DAY & ASSOCIATES
TREE AND LANDSCAPE CONSULTANTS

Evaluation of Trees Subjected to Reclaimed Water at Select Locations in Denver, CO

A Denver Water Project

Prepared for:

Denver Water Department
Attn: Donna Pacetti
1600 W. 12th Ave.
Denver, CO 80204

Prepared by:

Steven J. Day, M.S., RCA, CPAg

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Diagnostic, Technical, Forensic, Appraisal, Research, and Educational Services
7066 W. Arlington Drive • Littleton, Colorado 80123 • (303) 973-1515 • Fax (303) 973-5061

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INTRODUCTION

Use of reclaimed (recycled wastewater) water for irrigating landscapes is increasingly prevalent, and is expected to be an important component for the continued and future irrigation of parks, golf courses, open spaces, and commercial and industrial facilities, especially in arid and semi-arid regions of the United States. The use of recycled water provided by Denver Water is certain to increase substantially at many parks and golf courses throughout the metropolitan Denver area.

It is widely recognized that the quality of reclaimed water, at least with respect to certain landscape plants, is generally lower than that of potable water. Practical experience and results of empirical research have demonstrated that concern over the quality of reclaimed water used to irrigate landscape plants is focused primarily on the concentration of, and chronic exposure to: total soluble salts / solids; electrical conductivity (EC); bicarbonate; pH; and specific ions (esp. sodium, chloride, and boron).

The evaluation of landscaped sites for irrigation using reclaimed water should consider tactics which minimize and manage potential adverse effects of such water. For example: selecting tree species with known intermediate to high salt tolerance; selecting high quality nursery trees; using proper planting techniques; implementing a proven short- and long-term postplanting maintenance program; improving soil quality; and fine-tuning irrigation practices.

This report summarizes the results of an evaluation of numerous species of trees growing at several sites currently irrigated to some degree using reclaimed water provided by Denver Water. In addition, trees were evaluated at one site that had not been subjected to reclaimed water as of the summer of 2009. The primary purpose of the study (evaluation) was to assess the overall condition of the subject trees, and to sample foliage which was tested for specific parameters of concern with the use of reclaimed water. It was not the purpose of this study to evaluate or assess soil or soil water conditions as they might affect trees at the same sites.

ANALYSIS AND FIELD PROCEDURES

During the summer of 2009, select trees in six parks, two golf courses, and the Denver Zoo were evaluated and sampled. The park sites are Cheesman Park (control site), City Park, Greenway Park, Jackie Robinson Park, Swansea Park and Washington Park. The golf courses are City Park Golf Course and Park

Hill Golf Course. For each park site and the zoo, 10 samples were submitted for foliar analysis. For each golf course, 20 samples were submitted for foliar analysis. (The results of all laboratory tests are attached as an exhibit.)

For each of the nine study sites, the species of tree and its condition at the time of the evaluation are noted below. Where practicable and/or available, numbered metal tags were affixed to the trunk of subject trees, and tree locations were identified on a site map (see attached site maps). Tree locations on the site maps are approximate, and were not surveyed or determined by GPS.

For each tree evaluated, four foliar samples representing the four cardinal directions of the crown were obtained, stored in a cooler, and sent the same day to Colorado Analytical Laboratories in Brighton, Colorado. All samples were taken from the lower 10 feet of a tree's crown, and all samples were of live foliage and twigs. Only one evaluation and sampling regimen was performed for all sites; no follow-up work at any site is currently planned as part of this study.

STUDY SITES

Cheesman Park (Control)

Date of observations and sample collection: August 6, 2009

Tree No.	Species	Condition
1	Ponderosa pine	Fair. Moderate dieback in mid-crown; minor chlorosis.
2	White (concolor) fir	Fair. Moderate dieback; tip dieback and foliar burn in upper crown.
3	Austrian pine	Good
4	White (concolor) fir	Good
5	Colorado blue spruce	Good
6	Ponderosa pine	Good
7	American linden	Good
8	Colorado blue spruce	Good
9	American linden	Good
10	Austrian pine	Good. Misshapen crown, but healthy foliage.

City Park

Date of observations and sample collection: August 5, 2009

Tree No.	Species	Condition
1	Colorado blue spruce	Fair. Moderate dieback of interior branches.
2	White (concolor) fir	Fair. Moderately thin crown.

3	Scotch pine	Good
4	Douglas-fir	Fair. Moderate dieback of mid- to lower crown.
5	Golden raintree	Good
6	Golden raintree	Good. Minor dieback.
7	Colorado blue spruce	Fair. Moderate dieback and crown thinness.
8	Scotch pine	Fair. Moderate dieback and crown thinness.
9	Douglas-fir	Fair. Moderate dieback and crown thinness.
10	White (concolor) fir	Fair. Moderate dieback and crown thinness.

