CONTROL OF WATER EVAPORATION LOSS AT JODHPUR

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The control of water evaporation was studied at Jodhpur (Rajasthan) on aluminium pans and specially built concrete tanks with n-alkoxy ethanol, $CH_3\ (CH_2)_{16}\ CH_2O.\ CH_2\ CH_2OH$. Effect of different solvents was studied. Hydrocarbon solvents gave the best performance. Alcoholic solutions gave poor results. It was found that n-alkoxy ethanol always gave higher reduction in evaporation than cetyl alcohol or stearyl alcohol or their admixture, singly or combined with n-alkoxy ethanol in different proportions. The material heated upto 110°C was stable and did not show any loss in its efficiency and performance.

25–35 per cent conservation of water can be obtained during summer and 50–60 per cent during winter. For the other periods the saving lies between these limits.

Biswas *et al.* developed n-alkoxy ethanol $CH_3\ (CH_2)_{16}\ CH_2O\ CH_2\ CH_2OH$ for use as evaporation retardant and found it superior to cetyl alcohol under laboratory conditions[1]. Subsequent studies by them with this material in evaporimeter pans (4 ft. dia), placed 2 ft above the ground in open field[2] confirmed this result.

Chaudhuri and Bhati studied the performance of n-alkoxy ethanol at Jodhpur, the meteorological conditions of which are generally representative of those in Western Rajasthan desert.

It was shown by them[3] that the n-alkoxy ethanol gave better evaporation reduction than cetyl alcohol. Since the results obtained were based upon experiments conducted in glass trough having a surface area of 750 sq. cm, it was decided to conduct experiments on larger water surface. Consequently experiments were conducted with large evaporimeter pans and specially constructed concrete tanks, with a view to (*i*) check the earlier observation and its applicability to larger water surface, and (*ii*) consider application to natural water reservoirs in western parts of Rajasthan.

The evaporation experiments were conducted in the open within the premises of Defence Laboratory, Jodhpur.

MATERIAL AND METHODS

The following types of reservoirs were used for measuring evaporation rate from water surface at Jodhpur during the years 1963 and 1964.

Glass Trough—The glass trough had a surface area of 750 sq. cm. Its depth was 15 cm.

Aluminium pan—The aluminium pans were fabricated from INDAL 3S Sheet 3 mm thick. The pans were of two types (*i*) *Circular*—122 cm dia. and 25·4 cm depth, and (*ii*) *rectangular*—152·4 cm × 76·2 cm × 25·4 cm (depth). They had a surface area of 1·1678 sq. m. and 1·1612 sq. m. respectively and were placed on 10 cm high wooden base constructed with crossed wooden bars.

TABLE 1

MONTHLY EVAPORATION (IN MM) FOR DIFFERENT TYPES OF RESERVOIRS

Year	Month	Glass Trough	Type of Reservoir Circular Pan	Concrete Tank	Natural Reservoir
1963	May	521	451	415	—
	June	—	462	322	270
	July	468	384	306	241
	Nov.	186	170	127	—
	Dec.	149	135	111	—
Depth of water (in cm)		12	22	120	60
1964	Jan.	139	124	100	
	Feb.	182	172	133	
	March	306	269	—	
	April	430	377	290	
Depth of water (in cm.)		12	22	60	

Concrete tank—The concrete tanks 6·10 m × 3·05 m × 1·32 m (depth), sunk into the ground, were specially built from stones (Fig. 1). The floor has a slope (2·54 cm) and was provided with a pocket (28 cm. dia and 24 cm depth) to facilitate cleaning and pumping out of the last traces of water. The tanks after construction, were cured by soaking in tap water for 10 days. A double coat of chlorubber paint, obtained from M/s Shalimar Paint Colour and Varnish, Co. Pvt. Ltd., Delhi was applied by brush to the interior of the tanks to prevent seepage. The tank had a surface area of 18·6 sq. m.

Natural Reservoir—The natural water reservoir (surface area 4000 sq. m., average depth at centre 60 cm.) near Chitra Palace, Jodhpur was used for measuring evaporation loss under natural conditions.

