EVAPORATION REDUCTION FROM LAKE NASER USING NEW ENVIRONMENTALLY SAFE TECHNIQUES

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ABSTRACT

Egypt is one of the countries facing great challenges due to its limited water resources represented mainly by its fixed share of the Nile water. The increase in water demand is attributed to the increase in population, the upsurge in industrial activity, and the increase in the new reclaimed farmlands. The limited water supply and the increased future demand necessitate the importance of optimum use of water resources which might be obtained through reduction of water losses. The reduction of evaporation losses has recently received increasing attention because of the increase in water demand and the decrease in water availability. The evaporation loss from Lake Naser is an influential factor in the Egyptian water budget. Therefore, the aim of this research is to use a new technique (Pontoon Framework and Circular Foam Sheets) that can save evaporation water losses as a non-conventional water resource. It could be concluded from the research that water evaporation can be reduced and controlled using environmentally safe techniques.

INTRODUCTION

Generally, water is a crucial element for human beings and natural systems. In Egypt, the rapid population growth, urbanization, deforestation, and industrialization always increase the demand and competition for water even under reasonable flood conditions. The water resources are exclusively limited to the River Nile, Rainfall and Flash Floods, Groundwater in the deserts and Sinai and possible desalination of sea water. Each resource has its limitation when used as far as the quantity, quality, space, time, and economic values are concerned. Therefore, this research is an attempt to bridge the gab between the limited water resources and the increasing demands.

Egypt's Water Demands can be categorized into four main classes namely; the Crop Consumptive Use, Municipal Water Requirements, Industrial Water Requirements, and Navigational Requirements. Figure (1) shows the water requirements by year 2025, as compared with the actual requirements in year 1997.

The water resources balance indicates that the currently available resources for use are 55.5 billion m^3/year, whereas the actual water demands are about 63 billion m^3/year. This means that a water deficit of 7.5 billion m^3/year still needs to be compensated. This may be achieved by water consumption rationalization, recycling and management policies. Such policies can hopefully fill in the gaps between water needs and demands. Therefore, the better use and management of fixed water resources may be considered a top priority that can minimize the water system losses.

OBJECTIVE

The main objective of this research is to compute the evaporation losses from Lake Nasser precisely and introduce a new technique to decrease them.

DATA COLLECTION AND PROCESSING

The Egyptian Meteorological Authority (EMA) operates a network of meteorological stations comprising about 100 stations covering the entire area of Egypt. Of these stations, six are distributed on the surface area of Lake Nasser upstream the High Dam. These stations are operated either by the weather authority or the High Aswan Dam Authority. The locations of these stations with respect to the Lake boundaries are illustrated in Figure (2). The actual data of these stations are used to compute the amount of water lost by evaporation from the lake.

The present research is based on several sets of field data representing the lake. Topographical maps for the lake representing 20 m interval contour were used to extract the lake surface area at different levels. These maps were scanned and digitized to the computer with the emphasis on the contour lines between 160 and 180 m and the spots in between which represent the low and high water levels respectively. These maps were produced by the Egyptian Survey Authority (ESA) in 1991. They were compiled from aerial photography of 1988. Field surveys were conducted for verification and compilation in 1990. The scale of the maps is 1: 50000 with contour interval of 20 m starting with contour level 160 m. They are referenced to Ellipsoid (Helmert 1906) and their projection is Transverse Mercator with specific parameters. A number of 24 maps are covering the lake area.

COMPUTATION OF EVAPORATION LOSSES

Evaporation from water surface is a continuous process affected by many meteorological parameters usually used in the computation of the amount of water lost by evaporation. The most common methods and procedures used to estimate the evaporation losses depend on theoretical analyses, whereas others depend on formulae based on atmospheric elements. Some of these methods are applied below to compute the amount of water lost by evaporation from Lake Nasser.

METHODS OF COMPUTATIONS

Four methods from the literature are used to estimate the evaporation rate as follows:

1. Method (I) Evaporation Pan

This method, first applied by Varshney R.S. (1977), is tried in Egypt. In this method, evaporation is measured by a diverse assortment of instruments and methods. Some of the smaller instruments used are the Piche evaporimeter, the evaporation scale of H Wild and porous clay bulbs of various designs, called atmometers. These instruments measure evaporation from very small amounts of water, micro-scopic when compared to volumes considered in engineering hydrology.

Although there is only one gauge in Aswan meteorological station, the method is still applicable. The coefficient of this gauge is between (0.55 – 0.80). It means that there is an error in reading about (± 25 %).

