IRRIGATING FORAGE WITH RECYCLED WATER: PROBLEMS AND POSSIBILITIES

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ABSTRACT

Irrigation with reclaimed municipal wastewater is a modern form of recycling that is practiced throughout the arid and semi-arid regions of the world. In California and the US Southwest, water recycling and conservation are the only significant new sources of water available to meet the increasing domestic, industrial, and environmental demands. With good agronomic management, the potential for damage to soils and human health due to this practice has been shown to be minimal. Risks sometimes associated with land application of sewage sludge (e.g., heavy metal accumulation in soil) are rarely at issue with treated effluent. Treated effluent usually contains significant fertilizer nitrogen, mostly in the organic form and in some instances in the ammonium form. In low-rainfall regions, farmers using treated municipal effluent must take care to monitor salinity, which is elevated compared to that in the municipal freshwater source. Wastewater storage capacity must be available for times when the crop water demand is low. Forage crops, including in the best cases alfalfa, are ideal for irrigation with treated municipal wastewater. For good results, the treatment entity and the farmer must be dedicated to development and implementation of a nutrient and water management plan that serves both parties.

Key Words: forages, municipal wastewater, recycling, irrigation, regulation

INTRODUCTION

Application of treated municipal wastewater to agricultural land is a well-established practice in most of the developed world. It can be traced back to the ancient practice of sewage farming, in which the main objective was to remove raw sewage from urban populations. Sewage farming was gradually replaced in the 19th and early 20th centuries by engineered wastewater treatment systems – so-called “unit processes” -- that more effectively protected the population from disease and required a smaller land area. The residual products of sewage treatment plants – sludge and the treated effluent – have traditionally been handled in different ways. In the US, until the 1970s, the effluent was commonly discharged to the ocean or inland surface waters. Beginning with the passage in 1972 of the Clean Water Act, discharge of nutrients and salts into surface waters has been curtailed, and there has been a dramatic increase in land application of the treated wastewater and other urban and industrial reuses.

Thus, the practice of irrigation with recycled municipal wastewater is well established. In locations where it has been followed for more than 30 years, it has caused no harm to soils or crops; and in fact has produced economic benefit by reducing fertilizer costs to the farmer

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(Asano and Pettygrove, 1987). Worldwide, reclamation and reuse of treated municipal effluent is most common in Israel, California, and a few other arid or semi-arid regions. California, with a little more than 10% of the country's population accounts for about one-quarter of the planned or intentional reuse in the US. However, reuse in California represents only about 4% of the urban supply and 1% of the agricultural supply in the state. This is in contrast with Israel where recycled municipal wastewater supplies 15-30% of the agricultural usage (Shelef, 1991).

In California in 2001, about 545,000 acre-ft of municipal treated wastewater were recycled (State Water Resources Control Board, 2002). In the Central Valley where nearly all recycled water went to agricultural uses, the amount was 150,000 acre-ft. In Southern California (coastal plus inland regions) that amount was about 285,000 acre-ft; however agricultural reuse accounted for only a small portion, with landscape, industrial, and recharge of groundwater being the most common uses. One of the largest single reuse projects in California is in Monterey Co., where more than 12,000 acre-ft per year of tertiary treated wastewater are used for production of vegetable crops. That project was implemented in part to reduce seawater intrusion by reducing groundwater pumping near the coast.

Recycled Municipal Water is a Critical Component of California's Water Supply

For more than 30 years, it has been the policy of the state of California to encourage reclamation and reuse of treated municipal wastewater. Demand for fresh water for domestic use, for golf courses, for industrial uses such as manufacture of computer chips, and for protection of aquatic species – so-called in-stream use – has increased steadily in the state. Few new freshwater sources are available for development. Climate change and decreased availability of Colorado River water threaten even the currently available supply. Conservation and reuse are the only significant affordable new sources of water to meet these demands. The state's strategy, as embodied in Title 22, is to encourage the use of less highly treated municipal effluent for feed and fiber crops, golf courses and other landscaping – while conserving fresh water for potable use and more highly treated wastewater for other appropriate uses such as the irrigation of food crops. However, in some situations, in the long run, it may be more economical to treat to the level required for unrestricted use. For example, Richard et al. (1993) estimated that incremental treatment costs to produce reclaimed water suitable for unrestricted use ranged from $90 to $400/acre-ft. In some locations, this would be less than the cost of transporting the water to distant farm locations where a lower level of treatment would suffice.

