Retardation of Evaporation from Open Water Storages

Es. P. Kumaraswamy

Irrigation Research Station, Poondi Public Works Department, Madras, India

In the present context of overall development and scientific advancement the demand for water has increased considerably as a result of the increase in population and industrial activity. But the available resources of water, particularly in the arid and semiarid regions, are limited. Any development of water resources should therefore ensure efficient control, conservation, and use of available water. This goal would mean the restriction of all avoidable losses, such as evaporation losses and seepage losses. Whereas seepage loss in watercourses and fields returns to streams and aquifers for reuse, evaporation loss signifies water that is finally lost from the available supply. Hence there is need for more emphasis on minimizing, if not preventing, the vast losses due to evaporation. In Australia, the United States, and other countries, research carried out during the past decade indicated that straight chain and fatty alcohols possessed the capacity to spread and thus to give cover on the water surface and suppress evaporation. Cetyl or stearyl alcohol or a combination of both was found to be specially adaptable. Experiments were taken up in arid zones of India to assess the efficacy of these alcohols under Indian conditions.

This report deals with such an experiment conducted at Buderi, where, in addition to efficacy, practical feasibility was also studied. The various methods of application of the compounds on the water surface and the techniques of testing and assessing the results of the field tests are discussed.

Engineers and hydrologists engaged in the design and operation of storage reservoirs particularly in the arid and semiarid regions are well aware of the enormous loss of water by evaporation. For the Indian subcontinent, this loss generally varies from 1.9 to 2.2 meters (6 to 7 feet) of storage of water per year. It is a universally acknowledged fact that lack of water more than anything else hampers and restricts the development of certain areas on both the agricultural and the industrial fronts. In the dry regions, particularly, a rapidly increasing population tends to accentuate the critical water supply position. In irrigation, depths of water evaporated from the surfaces of ponds, lakes, reservoirs, seepage areas, rivers, canals, and open conduits constitute a loss of water that otherwise could be delivered to the fields.

Storage reservoirs are a major source of loss of water since they expose vast surfaces to evaporation. In the case of small reservoirs and tanks, which are usually shallow, the loss by evaporation may frequently be more than the amount actually used. In such cases, evaporation control will increase the quantity of water available for beneficial use and will improve the quality of water, since evaporation removes only pure water.

Methods of evaporation control should aim at exposing the least possible extent of water surface. Control methods include impounding water in narrow, deep reservoirs and covering water with a fixed or floating roof. If the water surface could be kept covered, the evaporation losses would be minimized to a very great extent. But this method is impractical, and the cost is prohibitive even for very small areas. So recourse was taken to the use of a monomolecular film to provide a floating cover. Alcohols having long chain structures (such as cetyl alcohol and cetyl stearyl alcohol) form a monomolecular film on contact with water; this film is sufficiently enduring under field conditions. The field tests show that a monomolecular film of cetyl and cetyl stearyl alcohols can reduce evaporation losses significantly. In this report, studies conducted relating to the use of monomolecular film and the measurement of actual evaporation losses and seepage losses in the field are dealt with.

EXPERIMENTAL SETUP

Experiments were carried out in Buderi tank near Poondi in Madras state. This tank is situated just 3.2 km (2 miles) southwest of the irrigation research station at Poondi and is adjacent to the Poondi Reservoir on the western side. The tank has a water spread of about 11.2 ha (28 acres) at full-tank level and a maximum depth of 3.7 meters (12 feet). It was ideal for conducting studies because the water was not used for irrigation or any other purpose and the inflow was limited to monsoon periods only.

The land pans and the meteorological instruments were located on the periphery of Buderi Lake. The meteorological instruments were (1) a maximum-minimum thermometer for recording temperature, (2) a wet and dry thermograph for automatic continuous record of the wet and dry bulb readings, (3) a recording type of rain gage, (4) a hair hygrograph for automatic continuous record of relative humidity, (5) two anemometers (one at 1.9 meters and the other at 4.3 meters of elevation from the ground level) to record the wind velocities, and (6) a wind vane for recording the direction of the wind.