2. Method (II) Bulk Aerodynamic

This method is applicable on Lake Nasser taking into consideration the values of average air temperature at the lake. It is found that the appropriate coefficient (N) in equation (1) equals to 0.1296 *(Omar, M.H., 1981)*.

$$E = N\,U\,(e_s - e_d) \tag{1}$$

in which:

E : Evaporation (mm/day),
N : A constant equal to 0.1296,
U : The wind velocity at height 2.0 m above water surface (m/sec),
e_s : A saturated vapor pressure at water temperature (Hectopascal) ,and
e_d : A vapor pressure of air 2.0 m above water surface (Hectopascal).

3. Method (III) Modified Bulk Aerodynamic

This method represents the bulk Aerodynamic method with some modifications added by the Russian. These modifications can be expressed as follows:

$$E = 0.13\,(1 + 0.7\,U_2)\,(e_a - e_d) \tag{2}$$

in which:

E : evaporation rate (mm/day),
U_2 : wind velocity 2.0 m above water (m/sec),
e_a : saturated vapor pressure at air temperature (Hectopascal), and
e_d : vapor pressure in air 2.0 m above water (Hectopascal).

The main difference between this method and the previous one is that this method always gives a value for evaporation even if the air velocity is equal to zero.

4. Method (IV) Penman Method

Penman (1948) presented a theory and a formula for the estimation of evaporation from weather data, which allow the computation of evaporation from a free water surface using readily available standard meteorological data only as follows:

$$E = \frac{\frac{\Delta}{\gamma}(R_n + E_a)}{\frac{\Delta}{\gamma} + 1} \tag{3}$$

$$R_n = \left[(1-\alpha)RG - \in \frac{\left(352.8 - 0.195\sigma T_k^4\right)\left(0.1 + 0.9\frac{n}{N}\right)}{59} \right] \tag{4}$$

$$E_a = 0.26(0.5 + 0.7U2)(e_a - e_d) \tag{5}$$

in which:

E : evaporation rate (mm/day),
R_n : solar balance for water surface,
R_n : $R_{ns} - R_{nlg}$,
R_{ns} : short wave radiation. = RG (1 – α),
RG : short wave radiation actually received at the earth from sun and sky,
α : reflection coefficient = 0.04 to 0.09 ,and
R_{nlg} : long wave radiation.

This method is considered to be the best method in estimating the evaporation losses because it takes into consideration the energy budget method and the bulk aerodynamic method. The result of this method is in good accordance with the evaporation gauge method.

ESTIMATION OF EVAPORATION LOSSES FROM LAKE NASSER

The amount of water lost by evaporation from Lake Nasser was calculated according to some available data at the two stations of Aswan and Abu Simble using the abovementioned four methods. Tables (1 & 2) present the calculation results. Also, Figures (2 & 3) show these results. It is clear that the four methods give very close results in the months experiencing low temperature (November, December, January and February). As for the rest of the year, the results of methods (I and IV) are very close to each other and the results of methods (II and III) show good agreement together but are higher than the other two methods (I and IV).

To enhance the estimation of evaporation and reach more accurate results, recent data have been collected with the help and under the supervision of Aswan High Dam

Authority from the four meteorological stations scattered about in Lake Nasser. These data show the average monthly and yearly rate of evaporation from the different stations. They are presented in Tables (3 & 4).

CALCULATION OF WATER VOLUME LOST BY EVAPORATION

The volume of water lost by evaporation was calculated using the two following methods:

1. The Average Yearly Evaporation Rate

In this method, the annual volume of the water lost by evaporation was calculated based on the total yearly average of the evaporation rate. The yearly average of the evaporation rate at each of the four meteorological stations was calculated using the monthly average. Then, the total yearly average for the lake was computed by taking the average of the yearly average of the four stations. Table (3) shows the calculation result where the yearly average of the daily evaporation rate (E) reached 6.33 mm/day.

The annual volume of the water lost by evaporation can be calculated from the following equation:

$$V = E \text{ x } A \text{ x } 365 / 1000000 \tag{6}$$

in which:

V : annual volume of water (milliard m^3 / year),

E : evaporation rate (mm/day),

A : surface area of Lake Nasser (km^2) calculated by the equation of Abu Atta (1978):

$$A = 22.296 * e^{0.0311\,(WL)} \tag{7}$$

(WL) : average monthly water level.

2. The Average Monthly Evaporation Rate

In this method, the monthly average of evaporation rate will be used in calculations in stead of the yearly one. The monthly average was calculated by taking the average of the monthly average at the four stations as shown in Table (4).

Using equation (7), different 12 surface areas of Lake Nasser corresponding to the 12 monthly averages of the water levels can be calculated. Then, the monthly volume of the water lost by evaporation can be calculated for each water level and surface area. Finally, a summation of the monthly volumes gives the required annual volume of water lost by evaporation. This can be calculated as follows:

$$V = \sum_{12}^{1} \left(A \times E_m \times n / 1000000 \right) \tag{8}$$

in which:

V : annual volume of water (milliard m^3/year),

E_m : average monthly Evaporation rate (mm/day),

n : No. of days for each month, and

A : surface area of Lake Nasser (km^2) calculated by equation (7).