However, it should be stated that even in water-short regions such as California and in spite of the long successful history of irrigation of crops with recycled municipal wastewater, many reuse projects in the state encompass a combination of two objectives: (1) Land treatment, in which the emphasis is on use of the soil to further purify water and keep it from being directly discharged to surface waters; and (2) Water recycling or reuse. Where the recycled water is subjected to advanced (tertiary treatment) and where fresh water supplies are unavailable or available only at a very high price, the second objective predominates. This is the situation in some parts of Southern California. In the San Joaquin Valley where water is also increasingly in short supply and the urban and environmental demands for water are growing, one might think that the objective of enhancing water supply would predominate over land treatment and disposal. This is usually not the case in the SJV, probably due to a combination of institutional and physical constraints. The areas of the San Joaquin Valley experiencing the most urban and industrial growth are on the east side of the valley and in the foothills bordering the valley. Water is still not very expensive compared to the cost of additional treatment. Transport of the water via long pipelines to agriculture on the west side of the valley would be quite expensive. Farmers closer to the urban boundary who are growing tree fruits and nuts, vine crops, vegetables, and other specialty crops may be uninterested in or even skeptical of using what they mistakenly view as "sewer water", when surface and groundwater supplies are still available. Land application by municipal treatment plants on publicly owned land that is not carefully managed constitutes a haphazard or unplanned form of groundwater recharge and in the short run is less expensive than recycling.

However, as water quality impacts of this approach are considered, e.g., as salts, nitrate, and other constituents reduce the beneficial use of groundwater, it is likely that cities will increasingly be willing to upgrade their recycling efforts. Farmers should consider that long-term contracts for treated municipal effluent are a form of insurance against future droughts. Golf course operators and other landscape users in Southern California find this feature of recycled water attractive.

Regulation of Municipal Wastewater Recycling

Reuse of municipal treated effluent is regulated by the State of California under Title 22 of the California Code of Regulations. The regulations are described in the state Department of Health Services "Purple Book" which is available at the agency's web site (California Department of Health Services, 2004). A description of regulations is well beyond the scope of this brief article; it includes such requirements as the need for color coded pipes, signage, worker protection, and monitoring. For many of the regulations, the wastewater treatment entity or municipality/county, not the end user of the treated water, is responsible for compliance; but the end user will be the one implementing some of these requirements.

Irrigation with raw sewage is illegal and has been so for many years throughout the world. Until recently in California, some crops were irrigated with primary effluent. Primary treatment consists of removal of settleable organic and inorganic solids by sedimentation and the removal of materials that will float by skimming. Recycling of primary effluent without further treatment is no longer allowed in California.

Secondary treatment in most cases follows primary treatment and involves the removal of biodegradable dissolved and colloidal organic matter using aerobic biological treatment processes. The solid residue of primary and secondary treatment is sewage sludge. The significance of secondary treatment is that most of the metals and a portion of the nutrients stays with the sludge, and therefore where the treated effluent is applied to land, contamination of the soil or crops with heavy metals is not an issue.

As shown in the following list, irrigation of some crops with undisinfected secondary effluent is encouraged. These crops include forages and pasture, where it is not used for animals producing milk for human consumption. Treatment requirements for various crop and landscape plants are taken from the California Dept. of Health Services (2004).

Surface irrigation uses requiring tertiary treatment*

- Food crops, including all edible root crops
- Parks and playgrounds
- School yards
- Residential landscaping
- Unrestricted access golf courses
- Any other irrigation use not specified and not prohibited

Surface irrigation uses requiring disinfected secondary-2.2 recycled water*

- Food crops where the edible portion is produced above ground and not contacted by the recycled water.

Surface irrigation uses requiring disinfected secondary-23 recycled water*

- Cemeteries
- Freeway landscaping
- Restricted access golf courses
- Ornamental nursery stock and sod farms if harvest, retail sale, or public access occurs within 14 days of irrigation
- **Pasture for animals producing milk for human consumption**
- Any nonedible vegetation where access is controlled so that the irrigated area cannot be used as if it were a park, playground or school yard.

