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Evaporation Reduction in Water Resources: Effect of Hexadecanol Concentration on Evaporation Rate under Algerian Arid Conditions

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Abstract. The evaporation rate of Algerian arid zones open water bodies is extremely large and reaches 3.8 m per year. To minimize these losses in water reservoirs monolayers of Hexadecanol are used.
To check the efficiency of Hexadecanol monolayer and determine the adequate quantity of substance to use, a comparison was performed between the evaporation rate of water across two kinds of interfaces, namely an air/water interface and an air/monolayer/water interface (using Hexadecanol monolayer). Trials were conducted under natural conditions by using three tanks of one meter square surface which were partially buried. The first tank surface was covered by Hexadecanol at a concentration of 0.09 g/m^2, the second by Hexadecanol at a concentration of 0.15 g/m^2; and the third (the 'control') contained only water. Both monolayer treatments were applied to the respective water surface every three days.
Daily observations spanning one month showed that films reduced the losses by evaporation and the rates of the evaporation reduction are significant (19% in the first tank and 24% in the second tank). Analysis with respect to prevailing meteorological conditions is presented and implications for the use of Hexadecanol in the Algerian arid zone are discussed.

Keywords: Open water bodies, evaporation, Hexadecanol, arid zones, Algeria.

1. Introduction

Algerian arid zones are characterized by high temperatures (up to 50 ℃), weak precipitation (less than 200 mm) [1], low rates of humidity, and high evaporation (2 to 3 or 4 m/year in arid zones and 5 to 6 m/year in hyper-arid zones according to Rognon (2000) [2]. The shortage of water areas in these zones with the presence of the intense evaporation increase the risk of the drought and desertification, leading to the necessity of finding means to reduce the evaporation in order to preserve the existing water resources.

The purpose of the present paper is to present an evaporation reduction technique, namely the use of Hexadecanol which is a chemical substance capable of forming very thin layer of single molecule thickness (abbreviated to "monolayer") on the water surface. A study was undertaken in the region of Touggourt (south-east of Algeria) by studying the effect of its concentration on rate of evaporation. This region is characterised by an arid climate: high temperatures, weak precipitation, dry winds, weak humidity, and long duration of sunshine. The combination of those meteorological factors favourites the rapid evaporation of water storages.

2. Experimentation

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The study was undertaken during spring season when the average air temperature was more than 25 ℃ with a maximum temperature of 33 ℃, the average of rate of humidity was more than 48 % and duration of sunshine of 330.2 hours (46 % of the totality of the period of study), the wind was of 3.1 m/s [3]. For the site, the experiment was performed in Nezla region, approximately 160 km in the northeast of Ouargla which is situated in south-east of Algeria (Figure 1).

Fig. 1: Geographic situation of Touggort [4]

3. Materials and Method

3.1. Materials

Tanks: to study the efficiency of the film under natural conditions and to be close to the conditions of open water storages it was evident to use tanks (see Figure 2). This instrument allows eliminating inflow, outflow and seepage (which are very difficult to estimate). The evaporation (E) in this case is equal to the precipitation (P) and the change in level ΔH:

$$E = P + \Delta H \quad [5]$$

The tanks used in this experiment were of one meter square surface area and a half meter depth.


Fig. 2: Tank [5]

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. Several chemical substances can form, on the surface of water, a film of single row of molecules directed with regard to this surface in the same way: the hydrophilic liqueur brandy managed downward and the hydrophobic managed upward. The formed film on the water surface is not disrupted by winds of less than 7 m/s if the supply of the water surface by the chemical substances is made regularly and continuously [8]. For

our study we chose Hexadecanol ($C_{16}H_{34}O$). This choice is based on advice that Hexadecanol is suitable for actual use in the natural conditions [9].

3.2. Applied Method

The tanks were 80 % filled with water and were partially buried, keeping a 50 cm space between tanks and a 10 cm height above the natural level of the ground. Hence the water levels were effectively at ground level.

For chemical substances which are in the form of powder were put on the water surface to form monolayer of the first two pans every three days as follows:

- First tank: 0.09g of Hexadecanol;
- Second tank: 0.15g of Hexadecanol and
- For the tank 3 no monolayer was applied and was considered to be the 'control' pan.

