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*Reducing Lake Evaporation
in the Midwest*

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Reducing Lake Evaporation in the Midwest

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Abstract—During the summers of 1957 and 1958 studies were conducted on two lakes in central Illinois to determine a practical method of applying monomolecular layers and to learn the effectiveness of the layers in reducing evaporation. Results showed a saving of 43 per cent in 1957 and 22 per cent in 1958 of the water normally lost to evaporation. A method was developed for determining the strength of the monolayer by measuring the heat gradient near the water surface.

Introduction—Reducing evaporation from water surfaces has been studied extensively in the arid regions of Australia, Africa, and the United States, and interest in the subject is developing in humid regions as well. In the United States, for example, dry climatic conditions that are ordinarily associated with the Southwest have, during drought periods, extended into normally humid areas. Thus in Illinois where the rainfall is generally favorable, averaging from forty-seven inches in the south to thirty-two inches in the north, experiments in retarding evaporation were begun following the severe drought of 1951-1955.

Project area—In an earlier paper [Roberts, 1957] chemical studies and field research on this subject were reviewed, and a report was made on work done in 1956 by the Illinois State Water Survey with a fatty alcohol called hexadecanol. In the present paper a summary is given of results obtained during the summers of 1957 and 1958 when two adjacent lakes in central Illinois were made available for a study of ways of applying monolayers for suppressing evaporation from water surfaces. The lakes are located at the Department of Conservation fish hatchery near Mattoon in east central Illinois (Fig. 1). The north lake covers 2.8 acres and receives runoff from 2.4 acres of sodded grass. The south lake extends over 2.3 acres and has a watershed of 1.4 acres of relatively flat sod. The area which contributes runoff is west of the lakes, and the opposite shores of the lakes are bordered by levees. The lakes are adjacent to Paradise Lake, the municipal

water source for Mattoon. Water from Paradise Lake can be pumped into either of the small lakes to compensate for water losses.

Each lake was equipped with an instrument pier on which automatic water-level recorders were installed. At various times, water-temperature and air-temperature recorders were located on the piers. A weighing-bucket rain gage was located to the west, near both lakes.

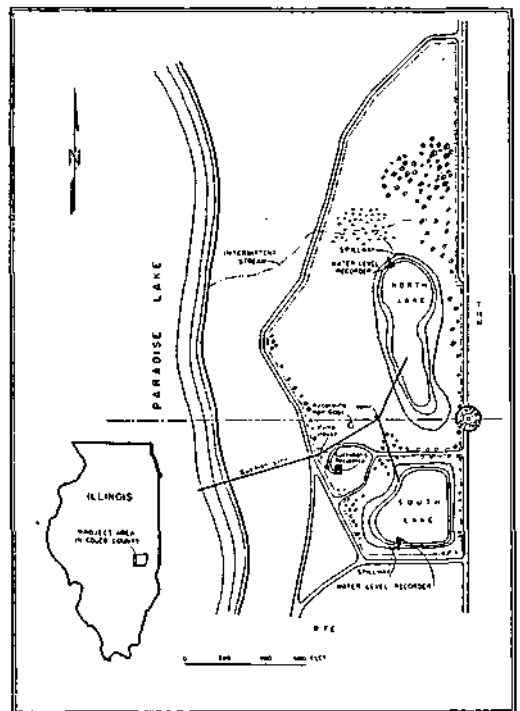


FIG. 1—Research area.

During the 1957 test, the south lake was used as a control, and all experiments with fatty-alcohols were performed on the north lake. In 1958 this procedure was reversed; the south lake was used for testing and the north lake was a control.

Preliminary study—Six weeks of study preceded application of the first monolayers. The charts of lake level fluctuation showed nearly constant seepage from both lakes. This was determined by comparing the nighttime slope of the lake-level curves, when evaporation was negligible, with the daytime traces, which included evaporation. The same rate of evaporative loss from both lakes was assumed in order to study the seepage rate for different lake levels. Within measurable limits, no significant change in seepage rate could be detected. Water losses from both lakes were the same except after heavy rains, when the north lake, with its larger watershed, showed an apparent reduction in water-loss rate because additional runoff reached it. This effect seldom persisted for over 36 hours. During times when water was being added to one of the lakes, the water-level records were of little value for determining evaporative losses.

Application program—Beginning in late June

1957 various forms of hexadecanol and octadecanol were, in turn, spread on the lake. These included extrusions, flakes, beads, and powders. They were dispersed from mesh-float containers anchored in the lake, applied to the lake surface from a boat, or fed from slurry pots. Detection of film strength was made by tests already described [Crow and Daniel, 1957; Bur. of Reclamation, 1957].

