



Water Management For Nurseries

Water issues

Risk of contamination of nursery stock from stream water containing *Phytophthora* spp. and other plant pathogens

Treatment of nursery runoff and recirculating water for removal of pathogens



Zoospores

Each sporangium can hold about
30 swimming zoospores!



Inoculum levels

Inoculum threshold for infection between 50 and 1000 zoospores/ml, depending on species and conditions

Repeated exposure increases the chances of infection

Symptoms of *Phytophthora*

- Damping off
- Wilting
- Water-soaked lesions
- Total plant collapse



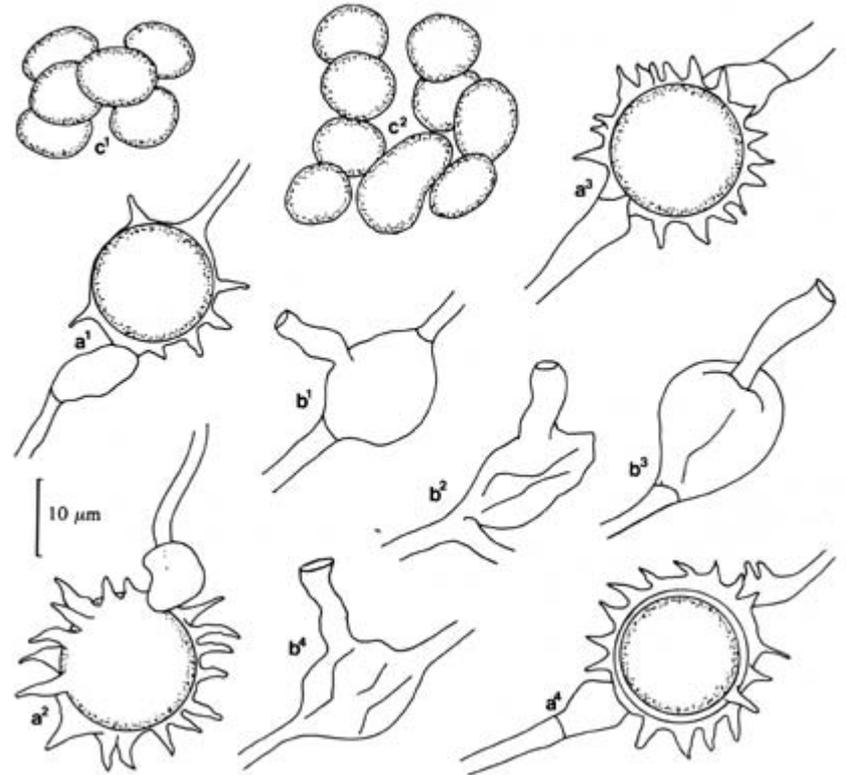
Pythium

More than 100 species identified

“Damping off” of seedlings

Pythium wilt

Root disease



Pythium echinulatum

Pythium diseases



Pythium root rot on Chrysanthemum. Notice the lack of roots.



Pythium root disease on turfgrass can cost thousands of dollars worth of damage on golf courses.

1. Have you experienced any problems with *Phytophthora* or *Pythium* at your nursery?

Yes	
No	
Not sure	

Phytophthora spp. in WA nurseries

Clade	Species	Substrate
2	<i>P. citrophthora</i> *	water
2	<i>P. inflata</i> *	water
2	<i>P. plurivora</i> *	water, soil, plant
6	<i>P. taxon 'pgchlamydo'</i>	water, plant
6	<i>P. gonapodyides</i>	water, plant
6	<i>P. lacustris</i> (= <i>P. taxon 'salixsoil'</i>)	water
6	<i>P. inundata</i> *	water
8	<i>P. ramorum</i> *	water, soil, plant
8	<i>P. syringae</i> *	water, plant
9	<i>P. hydropathica</i> *	water

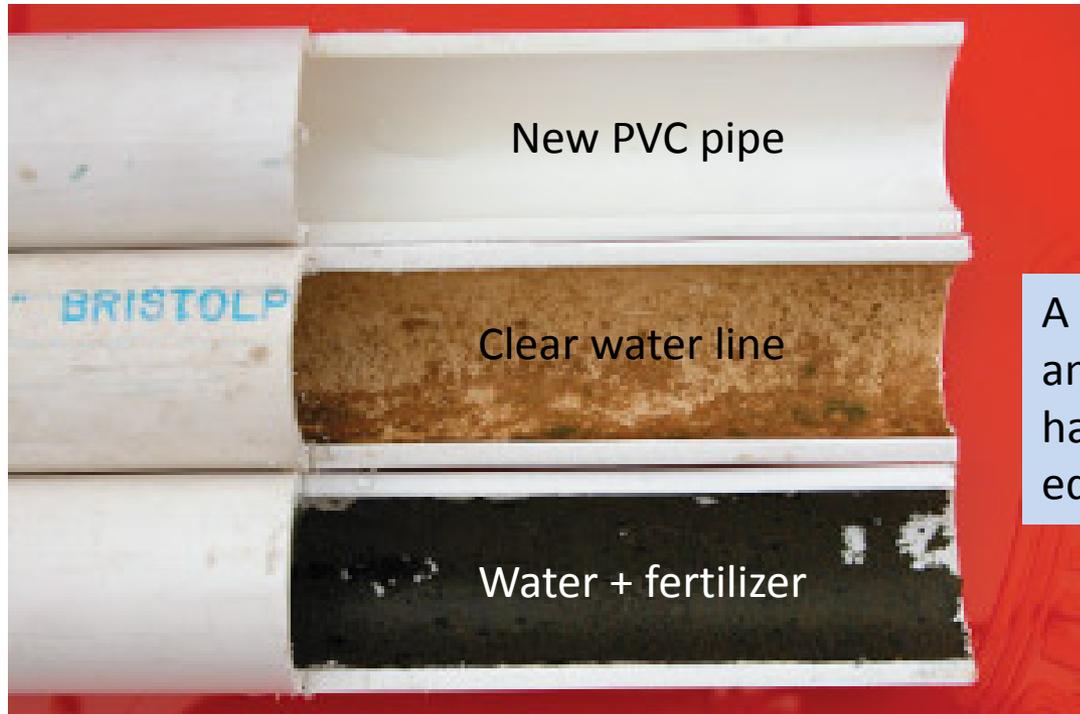
*known plant pathogens

Sources of inoculum

- Biofilms and algae
- Infested soil and crop debris
- Irrigation system
- Standing water



