The Impacts of Salinity on Reuse Irrigation

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The City of Hollywood (COH) operates the Southern Regional Wastewater Treatment Plant (SRWWTP) located in Broward County, Florida. This facility is permitted to treat 50 mgd annual average daily flow (AADF), with a permitted discharge into deep injection wells and the Atlantic Ocean through an ocean outfall. Being in a coastal community, the collection system is subject to salt water intrusion, and although an infiltration/inflow reduction program has been implemented, the total elimination of salt water intrusion is not considered feasible. The facility is also permitted to provide effluent disposal for the Town of Davie and City of Cooper City (D/CC), which makes up much of the City's reclaimed water.

Reclaimed water is provided to major irrigation users within the Hollywood limits, which are primarily golf courses, through a permitted 4-mgd public access reuse system. The reuse system is supplied by using the lower salinity effluent from Davie/Cooper City that discharges to a wet well at the SRWWTP. It can be used for reuse, with the remainder overflowing to the effluent pump station, where it combines with treated effluent from the SRWWTP and concentrate from the water treatment plant for ultimate disposal via deep well injection or surface water discharge. The effluent diverted to the reuse facilities is then filtered and chlorinated to meet high level disinfection requirements prior to distribution. The SRWWTP has an effluent filtration capacity of 8 mgd with two discrete filter banks. The facility also provides filtration and disinfection to a portion of the higher salinity SRWWTP effluent, which is directed to on-site non-potable water for wash-down, foam control, chemical blending, and other uses.

With the renewal of its wastewater treatment plant permit in 2007 and proposed regulatory requirements regarding reuse, a reuse master plan was prepared to identify current and potential major reclaimed water users and their demands. The reuse master plan showed that within Hollywood's current service area, the maximum potential reuse demand from all current and potential large reuse customers was approximately 12 mgd, which is about 25 percent of the permitted plant flows.

The recent passage of Senate Bill 1302, known locally as the Outfall Rule Change, became effective July 1, 2008. It requires that 60 percent of the facility flows be reused for beneficial purposes, and that the use of outfalls for wastewater disposal be restricted to wet weather flows from permitted reuse systems by 2025. This will be problematic for Hollywood since its current effluent has higher conductivities and/or salinities than recommended for reuse irrigation.

In looking at options to meet this requirement, a pilot study was performed to evaluate the impact of the higher saline effluent, with blends of lower saline effluent compared to potable water to determine the impact of these water sources used for irrigation on typical landscape species and turf grasses.

Materials and Methods

In order to evaluate the impact of the high salinities on the different landscape species, a plan of study was developed to conduct a field demonstration experiment on the grounds of the SRWWTP. The plan outlined a schedule, layout, plant species, irrigation treatments and blending tables, watering schedule, maintenance and monitoring requirements, and equipment necessary to carry out the study. A meeting was held with Hollywood staff prior to the study to review the different roles necessary to carry out a successful study.

Twelve plots were established that consisted of smaller subplots used for planting various species of locally obtained turf grasses, trees, and shrubs, using the six different irrigation treatment levels. Six plots were used for spray irrigation of turf grasses (See Figure 1) and six plots were used for drip irrigation for trees and shrubs. Plot replicates were randomly arranged to negate localized influences, as shown in Figure 2.

The salinity of the irrigation treatment levels consisted of: a control using potable water with a mean conductivity of 0.3 dS/m; Davie/Cooper City low saline reclaimed water with a conductivity of approximately 1 dS/m; Hollywood high saline treated effluent, which ranged between 1 and 6 dS/m; and three

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Figure 1 – Spray Irrigation of Grasses

Figure 2 - Plot Configuration at the SRWWTP

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blends of the Hollywood and Davie/Cooper City effluent to provide target conductivities of 2, 3, and 4 dS/m. The actual conductivities of the blends during the pilot study slightly were different than anticipated due to the lower conductivity of the Hollywood effluent. This resulted in Blend 1 having an average conductivity of 2 dS/m, Blend 2 having an average conductivity of 2.5 dS/m and Blend 3 having an average conductivity of 3 dS/m. The conductivity variability of the Hollywood effluent compared with the Control and Davie and Cooper City is shown in Figure 3.

Table 1 provides a summary of the tree, shrub, and plant species that were utilized in the study. It should be noted that during the study it was discovered that the landscape supplier had substituted Star Jasmine (a more salt tolerant species) for Orange Jessamine, which had not been available. Upon exhibiting no significant difference in growth within the first six months, it was decided to replace the Star Jasmine with Gardenia, known for having a low salt tolerance.

