Evaluation of Treated Effluent Applied as Drip Irrigation to Landscape Plants[1]

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Abstract

In 2004, treated effluent from the Hampton Roads Sanitation District (HRSD) Virginia Initiative Plant (VIP) was evaluated as a drip irrigation application to landscape plants. Landscape plants common to eastern Virginia were installed in raised beds and irrigated at the rate of 2.5 cm (1 in) per week for four months using a drip system. Aesthetic quality ratings, and soil and water analyses were conducted every four weeks. No significant differences were observed in the aesthetic quality ratings of the plants after four months of irrigation, even though both water and soil analyses showed significantly higher levels of sodium and chloride in the effluent treatment beds. When irrigating with treated effluent, particular attention should be paid to salt levels and subsequent accumulation in planting soil, especially during periods of limited natural rainfall or extended irrigation. Irrigation with treated effluent should be based on landscape species composition, local climate conditions, and irrigation method.

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

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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 levels 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 (3,5,8). Long term irrigation with treated effluent can cause salts to build up in the soil which can also lead to foliar burn or chlorosis and even stunting and plant mortality (15). Previous studies by Fox et. al. showed that overhead irrigation with HRSD VIP treated effluent caused significant plant injury and salts buildup in the soil (5). This study evaluated 24 species of landscape plants common to eastern Virginia for tolerance to treated effluent applied via drip irrigation. Federal (18,19), state, and city water quality standards do exist for treated effluent; however, an understanding of the quality of the effluent water, the specific site conditions, species sensitivity, and the irrigation delivery system 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 water or reclaimed water); the treated liquid product of municipal wastewater treatment plants. While irrigating 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. One additional benefit to using treated effluent as an irrigation source is that it may contain some nutrients essential for plant growth. If water quality is good, treated effluent can improve landscape plant growth and reduce fertilizer requirements (6,16).

Water quality is extremely important when deciding whether treated effluent is a viable irrigation water option (9,18). A particular concern when using treated effluent for irrigation is soluble salt concentrations. Salt tolerances vary anong landscape plant species, and can even vary from one cultivar to another (1,4,10,11,13). Some plants, such as Chinese juniper (*Juniperus chinensis*), tolerate very high salt levels, while others, such as red maple (*Acer rubrum*), are sensitive to low salt levels (3,20). 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 (1,8,10,14,17). In addition to these salt ion concentrations, levels of boron and heavy metals should be monitored, as 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 .75 dS/m (mmhos/cm) is generally safe for most landscape plants (1,7,10). 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 levels of sodium buildup than sandy soils (4,15). Sodium ions in high concentrations can displace calcium and magnesium ions and bicarbonate ions can destroy soil structure (1,10,12). This is especially important when irrigation water with high soluble salts levels 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 drip systems because saline water coats plants repeatedly, burning and desiccating the foliage of sensitive species (3,10,14,20).

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 the plant.

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

Materials and Methods

The HRSD VIP, Norfolk, VA (U.S. Dept. of Agriculture zone 7b) was selected as the test location. Irrigation studies had been conducted at this site previously. The study was set up as a completely randomized design (CRD) with two treatments (potable water and treated effluent) and three replications. In June 2003, six raised beds measuring 4.9 m x 4.9 m x 37 cm deep (16 ft x 16 ft x 12 in) were constructed out of pressure treated lumber. Each bed was filled with 6.9m (9 yd) of sandy loam soil, and pre-irrigation soil samples taken. Plant species that are commonly grown in eastern Virginia landscapes, with a range of susceptibility to damage from soil salt exposure (4,8,11,14) were selected (Table 1). Species selection was also based on observations made in previous irrigation studies by Fox et.al. One of each tree species, two of each shrub species, three of each perennial species, and six of each annual species were included in each bed; a total of 24 species, were planted in May of 2004. 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.

The drip irrigation system for each bed consisted of Rainbird landscape dripline, model # LD-09-12-500, laid out on 30.5 cm (12 in) centers. 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 June, with a total of 2.5 cm (1 in) of water applied per week to each bed in a split application.

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 July through October. The same person rated plants each month. An average rating was taken for species with multiple plants. As in the previous studies, 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 as the visual ratings, 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), sodium, sulfate, sulfur, zinc, manganese, iron, copper, and boron concentrations. Irrigation water analysis included: sodium, calcium, magnesium, chloride, phosphorus, sulfate, nitrate, carbonate, bicarbonate, phosphorus, potassium, boron, electrical conductivity (EC), pH, total dissolved solids, and sodium adsorption ratio (SAR).