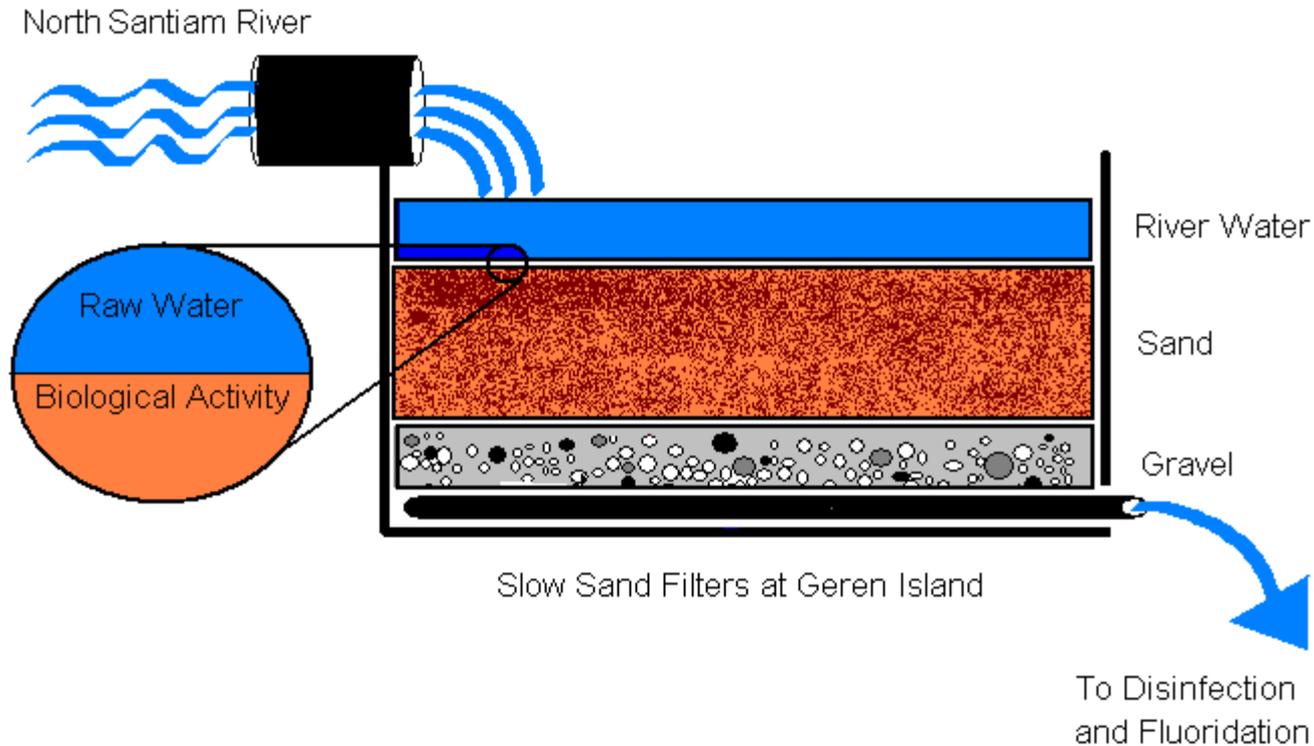
Biofilms



A complex of bacteria, fungal, and algal growth that can harbor pathogens and clog equipment.

Photo: Peter Konjoian.
<http://www.greenhousegrower.com>

Biofiltration



However, some bacteria and fungi in biofilms can eliminate some waterborne plant pathogens, such as Oomycetes (*Phytophthora* and *Pythium*), as well as excess nutrients.

Recycled irrigation water is a source of inoculum in greenhouses

Water molds such as *Phytophthora* and *Pythium* can spread rapidly in recirculating irrigation water and cause serious damage within a few days.





