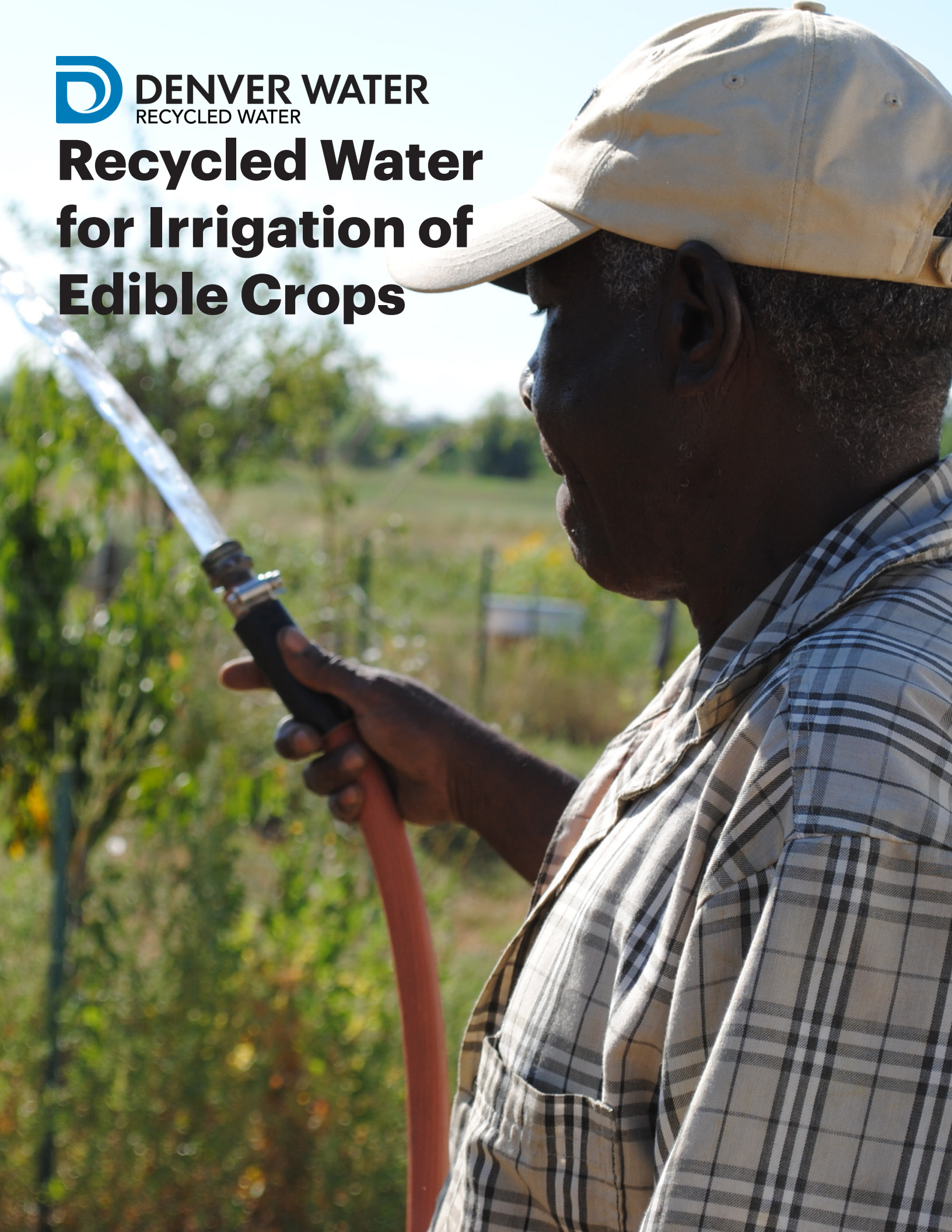
DENVER WATER
RECYCLED WATER

Recycled Water for Irrigation of Edible Crops



Cover design by Lauren Christensen

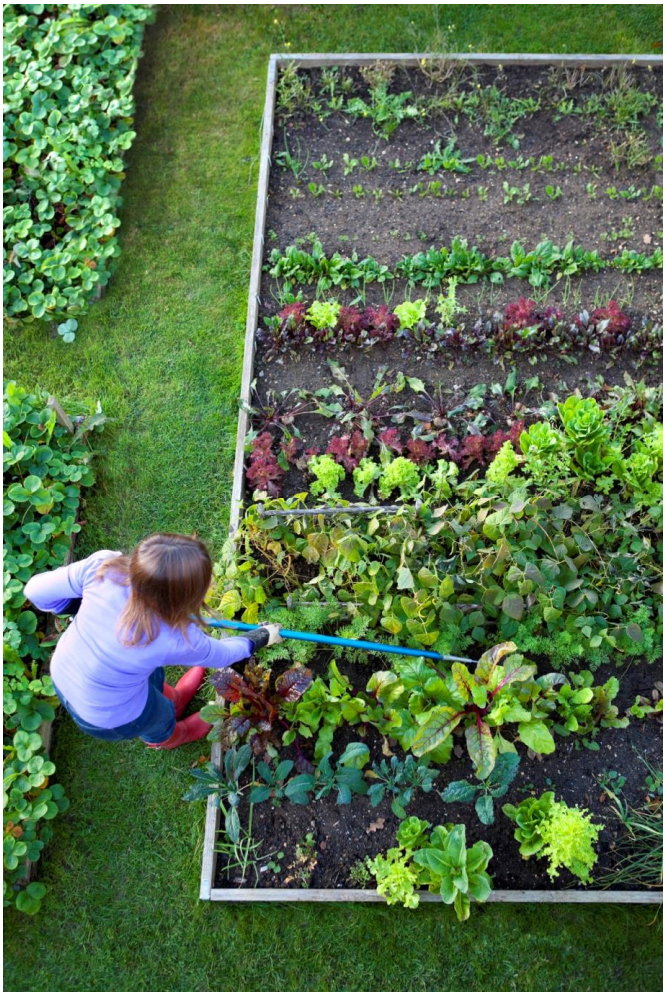
Cover photo by Heidi Oberman

White Paper

Recycled Water
for
Irrigation of Edible Crops

prepared for

DENVER WATER
RECYCLED WATER



November 2015

prepared by

Bahman Sheikh, PhD, PE

www.bahmansheikh.com

(this page is intentionally blank)

Table of Contents

List of Tables

List of Figures

ABBREVIATIONS

AF	Acre-feet
AFY	Acre-feet per year
CEC	Constituents of Emerging Concern (also, microconstituents)
MBR	Membrane bioreactor (combination of membrane filtration and biological treatment)
mgd	Million gallons per day
mg/L	Milligrams per liter (parts per million)
µg/L	Microgram per liter (parts per billion)
MWRSA	Monterey Wastewater Reclamation Study for Agriculture
ng/L	Nanogram per liter (parts per trillion)
SAR	Sodium Adsorption Ratio
TDS	Total Dissolved Solids
TM	Technical Memorandum
USEPA	United States Environmental Protection Agency

GLOSSARY

Acre-foot	Volume of water equal to 325,850 gallons
Absorption	Process of movement of water and dissolved substances from the soil solution into the plant root system.
Adsorption	Electrical attraction between negatively charged soil clay particles and positively charged ions (cations such as sodium, calcium, magnesium, etc.)
Disinfection	Deactivation, killing, and making non-viable pathogenic microorganisms in water by use of chlorine, ozone, Paracetic acid, pasteurization, or ultraviolet (or other) irradiation.
Effluent	Treated water exiting from a given process or at the end of a treatment process train.
Influent	Water or wastewater entering a treatment plant. Also, partially treated effluent from one process entering the next process in the treatment train.
Microconstituents	Extremely low concentrations of pharmaceutical compounds, personal-care products, hormone-like substances, etc. remaining in water after treatment.
Percolate	Water having traveled through a membrane, or a depth of soil or a thickness of sand and/or other porous media (filtered water)
Primary	Treatment stage at which wastewater is allowed to settle so that the heavy material settles to the bottom and the floatables rise to the top and are removed.
Process Train	A series of processes in tandem and sequentially arranged to maximize removal of pollutants from water as it progresses through the train.
Secondary	Treatment stage at which wastewater is provided with dissolved or bubbled air or pure oxygen so that indigenous microorganisms can digest the organic matter in wastewater and convert it into sludge for removal from the water.
Tertiary	Treatment stage at which clarified secondary effluent is filtered through thick layers of permeable soil, engineered sand, and/or anthracite.

(this page is intentionally blank)

ACKNOWLEDGMENTS

This White Paper is an initiative of Denver Water as part of its effort to expand the existing list of uses of Category 3 recycled water allowed by Colorado Regulation 84. Denver Water personnel who have spearheaded this effort and provided review comments and revisions of earlier drafts are:

- Jenny Murray
- Brenley McKenna
- Damian Higham

Denver Urban Gardens' (DUG) Shannon Spurlock, representing a large number of potential users of recycled water for irrigation of edible (food) crops, is the primary advocate and consistent mover for the necessary change in Regulation 84. This White Paper benefited greatly from review comments and highly valuable recommendations for change provided by:

- Members and staff of the Colorado Food Systems Advisory Council
- John Stulp, Water Policy Advisor to Governor Hickenlooper
- Kevin Reidy, Colorado Water Conservation Board, Colorado Department of Natural Resources
- Jacob Bornstein, Colorado Department of Natural Resources
- Patrick Pfalzgraff, Director, Colorado Department of Public Health and Environment Water Quality Control Division,
- Lillian Gonzales, Colorado Department of Public Health and Environment
- Elizabeth Lemonds, Colorado Department of Public Health and Environment
- Maureen Egan, Colorado Department of Public Health and Environment
- Janet Kieler, Colorado Department of Public Health and Environment
- Nathan Moore, Colorado Department of Public Health and Environment
- Dr. Dawn Thilmany, Colorado State University Extension and Department of Agriculture and Resource Economics
- Marisa Bunning, Colorado State University Extension
- Martha Sullins, Colorado State University Extension
- Anne Wilson, Denver Public Schools
- Dr. Lyn Kathlene, Spark Policy Institute
- Danica Lee, Public Health Inspections Division, Denver Department of Environmental Health
- Jeff Tejral, Denver Water
- Wendy Peters Moschetti, WPM Consulting, LLC (Now with LiveWell Colorado)
- David Takeda, MSK Consulting, LLC
- John Rehring, Carollo Engineers

Professor Douglas A. Rice, Laboratory Director at Colorado State University—Environmental Health Services, provided valuable water quality data from rivers used for irrigation of food

crops. Many people helped move the mission of this White Paper forward with their insight and active participation in discussions. Among them, we are specially indebted to Dr. Jill Litt, Colorado University at Boulder, Jim Faes, Denver Public Schools, Laurel Mattrey, Denver Public Schools, Bill Midcap, Rocky Mountain Farmers Union, and Robert Sakata, Sakata Farms and Colorado Fruit and Vegetable Growers Association.

Bahman Sheikh is responsible for omissions and discrepancies that remain in the document. Readers of this White Paper are encouraged to send comments and any corrections to bahman.sheikh@gmail.com.

Recycled Water for Irrigation of Edible Crops

INTRODUCTION

Water supply can keep pace with future demand of a growing population and an expanding economy as conservation measures are followed and as additional water resources are developed. One of the additional sources of water supply, which actually increases with increasing population, is treated wastewater. Traditionally, wastewater was considered waste and was (after some treatment) wasted, disposed of, or returned to the environment. Today, many communities are recognizing the importance of turning this waste into a valuable resource by treating it further and recycling it into usable water. Recycled water adds to the already diverse sources of water available in Colorado. Greater diversification of water supply sources also increases the reliability of water supply availability in times of drought and concerns about the future impacts of climate change on other water resources.

The Governor-appointed **Colorado Food Systems Advisory Council** (COFSAC 2015), dedicated an issue brief to *Use of Reclaimed Water for Food Crops*, with positive statements and recommendations about safety of use of this water resource, where available. Of special interest to this White Paper and consistent with its conclusions are the following "regulatory amendments" recommended by COFSAC:

- Consider amending State Regulation 84, based on the following recommendations from Denver Water:
  - Remove the prohibition against food crop irrigation with reclaimed water from Regulation 84;
  - Insert language in Regulation 84 specifically permitting irrigation of food crops with reclaimed water meeting certain criteria;
  - Develop a regulatory framework to enable farmers, greenhouses and community gardens to use reclaimed water.
- Encourage input from multiple stakeholders regarding the inclusion of detailed water treatment specifications and/or finished (treated) water quality specifications, which must be approved by the Water Quality Control Commission.

Public Health, Food Safety, and Sustainability of Recycled Water

Protection of the public's health against exposure to impurities (microbes and chemicals) in the wastewater is of utmost importance for producers and distributers of recycled water. Therefore, wastewater is typically subjected to several well-tested and proven treatment processes before it is sent into a separate distribution system to the users of the water.

Concern about food safety is related to irrigation water quality and the extent to which irrigation water comes in contact with the edible portion of the crop, if pathogens or toxins are present in the irrigation water and if they persist to the extent that they might endanger public health. The edible fruits and nuts from tree crops (walnuts, oranges, peaches, etc.) generally do

not come into contact with the irrigation water and its constituents. Except for tree crops with peeled fruit and food crops that are processed at high temperatures before human consumption, nearly all crops would become exposed to microorganisms, including pathogens, if they are present in the irrigation water. Therefore, many research studies have been conducted in recent decades to expand our understanding of the conditions under which it is safe to irrigate food crops with recycled water, compared with irrigation with other sources of water. This White Paper summarizes the results of these studies to the extent that they apply to conditions in Colorado related to edible crops grown on farms, greenhouses, and in community gardens.

Reclaimed, Recycled, Reused

Throughout this White Paper, the terms "recycled" and "reclaimed" are used synonymously and interchangeably. Both terms refer to **water** that has been produced as a result of treatment of municipal wastewater, at a level of water quality that makes it fit for the specific uses allowed by regulation. The reason for using both terms, rather than staying consistently with one or another is that some states have adopted one term and other states have adopted the other term. In Colorado, Regulation 84 makes most references to and defines "reclaimed water", but it also uses the term "recycled water" on several occasions. Another term, "reused water" is employed, notably in Texas and by a few authors of papers and conference reports. This White Paper eschews use of the latter term.

In recent years, advocates of projecting a positive public image for water reclamation have recommended avoiding any adjectives, because, they argue: water is water and its history and provenance should not trump its quality and usefulness. This argument is worthy of consideration, especially for potable reuse where the quality of water is as good as, or better than potable water derived from naturally occurring sources. However, this White Paper does not address potable reuse, restricting its focus to non-potable uses, specifically irrigation of edible crops on farms, urban gardens and schoolyards. For the purposes of this White Paper, "recycled water" and "reclaimed water" have the same meaning, although the former may eventually be preferred for consistent usage because of its positive image, associated with the green movement's strong support for recycling in general. Similarly, "water reclamation" is used in the same sense as "water recycling".

Source: Denver Water Website's Conservation page:
http://denverwater.org/Conservation/UseOnlyWhatYouNeed/

PUBLIC HEALTH FRAMEWORK FOR FOOD SAFETY USING RECYCLED WATER FOR IRRIGATION

Having a strong regulatory framework is key to the protection of public health and safety, especially where the raw material source of recycled water originates in human waste. Regulatory criteria for water reuse have evolved in the past several decades, in large part as a response to successful field experience and advanced treatment technologies, real-time monitoring of product water quality, and sophisticated automatic control systems.

"The Colorado Department of Public Health and Environment (CDPHE) Water Quality Control Commission (WQCC) developed Regulation 84, which guides the use of reclaimed domestic wastewater. This regulation currently authorizes the use of reclaimed water for landscape-related beneficial uses, such as non-potable irrigation (including single-family residential irrigation), and various commercial and industrial uses, such as cooling-tower use, dust control, soil compaction, mechanized street cleaning, fire protection, and zoo operations."[1]

Regulation 84 currently authorizes the use of reclaimed water for landscape irrigation (including single-family residential irrigation) and various commercial and industrial uses such as cooling tower make-up water, dust

Colorado Water Plan Chapter 6

"The WQCC promulgated Regulation 84 in 2000, and since then, has amended it four times in order to add new uses. As Colorado plans its reuse future, continued flexibility will be paramount to addressing water resource challenges. To many municipalities, reuse is critical in addressing identifies supply gaps in Colorado. Nonetheless, while reusing wastewater can help close the water supply gap, appropriate public health and environmental protections must remain in place. The CDPHE is committed to working with stakeholders to ensure that health and environment are protected while water reuse expands--but the CDPHE needs additional funding to support expanding safe and environmentally friendly water reuse. Without the ability to expand reuse, the gains that are forecasted to foster permanent growth in the reuse of limited water supplies may not be realistic."

-- Colorado Water Plan, November 2015, p. 6-76

California's Water Recycling Criteria—Title 22

California's regulations for water recycling, earliest in development, are the most extensively evolved, and the most widely emulated. Title 22 allows 43 specifically named non-potable uses of reclaimed water, each with a specific level of water quality. In particular, it allows "irrigation for food crops where recycled water contacts the edible portion of the crop, including all root crops". In addition, Title 22 allows fewer uses of recycled water at three lower levels of water quality, each based on prescribed treatment trains. Prescription of treatment sequence was deemed necessary when wastewater treatment technology was not quite as developed as it is today. A summary chart showing the 43 allowed uses of recycled water under California's Title 22 is reproduced in Appendix A, with reference to the original source document.

