SAFETY AND SUITABILITY OF RECYCLED WATER FOR IRRIGATION OF EDIBLE CROPS

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Introduction

An evaluation of the safety of use of recycled water to irrigate edible crops, primarily in California and Florida is presented in this paper. The current regulatory framework for such water reuse activities in these two states along with U.S. national guidelines are summarized and compared. The safety of irrigation of edible crops using recycled water is evaluated from the perspectives of pathogenic microorganisms, heavy metals, and the microconstituents (trace organics, pharmaceuticals and personal care products, hormonally active substances, etc.). In addition, the paper includes an assessment of the suitability of recycled water for irrigation from the view of potential impacts on vegetation and crops produced, soils, and on the marketability of the crops. The discussion focuses on irrigation of the so-called "salad crops"—leafy vegetables and other edible crops that typically are eaten raw. California and Florida use different terminology in the water reuse arena. Florida professionals use the term "reclaimed water" to refer to treated domestic wastewater that is used for beneficial purposes and they refer to the practice as "water reuse." California and Australia use the terms "recycled water" and "water recycling." In this paper, "recycled water" is used, except where Florida-specific information is discussed, where "reclaimed" and "reclamation" are utilized.

Regulatory Framework

This section compares California's and Florida's rules governing the use of recycled water to irrigate edible crops (see Table 1). In addition, U.S. EPA/USAID guidelines for this reuse practice are presented.

California's Regulatory Framework

Since the late 1950s, California regulations governing use of recycled water have undergone an evolutionary change, reflecting advances in treatment technology, expanding demand for use of water for non-potable applications, and a gradual improvement in public and customer acceptance of recycled water. Several key developments in recent years have influenced the regulatory regime in California, although regulatory change in the water reuse arena comes at an extremely slow pace. Some of these milestones are listed below:

1. The 11-year research into the safety of irrigation of food crops in Monterey County, described in a subsequent section.
2. The National Water Research Institute's <u>Ultraviolet Disinfection Guidelines for Drinking Water and Water Reuse</u> (NWRI, 2003).
3. The five-year research project, now nearing completion, entitled "Filter Loading Evaluation for Water Reuse" (Sheikh, 2006).

4. Discovery in recent years, of the potential for some *Giardia* cysts and *Cryptosporidium* oocysts to survive through filtration and chlorination.
5. Legislative initiatives to expand allowed uses for recycled water, e.g., for toilet flushing in commercial buildings and apartments.
6. A legislative goal to reuse annually one million acre-ft (890 MGD) of water by 2010.

Table 1. Comparison of Water Reuse State Rules and National Guidelines.

Parameter	California	Florida	U.S. Guidelines
Reference	(CCR Title 22, 2001)	(FDEP, 2007a)	(USEPA, 2004)
Indicator Organism	Total Coliforms	Fecal Coliforms	Fecal Coliforms
% < Detection	50% < 2.2/100 mL	75% < detection	50% < detection
Maximum	23/100 mL	25/100 mL	< 14/100 mL
Turbidity (Aver.)	≤ 2 NTU	---	≤ 2 NTU
Turbidity (Max.)	10 NTU	---	5 NTU
Total Suspended Solids	---	< 5.0 mg/L (maximum)	< 5 mg/L
Organics Removal	---	$CBOD_5$ < 20 mg/L (annual average)	BOD_5 ≤ 10 mg/L
Chlorine Residual	---	> 1.0 mg/L	> 1 mg/L
Chlorine Contact Time (minutes)	≥ 90 (modal)	> 15 minutes (peak flow)	> 30 minutes
Chlorine CT	> 450 mg/L-min.	---	---

California's requirements for irrigation of edible crops shown in Table 1 apply to direct contact (e.g., sprinkler) irrigation of the salad crops. California allows lower levels of treatment and disinfection for other classes of crops.

As discussed later in this paper, use of recycled water for irrigation of food crops has been controversial at times. These public controversies have a disproportionate influence on California regulators, causing them to exercise even more caution and conservatism than they normally do. The legislature has decreed that Title 22 regulations be enforced uniformly in different parts of the State. Still, some local health authorities zealously impose more stringent requirements at the permitting stage of new projects. This is in stark contrast with Florida regulators who tend to be supportive of water reuse, giving active encouragement to agencies proposing new projects.