GENERAL SUGGESTIONS FOR DECREASING EVAPORATION LOSSES

There are a considerable number of ideas and techniques introduced by water resources management specialists to decrease the amount of water lost by evaporation from open water surfaces. They can be summarized as follows:

1. Ideas Proposed to Decrease Evaporation Losses from Lake Nasser

- Changing water levels upstream Aswan High Dam.
- Cultivating special Crops on the lake surface.
- Closure of secondary channels (khores).

2. Techniques to Decrease Evaporation Losses from Open Water Surfaces

- Use of floating sheets.
- Use of monomolecular films.
- Changing the water color.
- Use of wind barriers.
- Shading the water surface.
- Use of floating covers.

THE PROPOSED NEW TECHNIQUE

The previous studies which dealt with the evaporation reduction from open water surfaces have had some shortcomings. For example, applying the technique in which all the water surface is covered is not practically acceptable as the complete coverage of the surface prevents the exchange between air and water, a matter which affects the oxygen demand needed by the aquatic ecology. Another shortcoming is the use of cover sheets with irregular shapes which lead to the overlapping of sheets when the wind speed becomes faster. In addition, the previous studies have not mentioned the effect of wind speed on the proposed cover systems and how they could cope with such a problem. Fortunately, such weaknesses have been overcome during the application of the proposed technique.

The new technique is based on the concept that the evaporation can be reduced from open water surface using floating cover sheets. The percent coverage, kind of cover material, and the control of wind effect on the cover sheets were studied.

1. The Percent Coverage of Water Surface

Different geometric shapes (triangular, trapezoidal, square, irregular, circular, and rectangular) for the cover sheets were studied to find the best one which gives the maximum percent coverage and permits oxygen exchange between air and water. The study showed that the most suitable shape achieving the maximum coverage and permitting sunlight penetration through water was the circular one.

1.1 Method of Calculation of Percent Covered Area Using Circular Sheets

If "n" circular sheets with a constant diameter "D" are arrayed in a square unit area, the total area of the circular sheets will be n π (D2/4) and the square unit area will be {D * (n)½ } {(n)½ * D}.

The uncovered area in the square unit area is equal to the difference between the total area of the circular sheets and the unit area.

$$A_{uncovered} = (nD^2 - n\pi D^2/4) = nD^2 (1 - \pi/4)$$

And the percentage of the uncovered area to the unit area is

$$\%A_{uncovered} = \frac{nD^2}{nD^2}(1 - \frac{\pi}{4}) \times 100 = 21.50\%$$

Consequently, the percentage of the covered area will be

$$\% A_{covered} = 100 – 21.5 = 78.5\%$$

The percentage of the uncovered area can be increased to reach a value of 82.7% from the unit area using small circular sheets in between the big ones as shown in Figures (6a and 6b).

This can be calculated as follows:

Let the big circular sheets have a diameter (D) and the small circular sheets have a diameter (D_s). Assuming an (n) number of circular sheets are put together in a unit area of dimensions (n*0.5*D) X (n*0.5*D), the area of big circular sheets will equal (n π D^2/4). The unit area will be equal to (nD^2) and the difference between them will equal the uncovered area.

Then, $A_{uncovered}$ = (nD^2 – n π $D^2/4$ – n π $D_s^2/4$) but the ratio between D^2 and D_s^2 is equal to 0.171 as shown in fig (-) then the percentage of "$A_{uncovered}$" to the "total unit area" will equal:

$$\%\ A_{uncovered} = \frac{nD^{-2}}{nD^{-2}}(1-\pi/4-0.171\times\pi/4)\times 100$$

$\%\ A_{uncovered} = 17.2\%$

$\%\ A_{covered} = 100 - 17.2 = 82.7\%$

Generally, the percentage of coverage using circular sheets can be increased to 82.7% or more using more and smaller circular sheets.

2. Kind of Cover Material

Different coverage materials were subject to experimentation and comparison as far as their ability to reduce evaporation from open water surfaces and their durability and cost are concerned. These materials were, for instance, the waxen texture sheets, polystyrene, foam, foamed rubber, perlite ore, plastic sheets, poly laminated plastic, polystyrene beads and polystyrene rafts as shown in Table (5). Finally, the results revealed that the most suitable material is the foam sheets.

3. Control of Wind Effect on Cover Sheets

In order to ensure that no damage will befall or happen to the covering foam sheets because of the wind, a safe fixing system is proposed as shown in Figures (7 and 8). It is a pontoon made up of different components as follows:

- A floating frame made of Wooden or PVC cross sections
- A trash rack
- A Mooring point
- A chain
- A concrete anchorage block.