[1] Colorado Water Plan, November 2015, p. 5-9

control, soil compaction, mechanized street cleaning, fire protection, and zoo operations. The current Regulation specifies various approved uses, treatment and water quality requirements for specific reuse categories, conditions for use, monitoring, recordkeeping, and reporting. Regulation 84 specifically prohibits irrigation of food crops with recycled water, with the following definition:

> "**Agricultural Irrigation** means use of reclaimed water for the irrigation of crops and trees, **excluding crops produced for direct human consumption**, crops where lactating dairy animals forage, and **trees that produce nuts or fruit intended for human consumption**."[2]

In order for farmers, greenhouse growers, and urban gardeners to be able to irrigate with recycled water, there needs to be a change in Regulation 84 whereby a treatment level would be specified as being acceptable for use of recycled water for edible crop irrigation. A proven treatment train or a scientifically established water quality criterion can be adopted to protect the public health. Both Regulation 84 and Title 22 have the necessary requirements (albeit with relatively minor differences) to meet this goal. This White Paper will describe the differences in methodologies and possible additional requirements that will allay concerns about those differences. The currently allowed water quality standard for irrigation of non-food crops, is Category 3 Standards, defined as follows:

> **Category 3 Standards:** Reclaimed water for uses where Category 3 water is required shall, at a minimum, receive secondary treatment with filtration and disinfection. The following reclaimed water standards shall apply at the point of compliance:

Parameter	Limit
E. coli/100 ml	**None detected** in at least 75% of samples in a calendar month and 126/100 ml single sample maximum.
Turbidity, NTU	Not to exceed 3 NTU as a monthly average and not to exceed 5 NTU in more than 5 percent of the individual analytical results during any calendar month.

It is a goal of this White Paper to recommend changes to Regulation 84 that would allow use of recycled water (possibly by defining a new Category 4) for irrigation of edible crops.

In addition to Regulation 84, the US Food and Drug Administration (FDA) Food Safety Modernization Act (FSMA)'s Produce Rule applies to most agricultural producers of food crops—with the exception of those with an annual maximum gross income from sale of

[2] Colorado Department of Public Health and Environment Water Quality Control Commission, "Regulation No. 84 Reclaimed Water Control Regulation, Amended June 10, 2013, Effective July 30, 2013. Page 1. [red color and boldface type ae added for emphasis—not in original document]

produce under $25,000. Specifically, it is required[3] to test the quality of agricultural water to ensure that there is **no detectable generic E. coli in 100 ml** agricultural water when it is:

> (1) Used as sprinkler irrigation water;
>
> (2) Applied in any manner that the water would directly contact covered produce during or after harvest activities (for example, water that is applied to covered produce for washing or cooling activities, and water that is applied to harvested crops to prevent dehydration before cooling), including when used to make ice that directly contacts covered produce during or after harvest activities;
>
> (3) Used to make a treated agricultural tea;
>
> (4) Used to contact food-contact surfaces, or to make ice that will contact food-contact surfaces; or
>
> (5) Used for washing hands during and after harvest activities. (p. 238)

The latest version of the FSMA is in the process of establishing "sufficient interval of days[4] between last irrigation and harvest to allow time for potentially dangerous microbes to die off." It is anticipated that any future changes in Regulation 84, allowing irrigation of edible crops with reclaimed water will necessarily be consistent with the applicable FSMA rules. The current definition of Category 3 reclaimed water, as shown above, meets the FSMA rule requirement for coliform assay.

REGULATORY FRAMEWORKS FOR IRRIGATION WITH RECLAIMED WATER

Monitoring of the product water for E Coli and continuously recording the turbidity provide for definitive and reliable indications of the safety of reclaimed water for use in the most intimate nonpotable applications, such as irrigation of edible crops. These standards have been established based on controlled experiments, pilot projects, research, and many years of field experience in several states and other developed countries abroad.

Robustness and reliability of treatment processes is a function of the technologies used and design details implemented in a given treatment plant. When California's Title 22 was first written in 1958, the state of the art in water reclamation was in its infancy. Public health regulators needed to spell out how a water recycling treatment plant should be designed and operated to produce a safe reclaimed water. By now, over six decades of experience have been gained in water recycling from

[3] § 112.45, subpart N requiring use of a quantitative, or presence-absence method of analysis.

[4] For example, if lettuce is spray-irrigated with recycled water, the grower would stop irrigation 7 days (more or less, depending on the final rule) before harvest is initiated. Most growers stop irrigation long enough before harvest so that the field becomes dry and accessible to harvest equipment and field crews. Thus, this requirement, in most cases, is not an additional burden.

hundreds of treatment plants in several US states, and other industrialized countries around the world. This vast experience record provides a wealth of expertise to designers of new treatment plants producing reclaimed water. Therefore, it is not necessary to specify one specific treatment train in regulations any longer—thus opening the wider range of technologies available to the profession.

Crafting a modern regulatory framework for water reclamation in Colorado provides the opportunity to take advantage of this vast experience record. Based on that experience, the Water Quality Control Commission can establish science-based and safe water quality criteria, and reliability and performance standards.

California's water recycling regulations have proven highly effective in (a) protecting the public health, and (b) promoting confident expansion of uses of recycled water. They have also become somewhat outdated over the last half-century since their original adoption, lagging behind scientific knowledge and technological developments in the field. Some states and other countries initiating their own water reclamation programs, have drawn inspiration from the success of water recycling experienced in California, under its Title 22 regulations. They have adopted similar or less-conservative limits (higher numerical standards) as being adequate protection for the public health, without imposing unnecessary additional requirement. A summary of regulatory requirements of ten States are shown in Table 1, providing a comparative view of their standards. There has been no evidence in the published literature to indicating that any one of these States' standards is less safe or less protective of the public's health than the others.

California's additional regulatory requirements beyond water quality criteria include coagulation, rapid mix, sedimentation, filter loading rates, and disinfection details. At this stage of development of science and technology, such prescriptions of detailed design of treatment systems are largely unnecessary—as requirements. Instead, pilot treatability studies may be required to establish proper design criteria for a given community's wastewater patterns, climatic conditions, and other constraints. Various combinations of process units can be incorporated in the treatment train where they are found necessary or desirable to produce the regulation-specified quality of reclaimed water with attendant reliability and robustness. Recommendations are presented in a section at the end of this document for suggested target water quality standards.

Table 1. Treatment Trains Prescribed and Numerical Standards Specified for Irrigation of Food Crops with Recycled Water

Requirement	Arizona	California	Colorado	Florida	Hawaii	Idaho	Nevada	Texas	Utah	Washington
Treatment Train	Secondary treatment, filtration, disinfection	Oxidized, coagulated, filtered, disinfected	Not covered	Secondary treatment, filtration, disinfection	Oxidized, filtered, disinfected	Oxidized, filtered, disinfected	Secondary treatment, disinfection	NS*	Secondary treatment, filtration, disinfection	Oxidized, coagulated, filtered, disinfected
BODS	NS	NS	Not covered	20 mg/1 CBODs	NS	5 ï 10** mg/l	30 mg/1	5 mg/l	10 mg/L	30 mg/1
TSS	NS	NS	Not covered	5 mg/1	NS	NS	NS	NS	NS	30 mg/1
Turbidity	2 NTU (Avg)	2 NTU (Avg)	Not covered	NS	2 NTU (Max)	2 - 0.2 NTU (Median)***	NS	3 NTU	2 NTU	2 NTU (Avg)
	5 NTU (Max)	5 NTU (Max)				5 - 0.5 NTU (Max)				5 NTU (Max)
Coliform	**Fecal**	**Total**	**E. Coli**	**Fecal**	**Fecal**	**Total**	**Fecal**	**Fecal**	**Fecal**	**Total**
	None detectable (Avg)	2.2/100ml (Avg)	Not covered	75% of samples below detection	2.2/100 ml (Avg)	2.2/100 ml (Avg)	200/100 ml (Avg)	20/100 ml (Avg)	None detectable	2.2/100 ml (Avg)
								4 enterococci /100 mL		
	23/100 ml (Max)	23/100 ml (Maxin30 days)	Not covered	25/100 ml (Max)	23/100ml (Max in 30 days)	23/100 ml (Max)	400/100 ml (Max)	75/100 ml (Fecal max)	NS	23/100 ml (Max)

*NS = Not Specified by State Regulationsð a case in which producer of reclaimed water must comply with water quality standards using whatever treatment train can achieve that quality.
**Groundwater rechargeð 5, Irrigationð 10
***Granular or cloth mediað 2, Membrane filterð 0.2
SOURCE: EPA Guidelines for Water Reuse, 2004, page 155 with updates and additional statesô data from Dr. James Crook.

ORGANIC FARMING AND RECYCLED WATER

Organic farming protocols are based in large part on the standards set by the International Federation of Organic Agriculture Movements (IFOAM), an international umbrella organization for organic farming organizations established in 1972. The USDA National Organic Standards Board (NOSB) definition as of April 1995 is:

> "Organic agriculture is an ecological production management system that promotes and enhances biodiversity, biological cycles and soil biological activity. It is based on minimal use of off-farm inputs and on management practices that restore, maintain and enhance ecological harmony."[5]

The general requirement for organic farming is that natural materials are allowed and synthetic materials are prohibited—with very specific situational exceptions. Recycled water, a natural material, is not treated any differently from any other source of water in the lists of exceptions to the general rule.

Recycled water is an accepted irrigation water source for certified organic crops. There are numerous certification programs for crops produced using organic methods and materials. Under the National Organic Program (NOP), products sold as organic in the United States must be certified by a USDA-NOP accredited certification agency. The following list is not exhaustive[6], but represents the most prominent venues for guidance on organic farming:

- National Organic Standards Board (NOSB)
- Organic Crop Improvement Association
- California Certified Organic Farmers
- Oregon Tilth
- Quality Assurance International
- Indiana Certified Organic

The Colorado Department of Agriculture (CDA) is a USDA accredited certification agency. The CDA verifies that the requirements of organic production and handling practices meet the national standards. It certifies crop, wild crop, process handling and livestock categories.

There are no prohibitions against use of recycled water in any of the organic farming certification programs. Recycled water that meets applicable regulations is treated as any other source of water that an organic farmer would use for irrigation of crops. As a result, organic farmers in the Monterey area, Watsonville, and Sonoma County, in California (among others in

[5] Gold, Mary. "What is organic production?". National Agricultural Library. USDA. Retrieved 1 March 2014. http://www.nal.usda.gov/afsic/pubs/ofp/ofp.shtml

[6] It is estimated that there are over 50 organic certification agencies in the United States, and an equal number in all other countries, combined.

the nation), have successfully grown and marketed their organic crops, using recycled water for irrigation.

FOOD SAFETY AND IRRIGATION WITH RECYCLED WATER

The primary concern and duty of water professionals engaged in water recycling is the protection of public health. First, by provision of water, a resource essential to maintaining life itself, and secondly by ensuring that the water's past history as sewage does not carry over in any way that would compromise the public's health and safety. To this end, studies of food safety under recycled water irrigation regimes are relevant. The Monterey Wastewater Reclamation Study for Agriculture (MWRSA) (Sheikh *et al*., 1998), a research pilot project conducted in California, is the most comprehensive study to provide solid, long-term data in this field. The main conclusions drawn from the results of MWRSA are:

- No virus was ever found on samples of crops grown with the two types[7] of reclaimed municipal wastewater used in the study.
- Levels of naturally-occurring bacteria on samples from crops irrigated with recycled water were equivalent to those found on well-water-irrigated crop samples.
- No viruses were detected in any of the samples taken from either type of reclaimed water.
- When pushed to the limits of their performance, through massive seeding with vaccine-grade poliovirus, both treatment processes exhibited equal ability to remove an average of five logs of seeded virus (i.e. if 100,000 units of virus were introduced to the treatment plant they would all be removed by the treatment process).
- There was no tendency for heavy metals (cadmium, zinc, iron, molybdenum, etc.) to accumulate in soils or plant tissues attributable to the irrigation use of recycled water.

The treatment trains of two types of recycled water used in this research study and the treatment train of the Colorado Category 3 recycled water are compared in Table 2.

[7] The two types of recycled water used in MWRSA were: (1) disinfected tertiary recycled water in full compliance with Title 22, including coagulation, rapid mix, sedimentation, filtration, and disinfection; and (2) disinfected tertiary recycled water with in-line coagulation, filtration, and disinfection. The two types of disinfected tertiary recycled water were shown to be equal in their effects on crops and soils and for human health protection.

Table 2 Comparison of Colorado Category 3 Recycled Water Treatment and Quality with the Treatment and Quality of MWRSA Recycled Waters

Treatment Process/Water Quality Criteria	MWRSA Full Title 22	MWRSA Filtered Effluent	Colorado Category 3
Secondary Treatment	YES	YES	YES
Coagulation	YES	YES[8]	NO
Rapid Mix	YES	NO	NO
Sedimentation	YES	NO	NO
Filtration	YES[9]	YES	YES
Disinfection	YES[10]	YES	YES
Effluent E. Coli Objective	Not specified	Not specified	Non-detect in 75% of samples, <126/100 ml in single Sample
Effluent Total Coliform Objective	<2.2 MPN/100 mL	<2.2 MPN/100 mL	Not specified
Turbidity Objective	<2 NTU	<2 NTU	<3 NTU as a monthly average, <5 NTU in >5% samples per month

[8] This recycled water type only involved in-line addition of coagulant on an as-needed basis, without the rapid-mix and sedimentation steps. This variant recycled water makes it much closer in character to the Colorado Category 3 requirement. Its equivalence to the "Full Title 22" recycled water was demonstrated in the five-year field research, MWRSA, discussed in this White Paper. For irrigation of all edible crops, this level of treatment is deemed adequate and safe.

[9] California's rule (§60301.320) defines a minimum standard for "filtration" as water that:

(a) Has been coagulated and passed through natural undisturbed soils or a bed of filter media pursuant to the following:

(1) At a rate that does not exceed 5 gallons per minute persquare foot of surface area in mono, dual or mixed media gravity, upflow or pressure filtration systems, or does not exceed 2 gallons per minute per square foot of surface area in traveling bridge automatic backwash filters; and

(2) So that the turbidity of the filtered wastewater does not exceed any of the following:

(A) An average of 2 NTU within a 24-hour period;

(B) 5 NTU more than 5 percent of the time within a 24-hour period; and

(C) 10 NTU at any time.

[10] California's rule (§60301.230) sets a disinfection standard for chlorination of: "CT (the product of total chlorine residual and modal contact time measured at the same point) value of not less than 450 milligram-minutes per liter at all times with a modal contact time of at least 90 minutes". The CT rule (450 mg•min/L) is effective for disinfection of bacteria and viruses when combined chlorine compounds (e.g., chloramines) are used as disinfectant. However, this limit is set far too high for situations in which free chlorine is available for disinfection. In such cases, a CT as low as 3 mg•min/L has proven to be equally effective (Metcalf & Eddy 2013) . Therefore, a verbatim copying of California's Title 22 is not recommended. It is preferred that the CT requirement not be promulgated—and if it is, a distinction be made for each method of chlorination. A substitute requirement could be a showing of 4-log virus removal with the disinfection method proposed—but without a periodic virus monitoring requirement.

While there are distinct differences in both treatment and water quality criteria, the California "disinfected tertiary recycled water", may be only slightly more protective of food safety than its Colorado counterpart, "Category 3 reclaimed water", when used for irrigation of edible crops. Had a third quality of recycled water—conforming precisely to the Colorado Category 3 recycled water—been used in the MWRSA research project, no significant differences would have been observed in the parameters of food safety, worker safety, or shelf-life of the produce[11].

To provide further food safety information in Monterey County, CA, a more narrowly focused study was undertaken in Monterey County. (This study was in response to an epidemic outbreak of disease among people who had consumed spinach grown in a field where feral hogs had contaminated the field with animal feces from a neighboring feedlot.) The study was specifically designed to determine whether or not pathogenic microorganisms of concern to food safety, such as *E. Coli* 0157:H7, *Cyclospora*, enteric viruses, and *Salmonella* were present in disinfected tertiary recycled water. Samples were taken from the final product water as well as raw wastewater, secondary effluent, and a control source of water (well water).

The results showed that viable microorganisms of public health concern were not present in the recycled water. This finding corroborates and strengthens

Indicators of Disinfection Efficiency

The key criterion used as a measure of efficiency of disinfection of recycled water in California is **total coliform** and in Colorado it is **E. Coli**. Each criterion has its respective standard (2.2 MPN/100 mL for total coliform vs. non-detect for E. Coli) for achieving a virtually pathogen-free reclaimed water. These criteria and their corresponding standards are considered equal for routine monitoring of reclaimed water production for the most intimate non-potable uses of the water—including irrigation of edible crops.

The World Health Organization (WHO) uses E. Coli in their international Guidelines for Water Reuse. Numerous European and other countries also rely on E. Coli to assure proper levels of disinfection for the intended uses. On the other hand, besides California, the State of Washington, Germany, Australia, and Canada rely on total coliform. Still others use Fecal coliform as their indicator of disinfection efficacy (with non-detect being the standard for irrigation of edible crops). It is not possible to give a definitive preference to one criterion over another. For all practical purposes they are equally protective of public health.

