Agricultural Reuse: Using Reclaimed Water to Irrigate Edible Crops in Florida

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This paper examines agricultural reuse in Florida with a focus on the use of reclaimed water to irrigate edible food crops. Current rules and experience are reviewed along with research related to irrigation of edible crops. Emphasis is placed on whether or not there is need to continue the prohibition on direct contact irrigation methods when reclaimed water is used to irrigate some types of edible crops.

REUSE IN FLORIDA

Reuse has become very popular in Florida. In 1998, 451 domestic wastewater treatment facilities provided 490 mgd of reclaimed water for reuse (1). The combined capacity of these reuse systems totaled 1,009 mgd. The total reuse capacity represents 45 percent of the total permitted domestic wastewater treatment plant capacity in Florida.

In 1998, 88 mgd of reclaimed water was used to irrigate about 33,500 acres of agricultural land (1). Although most of this reclaimed water was used to irrigate feed and fodder crops, 20 mgd was used to irrigate over 15,200 acres of edible crops. The permitted reuse capacity of all edible crop systems was 41 mgd. While citrus represents the primary edible crop irrigated with reclaimed water, a wide range of other edible crops (tomatoes, cabbage, peppers, watermelon, corn, eggplant, strawberries, peas, beans, herbs, squash, and cucumbers) also are irrigated with reclaimed water.

Reuse Rules: Florida’s regulations governing water reuse (2) 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. This rule, 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 so-called “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.
When Chapter 62-610, F.A.C., was originally adopted in April 1989, the edible crop rule allowed any type of application system for use with the salad crops. This was based on review of reuse experience and studies conducted elsewhere in the U.S. and world and a unanimous recommendation from the Reuse Technical Advisory Committee (TAC) – a panel of reuse and public health experts that provided technical input into the rulemaking activity. Adoption of this rule (specifically the fact that direct contact methods were allowed for the salad crops) was immediately greeted with negative press coverage. In an effort to maximize public acceptance of water reuse and to forge a strong partnership with the Florida Department of Health, the Florida Department of Environmental Protection (DEP) immediately moved to revise the rule dealing with edible crops. As a result, Chapter 62-610, F.A.C., was amended later in 1989 and the current prohibition on direct contact methods for irrigation of the salad crops was added.

The rule governing irrigation of edible crops [Rule 62-610.475, F.A.C.] also includes provisions allowing for demonstration studies of direct contact methods for irrigation of edible crops that are not peeled, skinned, cooked, or thermally processed before human consumption (2). These provisions were added to the rule in 1989, when the prohibition on direct contact methods was adopted. At that time, it was hoped that someone would conduct a study in Florida documenting the viability of direct contact methods. To date, no one has undertaken such a study, and state funding has not been secured to fund a study.

**FLORIDA AGRICULTURE**

Florida is a major agricultural state, which leads the U.S. in the production of oranges, grapefruit, limes, tangelos, corn (fresh market), green peppers, tomatoes (fresh market), and watermelons (3). Florida also ranks in the top three states in the production of strawberries, and head lettuce. In 1996, cash receipts for farm production in Florida totaled about $6.1 billion, which ranked ninth among the states in the U.S. (4).

Florida’s agriculture lands totaled about 3.70 million acres in 1995, of which 1.97 million acres (53%) were irrigated (5). Of the 925,000 acres devoted to fruit crops, 894,000 acres (97%) are irrigated. Citrus accounts for 92 percent of the area planted in fruit crops. Of the state’s 851,000 acres of citrus, over 97 percent is irrigated. Irrigation is used on 68 percent of the 798,000 acres of field crops (including sugarcane, cotton, and others) and on 93 percent of the 297,000 acres planted in vegetables.

Flood, ridge and furrow, and subsurface irrigation methods (collectively referred to as “seepage irrigation” by USGS) are used on 51 percent of lands being irrigated in Florida (5). Micro-irrigation methods are used on 31 percent and sprinkler irrigation methods are used on the remaining 18 percent of irrigated lands. Virtually all of the state’s 417,000 acres of sugarcane is irrigated using seepage methods. Micro-irrigation methods are used on over 67 percent of the 830,000 acres of irrigated citrus groves.
In 1995, about 3,240 million gallons per day (mgd) of freshwater was used for irrigation in Florida (5). Of this total, 53 percent was surface water and 47 percent was ground water. Irrigation accounted for 45 percent of the total freshwater used in Florida. Citrus accounted for about 44 percent of the total irrigation water. Florida’s irrigation water use ranked 13th among the states in the U.S. (6). All 13 states using more irrigation water are located west of the Mississippi River.

Agriculture in Florida uses over 750 mgd of surface water to irrigate vegetables and fruit crops (5). The surface waters used are Class III (recreation and fish and wildlife) or Class IV (agricultural water supplies) waters (7). Class III waters are held to a microbiological standard of 200 fecal coliforms per 100 mL (average), while there are no microbiological standards for Class IV agricultural waters. These surface water quality standards are significantly less restrictive than the no detectable fecal coliform standard imposed on reclaimed water used to irrigate edible crops in Florida (8).

