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The Potential for Fatty Alcohols Monolayers to Reduce the Water Evaporation of Open Water Storages in Southern Algeria

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***Abstract*— The ability of a monolayer to retard the evaporation of the water on which it is spread is often reported as the fractional reduction in evaporation rate. This fraction varies with the experimental conditions. Its relationship with evaporation resistance, an absolute measure of the effect, and with various environmental factors is described.**

***Keywords* — fatty alcohols, evaporation reduction, water evaporation, monolayer performance, arid climate.**

I. Introduction

Efficient use of stored water is highly desirable, but often a large proportion of it is lost by evaporation. In the early 1950s the possibility of reducing this evaporative loss motivated W.W. Mansfield of C.S.I.R.O. [1] to try to scale up the laboratory experiments of Rideal [2], Langmuir and Schaefer [3], and Sebba and Briscoe [4], who had shown that water evaporation could be reduced by spreading a water-insoluble monolayer over the surface. The most promising monolayer materials were the long-chain alcohols, hexadecanol (cetyl alcohol) and octadecanol (stearyl alcohol). Various spreading techniques were investigated, but the one finally chosen for large reservoirs was the broadcasting of flakes of the alcohol, generated from a cake of the material by a rotating wire brush and blown from a tube over the stern of a small boat which zigzagged across the reservoir [5]. In suitable conditions evaporative losses were reduced by up to 60%. Unfortunately, however, the monolayers were removed by moderate winds and this, together with other problems, eventually led to a reduction in research effort.

The purpose of the present paper is to examine the performance and the efficiency of hexadecano and octadecanol monolayers under Algerian arid climate.

II. Material And Methods

A. Experimental site

The experiments were carried out at the Algerian National Institute of Agricultural Researches Experimental Station in Touggourt -southern Algeria- (33°4'18"N 6°5'45"E), which has an arid climate.

B. Evaporation measurements

To facilitate measurement of the evaporation rate measurements were made on a small scale water surface (Colorado evaporation pan of 1 meter square and half meter deep). This choice was also justified because there is a large body of knowledge on the physical behaviour of open pan evaporation. This gives a valuable basis for the interpretation of the results and their application to dams. From the small scale evaporation analysis, the application of the results to full scale dams was investigated through extrapolation of the overall evaporation reduction coefficients from pans to dams.

Pan coefficient depends on the pan and the surrounding environment.

C. Monolayers

Monolayers are films that are one molecule thick formed at a phase boundary such as the air/water interface [6, 7]. The molecules are amphiphilic as each has both a hydrophilic part and a hydrophobic part. Those amphiphiles that form insoluble monolayers at the air/water interface have hydrophobic parts that render the whole molecule insoluble in water while the hydrophilic part serves to anchor each individual molecule to the water surface and thus tends to prevent the molecules from piling on top of one another as in an oil drop.

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Monolayers can exist in a number of different surface states, but the ones of interest here are the condensed states where the molecules are packed closely together: primarily the solid and liquid-condensed states. The most common structure for molecules that do form condensed monolayers consists of a long (>C12), linear, fully saturated alkyl chain with a polar group at one end [8].

In our experience the used compounds were the long-chain alcohols, hexadecanol and octadecanol which are, according to lot of authors (such as Pittaway [9] and Craig, [10]) the most promising monolayer materials during field trials.

D. Experimental protocol

The Colorado evaporation pans were partially buried and placed one near each other keeping 50 cm separation, and located 2 m from the meteorological station. The evaporation pans were filled by water by 80% of total volume, and covered by wire mesh to prevent animals drinking.

The first pan was covered by octadecanol monolayer; the second by mixture of hexadecanol and octadecanol monolayer (1:1) ; and the third (the 'control') contained only water. Both formulations were applied as powder and put on the respective water surface every three days, in order to form a monolayer. In addition to the water losses by evaporation in pans, air and water temperature and wind velocity were measured every day.

