Evaluation of Treated Effluent as an Irrigation Source for Landscape Plants[1]

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Abstract

Treated effluent from the Hampton Roads Sanitation District (HRSD) Virginia Initiative Plant (VIP) was evaluated in 2000 and 2001 as an irrigation source for landscape plants. Landscape plants common to eastern Virginia were installed in raised beds and overhead irrigated at the rate of 2.5 cm (1 in) per week for five months. Aesthetic quality ratings, and soil and water analyses, were conducted monthly. Aesthetic quality ratings were lower on certain plants irrigated with treated effluent in both years of the study. Damage appeared to result from foliar contact by irrigation water high in dissolved salts. Soil tests showed salt accumulation in the planting soil. Damage that occurred on plants irrigated with treated effluent was species specific and included leaf burn, chlorosis, defoliation, stunting, and death. All symptoms were consistent with and typical of salt damage. Salt concentrations in this treated effluent were too high to allow use of this water as an overhead irrigation source for many landscape plants without further treatment or dilution. Irrigation with treated effluent should be based on landscape species composition, local climate conditions, and irrigation method.

Index words: municipal waste water, non-potable, reclaimed water, reuse water, salt tolerance, sewage effluent, wastewater, water management, water quality.

Significance to the Nursery Industry

A potential supplemental or alternative irrigation source for the nursery and landscape industries is treated effluent from municipal wastewater treatment plants. Valuable fresh (potable) water supplies can be conserved by using treated effluent (non-potable water) to irrigate golf courses, parks, school athletic fields, and nursery plants. Treated effluent is also generally less expensive than potable water (2), which can significantly impact an irrigation budget. A particular concern when using treated effluent for irrigation is plant sensitivity to high concentrations of salt in the water. Many landscape plants exhibit foliar damage, such as burning or chlorosis, when irrigated with treated effluent due to salty irrigation water or drifting spray repeatedly contacting foliage (3,7). Foliar burn or chlorosis and even stunting and plant mortality can be caused by long term irrigation with treated effluent which leads to salt build up in the soil. These studies evaluated 34 species of landscape plants common to eastern Virginia for tolerance to overhead irrigation with treated effluent and found that foliar damage varied widely by species. Federal (14), state, and city water quality standards exist for treated effluent; however, an understanding of the quality of the effluent water, specific site conditions, and species sensitivity is necessary in order to develop guidelines for short and long-term irrigation of nursery and landscape plants with treated effluent.

Introduction

Population growth and industrial development have stretched fresh ('potable') water supplies to their limit in many parts of the United States. Utilizing alternative water sources for nursery and landscape irrigation is a way to conserve finite and essential potable water resources. One alternative water source is treated effluent (also commonly referred to as non-potable or reclaimed water); the treated liquid product of municipal wastewater treatment plants. While irrigat-

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ing landscapes with treated effluent is common practice in states like Florida and California (2), Virginia is just beginning to seriously explore the potential for treated effluent as an alternative water source for landscape irrigation. In addition to conserving potable water resources, using treated effluent for irrigation could also impact waste water disposal, water use restrictions, and irrigation budgets. Some treated effluent may also contain nutrients essential for plant growth. If water quality is good, treated effluent can improve landscape plant growth and reduce fertilizer requirements (5, 13).

Water quality is extremely important when deciding whether treated effluent is a viable irrigation water option (8). A particular concern when using treated effluent for irrigation is soluble salt concentrations. Salt tolerances vary among landscape plant species, and can even vary from one cultivar to another (1, 4, 9, 10). Some plants, such as Chinese juniper (*Juniperus chinensis*), tolerate very high salts, while others, such as red maple (*Acer rubrum*), are sensitive to low salt concentrations (3, 15). Landscape plant sensitivity to salty irrigation water can influence plant selection, irrigation method, and frequency. Salt concentrations, mainly from sodium (Na), chloride (Cl), and bicarbonate (HCO_3) ions, should be carefully monitored because treated effluent can have concentrations of these salts that are too high for irrigation without further treatment or dilution (1, 7, 9, 12). In addition to these salt ion concentrations, levels of boron and heavy metals should be monitored, since they can be toxic to some plant species at low concentrations. The effluent treatment process should also kill all potential plant and animal pathogens to ensure human safety when the effluent is used for irrigation.