In developing the plots, grass and other vegetation were cleared prior to planting. The soil texture was tested and found to be a sandy loam. In order to provide a consistent soil base for all of the plots, the onsite soil was loosened and mixed with an enriched soil mixture recommended by the soil testing lab. The area was also disked prior to planting with weed control applied to eliminate any nuisance species. Sod, trees, and shrubs were planted with a two-inch layer of mulch in between the plots to discourage regrowth of any weeds.

The landscape species were initially irrigated with potable water or reclaimed water to establish the species prior to the application of saline water on the test plant species. Once the plantings were established, irrigation with the different treatment levels commenced in June 2009. The plots were irrigated once per week with approximately 300 gallons per plot and per irrigation event. This resulted in an application rate of approximately two inches per week. The study was initially to be conducted for a six-month period. However, after the first six months with no significant impacts to growth noted among the different plots, the study was continued for an additional six months to verify that these results were not due to the seasonal summer rainfall during the first half of the study.

Results

The plots were irrigated approximately once per week with the various irrigation treatment levels and measurements of turf grass weight, and tree and shrub dimensions were taken throughout the study period. The Control, Davie/Cooper City, and Hollywood irrigation waters were all analyzed for total dissolved solids (TDS), total suspended solids (TSS), chlorides, nitrates, sodium, magnesium, calcium, total nitrogen, total phosphorus, potassium, and conductivity on a monthly basis to characterize the waters.

The Sodium Absorption Ratio (SAR), which is the proportion of sodium ions compared to the concentration of calcium plus magnesium, was also calculated. Soils with an excess of sodium compared to calcium and magnesium can result in conditions that are not conducive to growth. A SAR greater than 15 can result in the plants having difficulty in absorbing water. Based on the average values for Hollywood, the SAR was well below 15 for all the irrigation waters, which is considered acceptable for coarse textured sandy soils. Soils that have a finer texture (e.g., silty clay loam) can experience permeability problems when waters having a SAR greater than 9 are applied (Water Reuse Foundation, Salinity Management Guide, 2007).

Table 2 provides a summary of the average water quality data of the Control, Davie/Cooper City, and Hollywood effluents. The water quality of Blends 1 through 3 were a range between the water qualities of Hollywood and Davie/Cooper City, depending upon the fraction of each that was used to make up the respective blend. In reviewing the water quality compared to the control, it should be noted that these waters did have much higher concentrations of calcium, magnesium, nitrogen, nitrate, potassium, and phosphorus—all essential plant nutrients.

Periodic inspections of the site were made over the course of the study. During these visits, weed infestations were noted and recommendations for weed removal and fertilization were provided. The plots were fertilized once during the study (September) with a granular 12-4-8 (12 percent nitrogen, 4 percent phosphorus, 8 percent potash) fertilizer, using approximately 8 ounces spread evenly on each plot for the grass plots. The shrubs were fertilized with granular 6-6-6 (6 percent nitrogen, 6 percent phosphorus acid, 6 percent potash) fertilizer, with approximately 2.6 ounces around the root zone of each shrub. The trees were fertilized with approximately 5.2 ounces of dry granular 6-6-6 fertilizer material per tree around the root zone.

Rainfall was also monitored during the study and Table 3 provides a summary of the rainfall data for Broward County in comparison to the 30-year average. In reviewing the

Table 1: Plant Species

Scientific Name	Common Name
Turf Grasses	
Cynodon dactylon	Bermuda Grass
Paspalum vaginatum	Seashore Paspalum
Stenotaphrum secundatum	St. Augustine Grass
Shrubs	
Hamelia patens	Firebush
Trachelospermum jasminoides	Star Jasmine
Psychotria nervosa	Wild Coffee
Schefflera arboricola	Dwarf Schefflera
Gardenia jasminoides	Gardenia
Trees	
Coccoloba diversifolia	Pigeon Plum
Conocarpus erectus	Green Buttonwood
Simarouba glauca	Paradise Tree
Swietenia mahagoni	West Indian Mahogany

