FACTS AND MYTHS ABOUT IRRIGATION WATER

by

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Background:
Serious nursery owners know that the quality of water used for irrigation has paramount importance to the health of the plants. It is not just the amount of the fertilizers in the irrigation water, but also the quality of the water itself that matters.

In many parts of the country, as water is getting scarce, municipal water is becoming quite costly for purchasing. In addition, increasing salinity of well waters, especially in the Western States, now requires some degree of treatment before water can be used in agriculture.

Water scarcity coupled with governmental requirements for elimination of infiltration and water discharge from the property is forcing many nursery owners to consider water reuse seriously. In the State of California many owners, with the help of Federal Grants, have been applying the so-called "Best Management Practices" to properly collect and divert the tail irrigation water into collection ponds, which then becomes available for irrigational reuse.

Potential Water Quality Problems:

It is well known that irrigation water should be free of particles that are larger than 50-100 micron, depending upon the type of irrigation system used in a particular nursery. Furthermore, the irrigation water should preferably have low salt content, usually measured by the electrical conductivity (EC) or the total dissolved solids (TDS) levels, to prevent certain ion toxicities and build-up of salinity. For example, it is advisable to have an EC of less than 1 dS/m, and the sodium and chloride levels less than 3-4 meq/L. Furthermore, the balance between sodium and the water hardness (calcium and magnesium) should be controlled to have the sodium absorption ratio (SAR) to be preferably less than 3-4. The pH with respect to the saturation value of the water, which varies from case to case, should be slightly on the corrosive side in order to maintain a scale-free irrigation system, and to prevent the precipitates of calcium and magnesium from forming on plant leaves. Iron and manganese values need to be kept low to prevent staining problems. Many additional parameters, e.g., concentrations of boron, fluoride, and heavy metals should also be low to reduce the likelihood of specific ion toxicity.

In addition to these physical and chemical parameters, another major concern is the biological integrity of the water. In other words, water needs to be free of any disease-causing microorganisms, e.g., viruses, bacteria, fungi, nematodes, cysts, etc., that, if spread through the irrigation water, may cause various plant diseases.

Hence, irrigation water needs to be treated properly to remove these undesirable physical, chemical and biological contaminants. Water treatment in general is not a novel idea. Municipal treatment plants use a variety of technologies to provide potable water to large populations, and to produce relatively good quality water from wastewater before discharging to the environment.

However, treatment of water for irrigation purposes is relatively new to the agricultural industry. As a result, many misconceptions about water treatment options have flourished among the nursery owners, primarily because of lack of reliable information. For example, it is common to see incorrect information being disseminated by agricultural consultants who have no expertise in water quality and treatment technologies.

Hence, this article is an attempt to define typical water quality problems faced by nursery owners, and review briefly different types of water treatment technologies available to solve each individual problem.

1. Low quality municipal water

Municipal water, if available for use in irrigation in a given facility, is generally free of disease-causing microorganisms; yet it may contain salt and hardness levels high for irrigation of certain types of plants. High concentrations of primarily calcium, magnesium, sodium chloride and sulfate cause elevated salt and hardness levels in water.

2. Low quality well water

Some nurseries might prefer to use well water to avoid high cost of municipal water. Well waters potentially have high salt and hardness levels, and can also be contaminated with disease-causing microorganisms. Some well waters might have high turbidity caused by suspended particles as well.

3. Low quality surface water

A surface water resource, such as a lake, pond, stream, can be used for irrigation if available to a nursery. Typically surface waters contain high levels of suspended solids and a variety of microorganisms. Sometimes high salt levels may also be observed..

4. Tail water

A relatively small fraction of the irrigation water applied to the plants is consumed by the plants (evapo-transpiration), and the rest is disposed as tail water. Tail water contains high concentrations of nutrients added to the irrigation water as fertilizers. Hence, the reuse of the tail water is obviously beneficial for the nursery owner for reducing the need for additional irrigation water and fertilizer. However, tail water usually contains high concentrations of suspended particles, organic matter coming from the growth media, microorganisms, and potentially higher levels of undesirable salts, e.g., sulfate and chlorine.

Water Treatment Technologies:

Several different types of technologies are available to address different water quality problems as outlined below:

Particle Removal:

Filtration is a common technology to take out particles from water. Granular-media filtration, e.g., sand or multi-media, is effective in removal of large particles (Suspended Solids). Bag and cartridge filters can remove smaller particles, typically in the range of 100 – 5 micron. These filters are not effective against microorganisms, except some protozoa. Micro- and ultra-filter systems are available to remove particles in the sub-micron range, if needed. These systems can remove most bacteria, but are ineffective against viruses.

