Introduction to the Workshop on Wastewater Utilization in Horticulture

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Cool, clear water! More than two-thirds of Earth is covered with water, snowfields, glaciers, and ice caps. Water is so common that it has been treated with neglect, if not contempt.

Only in recent years have we recognized that water shortage may become an issue that could surpass the political importance of the energy crisis of the 1970s (5). Long droughts in Africa have caused a collapse in food production and brought famine and death to the Sahel region south of the Sahara Desert. A short drought in the United States during the late 1970s brought water rationing, restricted production, and crop losses to several western states. Water supply problems have also become acute in urban areas of the Sunbelt. Residents of Phoenix, Ariz., enjoy all the water comforts of plentiful water even though the city averages only 20 cm of rainfall per year. Water usage and demand in the United States have been increasing steadily. In 1950 our nation pumped 46 billion m^3 of water from its aquifers (5). Today that figure has doubled. The increased in water usage is largely the result of agriculture's efforts to make the desert bloom and produce food and fiber. Agriculture has become the major user of water (5). Nearly one-half of the 3.6 billion m^3, consumed each day is used to irrrigate crops or fatten cattle.

The water problem has been further complicated by pollution. Until the mid-1970s, groundwater was believed to be protected from pollution by a living filter system — the soil (3). However, the system has proven to be no match for the 63,000 synthetic organic chemicals available. Soil microorganisms are overwhelmed, and genetic engineering may be necessary to produce microorganisms that will destroy the troublesome organic chemicals within the time frame required for recycling. Fertilizers, salts spread on icy roads, bacteria from septic systems, and salt water also have leached into the groundwater in some areas. In Florida, where the depth of the groundwater may be only 15 cm below the surface, groundwater is even vulnerable to contamination from car washes (2). More serious and disturbing is the presence of pesticides such as aldicarb (2-methyl-2-(methylthio)propanal *O*-[(methylamino)carbonyl]oxime), which is widely and successfully used in horticulture. Aldicarb has been found in groundwaters of Florida, New Jersey, and New York. Also 35% of the wells in California's San Joaquin Valley have been found to contain DBCP (1,2-dibromo-3-chloropropane), another pesticide used in horticulture. When the water quality is poor, new sources of clean water must be found. Disposing of contaminated water is difficult. Existing pollution protection laws prohibit surface water dilution with contaminated water. Drying, burning, or distilling of contaminated water is too costly, causes air pollution, and produces potentially hazardous chemical residues (8).

Water shortage and disposal problems may be in embryonic states, but it is almost certain that clean water will become limited if the present trend continues. Water will no longer be free and abundant, and clean water may be nonexistent. Restrictions on the use of available groundwater; allocations of ground water to urban, industrial, and agricultural users; and legislation aimed at curtailing waste of water are already the law in many areas. Agriculture and horticulture, as the major users of water, must learn to use less water and seek other sources of water to satisfy irrigation needs.

Horticulturists have already incorporated new technology into many of their production programs, which has enabled them to grow more horticultural crops with less water; however, more effort is needed. Techniques such as drip irrigation, sensors (e.g., tensiometers, which identify irrigation needs), growing plants with low water requirements, timing and scheduling irrigation to the growth needs of the plant, mulching, and establishing a minimum water quality standard for horticultural crops must be used to stretch agricultural water supplies (1, 4, 5, 6, 7). Recycling agricultural water and using treated municipal sewage effluent is a viable option for increasing horticulture's future water supply, and industry is already doing this. An aluminum manufacturing plant has established 7 quality grades of water in its production program. As water becomes polluted (grade 7), it is recycled to drinking water (grade one); then the water-utilization program starts all over again. A steel plant in Baltimore uses sewage effluent to cool metal during rolling. From original ore to finished product, 1000 kg of steel uses 228 m^3 of water (5).

There are benefits in horticulture's use of wastewater that industry cannot obtain. Agriculture wastewater and sewage effluents often contain significant quantities of heavy metals and other substances that may be toxic to people but beneficial to horticultural crops (3). Phosphorus and nitrogen are wastewater pollutants or plant nutrients that have been responsible for eutrophication of streams and lakes. There is no technologically feasible, economical alternative for effectively treating wastewater for discharge into streams and lakes at present (8). Disposing of wastewater through the irrigation of horticultural crops has practical applications. Plants use the nutrients, reducing the pollution load that wastewater contributes to our surface water supply (1). Irrigation instead of direct discharge may also help recharge the groundwaters if industrial water wastes can satisfy minimum horticultural standards.

This Workshop was organized to present some of the current activities and knowledge on wastewater utilization in horticulture. Risks, problems, benefits, and successes of wastewater utilization are discussed by knowledgeable speakers identified by the Municipal and Industrial Waste Utilization in Horticulture Working Group of the American Society for Horticultural Science. The purpose and hope of this Workshop is to encourage additional research in the use of wastewater in horticulture so that it becomes common practice. Much research is needed to determine the optimum water quality requirements of various horticultural crops. Horticulturists must also identify quantity and chemical composition of wastewater to apply for maximum plant growth and minimal environmental pollution under all soil and climatic conditions.

