Evaluating Water Treatment Technologies to Irrigate Crops With Saline Groundwater

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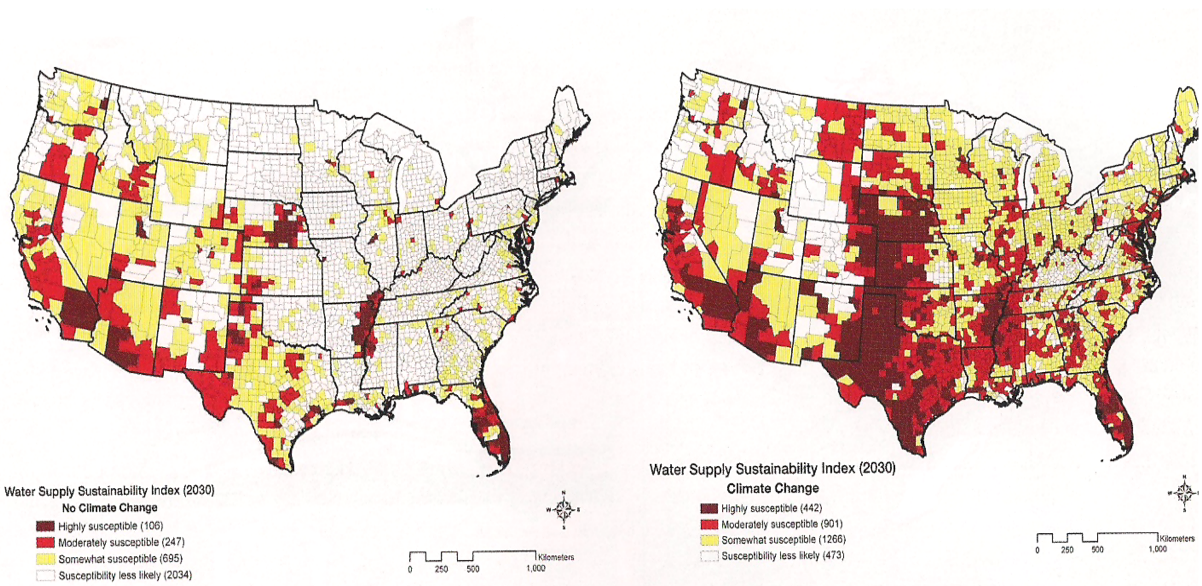
Abstract

Since the 1950's many irrigation experts have reported that low saline groundwater is a vast and underutilized resource in agriculture and that low cost energy water treatment technologies would be needed for its use in irrigation. Over the years, advanced treatment technologies have arisen to increase the benefits from the use of electricity and electromagnetic fields in non-chemical water conditioning or treatment applications along with farmer anecdotal information on crop benefits. However, standardized test protocols have not been developed that could directly measure and validate effectiveness to the marketplace. Over the past 2 years, paired crop production test trials were conducted in Arizona, California, and Texas with treated and untreated (control) low saline groundwater for irrigation of crops to develop standard test protocols. Tests were designed to measure: seed germination, root hair growth, plant growth, seed and seed pod development, plant survival due to drought and exposure to high temperatures in field trial test sites, and subsequent changes in salt cations and nitrogen levels.

FUTURE WATER SUPPLY AND DEMAND

During the 20th century, the global population increased 300 percent while demand for freshwater increased 600 percent. The world's water consumption rate is doubling every 20 years, outpacing by two times the rate of population growth. By 2025, global water demand will exceed supply by 50 percent, due to persistent regional droughts, shifting of the population to coastal cities, and industrial growth. Some regions in the US have seen ground water levels drop as much as 300 to 900 feet over the past 50 years and with no future pumping full recharge is likely to take centuries to millennia.



The above maps are of the calculated Water Supply Sustainability Index for the year 2030 with and without Climate Change Impacts plotted (NRDC, 2010) illustrating the significant impact that climate change will have on the sustainability of water supplies in the coming decades for the middle states of the US. The analysis by Tetra Tech integrating 7 soil and atmosphere moisture models examined the effects of global warming on water supply and demand in the contiguous United States

Impact of Droughts:

Droughts have a natural component that increases freshwater shortages. Floods have minimal benefits because they destroy homes, businesses, infra-structure (e.g., dams, mud slides), farm animals, and crops, where as droughts add uncertainty to rainfall patterns. While freshwater supplies remain relatively flat and water use efficiency improves about 1 percent per year, population growth has soared post WW-II.

