Lewis Stolzy checks test plot of mesquite grown with saline blowdown water.

Using "blowdown" water to irrigate crops

William A. Jury □ Lewis H. Stolzy □ Carl A. Fox
Henry J. Vaux, Jr. □ Ian R. Straughan

Though not profitable, it could be less expensive than disposing of cooling water by evaporation

For the last seven years we have been conducting experiments to study the feasibility of reusing power plant cooling water for crop irrigation. This particular power plant effluent, also called blowdown water, is a residual from the water cycle that is used to carry off waste heat from electrical power plant condensers. This water is internally cycled several times while being evaporated before being discarded, and it is quite concentrated, ranging between 3,000 and 7,000 ppm (parts per million) total dissolved salts for a plant operating in the arid Southwest.

The volumes of blowdown water discarded are substantial. For example, a 1,000 mW power plant operating at full capacity discharges approximately 3,500 acre-feet of blowdown water per year. All power plants operating inland must dispose of blowdown water in lined evaporation ponds, which occupy hundreds of acres. Thus, under present policy, a potential water resource is lost and the power plant (and ultimately the power consumers) must pay for an expensive disposal operation.

The purpose of our research is to learn whether or not it is possible to grow crops using this blowdown water for irrigation and, at the same time, meet existing standards for waste disposal. Thus, we had to determine both the crop yield potential of the water and the amount of salt carried below the field. Salt discharge below a field irrigated by blowdown water must be minimized to satisfy environmental constraints. Because of the potential groundwater contamination, the water had to be managed so as to minimize the leaching fraction (LF — ratio of drainage water to applied water).

The first three years of our experiment were conducted in 28 soil lysimeters (4 feet in diameter, 5 feet deep) containing four representative soil types from California. We grew alternate crops of winter wheat and sorghum using three levels of total dissolved salts — 1,500, 3,000, 6,500 ppm — within the range of anticipated concentrations in blowdown water. Minimum leaching fractions were maintained between 0.01 and 0.1 for the five crops grown during the three years.

In the fourth year, we moved the study to a 3.5-acre sandy field adjacent to the Southern California Edison electrical generating station at Etiwanda, California. Since that time, wheat and sorghum have been grown in this field, irrigated with a blend of blowdown water and well water maintained at approximately 3,000 ppm total dissolved salts. During the first year at the field (1978) we irrigated crops with fresh water to evaluate pre-existing fertility conditions at the site. After that period, crops have been grown continuously and subsequently harvested, with the exception of the 1981 sorghum crop, which was plowed over in midseason to clear the field for another experiment.

As would be expected, the first five crops grown in the lysimeters had a characteristic decrease in yield associated with salinization of the crop root zone (table 1). Even at the end of the third year, however, the yields were still high enough to show commercial potential for using the water. The increasing yields in the field experiment were most probably due to improved fertility at the field site, which had not been extensively cultivated before our arrival. The final wheat and sorghum yields shown are similar to those in the campus experiments within the lysimeters.

It is important to realize that each crop was grown under minimum leaching conditions. The average leaching fraction for all lysimeters during the three years of our campus experiment was 0.1. In our saline irrigated field experiments, including rain water, we have averaged a leaching fraction of 0.17. These minimum leaching conditions tended to maximize the adverse impact of the saline water on the crops while minimizing pollution of the drainage water. Thus, we feel that the high yields achieved under these conditions demonstrate that the blowdown water may offer a resource with a manageable environmental impact.

As previously mentioned, blowdown water is currently disposed of in lined evaporation ponds, usually made of compacted clay. Because these ponds must be capable of disposing of several thousand acre-feet of water annually, they are quite expensive to construct and maintain. Furthermore, since they spread over many acres, particle reorientation, soil cracking, settling, or simply the action of water on the soil contributes to the probability that the ponds will leak substantial quantities of water over time. This probability is taken into account when, for example, reservoir engineers design pond sizes. The most common method of pond sealing, compacted clay, is intermediate in its seepage rate and also in its cost (table 2). Because of its common use, this pond type was the standard against which we judged the projected seepage rate below our irrigation experiment and also the cost of constructing and maintaining our operation.