Of the above instruments the maximum-minimum thermometer, wet and dry thermograph, and hair hygrograph were mounted on standard Stevenson's screens under conditions stipulated by the Indian Meteorological Department. All the automatic recording gages were devised on a clockwork mechanism. The readings of the maximum-minimum thermometer and anemometers as well as the direction of wind (indicated by the wind vane) were observed at 8 A.M., 12 noon, and 4 P.M. every day. The standard charts for the automatic continuous recording instruments were changed at 8 A.M. every day. Apart from these, separate sensitive thermometers were used for measuring the temperature of the air, the water in the pans, and the water of the tank. The levels in the various pan and floating evaporimeters were noted daily.

METHOD OF DISPENSATION

There are various forms of applying the chemical cetyl stearyl alcohol onto the water surface; some of them are solutions, emulsion, powder, and pellet. The first three of these forms were used in the experiment.

Solution. Before starting the field experiments at Poondi, preliminary experiments were conducted in the Concrete and Soil Research Laboratory at Madras to arrive at a suitable solvent for the chemical. Of the several solvents tried, mineral turpentine was the least volatile, and, although it was a bit low, its solvent power for cetyl alcohol was sufficient. Hence this solvent was used in the field experiments conducted.

For application in the field, about 448 grams (1 lb) of cetyl alcohol dissolved in 7.6 liters (2 gal.) of mineral turpentine was found to be a good solvent at almost saturation limit for dispensing in solution form. The mineral turpentine helps in no way to reduce evaporation, but it helps the chemical to spread and cover the whole water surface quickly. The mineral turpentine, being volatile, evaporates and leaves the cetyl alcohol on the water surface.

The solution prepared was applied to the water surface by traversing the lake on boats as well as from the shore. Sprayers were used to spray the solution. Cylindrical dispensing units with conical bottoms were also set up on shore all along the periphery of the lake. The chemical dripped slowly and constantly from these units. Those units situated on the windward side were operated with consideration of the direction of the wind. This method proved to be advantageous on windy days.

Emulsion. Since the use of the solvent mineral turpentine was found to be costly, dispensing the chemical in emulsion form was tried. The emulsion was prepared in the following manner. The prescribed quantity of cetyl alcohol was powdered and placed in a drum with a little soap powder; 3.8 liters (1 gal.) of water was added to it. The mixture was then heated to 80°C, at which point the cetyl alcohol was completely dissolved. This mixture was then churned well for an hour until it turned into a paste. The requisite quantity of water heated to 80°C was added to this paste, and the mixture was again churned well for 1 or 2 hours. The churning could be done by either an electrically driven churner or a manually operated churner. In the former case the mechanism consisted of an electrically driven motor with a long spindle attached to its armature carrying a paddle with vanes on the other end. The emulsion could also be prepared to the same consistency with a manually operated churner; the two methods were equally good. To keep the mixture in emulsion form for a long time, an emulsifier called 'cheekol' was used. A mixture of 3.8 liters (10 gal.) of water poured into

448 grams (1 lb) of cetyl alcohol and melted and kept in a liquid form was used, and a few drops of cheekol were added to the mixture. The liquid was churned for 30 min, and the emulsion full of foam was prepared. The emulsion was transported to the place of injection and dispensed on the water surface.

To dispense this emulsion, a funnel with a regulating valve was employed. The dripping of the emulsion was regulated by the valve. The emulsion was dispensed throughout the water surface, and the film strength was tested. For preparing emulsion, quantities of cetyl alcohol varying from 0.9 to 1.35 kg (2 to 3 lb) were used daily.

Powder. Another form for application of the chemical is the powder form. The alcohol, which is supplied in the form of big lumps, had to be pulverized and made into a fine powder before it could be applied to the water surface. For this purpose a ball mill of 285-liter (75-gal.) capacity was installed. The ball mill is a cylindrical drum rotated at a constant speed by an electric motor through suitable reductions. A suitable quantity of small bits of steel called cylpebs is placed inside the cylinder; these cylpebs act as pulverizers. It takes about an hour to get a powder of uniform fineness. The powder thus obtained was applied to the water surface as a fine spray by the use of hand rotary dusters, which were operated manually by rotating a handle. The spray issuing from the nozzle can be adjusted by means of a lever. The dusters are portable and handy for operation, and the spraying can be done from shore as well as from a boat.

