

# Ions in Irrigation Water That Can Cause Problems in Christmas Tree Production

*As discussed in my last article, alkalinity and soluble salts are the most common water quality problems affecting Christmas tree production in the Great Lakes Region but there are other problems in water resources that occur naturally or by pollution in specific areas or as a result of improper production practices. Ions of sodium, chlorine, iron, boron, manganese, zinc, copper, and fluorine, all of which are essential elements except sodium and fluorine, have been found at concentrations in water that can cause problems with irrigation systems or plant growth. Since most of these are essential elements and could be included in a fertilizer, improper fertilizer handling and storage can cause problems if wells or reservoirs are contaminated. These ions are very rarely a problem in surface water sources (lakes, rivers, streams, ponds), when they are it is usually the result of human caused pollution.*

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**Figure 1** – Under canopy drip (left) and microsprinkler (right) irrigation will keep water off the foliage, eliminating foliar uptake of problem ions.

Under-canopy irrigation (Fig. 1) is a solution that works for all of these elements. Since these ions can be absorbed by leaves, part of the uptake path is eliminated. Another solution that works for them all is to dilute the poor quality water with good quality water if a second water source is available in a large enough volume for adequate dilution. Reverse osmosis (RO) systems can be used to remove practically all ions from water but is

expensive, has a low volume output and is high maintenance. RO is used for specialty and high value production that uses relatively low volumes of water such as propagation. Other solutions are a little more complicated or nonexistent.

Borate and fluoride (the ions of boron and fluorine) are very rarely found in irrigation water sources at harmful levels in the Great Lakes Region, but there are

a few hot spots including near MSU in areas of Mason Township for borate and areas of Wheatfield Township for fluoride. Both elements are practically nonexistent in surface water except as a result of pollution. The most common source of borate pollution is from coal ash from power plants or other coal burning facilities and can be extremely high. The coal ash is frequently stored in a reservoir or buried in a landfill. Some of these were not designed well and are leaking. we do have several of these sites in the Great Lakes Region so be aware of their locations (Fig. 2). Fluoride pollution can come from many sources but is rarely the cause of high



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**The Impact of Coal Combustion Residue Effluent on Water Resources: A North Carolina Example**

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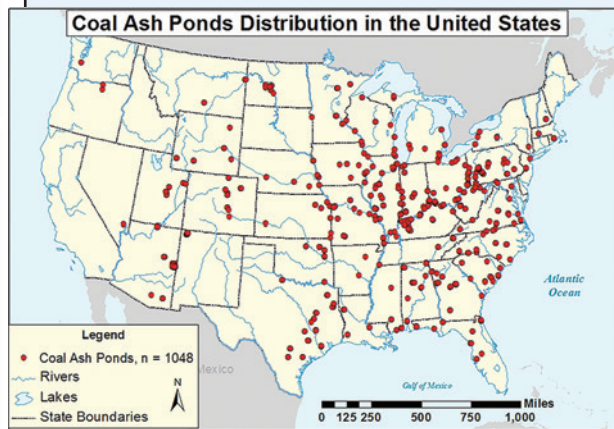
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**Figure 2** – Coal ash ponds in the lower 48 US states. Reprinted with permission from L. Ruhl, A. Vengosh, G.S. Dwyer, et al., 2012. The impact of coal combustion residue effluent on water resources: A North Carolina Example. Environmental Science & Technology. Copyright 2012 American Chemical Society.



**Figure 3** – Different stages of iron residue (orange) on irrigation heads and filters. Residue from calcium carbonate (white) can also be seen. Note the orange color of the sidewalk, a result of constant irrigation with high iron water.

levels in water. Some municipalities treat their water with fluoride but this is not often an irrigation source for wholesale production, however, if municipal water is used for irrigation it is important to know if it has been fluoridated. Borate and fluoride in groundwater can be from natural bedrock formations, such as in Mason and Wheatfield Township. Boron is found in groundwater in the Great Lakes region between 0.02 to 6 ppm but extremely high concentrations of up to 24 ppm have been found in groundwater wells near leaking coal ash retention basins. Boron is a micronutrient needed in very low amounts even for a micronutrient. It is easy to go from sufficient to excess to toxic boron levels with small additions of boron. Boron should be less than 0.5 ppm and preferably less than 0.1 ppm in irrigation water. Fluoride in the groundwater in the Great Lakes region varies between 0.1 to 4 ppm. Fluoride will accumulate in plants, so systems

reliant on more frequent irrigation (container production) and longer production duration will result in greater problems. Most plants can tolerate fluoride levels below 1 ppm in irrigation water. Some sensitive plants, mostly annuals, indoor foliage plants and some perennials, are sensitive to levels above 0.5 ppm. I have never heard of a report of field grown Christmas trees being affected by fluoride. Fluoride cannot be easily and cost-effectively removed from water in adequate volumes of water for whole-farm irrigation in most cases. Dilution or RO is the only practical solution for borate or fluoride in water.

