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SECTION 4: Emerging Issues and Regulatory Approaches for Water Reuse

Emerging Issues from a Grower's Perspective

ONE WAY TO DEAL WITH PUBLIC PERCEPTION IS TO COMBAT IGNORANCE. THERE HAVE BEEN MANY TESTS AND STUDIES ABOUT THE USE OF RECYCLED WATER, BUT THE INFORMATION IS NOT WIDELY AVAILABLE.

Food safety and public perception are very important issues on the minds of growers today, according to Dale Huss of Ocean Mist Farms. Water quality is declining across the country and it is increasingly more difficult to meet the discharge requirements set by regional water quality boards.

Growers are concerned about increasing business costs due to the lack of good water quality and the added costs to irrigate and pump the water for their crops. Increasingly, water doesn't have time to recharge and brine seeps into the water system. When you add the high cost of irrigating a crop to a slight change in market demand, long-lasting and devastating financial effects can occur to growers. An example of this demand shift occurred with the recent food safety concerns and the topic of recycled water regarding fresh spinach in September 2006. Recycled water was not implicated, though public perception about the safety of eating spinach resulted in a huge loss to farmers that almost shut down the entire spinach industry. Even 4 weeks after the spinach food safety issue was resolved, demand was only at 25 percent of normal. It may take a few years before the spinach industry can recover. This scare made retailers demand changes in general agriculture profiles and manufacturing programs. Today, all inputs into crops are under a magnifying glass, including irrigated water. Changes are expected to sweep through the industry from coast to coast. One way to deal with public perception is to combat ignorance. There have been many tests and studies about the use of recycled water, but the information is not widely available.

Seawater intrusion is a big concern for growers and further research and outreach could significantly help to reduce soil and water quality degradation. Many growers want to join together because of declining water quality. The key to success in overcoming some of the issues of declining water quality and food safety may be a team approach that has growers and other stakeholders working collaboratively on these issues. True team efforts may help share the increasing costs of declining water quality between the public and agriculture.

Are Pathogens a Concern for Recycled Water?

Jeanette Thurston-Enriquez examined the pathogens likely to occur in reclaimed water, their reduction by various wastewater treatment practices, pathways of pathogen transmission, and research needs necessary for determining pathogen threats to public health.

A number of health risks can develop when humans come in direct, or indirect, contact with recycled water. These health risks are posed by regulated and non-regulated chemicals, pathogens, and emerging contaminants. Three water quality contaminants, pathogens, pharmaceuticals, and personal care products, have been identified as emerging challenges regarding the application of recycled water for irrigation. Food safety and human health experts have focused on human health effects of pathogens (see Table 1). These pathogens have been found in lakes, streams, rivers, and other water bodies where humans may come in direct contact. Water resource professionals are investigating the source, transport, fate, and persistence of pathogens in water and soil, as well as if these pathogens pose health risks to human populations.

Multiple factors contribute to transmission and persistence of pathogens in the environment. These factors include

- high numbers are shed in feces;
- increased survival in the environment;
- low infectious dose for humans;
- increased resistance to disinfection/treatment;
- multiple routes of transmission; and
- animal and humans can become infected by some waterborne pathogens and, therefore, there are multiple sources of these pathogens.

Hundreds of pathogens may be present in untreated wastewater and we cannot test for them all. Problems arising from testing include a lack of sensitive methods, the high cost, the amount of time required to test, and the need for special training. Nevertheless, we must ask ourselves, "How do we determine if pathogens are present in water?"

Often, levels of indicator bacteria are used to determine the microbial water quality of various water sources. Typically, these indicators attempt to assess the presence or degree of fecal contamination; however, these microbial indicators have deficiencies when used to detect the presence of pathogens. Pitfalls to using indicators as surrogates for pathogen detection include:

- indicator absence ≠ pathogen absence;
- indicator presence ≠ pathogen presence;
- pathogens can re-grow in aquatic environments and water distribution systems;
- presence of indicators is not necessarily indicative of a health threat; and
- no relationship exists between indicators and enteric viruses or protozoan pathogens.