CHARACTERISTICS OF MONOLAYER

Experiments have shown that a method of detecting the presence of a monolayer and determining the degree of compression is required in evaluating the effectiveness of the monolayer as an evaporation retardant. Indicator oils of standard strengths were employed for this purpose. However, it has been found that the location of the monolayer on a large surface can be observed visually and also can be photographed easily from vantage points above the water surface. During periods of calm wind conditions the whole lake surface took on a glossy appearance, characteristic only of the areas covered by the monolayer. A compressed monomolecular film was remarkable for its ability to quiet ripples on the water surface. However, during rough conditions of weather it was impossible to spot the covered regions except in small streaks.

Dosage. Several factors affected the rate at which the alcohol was applied to the reservoir, the most important being previous film coverage, wind, and the operational procedure used. For Buderi Lake it has been observed that the rate of application varied from 46 to 225 grams (0.1 to 0.5 lb) for the first two methods and was about 360 grams (0.8 lb) for the powder method. Applications were made during the daylight hours for short periods ranging from 7 to 10 days. The film losses by wind action, attrition, and so on were made up by fresh dosage.

Pressure and durability of monolayer. Film pressure was tested by indicator oils of standard strength. If the film does not exert sufficient pressure, a drop of indicator oil will disperse. If the pressure is higher than that of the indicator oil, the oil will stand as a discreet drop. The use of such indicator oils of different strengths made it possible to assess fairly accurately the presence of a monolayer and its surface pressure within a range. The following indicator oils were used: Shell high-speed diesel oil, 13 dynes/cm; Shell vitriol 13, 16 dynes/cm; Shell vitriol 21, 24 dynes/cm; and Shell Ensisfluid, 40 dynes/cm.

It was concluded after experiments in other parts of the globe that for a film pressure of <5 dynes/cm, the retardation of evaporation was little; however, between 5 and 40 dynes/cm, retardation increased steadily to its maximum. Also, 40 dynes/cm was the equilibrium value at which the film was found to offer maximum resistance to the escape of water molecules.

The factors that adversely affect the maintenance of the monolayer are strong winds and the bacterial and protein content of water. But wind may be considered as being the most important. At wind speeds of 2.2–4.4 m/sec (5–10 mph), with variable directions, extensive areas can be covered with relative ease; with a speed of <2.2 m/sec (<5 mph), practically the whole lake can be covered with the monolayer. However, at wind speeds of 9 m/sec (20 mph) it is impossible to maintain the film on the water surface.

ASSESSMENT OF EVAPORATION

The total loss from the lake is constituted by the losses due to seepage from the lake and losses due to evaporation. The seepage loss from any lake or reservoir is governed by the characteristics of the soil forming the bed and banks and by the depth of the water column.

The lake level fluctuations during an untreated period and the loss from the untreated floating pan evaporimeter for the same period were determined. To allow for the vast surface of the lake, a coefficient of 0.8 was used with the loss from the untreated floating pan to obtain the natural evaporation from the lake. The natural evaporation loss thus obtained was subtracted from total loss from the tank to give the seepage loss, which was assumed to be the same for the next treated period, the consecutive periods being made so short that the lake level did not fall by more than 15 cm during the test periods.

The total loss from the lake was determined by the fall in water level. By subtracting the seepage loss from the total loss, the evaporation loss could be arrived at. The evaporation losses from the tank were arrived at from the floating pan evaporimeter, the pan coefficient used being 0.8. The value of evaporation loss obtained during untreated periods was taken to be the evaporation loss during treated periods. To make this method applicable, experiments were carried out with alternate treated and untreated periods (7–10 days each).

COMPARATIVE STUDY OF THE THREE METHODS OF DISPENSATION

Though all three methods basically give rise to the same effect (i.e., the formation of a monomolecular film on the water surface), each method has its own merits and demerits from the points of view of application, economy, ease of operation, effectiveness, and so on. All three methods are applicable to field conditions, and, for large reservoirs, boats are used for carrying out spraying operations.

For preparing the solution, large quantities of mineral turpentine are required, and this necessity increases the cost. Only water and a very small quantity of cheekol or some emulsifier like soap are required for emulsion. So far as the powder form is concerned, larger quantities of powder have to be sprayed to obtain good results. The following statement gives a quantitative idea of the savings that have been achieved under the various methods:

Form of Application	Liters Saved per Rupee Spent
Solution	5130
Emulsion	10,830
Powder	low and highly inconsistent

Cost of operations and quantities of water saved are given in Appendices 1 and 2.