The authors speculate that this difference in regulatory attitude is responsible for the relatively slow increase in the volume of water reused in California and the much faster increase in Florida. Presumably, a worsening water supply picture, brought about by global warming and population increase, will eventually lead to some relaxation of overly-stringent requirements on new water reuse projects in California.

Florida's Regulatory Framework

Florida's rules governing water reuse (FDEP, 2007a) are contained in Chapter 62-610, Florida Administrative Code (F.A.C.). The use of reclaimed water to irrigate edible crops is addressed in Rule 62-610.475 in Part III of this chapter, which requires that the reclaimed water receive secondary treatment, filtration, and high-level disinfection (see Table 1). Florida requires this level of treatment for irrigation of any type of edible crop (salad crops, citrus, crops that will be cooked or thermally processed, nuts, vineyards, etc.). Rule 62-610.475, F.A.C., which was established in 1989, specifically allows for the irrigation of edible crops with reclaimed water. The only limitation is that direct contact application methods (spray irrigation) are not allowed, if reclaimed water is to be used to irrigate crops that will not be peeled, skinned, cooked, or thermally processed before human consumption (the "salad crops"). Indirect contact methods (drip, subsurface, and ridge and furrow irrigation) may be used to irrigate the salad crops. Any type of irrigation system may be used to irrigate tobacco, citrus, and any crop that will be peeled, skinned, cooked, or thermally processed before human consumption. As presented by York, *et al.* (2000), there is no technical or health justification for the prohibition of direct contact methods for irrigation of the salad crops.

U.S. Reuse Guidelines

In developing Guidelines for Water Reuse (USEPA, 2004), the EPA's Technical Advisory Committee considered available research, studies, and practices when considering irrigation of edible crops. The guidelines for irrigation (including spray irrigation) of food crops that are not commercially processed before human consumption are presented in Table 1.

Field Experience with Recycled Water Irrigation

Edible crops are irrigated in many arid and semi-arid (and poorer) parts of the world with untreated or inadequately treated wastewater. This practice has led to extremely poor hygiene, recurring epidemics, and high infant mortality in such places. The industrially advanced countries of the world have developed wastewater treatment systems that are highly robust and fully protective of field workers and consumers of edible crops grown with recycled water. In the U.S., both California and Florida are major agricultural states. Use of recycled water in these states is summarized, and two landmark water reuse projects in these states are highlighted.

California's Experience

It is estimated that California recycled about 540 MGD in 2007. Approximately half (46%) of the recycled water delivered in California is used for irrigation of agricultural crops, ranging the gamut of produce from artichokes to zucchini. Major recycled water users for agriculture in California are found in Orange, Sonoma, Napa, and Monterey Counties. While use of recycled water for irrigation of the salad crops on a large scale is relatively new to California, over 10 years of experience with this use of recycled water have been flawless and highly successful in terms of market acceptance and a complete lack of adverse public health outcomes.

Castroville Project: The agricultural lands surrounding Castroville, CA are some of the most productive in the world for cool weather vegetable crops. Extensive farming combined with low rainfall and a normally dry river has resulted in groundwater usage far in excess of the amount of replenishment. The result has been the drawdown of the groundwater table to the point where seawater intrusion has moved inland about eight miles since it was first documented in 1944. The Monterey County Water Recycling Projects' (MCWRP) purpose is to counteract seawater intrusion by replacing groundwater with recycled water for irrigation. The MCWRP consists of a 29.6-MGD tertiary treatment facility combined with a 12,000-acre distribution system network. Water flows by gravity through 46 miles of pipeline to 112 flow-metered turnouts that provide water to 222 parcels of farmland. Currently there is only about 22 MGD of recycled water available. Because of seasonal fluctuations in demand and a lack of seasonal storage, even with 100-percent reuse, 22 supplemental wells connected into the distribution system are needed to provide irrigation water during heavy demand. On a yearly average, the growers receive 62 percent recycled water and 38 percent groundwater. During the peak summer growing season, the growers receive roughly equal amounts of recycled water and groundwater. These projects began providing water for crop irrigation in 1998. The main crops are artichokes, lettuce, strawberries, celery, broccoli, cauliflower, and spinach. Flowers and bulbs (76 acres) are the only non-food crops irrigated. Irrigation methods include sprinkler, furrow, surface drip, shallow buried drip, and deep buried drip. The growers voluntarily use the recycled water even though it is more expensive than pumping groundwater. In 2007, growers on 11,554 acres used 19.2 MGD of blended water and produced about $161 million in crops. This project has been successful due to an effective partnership of the involved parties. Every month, growers, the recycled water provider, the County Water Resources Agency, and the County Environmental Health Department meet to review water quality, water safety, and perception issues. This partnership has greatly increased the buy-in of the growers while helping the water provider to improve their product and service to the growers.