How pathogens spread in nursery irrigation water

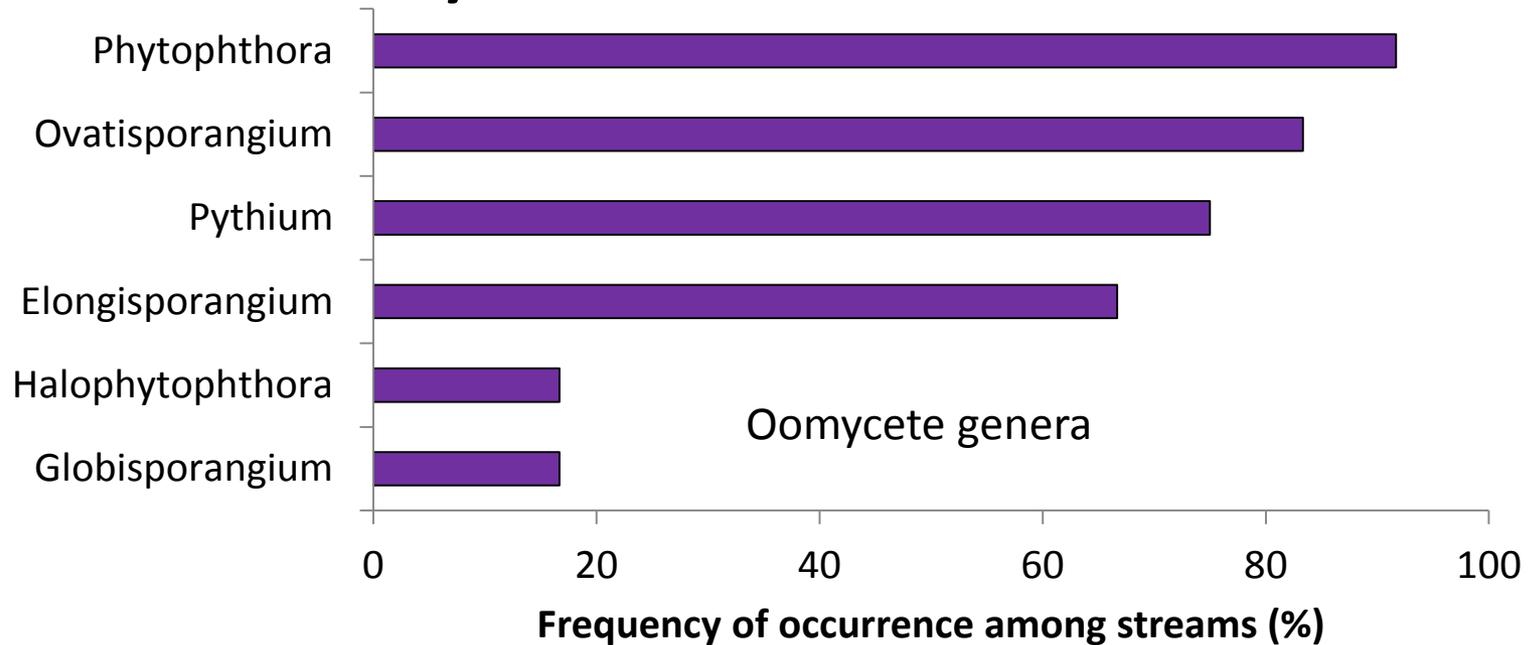
Overhead

- Wets soil surface & aboveground parts
- Splashing of soil and inoculum

Drip

- Does not wet aboveground plant parts
- Over-irrigation promotes root disease

Oomycetes in our streams



2011 stream monitoring in western WA

26 oomycete species identified

14 named species

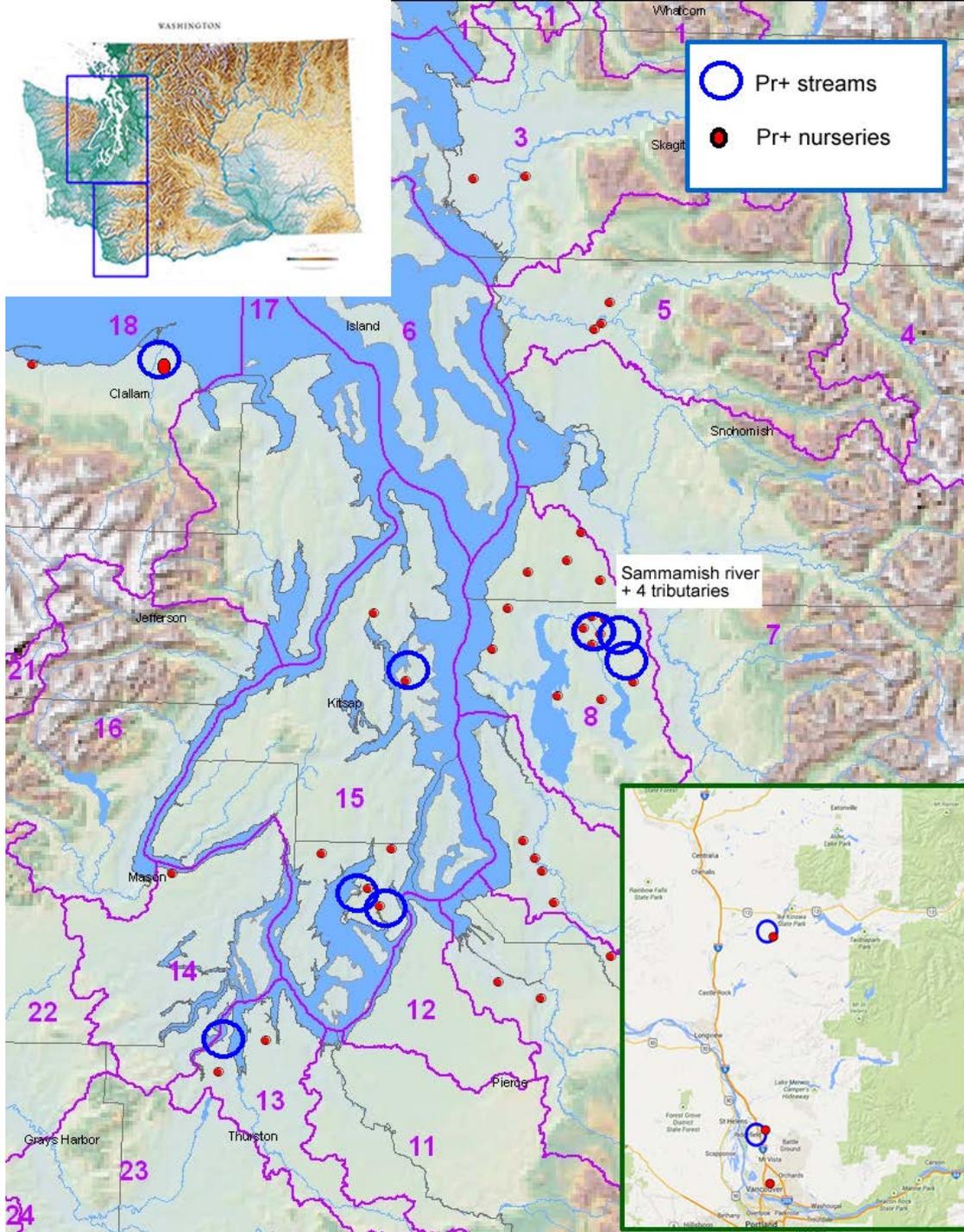
4 partially described species

8 new, undescribed species

About half are known or suspected to be plant pathogens

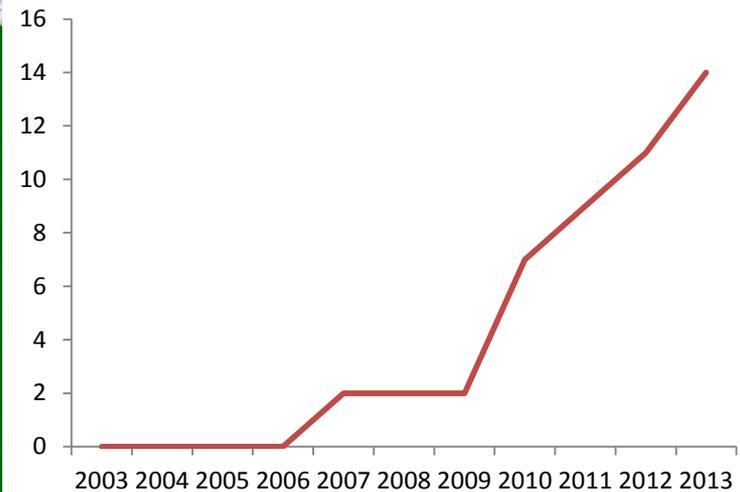
Plus fungi, bacteria, and other organisms that were not culturable

Stream monitoring



Number of streams containing *P. ramorum* continues to increase in WA

Most are associated with Pr+ nurseries



Management of waterborne plant diseases



Prevention is the most effective method.

Prevention BMPs - water

- Monitor and test water from any source other than municipal or well
- Treat surface or recaptured water before using for irrigation



Phytophthora breeds in standing water



Plants that tip over into puddles containing inoculum (zoospores) become infected within 10 seconds!

