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Evaporation Reduction from Impounding Reservoirs in Arid Areas Using Palm Leaves

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Abstract: Kingdom of Saudi Arabia experiencing water shortage due to limited water resources, high evaporation rate and stress on water demand. Evaporation reduction can help in increasing water saving. Due to the large number of date palm trees in the Kingdom, a massive waste from these trees is disposed annually. Palm leaves as an agricultural waste can be converted to mats and then used as a floating cover on water surface to reduce evaporation. In this study, three pools were constructed at a selected site at King Saud University, Riyadh, Kingdom of Saudi Arabia in order to test the affectivity of the proposed mat. Data collected from the study site shows that evaporation from fully concealed pool area is about 63%, while that form half concealed pool area is about 26%. This result confirms the affectivity of the mats in evaporation reduction. A proposed parabolic relationship between evaporation reduction and concealed area by the mats is presented. Water quality analysis shows that the mats have no serious affect on water quality.

Key words: Palm leaves, mat, evaporation reduction, open water surfaces, arid region

INTRODUCTION

The demand on water is increasing globally due to rapid increase in the world population, rising standards of living, increasing urban areas and expansion in both industrial and agricultural sectors. But, in the arid and semi-arid regions, water shortage is faced because of the limited water resources and high evaporation rates. Water is stored in reservoirs in order to regulate its availability over the year. Also, the water resources are not distributed uniformly throughout the area of any region. Thus, impounding reservoirs can give flexibility to meet water demand at various places of the country.

Evaporation is a natural phenomena in which large volumes of water are lost. The amount of water losses by evaporation is mainly depends on the climate and its rate is changing from country to country depending on the location. The evaporation rate is maximum in countries located in arid region. In arid regions, high evaporation rate from open water bodies is considered as serious problem in water resources management. For example, in Kingdom of Saudi Arabia, the annual average evaporation from open water surfaces is estimated to be 2500-3000 mm, while annual average rainfall rate ranges as 100-150 mm. This is highlighting the seriousness of water loss problem from open water bodies, such as impounding reservoirs. The scarcity of water can be attributed to limited water resources, the high evaporation rate needs to be reduced as a means of water conservation. Covering of the reservoir surface can help in reducing evaporation. There are many materials, either chemicals or physical covers were developed to reduce evaporation from open water bodies. Those materials are designed to suit certain climatic conditions. Some are not economically feasible but they may have negative environmental impacts.

The trials for evaporation reduction using cover are not new and started in the beginning of the last century. Oroud (1998) evaluated the lateral heat conduction across a large circular sunken pan located in a hot, dry environment using a numerical procedure. Khan and Issac (1990) studied the efficiency and economy of various types of evaporation reduction techniques.

A field study of effectiveness of fatty alcohol mixtures as evaporation reducing monomolecular films was carried out at Lake Hefner, Oklahoma by Bean and Florey (1968). Their study on evaporation from lake Hefner was focused in particular upon the evaporation reduction by monomolecular films of mixtures of hexadecane and octadecane. They found that evaporation as determined by eddy flux method, was reduced on the average by 58%. Barnes (1993) pointed out that monolayers are potentially most effective in

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conditions where the rate of evaporation is high. Craig (2006) used Pressure Sensitive Transducer (PST) as an analysis technique to evaluate various types of covers for evaporation reduction from a dam located at Queensland, Australia. The technique revealed that evaporation reductions were approximately, 75% for shade cloth covered dams, up to 95% with dams covered with a properly functioning floating cover and approximately, 15-30% with dams covered with acetyl alcohol based chemical monolayer. Alvarez *et al*. (2006) studied the effectively of different types of shading meshes in evaporation reduction. Data from covered pan with various types of meshes and that without meshes at summer revealed that shading the pan induced a significant decrease of the daily evaporation rate, ranging from 50% for the aluminized screen to near 80% for the colored-polyethylene meshes.

Craig *et al*. (2007) highlighted that the use physical covers could substantially reduce evaporation from reservoir but they recommended using the physical cover with the small reservoirs (with surface area <10 ha in size) due to their ecumenical feasibility. They concluded that physical covers can also be used on larger dams, but they are generally uneconomic due to the high capital investment required and despite the very good evaporation protection provided. They recommended that cost-effectiveness and the environmental impact of this strategy must be evaluated.