RESEARCH, STUDIES, AND GUIDELINES

EPA’s Reuse Guidelines: In developing Guidelines for Water Reuse (9), the EPA’s Technical Advisory Committee considered available research, studies, and practices, when considering irrigation of edible crops. For irrigation (including spray irrigation) of food crops that are not commercially processed before human consumption, it was recommended that the reclaimed water have BOD less than 10 mg/L, average turbidity less than 2 NTU, and fecal coliforms less than detection (median value). If total suspended solids (TSS) are used in lieu of turbidity, the guidelines recommended that average TSS be less than 5 mg/L.

National Research Council (NRC) Study: The NRC conducted a comprehensive evaluation of the use of reclaimed water and residuals in food crop production (10). The NRC concluded that: “Current technology to remove pollutants from wastewater, coupled with existing regulations and guidelines governing the use of reclaimed water in crop production, are adequate to protect human health and the environment.” They also noted that “food crops thus produced do not present a greater risk to the consumer than do crops irrigated from conventional sources.”

World Health Organization (WHO): The WHO developed guidelines for the use of reclaimed water to irrigate edible crops (11). These guidelines were based on major epidemiological investigations and on input from internationally acclaimed health experts. 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 helminths be less than 1 egg per liter (mean).

Monterey County, California: This landmark, five-year study (12) investigated the use of reclaimed water to irrigate edible crops (artichokes, broccoli, cauliflower, celery, and lettuce). Ground water served as the control. The reclaimed water used met treatment and disinfection requirements similar to Florida’s. Health studies concluded that irrigation with reclaimed water posed no increased health risks to workers. Irrigation
with reclaimed water was found to produce excellent yields of high-quality produce. No differences in plant vigor or appearance, shelf life or quality, or in spoilage rates were observed. Marketability studies concluded that labeling of crops would not be needed and that business risks to growers were extremely low. Heavy metals did not accumulate in crops or soils. Chlorine residuals had no effect on crops. Salinity and sodicity in the reclaimed water fell in the favorable range and no significant reductions in soil permeability were noted. No virus, *Salmonellae*, *Shigellae*, *Ascaris lumbricoides*, *Entamoeba histolytica*, or other parasites were found in the soils or crops. The study found no aerosol transmission of pathogens.

In a follow-up study in Monterey County, Sheikh and Cooper (13) evaluated several protozoan (*Giardia*, *Cryptosporidium*, and *Cyclospora*) and other pathogens (*Escherichia coli* 0157:H7, *Legionella*, and *Salmonella*). The only pathogen found in the reclaimed water was *Giardia*, which was detected in 80 percent of the samples at concentrations ranging from 3 to 9 cysts per 100 L. However, all *Giardia* cysts were devoid of internal structure and were considered to be non-viable.

**Melbourne, Australia:** This three-year study (14) investigated the use of reclaimed water and ground water to irrigate cabbage, carrots, celery, lettuce, spinach, and tomatoes. The reclaimed water received a lower level of treatment (secondary and disinfection) than what is required in Florida. The investigation included sampling for viruses, *Salmonella*, and several indicator organisms. They concluded that irrigating with reclaimed water posed no risk of viral infection and no health risk related to heavy metals. Yields were highest with the use of reclaimed water and balanced fertilization. It was concluded that use of reclaimed water could save 75 percent of the cost of chemical fertilizers. Use of reclaimed water resulted in the production of high-quality crops. While the reclaimed water delivered to the storage pond contained an average of 210 PFU/100 L, virus was not detected on crops irrigated with reclaimed water. *Salmonella* was not detected in the reclaimed water or on the crops. Concentrations of indicator organisms on crops irrigated with reclaimed water did not differ significantly from concentrations found on produce in local markets.

**Water Conserv II:** This is one of the world’s largest reuse projects featuring agricultural irrigation and ground water recharge (15). The project is a joint venture between Orange County and the City of Orlando. Reclaimed water from two water reclamation facilities is conveyed to a distribution center west of Orlando and is used by 60 growers to irrigate about 4000 acres of citrus. Reclaimed water also is used for irrigation of nine landscape and foliage nurseries, three tree farms, two landfills, and the Orange County National Golf Center. An extensive network of rapid infiltration basins is used for ground water recharge. This award-winning project has been operating for 13 years and currently uses about 30 mgd of reclaimed water.

Facing “no discharge” limits, the City and County proposed this agricultural reuse project in the early 1980s. Citrus grove owners initially were skeptical of the plan because of their concerns about possible heavy metal contamination, possible public health issues, flooding, and lack of flexibility in water application during periods of high rainfall.
Growers also raised concerns over psychological aspects and felt consumers might consider that fruit from trees irrigated with reclaimed water would be of poorer quality. Ultimately, Orlando, Orange County, and the growers developed a plan that provided for the establishment of reclaimed water standards, regular monitoring of the water, greater grower flexibility on timing of use, use of reclaimed water and ground water for freeze protection, and research on the effects of the reclaimed water on citrus tree performance (15,16).