Evaporation readings were taken daily except for natural reservoir for which monthly loss was calculated on the basis of readings for the period 23rd to 30th June and 1st to 13th July 1963.

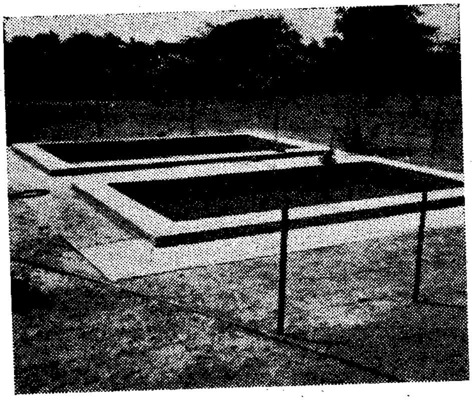

FIG. 1—Concrete tanks for evaporation experiments

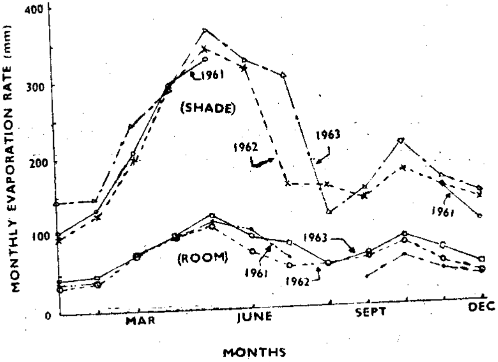

FIG. 2—Monthly evaporation from water surface in shade and room for the years 1961—63 at Jodhpur.

TABLE 2

RATIO OF EVAPORATION RATES USING THE EVAPORATION FROM CIRCULAR ALUMINIUM PAN AS THE STANDARD

Year	Month	Al. pan/ glass trough	Al. pan/Tank
1963	May	0·86	1·08
	July	0·82	1·25
	Nov.	0·91	1·35
	Dec.	0·91	1·22
	Average	0·88	1·23
1964	Jan.	0·89	1·24
	Feb.	0·94	1·29
	March	0·88	—
	April	0·88	1·30
	Average	0·90	1·27

No surface cleaning was made except that the reservoirs were all overflown and water drawn out to the correct depth at the commencement of an experiment. The water surface was replenished on alternate days in glass trough and aluminium pan while in concrete tanks replenishment was made every 6th day. The water in glass trough and aluminium pans was completely replaced by fresh water every two weeks and in concrete tanks every four weeks. When a set of experiments was completed, the reservoirs were thoroughly cleared of any residual film before commencing a fresh experiment.

Measurement of Evaporation Rate

The evaporation rate was measured by making use of an instrument[4] having a float to which was attached a pointer that moved on a scale graduated in mm. The float was placed in a wide glass tube provided with a spiral tube at the base to damp wave effect. The fall in the level of water was measured by the change in the position of the pointer on the scale.

The results on evaporation measurement with glass trough in shade, room and in the open for the years 1961, 1962 and 1963 are presented in Fig. 2 and 3 respectively.

Evaporation rates for 1963 and 1964 with aluminium pan, tank and natural reservoir are given in Table 1.

The average evaporation rate per day for all the months during 1961, 1962 and 1963 is shown in Fig. 4 and 5. Fig. 5 gives the over all daily average evaporation rate in the open for any month for the three years taken together. It will be seen from Fig. 5 that the evaporation rate in May and June is 17·0 mm. and 16·6 mm. per day respectively.