Although normal dispersion tests work well under laboratory conditions, water surfaces can become coated with dust films which, by action of innumerable wicks of dust particles, increase evaporation rather than retard it. Under such conditions a temperature test, developed on this project, is a valuable tool. It has been demonstrated [Roberts, 1957] that a strong monolayer cover traps heat that is normally lost by evaporation. By measuring under shade and using a sensitive temperature probe in conjunction with a high-accuracy thermistor thermometer, it was possible to measure temperatures in the ¼ inch of water immediately below the monolayer surface which were 4° to 7° F warmer than in the control lake. Water temperature

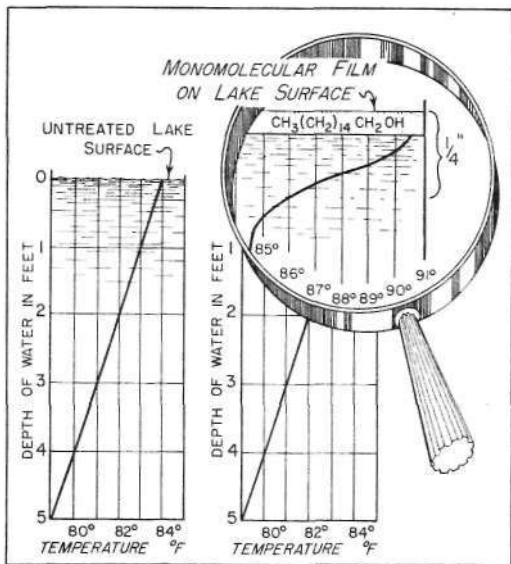


FIG. 2—Graphs of lake water temperatures with and without monomolecular film.



FIG. 3—Thermistor thermometer and temperature probe used to measure film temperature.

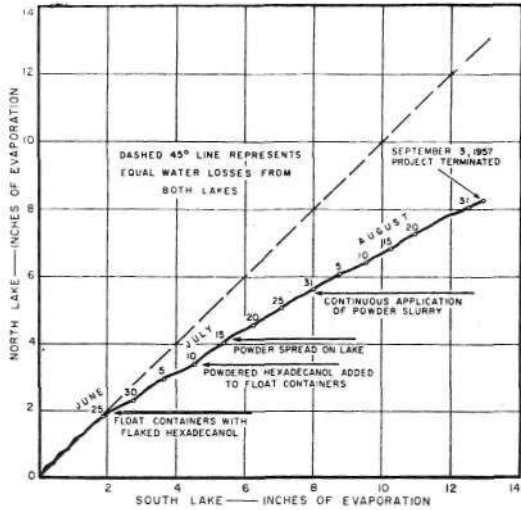


FIG. 4—Double-mass graph of 1957 experiments.

gradually decreased below that depth. This temperature difference could be detected whenever a strong film was present, and its absence indicated a weak or non-existent monolayer. The temperature curve is shown schematically in Figure 2. Apparatus for measuring temperature is shown in Figure 3.

The results of the 1957 tests are shown in Figure 4. This is a double-mass analysis [Kohler, 1949] in which the accumulated total of one series of observations is compared with the concurrent values of a second series. In the graph, daily amounts of evaporation from each of the lakes are plotted as rectangular coordinates, the north lake data being ordinates and the south lake data abscissas. Points falling on the 45° dashed line represent equal water losses. A section of the preliminary calibration period is included in the lower left of the double-mass plot to show that water losses from both lakes were practically equal before hexadecanol was used.

On June 26, 1957, two mesh-float containers, each holding 8 ounces of extruded hexadecanol, were placed in the north lake. In addition, one pound of hexadecanol in fine bead form was applied to the lake from a boat. The combination produced a strong monolayer as evidenced by tests on the following day. However, on the night of June 27 a storm deluged the area with 8 inches of rain. The chemical film was im-



FIG. 5—Hexadecanol cover in foreground produces calm water (compare with rippled surface).

paired, but it reformed during the following day.

On July 9 two new floats, each containing 10 ounces of powdered hexadecanol, were placed in the lake. Also, one pound of beaded hexadecanol was spread over the lake from a boat. This combination produced a strong monolayer which could be observed spreading against a 20-mile-per-hour wind (Figs. 5 and 6).

Although the powder in the floats spread when first put in the water, it tended to cake and remain in the floats. Also the floats accumulated growths which clogged the screens.