Florida's Experience

Water reuse has become very popular in Florida. In 2006, a total of 468 domestic wastewater treatment facilities provided 663 MGD of recycled water for reuse (FDEP, 2007b). The combined permitted capacity of these reuse systems totaled 1,368 MGD, which represented 58 percent of the total permitted domestic wastewater treatment plant capacity in Florida.

In 2006, 83 MGD of reclaimed water was used to irrigate about 38,500 acres of agricultural land (FDEP, 2007b). Although most of this reclaimed water was used to irrigate feed and fodder crops, 13 MGD was used to irrigate over 14,000 acres of edible crops. The permitted reuse capacity of all edible crop systems was nearly 59 MGD. While citrus (oranges, grapefruit, and tangerines) represents the primary edible crop irrigated with reclaimed water, a wide range of other edible crops (cabbage, cucumbers, figs, grapes, herbs, peas, pecans, peppers, persimmons, strawberries, and tomatoes) also were irrigated with reclaimed water.

Water Conserv II: Water Conserv II is one of the largest agricultural irrigation projects of its type designed for the use of reclaimed water. The project distribution center is located west of Orlando, FL and provides irrigation for over 3,200 acres of agricultural crops – predominantly citrus. Reclaimed water is also used to irrigate several golf courses, landscape nurseries, and numerous residential properties. The project provides some freeze protection for citrus and eliminates the installation, operation, and maintenance costs for irrigation pumping systems. The reclaimed water is filtered and chlorinated, is odorless and colorless, and has been used successfully for crop irrigation for over 20 years. Excess reclaimed water is used to recharge the area's ground water using an extensive network of rapid infiltration basins. Water quality standards were established, and continued intensive sampling ensures water of excellent quality for irrigation. The reclaimed water meets or exceeds drinking water standards for most regulated parameters, including NO_3, SO_4, Na, Cl, Cu, Zn, Se, and Ag. Initial fears that reclaimed water would cause flooding, disease, or heavy metal problems proved to be unfounded (Parsons *et al.*, 2001a). In the sandy well-drained soil, high irrigation rates with reclaimed water (100 inches/year) promoted excellent tree growth and caused no major problems (Parsons *et al.*, 2001b). This reclaimed water cannot provide complete nutrition, but does supply all the Ca, P, and B required by trees under Florida conditions. As with the MCWRP, the cornerstone of this award-winning reuse system is exceptional customer service. This reuse project also features an ongoing research effort in support of the project and the agricultural community.

Safety of Recycled Water Use

This section of the paper examines the human health aspects of irrigation of edible crops with recycled water. The discussion focuses on issues related to pathogens, heavy metals, and microconstituents.

Monterey Wastewater Reclamation Study for Agriculture (MWRSA)

MWRSA (Sheikh, *et al.*, 1998a) was inspired by growers in the fertile Salinas Valley of California, when they were faced with the prospect of either (a) losing their groundwater wells to seawater intrusion, or (b) using recycled water. The growers demanded and received a very large research project that investigated the safety of using disinfected tertiary recycled water for irrigation of raw-eaten food crops. For five years, several vegetable crops were grown on 96 randomized plots, one-third irrigated with well water and the other two-thirds with two different tertiary recycled waters. Several thousand samples were collected from the waters used, crops harvested, and soils irrigated in the project over the five-year period. Samples were analyzed for viruses, bacteria, protozoa, chemicals, and other characteristics of interest to the farmers. No statistically significant differences of public health consequence were detected attributable to the source of water. The encouraging results from this intensive and relatively long-term research project led to obtaining the necessary approvals and moving forward with the installation of a pressurized distribution system for use of recycled water on a large scale (see previous discussion of "Castroville Project").