For preparing and dispensing the emulsion or solution, no power-driven equipment is required; but for preparing the powder form a ball mill is required. When sprayed through hand rotary dusters, the powder at times chokes the nozzle; it also forms into lumps if stored for long periods. From economic considerations and facility of operation, the emulsion method appears to be the best under local conditions. But if we consider the fact that the alcohol is an imported commodity in comparison with mineral turpentine, which is manufactured indigenously, the solution method may compare favorably with the emulsion method.

DISCUSSION AND CONCLUSIONS

The aim of the study was to assess the efficacy of the straight chain alcohols in reducing evaporation under Indian conditions and recommend a suitable method of dispensing the chemical. The experiments at Buderi were done during a period extending over 6 years. Three methods of dispensation were tested, namely, solution, emulsion, and powder form. Initially, the solution method with the alcohol dissolved in mineral turpentine was adopted. This method was amenable to easy dispensing, and spreading was very effective. The cost of the turpentine storage and the transportation charges were the disadvantages. Next, the emulsion method was attempted. This method has been almost condemned in the western countries. Initially, emulsion was prepared with the help of an emulsifier, but, later, manually prepared emulsion was seen to be as good. The cost of preparation was thus very low in comparison with the solution method. The spreading was quite good under moderate wind. This method does not require power or an auxiliary chemical and appears ideal for Indian conditions. As a third method, the powder form was tried. This method required equipment such as a ball mill, dusters, sprayers, and so on. The ball mill required a power supply, and the application of the powder required petrol and oils. Moreover, the powder could only be stored for about a week, after which it had a tendency to clot together to form small lumps. During dusting or spraying a part of the powder was carried away by the wind and lost, so the alcohol required was roughly double that needed for the solution method.

The efficacy of spraying alcohol was found to decrease with an increase in temperature. It is clearly observed that percentage savings for the tropical climate of this country are about 20% as against 50–60% in the United States, Australia, and other places where the climate is temperate. It is also to be mentioned that alcohols have to be imported, and an attempt at mass production of an indigenous equivalent has not yet succeeded. Study with a small sample, however, indicated that an indigenous equivalent will be even slightly better than the imported alcohol, but the problem of mass production does not appear to have been taken up.

APPENDIX 1: SOLUTION METHOD

Treatment period: February 1 to February 9, 1960 (8 days)

Evaporation loss from untreated floating pan: 17.5 mm

Natural evaporation loss: 17.5 mm × 0.8 = 14 mm

Total loss from the tank during the same period: 31 mm

Seepage loss for 8 days: 2.5 mm × 8 = 20 mm

Restricted evaporation loss: 31 mm − 20 mm = 11 mm

Savings due to treatment: 14 mm − 11 mm = 3 mm

Percentage savings: (3/14) × 100 = 21.4%

APPENDIX 2: EMULSION METHOD: COST OF OPERATIONS AND QUANTITY OF WATER SAVED

Method of Calculation

To work out the cost of operations, the following rates were adopted: 448 grams of cetyl alcohol, Rs1.50; three mazdoors for spraying and rowing the boat per day, Rs4.50; and petty expenses per day (such as firewood and soap powder for making the emulsion), Rs0.50. The quantity of water that would have been lost if the film had not been applied is determined from the water level capacity curve.

Sample Calculation

Duration of test period: 10 days.

Water level in the tank at the start of the experiments: 3.7 meters.

Depth of water that would have been lost owing to natural evaporation of lake if not treated: loss from untreated floating pan times 0.8, i.e., 51.55 × 0.8 = 41.24 mm.

Quantity of water for the loss of 49.5 meters of head: 1200 m^3.

Percentage savings due to treatment: 20%.

Quantity of water saved by treatment: 6000(20/100) = 1200 m^3.

Total cost of operation: cetyl alcohol cost 30 × 1.5 = Rs45.00; labor charges were 4.5 × 10 = Rs45.00; petty expenditures toward firewood, soap powder, and so on amounted to 0.50 × 10 = Rs5.00; the total was Rs95.00.

Quantity of water saved per rupee: 1200/95.00 = 12.6 m^3, and 12.6 m^3 × 995 liters = 12,500 liters.