City Park Golf Course

Date of observations and sample collection: August 11, 2009

Tree No.	Species	Condition
1	Scotch pine	Poor. Decline; thin crown; moderate scale infestation.
2	Colorado blue spruce	Fair. Moderate foliar desiccation; thin lower crown.
3	Austrian pine	Good. Moderate foliar desiccation.
4	American linden	Good
5	Scotch pine	Good. Minor storm damage (broken branches).
6	Silver maple	Fair. Chlorotic; moderate dieback.
7	Ponderosa pine	Good
8	American linden	Good
9	Silver maple	Fair. Chlorosis.
10	Ponderosa pine	Good
11	Austrian pine	Fair. Below average needle growth / length.
12	Colorado blue spruce	Fair. Moderate browning and discoloration of needles.
13	Honeylocust	Good
14	Crabapple	Good
15	Crabapple	Good
16	Lanceleaf cottonwood	Good
17	Rocky Mountain juniper	Good
18	Rocky Mountain juniper	Good
19	Honeylocust	Good. Minor dieback.
20	Lanceleaf cottonwood	Good. Minor dieback.

Denver Zoo

Date of observations and sample collection: August 21, 2009

Tree No.	Species	Condition
1	Crabapple	Good

2	Catalpa	Good
3	Japanese pagoda tree	Good. Minor dieback.
4	Ginnala maple	Fair. Moderate chlorosis.
5	Golden raintree	Good
6	Honeylocust	Good. Minor honeylocust plant bug infestation.
7	Columnar English oak	Good
8	Yellowwood	Fair. Leaf mottling; minor chlorosis; minor dieback; marginal leaf burn.
9	Apricot	Good
10	Willow sp.	Fair. Minor chlorosis.

Greenway Park

Date of observations and sample collection: June 29, 2009

Tree No.	Species	Condition
1	Colorado blue spruce	Fair. Moderately thin lower crown.
2	Colorado blue spruce	Good
3	Honeylocust	Good
4	Honeylocust	Good
5	Red maple	Fair. Moderate chlorosis.
6	Red maple	Good. Minor chlorosis.
7	Austrian pine	Good
8	Austrian pine	Good
9	Hybrid elm	Good. Moderate infestation of elm leaf beetle and miner.
10	Hybrid elm	Good. Moderate infestation of elm leaf beetle and miner.

Jackie Robinson Park

Date of observations and sample collection: June 11, 2009

Tree No.	Species	Condition
1	Norway maple	Good
2	Norway maple	Good
3	White (concolor) fir	Good
4	White (concolor) fir	Good
5	Colorado blue spruce	Good
6	Colorado blue spruce	Good
7	Austrian pine	Good
8	Austrian pine	Fair. Moderately thin crown.
9	Red oak	Good. Minor chlorosis.

10	Red oak	Good. Minor chlorosis.

Park Hill Golf Course

Date of observations and sample collection: August 13, 2009

Tree No.	Species	Condition
1	Honeylocust	Fair. Moderate dieback; needs pruning; moderate cankering of random branches.
2	Pinyon pine	Fair. Minor dieback.
3	Ponderosa pine	Good. Minor chlorosis.
4	Colorado blue spruce	Fair. Moderate dieback; crown thinning.
5	Austrian pine	Good
6	Ponderosa pine	Good. Minor chlorosis; minor dieback.
7	American linden	Good
8	Honeylocust	Fair. Moderate dieback; cankering; girdling roots.
9	American elm	Good
10	Green ash	Fair. Minor dieback; old ash borer infestation.
11	Scotch pine	Good
12	Colorado blue spruce	Fair. Minor dieback.
13	Green ash	Fair. Moderate dieback and decline; minor chlorosis.
14	Pinyon pine	Fair. Pitch mass borer infestation; minor dieback.
15	Austrian pine	Fair. Minor dieback; minor foliar desiccation.
16	American elm	Good. Minor dieback; European elm scale infestation.
17	Rocky Mountain juniper	Fair. Moderately thin crown.
18	Rocky Mountain juniper	Good
19	Scotch pine	Fair. Moderate dieback; minor chlorosis.
20	American linden	Fair. Dead leader.

Swansea Park

Date of observations and sample collection: June 11, 2009

Tree No.	Species	Condition
1	Ponderosa pine	Fair. Minor crown thinness.
2	Ponderosa pine	Good. Minor dead branches.
3	Littleleaf linden	Good
4	Littleleaf linden	Good
5	Bristlecone pine	Canceled / pulled from study.
6	English elm	Fair. Significant elm leaf miner infestation; minor small branch dieback.