World Health Organization (WHO) and World Bank Studies

The WHO developed guidelines for the use of recycled water to irrigate edible crops (WHO, 1989). These guidelines were based on major epidemiological investigations sponsored by the WHO and World Bank (Blum and Feachem, 1985; Cross and Strauss, 1985; Shuval, *et al.*, 1985) and on input from internationally acclaimed health experts. Given that there is no documentation of any adverse health affects associated with use of recycled water in the U.S., these health studies focused on areas outside of the U.S. in order to find adverse health impacts in areas employing untreated or inadequately treated and disinfected wastewater. For irrigation of edible crops likely to be eaten uncooked, the WHO recommended that fecal coliforms be less than 1,000 per 100 mL (geometric mean) and that helminthes be less than 1 egg per liter (mean). While well-supported by epidemiological data, the WHO guidelines (WHO, 1989) are significantly less stringent than standards employed in California or Florida.

National Research Council (NRC) Study

The NRC conducted a comprehensive evaluation of the use of recycled water and residuals in food crop production (NRC, 1996). The NRC concluded that: "Current technology to remove pollutants from wastewater, coupled with existing regulations and guidelines governing the use of recycled water in crop production, are adequate to protect human health and the environment." They also stated "food crops thus produced do not present a greater risk to the consumer than do crops irrigated from conventional sources."

Melbourne, Australia Study

This three-year study (Smith, 1982) investigated the use of recycled water and ground water to irrigate cabbage, carrots, celery, lettuce, spinach, and tomatoes. The recycled water received a lower level of treatment (secondary and disinfection) than what is required in California and Florida. The investigation included sampling for viruses, *Salmonella*, and several indicator organisms. They concluded that irrigating with recycled water posed no health risks (focus was on viruses and heavy metals). Yields were highest with the use of recycled water and balanced fertilization. It was concluded that use of recycled water could save 75 percent of the cost of chemical fertilizers. Use of recycled water resulted in the production of high-quality crops. While the recycled water delivered to the storage pond contained an average of 210 PFU/100 L, virus was not detected on crops irrigated with recycled water. *Salmonella* was not detected in the recycled water or on the crops. Concentrations of indicator organisms on crops irrigated with recycled water did not differ significantly from concentrations found on produce in local markets. Further, the study found no difference in quality and marketability of produce grown with recycled water or other irrigation waters.

2006 Outbreak of *E. coli O157:H7*

The 2006 outbreak of *E. coli O157:H7* associated with spinach is an isolated incident and not a typical example of the current state of food safety in the USA. For some time, it has been known that grain-fed cows can be a significant source of *E. coli O157:H7* via translocations of their fecal matter. Most growers work to prevent wind or water from carrying manure from a feedlot to their fields. Contamination did occur in San Benito County, CA between cow manure and spinach (by way of wild pigs traipsing across the feedlots and then the neighboring spinach field.) This spinach was processed with a chlorinated water wash and packaged on August 15, 2006. A brief history of the outbreak is presented in Table 2.

There were many negative consequences of this outbreak. There were 205 confirmed illnesses, 103 were hospitalized, 31 developed hemolytic-ureic syndrome, and three died. The final report identified just one herd of cattle as the probable source of contamination of a single field of spinach. The mechanism of transfer of the *E. coli* from cattle to spinach was either wild pigs, river water, or well water. The processing facilities had another set of problems. Three other fields that provided spinach on the same day as the contaminated spinach had sources of *E. coli O157:H7* nearby. Almost immediately after the outbreak was identified, claims surfaced on the Internet and in some newspapers suggesting that the probable source of contamination was from the Castroville Project and its recycled water. Cable News Network (CNN) sent a film crew to MRWPCA's treatment plant. However, after a thorough investigation and interviews, the CNN crew left without a story. The treatment plant has tested for *E. coli O157:H7* in its raw sewage and recycled water since the inception of irrigation with recycled water without a single positive test. The Centers for Disease Control (CDC), U.S. Food and Drug Administration (FDA), and California Department of Public Health (CDPH) have never come to the site to investigate an *E. coli O157:H7* incident, as there is no reason to believe the recycled water could be a source of contamination.