Table 2: SRWWTP Pilot Study Water Quality Data Summary

Parameter	Units	Control	D-CC	COH
Conductivity	dS/cm	0.3	1.0	3.3
pH	SU	8.63	6.80	6.83
Chlorides	mg/L	34	179	844
Total Dissolved Solids	mg/L	156	562	1906
Total Suspended Solids	mg/L	1.85	2.01	4.21
Chlorine Residual	mg/L	2.05	0.84	0.54
Hardness	mg/L	65	155	416
Sodium	mg/L	26.5	124.8	384.7
Calcium	mg/L	23.7	46.7	99.4
Magnesium	mg/L	2.1	10.5	44.1
Total -Nitrogen	mg/L	0.9	17.0	13.6
Nitrate-Nitrite	mg/L	0.6	14.9	9.0
Total Potassium	mg/L	2.3	12.7	22.3
Total Phosphorus	mg/L	0.2	1.6	1.2
SAR	--	1.4	4.0	8.3

Table 3: Broward County Rainfall

Month	Actual Rainfall	30 Yr. Avg.
Jun-09	15.57	8.91
Jul-09	3.38	6.04
Aug-09	6.95	7.41
Sep-09	6.78	7.70
Oct-09	1.70	5.57
Nov-09	1.55	3.55
Dec-09	3.76	2.21
Jan-10	0.95	2.34
Feb-10	2.94	2.47
Mar-10	7.51	2.78
Apr-10	5.57	3.32
May-10	2.60	5.35
Total	**59.26**	**57.65**

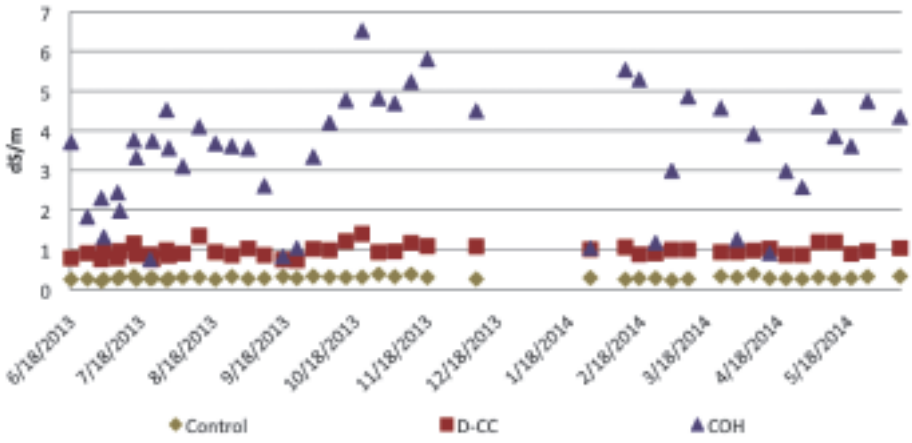

Figure 3 – Conductivity of Various Irrigation Waters

data, it appears that during the pilot study period, the actual rainfall was slightly above average, with considerable rainfall at the beginning of the study period. However, the rainfall overall was comparable to the 30-year average. The significant rainfalls that did occur at the beginning of the study, and during the months of March and April, may have resulted in reducing the impact of the higher salinity waters.

The pilot study was conducted from June 2009 to June 2010, with the planting done in March 2009. However, due to higher rainfalls during the initial months, irrigation with the different treatment levels did not commence until June 2009. Initial tensiometer readings were taken by Hollywood staff to monitor soil water status. This was performed to determine the best time to commence irrigation and avoid overwatering. Once a watering schedule was established, routine tensiometer readings were discontinued.

Plant growth was evaluated over a one-year period to determine the degree of impact the higher salinity Hollywood effluent would have on different plant species, and to determine if there was an optimum blend of Hollywood and Davie/Cooper City water for the

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Table 4: Percent Growth Over Study Period for Shrubs

Shrubs	Blend 1	Blend 2	Blend 3	D/CC	COH	Control
Firebush	127%	110%	86%	101%	123%	92%
Wild Coffee	21%	46%	6%	25%	58%	38%
Star Jasmine	15%	22%	10%	9%	20%	8%
Gardenia	20%	14%	21%	20%	47%	32%
Dwarf Schefflera	121%	46%	44%	32%	137%	69%

Table 5: Percent Growth Over Study Period for Trees

Trees	Blend 1	Blend 2	Blend 3	D/CC	COH	Control
Pigeon Plum	20%	24%	26%	16%	59%	49%
Green Buttonwood	79%	77%	71%	75%	82%	56%
West Indian Mahogany	16%	45%	29%	39%	61%	105%
Paradise Tree	5%	29%	12%	23%	50%	31%

Table 6: Cumulative Dry Grass Weight (grams)

Grasses	Blend 1	Blend 2	Blend 3	D/CC	COH	Control
Bermuda	6112	2188	3039	3971	2189	1601
St. Augustine	10,909	5988	6887	6996	4235	4849
Paspalum	4112	1276	2028	2440	1714	268

Figure 4 – Plot Configuration

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different plant species. The grasses were mowed and weights of the mowed material measured at a minimum of once per month, depending on growth. The trees and shrubs were measured monthly, with the height and spread recorded to determine mean growth. During the study, all the Seashore Paspalum died on all of the plots and were replanted approximately six months into the study. This may have been due to the weekly watering schedule since Paspalum require frequent watering.