Data from 2004 were subjected to analysis using SAS ANOVA (SAS version 8.1, Cary, NC). Treatment means were separated using Duncan's mean separation procedure, with P = 0.05 level of significance.

Results and Discussion

Electrical conductivity (EC) measurements over the four months of the study were consistently higher for the treated effluent than for the potable water (Fig. 1), frequently above the .75 dSm^{-1} considered safe for landscape plants. As electrical conductivity is directly related to total salt ion concentrations, sodium (Na) and chloride (Cl) ion concentrations were monitored. Levels of these ions followed the same trend as the EC (Fig. 2). Electrical conductivity and sodium and chloride ion levels were abnormally low for August due to the dilution effect of excessive rainfall, 18.8 cm (7.4 in) over the three days prior to the sample collection and analysis. Bicarbonate (HCO_3) ion levels (Fig. 2) were also monitored since large amounts can precipitate calcium leading to sodium buildup in the soil. Though bicarbonate ion levels were consistently higher in the treated effluent, they remained in the slight to moderate potential hazard range. Factors that contributed to 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 process used to treat the effluent (personal communication with George Kennedy, Environmental Scientist, HRSD). Average water pH was 7.2 +/- .5 for both treatments.

Soil in beds irrigated with treated effluent water had higher sodium and chloride ion levels than soil irrigated withpotable water (Fig. 3). While rainfall amounts were average and above during the study (Fig. 4), the soil was not leached sufficiently to prevent the sodium and chloride salts from accumulating over the four months. When salts accumulate to high enough levels in the soil, plants will exhibit characteristic injury symptoms including tip and/or marginal leaf burn, chlorosis, necrosis, deformity, early defoliation, plant stunting, and even death.

Visual appearance of landscape plants is very important to landscape designers, managers, and the public. No significant differences were observed in the aesthetic quality ratings of the plants between the two irrigation treatments (Data not shown).

Use of a drip irrigation system eliminates the potential injury to plant foliage which can occur from frequent exposure to salty irrigation water such as with overhead systems. Drip irrigation systems also provide more efficient delivery of irrigation water. However, if water quality is poor, plant aesthetic quality could still be adversely affected even using a drip system. While no injury was observed on the plants drip irrigated with HRSD VIP treated effluent in the four months of this study, high salt ion levels in the effluent and subsequent increasing salts levels in the effluent treated soils indicate the potential for problems to occur with long term use of this irrigation water source. Though a very modern sewage treatment facility, the current treatment processes at the HRSD VIP do not reduce salt ion concentrations enough to permit use of this treated effluent as the only source of irrigation for landscape plants. Supplemental irrigation from natural rainfall or a potable water source is necessary to prevent salts from accumulating in the soil and the subsequent damage which would make plants aesthetically unacceptable in the landscape. Careful consideration should be given to initial and replacement plant selection when irrigating with treated effluent containing high soluble salts, even when using a drip irrigation system.

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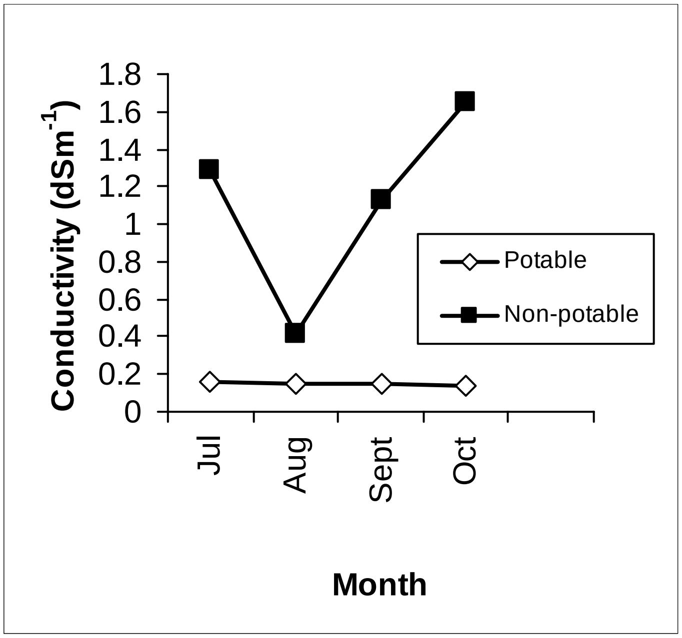

Fig. 1. Electrical conductivity of potable vs. non-potable (treated effluent) water, 2004.