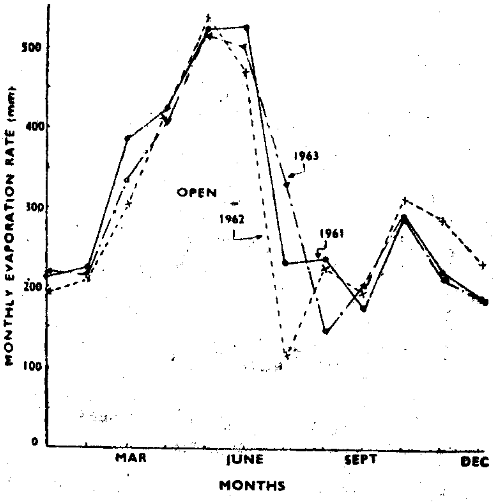

FIG. 3—Monthly evaporation from water surface in open atmosphere for the years 1961—63 at Jodhpur.

TABLE 3

PERCENTAGE REDUCTION IN EVAPORATION WITH C_{18}–GLYCOL ETHER POWDER. (AMOUNT OF POWDER IN MG. PLACED ON THE WATER SURFACE HAS BEEN SHOWN UNDER THE RESPECTIVE COLUMNS)

Date of Expt.	Glass Trough			Aluminium Pan		
	5 mg	10 mg	(Pet. ether sol.) 3 mg	77·6 mg	155·4 mg	(Pet. Ether Sol.) 46·7mg
16-5-63	6	11	53	23	30	54
17-5-63	6	6	24	15	15	47
18-5-63	0	0	12	0	6	19
19-5-63	0	0	0	0	0	0

Fig. 2 and 3 show that evaporation pattern for the three years is the same in open, shade or room. It is natural that evaporation will be highest in open, less in shade and least in room.

Ratio of evaporation rates

The ratio of rates of evaporation of water from different reservoirs with respect to monthly values of aluminium pan for a few months of 1963 and 1964 are given in Table 2.

The ratios indicate that the rate of evaporation in glass trough is more than that in the aluminium pan and the rate of evaporation in aluminium pan is greater than that in the tank. The overall average ratio for the combined years, 1963 and 1964 is 0·89 for aluminium pan/glass trough and 1·25 for aluminium pan/tank.

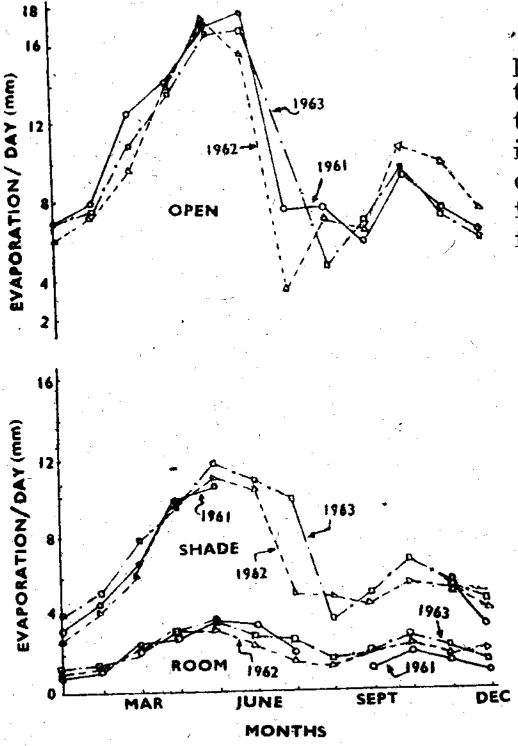

FIG 4—Average evaporation rate per day during a month for each of the years 1961, 1962 and 1963.

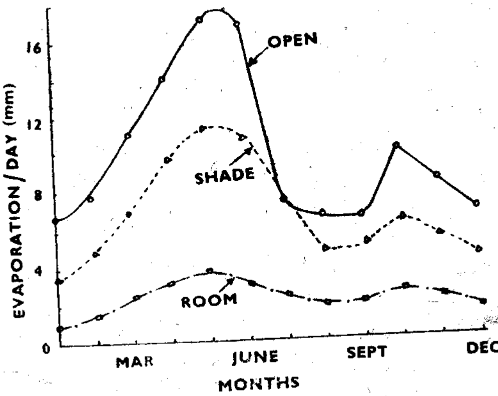

FIG. 5—Average evaporation rate per day of each month calculated on the mean value of the corresponding months of the years 1961—63.