4. Experimental Work for Estimation of Evaporation

The experiments were carried out in an open area in El Kanater El Khiaria beside the Nile River at Damietta branch – Cairo, Egypt. Two glass boxes with the same dimensions (1.0 m long, 1.0 m wide, and 0.25 m deep) were used as shown in Figure (5). Each glass box is kept in a wooden box and provided with a graded scale. There is an insulating filling material placed in between the glass box and the wooden box. The two boxes were calibrated for evaporation for one month. The readings were taken twice a week. By the end of the month, no difference in the average reading values of the two glass boxes was noticed. After calibration, the two glass boxes were filled with water to a level of 23 cm above the bottom of the boxes. One glass box was covered with circular foam sheets with a diameter of 20 cm and other smaller circular foam sheets with a diameter of 8.28 cm to give a coverage percentage equal to 82.7 %. The other glass box was left open (uncovered) in the same condition as a reference.

The readings were taken twice a week and recorded. Then, the evaporation reduction percentage was calculated from the following equation:

$$\% \, E_r = \left[\frac{(Vo - Vc)}{Vo} \right] \times 100$$

in which:

Vo : the volume of water lost form the open glass box,
Vc : the volume of water lost form the covered glass box, and
%Er : the percentage of Evaporation reduction due to coverage.

The calculated % Er for a percentage of coverage (82.7%) was equal to 74% with an efficiency of coverage equal to 90%.

CONCLUSION

1. The yearly average of the daily evaporation rate from Lake Nasser is 6.3 mm/day;
2. The average volume of the annual water lost by evaporation is about 12.5 milliards cubic meter. To save more than one million of cubic meters of lost water from Lake Nasser, 0.500 km^2 must be covered with Circular Foam sheets with an efficiency of coverage equal to 90%;
3. The Circular Foam System can be adjusted such that it does not affect the passage of sunlight to aquatic life;
4. Navigation can not be affected by the proposed technique either; and
5. The percentage of evaporation reduction can be controlled using different radii of circular Foam sheets.

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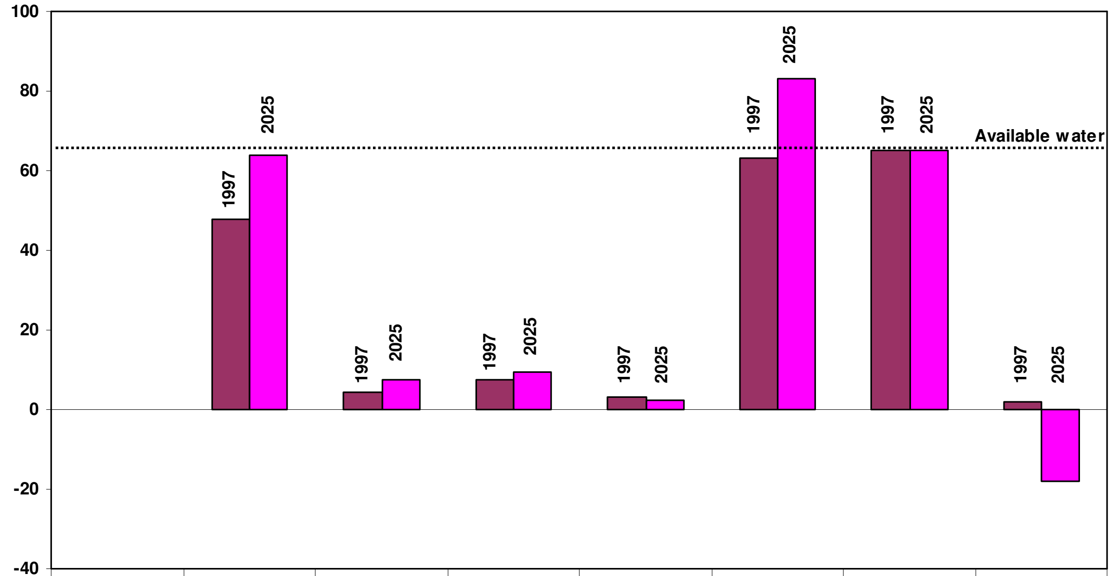

		Irrigation	Domestic use	Industry	Others	Total requirements	Available water	Difference
1997	0	48	4.5	7.5	3	63	65	2
2025	0	64	7.3	9.5	2.2	83	65	-18