TABLE 1.
PATHOGENS FOUND IN UNTREATED WASTEWATER

Pathogen	Disease/ Health Condition
E. coli O157:H7	*Diarrhea, kidney failure*
Salmonella	*Diarrhea, nausea, vomiting*
Cryptosporidium	*Diarrhea, vomiting, wasting disease*
Hepatitis A	*Fever, malaise, nausea, jaundice*
Adenovirus	*Respiratory disease, conjunctivitis, diarrhea*

Are Pathogens a Concern for Recycled Water? (cont'd)

TABLE 2. LEVELS OF MICROBES IN UNTREATED WASTEWATER

Microbe (per 100 ml)	Municipal Wastewater
E. coli	*104 –105*
Salmonella	*< 8,000*
Enteric Virus	*< 103*
Cryptosporidium	*10 –103*
Entamoeba Histolytica	*< 500*

TABLE 3. TREATMENT EFFECTIVENESS FOR A VARIETY OF MICROBES

Type of Treatment	% Reduction of Various Microbes
Primary	*5–40*
Trickling Filters	*18–99*
Activated Sludge	*25–99*
Anaerobic Digestion	*25–92*
Waste Stabilization Ponds	*60–99*
Tertiary (flocculation, sand filtration, etc.)	*93–99.99*

Adapted from Geldreich (1996)

Table 2 lists examples of the levels of microbes in untreated wastewater and Table 3 lists the reduction of microorganisms by conventional wastewater treatment practices. When testing wastewater, it is recommended to use a suite of indicators that reflect a broader spectrum of potential pathogens.

Instead of the traditional use of total coliforms or *E. coli*, assessing the presence of more resistant microbes such as enterococci and Clostridium may be better indicators of more resistant pathogens. Also, determination of water quality over time instead of instantaneous samples will reduce the threat of pathogens. The occurrence of pathogens in a given water supply is variable depending on season and environmental inputs.

Concerning reclaimed water treatment, there are many applicable technologies. Examples of these technologies include: ultraviolet light (UV), membrane filtration, ozone, and chlorination. Research shows that UV is capable of inactivating microbial pathogens; however, information on the effectiveness of newer UV technologies to reduce pathogens is lacking. Membrane bioreactors and reverse osmosis were shown to meet drinking water standards and California standards for recycled water. Finally, ozone and chlorination are proven technologies for addressing microbial contamination. However, there needs to be continued work to establish the effectiveness of these technologies as viable options for pathogen reduction.

Reclaimed water can be an important water source for crop irrigation especially in arid climates. Practices that can reduce pathogen transmission during crop irrigation would include reducing the potential for air transport by irrigating crops with drag tubes or drop sprinkler heads. When using spray irrigation, being conscious of weather conditions that may help to disseminate contaminated water is important. Also, understanding the microbial quality of the water is important for determining the water's best use.

To improve understanding of the health risks involved with pathogens in water, researchers need to determine the fate and dissemination of pathogens in the environment. We also need to improve the ways we detect pathogens in water samples. Since it is not possible to assess the presence of every possible pathogen in a water source, we must develop appropriate indicators to signal their potential presence. Given the high cost of analysis, new sampling strategies must reflect the most appropriate frequency and location for sample collection. We need to assess current and newer treatment technologies for reduction of pathogens in reclaimed water. These technologies, however, must not only be effective at pathogen reduction but must also be economical. Finally, we need to reconsider designation of appropriate uses for impacted water bodies and conduct risk assessments for human health concerns. Research needs include determining pathogen occurrence in recycled water, assessing or developing technologies to reduce pathogens in recycled water in order to achieve recycled water standards, and human risk assessments as a basis for choosing the best use for recycled water.

Laura Kennedy acknowledged that among emerging contaminants, unregulated chemicals include pharmaceuticals and personal care products. These and other contaminants pose considerable challenges to determining the health risks because there are no regulatory guidelines or limits, often we have limited toxicity data, and because risks are perceived but not always measured.