One method for evaluating the suitability of treated effluent water for irrigation involves testing for electrical conductivity (EC). Electrical conductivity of water is directly related to total salt ion concentration. An EC of less than 0.75 dS/m (mmhos/cm) is generally safe for most landscape plants (1, 6, 9). Water tests should be done regularly because the quality of treated effluent water at some wastewater treatment facilities varies over time. Though EC levels give a general guide to water quality, individual ion concentrations, especially Na, Cl, and HCO_3, still need to be monitored.

Soil drainage characteristics and composition of soil can influence the severity of plant damage from irrigation water with high salt content. For example, clay soils and soils high in organic matter exhibit faster and higher concentrations of sodium buildup than sandy soils (4). Sodium ions in high concentrations can displace calcium and magnesium ions, and bicarbonate ions can destroy soil structure (1, 9, 11). This is especially important when irrigation water with high soluble salts concentrations is applied on a long-term basis.

The type of irrigation system used can affect the severity of plant damage from salty irrigation water. More damage to plants usually occurs with overhead irrigation systems than with drip systems because saline water coats plant foliage repeatedly, burning and desiccating the leaves of sensitive species (3, 9, 12, 15).

Finally, microclimate can influence the severity of plant damage. Regions with moderate temperatures and adequate rainfall have fewer problems than regions that regularly experience high temperatures, low precipitation, or drought. Rainfall washes salts from the irrigation water off plant foliage and leaches salts through the soil profile, reducing or eliminating the potential for salt related damage to plants.

The objective of this research was to evaluate the treated effluent produced by the HRSD VIP as an overhead irrigation source for landscape plants common to eastern Virginia.

Materials and Methods

In January 2000, the HRSD VIP, Norfolk, VA (U.S. Dept. of Agriculture zone 7b), was selected as the test location. The study was set up as a completely randomized design (CRD), with two treatments (potable water and treated effluent) and three replications. In March 2000, six raised beds measuring 4.9 m × 4.9 m × 37 cm deep (16 ft × 16 ft × 12 in) were constructed of pressure treated lumber. Each bed was filled with 6.9 m^3 (9 yd^3) of sandy loam soil, and pre-irrigation soil samples taken. Plant species that were commonly grown in eastern Virginia landscapes, with a range of susceptibility to damage from soil or foliar salt exposure (4, 7, 10, 12), were selected (Table 1). One of each tree species, two of each shrub species, three of each perennial species, and six of each annual species were planted in each bed. Five centimeters (2 in) of shredded hardwood mulch was applied after planting. No fertilizer was applied to the beds. Weeds were controlled on a weekly basis by hand pulling.

An overhead irrigation system for each bed consisted of Hunter SRS-12 pop-up nozzles in each bed corner, set for 90 degree overlapping patterns. Three beds were connected to a City of Norfolk potable waterline and three beds were connected to a HRSD treated effluent (non-potable) waterline. Irrigation began in early May each year (2000 and 2001). Regardless of rainfall, a total of 2.5 cm (1 in) of water per week was applied to each bed in a split application of twenty minute duration.

An aesthetic quality rating scale was developed in consultation with commercial ornamental plant producers and landscape designers. Plants were visually rated every 30 days from May through October. The same person rated plants both years. An average rating was taken for species with multiple plants. Aesthetic quality ratings were made using a 1 (dead) to 5 (no damage) scale where: 1 = dead plant; 2 = severe damage such as stunting, dead stems, > 50% defoliation, leaf deformity, necrosis; 3 = moderate damage such as visible salt residue on foliage, < 50% defoliation, leaf deformity, necrosis, chlorosis, leaf burn; 4 = slight damage such as chlorosis, tip and/or marginal leaf burn, spotting; 5 = no damage, highest aesthetic quality. From a commercial perspective, aesthetically acceptable landscape plants were those that received a rating of four or five.