Since World War II, advances in irrigation technologies have allowed farmers to extend America's breadbasket through the entire Great Plains, transforming "The Great American Desert" into an expanse of green circles defined by the reach of central pivot irrigation systems. That groundwater for irrigation comes from the Ogallala Aquifer, a massive underground lake that stretches from southern South Dakota through northern Texas, covering about 174,000 square miles.

The Ogallala Aquifer is being drained at alarming rates, and some places have already seen what happens when local levels drop below the point where water can no longer be pumped. When combined with regional droughts and future climate shifts, these water shortages can only expedite the need for low cost energy water treatment technologies for saline ground waters.

Droughts and floods already complicate the prediction of widespread freshwater shortages and should Global Climate Change extend the duration, magnitude, and frequency of droughts and floods, then the water shortages and effects will greatly increase. With increased demand, extreme droughts greatly exacerbate freshwater shortages.

Agriculture, a critical component of the US economy and food and fiber supply, is the major user of ground and surface water in the US accounting for approximately 80 percent of the Nation's consumptive water use and more than 90 percent in many Western States. Groundwater is rapidly becoming more expensive to pump from increased depths. These water shortages have brought about the need to accelerate the development of new freshwater sources, expand reuse, recycled, and the use of more treated saline waters.

For much of the past decade, California has experienced a series of droughts impacting municipal water supplies and putting at risk more than 1/3 of the US food supply that is produced there. Future US water shortages will also limit and drive up the cost of food and energy.

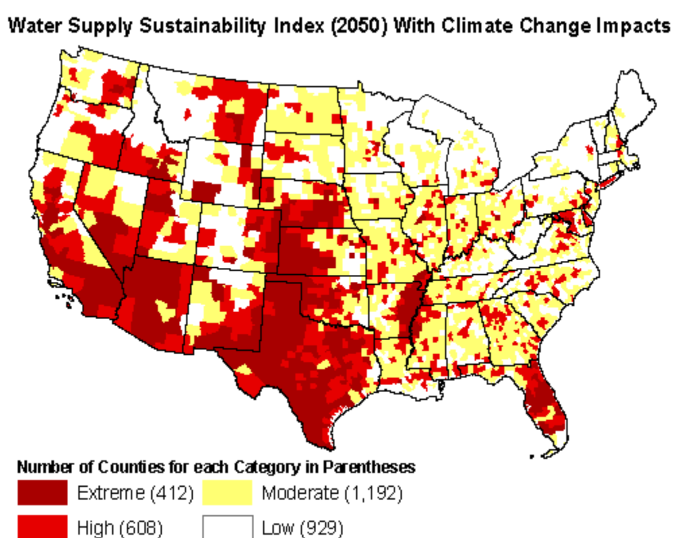
In the US, EPA and USDA for the past decades have focused on the need to reduce water waste by increasing recycling and water use efficiency. Such actions are essential to development of a national freshwater supply management plan but conservation alone is inadequate to solve the problem.

The supply and cost of freshwater is a critical global factor for sustainable development. High water costs impacts every nation’s economy, subsequently preventing them from being able to import goods and services that they need, disrupting global trade and producing a global economic quagmire. An early sign of the crisis will be a rapid increase in the cost of water to reduce use and to keep those freshwater supplies flowing.

Consequences of a widespread freshwater scarcity are far-reaching. Freshwater supply forms the third leg of the ‘economy-energy stool’ and estimates suggest that by 2025 freshwater scarcity will compete with energy as an internationally limited resource.

The continued future depletion of inland and ground water supplies will negate many of the federal and state environmental regulatory gains of the last 50 years: NEPA, CWA, ESA, etc. Freshwater scarcity exists in the arid US West, parts of the South, and now is an issue east of the Mississippi River during periods of drought. Droughts and water shortages have been projected to increase and spread to other regions of the US.

The Map on the right is of the Water Supply Sustainability Index predicted for the year 2050 with Climate Change Impacts, illustrating the significant impact that climate change will have on the sustainability of water supplies in the coming decades. The analysis by Tetra Tech integrating 7 soil and atmosphere moisture models examined the effects of global warming on water supply and demand in the contiguous United States, and found that more than 1,100 counties—one-third of all counties in the lower 48—will face higher risks of water shortages by mid-century as the result of global warming.



Source: National Resources Defense Council. (2010). http://www.nrdc.org/global-warming.watersustainability/

Underutilized & Unmapped Available Low Saline Groundwaters

Groundwater is commonly considered saline if it has a TDS concentration greater than 1,000 mg/L. This arbitrary upper limit of freshwater is based on the suitability of water for human consumption. Although water with a TDS greater than 1,000 mg/L is sometimes used for domestic supply in areas where water of lower TDS content is not available, but water containing more than 3,000 mg/L is generally too salty to drink.

