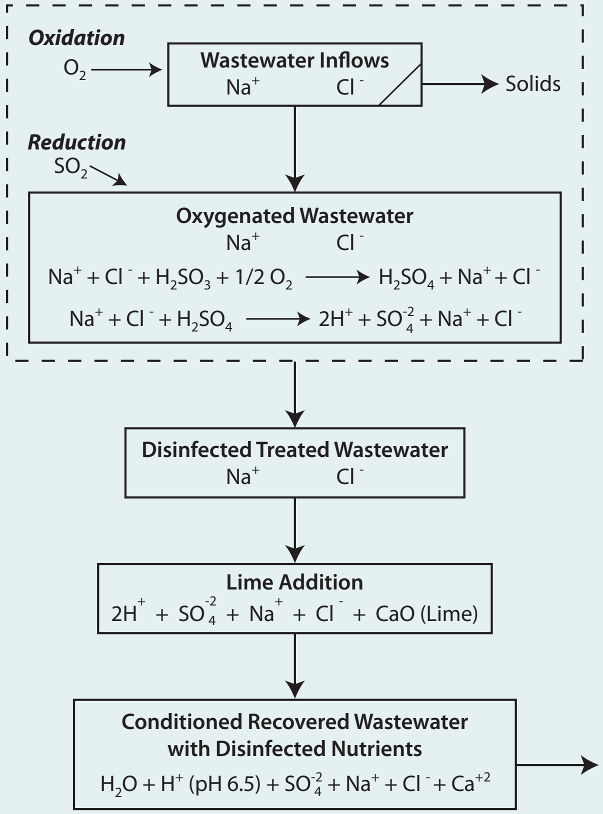
EARTH RENAISSANCE TECHNOLOGIES, LLC

Biobrimstone™ Wastewater Treatment Method Used to Overcome Salinity



The acid prevents the formation of gypsum ($CaSO_4 \cdot 2H_2O$) which could clog the soil pores and allows the soluble bivalent sulfate (SO_4^{-2}) cations to exchange on the soil Cation Exchange sites. This pushes the sodium ions (Na^+) off and allows them to leach downward along with the chloride ions (Cl^-).

1Agronomic Interpretation of the Wastewater Irrigation and Avocado Seedling Growth at the Saticoy - Jose Flores Treatment Facility in the spring and summer of 2008

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The Saticoy - Jose Flores Treatment Facility is located in Saticoy, California. Kelly M. Polk is the District Manager at the Montalvo Municipal Improvement District. This wastewater treatment facility uses the conventional wastewater treatment processes for purification. In this study, the treated wastewater was recovered using a Biobrimstone™ treatment method employing sulfurous acid in combination with lime for oxidation/reduction disinfection and water conditioning before use in a field experiment comparing the growth of avocado seedlings in vertical tubes at the Brokaw Nursery next door to the wastewater treatment facility.

The avocado seedlings were exactly the same variety used by the Brokaw Nursery. Robert Brokaw is the owner of the Brokaw Nurseries, Inc. in Saticoy, California. The nursery agronomist irrigated the normal avocado plants inside the nursery. Sam Garibay is the irrigation manager for the Brokaw Nurseries, Inc. This same nursery agronomist irrigated the avocado seedlings used in this special treatment study. Thus, all crop production conditions were maintained as much as possible in an identical manner for the nursery and for the experimental trial.

Terry Gong works with Harmon Systems International (HSI). Terry previously tested the Biobrimstone™ wastewater treatment technology at Saticoy and at Montalvo. This Biobrimstone™ treatment method may also be used to treat irrigation water. On each of the treatment sampling dates, Terry Gong applied the Biobrimstone™ treatment to the normally aerated wastewater from the Sequence Batch Reactors employed at the Saticoy treatment facility. I visited this site twice during the growth of these avocado seedlings.

This entire experiment was conducted by the Earth Renaissance Technologies, LLC's (ERT) owned by Stewardship Water & Gas Company's (SWAGCO) and Harmon Systems International (HSI). This organization was formed to blend SWAGCO's wastewater treatment technology with HSI's extensive irrigation water and soil conditioning technology to recover and condition wastewater for the end user's agricultural and soil needs. ERT holds key patents on its technology and has accumulated additional related water treatment technology, all of which are the subject of pending patent applications.