Elmund, G.K. et al. (1999) compared E. Coli with total coliform and fecal coliform as indicators of wastewater treatment efficiency, based on extensive data collected from two wastewater treatment facilities, an artificial wetlands, and a receiving stream. They conclude that "The results support development of E. Coli-based effluent and stream standards to protect public health."

==========

"**Escherichia coli** and to a lesser extent thermotolerant coliform bacteria are considered to best fulfill the criteria to be satisfied by an ideal indicator."

SOURCE: WHO, Guidelines, Standards and Health: Assessment of risk and risk management for water-related infectious disease, p. 20.

[11] This conclusion is based on the author's direct involvement in planning, managing and conducting MWRSA throughout its inception, field experimentation, and discussion of its results with professional colleagues throughout the duration of the project and its publication and presentations at conferences around the world.

the results of the five-year field pilot study near Castroville completed in 1987, which concluded that recycled water was safe for irrigation of all food crops.
Furthermore, comparison of results obtained from the Monterey recycled water with those obtained from raw and treated drinking water sources, both for *Cryptosporidium* spp. and for *Giardia* spp. provide an additional indication of safety of the recycled water. Occurrence and concentration of cysts of these protozoa in recycled water is comparable with or lower than in the other waters, some of which are sources of drinking water supply for communities in the United States and Canada (Sheikh et al, 1998).

Safety of Children Exposed to Recycled Water

An inventory of sites where recycled water is used in sites where children could become exposed to the water, such as parks, playgrounds, and school-yards, was compiled by WateReuse Research Foundation (Crook, 2005). At that time, over a thousand such facilities were identified in 11 states, including Colorado, as shown on Tables 3 and 4.

Table 3 Parks, Playgrounds, and Schoolyards Irrigated with Reclaimed Water

State	Parks, Playgrounds	School Grounds
Arizona	87	60
California	409	295
Colorado	98*	19**
Florida	486	213
Hawaii	8	2
Nevada	16	4
New Mexico	12*	9
North Carolina	1	1
Oregon	-	2
Texas	4	2
Washington	6	-
Total	1,127*	607

* Some cities that use reclaimed water at multiple sites did not provide the total number of sites; actual number of sites is higher.

** Does not include 60 schools where recycled water is used for irrigation only during drought periods.

Source: Crook, 2005, except for the Colorado data—see Table 4 for source of Colorado data.

Table 4 Colorado Parks, Playgrounds, and Schoolyards Irrigated with Reclaimed Water

City or System	Parks, Playgrounds	School Grounds
Aurora	4	60*
Broomfield	41	1
Colorado Springs	7	2
Denver	23	9
Louisville	2	--
Centennial	1	--
Superior	13	2
Westminster	8	5
Total	**99**	**19**

* Not on full-time irrigation; reclaimed water is supplied during drought periods. Not included in total.
Source: Brenley McKenna, Denver Water, from a direct survey of individual cities and water supply systems during the period May-July 2015.

While schoolyard gardens growing edible crops are not specifically listed in Tables 2 and 3, it can be surmised that the level of intimate contact with the water on a playground or a school yard freshly irrigated with recycled water is substantially the same as that in a school garden growing food crops. Regarding the safety of children at these sites, the authors concluded

> "Information obtained from the literature and other sources during preparation of this report support an overarching finding that the irrigation of parks, playgrounds, athletic fields, and schoolyards with highly treated reclaimed water is safe and does not present any known health risks to children or others who frequent those sites that are measurably different than risks associated with irrigation using potable water."

The Extent and Relevance of Microconstituents in Recycled Water

Microconstituents (also called constituents of emerging concern, CECs) are defined as chemicals of various origins remaining in water (including recycled water) at extremely low concentrations. While these chemicals have been present for many decades, their presence at parts per million or lower was not detectable until very recently. Advances in laboratory analytical methods have enabled detection of microconstituents and raised concern over their potential impact on public health. Fortunately, the possibility of microconstituents being absorbed into plant tissues is extremely low: The soil environment is capable of decomposing these compounds rapidly, and the root systems of plants include an osmotic barrier that excludes uptake of the larger organic molecules that make up the majority (entirety in many cases) of CECs. Several recent research studies have borne out this phenomenon, as summarized in a recent publication on risk assessment of pharmaceuticals and personal care products in nonpotable recycled water (Kennedy *et al.*, 2012).

Exposure of Agricultural Workers, Children on Playgrounds, Golfers, and Landscapers

WateReuse Foundation recently published a summary of scientific research on the potential impact of microconstituents remaining in recycled water after treatment to meet water quality criteria for specific uses.

The specific uses of recycled water for which exposure scenarios were calculated are (1) agriculture worker handling soils, vegetation and water in the field irrigated with recycled water, (2) child at play on grass irrigated with recycled water, (3) golfer playing on a course routinely irrigated with recycled water, and (4) landscape laborer maintaining and planting landscape materials irrigated with recycled water. The treatment levels for the recycled water exposure scenarios are at least equivalent[12] to those specified for the Colorado Category 3 standards, as shown above, in Table 1.

The computations in the exposure scenarios are based on concentrations of the specific microconstituents commonly found in recycled water multiplied by the amount of water inadvertently ingested during the exposure scenario at each occurrence, multiplied by the time duration necessary to accumulate the quantity of chemical that would be equal to one safe dose. A summary of that publication's data for the agriculture worker is presented in Table 5 , for the child playing on a playground in Table 6, for a golfer on Table 7, and for a landscaper on Table 8. Calculations leading to the information in these Tables are illustrated in Appendix B

[12] Near-equivalence of the Colorado Category 3 reclaimed water with recycled waters in the exposure scenarios (e.g., California's Title 22 disinfected tertiary recycled water) is based on the basic turbidity and coliform requirements—irrespective of details of process train, design, and other regulatory requirements. This White Paper intends to rely in that near-equivalency and recommend minimal additional requirements to permit use of Category 3 reclaimed water for irrigation of all edible crops.

Table 5 Recycled Water Exposure Scenario—Agriculture Worker in Field Irrigated with Filtered and Disinfected Recycled Water

Sampling of Microconstituents (Pharmaceutical, Personal Care Products, Etc.)[13]	Safe vs. Actual[14] Concentration in Recycled Water, µg/L	Length of Exposure before Accumulating Quantity of Chemical Equal to Safe Dose
Ibuprofen, Over the counter pain reliever	Acceptable: 1,700 Actual: 0.5	28,000 Years = 1 Advil tablet
17-beta estradiol, hormone replacement	Acceptable: 0.18 Actual: 0.0084	16,000 Years
Fluoxetine, antidepressant	Acceptable: 320 Actual: 0.031	83,000 years = 1 Prozac tablet
Sulfa-methoxazole, common antibiotic	Acceptable: 38,000 Actual: 1.4	220,000 years
PFOS, fluorosurfactant used in stain repellants, textiles, etc.	Acceptable: 310 Actual:0.09	5 years = 1 day of exposure from other environmental factors
Bisphenol A, component of plastic bottles, epoxy resins	Acceptable: 2,200 Actual: 0.29	7.1 years = 1 day of exposure from food[15]
DEET, insect repellant	Acceptable: 17,000 Actual:1.5	85 million years = 1 application to arms, hands and lower legs
Triclosan, antibacterial agent in soaps, deodorants, etc.	Acceptable: 3,100 Actual: 0.49	7,600 years = 30 seconds hand washing with antibacterial soap
Acetaminophen, over-the-counter pain reliever	Acceptable: 30,000 Actual: 0.55	350,000 years = 1 extra-strength Tylenol tablet

SOURCE: Adapted from WateReuse Research Foundation, 2011, available at website: http://athirstyplanet.com/sites/default/files/uploadsfiles/PDF/RA%20Fact%20AgWorker_6.4.11_Lo.pdf

[13] There are tens of thousands of anthropogenic chemicals in the environment, including in water supplies, and in recycled water, at extremely low concentrations. The compounds listed in Tables 5 through 8 are a few of the more commonly detected such chemicals.

[14] Acceptable concentrations are calculated concentrations at which adverse health effects are not expected from exposure to recycled water. In other words, levels at which contact with the water is deemed to be safe. Actual concentrations are the 90th percentile concentrations presented in Monitoring Strategies for Chemicals of Emerging Concern (CECs) in Recycled Water (based on California State Water Resources Board, 2010). This means that in a review of available studies in which PPCPs were measured in recycled water, 90 percent of the measured concentrations were equal to or less than the concentrations presented here.

[15] In one typical day's time, a person becomes exposed to the same amount of Bisphenol A from coming in contact with plastic bottles and epoxy resins as in 7.1 years' time working in a field irrigated with recycled water.

Table 6 Recycled Water Exposure Scenario—Child Playing in Playground Irrigated with Filtered and Disinfected Recycled Water

Sampling of Microconstituents (Pharmaceutical, Personal Care Products, Etc.)	Safe vs. Actual Concentration in Recycled Water, µg/L	Length of Exposure before Accumulating Quantity of Chemical Equal to Safe Dose
Ibuprofen, Over the counter pain reliever	Acceptable: 890 Actual: 0.5	67,000 Years = 1 Advil tablet
17-beta estradiol, hormone replacement	Acceptable: 0.39 Actual: 0.0084	160,000 Years
Fluoxetine, antidepressant	Acceptable: 180 Actual: 0.031	220,000 years = 1 Prozac tablet
Sulfa-methoxazole, common antibiotic	Acceptable: 70,000 Actual: 1.4	1,900,000 years
PFOS, fluorosurfactant used in stain repellants, textiles, etc.	Acceptable: 630 Actual:0.09	46 years = 1 day of exposure from other environmental factors
Bisphenol A, component of plastic bottles, epoxy resins	Acceptable: 1,300 Actual: 0.29	22 years = 1 day of exposure from food
DEET, insect repellant	Acceptable: 18,000 Actual:1.5	110 million years = 1 application to arms, hands and lower legs
Triclosan, antibacterial agent in soaps, deodorants, etc.	Acceptable: 1,400 Actual: 0.49	17,000 years = 30 seconds hand washing with antibacterial soap
Acetaminophen, over-the-counter pain reliever	Acceptable: 57,000 Actual: 0.55	3,000,000 years = 1 extra-strength Tylenol tablet

SOURCE: Adapted from WateReuse Research Foundation, 2011, available at website:
http://athirstyplanet.com/sites/default/files/uploadsfiles/PDF/RA%20Fact%20Child%20_6.4.11_Lo.pdf

Table 7 Recycled Water Exposure Scenario—Golfer Playing on Golf Course Irrigated with Filtered and Disinfected Recycled Water

Sampling of Microconstituents (Pharmaceutical, Personal Care Products, Etc.)	Safe vs. Actual Concentration in Recycled Water, µg/L	Length of Exposure before Accumulating Quantity of Chemical Equal to Safe Dose
Ibuprofen, Over the counter pain reliever	Acceptable: 1,600 Actual: 0.5	26,000 Years = 1 Advil tablet
17-beta estradiol, hormone replacement	Acceptable: 0.15 Actual: 0.0084	13,000 Years
Fluoxetine, antidepressant	Acceptable: 350 Actual: 0.031	91,000 years = 1 Prozac tablet
Sulfa-methoxazole, common antibiotic	Acceptable: 190,000 Actual: 1.4	1,100,000 years
PFOS, fluorosurfactant used in stain repellants, textiles, etc.	Acceptable: 1,800 Actual:0.09	29 years = 1 day of exposure from other environmental factors
Bisphenol A, component of plastic bottles, epoxy resins	Acceptable: 2,500 Actual: 0.29	8.9 years = 1 day of exposure from food
DEET, insect repellant	Acceptable: 38,000 Actual:1.5	190 million years = 1 application to arms, hands and lower legs
Triclosan, antibacterial agent in soaps, deodorants, etc.	Acceptable: 2,700 Actual: 0.49	6,600 years = 30 seconds hand washing with antibacterial soap
Acetaminophen, over-the-counter pain reliever	Acceptable: 150,000 Actual: 0.55	1,700,000 years = 1 extra-strength Tylenol tablet

SOURCE: Adapted from WateReuse Research Foundation, 2011, available at website:
http://athirstyplanet.com/sites/default/files/uploadsfiles/PDF/RA%20Fact%20Golf%20_6.4.11_Lo.pdf

Table 8 Recycled Water Exposure Scenario—Landscape Worker Maintaining Landscapes Irrigated with Filtered and Disinfected Recycled Water

Sampling of Microconstituents (Pharmaceutical, Personal Care Products, Etc.)	Safe vs. Actual Concentration in Recycled Water, µg/L	Length of Exposure before Accumulating Quantity of Chemical Equal to Safe Dose
Ibuprofen, Over the counter pain reliever	Acceptable: 530 Actual: 0.5	8,600 Years = 1 Advil tablet
17-beta estradiol, hormone replacement	Acceptable: 0.05 Actual: 0.0084	5,000 Years
Fluoxetine, antidepressant	Acceptable: 100 Actual: 0.031	26,000 years = 1 Prozac tablet
Sulfa-methoxazole, common antibiotic	Acceptable: 12,000 Actual: 1.4	69,000 years
PFOS, fluorosurfactant used in stain repellants, textiles, etc.	Acceptable: 96 Actual:0.09	1 year = 1 day of exposure from other environmental factors
Bisphenol A, component of plastic bottles, epoxy resins	Acceptable: 620 Actual: 0.29	2.2 years = 1 day of exposure from food
DEET, insect repellant	Acceptable: 5,200 Actual:1.5	26 million years = 1 application to arms, hands and lower legs
Triclosan, antibacterial agent in soaps, deodorants, etc.	Acceptable: 970 Actual: 0.49	2,400 years = 30 seconds hand washing with antibacterial soap
Acetaminophen, over-the-counter pain reliever	Acceptable: 9,500 Actual: 0.55	110,000 years = 1 extra-strength Tylenol tablet

SOURCE: Adapted from WateReuse Research Foundation, 2011, available at website: http://athirstyplanet.com/sites/default/files/uploadsfiles/PDF/RA%20Fact%20Landscaper_6.4.11_Lo.pdf

Decomposition of Microconstituents in the Topsoil

Numerous studies of attenuation of contaminants of emerging concern have been reported in the literature in recent years, including Laws et al. (2011), Le-Minh *et al.* (2010), Hoppe-Jones *et al.* (2010), and many more. In the following paragraphs, summaries of findings from a few of the most relevant studies are presented below.

Crites (2006) reported on a controlled field experiment in Central Oahu, Hawaii, where there was a concern about the potential for contamination of potable water aquifers underlying irrigated lands. Recycled water and well-water irrigation were compared side-by-side on 12 plots growing grass and other vegetation. Lysimeters were used to collect samples from soil at various depths below the soil surface. Nutrients, inorganic constituents, bulk organics, metals, pesticides, and hormone compounds were monitored in applied and percolate water from the 12 plots.

After 12 months of irrigation, the percolate quality from plots irrigated with recycled water was not significantly different from the control percolate for total organic compounds (TOC) and other health-related constituents of concern, including N-Nitrosodimethylamine (NDMA), Atrazine and Lindane, and the endocrine system disrupting compounds: estradiol and estrone. The results are shown in Table 9. The importance of this finding is that the irrigation-applied

recycled water had significantly higher concentrations of the organic compounds than well water. Furthermore, NDMA, one of the most readily mobile organic compounds, was not detected in the recycled water plots' percolate water at concentrations significantly different from the percolate from well-water irrigated plots.

Table 9 Summary of Applied and Percolate Water Quality—Oahu Soils on Permeable Volcanic Parent Materials

		Applied Water				Percolate Water		
Constituent	units	% Detects		Mean Concentrations		% Detects	Mean Concentrations	
		Recycled	Control	Recycled	Control		Recycled	Control
Hormones (ASL):								
Estradiol	ng/L	100	100	0.922	0.730	58	0.850	0.968
Estrone	ng/L	88	75	7.16	2.78	17	0.400	0.645
Hormones (UCB) and Pesticides:								
Estradiol	ng/L	33	0	1.0	0.15	0	0.3	0.3
Estrone	ng/L	67	0	7.2	0.20	0	0.4	0.4
Atrazine	ug/L	0	0	0.047	0.047	0	0.046	0.047
Lindane	ug/L	0	0	0.0044	0.0044	0	0.0059	0.0062
Nutrients, Bulk Organics, and NDMA:								
Ammonia	mg/L	100	9	4.24	0.013	24	0.017	0.021
COD	mg/L	91	0	46.3	2.0	41	14.4	10.5
Nitrate as N	mg/L	100	100	4.40	1.59	88	5.05	1.83
Nitrite as N	mg/L	100	0	1.23	0.0041	45	0.0190	0.0055
Potassium	mg/L	100	100	16.2	1.66	93	0.865	0.395
TKN	mg/L	100	0	4.61	0.14	6	0.15	0.14
TOC	mg/L	100	18	5.4	0.23	100	1.2	1.3
Total P	mg/L	100	91	2.58	0.211	10	0.041	0.037
NDMA	ng/L	91	36	11	3.3	32	0.79	1.9

SOURCE: Reproduced from Crites 2006, with minor format and style modifications.

The study concluded that "recycled water can be used safely for irrigation over the unconfined aquifer in Central Oahu." (Crites, 2005) It is noteworthy that the volcanic soils on Oahu are relatively permeable, representing worst-case conditions in terms of their potential for transmission of soluble constituents downward. This is corroborated by the author's finding of higher TDS and metal concentrations in the percolate from recycled water-irrigated plots than from well-water-irrigated plots. The Higher TDS and metal concentrations are specific to the recycled water available for the experiment. Since salts are soluble and mostly conservative, their impact on groundwater resources can be significant unless underlying strata preclude further downward advance of leached water.