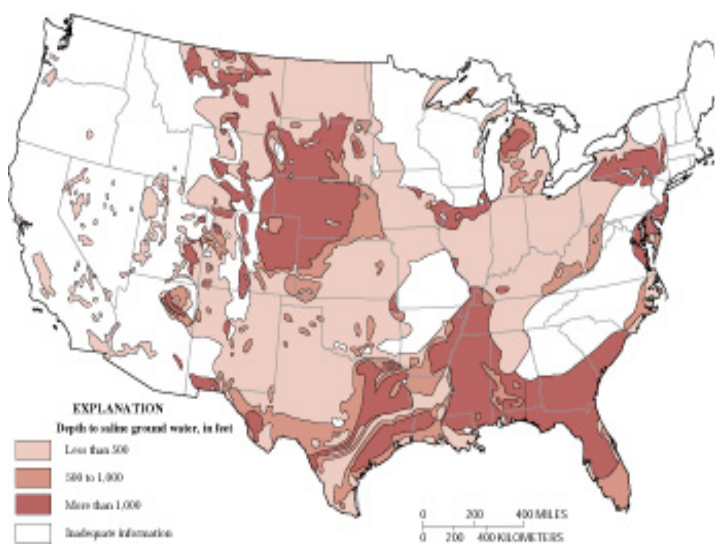
The U.S. Environmental Protection Agency has established a guideline (secondary maximum contaminant level) of 500 mg/L for dissolved solids. Groundwater with salinity greater than seawater (about 35,000 mg/L) is referred to as brine.

Little is known about the areas of most aquifers that contain saline water compared to the areas that contain freshwater, because the ability and the need to utilize saline ground water in agriculture has been limited. Most groundwater resource evaluations have been devoted to establishing the extent and properties of freshwater aquifers, whereas evaluations of saline water-bearing units have been mostly devoted to determining the effects on freshwater movement.

Much of the work to characterize saline groundwater resources in the United States was done in the 1950s and 1960s. Surveys of saline water resources of several States (for example, Winslow and Kister, 1956), and of selected areas within States (for example, Hood, 1963), were published in the late 1950s and early 1960s. Krieger and others (1957) undertook a preliminary survey of the saline water resources of the United States during this period.

Later, Feth and others (1965) prepared a generalized map of the depth to saline groundwater for the conterminous United States. This map provides a preliminary perspective on the location of saline ground-water resources, but provides limited information about critical factors required to understand the development potential of the resources such as aquifer hydraulic conductivity and well yields.

The map to the right presents the depth to saline groundwater in the United States (generalized from Feth and others, 1965), from USGS Fact Sheet 075—03, Oct, 2003.



Saline groundwater's in the US are not desalinated for agriculture because of the expense involved in desalinating these waters by current technologies would be cost prohibitive for there use in irrigation due to the quantities of water needed in agriculture. Development and application of low energy cost technologies that would make these waters suitable for municipal drinking water (less than 500 ppm US EPA Standards) and (less than 1,500 ppm for agriculture (tolerance varies by crop) would greatly increase sustainable economic development and agricultural production in southwestern and western states, and serve as a very useful technology in land reclamation and restoration.

Since the 1950's many irrigation experts have reported that low saline groundwater is an under utilized resource in agriculture. The prohibitive factor has been the salinity and presence of salt cations in these low saline groundwater supplies that place osmotic stress on plants.

New Water Conditioning Devices

The controversy and historical negativity associated with the use and benefits of electricity and electromagnetic fields in non-chemical water conditioning or treatment applications for low saline ground water is extensive. Many investigators have examined the effectiveness of these systems with mixed results. Welder and Partridge (1953), Wilkes and Baum (1979) and Limpet and Arber (1985) presented reviews of operating principles and claims for similar "new generation water conditioning devices." Hunter (2002) provides a similar review for currently available commercial devices, their proposed mechanisms of operation, review of the literature for valid scientific evidence of effective results in laboratory and field application and testing to provide comparative evaluations of comparable technologies to treat scale in water cooling towers.

A peer review paper written by Huchler (2002) presents an overview of the numerous systems using combinations of electrical, magnetic and mechanical means to replace water treatment chemicals. This paper describes devices marketed prior to 2002, their proposed mechanisms of operation, review the literature for clear evidence of effective action in laboratory and field applications and provide recommendations for evaluation in cooling towers where they are primarily used to prevent scaling. The intent of the Huchler paper was not to refute or corroborate claims by manufacturers about the effectiveness of the different devices, but rather to provide:

- An introduction to the current technologies and devices used in cooling and boiler systems,
- Provide descriptions of the mechanical and electrical principles by which they operate,
- Discuss possible mechanisms for action,
- Describe situations in which clear evidence of effective action is demonstrated in lab and field situations, and
- Provide recommendations for evaluating the claims of these devices in field situations.