Figure (1) Water demands in Egypt for years 1997 and 2025

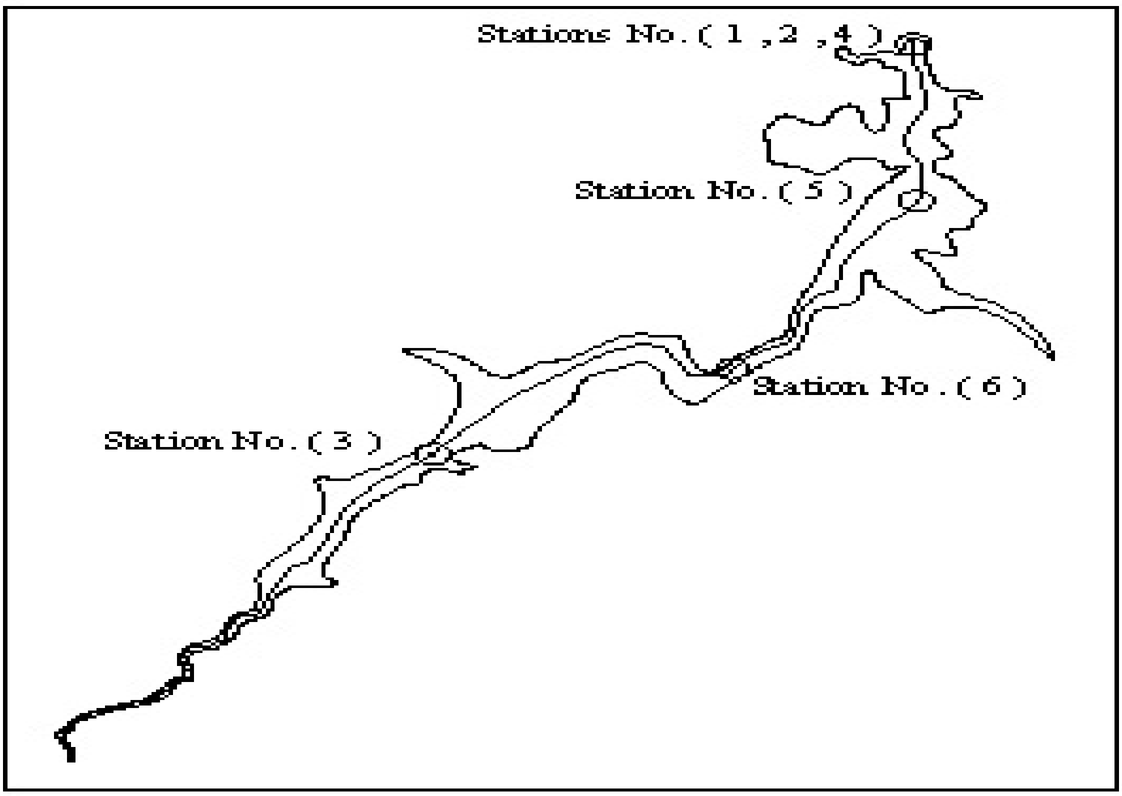

Figure (2): Locations of Metrological Stations over Lake Nasser

Table (1): The calculated evaporation rate (mm/day) for Abo Simble stations using the four methods

Method	I	II	III	IV
Jan.	There is no Pan gauge in this station	5.19	5.04	5.38
Feb.		5.45	5.58	6.23
March		9.11	9.02	8.74
April		12.5	12.68	10.57
May		16.25	16.22	11.86
June		18.83	18.79	12.83
July		15.07	16.04	11.66
Aug.		16.73	17.12	11.81
Sep.		17.01	16.84	11.26
Oct.		15.42	14.69	10
Nov.		9.23	8.79	7.3
Dec.		6.48	6.14	5.79
Annual Average		***12.27***	***12.24***	***9.45***

- Abo Simble Station – (Station Code = 62419) , (Station position : Lat. 22 º 22' – Long. 31 º 36' – Altitude = 187.00m)

Table (2): The calculated evaporation rate (mm/day) for Aswan station using the four methods

Method	I	II	III	IV
Jan.	5.2	5.25	5.27	5.43
Feb.	6.6	6.76	6.83	6.92
March	8.65	10.34	10.26	9.15
April	10.5	13.75	13.88	10.97
May	12.35	16.35	16.71	11.86
June	13.65	19.77	20.09	13.16
July	13	18.02	18.65	12.65
Aug.	12.45	16.76	17.49	11.94
Sep.	11.65	15.32	15.75	10.7
Oct.	10.1	12.16	12.52	9.02
Nov.	7.2	7.39	7.56	6.56
Dec.	5.65	5.57	5.59	5.31
Annual Average	***9.75***	***12.29***	***12.55***	***9.47***

- Aswan Station – (Station Code = 62414) , (Station position : Lat. 23 º 58' – Long. 32 º 47' – Altitude = 192.70m)