Salt and Hardness Removal:

Ions contributing to the hardness and E.C. (or TDS) levels in water can be removed successfully by membrane processes, such as nano-filtration and reverse osmosis. Ion exchange process also works effectively, yet is usually more costly or impractical compared to the membrane processes. Nanofilters usually operate at lower pressures and primarily remove hardness-causing ions. Nanofilters can also remove single-charged ions, such as sodium and chloride, but at lower efficiency. Reverse osmosis, on the other hand, operates at much higher pressures, but removes with high efficiency all types of ions. The major disadvantage of these processes is that they produce a concentrate (reject) stream at fairly large flow rates, reaching up to 60% of the feed water.

Disinfection (Inactivation of microorganism):

Microorganisms in water, e.g., viruses, bacteria, fungi, nematodes, cysts, as well as algae, can be inactivated by various types of disinfectants. In choosing the right disinfectant for nursery applications one should consider

1. The disinfection capability of the disinfectant,
2. The accumulation of the disinfectant in water, soil and plants, and its potential toxicity at elevated levels,
3. Chemicals produced when a disinfectant is applied to water (reaction products), and the potential problems and benefits of the reaction products,
4. Any other limitations associated with water quality,
5. The practicality and safety in using the disinfectant, and
6. Cost of disinfectant.

<u>1. Disinfection capability</u>

Ozone, chlorine dioxide and chlorine are chemical disinfectants proven for their high efficacy in water, if used properly. Chemicals, such as hydrogen peroxide and other peroxide-containing salts typically have weak disinfection capabilities. Heavy metals, e.g., copper and silver are even weaker disinfectants.

The comparative efficacy of disinfectants presented below indicates that ozone has the highest disinfection capability for various types of microorganisms among the top three disinfectants. The figures in the table indicate relative effectiveness of the particular disinfectant on a particular group of organisms, and are inversely proportional to the required disinfectant concentration and the contact time. For example, according to the available ozone is 8.5 times more effective (1.7/0.2) than chlorine dioxide in inactivating viruses under the same and noted conditions. That means ozone can be used either in much lower concentrations or requires less contact time to inactivate microorganisms compared to the other disinfectants on the list.

Microorganism	**Ozone (O_3)**	**Chlorine dioxide (ClO_2)**	**Chlorine (as HOCl)**
Enterobacteria * (2-log kill)	500	2.8	20
Giardia * (2-log kill)	3.3	0.2	0.02 – 0.06
Viruses * (2-log kill)	1.7	0.2	0.25
Cryptosporidium**	0.1 – 0.2	0.013	0.00014

* pH is 6 -10, and T= 5°C
** pH is 7, T=25°C, 2 log kill for ozone, and 1 log kill for chlorine dioxide and chlorine
Collection of data from various sources.

UV radiation is also an effective disinfection method for a variety of microorganisms. The radiation dose required for 3-log kill is given in the following table for various organisms in effective incident dose:

Organism*	**UV Dosage in microwatts-sec/cm^2**
E. Coli	6,600
Bacterial organisms	3,500 – 26,500
Viruses	6,600 – 440,000
Protozoa and mold spores	11,000 – 330,000

* Collection of data from various sources.

These data indicate a wide range of susceptibility of the microorganisms to UV radiation. In fact, the bacterial organism *E.Coli*, which is often the surrogate organism used to evaluate water quality, is one of the least resistant organisms to UV radiation. Hence, the absence of *E.Coli* in a UV-treated water does not necessarily indicate that water is free of many other organisms that might cause plant diseases.

In addition, the incident UV doses required for disinfection could be only a small fraction of the applied dose if water constituents, such as organic and iron compounds, absorb the UV light, especially at 254 nm wavelength where the light is most effective in inactivating the microorganisms. For example, when the UV absorption coefficient of water sample is measured by in a laboratory as 0.5 cm^{-1} at 254 nm, then only 32 percent of the light is expected to disinfect within 1 cm of light pathway. Suspended particles imparting turbidity to water further reduce the disinfection capability of UV light. Hence, it is important that the UV radiation systems be designed properly to take into consideration all the light absorbing constituents of water. The "Ultraviolet Disinfection Guidelines for Drinking Water and Water Reuse, 2003" states that the design UV dose for water reuse should be at least 100 milliwatts-sec/cm^2 after water is filtered through a media filter, and the filter effluent UV transmittance should be 55 percent or greater at 254 nm.

2. <u>The accumulation of the disinfect in water, soil and plants, and its potential toxicity at elevated levels</u>

Chemical disinfectants survive in water for certain periods of time after their application. For example, metals, e.g., copper, will not degrade and hence will potentially be taken up by the plants and soil. When certain concentrations of these chemicals are exceeded in water, soil and plant, they may exert toxicity in plants. Accidental overdosing or applications associated with reuse and recycling of tailwater treated with these disinfectants can easily lead to excessive concentrations in irrigation water. For example, copper could be toxic to a number of plants at 0.1-1.0 mg/L in irrigation water (Water Reuse for Irrigation, 2005). Furthermore, it is easy to accidentally overdose water with chlorine, chlorine dioxide and metals. Overdosing with ozone is usually not a concern because of its high reactivity to decompose back to oxygen.