Surface irrigation uses requiring at least undisinfected secondary recycled water (= "oxidized wastewater")

- Orchards and vineyards where the recycled water does not come into contact with the edible portion of the crop
- Non-food bearing trees (Christmas trees OK if no harvest or public access within 14 days after irrigation)
- **Fodder and fiber crops and pasture for animals not producing milk for human consumption**
- **Seed crops not eaten by humans**
- Food crops that must undergo commercial pathogen-destroying processing before consumption by humans
- Ornamental nursery stock and sod farms, if no harvest, retail sale, or access by public within 14 days of irrigation

*The term "disinfected tertiary" means a filtered and subsequently disinfected wastewater that meets numerical criteria specified in Title 22 and not shown here. The term "disinfected secondary-2.2" means recycled water that has been oxidized and disinfected so that median concentration of total coliform bacteria does not exceed 2.2 MPN (most probable number) per 100 milliters using the results of the last seven days for which analyses have been completed and which does not exceed an MPN of 23/100 milliters in more than one sample in any 30-day period. The term "disinfected secondary-23" means the same thing except that the equivalent MPN values for total coliform are an order of magnitude higher, specifically, 23/100 milliters for the last seven days and 240/100 milliters for any 30-day period.

Suitability of Recycled Municipal Wastewater for Forage Production

Particularly where the objective involves some combination of disposal/land treatment and providing water for beneficial use (irrigation), a forage cropping system is better suited than any other. In another paper in this conference proceedings (Nebeker, 2004) the author lists the reasons that alfalfa is an excellent crop to grow with treated municipal effluent. These include its deep root system and large nutrient removal capacity. No forage has the consistent market demand of alfalfa. But in some other respects, non-alfalfa forages may be superior for irrigation with treated effluent. Perennial and annual grass hays and annual rotations such as a silage corn-winter cereal forages double crop (commonly grown on dairies in California's Central Valley) have the following attractive characteristics, depending on species:

- Very high fertilizer nitrogen requirement; thus nitrogen in effluent provides a large economic saving to the grower (but only if it is measured!);
- Species can be selected that will tolerate temporarily saturated soil conditions much better than alfalfa;
- Some grasses are better on heavier soils than alfalfa;
- Some hay crops and a double crop like corn-grass hay require less frequent cutting and therefore allow for more flexibility on scheduling irrigations;
- May tolerate a lower level of management than alfalfa. This is extremely important where effluent irrigation is carried out on public land by treatment plant personnel with less knowledge of farming practices or who have less time available for crop management.

Limitations & Requirements

Farmers planning to use treated municipal effluent generally do not need to worry excessively about heavy metal and toxic constituent accumulations, exposure to pathogens, odors and other factors that the public commonly associates with "waste disposal". Farmers, planners, and the wastewater treatment plant operators do need to plan for and implement standard agronomic practices that too often are ignored. These include the following areas:

1. Irrigation system design and operation. Where the disposal objective "creeps in", overapplication and non-uniform distribution of water are more likely to result in deep percolation and groundwater contamination. Irrigation scheduling may be needed.
2. Irrigation water testing for nutrients, salt, and toxic elements (mainly boron). Laboratory reports to farmers need to use standard agricultural units of measurement. For example, salinity should be reported in units of deciSiemens per meter (dS/m, electrical conductivity), not milligrams per liter (mg/L) of total dissolved solids. Nitrogen content must be reported as total nitrogen, ammonium, and nitrate, all in milligrams per liter (mg/L). Sodium should be reported as SAR (sodium adsorption ratio, a unitless index of sodium hazard), not in milligrams per liter.
3. Regular soil testing for salinity, sodium, and possibly boron. Soil testing for nutrients is needed but on a less frequent basis. Testing for heavy metals, pathogens, and other constituents may in some instances be required for environmental monitoring purposes, but is typically not needed for agronomic purposes.
4. Nutrient management planning. Where there is a hazard of movement of nitrate and salts beyond the root zone and into groundwater, a nitrogen management plan is needed and must include consideration of N loading rates and N removal in the harvested crop.

5. Other agronomic management issues need attention: Does the agreement require the farmer to accept water and irrigate during rainy and cold periods or when the soil is saturated? For forage growers, will irrigation be required at times that could interfere with the optimum cutting and swathing schedule or would lead to soil compaction? It is critical that storage be provided for periods of low crop water requirement and for periods of above-normal rainfall.

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