Fortunately, iron does not often result in toxic symptoms in plants in the Great Lakes region but we do have many water sources with high iron content. Most of these high iron sources are groundwater sources that contain iron from naturally occurring deposits. However, iron contamination can be associated with mining and industrial

activities. Iron occurs either in the water soluble ferrous ( $\text{Fe}^{2+}$ ) or the insoluble ferric ( $\text{Fe}^{3+}$ ) forms. Low pH environments, such as unaerated water (think of groundwater) or acidic soils, drive iron from the ferric form to the ferrous form and vice versa. In soils, the ferric form is more common but will be converted to the ferrous form as pH decreases below 7. Iron is a micronutrient needed in fairly large amounts in comparison with other micronutrients and plants have mechanisms for sequestering iron that makes iron toxicity rare even for plants that grow best in low pH soils. The main issue with iron in water is residues formed on leaves and precipitates forming in irrigation systems (Fig. 3). Ferrous iron in groundwater will quickly be oxidized to the ferric form when exposed to air but will continue to be transported in irrigation in suspended form. Water high in iron usually has a combination of both forms by the time it reaches the plants. When irrigation is turned off or switched to a different set of lines, water remaining in the irrigation pipes and emitters will mostly oxidize to the ferric form and accumulate causing reductions in pipe flow and closing of emitter orifices. This will cause inefficiencies in irrigation and, especially with low-volume systems, can completely clog. Iron has been known to decrease pipe diameters in half or more from the sediments and films forming in the pipes. The iron containing irrigation water that leaves the irrigation system can leave a residue on whatever it contacts, plants, pots, production groundcover, and other surfaces (Fig. 4). With evergreens, residues will build up on foliage and remain until the leaves senesce. Water with iron less than 5 ppm is ideal but as the iron concentration increases, the buildup of residues in and out of the irrigation system becomes worse.

There are several well-established methods for decreasing iron in irrigation water. Probably the oldest method and most effective methods is to have settling reservoirs to aerate the

water and let the ferric iron settle out. Water movement the reservoir should be slow to allow for settling to occur. Unless the settling reservoir doubles as a recycling reservoir, nutrient content should be low so slow movement shouldn't result in problems associated with low aeration. Another long-established method are greensand filter systems. These use a combination of potassium permanganate injected into the water to oxidize ferrous to ferric iron and filtration. Some of the manganese is converted to solid manganese oxide and the potassium (a macronutrient) and some manganese remains dissolved. The water is then passed through glauconite "greensand" filters to remove the solid ferric iron oxide and manganese oxide. The greensand filters are back-flushed when pressure in the system drops to predetermined levels to remove the precipitated compounds. Another method is to inject acids to keep water pH below 7 so that iron remains in the



**Figure 4** – Iron residue at the MSU research nursery. The rock groundcover was white limestone that has now turned bright orange after years of irrigating with high iron water. Also note the residue built up on the end wall and hoop ribs.

soluble ferrous form but this can still result in residues once the water leaves emitters. Finally, oxidizers, such as those used for water sanitation, can be injected into the water to convert ferrous to ferric iron and then passing the water through an iron-selective cation exchange filter (like the greensand filter). However, sanitizing

effects will be reduced as the oxidization reactions are spent on iron rather than pathogens.

Copper, manganese and zinc are more a nuisance, similar to iron, than a problem like boron and fluoride. All three are micronutrients. They are even less frequently found in irrigation water sources at problem levels than boron,

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fluoride and iron. They are needed in more quantity than boron and plants can tolerate a higher concentration range but if water is high in any of them toxicity should still be monitored in the plants. The main problem with these ions is the formation of precipitates that clog emitters. Ideally the concentration in water should be less than 1 ppm for manganese, 0.3 ppm for zinc and 0.2 ppm for copper. The usual source of these ions is related to pollution from mining activities. Copper can leach out of any copper plumbing if water is acidic but it is an extremely rare irrigation system that has any copper pipe involved. There are some copper ionizing systems for pathogen control and background levels of copper in water need to be considered before installing these systems. These three nutrients can be kept in solution by acid injection to reduce clogging of emitters.