Improve irrigation efficiency

- Group plants with similar needs together
- Timing – multiple intervals vs single
- Monitor soil moisture



Improve drainage

- Infiltration
- Open ditch
- Underground
- Vegetated buffer



Climate change predictions

Annual precipitation amounts will be similar (+ 1-2%)

But a changed seasonal cycle –

Wetter autumn/winter

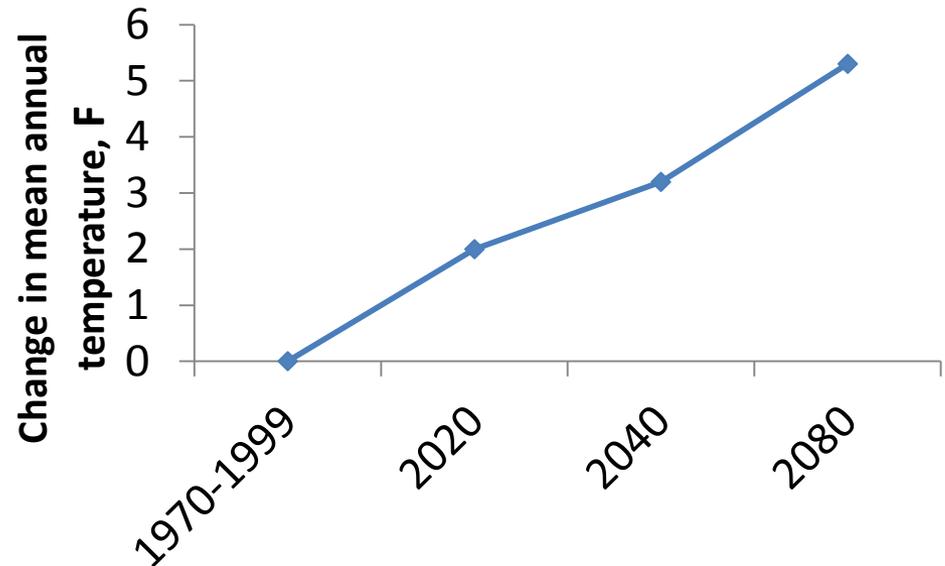
Dryer summer

Meaning:

More irrigation needed in summer months

More runoff in winter months

Predicted change in mean annual temperature for WA



Water supply

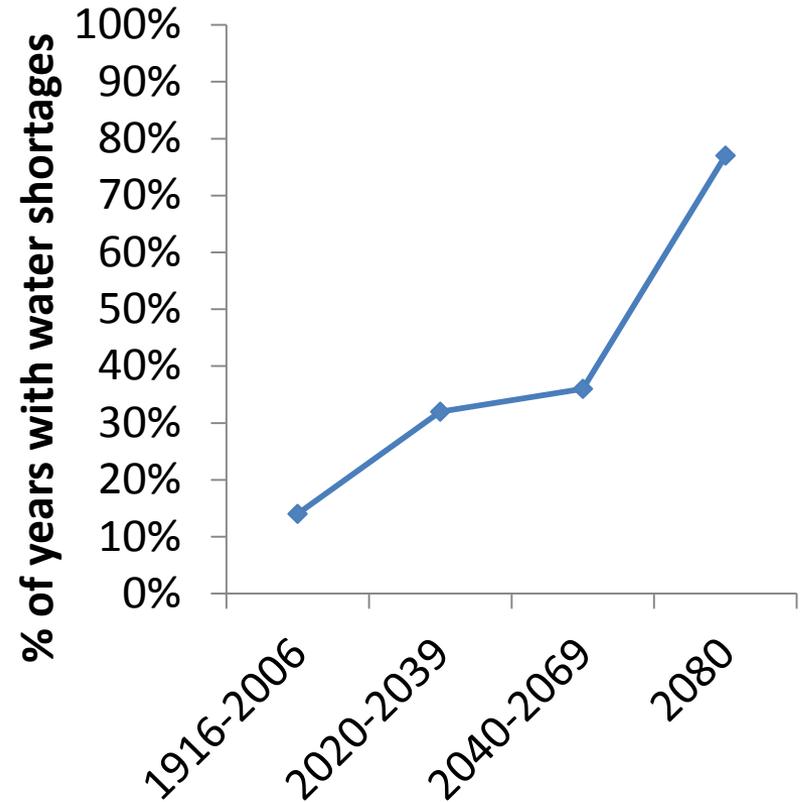
Western WA

Shift in peak river flow from late spring to winter

Reduced summer and fall storage

Adequate water supply through 2020 if no major changes in demand occur

Eastern WA



2. What water sources do you use for irrigation?

Check all that apply:

Municipal	<input type="checkbox"/>
Well	<input type="checkbox"/>
Surface water (river or stream)	<input type="checkbox"/>
Captured rain water	<input type="checkbox"/>
Recycled water from retention pond	<input type="checkbox"/>
Other	<input type="checkbox"/>

Methods for cleaning up water

- Methods should be scalable for various size nursery sites with differing water flow patterns
- Treatments developed for stormwater and agricultural wastewater can be adapted for removing inoculum from irrigation water

Water quality affects pathogen biology and treatment effectiveness

- pH – measures acidity of water (5.5-7.0)
- EC – salt level of water (high EC causes plant stress)
- DO – dissolved oxygen
- TSS – total suspended solids or turbidity
- Chlorophyll a – amount of algae in water
- ORP – antimicrobial activity

Pond water quality fluctuations driven by algae blooms

Chlorophyll a, dissolved oxygen (DO), and pH on diurnal cycle.

Oxidation-reduction potential (ORP) and temperature negatively correlated with DO.

ORP highest in morning and lowest in evening.