This research proposes using palm tree leaves as covering mats for evaporation reduction form impounding reservoirs. Palm tree is one of the most available trees in Saudi Arabia. It has the potential to stand severe hot weather. So, it has the advantages of economic and environmental feasibility as a new material for evaporation reduction.

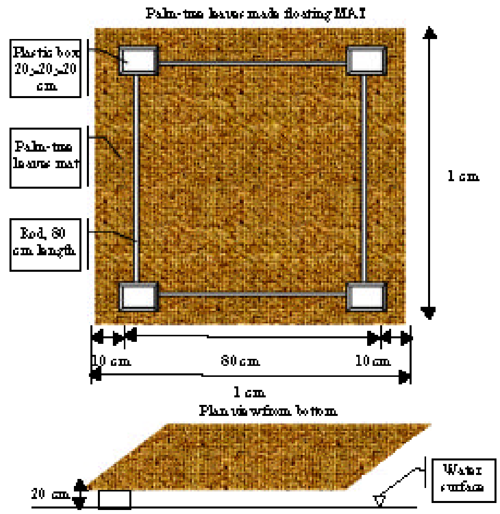

Fig. 1: Details for palm leave mat used for evaporation reduction

Fig. 2: General view of pools and the site used for the study

MATERIALS AND METHODS

Mats of palm tree leaves were designed in square shape 1×1 m and thickness of about 5 mm. Plastic boxes 20×20×20 cm were used to keep mats floating on water surface with no contact with water. Such a contact spoils the leaves and gives water a chance to enter between mat openings and to evaporate. Cost of the product was about US$ 7 m^{-2} (It should be noted that cost is based on small scale product). Figure 1 shows a unit of the designed mat for covering 1 m^2 of water surface.

To test the affectivity of the proposed material in evaporation reduction, three pools made of fiber glass were constructed at a selected site within the campus of King Saud University, Riyadh, Kingdom of Saudi Arabia. Each pool is 10 m long, 5 m wide and 1.5 m deep and it is filled with water. The first pool surface was covered by about 95% of area with mats (assumed fully covered), while second pool was half covered and third pool was left uncovered. The study site was protected by two meters fence in order to avoid any disturbance. Figure 2 shows these pools (reservoirs).

Class A evaporation pan is fixed in the site of the pools to get daily pan evaporation record. Also, weather station was fixed in the site to measure air temperature, wind speed, relative humidity and solar radiation. Water depths were visually recorded from a graduated metal staff fixed in each pool. Surface water temperature is recorded for each of the three pools. For pool, which is 95% surface covered, water temperature beneath mats was also measured. Samples of water from the three reservoirs were taken weekly to check some water quality parameters. Data collection started on 22/3/2009 and will continue for several months. The evaporation data from the pools is taken during summer season (months with maximum temperature in the year) three times weekly where peak evaporation rate occurs. On the other hand, data will be collected on weekly basis during winter time where evaporation has minimum value.

RESULTS AND DISCUSSION

Kingdom of Saudi Arabia is a country with limited water resources and located in arid region. The country has very high annual average evaporation with very low annual average precipitation. So, the water is precious resource in the country and conservation of water resources is intended and it is part of the national water management plan. In Saudi Arabia, there is a lot of agricultural wastes and mainly that from date palm. Due to the large number of date palm trees, leaves are the main agricultural waste from such trees. Thus, making use of this agricultural waste in evaporation reduction will help to get rid of massive agricultural waste and reduce the wastage of large water volumes evaporating annually from open water bodies.

In this study, palm leaves are converted into a form of thin mat in order to use it as a floating cover to control high evaporation rates from open water surfaces. The mat is designed to be square in shape (1×1 m) with a thickness of 0.5 cm. Every mat is fixed on wooden frame, which is tied to four plastic floats (20×20×20 cm) at the corners. It makes the mats fall under the type of floating covers.

Water depth is measured 3 times weekly from each pool and Fig. 3 shows the recorded data from the pools for 42 days started from 23 March 2009. The results show, a significant evaporation reduction from the concealed pool area compared with unconcealed pool area. This confirms the affectivity of the mats in evaporation reduction because it provides a barrier between the system and the atmosphere. This barrier directly reduces the energy from the sun to the system by reducing the impact of solar radiation. The half covered pool area is included in the experimental study in order to simulate the impact of wind on the floating cover. This problem will be encountered, when the floating mats used in a real project and the pieces of mats may be pushed out by the wind and part of the concealed area becomes unconcealed (expose directly to the weather). This test is considered as a test, which account for the instability of floating cover under windy conditions.