For several decades people have been looking for a technology to solve problems of deposits of minerals (scaling) in water pipes and pumps. The history of non-chemical water treatment systems (NCWTS) to reduce or eliminate the impact of minerals found in hard water is long and controversial, marked by many claims for and against the effectiveness of NCWTS (Huchler, 2002).

Non-chemical Water Treatment System Terms and Descriptions

There is no single term is used that describes all of these devices. The awkward term "non-chemical water treatment systems" describes a host of technologies including magnetic, electromagnetic, electrostatic, and AC induction. Welder and Partridge (1953) used the term "water conditioning gadgets"; Wilkes and Baum (1979), the term "water conditioning devices." "Physical water treatment" and "electronic water treatment" are also general terms currently used by some proponents of these devices.

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The science of magnetic water treatment is poorly understood as the technologies have evolved by trial and error over the past 20 years and its application for the prevention of scaling and corrosion in cooling towers is debated by two camps, Donaldson and Grimes (1988), and Raisen (1984) have reported positive results from published field studies. However, if one conducts an in-depth search of the literature, one may not find ever one published peer reviewed paper developing specific protocols for testing the effectiveness of any of these technologies, as you would find published by ASTM.

So in the near future, if a farmer is forced to use low saline ground water because of droughts, the problem is how to select the most effective (increase crop production per acre, reduce irrigation water use, reduced fertilizer and nutrient use, increase the health of plants, increase disease resistance, and provide low energy cost COTS (Commercial Off-The-Shelf) technology that can be used to treat low saline ground water and make salt cations less available to plants.

TransGlobal H2o, LLC (TGH2o) in Houston, TX approached me in the fall of 2011 to develop standardized testing protocols to measure the effectiveness of their COTS water treatment technologies for the utilization of low saline groundwater to irrigate crops grown in saline soils in arid regions. The studies began in 2012 with barley (AZ), and added other crops: spinach (CA), greenhouse tomatoes (CA), and pecans (TX), with the following to be developed in the fall of 2013: carrots (CA), and strawberry's (CA), and in 2014 cotton (TX). These field tests were developed as Cooperative Farm Demonstration Projects to prove the benefits of the technologies to large farm enterprises the benefits of the technology as part of TGH2o's ongoing R&D and its marketing strategy.

METHODS AND MATERIALS

In the barley-paired field trials (2012), the following test protocols were utilized:

- Paired Field Trials were irrigated with treated (TGH2o technologies) and untreated (controls) local low saline groundwater (1,500 TDS) for barley seeds in the trails.
- Barley seeds were planted in rows in the designated treated and untreated test plots and the subsequent seed germination, root growth and plant growth data were collected from treated and untreated rows and photographed weekly to determine the plant maturation rates, plant production rates per acre, and subsequent economic benefits.

Paired Field Tests in 2012 to the Present

This past year, paired (replicate) test trial protocols were developed and initiated with treated and untreated (control) low saline groundwater to irrigate spinach (CA) greenhouse tomatoes (CA), and pecans (TX) with TGH2o LLC technologies.

The objectives of these trials were to determine if specific anecdotal information associated with crop benefits that farmers had identified over the past 18 years from using TGH2o water conditioning technologies (Advanced New Patents Pending) could be scientifically measured, and if the physical, chemical and biological processes - mechanisms influencing the effectiveness of this treatment technology, could be determined and optimized.

SUMMARY OF THE RESULTS (Completed 2012 Studies)

As summary of the results (crop benefits) comparing the results defined as crop benefits from barley paired field studies conducted in 2012 under the standardized paired field tests in large field plots from the use of treated and untreated (control) irrigation water:

