Evaporation Suppression by Chemical and Mechanical Treatments[1]

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There is an abundant supply of water on and beneath the earth's surface. The pressing problem is to supply water of suitable quality in adequate quantities to deficient areas. Monomolecular films have the potential to significantly reduce evaporation and thereby increase the portion of reservoir storage available for domestic and economic uses.

Previous Investigations

Large volumes of water are lost to evaporation from above-ground reservoirs. Evaporation from Lake Carl Blackwell, the water supply for Stillwater and Oklahoma State University, was 69.4 inches in 1956 (Crow and Daniel, 1958). Evaporation was over four times as great as use by the population of 20,000.

It was first observed in laboratory experiments that a film of fatty alcohols would significantly reduce evaporation (Rideal, 1925; Langmuir, 1927). Numerous investigators have demonstrated the effectiveness of monomolecular films, primarily 1-hexadecanol, in reducing evaporation. Tests indicate that long-chain alcohols, 1-hexadecanol and 1-octadecanol, will form a compressed film which will reduce evaporation 25% or more under field conditions if a complete film cover can be maintained. However, under natural conditions the chemical film is readily blown from the water surface. In field studies at Lake Hefner, U. S. Bureau of Reclamation researchers found wind to be the most important single factor in the application and maintenance of a film (Price, Garstka, and Timblin, 1959). An inverse relationship exists between the portion of reservoir covered by film and wind velocity (Crow and Sattler, 1958). Experimental data showing the relationship between wind velocity and film application rate required to maintain a monomolecular film on a small reservoir has been published (Crow, 1961).

Wind, in addition to removing a monolayer from a water surface, contributes to evaporation under natural conditions. Evaporation rates increase as wind welocity increases.

Methods to Modify the Effects of Wind on Evaporation

Since wind readily removes monolayers from a water surface and directly influences evaporation, the logical approach is to eliminate or modify the wind pattern at the water surface. This may be accomplished by (1) continuously replenishing the monolayer at the upwind shore, (2) reducing wind speed near the water surface, or (3) restricting the movement of the monolayers by confinement within a network of floating compartments.

The objectives of the research reported in this paper were:

1. To determine evaporation reduction when the monolayer was continuously replenished at the upwind shore.

[1]This research was financed jointly by the Oklahoma Agricultural Experiment Station and the U. S. Bureau of Reclamation. Paper approved as Oklahoma Agricultural Experiment Station Manuscript No. 1277.

2. To develop systems of fixed or floating wind barriers and evaluate their effect on evaporation with and without a chemical film.

EXPERIMENTAL FACILITIES AND TEST EQUIPMENT

Two adjacent ponds, 100 x 120 x 7 feet, were constructed in 1956 with a buried vinyl plastic liner to prevent seepage. The ponds are located on the crest of a ridge and receive no surface runoff. Water was supplied from the University water system to assure an accurate water budget during each test.

The water level of the ponds was measured with micrometer-type point gages located in stilling wells adjacent to the ponds. Wind speeds were measured with a cup-type totalizing anemometer set two meters above the mean water surface.

Four types of wind barriers were constructed and tested on the test pond. They were designated vertical open barriers, vertical closed barriers, flat closed barriers, and natural mesh shade.

The vertical open barriers were constructed from a picket-type snow fence with 2 inches of open spaces between the 1.5-inch pickets. A grid 14.5 feet on centers was supported on the test pond in a vertical position by floats and cables allowing for various height settings above the water surface. Vertical open barriers were converted to closed vertical barriers by stapling vinyl chloride sheet plastic to the pickets.

Flat closed barriers were constructed from strips of Styrofoam 1 inch high and 4 inches wide. The strips were joined together providing closed compartments 8 feet square.

Natural colored polypropylene mesh providing 6% shade was suspended on cables approximately 6 inches above the water surface of the test pond.

Two additional products, 1-inch diameter white plastic spheres and black polypropylene mesh, were available in a limited quantity for testing. They were tested on Class A evaporation pans. The plastic balls were floated on the water surface. The black mesh was similar to the natural-colored mesh with a larger thread size and provided 47% shade. It was stretched over the lip of the evaporation pan.