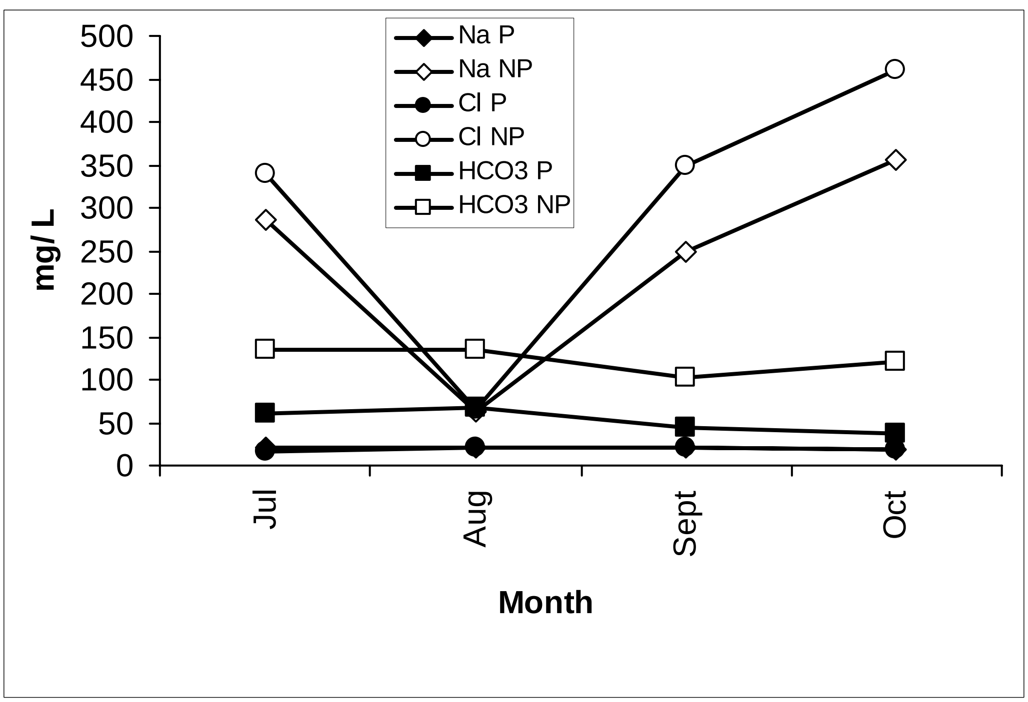

Fig. 2. Sodium (Na), chloride (Cl), and bicarbonate (HCO_3) levels July through October, 2004, for potable (P) and non-potable (NP) drip irrigation treatments.

