REVERSE OSMOSIS (MEMBRANE FILTRATION)

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Background

Reverse osmosis, along with some other membrane filtration methods, can be used to filter pathogens from irrigation water. Fine filtration options, as categorized based on the smallest particle size filtered, are as follows:

Membrane filtration type	Particle size filtered (micron)
Microfiltration	1 - 0.1
Ultrafiltration	0.1 – 0.01
Nanofiltration	0.01 – 0.001
Reverse osmosis	<0.001

In these filter systems, water is passed through the filter and small particles and impurities are removed. These impurities remain in concentrated brine on one side of the filter and the pure water found on the other side of the filter is used for irrigation.

The fine pore size of the filter used in reverse osmosis (RO) removes impurities (i.e. salts and ions) and other small particles (i.e. pathogens). To learn more about the ability of fine filters to filter non-pathogen particles, see the page on filtration.

Application method

In an RO system high pressure is used to push water through a membrane which prevents unwanted particles from passing through. As a result, the filtered particles collect on one side of the membrane in a "brine" and the particulate-free water passes on to irrigate plants. This same method applies to other fine filtration methods, although the amount of pressure required will be lower. The filter membrane is typically composed of cellulose acetate or an aromatic polyamide. There are pros and cons to either material. Cellulose acetate has a higher

flux than an aromatic polyamide membrane and as such a smaller membrane surface area is required. Aromatic polyamide, unlike cellulose acetate, is not prone to bacterial attack. However, a cellulose acetate membrane may be kept free of bacteria by application of low concentrations of chlorine (aromatic polyamide, conversely, is not resistant to chlorine). Aromatic polyamide membranes may also be used at a higher temperature than cellulose acetate (35ºC compared to 30ºC), and can be used over a wider pH range (4-11) (ROchemicals, 2012).

Safety and handling information

Because water treated with RO does not contain any minerals, it has a corrosive effect on metal piping, and as such cannot be pumped through galvanized or copper pipes.

Critical Levels for Pathogens

Filters of varying fineness have the ability to target pathogens of different sizes. Reverse osmosis systems are able to remove impurities as small as 0.0009 microns (which covers many common pathogens). However, filters larger (less fine) than this are often capable of sufficiently removing common pathogens. The table below summarizes the findings of the research that has been done on the largest pore size able to filter major pathogens. Generally, larger pathogens such as protozoa, bacteria, and zoospores can be removed using various levels of microfiltration (Witgens, 2004). Ultrafiltration, or anything finer, may be used for removal of viruses, as well as all of the previously mentioned pathogens (Fisher, 2011).

Microorganism	Pathogen Propagule	Filter size (μm)
Pythium spp.	Zoospore	0.5, possibly as large as 7 (Tu and Harwood, 2005)
Bacteria	Bacterium	0.01 (Tu and Harwood)
Tomato mosaic virus	Virus	30K* ultrafilter for 99% removal; 5K ultrafilter for 100% removal (Liu et al., 1999)

30K refers to the maximum weight of particle (in kilodaltons) that may be filtered

Monitoring (From ROchemicals, 2012)

In order to ensure the membrane filtration system is working efficiently, and to determine when cleaning is required, a number of characteristics can be monitored. Most simply, flux across the membrane may be monitored using a digital flow meter. Pressure drop across the

RO system (difference between pressure of water going in and water coming out) can also be monitored. If pressure drop changes from its constant value this indicates a blockage. Finally, salt rejection (the percentage of total dissolved salts that is removed from the feed water) can also be monitored by measuring the electrical conductivity of the permeated/filtered water on a daily basis. Many of these properties will be monitored by the purchased RO system itself.

The concentration of suspended solids in the water feeding into the RO membrane must also be measured to ensure pre-treatment equipment is operating properly. This property is measured as a silt density index (SDI). SDI of the water entering into the RO membrane should be < 3.

In combination with other technology

In order for RO and fine filtration to be feasible, the irrigation water requires pre-filtration (and possibly additional treatment) to remove larger materials prior to reaching the filter. Pre-filtration reduces clogging of and damage to the filter. See the page on pre-filtration for further information. An irrigation specialist, or the company you are contacting to set up the membrane filtration system, should be consulted to determine what level of pre-filtration is required for your system.

Cost for Technology

The costs of RO/membrane filtration for greenhouse and nursery pathogen control are relatively high. However, it is difficult to give cost estimates for standard facilities of different sizes as pre-treatment required, and resultantly total cost, will vary greatly depending on the characteristics of the facility (water quality, irrigation methods, etc.). As such, if you are interested in learning more about the potential cost of implementing membrane filtration for your particular facility, you should contact a manufacturer (some examples at the bottom of this page).

Costs- Maintenance

Even with removal of larger particles, clogging will occur as a result of precipitates forming on the brine side of the membrane. Please visit http://www.ag.unr.edu/walker/WebPublications/FS-05-08CSREES.pdf for a list of ions that may precipitate and clog the membrane. Due to risk of clogging, membranes must be cleaned frequently. The membrane must be cleaned before the clog becomes severe (ROchemicals,

2012). The need to clean the membrane is typically indicated by a drop in permeate flux, a drop in salt rejection, or an increase in the applied pressure needed to maintain flux (Ang et al., 2006).

Pros and Cons

Pros:
- Effective for the removal of a variety of pathogens
- Non-hazardous to workers and the environment
- Effectiveness not dependent on pH
- No risk of phytotoxic effects
- If the installed filter is fine enough, salt content of water will be controlled and other impurities (iron, manganese, chlorine, etc., which otherwise could react with fertilizers to unexpected, potentially detrimental, results) removed (Fisher, 2011).

Cons:
- At the moment, high cost is likely prohibitive for widespread use in general pathogen control
- Filters require frequent cleaning
- The RO filter does not recover all the water that is sent through it. That is, a certain proportion of the water pumped towards the filter does not pass through, and ends up as waste water (part of the brine). While water recovery of household systems is typically very low, water recovery in large-scale systems can be as high as 70-90% (Siemens, 2011).   Left over brine must then be disposed of at a cost, which will depend on the method of disposal chosen. Potential disposal methods include discharge to a water body, well injection, and use of evaporation ponds (Malaeb and Ayoub, 2011).

Summary

Overall, while RO and fine filtration technology present an effective means of removing pathogens, for many facilities these methods may not be cost effective for treating the entire irrigation system. However, for facilities using greywater (salt water, wastewater) or brackish water, a reverse osmosis system may be useful for controlling both salt content and disinfection of irrigation water (van Os, 2010). As well, RO or fine filtration systems may be feasible for treating the water of especially disease prone areas of the facility, such as plant propagation

areas (Roseman, 2012). Interested operators should contact RO system manufacturers (some listed below) to find out more and help determine whether this system is right for them.

Suppliers

Some examples of suppliers of reverse osmosis systems include:

Producer	Product name	Producer website
Siemens		http://www.siemens.com/entry/ca/en/

References

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