Table 2. History of the 2006 Spinach *E. coli O157:H7* Outbreak.

Date	Event/Milestone
August 15, 2006	Contaminated spinach packaged.
August 19, 2006	First confirmed case in a person reporting fresh spinach consumption.
August 23, 2006	An unusual number of *E. coli* illnesses began to appear.
September 8, 2006	Wisconsin identified a cluster of illnesses.
September 12, 2006	Wisconsin confirmed match of *E. coli* strain with other states.
September 13, 2006	CDC informed the FDA of the outbreak.
September 13, 2006	Illness initiation date of the last two victims.
September 14, 2006	FDA issued a warning not to eat bagged spinach.
September 15, 2006	FDA issued a warning not to eat fresh spinach either.
September 21, 2006	FDA announced that Monterey, San Benito, and Santa Clara Counties, in California, are the only locations involved.

Date	Event/Milestone
September 29, 2006	FDA identified brand names of recalled spinach.
October 12, 2006	CDC issued short report on outbreak. Four fields were identified as possible source(s).
March 23, 2007	CDPH issued Final Report.
May 7, 2007	CDPH issued Addendum to Final Report.

Pathogens

From a public health perspective, the pathogenic microorganisms of concern are bacteria, helminthes, viruses, and protozoan pathogens. State rules and guidelines highlighted in Table 1 share a significant commonality – the need to provide reasonably high levels of treatment, followed by filtration and effective disinfection. The literature supports the fact that water reclamation facilities in Florida and California reliably and effectively control pathogens such that recycled water can be safely used to irrigate edible crops as well as residential lawns (Nelson, *et al.*, 2003; Sheikh, *et al.*, 1998a; York and Burg, 1998; York, *et al.*, 2000).

Pathogenic bacteria are reasonably well controlled with normal basic disinfection designed to meet a fecal coliform standard of 200 organisms per 100 mL. Inclusion of filtration in the treatment facilities and provision of higher disinfectant residuals in a high-level disinfection facility, as required for irrigation of edible crops and residential lawns, provides a very effective means of inactivating bacterial pathogens. The helminthes (worms) are larger organisms and are effectively removed in the secondary clarifier. Provision of filtration following the clarifier provides assurance of effective removal of helminth ova. High-level disinfection, which involves the coupling of filtration with disinfection, was designed to control viruses effectively. Monitoring data and studies of full-scale water reclamation facilities demonstrate effective control of bacterial, helminthic, and viral pathogens. Studies and monitoring data coupled with infectivity studies and their data also support the effective control of the protozoan pathogens – notably *Giardia* and *Cryptosporidium*. As reported by York and Walker-Coleman (2004), Florida's routine monitoring for *Giardia* and *Cryptosporidium* demonstrates that concentrations of these organisms in recycled water are generally very low (43% and 69% of observations of *Giardia* and *Cryptosporidium*, respectively, were less than detection). Further assurances are provided by infectivity studies conducted on recycled water that demonstrate that cysts and oocysts that may pass through the water reclamation facility are not capable of causing infection (Garcia, *et al.*, 2002; Huffman, *et al.*, 2003). In addition, York and Burg (1998) reported that concentrations observed in recycled water were comparable to concentrations in high-quality surface waters.

Given that measurable concentrations of the protozoan pathogens may be found in recycled water, the following is an examination of its significance. The focus will be on *Giardia*, which generally has a higher potential for being found and in larger concentrations than *Cryptosporidium*. York and Walker-Coleman (2004) reported a median value of 3.5 cysts per 100 L with a 90-percentile value of 352 cysts per 100 L. The following assumptions were made:

1. The growing season is 90 days.
2. The field is irrigated every day (a conservative assumption) – 90 days total.
3. Each irrigation day results in 1 mL of recycled water either being incorporated into or left as a residual on a single piece of fruit or vegetable (assume this is a tomato).
4. Ten percent of all cysts in the recycled water are fully infective (a conservative assumption).