TABLE 4

METEOROLOGICAL DATA

June	Temp (°C)		Wind Velocity (Km/hr)	
	max.	min.	Max.	Min.
2	35·7	23·9	4·5	1·8
3	39·8	25·2	9·4	2·4
4	39·3	25·4	19·2	8·8

Evaporation rate with C_{18}-glycol ether

Evaporation experiments were performed with solid C_{18}-glycol ether in the form of powder and casting.

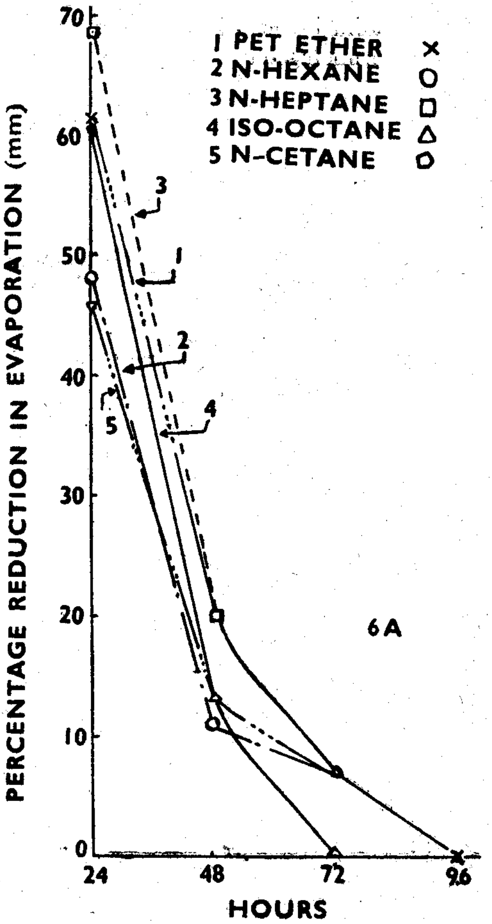

FIG. 6A—Effect of solvents on the performance of C_{18}-glycol ether

Powder—A weighed quantity of C_{18}-glycol ether, powdered and sieved through 150 mesh B.S. sieve, was placed on the water surface. The results are given in Table 3.

In addition to above experiments, powder as well as crystals were used in muslin bags. These bags were suspended in contact with the water surface. By this method, only 12 per cent reduction was obtained on the first day and thereafter the efficiency fell to zero.

Casting—The castings were made by melting the n-alkoxy ethanol and pouring the melt into the glass tubes. Two types of castings were made, one of 6 mm diameter and the other of 10 mm diameter each of length 10 mm. A few of the castings were placed on the water surface of the aluminium pans, 6mm castings being in one and 10 mm in the other. Evaporation reduction was only 6 per cent on first day in each case and on subsequent days no conservation was noted. The experiments were performed between 2nd and 4th June 1963. The reduction in evaporation by petroleum ether solution containing 46·7 mg of the n-alkoxy alcohol (46·7 mg of n-alkoxy alcohol is equivalent to 40 mg per sq. metre of water surface) was 56 per cent on 2nd June, 24 per cent on 3rd June and 6 per cent on 4th June, 1963.

TABLE 5

AVERAGE PERCENTAGE REDUCTION IN EVAPORATION BY SPREADING EVERY 48 HRS, 40 MG/SQ.M OF C_{18}–GLYCOL ETHER FROM PET. ETHER SOLUTION

Month	Period	Average reduction/day		
		Glass Trough	Al. Pan	Tank
March (1963)	2 to 17	—	32·4	—
Jan. & Feb. (1964)	29 Jan. to 17 Feb.	47·1	51·2	52·7
April (1964)	14 to 29	—	35·0	32·0

Due to wind, the castings floated away from the centre. Ambient temperature and wind velocity for these dates are given in Table 4.