Concerns regarding unknown or perceived health risks can be an obstacle for use of recycled water for irrigation of agricultural crops. However, these concerns may not be based on actual scientific or technical reasons. In order to determine whether the use of recycled water on agricultural crops is a legitimate public health concern, the health risks need to be evaluated. Risk assessment is a tool that can quantify the potential for adverse health effects. For decades, regulatory agencies have used risk assessments to make informed, defensible management decisions regarding drinking water, wastewater, and environmental remediation. The key components of any risk assessment are identifying the hazards and estimating realistic exposures to humans in order to quantify the risk. By definition, risk is dependent on both hazard and exposure, so if either the exposure or hazards are sufficiently low, the risk will be negligible.

Several exposure scenarios were presented that could occur by using recycled water on agricultural crops and several approaches to quantify the potential health risks were explored. Exposure to chemicals in recycled water could occur through both direct and indirect pathways. The magnitude of exposure depends on the nature of the exposure and the concentration of the chemical in the water. The health risks, in turn, are dependent on the magnitude of exposure and the toxicity of the chemical. After quantifying the health risks, the significance of those risks are evaluated. One approach is to compare the quantified health risks to an accepted standard risk level. While this approach is straightforward, it may not provide sufficient context for decision-makers. Another approach is to compare the health risks from using recycled water on agricultural crops with health risks from other common activities to provide a relative comparison of risk. These evaluations demonstrate how risk assessment can address concerns about health effects associated with using recycled water on agricultural crops.

CONCERNS REGARDING UNKNOWN OR PERCEIVED HEALTH RISKS CAN BE AN OBSTACLE FOR USE OF RECYCLED WATER FOR IRRIGATION OF AGRICULTURAL CROPS. HOWEVER, THESE CONCERNS MAY NOT BE BASED ON ACTUAL SCIENTIFIC OR TECHNICAL REASONS.

Health Issues Related to the Use of Recycled Water on Crops (cont'd)

TABLE 4.
PHARMACEUTICALS IN TREATED RECYCLED WATER

Drug	Secondary		Tertiary	
	RANGE (NG/L)	MEAN (NG/L)	RANGE (NG/L)	MEAN (NG/L)
ACIDIC				
Diclofenac	<10-62	40	<10-110	40
Ibuprofen	<10-320	100	<10-37	13
BETA-BLOCKER				
Metoprolol	9-160	56	<10-130	35
Propranolol	5-33	15	<10-61	21
ANTIBACTERIAL				
Ciprofloxacin	<30-860	230	<30-180	87
Sulfamethazine	<30-500	100	<30-450	110

Sources: Huang and Sedlak 2001; Kolodziej et al. 2003; Grosset al. 2004; Sedlak et al. 2005.

Unregulated chemicals have been detected in wastewater effluents, generally at trace concentrations (Table 4). However, public scrutiny and concern is growing as these emerging contaminants continue to appear in drinking water supplies and other water sources:

"Various medications are detected in drinking water that has been derived from treated sewage. The health risk, if any, is unknown."—LA Times, January 30, 2006;

"Drug traces found in Grand Rapids drinking water." —U.S Water News, April 2007.

We know little about the impact of these pharmaceuticals on human health. However, recent investigations show deleterious effects of these or other pharmaceuticals on fish and other aquatic species. New risk assessment tools will explore the potential risk of these unregulated compounds on humans or other species.

The EPA and many states widely use risk assessment studies and practices. Risk assessment also is the basis of regulatory guidelines for drinking water and wastewater. Overall risk is a function of toxicity and exposure: Risk = Exposure x Toxicity. Human exposure, therefore, does not directly result in risk. The overall risk is dependent on concentration, the exposure scenario, and toxicity (a measure of response to different dosages).