It was desired to compare the effectiveness of a combination of barriers and chemicals with a continous chemical film in reducing evaporation. An application system was constructed to apply chemicals to the test-pond surface continuously. Automatic controls regulated the rate and point of application of the monolayer-forming solution in response to wind speed and direction. The chemical used was a blend of straight-chain saturated higher alcohols with 5% C_{14}, 44% C_{16}, 46% C_{18}, and 5% C_{20}.

Procedure—The procedure for making a test was to fill both ponds to the same elevation. A treatment was applied to the test pond with the second pond serving as a check. Changes in water level and wind travel were recorded at 12-hour intervals. Wind travel was measured two meters above the mean water surface elevation of the ponds.

Tests were made on the ponds with the barriers in place. A subseqent test was made with chemical added in combination with the barriers at about 4-day intervals.

Tests were made on evaporation pans by applying treatments to three pans and using the fourth as a control. The water level in the pans was measured at 12-hour intervals.

Results and Conclusions—Evaporation reduction is expressed as a percentage of evaporation from the untreated reservoir. Table I gives results from the pond tests for various barriers along with average wind velocity, barrier height and L/H, the ratio of distance between barriers to their height.

TABLE I. EVAPORATION REDUCTION FROM TREATMENTS ON EXPERIMENTAL PONDS

Treatment	Barrier Ht. (ft)	L/H	Avg. Wind Speed (mph)	Evaporation Reduction (%)
	Without Chemical Film			
Vertical, open barriers	1.20	12	6.8	6
Vertical, closed barriers	0.90	16	10.3	9
Vertical, closed barriers	0.25	58	6.1	0
Flat, closed barriers	0.08	100	7.2	11
Natural mesh, 6% shade	—	—	6.5	35
	With Chemical Film			
Vertical, closed barriers	0.90	16	5.8	31
Vertical, closed barriers	0.25	58	5.8	11
Flat, closed barriers	0.08	100	7.1	21
Natural mesh, 6% shade	—	—	5.9	45
Continuous monolayer	—	—	6.9	36

It is apparent that barrier height and configuration affect evaporation from ponds. Closed vertical barriers were more effective than open vertical barriers when no monolayer was applied. Evaporation reduction was greater from closed vertical barriers at the greater height. At comparable heights, flat closed barriers were more effective than the narrow vertical ones. This increase in effectiveness may be due to the broader width of the barrier or closer spacing of the grid. Natural mesh provided the greatest evaporation reduction.

Vertical and flat barriers gave less evaporation reduction than natural mesh or a continuous monolayer. Natural mesh with and without a monolayer was as effective as a continuous monolayer. The mesh reflects incoming radiation and prevents energy from reaching the water surface.

High evaporation reduction was obtained on the evaporation pans as shown in Table II.

TABLE II. EVAPORATION REDUCTION FROM TREATMENTS ON CLASS A EVAPORATION PANS

Treatment	Per cent Reduction
Natural mesh, 6% shade	26
Black mesh, 47% shade	44
White floating spheres	78
Continuous monolayer	70

Most spectacular was the performance of the white plastic spheres. Additional studies are needed to determine their performance on a larger reservoir. As expected the mesh with the higher shade value gave the greater evaporation reduction.

The performance of the natural colored mesh was poorer on the pans than on the ponds. This is possibly due to the sheltering effect of the lip of the evaporation pan. The water surface of the pans does not develop as severe wave action as on the ponds. Thus, the mesh cannot freely act to modify the wind patterns on the pans.

SUMMARY

The ability of mechanical barriers and a combination of mechanical barriers and a chemical film to reduce evaporation from a reservoir has been shown. Additional research is needed to determine the proper spacing and configuration for the mechanical barriers. It is reasonable to expect that barriers can be designed to maintain a 100% monolayer on a water surface under most wind conditions encountered above a water surface.

Polypropylene mesh, in addition to reducing wind speed at the surface, reflects incoming radiation and prevents part of the energy from reaching the water surface.

Limited pan tests indicate that floating white plastic spheres are a good evaporation retardant. Additional studies are needed to prove their performance on a larger water surface.

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