To promote grower acceptance of the plan, rigorous water quality guidelines for citrus trees were developed by the University of Florida for this project (17,18). The maximum average concentration limits for sodium, chloride, barium, chromium, copper, selenium, silver, sulfate, and zinc are more stringent than Florida’s drinking water standards.

To promote research on agricultural reuse, the City and County established the Mid-Florida Citrus Foundation (a nonprofit research foundation), dedicated over 100 acres for research, and established a relationship with the University of Florida to conduct research in support of this project (15).

Studies were conducted to determine if citrus could tolerate high application rates of reclaimed water. In research plantings, very high rates of up to 100 inches/year were applied to two citrus varieties, Hamlin orange and Orlando tangelo, on four rootstocks. Application of 100 inches of reclaimed water significantly increased canopy volume and fruit yield compared to 16-inch applications of ground water and reclaimed water (19). This excessive irrigation diluted the soluble solids somewhat, but because of the greater total fruit production, total soluble solids per acre were increased by the high irrigation rate. Growers of fruit for juice processing are paid on the basis of total mass of soluble solids, so the greater total soluble solids production at high irrigation rates was beneficial to them.

Weed growth was greater where high rates of reclaimed water were used (19). Weed growth can be controlled with proper herbicide use and mowing and is not as great a problem in mature groves. Irrigation with reclaimed water increased soil and leaf phosphorus, calcium, and sodium. Leaf levels of sodium, chloride, and boron were elevated but remained below toxic levels (20). Annual energy savings from eliminating irrigation pumping costs can be as much as $128/acre (15).

In an evaluation of the nutritional value of this reclaimed water, trees that were given no fertilizer and irrigated only with reclaimed water took two to five years to show deficiency symptoms and yield declines. In experimental plots, high application rates of reclaimed water maintained yields for one year, but yields declined in the second year without additional fertilizer application (21). Although reclaimed water provides all the phosphorus, calcium, and boron required by trees in central Florida, this water cannot supply sufficient nitrogen, even if it is applied at high [100 inches/year] rates (22).

The 13 years of successful operation of Water Conserv II and data generated from the ongoing research program have demonstrated the acceptability of using reclaimed water.
for irrigation of citrus. Research and experience have shown that the growers’ initial fears were unjustified, and grower acceptance of reclaimed water has increased significantly. Cross, et al. (15) noted that “citrus trees irrigated with reclaimed water are in better condition, produce larger crops, and have better soil and leaf mineral profiles than those irrigated with well water.” Significant problems have not resulted from irrigating with reclaimed water.

**Other Florida Research:** Studies with reclaimed water were carried out on mature grapefruit trees in poorly drained soils near Vero Beach. In one study, canal water was compared with reclaimed water applied at low, moderate, and high rates (23). Grapefruit yield and canopy growth were greater at the low and moderate reclaimed water irrigation treatments. It was suggested that for this flatwoods soil with a hardpan, irrigation rates should be less than 1.2 inch/week. When drainage was reduced because of weed buildup or drainage pipe blockage, trees became unproductive and stunted. It was concluded that fertilizer rates could be lowered without reducing yield when using reclaimed water.

Another study showed that young grapefruit trees were not adversely affected by simulated reclaimed water irrigation if sufficient fertilizer was applied (24). Reclaimed water alone did not provide adequate nutrition for the trees. Irrigation rates of 0.75 or 1.0 inch/week did not affect young tree growth differentially.

**FUTURE DIRECTION**

**Research Needs:** As noted previously, the DEP had hoped to conduct a study of edible crop irrigation using reclaimed water in Florida. The possibility of such a study was introduced as a possible research need at a 1999 workshop (25) sponsored by the National Water Research Institute (NWRI). This concept received virtually no support from the other delegates (experts in water reuse, health, and environmental engineering and science) to the NWRI workshop primarily due to the delegates’ belief that previous research (as discussed above) had conclusively demonstrated the acceptability of the practice.

The available literature and extensive agricultural reuse practice in California have demonstrated the acceptability of using reclaimed water to irrigate edible food crops – including the use of spray irrigation on crops that will be consumed raw.

**Possible Rulemaking:** Chapter 62-610, F.A.C. (2), currently prohibits the use of direct contact irrigation methods (spray irrigation) using reclaimed water for irrigation of edible crops that will not be peeled, skinned, cooked, or thermally processed before human consumption. Based on the literature cited in this paper and the experience in California, Florida’s prohibition on direct contact application methods may not be justified. As a result, when Chapter 62-610, F.A.C., is next opened for revision, it is suggested that DEP revisit the issue of allowing direct contact methods for the irrigation of all types of edible crops.
REFERENCES

1. Florida Department of Environmental Protection. 1998 Reuse Inventory. Tallahassee: Florida Department of Environmental Protection. 1999.