Replenishment of Films

In their earlier experiments on glass trough, Chaudhuri and Bhati[3] recommended replenishment of films on alternate days. Further experiments on the replenishment of

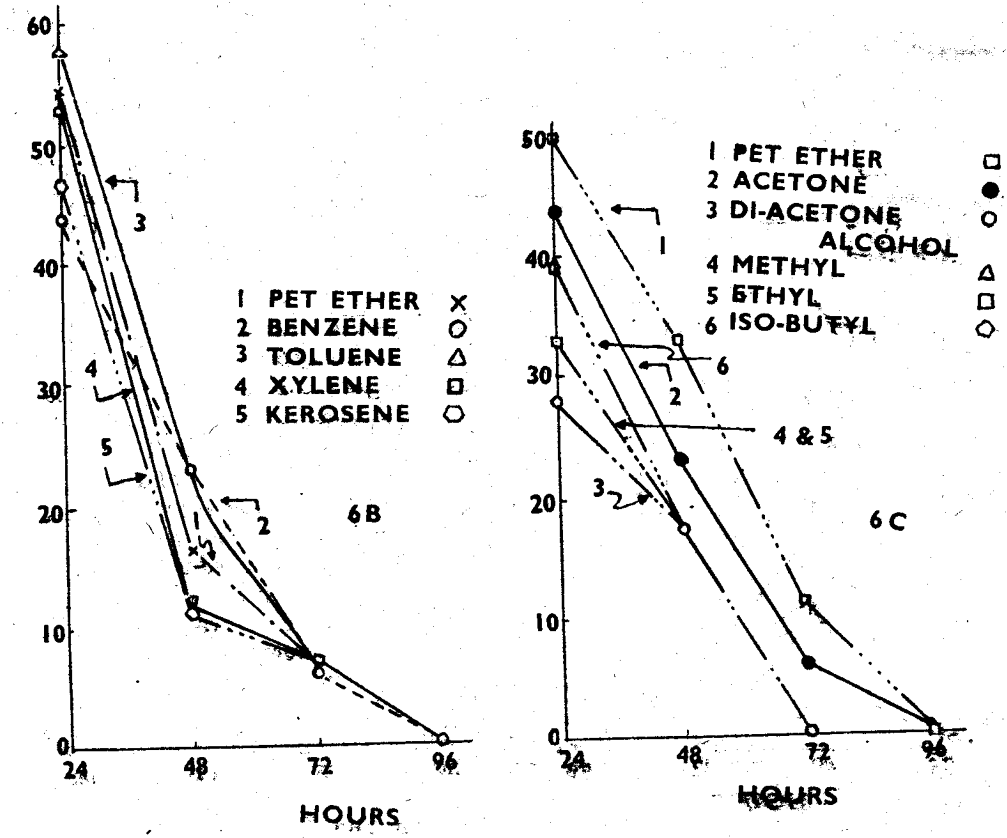

FIG. 6 (B.C.)—Effect of solvents on the performance of C_{18}-glycol ether.

TABLE 6

METEOROLOGICAL DATA

Year	Month	Temp. °C		Wind velocity (Km/hr)		Relative humidity	
		Max.	Min.	Max.	Min.	Max.	Min.
1963	May	41·0	26·8	7·6	5·3	33·6	11·5
	June	40·3	28·6	15·9	13·6	54·9	25·8
	July	38·6	28·2	18·5	12·1	60·8	34·5
	Nov.	30·9	15·7	7·3	4·3	—	—
	Dec.	27·3	11·7	5·2	4·2	39·2	19·5
1964	Jan.	22·8	6·8	5·8	3·2	50·2	19·5
	Feb.	28·6	12·0	5·3	4·3	39·2	12·3
	April	40·3	23·3	7·7	4·8	29·9	8·3