One week later tests indicated poor film coverage, so it was decided to omit the floats and spread the chemical manually from a boat rowed around the lake. This produced a good

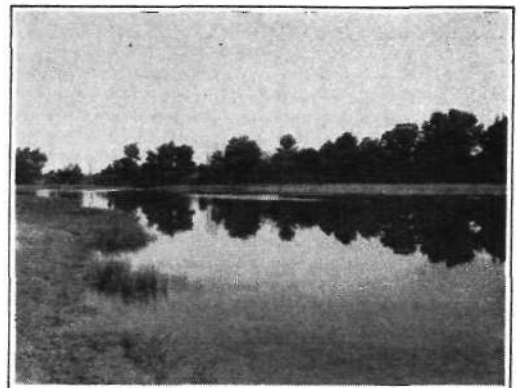


FIG. 6—Same view as Fig. 5 taken fifteen minutes later. The monolayer had spread over all but a small central area of the lake.

monomolecular cover, but it was necessary to add the chemical daily in order to maintain measurable film strength.

Chemical life of film—A search of the literature showed that the dosage required for any water surface depends not only upon the quantity of the hexadecanol but also on the perimeters of the individual particles. The rate of spreading varies with the total length of the contact between the particles and the surface of the water. Therefore powdered hexadecanol was used to provide a very large perimeter for a given amount of material.

The rate at which a monomolecular layer of hexadecanol spreads [Mansfield, 1956] is 1.01×10^{14} molecules per centimeter per second, and the number of molecules required to form a complete monolayer of hexadecanol is 5.14×10^{14} molecules per square centimeter. Thus 5 cm of perimeter of solid should be sufficient to generate approximately 1 cm^2 of complete film per second.

Up to this point in our testing we had found that the physical form of hexadecanol had little effect on its active life. A study of the water-level recorders showed that there was appreciable reduction of evaporation from the treated lake for a maximum period of three days after each application of hexadecanol. After that time, biological attrition, together with physical factors such as wind and rain, removed the protective layer. It was apparent that before hexadecanol could retard evaporation efficiently it would be necessary to apply the chemical continuously.

Continuous film application—The month of August 1957 was spent in testing the effect of continuous application of powdered hexadecanol to the north pond. On July 30, 1957, a 20-gallon open-end tank (Fig. 7) was installed on the east shore of the north pond, and two similar tanks were installed on the west shore. These were filled with slurries of powdered hexadecanol which were permitted to enter the lake through $\frac{1}{4}$ -inch discharge pipes. Flow was controlled through valves so that approximately 100 drops of slurry per minute were permitted to enter the pond from each tank. Copper sulfate was added to each of the slurry pots to counteract biological attrition of the hexadecanol. The initial charge to each tank was 3 pounds of

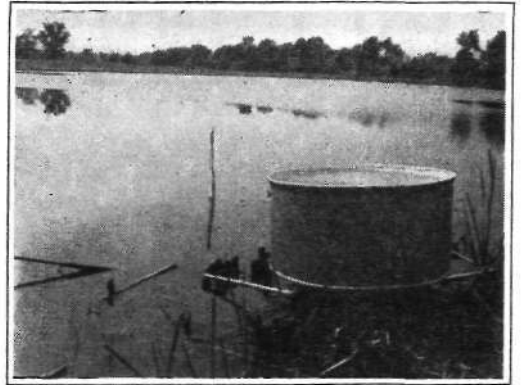


FIG. 7—Hexadecanol slurry from tank generates monolayer as indicated by calm water. Fingers of monolayer from other tanks show at sides of pictures.

powdered hexadecanol mixed in a slurry with lake water. The tanks were inspected and serviced twice daily.

Theoretically, 0.02 lb of hexadecanol forms a compact monolayer film on an acre of water surface. In practice considerably more chemical is required. For instance, the three slurry pots discharged 6 pounds of powdered hexadecanol in 7 days, or enough chemical to cover nearly 100 acres of water at maximum efficiency.

In accounting for the wasted chemical, it is estimated that approximately one half collected along the leeward shores, where it was removed by birds and insects. Ducks taking off from the lake opened long gaps in the monolayer by removing the film on their feathers. Aquatic life nibbled at the surface frequently and biologic attrition of the layer was probably continuous. Thus only a small percentage of the original slurry was available to maintain the monolayer on the lake.