7	English elm	Good. Significant elm leaf miner infestation.
8	Colorado blue spruce	Good
9	Colorado blue spruce	Good. Minor winter burn and foliar desiccation.
10	Austrian pine	Good
11	Austrian pine	Fair. Minor crown thinness.

Washington Park

Date of observations and sample collection: June 30, 2009

Tree No.	Species	Condition
1	Colorado blue spruce	Good
2	Colorado blue spruce	Good
3	Red oak	Fair. Moderate dieback throughout crown.
4	Red oak	Fair. Moderate dieback in lower half of crown.
5	Kentucky coffeetree	Good
6	Kentucky coffeetree	Good
7	Ponderosa pine	Good. Minor spider mite infestation.
8	Ponderosa pine	Fair. Moderate dieback associated with crowding.
9	White (concolor) fir	Poor. General dieback and decline.
10	White (concolor) fir	Poor. General dieback and decline.

RESULTS AND RECOMMENDATIONS

LABORATORY TEST RESULTS

Cheesman Park (control)

With the exception of white fir, overall the foliar sample results are acceptable. The sodium level of 602 ppm in white fir is relatively high; however, this does not appear to be causing a problem as of the summer of 2009.

City Park

Across all tree species tested, the sodium levels are excessively high. The observed symptoms of crown thinness, foliar burn and desiccation, and dieback comport with high sodium levels in plant tissue.

City Park Golf Course

Sodium levels across all species tested are high to extremely high. Symptoms observed at this site comport with high sodium concentration in the foliage. Crown dieback, foliar burn and desiccation, varying degrees of decline, and crown thinness are the most obvious.

Denver Zoo

With only a few exceptions, the foliar analyses are acceptable across all species tested. Interestingly, the boron level is high in virtually all samples; however, typical symptoms are not being expressed as of the summer of 2009.

Greenway Park

The constituent of most concern is sodium (Na). Overall, the level of sodium is high enough to cause foliar burn (marginal and interveinal necrosis, and needle desiccation). For Colorado blue spruce, sodium should not exceed 250 ppm, and in this case it is over 1,000 ppm.

Jackie Robinson Park

There does not appear to be a problem or concern with any foliar constituents as of the summer of 2009. Although the boron levels register as high, foliar symptoms of boron toxicity are not being expressed as of the summer of 2009.

Park Hill Golf Course

Sodium and boron levels across all species tested are high to extremely high. In many cases it may be difficult or impossible to discern whether most of the foliar burn and tip dieback symptoms are the result of either sodium or boron toxicity. In reality, it probably is both to some degree, but most of the toxicity probably is the result of high sodium ion concentration.

Swansea Park

Overall, the sodium levels are quite high, and are likely contributing to the symptoms of foliar burn and desiccation, and chronic (but not severe) dieback. The levels of other constituents are not a significant concern as of the summer of 2009.

Washington Park

Sodium levels in Colorado blue spruce, white fir and ponderosa pine are high, and the symptoms expressed by these species corroborate this fact. In particular, and of most concern, is white fir. White fir in this park are declining irreversibly, and the symptoms of dieback, desiccation and foliar burn are prevalent and obvious.

BIOTIC AND ABIOTIC STRESSORS

Many symptoms expressed by trees at all nine study sites are commonly observed and diagnosed at any park or golf course along the Front Range of Colorado, regardless of the source or quality of irrigation water. The elevation, sunlight intensity, low relative humidity, winter weather conditions, temperature extremes, drought cycles, soil compaction, people pressures, deleterious insects and diseases, and other factors common to this geographic region adversely affect the health and longevity of trees. Common symptoms and signs observed at all nine sites include, but are not limited to, scale and borer infestations, mechanical wounds to trunks, storm damaged branches, decay, cavities, lightning strike injuries, fungus cankers, poor drainage, and drought related dieback.

It is well known and understood that the potential deleterious effects of adverse constituents in reclaimed water can contribute to or exacerbate the otherwise independent symptoms and signs noted above. The challenge for plant biologists and pathologists is to determine to what extent water quality actually increases or decreases the degree and severity of biotic and abiotic stressors of trees. Generally speaking, however, high levels or concentrations of adverse constituents in reclaimed water increases the degree and severity of stressors. In light of this, over the past many years there are certain practical tactics or procedures used by landscape managers and golf course superintendents to mitigate or minimize the real or potential effects of adverse constituents in reclaimed water. Some of the more successful and practical tactics are explained below.

