each week a volume of water equivalent to a 4⅔-inch irrigation was applied to each plot. After 5 feet of water had been applied, the application rate was doubled so that, by the end of the project, each plot had received a total of 17 feet of water.

Five sets of soil samples were collected: before treatment; after 70, 103, and 168 inches of water had been applied; and after termination of the treatments.

The SAR values for the 0- to 3-inch depths are shown in figures 1 and 2. Similar relationships were found at lower depths. City water had a negligible effect on the SAR. Effluent water raised SAR levels at both sites, but gypsum acted to lessen this effect. Maximum SAR values of 4.5 to 5.5 were reached after less than half the total amount of effluent water had been added. Further applications did not increase the SAR value. Electrical conductivity of the saturation extract (ECe) for the surface foot of soil from effluent-treated plots did not rise above 1.9 mmhos at either site.

Chemical Composition of Waters Used for Irrigation

Item	City water		Morro Bay effluent	
Calcium	58	mg/l	62	mg/l
Magnesium	96	mg/l	45	mg/l
Sodium	77	mg/l	269	mg/l
Potassium	1.5	mg/l	12	mg/l
Ammonium	.		24	mg/l
Chloride	144	mg/l	321	mg/l
Sulfate	55	mg/l	81	mg/l
Bicarbonate	543	mg/l	505	mg/l
Boron	0.1	ppm	0.6	ppm
EC x 10	1.1		2.0	
SAR	1		6	
SARadj	4		16	
pH	8.2		7.6	

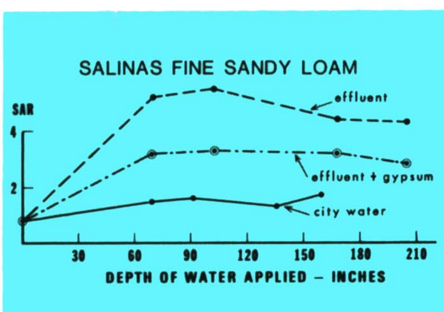

Fig. 1. Sodium adsorption ratio (SAR) values of saturation extracts of Salinas fine sandy loam (0- to 3-inch depth) versus total depth of water applied.

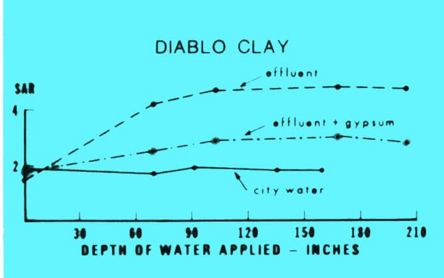

Fig. 2. SAR values of saturation extracts of Diablo clay (0- to 3-inch depth) versus total depth of water applied.

Infiltration rates

Infiltration tests were made at approximately three-week intervals throughout the six months of water application. Initial rates were high for the Salinas fine sandy loam (12 inches per hour) and gradually declined to about 7 inches per hour after six months. There was no significant difference in infiltration rates between city water and effluent water, with or without gypsum on the plots.

Initial rates were moderate for the Diablo clay (1 inch per hour), and actually increased during the experiment to around 4 inches per hour. These high rates were attributed to the applied water being conducted downward through vertical cracks in the soil, which never closed up completely. To compensate for this anomaly, duplicate 6-inch-diameter infiltrometer rings were driven into each plot. Resulting in-ring infiltration rates were dependent on whether or not the rings intersected cracks. Those that did gave rates of 1 to 3 inches per hour. Those that did not gave rates as low as 0.01 inch per hour. Again, there was no consistent difference between the city and effluent waters.

Conclusions

On the basis of information obtained in this trial, it may be concluded that use of this effluent water on these soil types would not be expected to result in excessive sodium accumulation and serious water penetration problems.

Even though amounts of water equivalent to at least four years of irrigation were applied, soil SAR values leveled off and remained below 6 in the effluent treatments. At this level, no lowering of infiltration rates would be expected from continued use of effluent water, and none was found.