Soil and irrigation water samples were collected at the same time visual ratings were assigned, and were analyzed by A&L Laboratories, Inc., Richmond, VA. Soil analysis included organic matter (colorimetric up to 9.9%); available phosphorus, (P1, weak Bray and p2, strong Bray); exchangeable potassium, calcium, magnesium; soil pH; cation exchange capacity (CEC); percent base saturation of cation elements; total soluble salts (TSS); and sodium, sulfate, sulfur, zinc, manganese, iron, copper, and boron concentrations. Irrigation water analysis included sodium, calcium, magnesium, chloride, phosphorus, potassium, boron, sulfate, nitrate, carbonate, bicarbonate, electrical conductivity (EC), pH, total dissolved solids, and sodium adsorption ratio (SAR).

In late October 2000, irrigation was discontinued and all plants were removed from the beds. In April 2001, beds were refilled with sandy loam soil and amended with 7.62 cm (3 in) of compost, which was tilled in to a depth of 30.48 cm

Table 1. Species used.

2000	2001
Annual begonia (*Begonia* x *semperflorens-cultorum* Hort.) annual vinca (*Catharanthus roseus* L. 'Pink Cooler') dianthus (*Dianthus chinensis* L.) geranium (*Pelargonium* x *hortorum* L.H. Bailey) marigold (*Tagetes erecta* L. 'Antiqua Yellow')	**Annual** begonia (*Begonia* x *semperflorens-cultorum* Hort.) dianthus (*Dianthus chinensis* L.) geranium (*Pelargonium* x *hortorum* L.H. Bailey) petunia (*Petunia* x *hybrida* Hort. Vilm.-Andr.) marigold (*Tagetes erecta* L. 'Antiqua Yellow')
Perennial coneflower (*Echinacea purpurea* L. 'Magnus') daylily (*Hemerocallis* L. 'Stella de Oro') liriope (*Liriope muscari* (Decne.) L.H. Bailey 'Variegata') black-eyed Susan (*Rudbeckia fulgida* var. *sullivantii* Boynt. & Beadle 'Goldsturm') sage (*Salvia nemorosa* L. 'May Night') sedum (*Sedum* L. x 'Autumn Joy') verbena (*Verbena canadensis* (L.) Britt. 'Homestead Purple')	**Perennial** coneflower (*Echinacea purpurea* L. 'Magnus') daylily (*Hemerocallis* L. 'Stella de Oro') liriope (*Liriope muscari* (Decne.) L.H. Bailey 'Variegata') black-eyed Susan (*Rudbeckia fulgida* var. *sullivantii* Boynt. & Beadle 'Goldsturm') sage (*Salvia nemorosa* L. 'May Night') sedum (*Sedum* L. x 'Autumn Joy') verbena (*Verbena canadensis* (L.) Britt. 'Homestead Purple')
Shrub butterfly bush (*Buddleia davidii* Franch. 'Nanho Blue') boxwood (*Buxus sempervirens* L. 'Suffruticosa') gardenia (*Gardenia augusta* (L.) Merrill. 'Chuck Hayes') juniper (*Juniperus chinensis* L. var. *sargentii* 'Viridis') dwarf nandina (*Nandina domestica* Thunb. 'Firepower') mugo pine (*Pinus mugo* Turra.) cherrylaurel (*Prunus laurocerasus* L. 'Otto Luyken') azalea (*Rhododendron* L. x 'Delaware Valley White') Japanese spiraea (*Spiraea japonica* L. 'Neon Flash') dwarf viburnum (*Viburnum tinus* L. 'Compactum')	**Shrub** abelia (*Abelia* x *grandiflora* (Andre) Rehd. 'Edward Goucher') barberry (*Berberis thunbergii* DC. 'Crimson Pygmy') butterfly bush (*Buddleia davidii* Franch. 'Nanho Blue') boxwood (*Buxus microphylla* Sieb. & Zucc. 'Wintergreen') red twig dogwood (*Cornus sericea* Michx.) cotoneaster (*Cotoneaster dammeri* Schneid. 'Coral Beauty') forsythia (*Forsythia* x *intermedia* Zab. 'Spring Glory') gardenia (*Gardenia augusta* (L.) Merrill. 'Chuck Hayes') St. John's wort (*Hypericum patulum* Thunb. 'Hidcote') juniper (*Juniperus chinensis* L. var. *sargentii* 'Viridis') dwarf nandina (*Nandina domestica* Thunb. 'Harbor Dwarf') mugo pine (*Pinus mugo* Turra.) cherrylaurel (*Prunus laurocerasus* L. 'Otto Luyken') azalea (*Rhododendron* L. x 'Delaware Valley White') Japanese spiraea (*Spiraea japonica* L. 'Neon Flash') arborvitae (*Thuja occidentalis* L. 'Smaragd') dwarf viburnum (*Viburnum tinus* L. 'Compactum')x
Tree red maple (*Acer rubrum* L.) river birch (*Betula nigra* L.) eastern redbud (*Cercis canadensis* L.) crape myrtle (*Lagerstroemia indica* L. 'Natchez')	**Tree** red maple (*Acer rubrum* L.) river birch (*Betula nigra* L.) eastern redbud (*Cercis canadensis* L.) crape myrtle (*Lagerstroemia indica* L. 'Natchez') crab apple (*Malus* sp. Mill.)