Key Participants in this Field Experiment

Kelly M. Polk	District Manager, Saticoy Sanitary District and Montalvo Municipal Improvement District
Mark Capron, P.E.	Ventura Regional Sanitation District
Stan Rush	Operator, Montalvo Municipal Improvement District
Stephen Martin	District Sales Rep, Ten Cate Nicolon
Terry Gong	Partner, Harmon Systems International, LLC
Marcus G. Theodore	CEO, Stewardship Water & Gas, LLC
Larry Wardle	Vice President Stewardship Water & Gas, LLC

Thomas A. Ruehr — Professor, Earth and Soil Sciences Department, Cal Poly State University. San Luis Obispo, CA 93407
Robert Brokaw — Owner Brokaw Nurseries, Inc.
Sam Garibay — Irrigation manager, Brokaw Nurseries, Inc.

Results and Discussion

The concentration of nitrogen, phosphorus, calcium, magnesium, potassium, sodium, sulfur, boron, copper, iron and zinc are in the normal range in the plant tissue (see Table 1). Manganese is slightly elevated in the plant tissue. Overall, the Biobrimstone™ treated wastewater did not adversely affect the overall nutrient quality of the plants.

On June 4, 2008, a strong wind storm during the week had resulted in some visible wind damage on the tips of the avocado leaves. Subsequently, the avocado plants developed the normal secondary new growth typical of the normal avocado seedlings inside the nursery (see Table 2).

The Biobrimstone™ treated water was analyzed during each treatment cycle. Two of the test plants died. However, this is within the normal range of seedling viability for avocados. The average treated irrigation water composition had total nitrogen of 59 ppm N, while the phosphorus was 6 ppm P, calcium was 426 ppm Ca, magnesium was 84 ppm Mg, potassium was 23 ppm K and sodium was 310 ppm Na (see Table 3). The sodium is a result of the sodium in wastewater resulting from sodium soaps and detergents plus the table salt (sodium chloride) used by people on their food. This sodium level did not inhibit the growth of these avocados. The other nutrients were adequate and not in excess.

The treated water had an average composition of anions reflecting 10 ppm carbonate, 52 ppm bicarbonate, 1256 ppm sulfate, 117 ppm chloride, 118 ppm nitrate, 0.4 ppm fluoride, and 1.0 ppm of boron (See Table 4). The Biobrimstone™ treatment process adds sulfur, thereby explaining the slightly elevated sulfate concentration. This sulfate concentration does not present a problem for crop production. In fact, the elevated sulfate will counteract the chloride concentration in plants to some degree. Avocados are very sensitive to chloride. No evidence of chloride toxicity appeared on any of the plant leaves. The nitrate concentration corresponds to about 27 ppm of nitrate-nitrogen. This nitrate serves as an important nutrient to stimulate the avocado seedling growth. The fluoride level and boron level are marginal. Nevertheless, these ions did not result in any inhibition of plant growth.

The treated irrigation water concentrations of metal micronutrients averaged 3.35 ppm copper, 111 ppm of iron, 32 ppm of manganese and 20 ppm of zinc (see Table 5). The iron and manganese levels are higher than usual, but when they are applied to soil or potting mixes, these two metal micronutrients accumulate as iron oxide and manganese oxide. Some of the manganese appears to be absorbed by the avocado roots and was accumulating in the plant tissue. However, the plant concentration was not at a toxic or inhibitory level. The copper and zinc are supplying adequate levels of these elements to the avocado plants. No toxic symptoms appeared on any of the plant leaves, and the plant tissue analyses all are in the normal range.