The trial results also indicate that guidelines used for evaluation of the sodium hazard of irrigation waters may need to be modified to make them applicable to sewage effluents.

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Irrigating with wastewater in Sonoma County

Lloyd M. Harwood

Treated wastewater has been used successfully to irrigate forage crops on 1,100 acres in Sonoma County during the past two years. The city of Santa Rosa, with the help of federal and state funding, is delivering effluent to local farmers from a treatment plant with a dry-weather flow of approximately 5.5 million gallons per day.

The North Coast Regional Water Quality Control Board, which has jurisdiction over the area being served, has established discharge requirements governing the use of secondary-treated effluent for irrigation of forage crops. One important problem is wastewater disposal during winter months, when farmers cannot use the water. The Board also allows secondary-treated effluent from this plant to be discharged into Santa Rosa Creek during the winter months, as long as certain dilution factors are maintained.

Meanwhile, various cities and sanitation districts within Sonoma County are working on plans to irrigate an additional 4,000 acres with treated wastewater. These agencies are considering crop irrigation with wastewater for a specific purpose—to meet their discharge requirements with costs equal to or lower than other methods. The following comments were made by Brandon J. Riha, director of public works for Santa Rosa, in discussing plans for a large new regional treatment facility serving the cities of Santa Rosa, Sebastopol, Rohnert Park and Cotati:

"The decision to go to land irriga-

Estimated Profit or Loss Based on Operator Owning Own Irrigation System*

Crop	Total costs	Gross value	Profit	Loss
Barley	$162.58	$194.94	$32.36	
Wheat	166.42	205.10	38.68	
Oats				
Calif. Red	157.91	165.00	7.09	
Kanota	156.14	142.34		$13.80
Forage mix	195.08	183.30		11.78
Sudan				
Piper	211.24	207.45		3.79
Trudan 6	207.51	211.50	3.99	
Corn	235.55	361.50	125.95	

Note: Rent or interest on land not included.

*Rental charge for pump, motor, electrical panel, main line, and laterals was $45.15 per acre. Invoice price of the rental equipment was $66.36. Using a 10-year depreciation factor and interest charge at 10% on one-half of capital investment, the cost per acre would be $19.13.

Silage crops at $3.75 per ton for harvest costs.

Fertilizer rate on all crops: Nitrogen 64 lb per acre; phosphorus, 80 lb P O basis per acre (35 lb phosphorus).

Cultural costs: Tractor (75 h.p.) at $20 per hour; smaller tractor at $12 per hour tion . . . means the city can avoid the addition of costly treatment facilities. The operation and maintenance costs for wastewater reclamation have proven to be significantly less than full tertiary treatment. On the basis of a 20-year life, the city would pay approximately $430,000 annually in operation and maintenance costs for land irrigation as compared with approximately $935,000 for tertiary treatment."

Supplying effluent for irrigation may have two other beneficial effects in Sonoma County. The increased agricultural production resulting from irrigation would be reflected in the general economic activity of the area. Also, irrigation would result in productive open space near or adjacent to urban areas.

Although irrigation with treated wastewater clearly may have economic and other benefits for cities and sanitation districts, the question of potential benefits to agriculture must be considered separately.

Questions relating to effluent use by farmers in Sonoma County include: (1) economics of growing a second crop; (2) long-term effects on soil; (3) public health restrictions on use of effluent; (4) possible toxic elements in wastewater; and (5) value of nutrients in effluent for plant growth.

Much of Sonoma County has only limited experience with summer irrigation, because most of the open land is planted to winter forage crops supported by winter rainfall. Summer crop production also is limited by the prevailing clay soils and the low summer temperatures resulting from intrusion of marine fog.