Another major study of the destruction of microconstituents, also referred to as pharmaceuticals and personal care products (PPCPs), in soil was conducted in laboratory, greenhouse and field settings (McCullough *et al.* 2013). The authors concluded:

> "Results clearly show that with the exception of a few compounds, most PPCPs did not appear in the leachate under the conditions employed in this study. Trimethoprim and primidone were frequently found in the leachate for both soil types and at both irrigation rates. However, after accounting for leaching (or drainage) fractions, the mass removal for these PPCPs was always greater than 80%. Turfgrass serves as an effective biofilter for PPCPs during recycled water irrigation, despite the fact that many PPCPs are persistent and/or weakly adsorbing in soil. Conditions used in this study were simulations of worst-case scenarios in that the irrigation rates were high and that the leachate was monitored at 90 cm below the surface. The actual leaching risk for PPCPs may be even more limited under typical soil and management conditions."

The relevance of these conclusions to farms, gardens and other sites growing edible foods is that nearly all of the attenuation of microconstituents occurs in the top layer of the soil where biological activity within the aerobic zone leads to decomposition of such compounds (Crites 2006).

Potential for Uptake of PPCP/EDCs in Leafy Vegetables

Dodgen *et al.* (2013) studied the potential for uptake and accumulation of microconstituents in two leafy vegetables (lettuce and collards) in hydroponically grown cultures, using spiked ^{14}C-labeled compounds[16]. While some uptake and accumulation of the compounds in the leaf was observed with relatively high concentration of compounds in the hydroponic culture, the authors concluded that "Dietary uptake of these PPCP/EDCs by humans was predicted to be negligible" under normal field cultivation of the vegetable crops.

Long-Term Irrigation with Recycled Water

Groundwater quality was tested for endocrine disrupting compounds (EDCs), a subset of microconstituents, in the groundwater beneath a golf course that had been irrigated with recycled water for 25 years (Hudson, et al., 2005). Some of the conclusions reported by the authors:

- "The Las Positas Golf Course in Livermore, California is a hydrologically well-characterized site for studying the long-term occurrence, transport, and fate of EDCs originating from treated wastewater.
- "Highly specific and sensitive analytical methods involving SPE and isotope dilution LC/MS/MS were successfully developed for a range of target compounds including NP, AP1EC, AP2EC, 17b-estradiol, estrone, estrone 3-sulfate, and caffeine.
- "NP was not detected in LPGC groundwater (detection limit, 11 ng/L) despite average concentrations of 3000 ng/L in the irrigation water (i.e., LWRP tertiary-treated effluent);
- "The estrogenic bioassay showed a significant response to the LWRP samples that contained approximately 3 mg/L NP. No significant luciferase response was noted for cells exposed to LPGC

[16] Carbon-14 (denoted as ^{14}C) is a rare isotope of the common carbon (^{12}C), used in tracer studies by researchers because of its stability and ease of detection with great accuracy.

groundwater, which was consistent with analytical data showing no detectable NP or steroid estrogens in the groundwater samples."

(EDC = endocrine disrupting compound;
SPE =solid-phase extraction;
LC/MS/MS = liquid chromatography/tandem mass spectroscopy;
NP = 4-nonylphenol[17];
AP1EC, AP2EC = alkylphenol ethoxylates[18])

AGRONOMIC CRITERIA FOR SUSTAINABLE IRRIGATION WITH RECYCLED WATER

Under natural conditions, productivity of the soil depends on continuous cycling of the nutrients in the ecosystem. Cultivation of the land for crop production requires inputs of water, nutrients, and other resources to ensure an economical (profitable) yield and sustainability of the farm operation in the long term. Introduction of recycled water into the traditional agriculture sector requires some changes in routine operations and a closer monitoring of the possible impacts of the new water source.

Salinity, Sodicity, Boron, Metals, Nutrients

From a public health point-of-view, recycled water, treated to the Category 3 standard, is by far safer than raw waters drawn from surface water sources for irrigation—as shown in other parts of this White Paper. From an agronomic point-of-view, however, there are a few differences between recycled water and the water from which it typically originates. These differences can have significant impacts on the soils and plant materials if: (a) the differences are indeed very large, and/or (b) if irrigation and fertilization management is not modified to account for the differences in water quality. The differences can be generalized, though not universally applicable, thus:

- Higher salt content, potentially leading to soil salinity
- Higher sodium, higher sodium adsorption ratio (SAR), potentially leading to soil sodicity (black alkali) and reduced soil permeability
- Higher chloride
- Higher pH
- Possibly higher boron
- Higher nutrient content (nitrogen, phosphorus, potassium and micronutrients)
- Possibly higher suspended solids and turbidity

[17] NP and 17b-estradiol, were studied not only because of their potential estrogenic effects on receptors but also because they can be useful as tracers of wastewater residue in groundwater.
[18] A class of nonionic surfactants, and their metabolites are the most prominent group of EDCs identified in wastewater and treated wastewater.

These difference are usually within the tolerable chemical quality ranges of irrigation waters used in farming and landscapes. In most cases, the higher concentrations can be tolerated by plants and managed in the soil with proper irrigation scheduling and soil amendments. A five-year field research project in Monterey County, CA with a replicated random plot design showed no difference between plots irrigated with recycled water and those irrigated with well water (Sheikh, et al., 1998). The well water was pumped from a 600-ft deep aquifer with very high microbiological and chemical quality—there were no indicator organisms detected, low salinity, and non-detect heavy metals. On the other hand, the salinity and other chemical properties of the recycled water used in that research study represented a worst-case scenario for many of the parameters of concern. Over the 18 years since the pilot project ended and full-scale application of recycled water started, water quality from the full-scale plant's recycled water has been and continues to be superior to that of the experimental plant used in the pilot study.

The higher nutrient content of recycled water accounts for a fraction of its higher salt content and is (in most cases) a significant benefit. This is because the growers can reduce the amount and frequency of fertilizer application to the crop, when irrigating with recycled water. A recycled water containing 15 mg/L of nitrogen as N (whether it is in nitrate or ammonia form), would deliver 41 lb/acre of nitrogen for every acre-ft of water applied. A typical farming operation in the Denver area would apply about 3 ft of water (3 AF per acre) during an irrigation season, with an equivalent of 122 lb of N delivered per acre. For many crops, this represents about half of the nitrogen demand for crops, thus saving the grower considerably in fertilizer chemicals and application labor and energy use. In rare cases, the available nitrogen in the water can cause problems; for example, during the fruit setting stage of citrus crops, excess N in the soil can cause deformed shapes and reduced crop yield. Growers are generally aware of the chemical characteristics of their irrigation water. This knowledge gives them the tools necessary to adjust their fertilization practices accordingly.

Research Results on Long-Term Salt Accumulation in Soils

Pratt (2013) reported on a ten-year longitudinal study of salt content of soils continuously irrigated with recycled water in Monterey County, California. Samples were obtained at three depths over the ten-year period. The study concluded:

> "Analysis of the sites from 2000 – 2009 showed that most sites were accumulating Na and Cl. The accumulation of Na was significantly less than Cl. After Salinas river water was blended with the recycled water, most of the sites had decreases in both Na and Cl. However, three sites still have very high levels of Na and Cl and could be at risk for infiltration issues and Cl toxicity for the Cl sensitive crops grown in the project area (Hawkes, 1985). The accumulation of Cl is a very serious consequence and indicates that the use of recycled water with > 5 meq/L Cl [175 mg/L] requires mitigation."

The increase in chloride concentration in the soil solution over the ten-year period is particularly worrisome, because chloride is highly soluble and is not adsorbed on soil particles—it should have been steadily leached out of the root zone with each irrigation and with each rainfall episode. This raises the importance of monitoring and taking remediation measures as necessary when using recycled water with high levels of sodium and chloride. The Denver Water recycled water has much lower levels of sodium and chloride as shown in Figure 1.

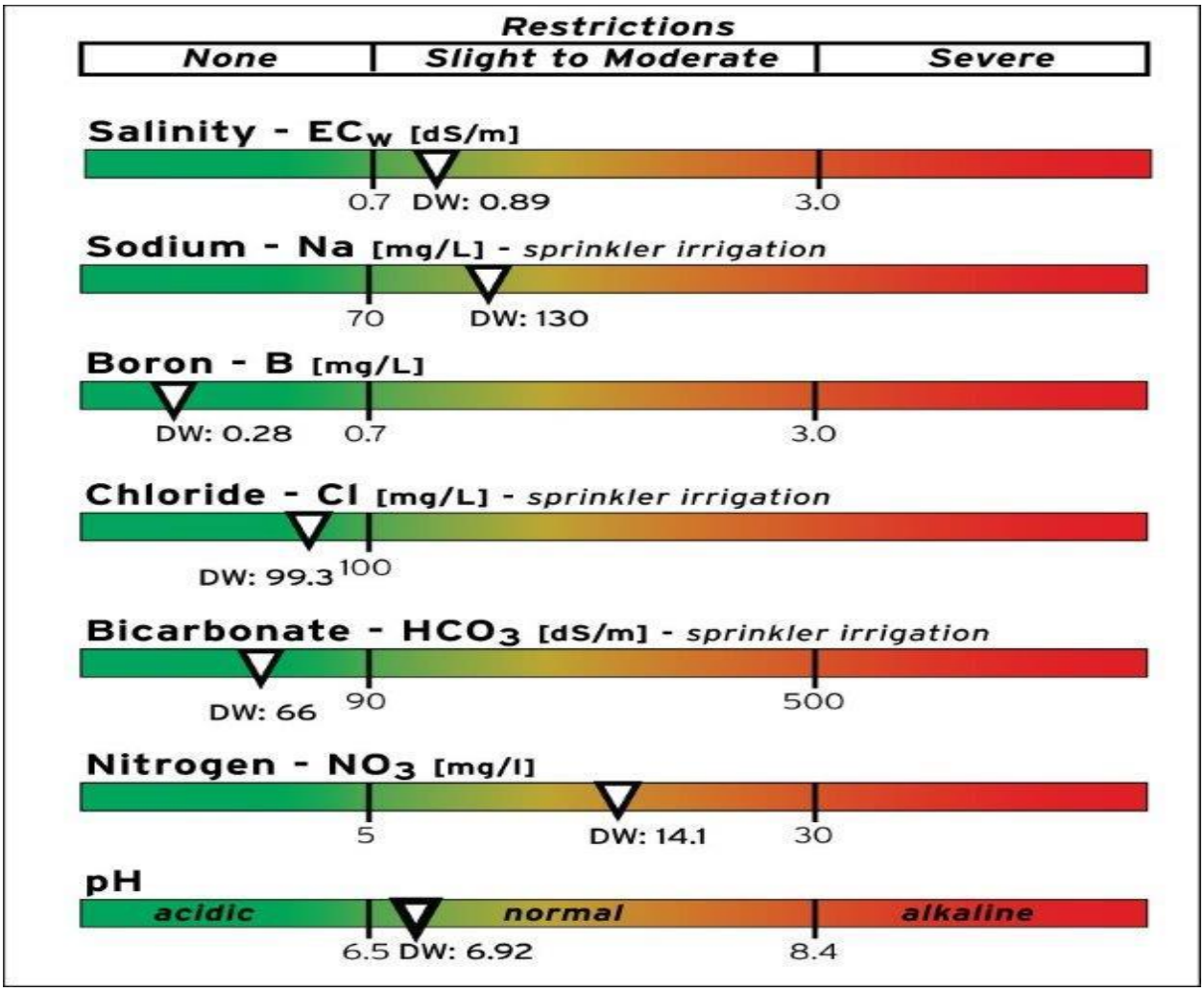


Figure 1 Quality of Denver Water's recycled water in the spectrum of potential restriction for irrigation use

Colorado-Specific Research Results

Vigorous research programs are underway at the academic institutions in Colorado. Specifically, the Colorado School of Mines continues to publish research results on various aspects of water reuse, with support from the federal government and WateReuse Research Foundation, among others.

Researchers at Colorado State University performed baseline soil sampling in 2004 and follow-up sampling in 2009 to investigate the impacts of recycled water use, mostly on salt impacts on ten Denver Water landscape irrigation sites in parks and golf courses (Qian, y. 2010). This study is an excellent local confirmation of potential impact from using recycled water over a relatively long period of time. A summary of major findings from this study is listed below. The findings are expressed in technical terms, providing managers of sites growing edible crops with guidelines for countering potential negative impacts from some of the constituents of recycled water.

- Soil salinity (as gauged by soil electrical conductivity) and soil organic matter content did not increase at most of the sample sites over the five-year period;
- On average there was a slight increase in soil pH from 2004 to 2009.
- The average indicators of sodicity (exchangeable sodium percentage, or ESP, and sodium adsorption ratio, or SAR) values approximately doubled over the five-year period.
- Results suggested sodicity is of greater concern than salinity at most of the testing sites, since soil ESP and SAR are two parameters that exhibited the most significant changes from 2004 to 2009. Soil and/or water amendment with calcium-based products may help to displace sodium and reduce ESP and SAR, especially at the surface (0-20 cm) depth. Continued increases of ESP and SAR could potentially cause reductions in soil hydraulic conductivity in soils with high clay content. Increased soil ESP and SAR may reduce soil aggregates stability and reduce overall soil health.
- Although recycled water also contains phosphorus, no increase in soil P was observed over 5 years with recycled water irrigation. Nitrate–N content decreased significantly with soil depth. Nitrate-N level beyond the turfgrass rootzone in 2009 samples was < 3 mg kg-1, well below the EPA standard for potable water quality (10 mg kg-1). This indicates that nitrate contamination of groundwater should not be a great concern when using recycled water for the irrigation of turf systems. Dense, well-managed, and active-growing turfgrasses serve as bio-filtration systems for removal of excess nitrate[19]
- All except two sites had a good to excellent irrigation uniformity (> 70%. Irrigation distribution uniformity). No clear relationship between irrigation distribution uniformity and measured soil parameters was observed. The 13.2% higher than average precipitation in 2009 growing season might have suppressed such relationships.

Another report from the City of Westminster, Colorado on "Reclaimed Water System Salinity Management Plan", published in 2009, provides strong support for use of recycled water for irrigation of crops and landscape—from agronomic perspectives of salinity and sodicity (Olson Associates, 2009). The main findings of the study are:

[19] Nitrogen removal by plants varies widely. While turfgrasses are efficient in nitrogen uptake, food crops also need nitrogen and absorb significant amounts from the soil—requiring more than the amount available in most recycled waters.

1. Reclaimed water produced by the City of Westminster is of good quality with slightly elevated levels of salinity [TDS = 615 mg/L], including sodium (98.6 mg/L) and chloride (115 mg/L) concentrations that are typical of reclaimed water produced throughout the western United States. In fact, reclaimed water as produced by the City compares very well not only to reclaimed water but even potable water that is used in other cities where users report few irrigation problems.

2. Water used for irrigation throughout the United States with salinity, measured as Total Dissolved Solids (TDS), sodium, and chloride concentrations similar to Westminster's reclaimed water can still be expected to result in increased accumulations salt, sodium and chlorides in soil and plants that requires additional management to alleviate potential soil and plant problems.

3. At nearly every site inspected where vegetative problems have been realized, there are also extenuating environmental factors that also contribute to vegetative stress and even death. At many locations, the existing environmental factors are likely the dominant plant stressors.

4. Many reclaimed water users seem to perceive that reclaimed water is the sole cause of problems with vegetation or that it poses a greater risk than is realistic given the water quality The landscape issues observed at customer sites are more likely the result of several factors that are more a result of complex environmental factors.

5. The dominant issue is that the City of Westminster has saline conditions that affect landscape success. The source of the salinity must be defined to be effectively managed; whether the source is groundwater, soil, reclaimed water, or a combination of all of these factors. Phase I of this project leads to the contention that environmental sources in soil and groundwater are the dominant contributors of salinity being experienced in the City. This single factor alone must be the core driver of developing a successful irrigation salinity management plan for the City of Westminster.

Recommendations for safe use of recycled water contained in this report are consistent with generally accepted irrigation water management practices worldwide, and available in a variety of publications in agronomy and soil science. These recommendations need not be implemented as regulation. Instead, a communication link between the producer of recycled water (treater) and end users of the water need be established to convey the water quality characteristics and any fluctuations. Growers are mostly quite capable of managing their cultural practices to adapt to varying water quality and other inputs.