What are some possible exposure scenarios that relate to using recycled water in agriculture? Direct exposure poses a risk for agricultural workers. Field workers may come in direct contact with water or plants that carry emerging contaminants. Indirect exposure also can occur for crop consumers when they purchase raw vegetables or fresh-cut vegetables and consume them without proper cleaning. Ecological exposures are considerable and effects are highly variable across species.

Quantifying the risk posed by direct exposure requires knowledge of the concentration of pharmaceuticals in recycled water. Assumptions also must be made regarding the intake, including the number of days per year of exposure, absorption through the skin, and the possibility of incidental ingestion. Toxicity data for dose-response and threshold effects of dosages generally are not available for these compounds.

Quantifying the risks posed by indirect exposure adds complications regarding the concentration in edible portions of crops and assumptions about crop uptake of these compounds. It is possible to use partition models to separate soil, water, and plant components. Within the plant component, one can further separate potential concentration in leaves, fruit, and roots. Independent evaluations of concentrations in soil and water may include exploring the effects of soil or water chemistry on compounds.

Finally, we can explore the relative risks posed by alternative routes for pharmaceutical contact. These relative risks evaluate possible contact through diet, drinking water, or airborne compounds. (Fig. 2)

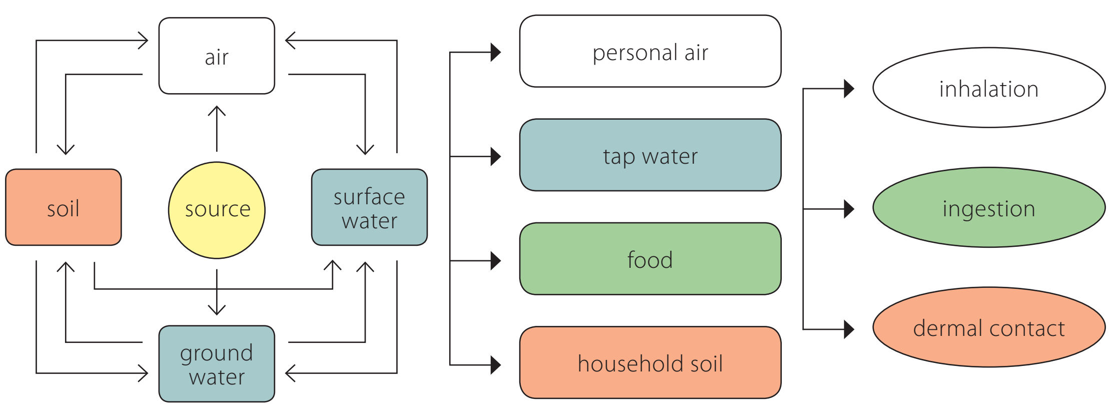

Figure 2. Exposure Scenarios (from CalTOX, A Multimedia Total Exposure Model For Hazardous Waste Sites, McKone, 1994).

California's Regulatory Approaches as They Pertain to Agricultural Water Reuse

TABLE 5. CRITERIA DEVELOPMENTS SINCE 1977.

Date	Regulatory Approach
1977	*Criteria based on best available treatment for highest exposure use and proportionally less treatment as exposure is reduced*
1977	*Pomona Virus Study (PVS)*
1980s	*Developed guidelines for discharge treatment based on risk analysis–consistent*
1988	*Direct filtration policy based on PVS*
1990s	*Two microbial risk assessment papers (Tanaka et al. 1998, and Asano et al. 1992) indicate risk associated with various uses is* $< 10^{-4}$
Since 2000	*Latest CCR Title 22 WRC—accommodates new filtration and disinfection technologies and implements the PVS and a* 10^{-4} *risk goal*

California has a broad range of regulatory approaches to ensure the safety of water resources in areas where recycled water is applied, according to **Robert Hultquist**, California Department of Health Services.