The economics of growing a second crop in Sonoma County vary from ranch to ranch. It appears that local dairymen probably have the most to gain, by producing their own forage instead of buying it. The largest cash investment would be in an irrigation system. Projected costs are available from a 52-acre study completed for the City of Petaluma in 1976 by the author and Dan Silacci, a local dairyman. This project was funded by the Sonoma County board of supervisors.

Only minor changes in soil chemistry were observed over the three-year test period. These included a slight increase in the total salts as indicated by the soil conductivity, a change in soil pH from slightly acid to nearly neutral, and a gradual increase in the phosphorus content of the soil.

A major problem on the heavy clay soils will be compaction resulting from necessary cultural operation when soils are at or near field capacity. (This is not an effect of the use of effluent as such, since most irrigation methods would result in a similar problem.) Lower water infiltration rates and reduced crop yields may result. However, it was observed that more frequent irrigations with smaller amounts of water per application reduced the effects of soil compaction on corn yields.

The present public health regulations allow the use of secondary-treated effluent on all types of forage crops. There is a restriction on milking dairy cattle being in a field while irrigation is occurring. However, this is good pasture management regardless of the water source.

The presence of elements toxic to plant growth or animal health in effluent appears to be minimal in the wastewater used in Sonoma County, although this may not be true in other areas.

Nearly all of the soils in Sonoma County are deficient in nitrogen, and many soils are also deficient in phosphorus. Irrigation with wastewater can significantly reduce fertilizer costs in the production of forage crops.

These studies were concerned primarily with forage crops. A farmer producing high-value food crops should examine public health restrictions very carefully before deciding to utilize wastewater for irrigation.

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Using food-processing wastewater for irrigation

Jewell L. Meyer

Food processing in California requires large amounts of water, most of which becomes waste. Since the late 1960s, the major canners, with about 10 plants in the Central Valley, have been irrigating crops with this valuable resource. Many processing plants produce 2 to 4 million gallons per day of effluent during the summer irrigation season. This is sufficient water to irrigate 400 to 800 acres of cropland at each site.

Monitoring of the effluent quality and its effect on crops and soils was begun in 1970, following the enactment of the California Porter-Cologne Clean Water Act. Since then, cooperative research involving the processors, Regional Water Resources Control Boards, and U.C. Cooperative Extension has shown that irrigation is a practical alternative to conventional treatment and evaporation ponds or to discharge to local streams.

The problem constituents in food processing wastewater are:

- Added nutrients (nitrogen and phosphorus). However, nutrients can be used by plants to produce food and fiber.
- Added salts, including sodium and other elements contributing to total dissolved solids (TDS). In general, salinity is increased about twofold during food processing. Occasionally, sodium concentrations increase enough to become a hazard to soil permeability. In that case, calcium—in the form of gypsum—is metered into the effluent to mitigate the problem.
- Fruit sugar resulting in biochemical oxygen demand (BOD). Elevated oxygen demand can occur with high-sugar fruits. However, odors and anaerobic soil conditions may be controlled by very shallow irrigation or by cultivation within three to four days after the effluent goes onto the soil.

Assuming most crops in California's Central Valley require 40 to 48 inches of water annually, between 180 and 225 acres are needed for each 1 million gallons per day of wastewater effluent during the processing season. For that reason, acreage requirements are large for proper irrigation management and total usage of processing effluent.

The key to use of processing wastewater has been (1) careful monitoring of effluent quality, (2) making management adjustments for water quality problems, and (3) sound irrigation principles. A normal irrigation season is 120 to 150 days. The food-processing season usually covers most of this time.

Crops that have been successfully grown with cannery wastewater include pasture grasses, alfalfa, sorghum, barley, oats, and grapes. These crops have yielded well, provided good irrigation practices are conducted. Wastewater applications should not exceed crop water requirements plus a reasonable leaching fraction, about 15 percent above crop needs. Deep soil monitoring has shown that agricultural crops use the major portion of added nutrients and that soil permeability has not been adversely affected at any monitoring site. Odors and surface layers of organic matter have not been a problem under proper cultural management.

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