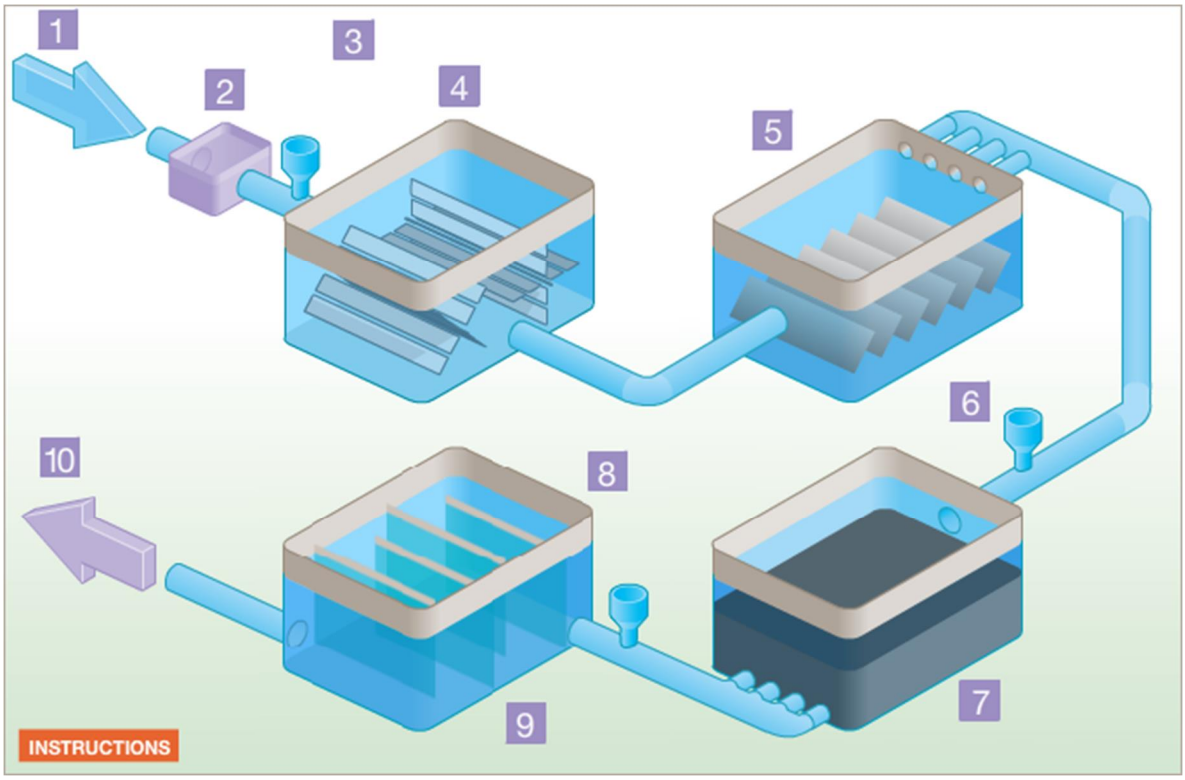
TREATMENT PROCESSES ENSURING SAFETY OF RECYCLED WATER

Treatment processes are necessary to achieve two goals. First and foremost, the primary goal in wastewater treatment and water recycling is protection of the public health. The secondary goal (especially for reuse) is to provide the quality of water that meets the needs of the

customer (end user) of recycled water. Protection of the public health can be achieved with minimal treatment if the public is protected from exposure to the water. However, this is not possible in most applications—irrigation of landscaping, irrigation of crops, decorative fountains, and cooling towers. Therefore, higher levels of treatment would be necessary so that even with complete immersion there would be minimal threat of microbial transmission to humans.

Fortunately, experience with treatment trains that can accomplish this level of protection—consistently and reliably—is abundantly available in Colorado. In fact the Category 3 Standard specified in Regulation 84 can be attained with treatment trains similar to that represented in Figure 1. While the specific unit processes shown in Figure 2 are not directly required for meeting Category 3 reclaimed water, these processes were obviously deemed necessary by design professionals at Denver Water in order to produce water that reliably meets the specified water quality parameters in Category 3 definition in Regulation 84.

Thus, for all practical purposes, use of Category 3 reclaimed water for irrigation of edible crops can be allowed now if reliability and accountability features can be built onto it to create a Category 4 reclaimed water. In a final section of this White Paper, specific recommendations for changes to Regulation 84 are presented for consideration.



Denver Water's website provides an interactive illustration of the treatment train in the following link: http://denverwater.org/docs/assets/18CF8B50-B715-4DC6-E3E4073E293045ED/RecycledWater.html

Figure 2 Treatment Process Train at the Denver Water Recycling Plant

(SOURCE: Denver Water http://www.denverwater.org/EducationOutreach/RecycledTreatment/#) This is an animated and interactive site that clearly illustrates every process in the treatment train, culminating in production of a water quality fit for irrigation of edible crops—with a relatively small, but highly consequential and beneficial change in Regulation 84.

The tertiary phase of the treatment process (filter beds in the above schematic) can be replaced, in future treatment plants, with microfiltration membranes, achieving an even higher level of treatment. Another possible future treatment alternative is the replacement of biological aeration reactor and the filter with a single membrane bioreactor (MBR) unit, similar to the schematic shown in Figure 3.

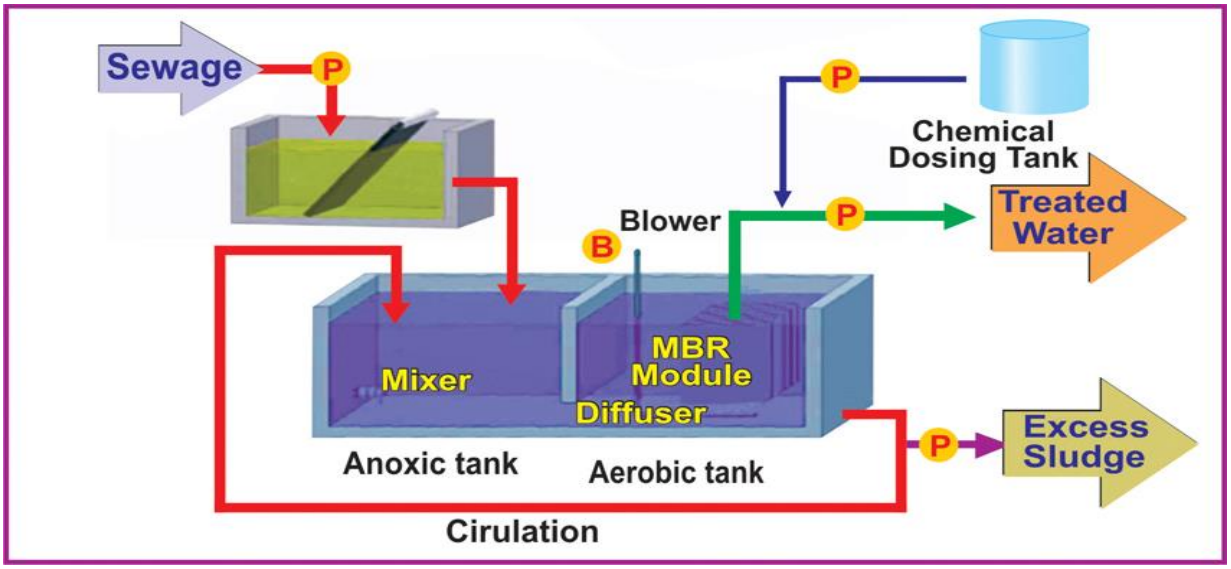


Figure 3 Membrane Bioreactor (MBR) Typical Configuration

The schematic is for illustrative purposes only, as there are many variations in design of treatment systems adapting to local conditions. One of the main advantages of the MBR system is that it takes a much smaller space (footprint) for the same flow and can be scaled to small, distributed, satellite plant applications. Note that the influent to the MBR system is raw wastewater (sewage) whereas the conventional tertiary treatment system depicted in Figure 1 receives secondary effluent as its influent stream.

DIFFERENT CATEGORIES OF RECYCLED WATER FOR DIFFERENT TYPES OF CROPS

The concept of “right water for the right use” is increasingly embraced by water agencies with customers whose water quality needs vary widely. Ultra-pure water is required for semi-conductor industries and high-pressure boiler feed; secondary effluent may be sufficient for low-contact irrigation, for example for orchards and freeway landscaping. Irrigation of vegetable farms, greenhouses, and community gardens, in which food crops are grown and where children may be in contact with the water poses a special situation in which a high degree of safety from microbial exposure is desired. Today’s wastewater (and water) treatment technologies are adaptable to these various levels of treatment. One agency in Southern California prides itself in serving five “designer waters” to its various recycled water clients.

Most other agencies produce recycled water quality that meets the requirements of their most demanding customer, thus serving a uniform product to all customers.

The graphic in Figure 4 represents a **qualitative** and generalized risk level associated with each level of treatment and for each type of customer (end user) of recycled water. Risk assessment and quantification is based on highly site-specific conditions, and Figure 4 is not based on any such computation of probable risk. This graphic is a simple-minded, comparative illustration, based on intuitive evaluation of risk under different treatment scenarios for different uses of recycled water. For comparison, the equivalent treatment level for Category 3 reclaimed water is illustrated with a vertical bar set at its approximate water quality/treatment levels, as risk-free as California's Title 22 disinfected tertiary recycled water.

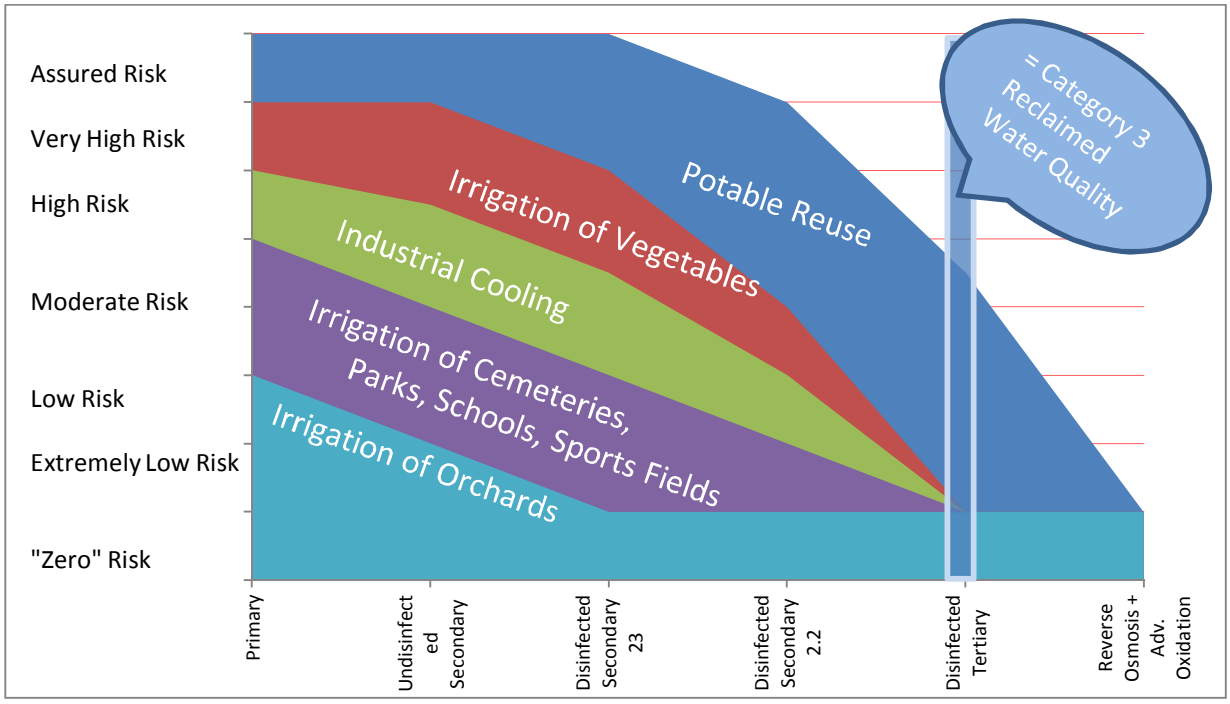


Figure 4 Risk vs. Treatment Level for Five Uses of Recycled Water

Raw water, commonly used for irrigation of all crops (including edible crops) has a much lower microbial and chemical quality because of its exposure to the environment. Dust, animal droppings, runoff from surrounding areas, and other input into the surface streams contaminate the raw water to varying extents. Raw water is not disinfected and cannot be guaranteed not to include pathogens. By contrast, the level of disinfection and microbial standards for Category 3 reclaimed water provide for a consistently safe irrigation water.

Figure 5 shows five-year E. Coli monitoring at eight stations along Cache La Poudre River, a source of raw water for irrigation by many farmers in Northern Colorado. The E. Coli indicator concentrations hovering around 100 cfu/100mL are much higher (by far inferior in microbial quality, from a food-safety perspective) than a recycled water meeting the Category 3 limit of non-detect 75 % of the time. Poudre River water quality is not an exception or an outlier. All surface waters are subject to contamination from wildlife, windblown contaminants and other external inputs.

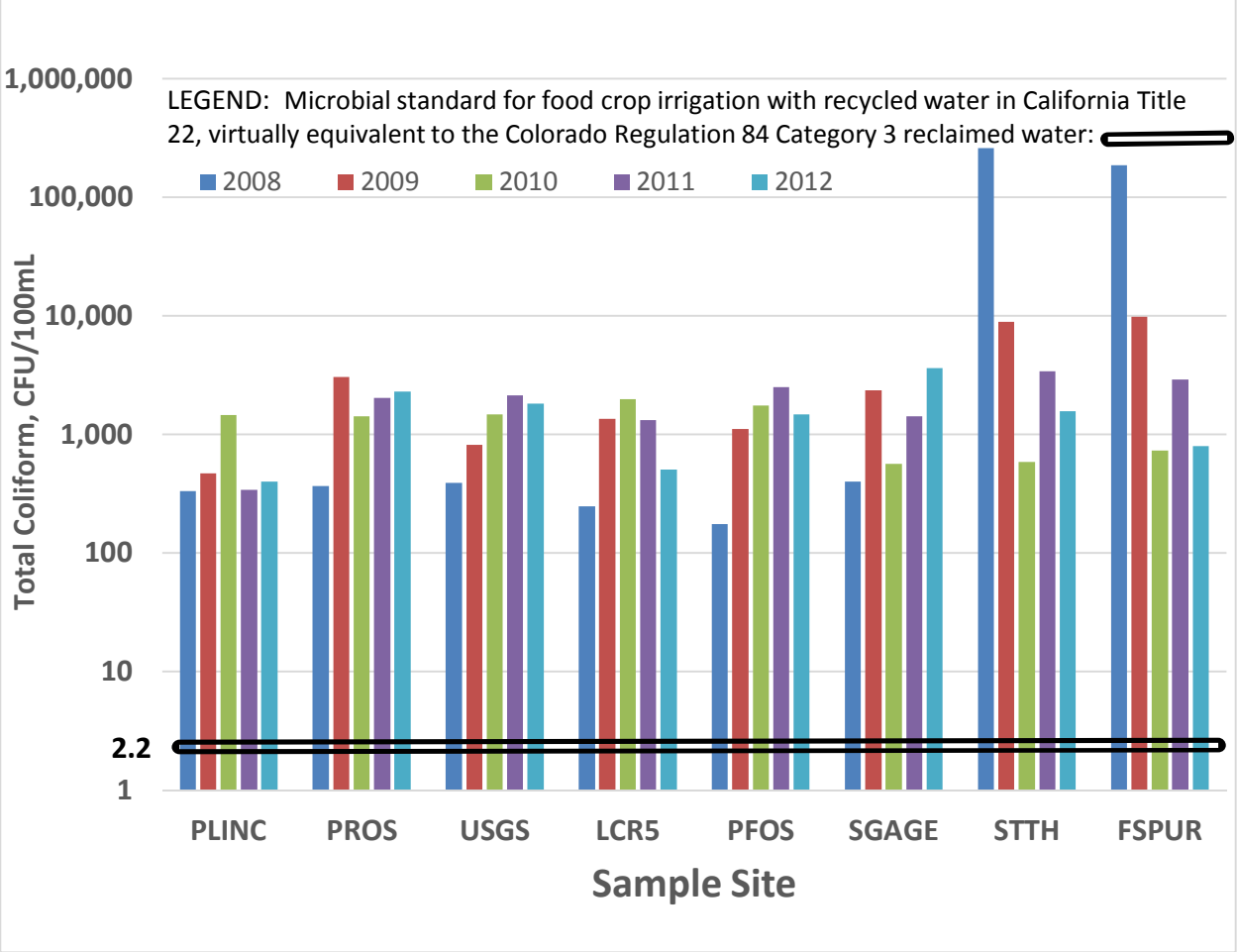


Figure 5 Results of Five-Year Microbial Monitoring on 8 Sites[20] on Cache La Poudre River
Source: Colorado State University, courtesy of Prof. Douglas A. Rice, Ph.D., Laboratory Director, Colorado State University - EHS

[20] Sample sites are situated at select locations along the river, from Fort Collins to Greeley.

Farmers' Experience with Recycled Water

Orange County, Florida

Water Conserv II Distribution Center, Surrounded by Citrus Orchards

Water Conserv II is the largest water reuse project of its kind in the world. It is a cooperative water reuse program between farmers, Orange County Government, and a private maintenance company. The recycled water irrigates up to 2,737 acres of citrus annually. Water Conserv II is also the first reuse project in Florida permitted by the Florida Department of Environmental Protection (FDEP) to irrigate crops produced for human consumption with reclaimed water. The project's reclaimed water meets FDEP's public access reuse standards and is permitted for use on all public access sites including residences and golf courses, food crops, foliage and landscape nurseries, tree farms, pasture land, the production of soil cement, and can also be used for fire protection.

Benefits to (voluntarily) participating citrus growers Include:

- A dependable source of irrigation water that is not subject to water restrictions during drought.
- Elimination of the effort required to secure, maintain and renew a consumptive use permit (CUP) for an irrigation well—a requirement that may be specific to Florida.
- Elimination of installation, operation and maintenance costs of deep wells or surface water pumping systems.
- Faster growth of young tree, due to continuous availability of nitrogen in the irrigation water.
- Elimination or reduction of some fertilizer applications, because of presence of nitrogen, phosphorus, potassium, and micronutrients in recycled water.
- Enhanced freeze protection capabilities.