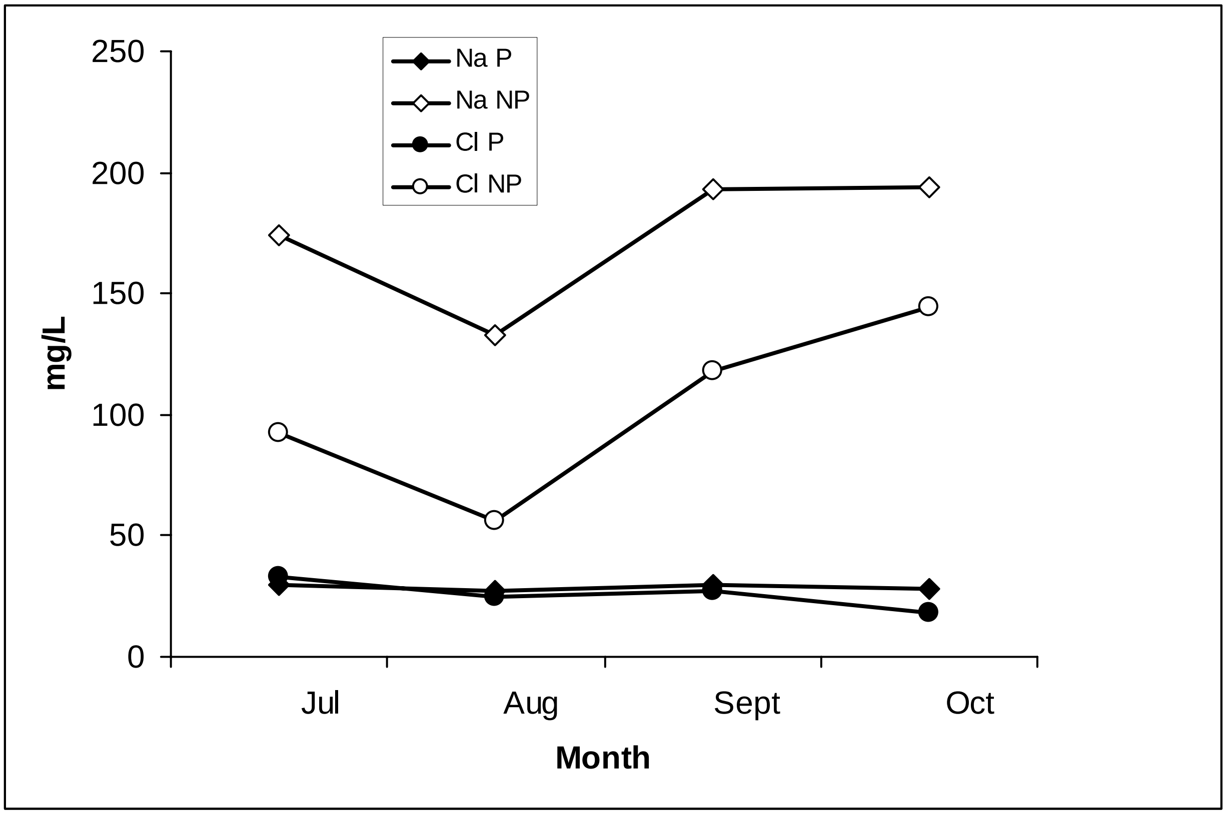

Fig. 3. Soil sodium (Na) and chloride (Cl) levels July through October, 2004, for beds drip-irrigated with potable (P) and non-potable (NP) water treatments. Each point represents the average of three replications.

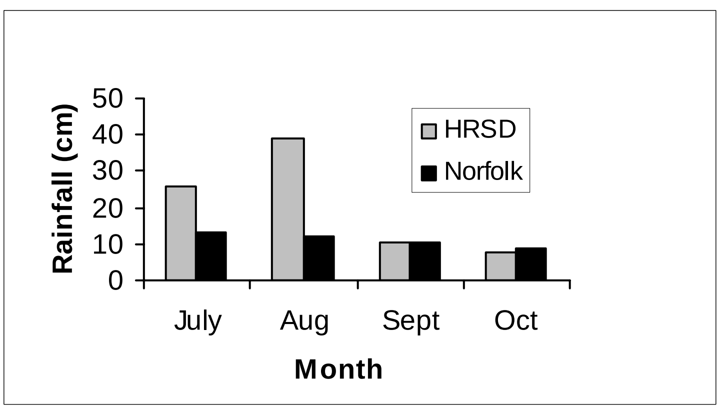

Fig. 4. Rainfall totals for HRSD VIP 2004 and City of Norfolk average.

Table 1. Species used.

	2004
Annual	
annual vinca (*Catharanthus roseus* L. 'Red Cooler')	
geranium (*Pelargonium* x *hortulanum* L.H. Bail.)	
marigold (*Tagetes erecta* L. 'Janie Deep Orange')	
petunia (*Petunia* x *hybrida* L. 'Dreams Red')	
Perennial	
black-eyed Susan (*Rudbeckia fulgida* var. *sullivantii* Boynt. & Beadle 'Goldsturm')	
daylily (*Hemerocallis* L. 'Stella d'Oro')	
liriope (*Liriope muscari* (Decne.) L.H. Bail. 'Variegata')	
sage (*Salvia nemorosa* L. 'May Night')	
sedum (*Sedum* L. x 'Autumn Joy')	
Shrub	
arborvitae (*Thuja occidentalis* L. 'Emerald')	
abelia (*Abelia* x *grandiflora* (Andre) Rehd. 'Little Richard')	
barberry (*Berberis thunbergii* DC. 'Crimson Pygmy')	
boxwood (*Buxus microphylla* Sieb. & Zucc. 'Wintergreen')	
cherrylaurel (*Prunus laurocerasus* L. 'Otto Luyken')	
gardenia (*Gardenia augusta* (L.) Merrill. 'Chuck Hayes')	
juniper (*Juniperus chinensis* L. var. *sargentii* 'Viridis')	
dwarf nandina (*Nandina domestica* Thunb. 'Harbor Dwarf')	
mugo pine (*Pinus mugo* Turra.)	
pyracantha (*Pyracantha koidzumii* (Hayara) Rehd. 'Victory')	
St. John's wort (*Hypericum patulum* L. 'Hidcote')	
Japanese spiraea (*Spiraea japonica* L. 'Neon Flash')	
dwarf viburnum (*Viburnum tinus* L. 'Compactum')	
Tree	
red maple (*Acer rubrum* L. 'Red Sunset')	
river birch (*Betula nigra* L.)	