It is necessary to note here that the condition of ensures the efficiency of the monolayer was the absence of the wind which created waves on the water surface. Thus it is necessary to make sure that the wind was quiet during the spreading of the powder on the water surface.

4. Results and Discussion

4.1. Results

Figure 3 and Figure 4 show the influence of meteorological parameters (temperature, humidity, wind and sunstroke) on evaporation reduction rate in tanks. The evaporation reduction rate decreases when temperature and wind increase.

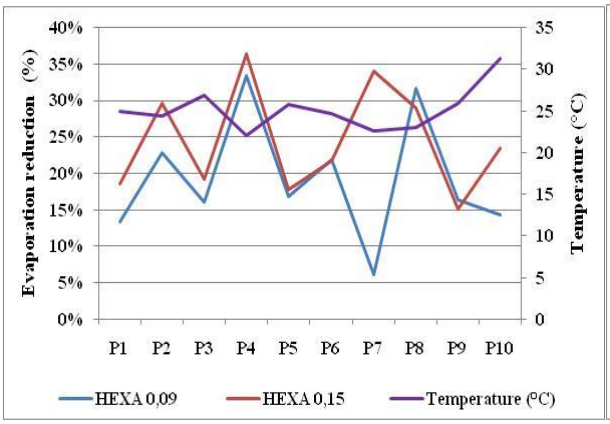

Fig. 3: Variation of evaporation reduction rate in relation to air temperature

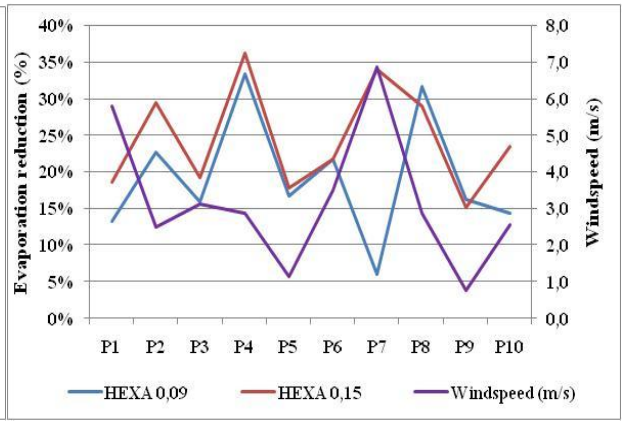

Fig. 4: Variation of evaporation reduction rate relation in to windspeed

For a good interpretation of results we have established the following graphs (Figures 5 and Figure 6) which show respectively the accumulated losses by evaporation in the three pans and the total rate of evaporation reduction.

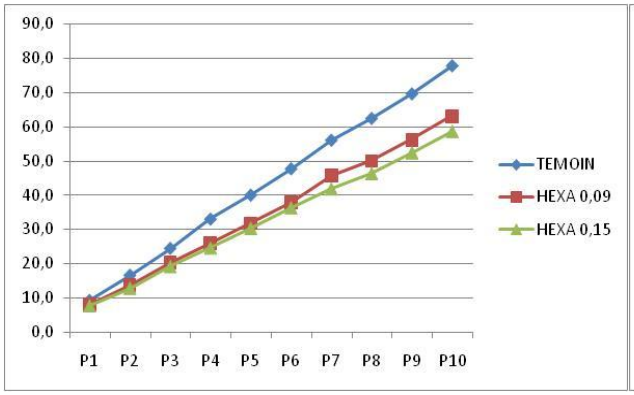

Fig. 5: Accumulate losses by evaporation in the three tanks (mm)

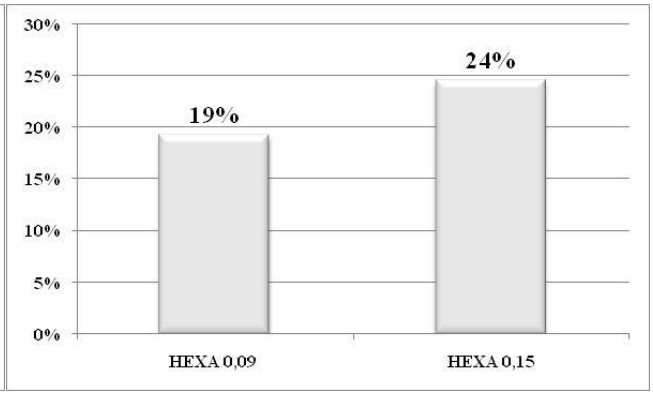

Fig. 6: Total rate of evaporation reduction of the all experimentation period (%)

The comparison between these curves demonstrated that there was difference which becomes more and more important as losses accumulate by evaporation from the control tank in comparison with the other tanks covered by monolayer.