Purple pipe delivering recycled water at the base of citrus tree for irrigation, and for frost protection in winter-time.

King County, Washington (condensed from USEPA, 2012, p. D-169)

The University of Washington conducted both a greenhouse study and a field trial to demonstrate the low potential for pathogen transfer (as indicated by presence of bacteria indicator species) and metal uptake from reclaimed water to garden vegetables. Lettuce,

carrots and strawberries were included in the study, as each of these are commonly grown by local farmers and each presents potential risk pathways to test the contaminants of concern. Lettuce is known for high uptake of heavy metals and has been used as an indicator crop for metal availability (Brown et al., 1998). The edible portion of carrots is grown directly in soil and so may be more susceptible to pathogen contamination. Strawberries are often consumed without washing, also making them likely candidates for pathogen transfer. In general, metal uptake for plants grown using reclaimed water was similar to that for those grown with tap water.

In the greenhouse study, there were also no differences in bacterial indicators between the tap water irrigated crops or the reclaimed water irrigated crops for both washed and unwashed samples. Total coliforms were the only bacteria detected and they were only detected in the tap water control. In the field trial, total coliform counts were higher for all vegetables grown using reclaimed water in comparison to the tap water. This was likely due to increased contact with soil and coliform bacteria in the soil. Fecal coliform and E. coli were not detected in any of the vegetable samples grown in the field trial.

Monterey County, California

Since 1998, a highly productive agricultural area in Monterey County, CA, has been using disinfected tertiary recycled water for irrigation of 12,000 acres of vegetable crops, including artichokes, broccoli, cauliflower, celery, lettuce, and strawberries.

In 1975, when the concept was first introduced to the farming community, they were skeptical about the safety, salt impacts, and sales stigma due to potential negative public perceptions of "sewer water" use on their crops and soils. It took a long-term research and demonstration pilot program conducted within the same farming areas (Sheikh et al., 1998) to allay the public health and safety concerns. Further motivation was added with persistent seawater intrusion into their aquifers, and severe water shortages and droughts recurring in the area. The combination of these factors worked to persuade farmers to use the recycled water provided from a regional wastewater treatment facility with a capacity of nearly 30 million gallons per day. Eighteen years later, one of the farmers in this area says: **"Farming in this region would not be possible today without recycled water"** (Huss, 2014).

Santa Cruz County, California

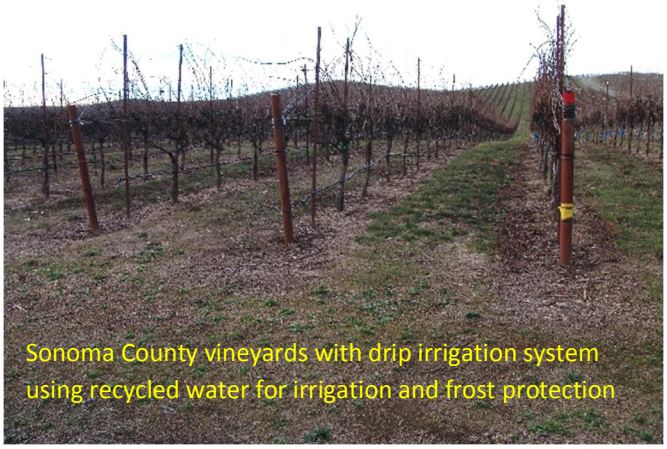
Several years after Monterey County started its recycled water service, farmers in the neighboring Santa Cruz County became interested in the possibility of irrigating with recycled water from the City of Watsonville's Water Resources Center, a wastewater treatment plant designed specifically for producing high-quality recycled water for irrigation of food crops.

Larse Farms, one of the largest strawberry producers in the world, switched to recycled water for irrigation and continues to produce and supply the market.

The Center is a joint effort of the City of Watsonville and the Pajaro Valley Water Management Agency to provide recycled water to 5,000 acres of vegetable farms throughout the coastal areas of South Santa Cruz and North Monterey counties. By treating wastewater and making it available to the local agricultural industry, the water recycling project protects groundwater that was being pumped more rapidly than the rate of replenishment. This imbalance in groundwater extraction was causing seawater intrusion into coastal aquifers, making the farmers' wells unusable.

Sonoma County, California

City of Santa Rosa, in Sonoma County, operates a 20 million gallon-per day water reclamation facility that provides disinfected tertiary recycled water to over 6,000 acres of farmland, including 1,436 acres of vineyards and 187 acres of vegetables and specialty crops[21]. The vineyards use (disinfected tertiary) recycled water for irrigation and frost protection. One of the most prominent wine makers in California, E.&J. Gallo Winery, has signed a 50-year purchase agreement for use of recycled water and has built a 60 acre-ft reservoir for off-season storage of recycled water. Some of the vineyards using recycled water produce brand wines that fetch high prices per bottle produced suggesting no negative perceptions about effects of recycled water on the high quality of wine.



Sonoma County vineyards with drip irrigation system using recycled water for irrigation and frost protection

[21] http://ci.santa-rosa.ca.us/departments/utilities/irwp/Pages/aricultural_reuse.aspx

COMMUNITY GARDENS USING RECYCLED WATER

During the 1970s, thousands of community programs had been organized, nation-wide, to provide land and resources to people without property of their own to use for gardening. The City of Chicago was a pioneer in municipally-sponsored community gardens. Programs were developed under the sponsorship of municipal parks departments, local Cooperative Extension services, nonprofit organizations, churches, schools, social service agencies, and neighborhood associations. The American Community Gardening Association[22] (ACGA) was formed in 1979 as a bi-national nonprofit membership organization of professionals, volunteers and supporters of community greening in urban and rural communities. The ACGA was formed as a by-product of two national community gardening conferences organized by the City of Chicago Department of Human Services in 1978 and 1979.

Denver Urban Gardens[23] (DUG) was established in 1985, in order to support Denver residents in creating sustainable, food-producing neighborhood community gardens. By 1993, DUG was the sole organization responsible for coordinating 21 active gardens, and by 1997, 32 new gardens and DeLaney Community Farm were established. Currently (October 2015), there are more than 150 urban gardens, schoolyard gardens and related food-producing sites are in operation in the Denver metropolitan area.

Most of the community gardens in the United States use municipal potable water for irrigation. Over the last decade, several have switched to recycled water or started operations with recycled water. WateReuse Research Foundation published a monograph dedicated to use of recycled water for community gardens (WateReuse, 2012). A few of the community gardens currently using recycled water are briefly described below.

Guadalupe Gardens in San Jose, California

Guadalupe Gardens is located on 38 acres south of Mineta San Jose International Airport. It includes a 4-acre demons-tration site for local homeowners and landscapers to witness the effective use of recycled water on a wide variety of lush and attractive plantings. A recycled water main runs through Guadalupe Gardens, making the supply of water available to all plantings in the garden. In order for gardeners and their helpers to acquire a plot, they are required to be trained

[22] https://communitygarden.org/
[23] http://dug.org/

in the use of recycled water. The primary focus of the training is on prevention of cross-connection and backflow into the potable water supply system of the community—as required by Title 17 of the California Code of Regulations.

There are 84 plots for use by community members on the one-acre area devoted to the community gardens. Currently, there is a waiting list with over 75 applicants for these plots. The website[24] dedicated to the garden describes the following features:

- Developed by the City of San Jose, South Bay Water Recycling, and the Guadalupe River Park Conservancy
- Santa Clara County Master Gardeners use a plot in the gardens for demonstration, education and research
- Addresses the Mayor's Green Vision goal to recycle or reuse 100% of the city's wastewater, ~100 mgd
- First community garden in California to be irrigated with recycled water
- One acre in size, with state-of-the-art design and plans to double the area in the future
- 29 individual plots for gardeners, (twenty 20' x 20' plots, and nine 15' x 20' plots)
- 4 accessible raised beds, (20' x 5' x 32"h)
- Shade structure, picnic tables, barbeque, compost bins, tool shed, and a sink for washing produce
- Centrally located and accessible by public transportation

Monterey Road, Glendale, CA Community Garden

The Monterey Road Eco-Community Garden is operated by the local nonprofit start-up Coalition for a Green Glendale. The 11,000-square-foot garden was approved by the City Council in 2008 and has since gone from a barren dirt lot to blossoming field for roughly two dozen local gardeners who pay about $80 a year per plot. The California Department of Public Health authorized the use of recycled water for the garden after a lengthy application process. The ability to use recycled water for the community garden was enhanced by the fact that Glendale Water & Power had a reclaimed water line along Monterey Road.

The recycled water, while not approved for drinking, is already used to irrigate much of the city's parkland after implementing tertiary

[24] http://www.grpg.org/the-park/river-park-gardens/community-garden

treatment and disinfection. The Monterey Road Eco-Community Gardens has a blogpost at http://montereygarden.blogspot.com/

King County, WA, Reclaimed Water and Biosolids Demonstration Garden

King County, Seattle University and the Salvation Army Renton Food Bank have partnered on a 5-year community garden project located on one acre of the South Treatment Plant facility in Renton, WA. This project is demonstrating the beauty, effectiveness and safety of using recycled nutrients on a community garden. The beds are amended with compost and organic fertilizer. Beds are planted with a variety of flowers, food crops, annuals and perennials. This project was designed and permitted to benefit the wastewater utility and the public by:

- Demonstrating the use of compost made with biosolids and increasing the public's understanding of the benefits of recycling carbon and nutrients.
- Providing an active learning site for the Seattle University Environmental Studies Urban Agriculture students.
- Creating a locally grown supply of fresh produce for the Renton Food Bank.
- Providing community education opportunities to expand knowledge of local water and food system challenges and solutions.
- Demonstrating the benefits of diversified and collaborative urban land use and the potential for material and resource sharing and conservation. Since start up in 2011, large quantities of landscaping waste and surplus building materials have been repurposed and recycled on site; reducing transportation and disposal costs to the utility and providing a cost effective source of materials and supplies for the garden.

Precautionary Measures to Further Ensure Safety

Use of filtered and disinfected reclaimed water for irrigation at urban gardens is demonstrated to be safe and beneficial to the community. There is no need for additional provisions for such use in the updated Regulation 84. Nonetheless, participants in urban gardens should be made aware of the fact that reclaimed water is in use and it should not be cross-connected to the potable water system and it is not intended for drinking. There are several additional reasons for taking precautionary measures when allowing members of the public to use recycled water for irrigation of food crops. Chief among them are the following:

- Prevent cross-connection of recycled water lines with potable water supply lines
- Promote community gardens as positive amenities for gardeners, neighbors and the public
- Produce wholesome and healthy locally-grown fruits and vegetables for the members and those to whom they donate and share produce.
- Establish fairness and equity among community gardeners
- Prevent damage to the land and groundwater
- Protect the future of community gardens in Colorado

Some community gardens have relatively lax rules for participants while others have extensive and detailed rules and regulations governing ownership, responsibilities, behavior, fees, and other matters in relation to the plot(s) they cultivate and manage. Because of the use of recycled water and the need to prevent cross-connection with potable water supplies, enforcement of appropriately nuanced rules is important. Training of persons growing food crops at a community garden irrigated with recycled water is an excellent precautionary measure with proven results. An example of rules, promulgated in all community gardens—including the Guadalupe Gardens—in San Jose, CA, is presented in its entirety in Appendix C. Major provisions of these rules are summarized below:

- Plot allocation and registration fees
- Gardening guidelines
- Plot-holder responsibilities
- Violations of community gardens program rules and regulations
- Hours of operation, behavior, tools, storage, amenities, water use, standard forms
- Garden product policy guidelines
- Contact information

ECONOMIC VIABILITY OF IRRIGATION WITH RECYCLED WATER

Cost of water is a very small fraction of production costs for crops, especially in the case of high-value vegetable crops grown intensively with big investments in land preparation, irrigation systems, and modern, technically advanced cultural practices. Switching to recycled water does not change this fact. However, in many cases, the price of water to the grower is artificially set below the price of potable water as an incentive to increase recycled water use as a means to conserve potable water resources. For example, Denver Water currently provides recycled water at 20% of the price of potable water. This provides a significant savings on the water component of farming cost when a grower shifts to using recycled water.

Another important cost savings is in the fertilizer application costs. Reclaimed water contains a significant amount of nitrogen supplying from 25% to 75% of the plants' need for nitrogen, depending on the crop being grown and the concentration of nitrogen (in ammonia and nitrate forms) in reclaimed water. Reducing fertilizer application labor and energy (gasoline for the tractors and pumps) is another significant savings.

A semi-quantitative analysis of costs and benefits of recycled water was conducted and widely reported and cited (Sheikh *et al.*, 1998). The study enumerated quantifiable and non-quantifiable benefits from reclamation and reuse of water, and argued that added altogether, these benefits far exceed the costs associated with treatment, distribution, and management of a recycled water system, as summarized in Table 10.

Table 10 Summary of Benefits of Typical Water Reuse Projects—Using 1998 Valuations

Benefit	Applicability	Value ($/AF)*
Water supply	Very common	$300 to $1,100
Water supply reliability	Very common	$100 to $140
Effluent disposal	Very common	$200 to $2000
Public health	Situational	**
Environmental benefits		
Upstream watersheds	Very common	**
Downstream watershed	Common	$400 to $800
Environmental restoration	Situational	**
Energy conservation	Situational	0 to $240
Economic development	Situational	**
Approximate Range of Total Value		**<$1000 to >$4,280**

*The range of dollar values in this summary is derived from specific examples cited in the paper [cited in References, with values given in 1998 dollars and with prevailing values in the 1990s]. These values do not necessary represent the entire range of possible values.

**While no dollar values are assigned to some benefits, there exist economic models and methods for assigning money values to these benefits—e.g. contingent valuation method, willingness-to-pay method, etc. Because results from these methods vary widely depending on specific situation, ranges of values are not given here.

The economic viability of irrigation of food crops with recycled water has been demonstrated over several decades in Florida, Arizona, Texas, Washington, and California. Major citrus growing areas in Orange County, Florida have been in successful production since 1987 in a program called Water Conserv II. In King County, Washington, recycled water is used for irrigation of leafy greens and fruits, and the produce is marketed to the public. In Monterey County, California, over the past 16 years, many of the growers have had such positive experience from using recycled water that they have switched from low-revenue crops to high-profit ones such as strawberries and raspberries on a massive scale. Table 11 shows the extent of this notable switch over a relatively short period, and its highly profitable financial implications for the local growers.

Table 11 Shift in Crop Areas and Values of Artichokes and Strawberries Grown in the Area where Recycled Water Is Used for Irrigation in Monterey County, CA

Crop		1998	2010-2014[2]	Change
Artichokes	Acres	4,200	3,900	-7%
	Dollars	25,262,000	35,522,000	41%
Strawberries	Acres	120	1,642	1,300%
	Dollars	3,641,000	130,027,000	3,500%

1. Crop values were obtained from Monterey County Office of Agricultural Commissioner's 2013 Crop Reports[25]. Crop acreages were provided by Bob Holden, MRWPCA.
2. Artichoke acreage is for 2010; strawberry acreage is for 2014.

[25] http://ag.co.monterey.ca.us/resources/category/crop-reports

RECOMMENDATIONS FOR WATER REUSE FOR IRRIGATION OF EDIBLE CROPS IN COLORADO

Before a legal/regulatory framework can be established to enable farmers, greenhouses and urban gardens to use recycled water, it will be necessary to (a) remove the prohibition against food crop irrigation with recycled water from Regulation 84, and (b) insert language in Regulation 84 specifically permitting irrigation of food crops with recycled water meeting certain criteria. These policy-prescribed criteria can be water quality standards, or they can be prescribed treatment trains that meet the desired safe level of water quality for irrigation of food crops. Alternatively, a combination of a number of prescribed treatment train options and water quality standards may be adopted in the regulations. A highly useful addition to the regulation would be a listing of approved uses of recycled water together with varying prescribed levels of water quality. That list, then could include, among other uses, "use for irrigation by properly trained farmers and members of the public for growing food crops."

USEPA's recommended treatment train, water quality, and other criteria for use of recycled water for agricultural irrigation are presented in a summary tabulation in Appendix D. These criteria are in current conformity with the water reuse criteria of several peer states and other industrialized nations of the world. These criteria, or an adaptation of them, can form a basis for amendments to Regulation 84. However, Regulation 84 is NOT the only controlling element that governs recycled water use in Colorado.