(12 in). A pre-irrigation soil sample was taken for each bed. The beds were then replanted with a new group of landscape plants, the same number per type as in 2000. Irrigation began the first of May.

The study was repeated in 2001 using the same parameters as described for 2000. Many of the same landscape species used in 2000 were used again in 2001, though there were some additions and deletions due to plant availability, results from the previous year, and additional information from the literature.

Data from each year and each species were analyzed separately. Plant quality and soil data after five months of irrigation each year were analyzed using SAS ANOVA (SAS version 8.1, Cary, NC). Treatment means were separated using the LSD test at $P = 0.05$ level of significance.

Results and Discussion

Salinity of the treated effluent (non-potable) water was higher than the potable water in both 2000 and 2001. Electrical conductivity (EC) measurements over the five months of each study were consistently higher for the treated effluent than for the potable water (Fig. 1), with the treated effluent frequently being above the 0.75 dS/m considered safe for landscape plants. Because electrical conductivity is directly related to total salt ion concentrations, sodium (Na), chloride (Cl), and bicarbonate (HCO_3) ion concentrations were monitored. Concentrations of these ions followed the same trend as the EC (Fig. 2). Factors that influenced the elevated salt ion concentrations in the treated effluent water include: the number of industries contributing and quantity of contributed effluent, number and length of stay of naval ships docked at the Norfolk Naval Shipyard, and the specific processes used to treat the effluent (personal communication with George Kennedy, Environmental Scientist, HRSD). Average pH was 7 ± 0.7 for both potable and non-potable water in both years.

Soil in the beds irrigated with treated effluent water had elevated sodium and chloride concentrations both years, but reached the highest concentrations over the treatment period in 2001 (Fig. 3). All other soil criteria were within acceptable ranges (data not shown). Rainfall totals and distribution during the growing period differed considerably between the two years of the study (Fig. 4). In 2000, rainfall amounts were above average for eastern Virginia every month except October. In 2001, rainfall amounts were close to or below