III. RESULTS

A. Evaporation rates

Fig. 1shows the evaporation rates in the three pan. Ti is well seen that highest values of evaporation rates were registered in the control pan and the lowest were reregistered in the pan covered by monolayers of mixture of hexadecanol and octadecanol.

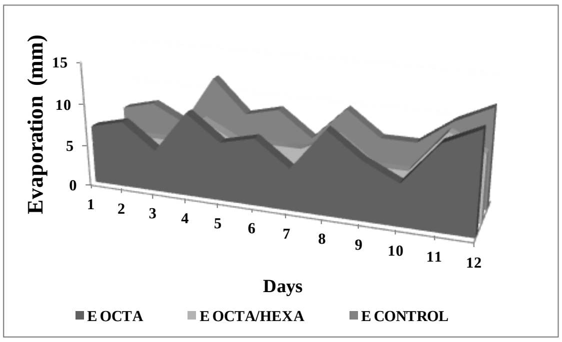

Fig. 1 Evaporation rates in the three pans (mm) (From 01/05/2013to 12/05/2013)

B. Evaporation reduction rates

To elaborate the comparison between evaporation depths in percentages between the control pan ($E_{CONTROL}$) and the covered pans (E_{OCTA} and $E_{HEXA/OCTA}$) with the help of following equation (Eq. 1):

$$ER_{(\%)} = ((E_{CONTROL} - E_{COVERED}) / E_{CONTROL})*100 \quad (1)$$

Where:
$ER_{(\%)}$ is the evaporation reduction in percentage;
$E_{CONTROL}$ evaporation rate in the control pan; and
$E_{COVERED}$ evaporation rate in the covered pans (so E_{OCTA} or $E_{HEXA/OCTA}$).

Fig. 2 shows the reduction evaporation rates for the experimental period. The saved water in the covered pans where 8% in the octadecanol pan and 24% in the hexadecano/octadecanol pan.

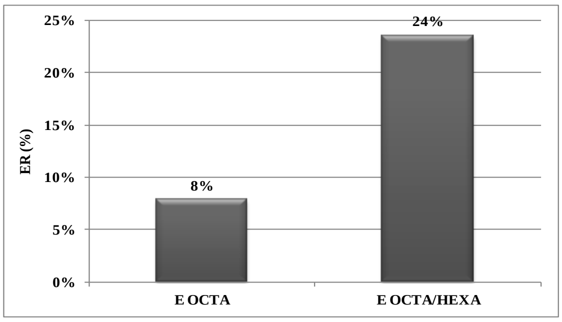

Fig. 2 Evaporation reduction rates (%) (From 01/05/2013to 12/05/2013)

C. Water temperature

Fig.3 shows that evaporation reduction is accompanied by a water temperature increase.

Water temperatures of the experimental period were the highest in the pan covered by mixture of hexadecanol and octadecanol monolayer, and the lowest in the control pan.

It is well seen also that the water temperatures are affected by the air temperatures. Water temperatures increase when air temperatures increase and inversely.

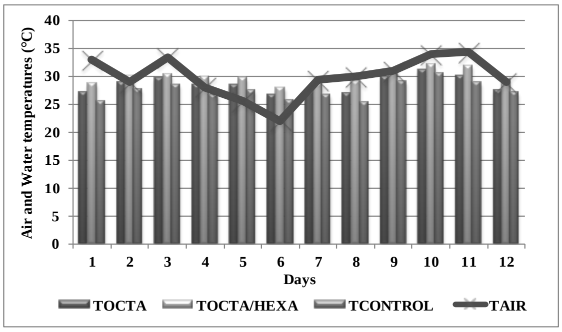

Fig. 3 Air and Water temperatures (°C) (From 01/05/2013to 12/05/2013)

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IV. Discussion

It is well known that the combination of high temperatures low humidity and dry winds create the strongest conditions for evaporation from open water [11, 12]. These meteorological parameters were present in the experimental site during the experimental period: temperature *T* average of 29.9 °C, humidity *H* average of 13 % with, and wind $u_{0.15m}$ at 0.15 m, average of 0.5 m/s, had caused losses by evaporation of about 8.5±2.1 mm/day in control pan.