Concerning the rates of the evaporation reduction in two tanks with regard to the control tank, the obtained values were 19% for the case of monolayer of 0.09 g of Hexadecanol and 24% for the case of monolayer of 0.15 g of Hexadecanol.

4.2. Discussions

The observed values of evaporation reduction rates during different periods confirm the efficiency of monolayers in the evaporation reduction of the water plans.

This efficiency varied according to the quantity of Hexadecanol used to form the monolayer and the meteorological factors especially wind and air temperature.

The observed rates of evaporation reduction allowed to say that when the concentration of Hexadecanol increases the rate increases. This is explained by the density of monolayers on the water surface: 0.09 g/m2/3days (equivalent to 15 molecular layers under perfect conditions) and 0.15 g/m2/3days (equivalent to 25 molecular layers, similarly). However, in both cases the movement of the surface with wind, and the degradation of the Hexadecanol with time and solar radiation, will case the actual thickness to be much less than the theoretical figure.

Wind speed is the biggest factor controlling the performance of monolayer. The average value measured during the period of experiment was 3.1 m/s and values did not exceed 7 m/s. Vines (1962) [10] reported that no evaporation reduction could be detected in their trials of Hexadecanol monolayers when winds exceeded 7 m/s, which corresponded to our experience where the wind speed did not exceed 6m/s and the monolayer was therefore effective.

For the temperature, Mansfield (1956, 1958) [11], [12] has found that the evaporation resistance of a monolayer, generated directly from a fragment of solid highly purified Hexadecanol placed upon a water surface, was approximately constant in the temperature range from 20 ℃ to 30 ℃, but that the resistance fell rapidly at higher temperatures such that at 50 °C it was about one quarter of its value at 20 ℃. Thus, the more the temperature increases the more the resistance to the evaporation is lowered. The temperature in our experience did not exceed 33 ℃ which suggests that monolayer was not strongly affected by temperature.

4.3. Economic Analysis

Economically, water saved during these 30 days was 44 mm in the first tank (0.09 g/m2/3days) and 57.25 mm in the second tank (0.15 g/m2/3days) which means respectively 0.044 m3 and 0.05725 m3. The real cost of water in Algeria is about 0.6 euro/m3 [13] and can reach 2.5 euro at rural regions [14] which means gains of 0.0264 euro in the first tank and 0.03435 euro in the second tank. Hexadecanol used during 30 days 0.9g was applied in the first tank and 1.5g in the second one. The cost of one kilogram of Hexadecanol is 8 euro (10 dollars) [15], which means 0.0072 euro (1st tank) and 0.012 euro (2nd tank).

The difference between the value of saved water and the cost of used Hexadecanol gives the economic efficiency of this method. In the case of first tank the difference is 0.0192 euro/m2 over thirty days, for the second one the difference is 0.02235 euro/m2 for the same period. The calculated costs show a small difference (0.00315 euro) this indicates that the applied quantity in the 2nd tank is preferable because it gives higher water saving for every euro spent on Hexadecanol.

5. Conclusion

The study of covering water surface regularly every three days with Hexadecanol monolayer confirmed the usefulness of this substance in the reduction of open water evaporation.

The rates of the evaporation reduction depend on quantity of Hexadecanol (concentration) used and on meteorological factors of the region.

Application of Hexadecanol at the rate of 0.15g/m2/3days gave the best rate of evaporation reduction (24%). Temperature and wind speed recorded during experience period did not affect strongly the performance of monolayer in comparison with values given by other authors.

Finally, we recognise that the obtained results in this small experiment are preliminary, and require further verification in the field, in larger experiments, over longer periods and over larger open water surfaces.

6. Acknowledgment

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