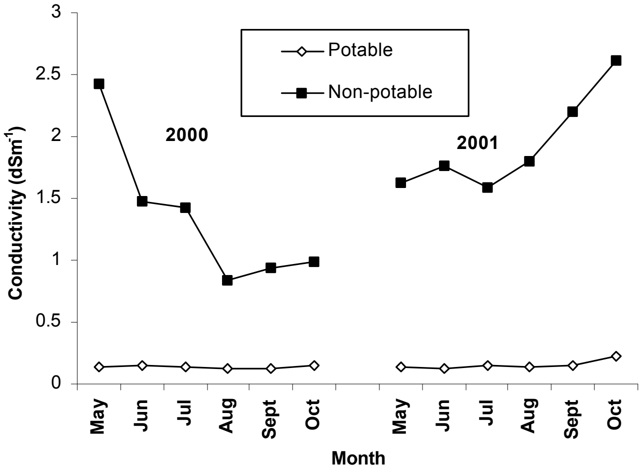

Fig. 1. **Electrical conductivity of potable vs. non-potable (treated effluent) water, 2000 and 2001.**

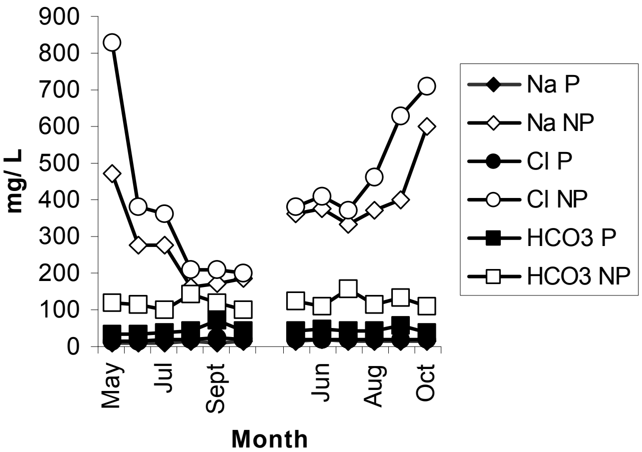

Fig. 2. **Sodium (Na), chloride (Cl), and bicarbonate (HCO_3) concentrations May through October 2000 and 2001, for potable (P) and non-potable (NP) (treated effluent) water.**

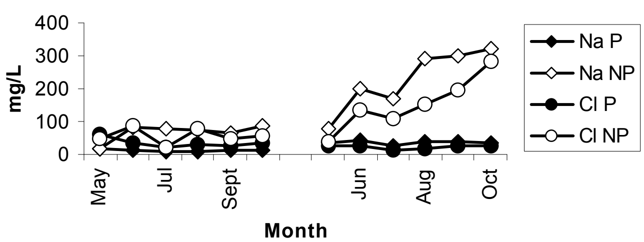

Fig. 3. **Soil sodium (Na) and chloride (Cl) concentrations May through October 2000 and 2001 for beds overhead irrigated with potable (P) and non-potable (NP) (treated effluent) water.**

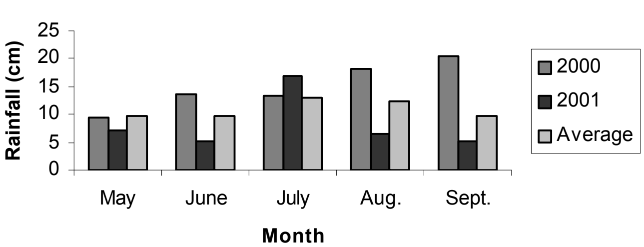

Fig. 4. **Rainfall totals for HRSD VIP 2000, 2001, and City of Norfolk average.**

average except for the month of July. Rainfall events were more evenly distributed through the growing season in 2000 than in 2001 (data not shown).

Visual appearance of landscape plants is very important to landscape designers, managers, and the public. The aesthetic quality rating scale for these studies was developed through consultation with commercial plant producers and landscape designers. Plants were visually rated every 30 days from May through October, with the same person rating plants both years for consistency. An average rating was taken for species with multiple plants. Aesthetically acceptable landscape plants were those that received a rating of four or five.