The general water quality data are summarized in Table 6. The pH of the Biobrimstone™ treated water averaged 6.6. The ideal pH for pH adjusted irrigation water is pH 6.5. The alkalinity was 60 mg/Liter, while the hardness was 1410 ppm. The Electrical Conductivity (EC) of the treated water averaged 3.39 mmhos/cm or dS/m. This value is slightly elevated. As long as water moves downward through the soil or potting mix and does not evaporate or concentrate in the soil, this level is satisfactory for crop production with careful irrigation water management. The Total Dissolved Solids (TDS) was 2554 milligrams per Liter or ppm. This level of soluble salts is related to the electrical conductivity. In this instance, multiplying the EC times 753 results in the value of 2554 ppm. The older literature value was to multiply the EC by 640 to approximate the level of soluble salts. The value of 753 is in the ball park and it is known the value of 640 was actually too low for most natural waters. I normally use a value of approximately 720, which is much closer to the value of 753 as determined in this study. The Sodium Adsorption Ratio (SAR) of this water averaged 3.7. Note the units of SAR are never given even though they are actually milliequivalents per Liter divided by the square root of the milliequivalents per Liter. The SAR is a water quality value closely related to the soil parameter of the Exchangeable Sodium Percentage (ESP). The SAR and ESP have nearly identical values when the magnitude of the value is less than 20. When the SAR reaches a level of about 6 to 9, then growers begin to experience water infiltration problems. However, in this instance, the SAR does not present an irrigation problem for the plants. The avocado plants had 310 ppm Na in the plant tissue (see Table 3). This was not an excessive level, even though avocados are somewhat sensitive to an elevated sodium concentration.

The microbial quality of the Biobrimstone™ treated water was monitored periodically. The treated water had an average of 665 total coliform organisms, but the fecal coliform count was only 2 most probably numbers per 100 mL of treated water. One high value is apparently an artifact. Recall, it is very difficult to maintain pure sterile conditions of sample bottles prior to exposure in the field. Subsequent testing has demonstrated the continued ability to maintain a very low level of fecal coliform organisms in the treated water. The other coliform organisms are probably associated with bird feces (commonly found in coastal regions). No public health threat exists from using this Biobrimstone™ treated irrigation water and no problem is anticipated as a contaminant on the plants. Only plants with a fruit or seeding having a protective coating (husk, peal or rind) and growing at least 2 feet above the soil surface should be raised with this type of recycled Biobrimstone™ treated wastewater.

Conclusions

Avocado seedlings were able to grow and thrive on the Biobrimstone™ treated municipally processed wastewater when used for irrigation. No rain water fell during the entire time of the experiment in Saticoy, California during the spring and summer of 2008.

Plant leaves were not washed prior to nutrient analysis. A slight coating of dust from the nearby road (only infrequently traveled) might account for some of the nutrient concentration in the plant tissue. The nutrients in the treated irrigation water were adequate without being excessive for normal avocado seedling growth.

The potting mix was not analyzed. The sodium adsorption ratio (SAR) and electrical conductivity (EC) were **not** at levels to be considered harmful to plants. The Biobrimstone™ water treatment process reduced the bicarbonate level and brought the treated water pH down to a value of 6.6 (which is nearly ideal). No water infiltration problems are anticipated from the continued use of this treated irrigation water for agricultural purposes.

No apparent salt accumulation occurred in the avocado plants. Avocado plants are sensitive to high chloride, but the chloride and sodium were not a problem in this study. Initially, concerns were expressed about the possible need for sprinkling the plant leaves to remove an excess salt concentration inside the leaf tissue. However, this was not necessary and the avocado seedlings developed normally. The avocado plants in this experiment grew somewhat more slowly than did the control avocado plants raised inside the nursery under the supervision of the same irrigation program.

The Biobrimstone™ treatment of the municipally processed wastewater resulted in a fecal coliform level below the normal level of concern for gray water regulations for recycling of this water on non-edible plants, lawns and golf course areas. This level of fecal coliform reduction was achieved without the utilization of active chlorine.