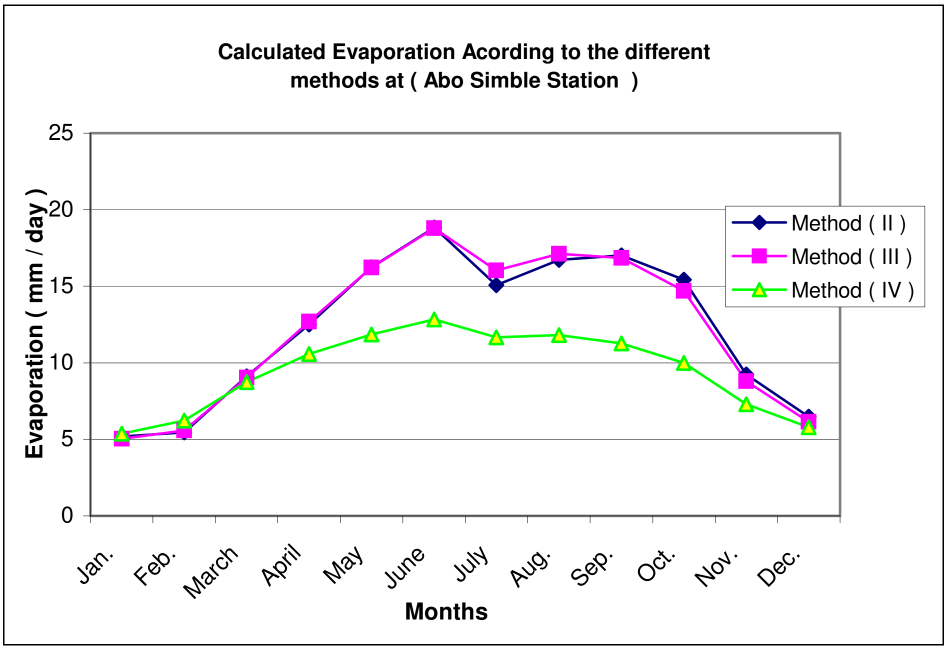

Fig. (3) The calculated evaporation at Abo Simble station using the different methods

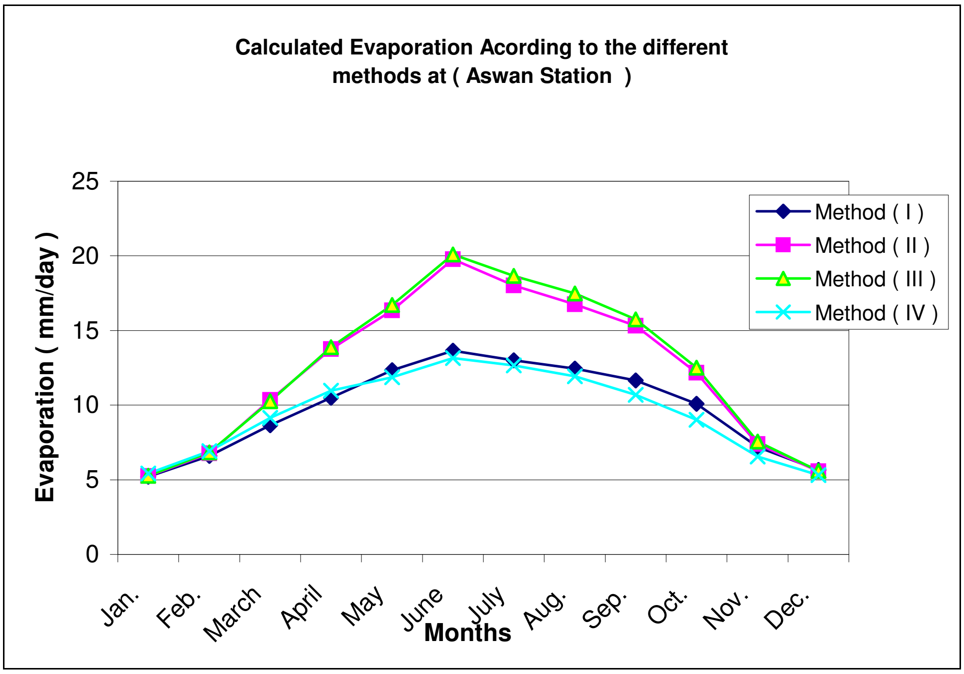

Fig. (4) The calculated evaporation according to the different methods at Aswan station

Table (3): Calculation of the yearly average of the evaporation rate (mm / day)

Station	**Aswan**	**Allaqi Khore**	**Wadi El Arab**	**Abo Simble**	**Yearly Average evaporation rate (mm / day)**
Jan.	5.1	4.94	4.77	4.6	
Feb.	5.22	4.75	4.64	4.52	
March	5.37	4.39	4.62	4.85	
April	6.21	5.32	5.47	5.62	
May	7.42	5.41	5.85	6.28	
June	8.26	7.92	7.61	7.3	
July	9.17	6.82	6.99	7.16	
Aug.	9.94	6.87	7.26	7.65	
Sep.	9.71	7.41	7.49	7.57	
Oct.	9.07	5.61	6.44	7.27	
Nov.	6.45	4.99	5.48	5.96	
Dec.	6.03	5.15	5.34	5.52	
Average	***7.33***	***5.8***	***6***	***6.19***	***6.33***