For 2000, analysis of visual rating data showed significant damage to sedum, crape myrtle, and red maple irrigated with the treated effluent (Table 2). The overall appearance of these plants was unacceptable for landscape use. The remainder of the 26 species in the 2000 trial exhibited minor or no damage symptoms from the treated effluent (data not shown). For 2001, analysis of visual rating data showed significant damage to 26 of the 34 species irrigated with treated effluent (Table 3). Species that died by the end of the season included abelia, azalea, cherry laurel, petunia, and coneflower. Damage symptoms were more severe overall in 2001, observed on more species, and occurred earlier in the season than in 2000. Plants that were damaged were most affected during the hottest and driest part of the summer. Damage severity and timing correlated to rainfall amounts and distribution. In 2000, rainfall quantity was elevated and distribution fairly consistent over the growing season causing soluble salts in the treated effluent irrigation water to be washed off plant foliage and leached through the soil. In 2001, a more typical rainfall quantity and distribution pattern was experienced. Rainfall quantity was lower than in 2000, and distribution was uneven over the growing season with longer intervals between significant rain events. Soluble salts built up on plant foliage and in the soil, causing more severe damage on more species than in 2000.

As evidenced by the observed plant damage, and the supporting soil and water data, the treated effluent from this facility (VIP) is high in soluble salts. Though a very modern sewage treatment facility, the current treatment processes do not reduce salt ion concentrations enough to permit use of this treated effluent as the only source of overhead irrigation for landscape plants. Supplemental irrigation from natural rainfall or a potable water source is necessary to prevent salts from accumulating on plant foliage and in the soil, and to prevent subsequent damage which makes plants aesthetically

Table 2. **Plant quality comparisons by species overhead irrigated with treated effluent, 2000.**

Species	Water treatment	Mean
sedum	P[z]	5.0[y]a[x]
	NP	3.7b
crape myrtle	P	5.0a
	NP	4.0b
red maple	P	5.0a
	NP	2.3b

[z]P = Potable and NP = non-potable water.

[y]Rating scale 1 = dead to 5 = no damage. Ratings of 4 or 5 are aesthetically acceptable landscape plants.

[x]Significance of mean values for quality ratings after five months of irrigation. Means followed by same letter are not significantly different at P = 0.05.

Table 3. **Plant quality comparisons by species overhead irrigated with treated effluent, 2001.**

Species	Water treatment	Mean	Species	Water treatment	Mean
begonia	P[z]	5.0[y]a[x]	cotoneaster	P	5.0a
	NP	3.0b		NP	1.0b
geranium	P	5.0a	forsythia	P	4.7a
	NP	2.0b		NP	2.0b
petunia	P	4.0a	gardenia	P	5.0a
	NP	1.0b		NP	3.3b
black-eyed Susan	P	4.0a	nandina	P	5.0a
	NP	3.0b		NP	3.3b
coneflower	P	4.0a	red twig dogwood	P	5.0a
	NP	1.0b		NP	1.7b
liriope	P	5.0a	spiraea	P	5.0a
	NP	4.0b		NP	4.0b
sedum	P	5.0a	St. John's wort	P	4.7a
	NP	3.7b		NP	2.0b
abelia	P	5.0a	viburnum	P	5.0a
	NP	1.0b		NP	4.0b
arborvitae	P	5.0a	crab apple	P	5.0a
	NP	4.0b		NP	2.0b
azalea	P	5.0a	crape myrtle	P	5.0a
	NP	1.0b		NP	3.0b
barberry	P	5.0a	eastern redbud	P	4.3a
	NP	3.0b		NP	1.7b
butterfly bush	P	5.0a	red maple	P	4.7a
	NP	2.0b		NP	2.0b
cherrylaurel	P	4.7a	river birch	P	5.0a
	NP	1.0b		NP	3.0b

[z]P = Potable and NP = non-potable water.
[y]Rating scale 1 = dead to 5 = no damage, ratings of 4 or 5 are aesthetically acceptable landscape plants.
[x]Significance of mean values for quality ratings after five months of irrigation. Means followed by same letter are not significantly different at $P = 0.05$.

unacceptable in the landscape. Careful consideration should be given to initial and replacement plant selection when overhead irrigating with treated effluent containing high soluble salts. Switching to a drip system might reduce foliar damage to landscape plants, although it might not adequately address salt accumulation in the soil.

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