Other controlling regulations, guidelines, and authorizations include:

- Food Safety Modernization Act Produce Rule
- Discharges to surface and groundwater
- Rights of downstream water rights holders

This white Paper addresses the impediments to use of recycled water due to the current prohibition in Regulation 84. Nonetheless, it is important for the stakeholders to be aware of the other hurdles and to abide by and/or resolve them after Regulation 84 has been revised to allow use of reclaimed water for irrigation of edible crops. In summary:

1. Evidence and examples abound for the safety and benefits of allowing use of recycled water for irrigation of edible crops—on the farm, in urban gardens and in schools where children can participate in producing the food that they consume.
2. The first step is for CDPHE Water Quality Control Commission to promulgate the needed change in the language of Regulation 84. Some possible items would include:
    a. Create in the Definitions section an item for "Edible Crops Irrigation", distinct from the existing "Agricultural Irrigation". Alternatively, remove the exclusionary phrase

from "Agricultural Irrigation", thus requiring all crop irrigation to use the same quality reclaimed water.

b. Create "Category 4 Standards", for use of reclaimed water for irrigation of farms and urban gardens producing edible crops. Under this definition, produced reclaimed water would meet coliform and turbidity limits set at levels similar to California's Title 22, with requirement of continuous monitoring of turbidity and daily coliform analysis. In addition, record keeping and reporting of results and any violations to CDPHE, on a monthly basis would be required

c. Allow treaters to choose the specific process trains, disinfection methods, and design features that will reliably meet Category 4 standards. Require submittal and prior approval of proposed water reclamation system design plans before the treater proceeds to construction and delivery of reclaimed water.

d. Avoid regulating water quality criteria for agronomic purposes, such as salinity, sodicity, and other specific ions, as growers commonly manage their cultural practices based on the available quality of water, types of soils under cultivation, and crop rotations in use.

e. Avoid regulating for contaminants of emerging concern (microconstituents), as they have been shown to have *de minimus* impact, especially when water is used for irrigation.

3. Stakeholders and partners already engaged in the revision process would agree on the need for change and collaborate in enactment of legislation (if needed) to facilitate the desired change in regulations. CDPHE, DUG, WateReuse Association, Denver Water, and other treaters and water customers are the main stakeholders and can each contribute to the fulfillment of the final objective: to make water reuse for edible crops a reality in Colorado. The process has begun and will need to move further along.

4. Provide outreach to the farming groups and gardeners to provide educational material and actions that makes accessible the wealth of information available on the safety of use of reclaimed water for irrigation of edible crops. WateReuse Association Colorado Section can play a significant role in this endeavor.

REFERENCES

Brown, S.L., R.L. Chaney, J.S. Angle, and J. A. Ryan. 1998. "Organic carbon and the phytoavailability of cadmium to lettuce in long-term biosolids-amended soils". J. Environ. Qual. 27:1071-1078.

California State Water Resources Board, 2010, "Monitoring Strategies for Chemicals of Emerging Concern (CECs) in Recycled Water; Recommendations of a Science Advisory Panel", Final Draft.

Colorado Department of Public Health and Environment Water Quality Control Commission, *Regulation No. 84 Reclaimed Water Control Regulation* (2013). https://

www.colorado.gov/pacific/sites/default/files/Regulation-84.pdf.

Crites, R., 2006, "Water Reuse and Groundwater Protection in Central Oahu" in Water Environment & Technology 46.

Crook, J., 2012. "Use of Recycled Water for Community Gardens", commissioned by WateReuse Research Foundation, available at http://www.watereuse.org/product/04-05-1

Dodgen, L. K., J. Li, D. Parker, J. J. Gan, 2013 "Uptake and accumulation of four PPCP/EDCs in two leafy vegetables", Environmental Pollution 182: pp150-156, Elsevier.

Elmund, G. K., Martin J. Allen and Eugene W. Rice 1999. "Comparison of Escherichia coli, Total Coliform, and Fecal Coliform Populations as Indicators of Wastewater Treatment Efficiency", *Water Environment Research,* Vol. 71, No. 3 (May - Jun., 1999), pp. 332-339.

Hoppe-Jones, C., Oldham, G., and Drewes, J.E. (2010). Attenuation of Total Organic Carbon and Unregulated Trace Organic Chemicals in U.S. Riverbank Filtration Systems. Water Research 44, pp 4643-4659.

Huss, D., 2014, Personal Communication; [Dale Huss is General Manager of Ocean Mist Farms, vegetable growers using recycled water in Monterey County.] Also, available from YouTube at: https://www.youtube.com/watch?v=oN48PH9sR6Y

Kennedy, L., J. Debroux, M. Millan, 2012 "Risk Assessment Study of Pharmaceuticals and Personal Care Products in Nonpotable Recycled Water to Support Public Review", Published by WateReuse Research Foundation, Alexandria, VA.

Laws, B., Dickenson, E., Johnson, T., Snyder, S., Drewes, J.E. (2011). Attenuation of Contaminants of Emerging Concern during Surface Spreading Aquifer Recharge. Sci. Total Environment 409, 1087-1094.

Le-Minh, N., Khan, S.J., Drewes, J.E., and Stuetz, R. (2010). Fate of antibiotics during municipal water recycling treatment processes. Review. Water Research 44, 4295-4323.

McCullough, M.D., D.A. Devitt, J. Gan, R. Green, S. Snyder, B. Vanderford, M.H. Young. 2012. "Attenuation of PPCP/EDCs through Golf Courses Using Recycled Water", Water Environment Research Foundation. Final Report WERFC108

Metcalf & Eddy 2013. "Wastewater Engineering: Treatment and Resource Recovery", 5TH Edition By Metcalf & Eddy, Inc. and George Tchobanoglous and H. David Stensel and Ryujiro Tsuchihashi and Franklin Burton, Copyright: 2014 Publication Date: Sep 03 2013, Table 12-5

Olson Associates and Colorado State University, 2009. "City of Westminster, Colorado Reclaimed Water System Salinity Management Plan Phase I Report".

Pratt, B., 2013. "Learning Through Using: The Challenges of Long-Term Use of Recycled Water", Proceedings, WateReuse Association, California Chapter Annual Conference.

Qian, Yaling, 2010. "Soil Analysis Before and Five Years after Recycled Water Irrigation", presented at WateReuse Symposium, Colorado State University Department of Horticulture and Landscape Architecture.

Sheikh, B., R.C. Cooper, R. Danielson, 1998. "Recycled Water Food Safety Study", for Monterey County Water Resources Agency and Monterey Regional Water Pollution Control Agency's Water Quality and Operations Committee.

Sheikh, B., 1998. Chapter 17, Tertiary Reclaimed Water for Irrigation of Raw-Eaten Vegetables, in "Reuse of Wastewater" edited by Prof. Takashi Asano, pp. 779-825

Sheikh, B., R.C. Cooper, K. E. Israel, 1999, "Hygienic Evaluation of Reclaimed Water Used To Irrigate Food Crops—A Case Study", Wat. Sci. Tech. Vol.40, No. 4-5, pp 261-267.

Sheikh, B, E. Rosenblum, S. Kasower, E. Hartling, "Accounting for All the Benefits of Water Recycling", Proceedings, Water Reuse '98, a joint specialty conference of WEF and AWWA in Orlando, Florida, February 1-4, 1998.

Thilmany McFadden, D., W. Peters Moschetti and the Colorado Food Systems Advisory Council. COFSAC 15-01. Preparing for Food Security in an Age of Limited Natural Resources Part I: Water. CSU DARE Food Systems Issue Brief. August 2015.

USEPA, 2012, Guidelines for Water Reuse, available at: http://water.epa.gov/aboutow/owm/upload/Water-Reuse-Guidelines-625r04108.pdf

WateReuse Research Foundation, 2011. "Recycled Water Exposure Scenario: The Landscaper," available at https://www.watereuse.org/product/09-07-11

WateReuse Research Foundation, 2011. "Recycled Water Exposure Scenario: Agricultural Worker" available at https://www.watereuse.org/product/09-07-12

WateReuse Research Foundation, 2011. "Recycled Water Exposure Scenario: Child at Play," available at https://www.watereuse.org/product/09-07-13

WateReuse Research Foundation, 2011. "Recycled Water Exposure Scenario: The Golfer," available at https://www.watereuse.org/product/09-07-14

APPENDIX A—ALLOWED USES OF RECYCLED WATER; CALIFORNIA

Recycled Water Use	Treatment Level: Disinfected Tertiary Recycled Water	Disinfected Secondary 2.2 Recycled Water	Disinfected Secondary 23 Recycled Water	Undisinfected Secondary Recycled Water
Irrigation for:				
Food crops where recycled water contacts the edible portion of the crop, including all root crops	ALLOWED	NOT ALLOWED	NOT ALLOWED	NOT ALLOWED
Parks and playgrounds				
School grounds				
Residential landscaping				
Unrestricted-access golf courses				
Any other irrigation uses not specifically prohibited by other provisions of the ***California Code of Regulations***				
Food crops, surface-irrigated, above-ground edible portion, not contacted by recycled water		ALLOWED		
Cemeteries			ALLOWED	
Freeway landscaping				
Restricted-access golf courses				
Ornamental nursery stock and sod farms with unrestricted public access				
Pasture for milk animals for human consumption				
Nonedible vegetation with access control to prevent use as a park, playground or school grounds				
Orchards with no contact between edible portion and recycled water				ALLOWED
Vineyards with no contact between edible portion and recycled water				
Non food-bearing trees, including Christmas trees not irrigated less than 14 days before harvest				
Fodder and fiber crops and pasture for animals not producing milk for human consumption				
Seed crops not eaten by humans				
Food crops undergoing commercial pathogen-destroying processing before consumption by humans				
Ornamental nursery stock, sod farms not irrigated less than 14 days before harvest				
Supply for impoundment:				
Nonrestricted recreational impoundments, with supplemental monitoring for pathogenic organisms	ALLOWED[2]	NOT ALLOWED	NOT ALLOWED	NOT ALLOWED
Restricted recreational impoundments and publicly accessible fish hatcheries	ALLOWED	ALLOWED		
Landscape impoundments without decorative fountains			ALLOWED	
Supply for cooling or air conditioning:				
Industrial or commercial cooling or air conditioning involving cooling tower, evaporative condenser, or spraying that creates a mist	ALLOWED[3]	NOT ALLOWED	NOT ALLOWED	NOT ALLOWED
Industrial or commercial cooling or air conditioning not involving cooling tower, evaporative condenser, or spraying that creates a mist	ALLOWED	ALLOWED	ALLOWED	

Prepared by Bahman Sheikh and edited by EBMUD Office of Water Recycling, who acknowledge this is a summary and not the formal version of the regulations referenced above.

Recycled Water Use	Treatment Level: Disinfected Tertiary Recycled Water	Disinfected Secondary 2.2 Recycled Water	Disinfected Secondary 23 Recycled Water	Undisinfected Secondary Recycled Water
Other Uses:				
Groundwater Recharge	ALLOWED under special case-by-case permits by the **RWQCB**[4]			
Flushing toilets and urinals Priming drain traps Industrial process water that may contact workers Structural fire fighting Decorative fountains Commercial laundries Consolidation of backfill material around potable water pipelines Artificial snow making for commercial outdoor use Commercial car washes, not heating the water, excluding the general public from the washing process	ALLOWED	NOT ALLOWED	NOT ALLOWED	NOT ALLOWED
Industrial process water that will not come into contact with workers Industrial boiler feed Nonstructural fire fighting Backfill consolidation around nonpotable piping Soil compaction Mixing concrete Dust control on roads and streets Cleaning roads, sidewalks and outdoor work areas	ALLOWED	ALLOWED	ALLOWED	NOT ALLOWED
Flushing sanitary sewers	ALLOWED	ALLOWED	ALLOWED	ALLOWED

* Refer to the full text of the the December 2, 2000 version Title 22: **California Water Recycling Criteria**. This chart is only an informal summary of the uses allowed in this version. Adapted for use in Site Supervisor Training Workshops by **South Bay Water Recycling**, San Jose, California. October 29, 2002. Jerry Brown, Coordinator, Site Supervisor Training The complete and final 12/02/2000 version of the adopted criteria can be downloaded from:

http://dhs.ca.gov/ps/ddwem/publications/regulations/recycleregs_index.htm

[2] With "Conventional tertiary treatment". Additional monitoring for two years or more is necessary with direct filtration.

[3] Drift eliminators and/or biocides are required if public or employees can be exposed to mist.

[4] Refer to Groundwater Recharge Guidelines, available from the California Department of Health Services.

APPENDIX B - CALCULATION OF EXPOSURE TO DIFFERENT CECs UNDER VARIOUS ACTIVITY SCENARIOS

In general, the authors followed EPA risk assessment guidance for calculating risks (see Exhibit 6-11 and 6-13 in http://www.epa.gov/oswer/riskassessment/ragsa/pdf/rags_a.pdf). Intakes (in mg/kg-day) were calculated using the following equation:

$$\mathbf{Intake=(C\times(EV\times EF\times ED\times 1/BW\times 1/AT)\times((DA\times SA)+(IR\times ET))}$$

where:

C = concentration in recycled water (mg/L)
EV = event frequency
EF = exposure frequency
ED = exposure duration
BW = body weight
AT = averaging time
DA = dermal absorption
SA = skin surface area
IR = incidental water ingestion rate
ET = event duration

Years to reach a comparison exposure were calculated using the following equation:

$$\mathbf{Years\ to\ Receive\ One\ Safe\ Dose = (Safe\ Dose\ (mg))/((Intake\times BW\times 365\ days/yr))}$$

APPENDIX C—SAN JOSE, CA COMMUNITY GARDENS PROGRAM 2014 RULES AND REGULATIONS

Community Gardens Program
2014 Rules and Regulations

I. Overview

San José Community Gardens are intended to be beautiful, safe, and peaceful oases amidst the fast-paced life of Silicon Valley. The following set of rules and regulations have been designed for the following reasons:

- To ensure that community gardens are safe
- To ensure that community gardens are pleasant places to be and to look at: for gardeners, neighbors and the general public
- To establish fairness and equity among community gardeners
- To prevent damage to the land and groundwater
- To protect the future of community gardens in San José

As in any group endeavor, individuals must give up some of their individuality to accommodate the function of the group. Community gardening is no exception.

The Rules and Regulations are reviewed and revised annually in an ongoing effort to improve and keep them relevant to changing conditions. If you have suggestions or concerns, please call the Community Gardens Program office at 793-4165. However, unless official changes are made, you must abide by these rules and regulations as they are currently written. Failure to do so may result in the termination of gardening privileges.

II. Who can participate in the San José Community Gardens Program?

Anyone age 18 or older who lives in the City of San Jose may participate in the San Jose Community Gardens Program.

III. Plot Allocation, Registration and Fees

1. One garden plot per residence. The Community Gardens Program uses the following guidelines to ensure that this rule is applied uniformly:
    - A primary gardener and/or gardener helper may not garden more than one garden plot
    - A primary gardener may be defined as an individual, Husband/Wife, domestic partners or an entity having sole interest in the plot
    - A primary gardener may choose to have a garden helper noted on the registration form to help maintain the plot in the gardener's absence due to a family emergency, illness or injury, vacation or other unforeseen circumstance
    - The Primary gardener and their helper, who have entered into a current and valid agreement with the City, shall be referred to as a "plotholder" in these rules
2. The person whose signature appears as the Primary Gardener on the Registration Form is ultimately responsible for the maintenance of the entire garden plot and for payment of all fees and charges.

3. The Primary Gardener is required to inform the Program Coordinator of any changes to his/her contact information, including home address and telephone number, including the primary gardener's helper's contact information. Failure to provide current contact information for both the primary gardener and helper may result in termination from the Community Gardens Program.
4. Garden plots are issued on a year-to-year basis from February 1 – January 31.
5. The City may, in its discretion, enter into a new agreement with a Primary Gardener in good standing provided that the annual registration form is completely filled out and signed, and all appropriate fees are paid by the due date of January 31.
6. Primary Gardeners desiring to continue using the plot are required to complete the Community Garden Registration/Agreement Form and pay their annual registration fee by the registration deadline of January 31. Those who do not meet the registration/agreement deadline will automatically lose the assigned plot and the assigned plot will be reassigned to a new gardener.
7. During registration, current and new gardeners may be required to provide proof of residency in the form of a photo I.D. and a copy of a utility bill. Other forms of proof are subject to approval by the City or the Volunteer Management Team.
8. If there are no vacant garden plots, prospective gardeners may add their name to the community garden waiting list by contacting the Community Gardens Coordinator (See section IX, page 8 of these Rules & Regulations for contact information) and they will be contacted—in the order on the waiting list—when garden plots become available.
9. Community garden plots are distributed to San Jose residents according to the council district they live in. Exception; if there are garden plots available at a particular garden and there are no people on the waiting list, a person living in any other council district may rent one at that garden.
10. Plotholders who do not intend to continue gardening the plot for any reason should promptly notify someone on the Volunteer Garden Management Team either verbally or in writing so that the plot may be reassigned to the next person on the waiting list.
11. Plotholders do not have any ownership interest in the plots and may not transfer a plot to anyone else, including a family member. The transfer of a plot will only be allowed between a husband and wife or domestic partners. Garden plots that become available will be re-assigned to new gardeners by the City's Community Gardens Program Coordinator.
12. New plotholders are required to complete the Community Garden Registration/Agreement Form and pay the total annual registration fee before they can begin gardening.
13. Full Payment of the annual registration fee is to be made by check or money order, payable to the garden. **Cash is not accepted.**
14. The annual registration fee is non-refundable unless proof of a family or medical emergency is provided to the City and reasonable notification is given. Refunds will be pro-rated with respect to the Period of Approval in the Registration/Agreement form.
15. Gardeners who sign-up after the registration period may have their water fee prorated. The prorated water fee is determined by calculating the individual monthly water cost and multiplying it by the number of months left in the current registration period. Administrative and operational fees are not prorated.
16. The annual registration fee includes a water, administrative and operational fee. The operational fee, which may include a key deposit, pest control and/or tools, is determined by the Volunteer Garden Management Team.
17. The water fee is determined by the Program Coordinator. The fee is calculated by using this formula; cost per square foot multiplied by the size of the garden plot (square feet) equals the water fee. The cost per square foot is determined by monitoring the gardens total annual water usage and the local water company's current rates.