In evaluating the conductivity of the Hollywood effluent there was considerable variabilty in the effluent conductivity but no significant trends noted. This is likely due to the hydraulic arrangement of the effluent pump station which receives Davie/Cooper City overflow when the customer demand for reuse water is low.

The overall growth of the landscape species observed during the pilot study from June 2009 through May 2010 is summarized, with Table 4 providing the percent change in growth for the shrubs and Table 5 showing the similar percentage for the trees. The growth was recorded monthly by calculating the size index for each plant, the average spread (growth in x and y direction) plus the height, and taking the mean of the individual plant growth for each species. The tree growth was calculated based on height and taking the mean for each species. The percent change was then calculated based upon the final growth minus the initial growth for each of the landscape shrub and tree species.

The growth for the grasses was determined by calculating the mean dry weight of the grass clippings for each of the test plots and calculating the cumulative weight of the clippings over time. The calculated total dry weight of the clippings over the study period is shown in Table 6.

Conclusions

The results of the pilot study generally indicate that the trees and shrubs species treated with irrigation effluent with conductivities often above 3 dS/m were not significantly different from that of the plants that received the control irrigation water using drip irrigation. It was also noted that the Hollywood conductivity varied significantly, and although it had an average of 3.3 dS/m, it was often below 3 dS/m, as well as being above 5 dS/m.

The pilot study also indicated that there was no significant variation in the growth of the grasses between the lower conductivity control and the Davie/Cooper City effluent than with the Hollywood effluent. The control had the lowest growth recorded for Paspalum

and the Bermuda grasses, which may have been due to the lower nutrient levels in the potable water. Blend 1 appeared to have the greatest growth for all three grass types, followed by the other irrigation treatment levels. It is unknown why Blend 1 resulted in better growth compared to the other irrigation blends since it was comprised of Davie/Cooper City and Hollywood water with an average conductivity of approximately 2 dS/m. This may have been due to the configuration of different plots and the drainage of the site shown in Figure 4, with Blend 1 being closer to the road and at a higher elevation. The plots used for irrigation for the Control and Hollywood effluent were also located at a slightly lower elevation and may have been subject to a higher groundwater table as well.

Based on the study results, it does appear that higher saline effluent can be utilized periodically for reuse irrigation, provided the soils are sandy in nature and that the salinity is not too high to cause detrimental discoloration of the leaves. The higher saline effluent applied to the different trees, shrubs, and grasses did not cause any measurable or significant negative impacts to the different landscape plant species or grasses during the course of the study. However, additional study is needed to evaluate what the long-term impacts of spray irrigation would be on the trees and shrubs since higher saline waters can cause discoloration to the leaves. The soils must also be taken into consideration when applying a more saline effluent since past studies have shown that plants grown in sandy soils can handle waters with a higher SAR than soils with higher clay contents.

Additional study is also needed with respect to turf grass before a definitive blend ratio is implemented. In determining the optimum blend, groundwater impacts must also be considered to ensure that the application of the reclaimed water does not negatively impact local groundwater. The drinking water standards applicable for groundwater in the area are 160 mg/L, 250 mg/L, and 500 mg/L, for sodium, chloride, and TDS, respectively.

When considering the impacts to groundwater, the rainfall should be taken into consideration. With an average rainfall of 1-in/wk or 52-in/yr, a groundwater dilution of approximately 35 percent would be achieved if irrigation were consistently performed at 2-in/wk. The Hollywood effluent, with an average concentrations of 384 mg/L sodium, 844 mg/L chloride, and 1,906 mg/L TDS, would likely exceed these standards, depending upon plant uptake and soil interactions.

The results of the study are best illustrated in Figures 5, 6, and 7, which show the initial Davie/Cooper City plots, followed by the Control and Hollywood plots at the end of the study.

Figure 5 – Initial Plots at Beginning of Study

Figure 6 – COH Plot at End of Study

Figure 7 – Control Plot at End of Study