Thus, the Biobrimstone™ treated municipally processed wastewater supplied nutrients to plants in the applied irrigation water. No hazard occurred from fecal coliforms and the level of EC and SAR were below the levels requiring corrective action. The EC will require careful irrigation management on the long term, but this is possible. No blending of treated water with normal irrigation water was necessary. The pH of the treated water was 6.6. At this pH, the soil pores are maintained in an open condition allowing for adequate salt leaching downward with additional water applications. The nutrient load added to the soil did **not** result in an inhibitory condition to the avocado seedling development. Based on the Saticoy test results, the Biobrimstone™ wastewater treatment method may be used to treat saline municipally processed wastewater or other saline irrigation water and field apply it for non-consumable crop production. This provides a new source of useful irrigation water for the agricultural industry. In a time of scarce water availability and increasing cost of plant nutrients, the Biobrimstone™ treatment provides a useful alternative to the purchase of additional fertilizer and expensive normal irrigation water.

If people are concerned or have questions, I may be contacted by e-mail at my Cal Poly address (truehr@calpoly.edu).

Saticoy - Jose Flores Treatment Facility

Table 1. Plant nutrient data for wastewater irrigation at the Saticoy - Jose Flores Treatment Facility in the spring and summer of 2008.

	Nitrogen	Phosphorous	Calcium	Magnesium	Potassium	Sodium	Sulfur	Boron
	Total							
	%	%	%	%	%	%	%	ppm
Avocado Plant Tissue Analysis								
September 10, 2008	2.54	0.19	1.03	0.38	1.29	0.01	0.35	73

Copper	Iron	Manganese	Zinc
ppm	ppm	ppm	ppm
13	166	177	39

Table 2. Avocado plants were transplanted on May 12, 2008 and subsequent height and appearance during the summer of 2008.

Date	Height Comments	Appearance
	inches	
May 12, 2008	7	new clonal seedlings
May 21, 2008	12	healthy
May 28, 2008	16	healthy
June 4, 2008	16	wind tip damage
June 15, 2008	16	starting to second growth
July 9, 2008	18	healthy second growth
	NH_4OH added	
July 24, 2008	19	healthy second growth
	NH_4OH added	
August 5, 2008	19. to 22	healthy second growth
	NH_4OH added	
September 17, 2008	24	healthy second growth
	NH_4OH added	

Table 3. Nutrient Data for Irrigation Water at the Saticoy - Jose Flores Treatment Facility in the spring and summer of 2008.

Sample	Date	Nitrogen Total	Nitrogen Nitrate + Nitrite	Nitrogen Kjeldahl N	Phosphorous	Calcium	Magnesium	Potassium	Sodium
		mg N / L	mg N / L	mg N / L	mg P / L	mg Ca / L	mg Mg / L	mg K / L	mg Na / L
Treated Effluent									
	June 12, 2007	5	3.0	2	2	177	68	23	315
	May 12, 2008	50	12.9	40	9	158	85	18	350
Batches with SO_2									
1	May 12, 2008	80	5.1	70	10	241	131	20	379
2	May 21, 2008	17	2.4	15	5	393	96	23	350
Leftover water:									
2	June 4, 2008					456	109	26	321
3	June 4, 2008	13	6.3	7	5	337	81	25	319
4	June 18, 2008	13	5.5	8	4	434	71	24	344
5	August 8, 2008	129	49.7	70	8	343	86	24	374
6	September 13, 2008	70	53.9	70	5	837	75	25	201
7	September 17, 2008	90	58.0	30	5	395	51	23	200
Batch Averages		59	25.8	38	6	426	84	23	310

Table 4. Anion Nutrient Data for Water at the Saticoy - Jose Flores Treatment Facility in the spring and summer of 2008.

Sample	Date	Carbonate	Bicarbonate	Sulfate	Chloride	Nitrate	Fluoride	Boron
		mg CO3 / L	mg HCO3 / L	mg SO4 / L	mg Cl / L	mg NO3 / L	mg F / L	mg B / L
Treated Effluent								
	June 12, 2007	< 10	390	840	110	13.5	0.2	0.85
	May 12, 2008	ND	140	1180	100	81	0.3	1.1
Batches with SO_2								
1	May 12, 2008	ND	ND	1710	109	22.3	0.4	1.2
2	May 21, 2008	< 10	< 10	1780	120	10.4	0.4	0.9
Leftover water:								
2	June 4, 2008	< 20	< 20	2410	120	10.5	0.4	1.0
3	June 4, 2008	< 10	<10	1840	120	28	0.5	1.0
4	June 18, 2008	ND	50	1250	120	26.6	0.6	1.0
5	August 8, 2008	< 10	110	1570	130	219	0.5	1.1
6	September 17, 2008	ND	70	970	110	262	0.3	0.9
7	September 17, 2008	< 10	60	920	110	259	0.1	0.7
Batch Averages		10.0	51.7	1255.7	117.0	118.2	0.4	1.0