RECOMMENDATIONS

Demonstrable improvements in tree color, growth rate and overall condition can occur with any tree species adversely affected by reclaimed water, primarily from the use of radial trenching soil replacement, and secondarily from the use of a supplemental watering program. Supplemental watering must include the use of potable water.

Radial trenching involves the removal of existing soil in several shallow radial trenches emanating from near the trunk outward past the drip line of the crown. Trenches are then backfilled with an amended

light soil mix. Sod may be laid over the newly filled trench. Local studies have shown that radial trenching operations should occur in the spring and can be repeated on the same tree every other year until the tree can sustain an acceptable level of foliar color, growth rate and overall condition. Details and specifications for radial trenching soil replacement around trees have been published in the Journal of Arboriculture, through the International Society of Arboriculture, Champaign, IL.

Supplemental watering, with or without the use of radial trenching soil replacement, should occur once per month during the months of October through March, and twice per month during the months of April through September. In most cases only high value trees, specimen trees, and trees with significant aesthetic and/or functional value will receive the two treatments or tactics described above.

Tree replacement or planting programs in locations irrigated with reclaimed water, especially on golf courses, should not include any spruce or fir species, or ponderosa pine. Austrian and Scotch pine can be used, provided there is adequate drainage, or the trees are planted in raised planter beds and/or berms. The use of pinyon pine, Bosnian pine, and Rocky Mountain juniper is acceptable under most planting conditions, except poorly drained sites. Deciduous trees generally do not appear to be significantly or permanently affected by reclaimed water.

The adverse effects of reclaimed water on conifer (e.g., pine, spruce, fir) foliage can be mitigated, in part, by reducing or eliminating direct application of irrigation water onto the foliage. Other remedial measures include frequent deep core aeration in turf areas, and overexcavation or enlargement of standard planting hole width.

Reducing the amount or concentration of sodium in Denver Water reclaimed water used for irrigation in landscaped areas, especially near susceptible conifers, will help mitigate the problems caused by high sodium levels in foliage and in the soil. Providing irrigation water with a sodium level below 75 mg/L (ppm) should be the goal when considering good health and longevity of landscape amenity trees.

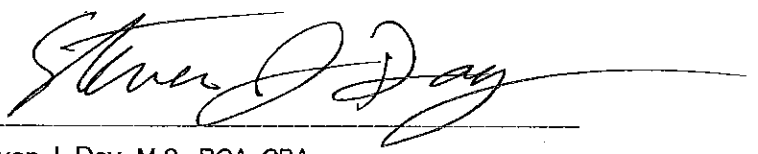
DISCUSSION AND CONCLUSIONS

The main focus of this study was on the extent to which, if any, certain potentially deleterious constituents in Denver Water's reclaimed water used to irrigate landscapes at the subject sites is adversely affecting the health or longevity of trees. Based on personal experience at other sites in the metropolitan Denver area using reclaimed water, and based on published research and other articles on the subject, in my opinion the only constituent in Denver Water's reclaimed water that is of concern to the health and longevity of landscape trees is sodium (Na). This opinion relates: i) exclusively to water sample results provided to me by Denver Water dated between 15 April 2004 and 10 March 2009 (during this period,

sodium levels ranged from a high of 190 mg/L (ppm) to a low of 97 mg/L); and ii) similar studies conducted in the metropolitan Denver area over the past 20 years at golf courses and business parks. Lowering the sodium level to 75 mg/L or less will help tremendously. Otherwise, the chronic effects of high sodium levels in foliage and soil will likely continue to be manifested for many years.

New landscape designs, master plans, and general planting programs should exclude the use of coniferous species identified as sensitive to, or intolerant of, high levels of sodium, bicarbonate, total soluble salts, and pH. When the use or retention of such species is unavoidable, certain measures can be taken to minimize or mitigate symptoms caused or aggravated by reclaimed water. These measures include, but are not limited to: i) best management and maintenance practices for landscape trees (i.e., pruning, fertilization, watering, insect and disease control); ii) establishing well-drained, well-aerated, and elevated planting sites; iii) planting new trees in overexcavated, wide planting sites or holes; iv) using high-quality nursery stock; and v) following proper planting techniques.

The use of reclaimed water to irrigate landscapes (especially parks and golf courses) is an increasingly important and efficient use of such a water source. It is anticipated that reclaimed water will improve in quality, and that its use in parks, golf courses, commercial and industrial sites, open space and similar environments will become more widespread and permanent. The use of reclaimed water, however, is not without concerns or problems with regard to the health of landscape plants, especially coniferous species such as ponderosa pine, blue and green spruce, and white fir. Future research should focus on long-term studies that monitor the growth, development and health of species tolerant to adverse constituents in reclaimed water.



Steven J. Day, M.S., RCA, CPAg
Day & Associates

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