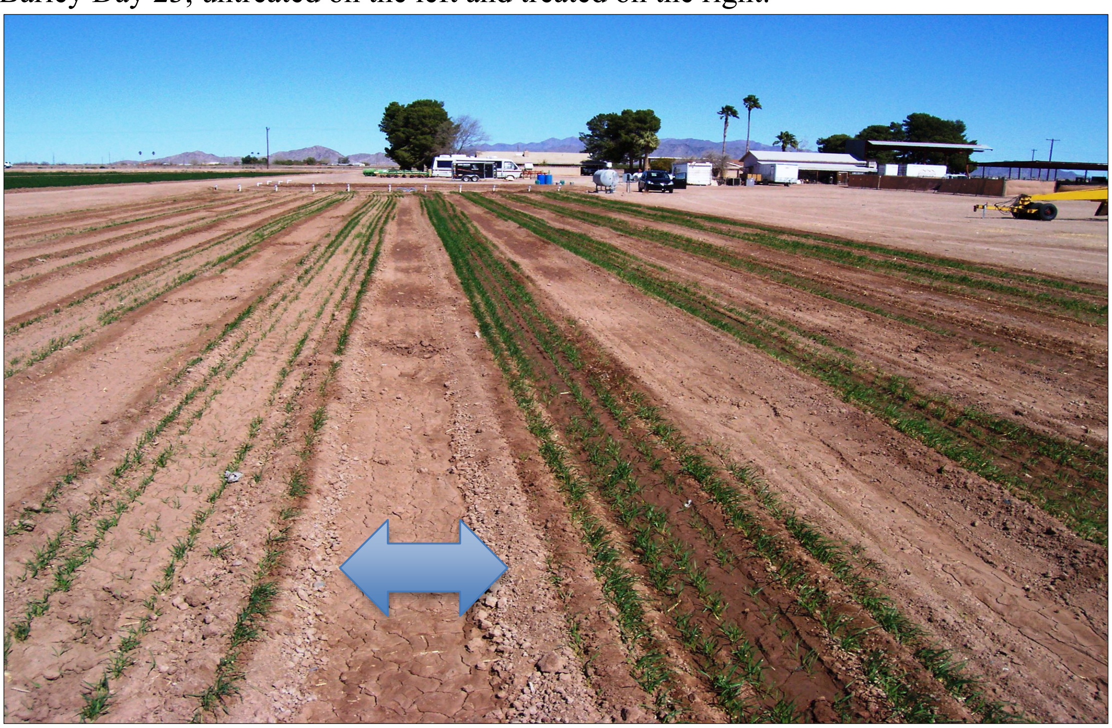
- Faster seed germination ~ 5-7 days – and development of root hairs.
- More seeds germinated ~5 times per unit area.
- Faster root growth ~ 5-7 days. Faster plant growth and leafing out.
- More plants survive seed germination and faster growing plants, more leaves
- Taller plants (2x) bigger leaves, healthier and greener plants
- Faster seed pods germination and seed development in seedpods ~10 days.
- More (1.5x) seeds produced per seedpod.
- Significantly reduced plant death (from osmotic stress) from plants irrigated with Treated water than those irrigated with Untreated water subjected to a two inch rain fall that dissolved into solution soil surface salts deposits from the Untreated water.
- Significantly reduced plant death (desiccation) due to exposure to heat from high air temperatures (112°-118 °F) and in period of high-dry winds in test sites irrigated with Treated water.
- Increased development of nitrogen fixing bacterial and nitrogen levels in soils treated with Treated irrigation water.

To provide visual data of the above results, from these paired field trials, a next series of photographs are presented from the barley (AZ) paired test plots (side-by-side) for the indicated specific stages of plant development and crop production.

Barley seeds Day 7 Following Planting: Germination rate differences. The photograph is of germinating seeds removed from rows watered with treated and untreated (controls) irrigation water that was planted on 2.9.2012 with weekly irrigation.

The right top pair of barley seeds is from untreated irrigation watered rows and show minor development. The three seeds with root hairs are from the rows that were irrigated with treated water. These seeds have begun germination and the formation of root hairs.

Barley Day 23, untreated on the left and treated on the right.



The plants on the right have been irrigated with treated water and have retained some of this water at the surface almost 36 hours longer than those watered with untreated water on the left of the blue arrow, indicating that the treated water has greater surface tension, cohesion and adhesion, less water loss (vaporization) providing more water to the plants on the right.

Barley Day 62: Untreated on the left and treated on the right. Notice: Untreated on the left are not surviving osmotic stress when compared to the plants irrigated with treated water on the right.

Barley Day 62: Close up photo of plants that survived in the untreated rows (left) and the treated rows (right). Notice: In the photo on the left, the row irrigated with untreated water that plant maturation and growth from seeds significantly reduced in density over the width of the row and height (~9 inches), and in the row irrigated with treated water and the plant density is far greater and plant height (~20 inches).

The same kind of results have been found with several varieties of spinach in the studies conducted in California, which found an increase of 15.7% to 17.5% in crop production per acre for an approximate gain of $1,700 per acre. A study in Mexico green houses found over 20% increase in pounds of tomatoes produced in high (9,000 TDS) saline groundwaters. Some preliminary studies with cotton on desert land in AZ where 2+ bales per acre would be considered a good crop using 1,500 TDS low saline water in ditch irrigation achieved almost 5 bales per acre, or approximately 100 boles per linear foot of row.

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