Finally, sodium and chloride (not the sanitizer chlorine). Sodium is not an

essential element and competes with several essential elements for soil binding sites and plant uptake, it also adds to total soluble salts. Sodium will replace potassium at its active sites but does not replace its function. Chloride is an essential element but is so ubiquitous that it is not applied specifically as a fertilizer, it tags along with other nutrients. These ions are usually found together and are fairly ubiquitous in the Great Lakes region but at acceptable levels. However, that has been changing as greater amounts of water are extracted from aquifer systems. Saline water is more dense than fresh water and has settled to the deeper parts of the aquifer over the millennia. The major ions in saline water are sodium and chloride but many other salts are present. Salt concentrations above 100,000 ppm have been found in saline waters deep in many Great Lakes aquifers. Usually this saline water is below where pumping systems extract groundwater. Unfortunately, salt water

intrusion is occurring in aquifers around the Great Lakes from these deep aquifer layers where heavy extraction is occurring as discussed in my spring issue article. Sodium chloride is one of the de-icing salts commonly used in the region and has caused noticeable increases in salt content in water resources. Confined and slow moving water systems are susceptible to excessive buildup that could damage plants. Chloride can become toxic at high enough concentrations and additionally can contribute to water transport issues related to total soluble salts. Sodium concentration in water is best when below 50 ppm but most plants can tolerate 100 ppm. Chloride concentration in water is best below 70 ppm, but definitely don't confuse this with chlorine concentration- 70 ppm chlorine will be very phytotoxic. More on chlorine and other sanitizers next time.

The sodium adsorption ration (SAR) is rarely an issue in the Great Lakes



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region, it is more commonly a problem in western states with sodic soils. SAR is the ratio of the concentration sodium [Na<sup>+</sup>], calcium [Ca<sup>2+</sup>] and magnesium [Mg<sup>2+</sup>] using the equation:

$$SAR = [Na^+] / \sqrt{(1/2([Ca^{2+}]) + [Mg^{2+}])}$$

These three ions compete for uptake by plants and binding sites in soils. Ideally SAR in water should be below 10 ppm for irrigating field production and below 3 ppm for container production. Having the proper ratio is important to ensure adequate uptake and availability in soils. Additionally, SAR above the recommended level in soil will interfere with proper aggregate formation in clay soils leading to problems with soil structure.

All of the issues I've discussed so far would best be dealt with by proper site selection for anyone contemplating expanding or starting a new operation. A comprehensive water test is well worth the initial cost when evaluating a

new site. However, there are many other considerations for site selection that could lead to compromise between the various parameters. Being aware of what it takes to manage poor quality water can help in deciding what and how much to compromise when evaluating the different site selection components. Established operations are stuck with what they have but need to know how to manage the problems. Established operations should also be aware of the

various water resources they may have to tap into. Often there are more than one aquifer layer below ground with different water quality levels. Extracting water from one level may be fine but another problematic. Pathogens are a water quality concern that is only distantly related to site selection. In the next issue we'll look at a few of the methods for sanitizing irrigation water from pathogens.




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3-2	10-18"	\$1.95	\$1.75	3-1/P+1	8-14"	\$1.55	\$1.35	2-1/P+1	8-14"	\$1.45	\$1.25	2-1	8-14"	\$1.25	\$1.10		
<b>Abies balsamea phanerolepis&gt;Canaan Fir</b>				<b>Picea abies&gt;Norway Spruce</b>				<b>Pinus nigra&gt;Austrian Pine</b>				<b>Husky</b>					
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<b>Abies concolor&gt;Concolor Fir</b> <i>*limited crop</i>				<b>Picea glauca&gt;White Spruce</b>				<b>Pinus resinosa&gt;Red Pine</b>				<b>Pseudotsuga menziesii&gt;Douglas Fir</b>					
2-0/3-0	12-18"	\$0.95	\$0.75	2-1	10-16"	\$1.45	\$1.25	2-1	8-14"	\$1.25	\$1.10	3-0	9-15"	\$0.95	\$0.75		
3-1/P+1	8-14"	\$2.50	\$1.95	2-2	15-24"	\$1.85	\$1.65	Husky				2-2	15-24"	\$2.25	\$1.95		
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