Losses by evaporation were significantly greater in the control pan compared with other pans which indicated clearly that monolayers have an effect in reducing the rate of evaporation. The evaporation rates were 7.8±2.3 mm/day in octadecanol monolayer pan and 6.5±1.6 mm/day in hexadecanol/octadecanol monolayer pan. This result is consistent with the observations of Saggai and Boutoutaou [13] who concluded that monolayers have good efficiency in evaporation reduction under Algerian arid conditions.

It is known that monolayers with two components can have interesting and potentially useful properties [8]. According to Gugliotti et al. [14] and McArthur and Durham [15], Octadecanol added to Hexadecanol yielded a mixture with a good spreading rate and a higher evaporation resistance than pure Hexadecanol which explains the obtained results. These information explain why the important evaporation reduction rate was registered in the case of pan covered by mixture hexadecanol and octadecanol monolayer (24%).

Water Temperature can affect the biological activity in the aquatic environment and by consequence aquatic beings. Evaporation reduction is accompanied by a water temperature increase [16]. Water temperatures of the experimental period in the three pans were: 27.4±1.6°C in the control pan, 28.5±1.5°C in the pan (Octa) and 30.0±1.3°C in the pan (Hexa/Octa).

The resulted water temperatures affect dissolved oxygen concentration, hydrogen ions concentration and by consequence affect the aquatic environment and beings which means that the use of monolayers can affect environment and aquatic beings.

Effect of monolayers on aquatic system has been studied by Wixson [17] and results have shown that there were no toxic effects.

Practically all trials of monolayers spread on open water storages report problems with moderate to high winds. A theoretical treatment has been presented by Mansfield [18].

Vines [5] reported that the dusting method for distributing hexadecanol encountered problems with winds in excess of 8 km/h due to retraction of the monolayer.

Evaporation savings of 10–20% were found with winds up to 16 km/h falling to 0% at 24 km/h [19]. Similar results were reported by Timblin et al. [20].

The values measured during the period of experiment did not exceed 14 km/h and the average was about 2 km/h.

V. Potential Effects On Storage Water Quality And Biology

The effects of application of monolayers and surface films on water quality are largely unknown and may vary on a storage by storage basis. Some researchers believe that the effects of monolayers on aquatic processes are relatively benign due to the fact that most water bodies already have naturally occurring microlayers that are formed by the break down of organic material [21]. The earliest evidence for the existence of surface films was inferred from observations on the movement of dust particles on the surface as affected by water currents [22]. Studies indicate that the thickness of these natural films varies from 100 to 500 nm [23]. In contrast, artificial surfactant films may be 40-50 nm thick [24]. Any study on the longer term impact of artificial monolayers needs to compare their impact relative to local microlayers, and the impact of naturally occurring microlayers on the efficacy of artificial monolayers. If ecological 'equivalence' can be established, the adverse impacts should be minimal.

Potential water quality impacts fall in to three categories: those that result from breakdown of the chemical product itself; those that relate to changes in gas transfer across the air water interface; and those that result from changes to the energy balance of the storage.

VI. Conclusion

One objective of the present work is to verify the efficiency of monalayers of fatty alcohols (mixture of Hexadecanol and octadecanol and pure octadecanol) in reducing evaporation from open water under Algerian arid environment.

The study has shown that monolayers reduce evaporation rates and these rates depend on the substance used to form monolayer. The best evaporation reduction rate was registered in the case of monolayer of mixture of hexadecanol and octadecanol (24%).

It is also seen that the monolayers contribute in rising water temperature and that there performance in reducing evaporation were affected by the air temperature and wind velocity.

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