3. <u>Chemicals produced when a disinfectant is applied to water (reaction products), and the potential problems and benefits of the reaction products,</u>

Ozone, chlorine dioxide, chlorine and hydrogen peroxide react with water contaminants after their application. Ozone and hydrogen peroxide are converted through a series of free-radicals to oxygen as the end reaction product. Oxygen in water is known to stimulate plant growth. The major reaction products of chlorine dioxide are oxygenated chlorine species, ClO_2^- and ClO_3^-. The reaction products of chlorine are primarily chlorinated organic compounds. The chlorinated species tend to accumulate in the irrigation water, soil, and in the plant material, potentially harming the plant or reducing its growth rate.

4. <u>Any other limitations associated with water quality</u>

Disinfection via UV radiation requires the water to be free of turbidity (suspended particles) and the UV-absorbing organic matter. Otherwise, the efficiency of light penetration and as a result the disinfection efficiency will be impacted adversely, as described above.

The pH of water is important in application of chlorine, since the efficacy of disinfection is reduced at pH values above 7 where the dominant species of chlorine switches from hypochlorous acid to hypochlorite ion, which is not as effective as a disinfectant. For ozone, chlorine dioxide and peroxide the disinfection efficiencies vary very little within the typical pH range of 8.5 – 6.0. Statements used by some, such as "ozone increases the pH of water" are not true. In fact in highly buffered irrigation waters, the pH does not change at all with ozonation. In certain applications where low buffered waters are ozonated at extremely high dosages to convert organic compounds to organic acids, the pH might reduce slightly. It is also not true that the pH of water should be lowered to 4.0-4.5 in order to achieve disinfection with ozone. These types of statements are made by those who are either not familiar with this technology, or intentionally ignore the vast amount of existing data in drinking water ozonation at thousands of water treatment plants in the US, Europe, Russia and even the developing world.

5. <u>The practicality, maintenance and safety in using the disinfectant</u>

For many applications, the delivery and storage of the disinfecting chemicals on site may be problematic because of safety concerns. Examples include pressurized chlorine tanks and concentrated peroxide solutions. These chemicals are considered hazardous, and their delivery and storage follow certain procedures established for hazardous material. Preparation of certain disinfectants on-site from concentrated stocks or powdered salts may not be practical. For example, the preparation of disinfectants, e.g., salts of hypochlorite or peroxides, may be left to the nursery operators who may not necessarily pay enough attention to correct dose adjustments and safety procedures. Yet, over or under dosing of disinfectants may cause either toxicity to plants, or insufficient inactivation of microorganisms.

Ozone and chlorine dioxide are both produced on-site because they are unstable for storage. Ozone is produced from oxygen gas in air, therefore requiring no raw material delivery or storage. Ozone gas is injected to water through a venturi, sparger, or other methods. A well- designed system has relatively low maintenance. However, a leakage in the ozone gas production line may create health problems for the workers if the system is improperly designed or maintained.

Chlorine dioxide is produced on-site by mixing sodium chlorite ($NaClO_2$) with chlorine gas (Cl_2) or with hydrochloric acid (HCl). An alternative production method involves reaction of sodium hypochlorite (NaOCl) with HCl and $NaClO_2$. Hence the production of chlorine dioxide requires the storage of chlorine gas, acids, sodium chlorite or hypochlorite solutions on site. Not only are these chemicals potentially hazardous, but also the mixing some of them on-site could create hazardous situations for the workers. Like ozone, any leakage of chlorine dioxide itself can create hazardous conditions.

The UV radiation is relatively safe to use, except that after their useful lifetime, the mercury-containing UV lamps should be disposed safely. Furthermore, fouling of the quartz sleeves around the lamps by iron, manganese, calcium and magnesium precipitates requires regular cleaning to maintain desired UV dosage.

6. Cost of disinfectant

The total cost of disinfection involves both the capital and the operational costs. For chlorine and peroxide-based disinfectants it is a recurring cost due to continuous purchasing of these chemicals, and the labor involved in on-site preparation. For ozone and UV radiation, the cost primarily involves the equipment cost and the power cost for operation of the equipment. For chlorine dioxide the chemical cost, the equipment cost and the power cost have to be taken into consideration.

Conclusions and Recommendations:

Overall water management in a nursery needs to be evaluated based on the quantity and quality of water required for different uses, and the water resources and water qualities available to the nursery. A comprehensive evaluation of all the options, which should include some degree of water reuse, may ultimately allow significant savings for the nursery owners in addition to eliminating environmental liabilities associated with disposal of fertilizer and pesticide laden waste discharges into the environment.

Most of the time, integrating several technologies to solve the water-related problems provides the most cost-effective solution. A sound and scientific approach to water management requires asking for help from professional companies that possess the knowledge-base in this area. These professionals can design and deliver systems that provide optimum solutions to any irrigation water problem.

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