Table 5 lists some major regulatory developments of the past 30 years. The California Water Recycling Criteria (WRC), established in the 1970s, were based on best available treatment for the highest quality (relatively unrestricted use) irrigation water and on proportionally lower treatment requirements as public exposure is reduced and restrictions on use increase. In the 1980s, California developed guidance for the treatment of wastewater discharges based on a risk assessment that validated the WRC for the various irrigation uses. In the 1990s, two microbial risk assessment papers (Tanaka et al. 1998, and Asano et al.1992) indicated that the annual risk of infection from consuming crops irrigated with reclaimed water meeting the WRC was less than 10^{-4} (one in 10,000). California adopted this level as the maximum level of acceptable risk when preparing the last version of the WRC. California recognizes that this is a relatively stringent risk goal, but considers it achievable and appropriate for a controllable public exposure.

A key consideration is that the WRC address only public exposure related directly to the reclaimed water or to the crop. They do not address occupational exposure or threats to the environment.

California has specific criteria for recycled water applied to agricultural products. In general, criteria for agricultural irrigation water differentiate between crops eaten raw, food crops not irrigated with recycled water, nursery stock and pasture, and those crops that have no direct food contact, such as vineyards (Table 6). The reliance on restricting the type or end use of the crop, method of irrigation, timing of harvest, and method of harvest for lower levels of reclamation treatment/quality is problematic. Crops have been embargoed pending the results of microbial monitoring when growers disregard the restrictions. California agencies may lose confidence in the regulatory approach if numerous violations occur.

Most states do not have irrigation water standards for recycled water. Three states have notable standards for recycled water used in irrigation (Table 7).

What is an acceptable risk of infection? The acceptable risk goal is a policy decision set by each jurisdiction. California established a water recycling criteria of 10^{-4} annual risk of infection for all uses. State and federal drinking water goals and World Health Organization guidelines for recycled water for agricultural irrigation cover additional considerations for risk infection. Examples of acceptable risks involve 10^{-6} (one in one million) daily risk of infection, or 10^{-3} (one in one thousand) annual risk of infection.

What are the most effective criteria to prevent or minimize risk of infection when using recycled water in agriculture? Criteria should be science-based and should achieve the stated risk goal. Effective criteria address treatment and quality, recognize operational limits, focus on reliability of standards, and promote regulator, health agency, medical community, public, and policymaker confidence. Use area restrictions are problematic for expanding recycled water for agricultural irrigation. Moreover, criteria address only direct exposure to recycled water or the crop—more information is needed to develop criteria for indirect exposure. Crops irrigated with recycled or discharge impaired water are shipped across state and international boundaries. Individual jurisdiction recycled water standards have not been reconciled with this commerce.

Finally, there is a need to reconcile differences among standards developed for individual jurisdictions. These differing standards produce serious challenges for agricultural producers and the consuming public.

Photo courtesy of NRCS

TABLE 6. CRITERIA FOR AGRICULTURAL IRRIGATION

Agricultural Product or Use	Treatment Level	Quantitative Standards
Crops eaten raw with recycled water contact	Secondary, Filtration, Disinfection	turbidity < 2 NTU average; 450 CT or 5-log virus reduction; ≤2.2 total coliform/100 mL median; 23 total coliform/100mL in 1 sample/mo.; ≤ 240 total coliform/100 mL always
Surface irrigation of food crops with no recycled water contact	Secondary, Disinfection	≤2.2 total coliform/100mL median; 23 total coliform/100mL in 1 sample/mo.
Nursery stock, sod farms, pasture for milk producing animals	Secondary, Disinfection	≤23 total coliform/100mL median, 240 total coli/100mL in 1 sample /mo.
Surface irrigation of seed crops, fiber, fodder (not food) crops, pasture for animals not producing milk, tree farms, vineyards and orchards with no food contact with recycled water	Secondary	

TABLE 7. BEST FOOD CROP IRRIGATION WATER STANDARDS

Colorado	Texas	California
Primary, secondary, and effective filtration	*Primary, secondary, and effective filtration*	*Primary, secondary, and effective filtration*
Disinfection to an acceptable risk	*20 fecal coliform/ 100 ml*	*126 E. coli/100 ml 2.2 total coliform/ 100 ml*

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