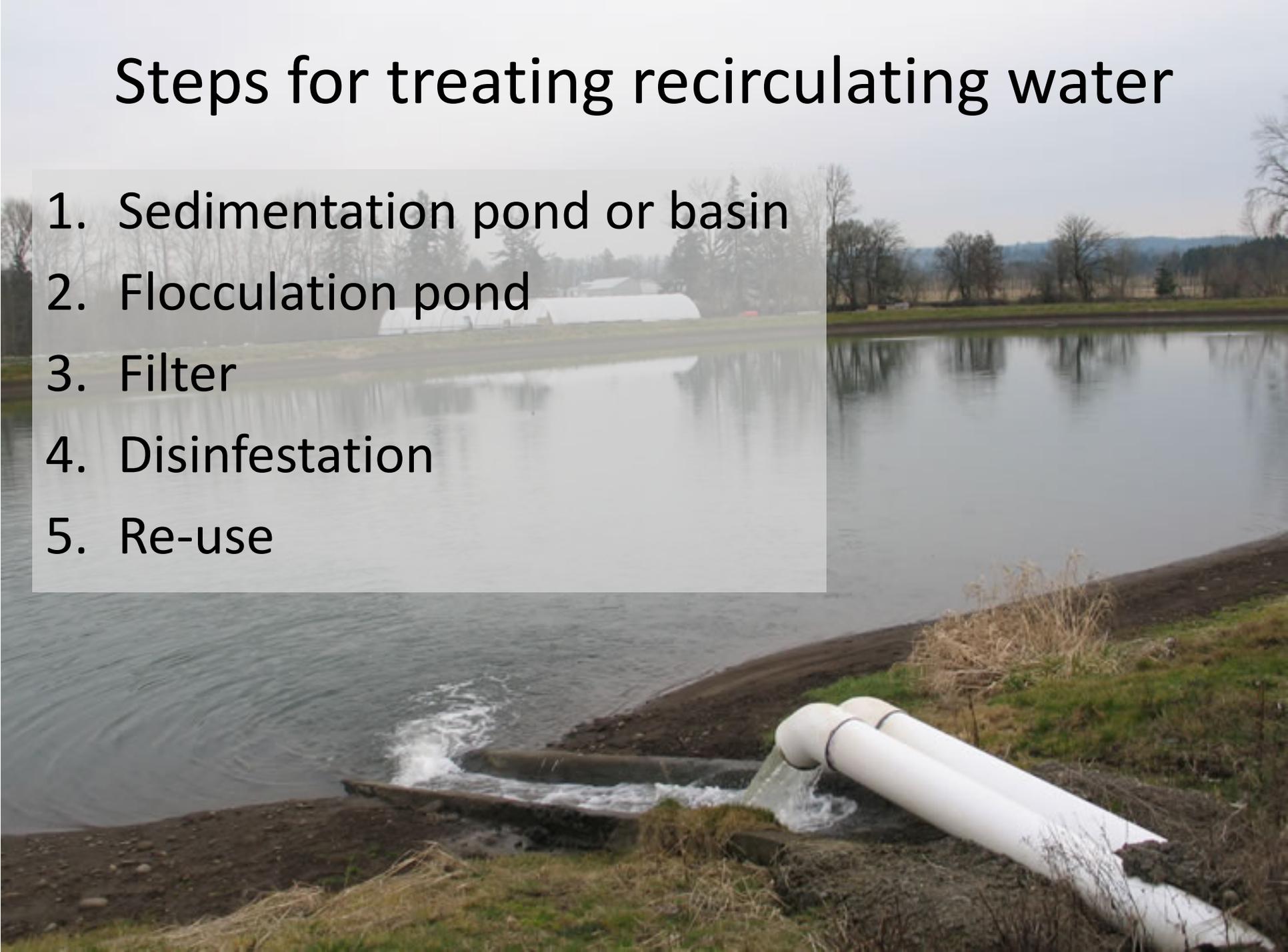
Turbidity and temperature dependent on weather conditions.



Hong, C. X., Lea-Cox, J. D., Ross, D. S., Moorman, G. W., Richardson, P. A., Ghimire, S. R., and Kong, P. 2009. Containment basin water quality fluctuation and implications for crop health management. *Irrigation Science* 27:485-496

Steps for treating recirculating water

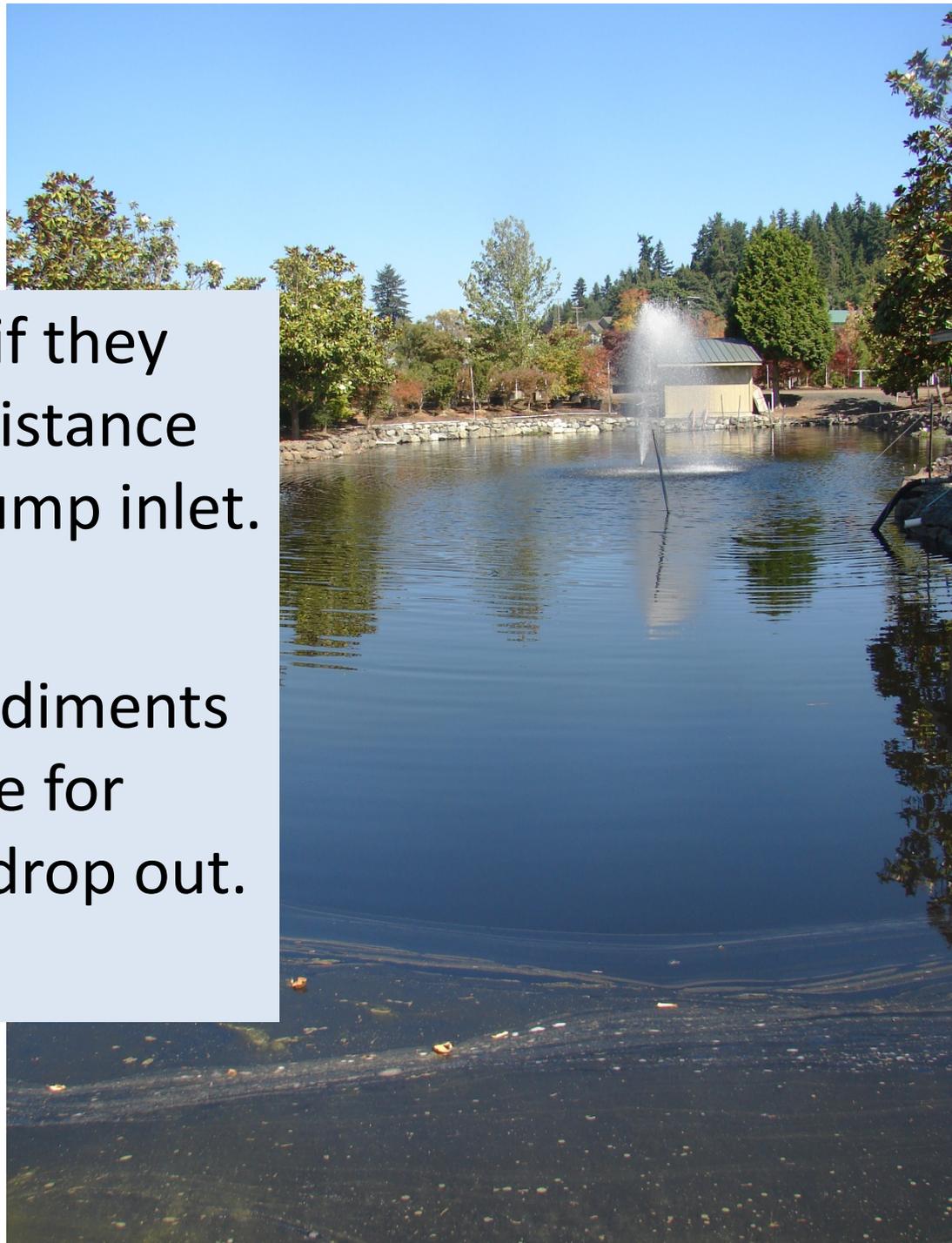
1. Sedimentation pond or basin
2. Flocculation pond
3. Filter
4. Disinfestation
5. Re-use



Sedimentation

Propagules settle out if they have to travel a long distance from runoff inlet to pump inlet.

Organic matter and sediments that the pathogens use for food and shelter also drop out.