TABLE 7

SOLVENTS TRIED FOR DETERMINING THE EFFICIENCY AND PERFORMANCE OF N-ALKOXY ETHANOL

Solvent	B.P (°C)	Solvent	BP (°C)
Aliphatic hydrocarbons		Aromatic hydrocarbons	
n-hexane	68·7	Benzene	80
n-heptane	98·4 (76 mm)	Toluene	110·6
iso-octane	99·2	Xylene	133–34 (by expt)
n-cetane	105–10 (0·1 mm; m.p. 18·1 °C)		
		Petroleum hydrocarbons	
		Petroleum ether	65-66 (by expt)
		Kerosene	Not determined
		Ketone & Ketoalcohols	
Alcohol		Acetone	56·2
Methyl alcohol	64·7	Diacetone alcohol	168
Ethyl alcohol	78·4		
Iso-butyl alcohol	108		

films on glass trough, aluminium pan and tanks were conducted during March, 1963 and January and April, 1964. The average reductions during the periods are shown in Table 5.

The film on aluminium pans was also replenished every 24 hrs, 72 hrs and 96 hrs, during the period 2-17 march, 1963. The corresponding average conservation was 35%, 28·2% and 20·2%. The replenishment of films on alternate days is considered necessary.

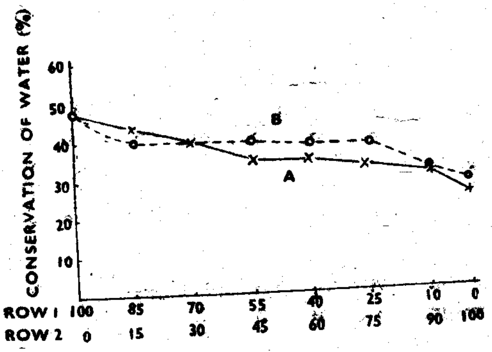

FIG. 7—Effect of admixture of cetyl or stearyl alchol with C_{18}-glycol ether on conservation of water,

Meteorological observations

Average maximum and minimum values of temperature, wind velocity, and relative humidity are given in Table 6 with reference to periods mentioned in Tables 1 and 5.

Effect of solvents

Solvents like petroleum ether, ethyl alcohol and kerosene have been used in producing film for evaporation control. In Australia, petroleum hydrocarbons (B.P. 90—160°C) were recommended for use. In Tanganyka,[5] kerosene was regularly used for a number of years and found to be both effective and economical.

Experiments were, therefore, undertaken to evaluate the effect of different solvents, given in Table 7, on the efficiency and performance of the n-alkoxy ethanol.

C_{18}-glycol ether was completely soluble at room temperature in the aliphatic, aromatic and petroleum hydrocarbons, acetone (a ketone) and diacetone alcohol (a ketoalcohol). It was soluble in methyl and ethyl alcohol on heating but only in small quantity at room temperature. The solubility at room temperature in methyl alcohol was 0·38%, in ethyl alcohol 3·6% and in isobutyl alcohol 6·2% approximately.

The evaporation reductions obtained with various solvents containing C_{18}-glycol ether are presented in Fig. 6. The solvents were chemically pure except the aliphatic hydrocarbon which were of high purity. Superior grade kerosene was used.

The solution of C_{18}-glycol ether was prepared in 0·5 per cent concentration in any of the solvents except methyl alcohol in which case it was 0·25 per cent. Appropriate volume of the solution was poured on the water surface so that the quantity of C_{18}-glycol ether transferred, corresponded to 40 mg. per sq. m. of the surface. The hydrocarbon solvents showed the highest reduction. Acetone also produced high reduction. The diacetone alcohol and methyl, ethyl and iso-butyl alcohols gave poor results.

The selection of the solvent should be made from hydrocarbon solvents. The selection and use of a hydrocarbon solvent will, however, depend upon availability, cost and appliances for handling in a typical environment of the country.