5. Over the 90-day period, 50 percent of all infective cysts on or in the tomato remain fully infective (a conservative assumption).
6. The tomato is eaten uncooked and is not washed.

Given the preceding assumptions, a person eating this tomato would ingest 0.00016 infective *Giardia* cysts, if the recycled water contained the median concentration (3.5 cysts/100 L). If the recycled water had a concentration equal to the 90-percentile value (352 cysts/100 L), the consumption of a single tomato would equate to a *Giardia* dose of 0.016 infective cyst.

Heavy Metals

From the perspective of human health related to individuals consuming crops irrigated with recycled water, heavy metals pose virtually no concern. This results from the fact that heavy metal concentrations in recycled water are generally significantly below the primary drinking water standards for these parameters and are comparable to other waters that are commonly used for irrigation.

Microconstituents

During the last 15 years, we have seen the "discovery" of a wide range of compounds in surface water, ground water, drinking water, and recycled water. Pharmaceuticals, personal care products, and other compounds and materials have been detected in waters in minute concentrations (typically in concentrations of parts per billion or parts per trillion). Collectively, these materials are referred to as the microconstituents (York, *et al.*, 2007). The microconstituents are not something "new" in water. They have long been in the water environment (as well as in air and soils), but, until recently, have escaped detection resulting from their extremely low concentrations and inadequacy of analytical methods and instrumentation. However, as our analytical capabilities have increased and as researchers have begun to look for specific compounds, we see reports of the microconstituents in various waters. This trend likely will continue in the future. The concentrations observed are infinitesimally small. For example, for pharmaceuticals and over-the-counter medications in the concentrations observed in water, lifetime consumption of recycled water as a drinking water supply (2 L per day) generally would represent a lifetime consumption less than a single therapeutic dose (Snyder, *et al.*, 2006).

An ongoing study of the microconstituents provides significant insight into these materials. Essentially, this study demonstrates that the microconstituents are ubiquitous, being present in extremely small concentrations in surface water, ground water, and recycled water. From that perspective, risks associated with the microconstituents for irrigation of edible crops are minimal, and no greater than from other types of water used for irrigation.

Returning to the irrigation assumptions made in an earlier section dealing with pathogens provides a view of the relative risk of exposure to the microconstituents. Consider the pharmaceutically active compound Ibuprofen (an over-the-counter pain killer). Concentrations found in surface waters and recycled water generally are on the order of 0.0002 mg/L, or less. The normal therapeutic dose for Ibuprofen is 400 mg. Using the same assumptions made previously, consumption of a single tomato would represent a dose of Ibuprofen of 0.000018 mg. In order to consume a single therapeutic dose (400 mg), a person would need to eat more than 22 million tomatoes.

Suitability of Recycled Water Use

Based on results of research projects and extensive field experience over the last century, it is an inescapable conclusion that recycled water is in fact suitable for irrigation of food crops.

Agronomically, there is no difference between recycled, surface, ground, and potable water; agronomists and farmers have long known how to manage salt (and sodium, in particular) in irrigation water – no matter the source of that water. From a microbiological perspective, it may be argued that disinfected tertiary recycled water is in fact superior to nearly all other alternative sources of water for irrigation of raw-eaten food crops. None of the other irrigation water sources are disinfected, and many contain large numbers of indicator bacteria.

Impacts on Vegetation and Crops

Studies comparing marketability, quality of produce, and grocery shelf quality of produce irrigated with recycled water and other high-quality irrigation waters have found no significant differences based on water source employed (Sheikh *et al*., 1998b).

Impacts on Soils

Most recycled waters do not inherently contain excessively high levels of salinity even though they typically contain about 150 to 400 mg/L more salts than potable waters from which they originated. The salinity of waters may affect plants due to osmotic hazards, i.e., plants must expend greater energy in extracting water from saline than non-saline soil solutions, and they may suffer reduced growth rates and foliar damage. Plants have a wide range of tolerance to salinity and many of them can be irrigated with recycled waters.