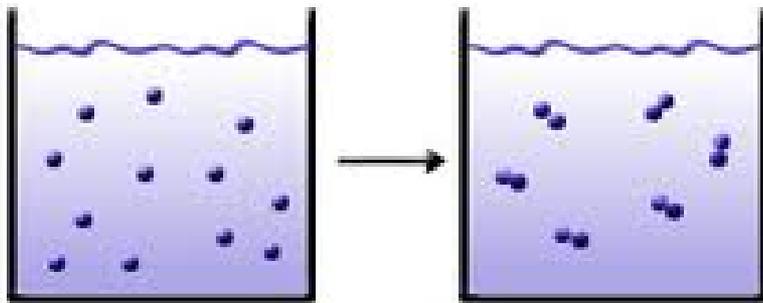


Flocculation to reduce turbidity

Particles aggregate to flocculants with opposite surface charge:

Polyacrylamide (PAM)

Alum



Flocculation



Filtration

Filter type	Size range	Removes	Use
Screen/mesh	20 – 5,000 μm	Soil, sediments, debris, algae, biofilm	Pre-filtration
Media	5 – 100 μm	Some pathogens, organic material, soil and sediment particles	Remove turbidity
Membrane	0.001 – 1.0 μm	Everything	Disinfestation



Mesh filter



Sand filters

Water treatment for greenhouses, propagation areas

- Ozone
- UV
- Chlorine
- Hydrogen peroxide
- Biosurfactants
- Membrane filtration
- Slow sand filtration
- Photocatalytic oxidation
- Copper or silver ionization
- Heat

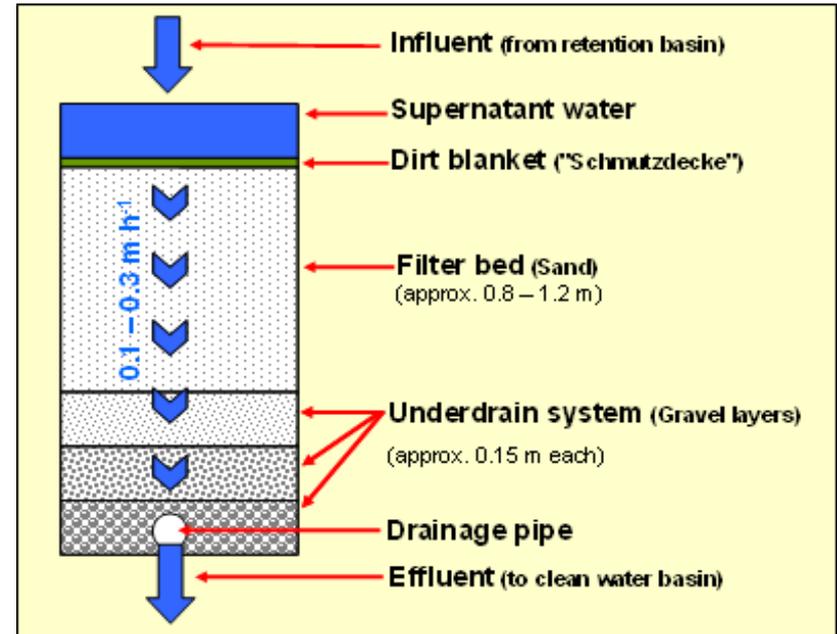
Water should be free of sediment, organic matter before treatment by one of these methods

Slow sand filtration (SSF)



Very effective at removing pathogens

Low flow rates and clogging require more area if a large volume of water is to be treated



Ufer, T., Werres, S. K., Posner, M., and Wessels, H.-P. 2008. Filtration to eliminate *Phytophthora spp.* from recirculating water systems in commercial nurseries. Online. Plant Health Progress doi:10.1094/PHP-2008-0314-01-RS.

Oxidizing Agents

Oxidation Scale (the higher the better)

Oxidant	Oxidation Potential, V
Fluorine	3.0
Hydroxyl radical	2.8
Ozone	2.1
Hydrogen peroxide	1.8
Potassium permanganate	1.7
Chlorine dioxide	1.5
Chlorine	1.4

ORP (oxidation-reduction potential) measures the antimicrobial activity of the water.

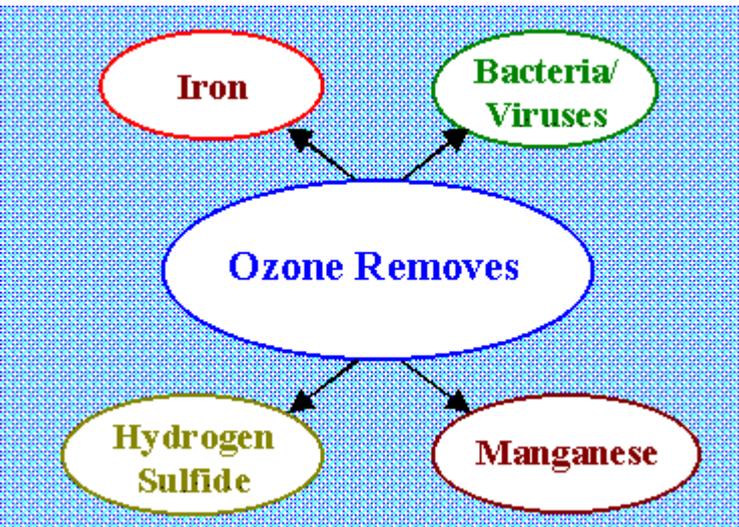
Efficacy of chlorine depends on water chemistry

pH should be between 5-6 (pond pH lowest in early morning, highest in afternoon)

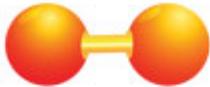
Hypochlorous acid (HOCl) is 20x more effective than hypochlorite ion (OCl⁻) as a disinfectant