Mixed Materials

Effect of admixture of other evaporation retardants with C_{18}-glycol ether or stearyl alcohol was studied. The proportion of admixed materials namely cetyl alcohol (m.p. 49°C) or stearyl alcohol (m.p.59°C) was varied in increasing concentration in steps of 15%. The evaporation reduction was studied with the mixed material in petroleum ether solution on aluminium pans during Nov. and Dec. 1963. The results are presented in Fig. 7. It will be seen that C_{18}-glycol ether (m.p. 52·2°C) gave the highest reduction *i.e.*, 48% while pure cetyl alcohol gave 25% and pure stearyl alcohol, 29%. The curve A indicates that admixtures with cetyl alcohol in increasing proportion with C_{18}-glycol ether brings down the rate of conservation of water until it reaches minimum value of 25% when it is pure cetyl alcohol. Similar results are obtained with stearyl alcohol. However, curve *B* shows that increasing the proportion of stearyl alcohol from 15 to 75% does not change the conservation rate of 40%. Thereafter further addition of stearyl alcohol brings down the efficiency until the conservation is minimum at 29% when the material is pure stearyl alcohol.

These results establish the fact that in order to achieve highest degree of conservation of water, C_{18}-glycol ether or stearyl alcohol is to be preferred without admixture with cetyl or stearyl alcohol.

The admixture of both stearyl and cetyl alcohol with C_{18}-glycol ether was also studied in a similar way as above in Jan. 1964. The average conservation of water during the five-day period of study (15-1-64 to 19-1-64) is shown in Table 8.

TABLE 8

CONSERVATION OF WATER WITH MIXED MATERIALS DURING THE PERIOD 15 TO 19 JAN. 1964

Material/composition	Average conservation of water in 5 days (%)
C_{18}-glycol ether (A)	56·4
Cetyl alcohol (B)	39·4
Stearyl alcohol (C)	41·0
70A + 15B + 15C	49·2
50A + 25B + 25C	49·2
30A + 35B + 35C	41·0

These results show again that C_{18}-glycol ether gave highest conservation namely 56·4% while simultaneous admixture of both cetyl and stearyl alcohol does not improve upon the performances. The ultimate conservation is, however, found to be different from the results presented in Fig. 7 for pure materials, due to different months of experimentation. It may be noted that *percentage reduction in water evaporation* is equivalent to the statement *per cent conservation of water.*

Stability of C_{18}-glycol ether to heat.

In order to find out the effect of temperature on C_{18}-glycol ether it was heated at 60°C and 110°C. At 60°C, a portion of the material was continuously heatd in an oven in open test tube for a period of 4 days while another portion was heated on alternate days for a period of 4 days (*i.e.*, total of 48 hours at room temperature). A third portion of the sample was heated at 110°C for 2 hours.

The above heat treated samples showed no change in melting point which is 52·2°C. Each of the samples was dissolved in petroleum ether and evaporation reduction results using aluminium pans showed no loss in efficiency (Table 9). The quantity of C_{18}-glycol ether spread on water was 40 mg. per sq. m.

TABLE 9

EFFECT OF HEAT ON C_{18}–GLYCOL ETHER AND ITS PERFORMANCE (EVAPORATION REDUCTION WAS STUDIED WITH PETROLEUM ETHER SOLUTION USING ALUMINIUM PAN)

Temp. to which C_{18}–glycol ether was heated	Period of heating	Evaporaton reduction (Average of three days) %	Date of expt.
60°C	4 days (continuously)	35·3	19—21 Feb. 63
60°C	4 days (alternate days)	37·6	
No heating	—	37·6	
110°C	2 hours	27·0	29—31 May, 63
No heating	—	28·3	

It will be observed that in February 1963 the sample at room temperature gave 37·6% reduction while the samples heated to 60°C gave 35·3 to 37·6% reduction. This showed that there had been no loss of efficiency of the material due to heating. The same is true when the sample is heated to 110°C. The low evaporation reduction, namely 27% (110°C) is mainly due to the higher wind velocity and temperature in May than in February. The corresponding value for the sample at room temperature during this period is also low, namely 28·3%.

During May 29-31, wind velocities were 2 to 23·4 km/hr. at 08·30 hrs, 21·8 to 17·4 km/hr. at 14·30 hrs and 30·0 to 14·8 km/hr. at 17·30 hrs. Atmospheric temperatures during these three days were 26°C to 29·7°C (min.) and 45·1°C to 45·3°C (max.). In Feb. 63, the maximum temperature for the period was below 31·5°C and wind velocity below 10 km/hr.

