchangers will depend on the volume of water that needs to be treated during a given time period.

*Water pH may be acidified to 4.5 to prevent calcium accumulation on the exchangers.

*Water must be cooled before using on plants.

Heat Treatment

Advantages

+No chemical residues – since no chemicals used.

+No additional chemicals - proper heating procedures will require no chemical treatment.

+Maintenance – no maintenance, unless calcium builds up on exchangers.

+Pathogen control - all pathogens will be killed.

+Algae control - the system will kill algae.

+Plant safe - if cooled sufficiently after heat treatment, there are no potential toxicities from heating.

Heat Treatment

Disadvantages

-Water cooling - must be cooled prior to usage.

-Lengthy treatment period - depending on temperature, heating duration up to 1.5 hours.

-Space allocation - since the efficacy is related to exposure time, tanks will be needed to hold treatment water and cooling water.

-High operation cost - for electrical source, natural gas, or oil.

-Water pH - acidification to approximately 4.0-4.5 prior to heating (to prevent calcium buildup on heat exchangers), and then will have to be neutralized (to crop requirements) after heat treatment.

-Clay and silt removal - clays and other soil particles are not removed or broken down.

-Chelates destroyed - temperatures up to 150F should not be a problem. However, accidental temperatures near boiling (212F) will denature chelates.

-Pesticide breakdown - please check pesticide labels for temperature stabilities in solutions.

Reverse Osmosis, Nanofiltration, Ultrafiltration and Microfiltration Processes

Mode of Operation: Membrane-mediated filtration.

*Pressure (energy) required to pump the water through the membranes.

*Smaller-pored membranes requiring more pressure to force water through the pores compared to the larger pored membranes.

Reverse Osmosis, Nanofiltration, Ultrafiltration and Microfiltration Processes

Membrane type	Approximate filtration pore size	Relative Cost	Advantages	Disadvantages
Reverse Osmosis	0.1 nm	High	*removes charged ions *removes compounds ≥ 250 amu *almost essentially all pathogens	***removes dissolved fertilizer**
Nanofiltration	1.0 nm	Moderate	*removes some charged ions. *removes compounds ≥200-1000 amu *removes essentially all pathogens	***may remove some chelates**
Ultrafiltration	1- 20 nm	Low	*removes bacteria *fungal spores *removes nematodes	***virus may not be removed**
Microfiltration	**100 to 10,000 nm**	**Lowest**	***requires least amount of energy**	***many pathogens will not be removed**

Reverse Osmosis, Nanofiltration, Ultrafiltration and Microfiltration Processes

*No correlation between weight and size since some particles are more dense than others.

*A Dalton = 1 AMU

Organism/particle	Weight (Daltons)[z]	Size (nm)
Water molecule	18	**0.20 nm**
Iron-EDTA chelate	526	**NA**
virus	7,000,000	**20 to 200nm**
E. coli	Over 3,000,000,000	**2000 nm**
Fungal spores	NA	**2000 to 5,000 nm**
Nematodes	**NA**	**300,000 nm and larger**

Reverse Osmosis, Nanofiltration, Ultrafiltration and Microfiltration Processes

Maintenance.

*Flushing -All membrane systems will require periodic flushing of membranes, the frequency of which is dependent on the cleanliness and the volume of water being treated during a given time period.

*Concentrate Disposal – The residues collected will need to be disposed of, the method of which will depend on regulations in your region.

*Membrane replacement – Membranes will need to be replaced after a given period of usage.

Turn a Challenge into an Opportunity

Do not let you attitude towards your handicap be your disability


Thank You