Table (4): The average monthly evaporation rate (mm / day)

Station	**Aswan**	**Allaqi Khore**	**Wadi El Arab**	**Abo Simble**	**Average**
Jan.	5.1	4.94	4.77	4.6	4.85
Feb.	5.22	4.75	4.64	4.52	4.78
March	5.37	4.39	4.62	4.85	4.81
April	6.21	5.32	5.47	5.62	5.66
May	7.42	5.41	5.85	6.28	6.24
June	8.26	7.92	7.61	7.3	7.77
July	9.17	6.82	6.99	7.16	7.53
Aug.	9.94	6.87	7.26	7.65	7.93
Sep.	9.71	7.41	7.49	7.57	8.05
Oct.	9.07	5.61	6.44	7.27	7.1
Nov.	6.45	4.99	5.48	5.96	5.72
Dec.	6.03	5.15	5.34	5.52	5.51

Table (5): Evaporation Reduction Achieved by Various Energy Reducing Methods

Method	Area of water surface covered (%)	Evaporation reduction (%)
1. Changing the water color :		
Dye in water	100	6.9
Shallow, colored pans	100	35-50
2. Using wind barriers : Baffles	-	11
3. Shading the water surface		
Plastic mesh	100	44
Blue polylaminated plastic		90
4. Floating covers :	78	
Perlite ore	78	19
Polystyrene beads	78	39
Wax blocks	78	64
White spheres	86	78
White butyl sheets	80	77
Polystyrene sheets	100	79
Polystyrene rafts	100	95
Continuous wax	95	87
Foamed rubber	95	90

- Source: (Evaporation of water emphasis on Applications and Measurements) (Franke Jones, 1992).