Table 5. Micronutrient Metal Data for Water at the Saticoy - Jose Flores Treatment Facility in the spring and summer of 2008.

Sample	Date	Copper	Iron	Manganese	Zinc
		mg Cu / L	mg Fe / L	mg Mn / L	mg Zn / L
Treated Effluent					
	June 12, 2007	0.02	0.1	0.02	0.08
	May 12, 2008	ND	110	70.00	ND
Batches with SO_2					
1	May 12, 2008	ND	220.00	150.00	40.00
2	May 21, 2008	0.04	1.40	0.06	0.04
Leftover water:					
2	June 4, 2008	0.05	1.30	0.07	0.05
3	June 4, 2008	< 0.01	0.59	0.03	0.03
4	June 18, 2008	< 0.01	0.27	0.03	0.05
5	August 8, 2008	< 0.01	0.16	0.06	<.02
6	September 13, 2008	20.00	560.00	70.00	100.00
7	September 17, 2008	< 0.01	0.25	0.02	0.04
Batch Averages		3.35	111.81	31.46	20.03

Table 6. Water Quality Data for Irrigation Water at the Saticoy - Jose Flores Treatment Facility in the spring and summer of 2008.

Sample	Date	pH	alkalinity	total hardness	E.C. ‡	TDS §	SAR ¶
			mg / L	mg / L	mmhos / cm dS / m	mg / L	
Treated Effluent							
	June 12, 2007	7	320	720	2.46	2000	5.1
	May 12, 2008	7.2	110	744	3.00	2110	5.6
Batches with SO_2							
1	May 12, 2008	6.2	ND †	1140	3.72	2610	4.9
2	May 21, 2008	7.9	ND	1380	3.57	2770	4.1
Leftover water:							
2	June 4, 2008	3.2	ND	1590	4.34	3450	3.5
3	June 4, 2008	6.4	ND	1170	3.64	2750	4.0
4	June 18, 2008	6.9	40	1370	3.18	2320	4.0
5	August 8, 2008	6.3	90	1210	4.06	2860	4.7
6	September 13, 2008	6.4	60	2400	2.94	2550	1.8
7	September 17, 2008	6	50	1200	2.67	2020	2.5
Batch Averages		6.6	60	1410	3.39	2554	3.7

† ND = Not detected
‡ E.C. = Electrical Conductivity
§ TDS = Total Dissolved Solids
¶ SAR = Sodium Adsorption Ratio

Table 7. Microbiological Evaluation for Irrigation Water at the Saticoy - Jose Flores Treatment Facility in the Spring and Summer of 2008.

Sample	Characteristic	Date	Coliforms Total	Coliforms Fecal
			MPN † / 100 mL	MPN / 100 mL
Treated Effluent				
		April 15, 2008	< 2	< 2
		May 12, 2008	50	< 1
		June 18, 2008	158	6
Batches with SO_2				
1		May 12, 2008	119	2
2		May 21, 2008	27	< 1
2	Leftover water	June 4, 2008	> 2420	2
3		June 4, 2008	16	< 1
4E	Raw Effluent	June 18, 2008	158	6
4		June 18, 2008	16	< 1
5E	Raw Effluent	August 8, 2008	> 2420	18
5		August 8, 2008	649	5
6E	Raw Effluent	September 13, 2008	> 2420	> 2420
6		September 13, 2008	1410	1
7E	Raw Effluent	September 17, 2008	> 2420	> 2420
7		September 17, 2008	> 2420	30
		** statistically disregarded		
Batch Averages			665	2

† MPN = Most Probable Number of microorganisms.