18. Four (4) ADA accessible garden plots are available at Guadalupe Community Garden. Individuals with a disability will have priority in renting any of the four ADA accessible garden plots. If any of these four ADA garden plots are not occupied, those plots may be assigned by the City on a temporary basis to the general public. Please note: Any ADA plot temporarily assigned to the general public must be relinquished at the end of the current growing season or at the end of the registration year once a qualified ADA person is interested in the plot.

    The definition of disability will be in accordance with the **Americans with Disabilities Act** (ADA) of 1990, Title 42, Chapter 126 or under California law.

IV. Gardening Guidelines

A. ORGANIC GARDENING

The Community Gardens Program adheres strictly to the gardening principles, concepts, and practices popularly called "organic." Products simply labeled "organic" or "natural" are not allowed unless they meet USDA or ORMI approval. The use of pesticides, herbicides, chemical fertilizers, or other such substances or practices inconsistent with organic gardening are prohibited. The use of fertilizer material or tillage methods harmful to the soil's structure, fertility or microorganisms is prohibited. The use of materials or products harmful to humans is prohibited. (Please refer to the "Garden Product Policy Guidelines" Section VIII, page 8 of these Rules and Regulations for more information.)

B. PLANTING SCHEDULE

1. Garden plots must be planted and maintained year-round.
2. Summer gardens must be planted by May 31st.
3. Remains of summer gardens must be removed by December 1st.
4. To prevent the spread of rust, garlic is to be planted in November and harvested by May. When garlic is left in the ground for too long, it is possible for rust to form on the garlic and then spread to other gardeners' plots.
5. Plotholders who do not actively garden during the winter either have to plant a cover crop, cover their plot with plastic or maintain their plot free of weeds.

C. PLANTING GUIDELINES

1. Plotholders may grow vegetables, herbs and flowers in their plot.
2. Plotholders must utilize at least 75% of the plot for planting vegetables, herbs or flowers. Plots are not to be used to store materials/tools not associated with gardening.
3. Plotholders may grow woody perennials, such as grapes and berries, trees, including fruit trees or any plants considered invasive, such as bamboo or mint, as long as it is in an above ground mobile container, planter, etc… Woody perennials such as grapes and berries, invasive plants, such as bamboo or mint and trees already existing in the garden plot must be removed by the gardener. Existing fruit trees planted in the garden plot may be left in place so long as the harvest is shared amongst all the current gardeners.
4. Crops should be rotated.
5. Crops must be harvested and not left on the ground to rot and go to waste.
6. Plotholders should grow a variety of plants and should never grow less than two types of plants at any one time.
7. The Volunteer Management Team must approve planting of water-intensive crops such as taro and sugar cane. Growing of rice is prohibited.
8. Respect the need of your neighbors' plants for sunlight. Do not plant tall crops, including those plants in above ground containers, in a way that will cause excessive shading to nearby plots.

9. All plants, planters, planter boxes and trellises must be placed inside plot perimeter. Plants may not over hang into the walk way. The City or the Volunteer Management Team has the right to trim excess plants over hanging into the walkway without prior notification.
10. Trellises or arbors may not be more than 6 feet high, may not shade neighbors plot and may not be installed permanently.
11. Fencing around the perimeter of garden plots must be installed inside of the plot border, may not shade neighbor's plots and/or be more than 6 feet high, and may not be installed permanently.
12. Garden plots, with fencing around the perimeter, must be accessible at all times. If there is a lock on the fence, a copy of the key or the access code must be provided to the volunteer garden manager and the Program Coordinator.
13. Community Gardens are publicly, maintained City Property and there is no presumption of privacy.

V. Plotholder Responsibilities

1. Plotholders are responsible for the year-round maintenance of their garden plots and the surrounding pathways. Plots and pathways must be kept free of weeds, trash and other debris at all times.
2. Common areas are maintained as a shared responsibility by all plotholders. Such maintenance will occur at garden cleanups scheduled by the Volunteer Garden Management Team and/or on an ongoing basis.
3. Plotholders are required to attend scheduled garden cleanups or make alternative arrangements with the Volunteer Garden Management Team to assist in the maintenance of the garden.
4. Plotholders are required to attend at least two garden meetings per year. If you are unable to attend a meeting, you are required to contact the Volunteer Management Team.
5. Plotholders must be involved in the hands-on cultivation of their plots.
6. Plotholders may not pay for someone else to garden their plot.
7. In the event of a family emergency, illness or injury, vacation, or other unforeseen circumstance, and if the plotholder's gardener helper is unavailable, the plotholder may arrange for another gardener to tend the garden plot but must notify the Volunteer Garden Management Team and provide the name of the other gardener, who already has a signed current and valid Community Gardens Registration/Agreement on file.
8. Plotholders are required to notify the Volunteer Garden Management Team of the following: irrigation problems such as water leaks, graffiti, theft, vandalism, rule violations, pest or disease problems.
9. Primary Gardeners and/or Gardener Helpers who have signed a current and valid Community Gardens Registration/Agreement may bring no more than 2 guests (collectively) to work on the garden plot with them at any one time, provided that the Primary Gardener and/or Gardener Helper shall be responsible for supervision of such guests at all times.
10. Plotholders and their guests must comply with all rules and regulations.
11. Plotholders will be held accountable for the behavior of their guests.

VI. Violations of Community Gardens Program Rules & Regulations

The City may enforce these Rules and Regulations, and in doing so will take action, including termination of the agreement with any gardener who is in violation of these Rules and Regulations. When a gardener violates the Program Rules and Regulations, the violation may be reported to the City using the Violation Incident Report (see pg. 7 for an example of VIR) which will be issued to the gardener by the Community Garden Coordinator or a member of the Volunteer Garden Management Team either in person, by mail or emailed.

Plotholders shall follow all reasonable instructions from the Volunteer Garden Management Team. City may issue a written warning or termination, as reasonably determined by City based upon the facts and circumstances. If a Plotholder believes that a warning or termination notice was issued in error, the Plotholder should contact the City's Community Garden's Coordinator in writing by letter or email (for contact information, see section IX, page 8 of these Rules & Regulations) identifying the relevant facts and circumstances that the termination or warning should be rescinded, within 14 consecutive calendar days of the date of the written notice of warning or termination. The decision of the City's Community Garden Coordinator is final.

VIOLATIONS WARRANTING IMMEDIATE TERMINATION BY THE CITY

1. Theft of tools and equipment
2. Theft of produce and plants
3. Vandalism of tools, equipment and City Property, including but not limited to animals.
4. The use of foul language and offensive behavior including but not limited to threats, intimidation, violence, racial/ethnic slurs and sexual harassment.
5. The use of alcoholic beverages and illegal drugs of any kind, in any area of the City's Community Gardens
6. Receiving more than two combined written warnings from the City or Volunteer Management Team in a calendar year
7. Failure to pay registration fee by the deadline

VII. At the Community Garden

1. **Hours of Operation:** Community gardens are open from sunrise to sunset. (Cornucopia and El Jardín open at 8:30 a.m.)
2. **Behavior:** Foul language or offensive behavior is prohibited.
3. **Gates:** In general, garden gates are be kept closed and locked at all times.
4. **Cars:** Vehicles are not allowed in the garden, except in designated parking areas.
5. **Smoking:** Smoking in the community garden is prohibited.
6. **Controlled Substances:** No alcoholic beverages or illegal drugs of any kind allowed.
7. **Bathroom:** Proper bathroom facilities must be used. Urinating or defecating in the community garden is prohibited.
8. **Garbage:** Unless your garden has arranged for garbage removal, you must take any garbage you generate with you to discard elsewhere. Discarding of garbage on the ground or in compost or green waste piles is prohibited.
9. **Green Waste:** Weeds and plant material should be composted on-site or placed in the green waste collection area(s). Green waste should not be thrown away or left in the pathways.
10. **No selling:** Produce from community gardens is primarily for family consumption. Excess food can be preserved for future use, shared with friends or neighbors, or donated to local food banks. **You may not sell your produce.**
11. **Harvesting:** Harvest only from your own plot. The unauthorized taking of produce from another gardener's plot will result in the immediate revocation of your garden plot.
12. **Water:** The amount of water used determines future water fees. No unattended and/or uncontrolled watering allowed. All gardeners are authorized to turn water off if it has been left unattended. Leaky water hoses must be replaced or repaired.

13. **Water timers**: Timers are allowed only if you do not share a water spigot with the neighboring plot.
14. **Excessive Watering/Watering Schedules:** Excessive water use may result in a fine, and/or a specific watering schedule may be implemented for an individual or the entire community garden, as determined by the garden manager and/or Program Coordinator. Excessive water use may be defined as the following; water allowed to leave the defined vegetable plot/bed; water allowed to run off into the pathway or adjacent plot; unattended water hoses left running in one spot for extended periods of time – minimum of 20 minutes. Those gardeners not adhering to a watering schedule or who continue to use water in excess may be terminated from the Program.
15. **Standing Water:** To reduce the breeding of mosquitoes and the spreading of West Nile Virus, no stagnant/standing water allowed, including but not limited to water in containers and buckets.
16. **Irrigation system:** The Volunteer Management Team must be notified of any alterations to the irrigation system and the City will have final approval of any changes. No alterations can be made to the irrigation system on Fridays, Saturdays, Sundays, or holidays because of the risk of an accident and the limited availability of City staff during these times. In the event of an irrigation emergency, you should contact your garden manager and/or the Community Gardens Program at (408) 793-4165. On weekends, please call the City of San José Call Center at (408) 535-3500. Any alterations to the MAIN irrigation line are prohibited.
17. **Tools:** Garden-owned tools are for garden use only and should be cleaned and returned to the toolshed after use. Tools must be kept locked in the tool shed overnight and should never be taken off the garden premises.
18. **Personal storage cabinets/containers:** Storage cabinets and/or containers must be kept clean and organized and within the plot. They may not be installed permanently and may not shade neighbors plot. City Staff has the authority to conduct an inspection of the inside of the cabinet/container at any given time with out prior notification.
19. **Personal BBQ's:** Personal bbq's are allowed only in designated areas and not near garden plots and/or in pathways. Ashes must be disposed of in a safe manner. Food preparation is allowed only in designated areas.
20. **Pests/Rodents:** Gardeners may trap and dispose of gophers, moles and ground squirrels. All dead animals must be wrapped in plastic or placed in a container and disposed of in the garbage. The use of chemicals, including over-the-counter smoke bombs, to eliminate or control these animals, including but not limited to gophers and ground squirrels, is PROHIBITED.
21. **Animals:** Pets are not allowed in community gardens. Feral cats can be kept at a garden for rodent control if the following guidelines are strictly followed:
    - If agreed upon by a majority of the gardeners at the garden
    - No more than 3 cats per garden
    - All cats must be neutered and immunized
    - When cat caretakers leave the garden, they must take the cats with them or make appropriate arrangements for their future care
    - Cats must be fed in an area far way from garden plots
22. **Bee Keeping:** Community gardens interested in Bee Keeping must apply for a Beekeepers Permit by submitting an application to the office of San Jose Animal Care and Services. Please contact the Community Gardens Program Coordinator for an application.

Violation Incident Report (VIR)
(SAMPLE)

Date: _____ **Time:** _____

Garden Name: _____

Name of Gardener (first/last): _____ Plot#: _____

Description of Violation: (Brief description)

_____
_____
_____

Reference: Current Community Gardens Program Rules & Regulations

Page (s): _____ Section (s): _____ Paragraph (s): _____ Line (s): _____

Witnesses (if applicable):

Name (first/last): _____ Plot #: _____

Name (first/last): _____ Plot #: _____

Plan of Action (if applicable):

_____
_____
_____

Expected Date of Correction (if applicable):

_____
_____
_____

Action Taken:

First Warning: Second/Final Warning:

VIR: mailed emailed handed to gardener

Garden Manager Signature: _____ Date: _____
(Or- Program Coordinator)

*** The white copy of this form must be submitted to the Program Coordinator.**

VIII. Garden Product Policy Guidelines

Any organic substance for use in any of the City of San Jose's Community Gardens must be approved by the U.S. Department of Agriculture's (USDA) National Organic Program or by the Organics Materials Review Institute (OMRI). To see if a substance is allowed in a community garden check the USDA National Organic Program National List, Subpart G, 205.601 and 205.602 or the OMRI Web site, www.omri.org

Organic Gardening: The form of agriculture that relies on techniques such as crop rotation, green manure, compost and biological pest control. Organic Gardening uses fertilizers and pesticides but excludes the use of manufactured (synthetic) fertilizers, pesticides (including herbicides, insecticides and fungicides), plant growth regulators, sludge and nanomaterials.

The following table includes, but not limited too, some substances that are allowed and prohibited:

	Allowed	Prohibited
PEST AND DISEASE CONTROL	- bacillus thuringiensis(Bt) - soap spray - Horticulture pepper/onion spray - sulfur - wood ashes - sour milk solution - lace wings - dormant oils - micro-cop or equivalent (orchard use only) - diatomaceous earth (DE) - baking soda - borax, boric acid - sluggo - lady bugs - tanglefoot - marigolds - beneficial nematodes - netting	- rotenone - pyrethrum (pyrethrate, pyrethroids) - nicotine sulfate - malathion - diazinon - sevin - organophosphates - Roundup - Finale - Dursban - organ chlorides - chlorpyrifos
	Allowed	**Prohibited**
FERTILIZERS	- cotton Seed - kelp - compost - manure - blood, bone, horn, and hoof meals - liquid fish or seaweed - fertilizers classed as "organic"	- ammonium sulfate - ammonium nitrate - muriate of potash - superphosphates - highly soluble chemical fertilizer - Ozmicote - Non organic Miracle Grow

IX. Gardens Program Contact Information

City of San Jose
Community Gardens Program
200 E. Santa Clara Street, 9th Floor Tower
San Jose, CA 95113-1905
Phone: (408) 793-4165
Fax: (408) 292-6416
Email: community.gardens@sanjoseca.gov
Web Site: www.sjcommunitygardens.org

APPENDIX D—USEPA'S SUGGESTED GUIDELINES FOR USE OF RECYCLED WATER FOR IRRIGATION

Reuse Category	Treatment	Water Quality	Monitoring	Setback	Comments
Food Crops [15] The use of reclaimed water for surface or spray irrigation of food crops which are intended for human consumption, consumed raw.	▪ Secondary (4) ▪ Filtration (5) ▪ Disinfection (6)	▪ pH = 6.0-9.0 ▪ ≤ 10 mg/l BOD (7) ▪ ≤ 2 NTU (8) ▪ No detectable fecal coliform/100 ml (9,10) ▪ 1 mg/l Cl_2 residual (min.) (11)	▪ pH – weekly ▪ BOD - weekly ▪ Turbidity - continuous ▪ Fecal coliform - daily ▪ Cl_2 residual – continuous	▪ 50 ft (15 m) to potable water supply wells; increased to 100 ft (30 m) when located in porous media (18)	▪ See Table 3-5 for other recommended chemical constituent limits for irrigation. ▪ Chemical (coagulant and/or polymer) addition prior to filtration may be necessary to meet water quality recommendations. ▪ The reclaimed water should not contain measurable levels of pathogens. (12) ▪ Higher chlorine residual and/or a longer contact time may be necessary to assure that viruses and parasites are inactivated or destroyed. ▪ High nutrient levels may adversely affect some crops during certain growth stages. ▪ See Section 3.4.3 in the 2004 guidelines for recommended treatment reliability requirements.
Processed Food Crops [15] The use of reclaimed water for surface irrigation of food crops which are intended for human consumption, commercially processed. ***Non-Food Crops*** The use of reclaimed water for irrigation of crops which are not consumed by humans, including fodder, fiber, and seed crops, or to irrigate pasture land, commercial nurseries, and sod farms.	▪ Secondary (4) ▪ Disinfection (6)	▪ pH = 6.0-9.0 ▪ ≤ 30 mg/l BOD (7) ▪ ≤ 30 mg/l TSS ▪ ≤ 200 fecal coli/100 ml (9,13, 14) ▪ 1 mg/l Cl2 residual (min.) (11)	▪ pH – weekly ▪ BOD - weekly ▪ TSS - daily ▪ Fecal coliform - daily ▪ Cl_2 residual – continuous	▪ 300 ft (90 m) to potable water supply wells ▪ 100 ft (30 m) to areas accessible to the public (if spray irrigation)	▪ See Table 3-5 for other recommended chemical constituent limits for irrigation. ▪ If spray irrigation, TSS less than 30 mg/l may be necessary to avoid clogging of sprinkler heads. ▪ High nutrient levels may adversely affect some crops during certain growth stages. ▪ See Section 3.4.3 in the 2004 guidelines for recommended treatment reliability requirements. ▪ Milking animals should be prohibited from grazing for 15 days after irrigation ceases. A higher level of disinfection, e.g., to achieve < 14 fecal coli/100 ml, should be provided if this waiting period is not adhered to.

SOURCE, USEPA, 2012, Guidelines for Water Reuse, p. 4-9. (For footnotes, which are quite extensive, refer to source document, available, free of charge, at: http://nepis.epa.gov/Adobe/PDF/P100FS7K.pdf
Tables 3-5, and Section 3.4.3 referenced on this page can be found in the original USEPA document.

(this page is intentionally blank)