The soil is the medium from which plants take up water and essential mineral nutrients, and it provides support to the plant root system. Salts have a tendency to build up in the root zone of actively transpiring plants because more or less pure water is lost to the atmosphere through evaporation and transpiration while dissolved mineral salts in the applied water are left behind in the soil solution. The presence of dissolved mineral salts exerts an osmotic effect on plants and some of its constituents like Na, Cl and B can cause specific ion toxicities to plants. In surface-irrigated soils (e.g., sprinklers) with no drainage impediments, the upper root zone is the zone of salt leaching while the lower root zone is the zone of salt accumulation.

Fortunately, most crops and many landscape plants have a denser rooting system in the shallower depths (upper horizons) where soil salinity tends to be lowest. Soil water is extracted from the more saline, deeper root zone only when the available soil water becomes limiting in the less saline portions. The extent of accumulation of salts in the lower root zone is regulated by the Leaching Fraction (LF), the ratio of depth of drainage water to depth of applied water. A LF of 0.15 to 0.2 is usually adequate to maintain salt balance for most agricultural crop irrigation and for typical irrigation water salinities. A Castroville Project soil study (Platts, *et al.*, 2004) concluded that recycled water produced slightly saltier soils initially, but soil salinity did not increase with time. Tanji et al (2008) created an interactive compact disc based on agronomic and soil science literature to assist horticulturalists in managing the salinity of recycled water. This "Salinity Management Guide" provides the link between plants, soils, salts and recycled water in a practical and user-friendly format for the practitioners in the field.

Marketability

A legitimate concern of growers using recycled water is the specter of a negative campaign by competitors who may one day claim they do not use "sewer water" to irrigate their crops, implying that those who use recycled water are producing inferior crops. This possibility has been raised frequently in recent years. However, the fear has remained just a possibility and has not materialized in the many places where farmers have actually used recycled water for crop irrigation.

A significant factor in favor of marketability of produce grown with recycled water is "distance." Social psychologists refer to the phenomenon of "contagion," whereby an object becomes abhorrent to members of the public by its close association with a known source of disgust and hatred. A famous example is the jacket that was once worn by Adolph Hitler. That knowledge is enough to make the jacket practically untouchable to most people who are aware of the history of the Holocaust, no matter how frequently and thoroughly the jacket may have been washed and disinfected. Recycled water has the potential to be associated with the raw material from which it was produced – sewage – which is somewhat universally regarded as "disgusting" and as "something to be avoided." This association diminishes with "distance." Distance can be provided with the length of time between irrigation and harvest, travel from the field to the processing shed, transformation in the food processing system, blending with produce from other fields, and presentation at the grocery store without reference to the source of irrigation water, as is the common practice.

A marketability study was conducted in Monterey before the project was implemented on a large scale (The Marketing Arm, 1983). The study targeted the major buyers of produce at national distribution centers. The findings of that study are quoted directly, below:

1. "There is no regulatory reason to label or to separate produce grown with recycled wastewater (assuming it is as safe as any other produce for public health).
2. The wholesale and retail produce industry would accept produce grown with recycled wastewater and feels it is unnecessary to label safe produce.
3. The produce industry would welcome information regarding produce grown with recycled wastewater as an aid in responding to potential customer inquiries.
4. There is an extremely low risk to growers using recycled wastewater of negative rumors occurring and affecting their business,
5. The 15 years' experience of the Irvine Ranch Company in marketing produce grown with recycled wastewater has set a favorable precedent for similar practices in Monterey County."

The Monterey Regional Water Pollution Control Agency prepared a highly structured emergency response plan in which a large number of potential contingency scenarios were developed. For each scenario with a possibility of negative public relations and marketability disaster, response plans were developed and instituted.

Conclusions

Key conclusions drawn in this paper include the following:

1. Use of recycled water for irrigation of food crops under regulatory regimes of California and Florida is safe and protective of public health.
2. Salts in recycled water can be managed with appropriate irrigation practices, including provision of an appropriate leaching fraction.
3. Experience has shown that crops grown with recycled water can be marketed without a negative public reaction.
4. Recycled water is subject to intense and stringent regulation (far more restrictive than prescribed in the WHO guidelines) and is more highly tested and evaluated than other sources of irrigation water.
5. Isolated claims against safety of recycled water for irrigation are now given scant credence by scientists and the popular media. Such claims no longer elicit the immediate attention they once did as legitimate opposing views.

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