DISCUSSION

March—June is grouped as a high evaporation period while July—Oct. and Nov.—Feb. as low evaporation periods. Chaudhuri and Bhati[3] reported that "the months of May and June account for 28·7% while the four months March—June accout for 51·0% (approx.) of the total annual loss which amounted to 3645 mm for the year 1961".

The evaporation values from Fig. 3 can be separated and grouped as in Table 10. Table 10 indicates that for all the three years approximately 50% evaporation takes place during March— June, 25% during July—Oct. and 25% during Nov.—Feb.

The average conservation of water that can be obtained by petroleum ether solution of C_{18}-glycol ether is 25 to 35% during March—June, 50 to 60% during Nov.—Feb. and intermediate between these two limits during July—Oct.

It is to be noted that evaporation loss occurs throughout the year. The Task Group Report on "Survey Methods for Evaporation Control[6]" state that "One of the strange aspects of evaporation is that ....year in, year out, rainy or dry, the annual evaporation loss remains the same". This fact is also borne out by the data presented above. The year 1963 was a drought year in Rajasthan. The rainfall for each of the group months during these years is shown in Table 10.

Conservation of water should be attempted throughout the year. In the summer months March—June the spreading of the film should be done on alternate days. In winter months Nov.—Feb., the film should be replenished every 4th or 5th day. During July—Oct., this should be done at intervals ranging between these two periods. Rainy days should be excluded.

Based on this study, the percentage conservation that can be gained on natural water reservoir cannot be fully predicted. In US study, class A pan evaporimeter showed 45-64% conservation with cetyl alcohol, but when this study was applied to 11×33 ft canal section, only 13% conservation was recorded[7].

During high wind periods the films of C_{18}-glycol ether in tank was swept in one direction thereby impairing its retardant efficiency considerably and often fully. During this period the circular aluminium pan gave high percentage reduction. It was thought that circular

TABLE 10

EVAPORATION (E) LOSS MEASURED FROM GLASS TROUGH

Year	Evaporation (E) loss in mm		
	Period		
	Mar.—June.	July.—Oct.	Nov.—Feb.
1961	1855 (1651) *i.e.* 50·9%	939 (836) *i.e.* 25·8%	851 (757) *i.e.* 23·3%
1962	1726 (1536) *i.e.* 49·5%	841 (748) *i.e.* 24·1%	919 (818) *i.e.* 26·4%
1963	1764 (1570) *i.e.* 49·3%	975 (868) *i.e.* 27·3%	833 (742) *i.e.* 23·4%
Average	1782 (1586) *i.e.* 49·9%	918 (814) *i.e.* 25·7%	868 (772) *i.e.* 24·4%
Rainfall (mm)			
1961	31·1	284·9	50·0
1962	18·7	303·2	Nil
1963	11·7	203·7	3·8

N.B.—The values within brackets are calculated values with respect to standard aluminium pan evaporimeter after multiplying (E) by 0·89.

shape of the pan annuls the effect of wind while the concrete tank is incapable of doing so, being rectangular. Consequently, experiments were conducted in circular as well as rectangular aluminium pan and the concrete tanks. The rate of evaporation was found to be the same in both circular as well as the rectangular aluminium tanks. It was, therefore, concluded that shape does not induce or retard the wind sweeping effect. Since the area of concrete tank was very large, the film once swept in one direction, could not again cover the water surface. The concrete wall may also be another factor which does not allow to dislodge the material from its anchorage.

The stability of C_{18}-glycol ether towards heat is significant while considering its storage/conservation under desert conditions. It may be observed that cetyl alcohol is susceptible to heat. The crystal form of cetyl alcohol is important as its ability to spread deteriorates when the proportion of alpha-phase is increased. Vines[8] used cetyl alcohol in hot weather for conservation of water in Australia by cooling it to about 15·5°C in order to maintain a high proportion of sub-alpha-phase in the individual particles.

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