2 ppm free Cl⁻ is recommended for
Phytophthora

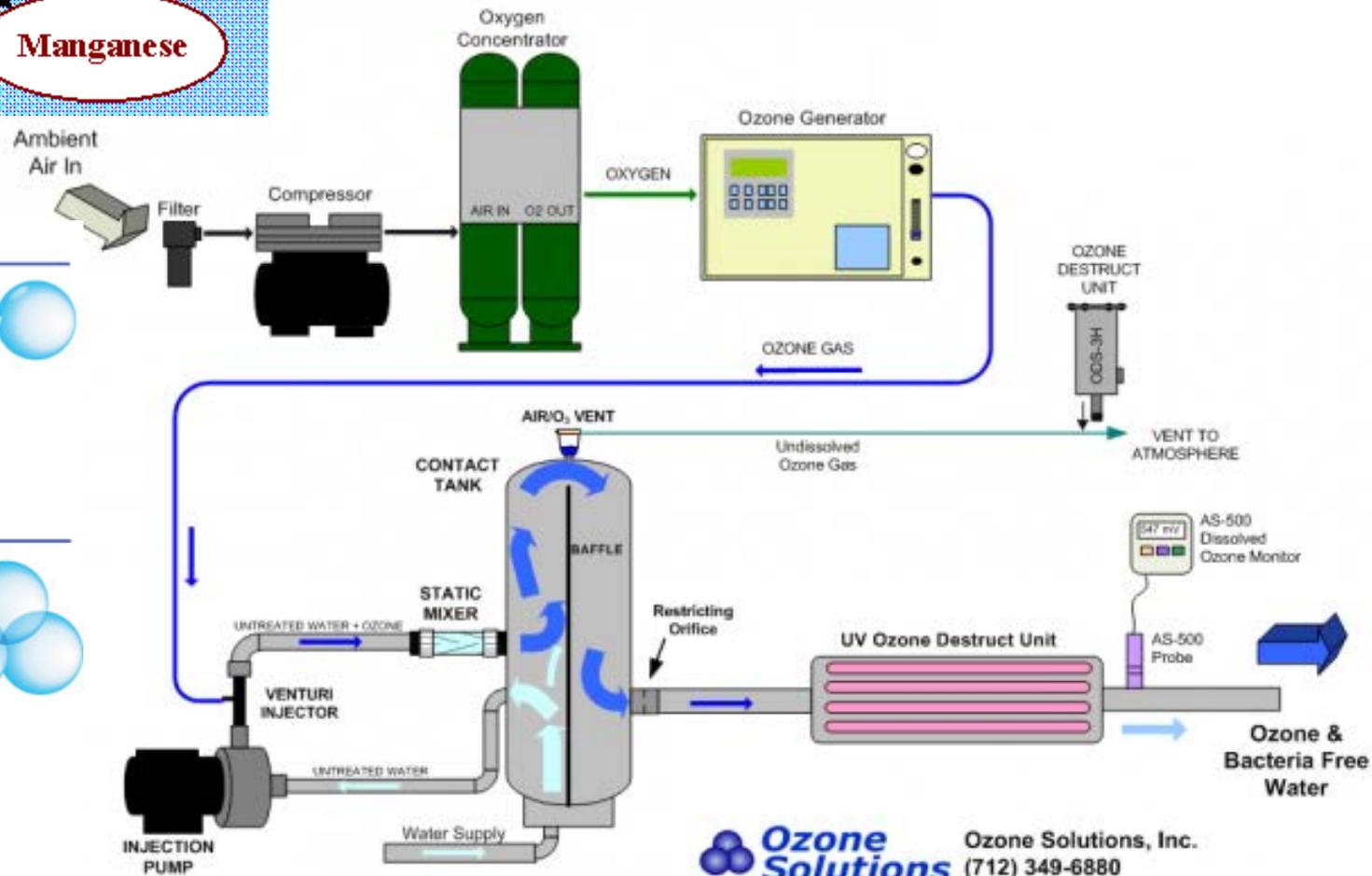
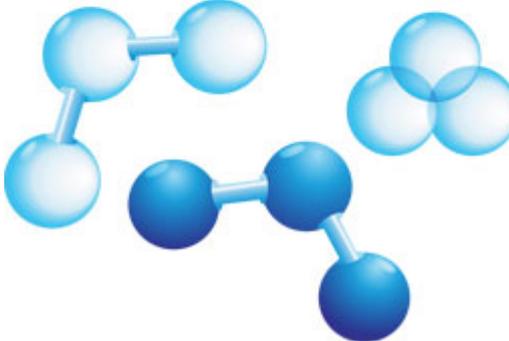
Ozone



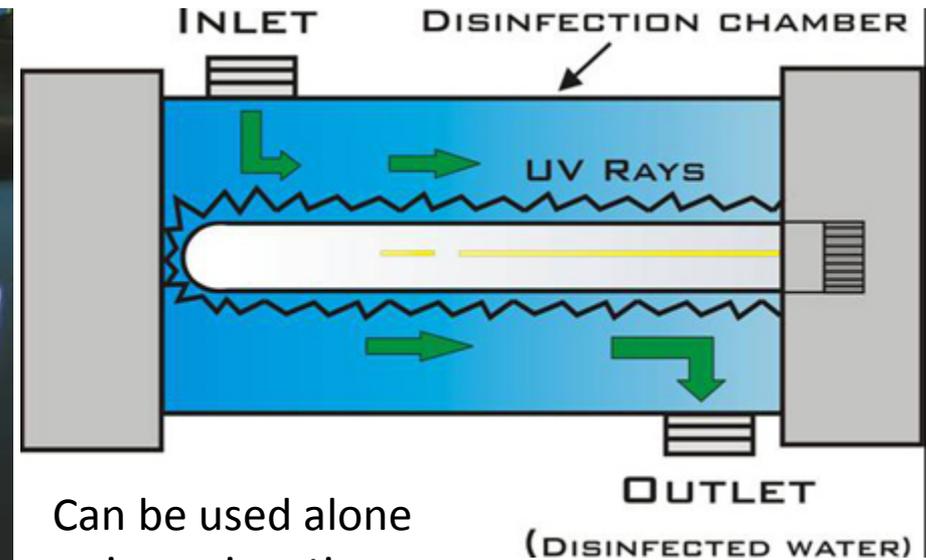
Oxygen O_2



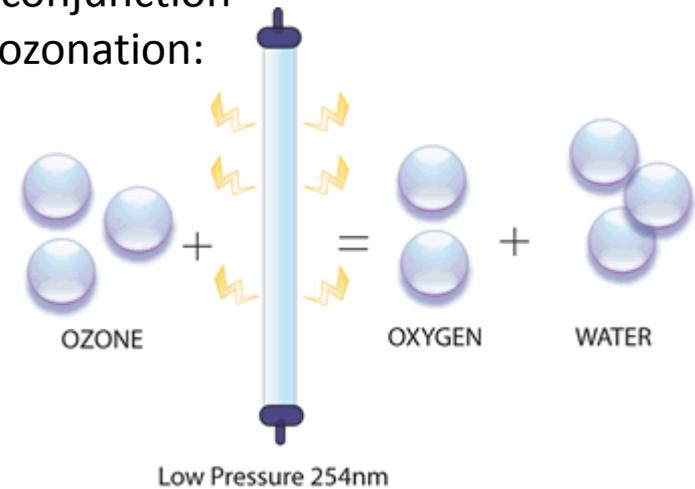
Ozone O_3



Ultraviolet Radiation (UV)



Can be used alone
or in conjunction
with ozonation:



Heating the water to 203°F for 30 seconds is adequate to kill most microorganisms that can cause plant disease.