The average reduction rates in evaporation using the mats are found as 63 and 26% for fully covered pool and half covered pool, respectively as shown in Fig. 4. The maximum and minimum ambient temperatures at the site were recorded as 39.5 and 25.4°C, respectively. Bean and Florey (1968) obtained a reduction rate of 58%, when they concealed the surface of Lake Hefner, Oklahoma, USA. This revealed that the result of the current study is in agreement with results obtained by Bean and Florey (1968).

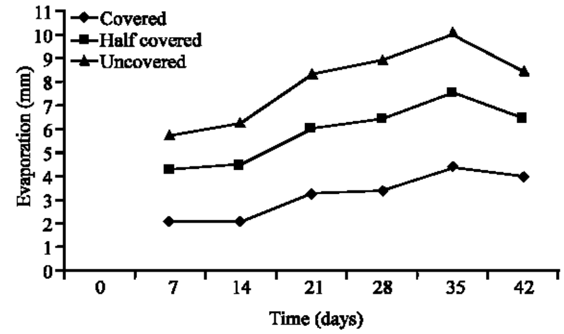

Fig. 3: Evaporation records from the three pools

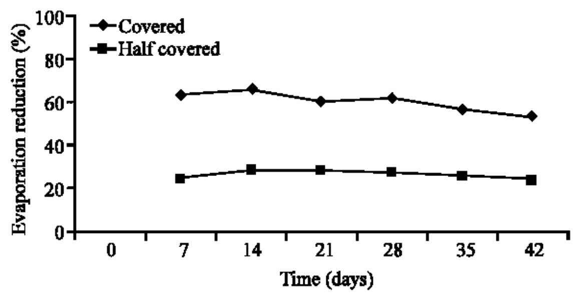

Fig. 4: Percentage evaporation reduction for covered and uncovered pools

It is important to highlight that for fully covered pool area, only 95% of the pool area is concealed and this is because mat pieces are distributed to float on the surface of the pool without overlapping. The 5% of the pool area left unconcealed because of the gaps left between mats pieces. Also, the 5% unconcealed pool area may allow rainfall into storage and some exchange of gases between water and air. This complies with the recommendations on covers issued by Department of Natural Resources and Mines, Queensland, Australia (2002). The amount of evaporation depends on the size of the water surface, thus saving in evaporation would depend on the cover type and the size of the area of concealed surface. From the collected data, the relationship between the evaporation reduction and the concealed pool area is demonstrated in Fig. 5. Therefore, based on the obtained results in Fig. 5, the following parabolic relationship can be proposed:

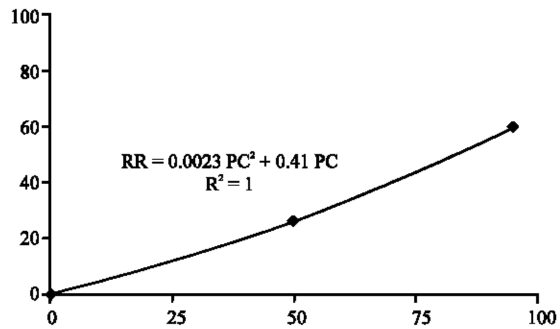

Fig. 5: Relation of evaporation reduction and covered area

$$RR = 0.0023(PC)^2 + 0.41PC \quad (1)$$

Where:

RR = The percentage of evaporation reduction

PC = The percentage concealed area of the pool

Equation 1 can be used to predict the amount of water savings due to evaporation from open water surface areas particularly from the impounding reservoirs if the proposed mat is used as a floating cover.

Samples of water were also taken from the pools in order to study the impact of the cover on water quality. The analysis of water quality of the samples revealed that there is no serious impact of the mat on the water quality.

CONCLUSION

Mats made of palm leaves are used as floating cover to reduce evaporation from open water surfaces. Experiments using three pools were conducted to tests the effectiveness of the proposed material in evaporation reduction. The constructed pool is 10 m long, 5 m wide and 1.5 m deep. The surface areas of the three pools are fully covered, half covered and uncovered, respectively. Data collected from experiments revealed that about 63% of evaporating water can be reduced using the proposed cover material. A parabolic relationship between the percentage of the covered area with mats and the percentage of evaporation reduction is proposed. This relationship will help to predict the percentage evaporation reduction from the water surface areas of the impounding reservoirs, which are using the proposed mats. Water quality tests show that the mats have no serious effect on the water quality of the fully covered pool.

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