Cost of applying hexadecanol—The 25 pounds of hexadecanol which were used during the month of August 1957 cost sixty cents per pound or about fifteen dollars. As the north lake covered approximately three acres, 8 pounds per acre were required for the month. One third of a pound was left in each tank at the end of the testing period. Examination of the water-level records during August 1957 showed that the water which was saved was approximately $\frac{1}{5}$ ft, or 43 per cent of the water which is



FIG. 8—Applying algacide to south lake. Note heavy cover of aquatic growth.

normally lost to evaporation. The total saving amounted to 65,171 gallons per acre, or 7,600 gallons for each pound of hexadecanol used. Thus, the cost of saving 1000 gallons of water amounted to 8 cents, approximately \$26 per acre-foot. This figure does not take into account the cost of the slurry tanks and fittings or the time necessary for servicing.

Research program for 1958—Aquatic vegetation was an objectionable factor during the 1958 study. Some algae growths developed on the periphery of both lakes during the 1957 experiments but these were controlled by application of copper sulfate. In September 1957 a heavy growth appeared on the south lake. This condition persisted throughout the winter, and in May 1958, 80 per cent of the lake was covered with aquatic growths. An algacide was ap-

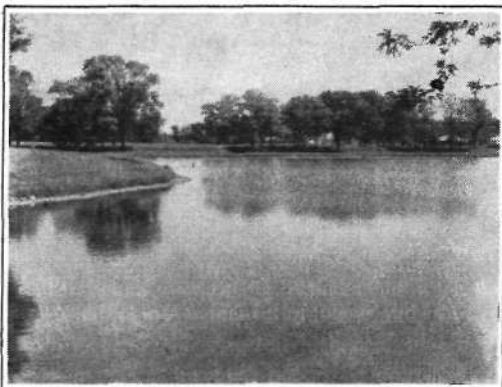


FIG. 9—Same view as Fig. 8 taken one week later shows no evidence of algae growth.

plied to the south lake on May 20 and one day later all aquatic growths submerged and were not in evidence throughout the summer of 1958 (Figs. 8 and 9).

During the summer of 1958 the experiments were repeated, with the north lake used as a control. Unfortunately, there were nearly 22 inches of well-distributed rainfall during the four months, May through August. In addition, temperatures were below normal. Consequently, natural evaporation was greatly reduced and there was little need for or effect from using monomolecular layers. However, the 1958 tests were valuable because they led indirectly to the finding of an effective means of removing algae growths from lake surfaces. They also provided additional evidence that the slurry method, as used in Texas [Dressier and Johanson, 1958; *Chem. Eng. News*, 1958], has advantages over other methods of generating monomolecular layers on small lakes in Illinois.

Figure 10 shows the results of the work in 1958. The water that was saved represents 22 per cent of that which was normally lost by evaporation.

Conclusion—Experience with the lakes at

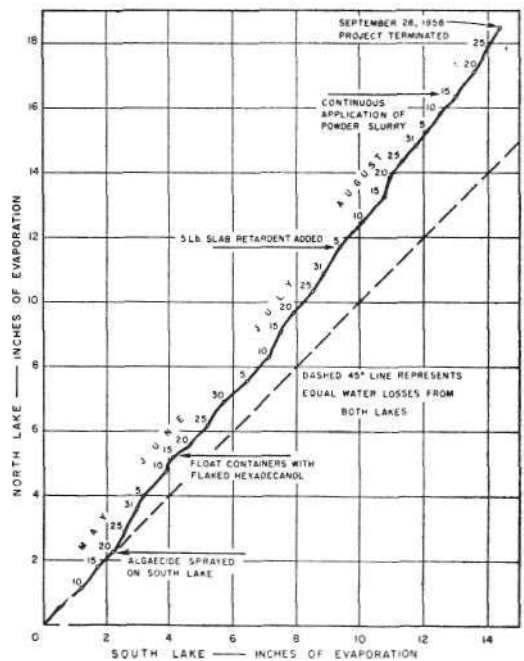


FIG. 10—Double-mass graph of 1958 experiments.

Mattoon indicates that the estimated cost is conservative. No attempt was made to limit the amount of hexadecanol used in order to arrive at a minimum cost. A stricter rationing of the chemical might have effected some saving of the monolayer which was washed up on the windward shore. Problems that ordinarily would not confront owners of small lakes occurred at these lakes because they were used constantly in the fish hatchery program. Thousands of fingerlings were added or removed from the lakes during the periods of testing. These plus other aquatic life, such as turtles, fed on the monolayer constantly. It seems reasonable that on an average small lake it would be possible to double the effect of the monolayer so that applying hexadecanol worth one cent at the present price would result in a saving of perhaps 250 gallons of water.

Acknowledgment—Arrangements for using the lakes were made through the cooperation of Sam A. Parr of the Illinois Department of Conservation. Richard Wiley, Pish Hatchery custodian, and his assistants cooperated constantly during the testing program. Their enthusiastic interest added greatly to the success of the project. This

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