Using a theoretical chemistry model, which we developed, we have been able to estimate the concentration and amount of salt flowing beneath a root zone of a specified leaching fraction (table 3). For evapotranspiration conditions expected to occur in the southern California deserts, the average seepage rate below a clay-lined evaporation pond, as shown in table 2, would correspond approximately to a 0.4 leaching fraction. Thus, a clay-lined pond with this characteristic would actually produce more salt in the drainage than would an irrigation system with either a 0.1 or 0.2 leaching fraction of applied blowdown water. Consequently, even if we were not able to achieve leaching fractions as low as 0.2 in a large-scale commercial operation, we could still allow more leaching to occur without exceeding the emissions of the conventional method of disposal.

To put these calculations into an agricultural perspective, we also calculated the cost of operating a farm adjacent to a 1,000 mW power plant, using blowdown water with a sprinkler irrigation system. Because of the yield reduction, a farming operation using blowdown water on the conventional crops we studied (wheat, sorghum) would produce a small deficit each year if attempted as a business venture ("Reuse of Power Plant Cooling Water for Irrigation," Water Resources Bulletin, 16:[5] October 1980, Jury *et al.*). However, because the irrigation setup is so much less expensive to construct and maintain than a lined evaporation pond, this method of disposal could save a considerable amount of money, which subsequently could be used as a subsidy to support a farming operation.

When this savings (table 4) is combined with the costs of farming, a profitable venture emerges that could be managed adjacent to the power plant, producing a significant savings to consumers while maintaining existing standards of environmental protection. In the arid Southwest, more exotic crops, such as jojoba, guayule, and mesquite, may also be profitable when irrigated with blowdown water.

William A. Jury and Lewis H. Stolzy are Professors of Soil Physics, Department of Soil and Environmental Sciences, University of California, Riverside; Carl A. Fox is Research Scientist, Research and Development, Southern California Edison, Rosemead; Henry J. Vaux is Associate Professor of Resource Economics, University of California, Riverside; and Ian R. Straughan is Manager, Geoscience Systems Research and Development, Southern California Edison, Rosemead.

Monitoring stations consisting of tensiometers, salinity sensors, and neutron probes measured chemical and water status at 16 locations in a 3.5-acre field irrigated with blowdown water.

TABLE 1. Grain yields in lysimeter (U.C., Riverside) and field (Etiwanda, California) experiments

Date	Crop	Yield*	
Lysimeters		*lb/acre*	*bushels/acre*
12/75 - 6/76	Wheat	7,376	122.9
7/76 - 12/76	Sorghum	6,038	107.8
12/76 - 6/77	Wheat	5,280	88.0
7/77 - 11/77	Sorghum	3,273	58.4
12/77 - 6/78	Wheat	4,218	70.3
Field			
12/78 - 6/79	Wheat	3,228	53.8
12/79 - 6/80	Wheat	3,648	60.8
7/80 - 12/80	Sorghum	4,192	74.8
12/80 - 6/81	Wheat	5,779	96.3

*Yield data shown for lysimeter experiments are for the medium treatment of 3,000 ppm water, which is similar to field conditions. Wheat experiments received varying amounts of rain water during the winter in addition to irrigation at the power plant facility.

TABLE 2. Total annual costs and approximate seepage rates of alternative evaporation ponds (in 1980 dollars)

Lining type	Annual cost*	Approximate seepage rate
		inches/year
Exposed asphalt panel	$2,472,830	4
Exposed synthetic membrane	1,800,639	1
Compacted clay	599,998	35
Concrete	347,773	400
Asphalt concrete	244,157	120

*Includes amortized capital cost for 20-year operation, with estimated maintenance costs.

TABLE 3. Estimated salt emissions below evaporation pond and two irrigated fields using blowdown water from 1000 mW power plant

Disposal method	Land area	Drainage conc.	Salt emissions
	acres	*ppm*	*English tons/yr*
Evaporation pond, (clay lined), LF* = 0.4	520	14,000	30,000
Irrigated field, LF = 0.2	670	25,000	28,000
Irrigated field, LF = 0.1	760	48,000	27,000

*LF = leaching fraction = (drainage/input)

TABLE 4. Savings attributable to blowdown disposal through irrigation as compared with pond evaporation (1980 dollars)

Pond type	Annual saving
Exposed asphalt panel	$2,151,467
Exposed synthetic membrane	1,548,850
Compact clay	433,879
Asphalt concrete	62,441
Concrete	49,200