5. Check all water treatment methods that are used at your nursery

Chlorination	<input type="checkbox"/>
Filtration	<input type="checkbox"/>
Ultraviolet radiation	<input type="checkbox"/>
Ozone	<input type="checkbox"/>
Constructed wetland	<input type="checkbox"/>
Biofilter	<input type="checkbox"/>
Flocculation/sedimentation	<input type="checkbox"/>
Other	<input type="checkbox"/>
None	<input type="checkbox"/>

Nursery runoff water

Contains

- Sediments
- Pesticide residues
- Nutrients
- Pathogens



Runoff treatment

- Interception
 - Filters
 - Conveyances
- Detention
 - Ponds
 - Flocculation
 - Chemical treatments (algaecide, chlorine)



6. How do you manage waterborne disease problems in your nursery?

Reduce water application	
Chemical control with fungicides	
Treatment of irrigation water	
Change to non-host plants	
Change drainage patterns	
Remove diseased plants and destroy dead plant material	
No treatment	
I don't have problems with waterborne diseases	

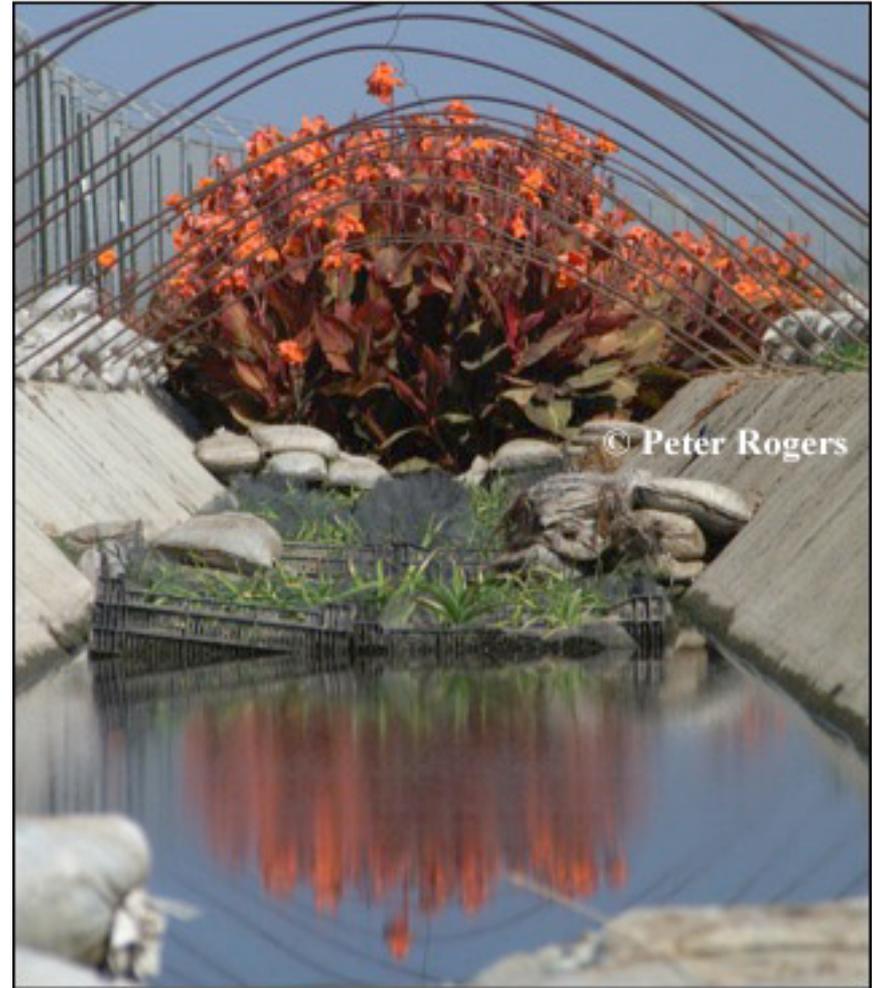
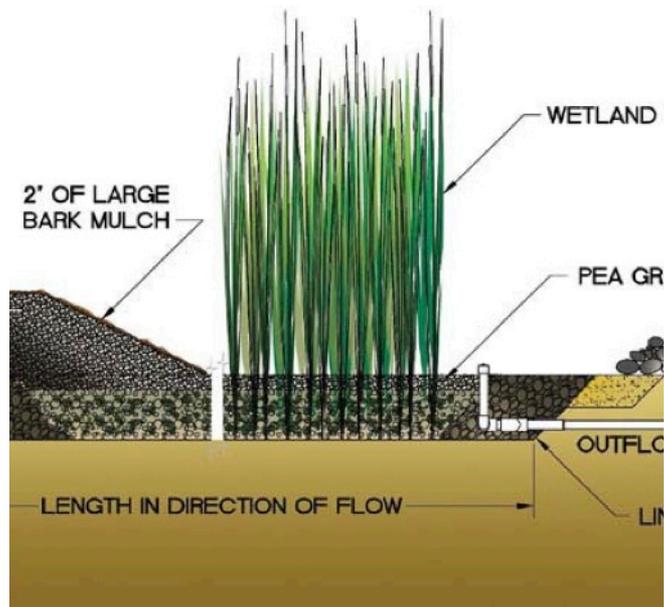
Stormwater

- Source of pollutants: heavy metals, nutrients, pathogens
- Use similar methods to treat stormwater and nursery runoff



Using plants to treat water

- Reduces sediment
- Removes nutrients
- Reduces pathogens (??)



Rain gardens at WSU



Treatments:

1. Shrubs
2. Shrubs and small trees
3. Grasses (managed meadow)
4. No plants

Biofilters

- Peat – used in septic systems
- Slow sand filtration - proven to remove *Pr* inoculum from nursery runoff
- Bioretention soil mix – for stormwater
 - 60% sand/40% compost or other organic material
 - Plants increase effectiveness
 - Can be amended with biocontrol fungi

Stormwater Biofilters at WSU

Treatments

1. 60% sandy aggregate and 40% compost.
2. 80% sandy aggregate and 20% compost.
3. 60% sandy aggregate, 30% compost and 10% water treatment residuals.
4. 60% sandy aggregate, 15% compost, 15% shredded bark and 10% water treatment residuals.
5. 60% sandy aggregate, 10% biosolids, 15% shredded bark, 10% water treatment residuals, and 5% sawdust.



All treatments are planted with the same plant palette consisting of slough sedge (*Carex obnuta*), red osier dogwood (*Cornus sericea*) and red switch grass (*Panicum virgatum*).

Biofiltration system at a nursery

Pond receiving nursery runoff

Septic tank vaults containing

1. Sand
2. Sand:Compost:Peat (60:20:20)



Mycofiltration

Using organic materials colonized by basidiomycete fungi to remove pathogens from runoff water.

Tested to remove fecal coliform bacteria from stormwater and an urban creek: initial tests showed 24-38% removal.

Developed by Fungi Perfecti LLC, Olympia, WA.



7. If you were going to treat water at your nursery, which of the following methods are you interested in trying?

Chlorination	Biofilter
Filtration	Flocculation/sedimentation
UV radiation	Other
Ozone	None
Constructed wetland	