Water is not an infinite resource. The "water affluent" residents of Phoenix, Ariz. are squandering geological water accumulated over millions of years. What is to become of the lush cotton fields surrounding that city, the golf courses, and the green suburbia when that geological accumulation is exhausted? The people of Phoenix are not alone.

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Problems of Using Wastewater on Vegetable Crops

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If wastewater is to be recycled safely for agricultural production the problems associated with using it on vegetables need to be known. The objective of this review is to determine those problems. Several earlier reviews dealing with the use of wastewater in agriculture have been published (5, 7, 9, 19, 27, 30, 31, 42). Raw wastewater, or primary effluent, is not considered in this paper because secondary effluent is the type of wastewater generally used for irrigation in the United States (42). Primary treatment involves only settling tanks, from which anything in the raw sewage that can float or sink is removed. Sewage from primary treatment is subjected in secondary treatment to the action of living microorganisms: e.g., activated-sludge processes, trickling filters, treatment ponds (42). Also, this paper is limited in discussion to municipal wastewater and does not mention wastewater from industry, including wastewater from vegetable-processing plants. This review is divided into 3 areas: physical, chemical, and biological problems.

PHYSICAL PROBLEMS

Soil aeration and excess water

Wastewater is applied to land to dispose of it, and large amounts are sometimes added to small areas, resulting in flooding (25). In regions where evapotranspiration is low the excess water can remain on the land for several days. Crops require at least 10% by volume of air in the soil (50). This value is a lower limit, and it is reasonable to expect a different air-content limit with different vegetables and at different stages of growth. For example, yields of tomatoes are reduced by one day of O_2 deficiency at the seedling stage, and yields of peas are reduced by one day of O_2 deficiency at the early-bloom stage (23). In addition some heavy metals (e.g., Mn, Fe) may become more available under waterlogged conditions than under aerobic conditions (25). Therefore application of wastewater in excess of the water needs of a plant can be a problem (25) unless the soil is adequately drained or evapotranspiration rates are high.

Suspended solids and clogging

Suspended solids received by the soil are fine and mainly in the organic form because wastewater from secondary treatment has been screened and settled (9). Suspended solids in secondary effluent range from 13 to 62 mg·liter^{-1} (ppm), with a typical value of 25 mg·liter^{-1} (42) (Table 1). These solids accumulate on the soil and form a layer of high hydraulic impedance that reduces the infiltration rate. Hydraulic impedance of the clogged layer is directly proportional to the concentration of solids in the wastewater. The layer is also an O_2 sink, as it consists of biodegradable organic material and can kill seedlings. Nitrogen can be immobilized initially after the layer is worked into the soil (9). Drying restores the infiltration rate since the clogged layer decomposes.

Soil warming with power-plant waste heat. Generating electricity from steam is inherently inefficient. Only about one-third of the energy available from burning fuel is converted to electrical energy. The remaining two-thirds are wasted (33, 34). This waste heat is a valuable resource that could be used agriculturally if the steam plant is close enough to fields or greenhouses for heated water to be pumped through pipes below the surface to raise soil temperature. Growth increases with an increase in temperature, up to an optimum (26).

Waste heat, generated during electrical-energy production, has been used to increase soil temperature in plastic-covered greenhouses in Oregon (6). Increased yields of vegetables and fruits in an open field in the Willamette Valley in Oregon were obtained with waste heat (35). Yields of agronomic crops in the same region also were increased by soil heating (35). An economic analysis showed, however, that only high-value crops, such as vegetables, can be produced profitably with soil warming (38). The technique is expensive because of the cost to install the equipment.

Dissipation of heat is enhanced by irrigation, which improves thermal contact between the soil and the pipes and increases thermal conductivity (15). Therefore, if waste heat and wastewater for irrigation were used simultaneously, the economics might be more favorable than if just one were employed. Using 2 waste products together for agricultural benefit is a desirable goal.

CHEMICAL PROBLEMS

Salts

Salt concentrations in domestic wastewater vary widely, according to the salinity of the local water source and the chemicals added during treatment (44). For example, the salt content of the secondary effluent produced in Phoenix, Ariz. is 800 mg·liter^{-1} (800 ppm) (Table 1). Good drinking water has less than 500 ppm total dissolved solids (5). The conductivity of 800 ppm salt is about 1.3 mmho·cm^{-1} (45). Salinity effects are mostly negligible at 0–2 millimhos·cm^{-1}, and only tolerant crops yield satisfactorily at 8–16 mmho·cm^{-1} (3). Crops vary greatly in tolerance to salinity (3, 45). Salinity is generally of concern only in arid regions, in which accumulated salts are not flushed from the soil by precipitation. Salinity can cause trouble, however, in coastal areas (e.g., Florida) because of salt intrusion. No problems from salinity have been reported at sites in Arizona, California, New Jersey, New Mexico, New York, Texas, Utah, and Wisconsin, where wastewater has been used for as long as 56 years (44).

Calcium and magnesium

Concentrations of Ca and Mg are high in the Arizona effluent (Table 1), and clay in the soil does not deflocculate. Therefore the flocculating effect of wastewater on clay will be beneficial (8). The bicarbonate content in the Arizona effluent, however, may be too high for sprinkler irrigation of fruit or vegetable crops because it may leave a white residue on fruits and leaves. The bicarbonate is otherwise not a problem (8).

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