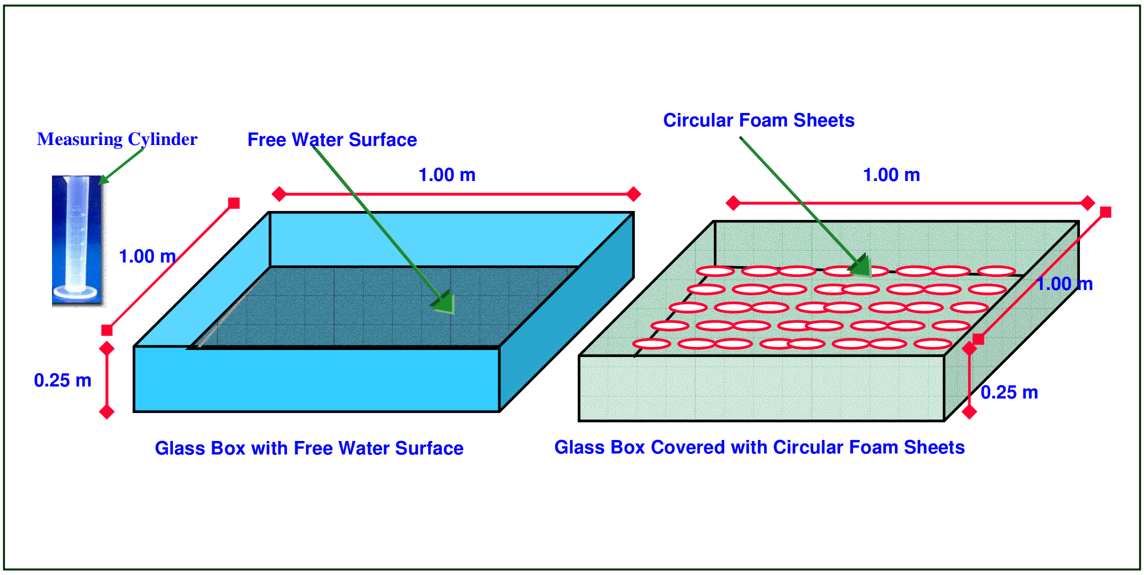

Figure (5) Estimation of Evaporation Reduction Using Circular Foam Sheets

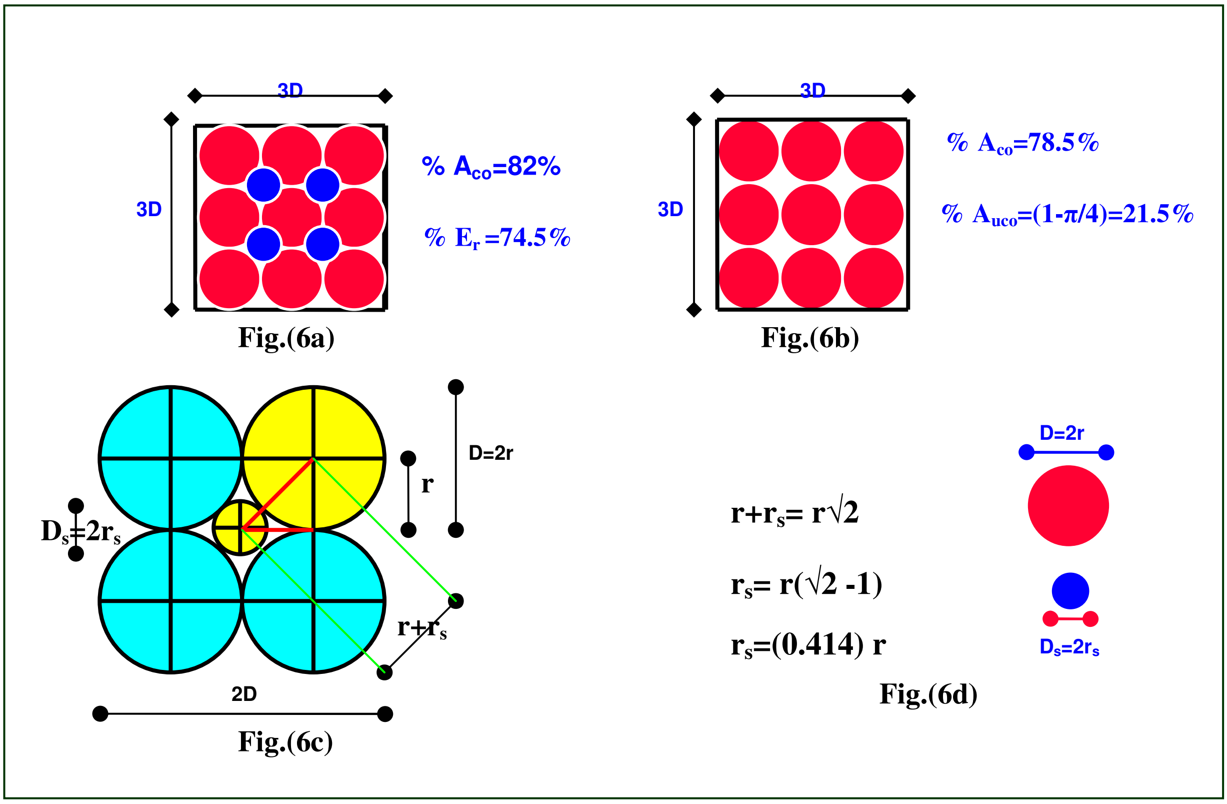

Fig.(6) Determination of Uncovered Area on Open Surface Using Circular Foam Sheets

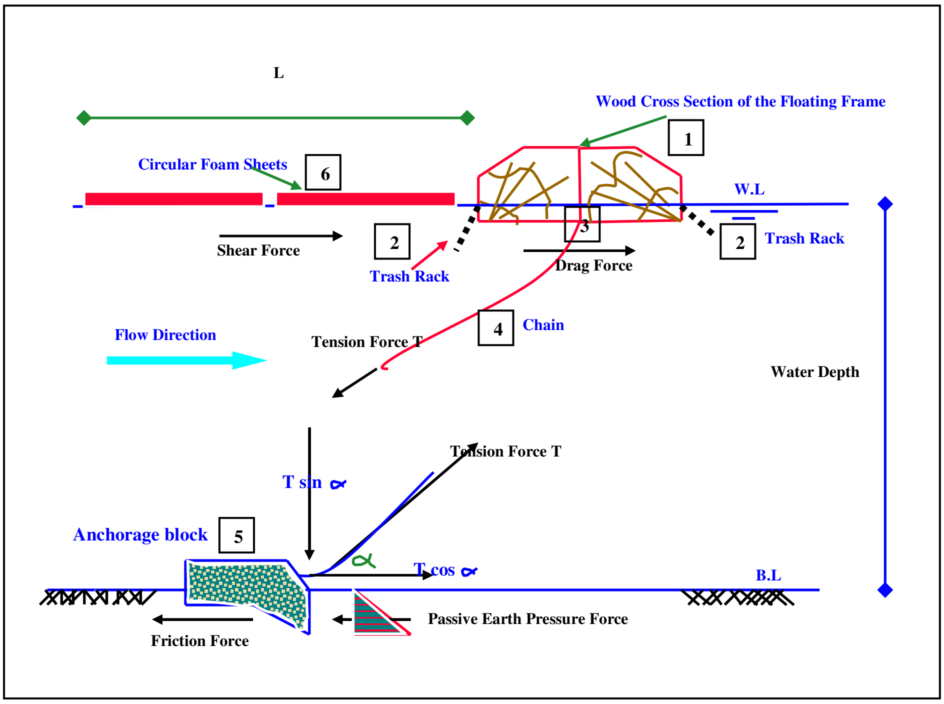

Fig. (7) The Components of the Proposed Technique and the Applied Forces acting on them

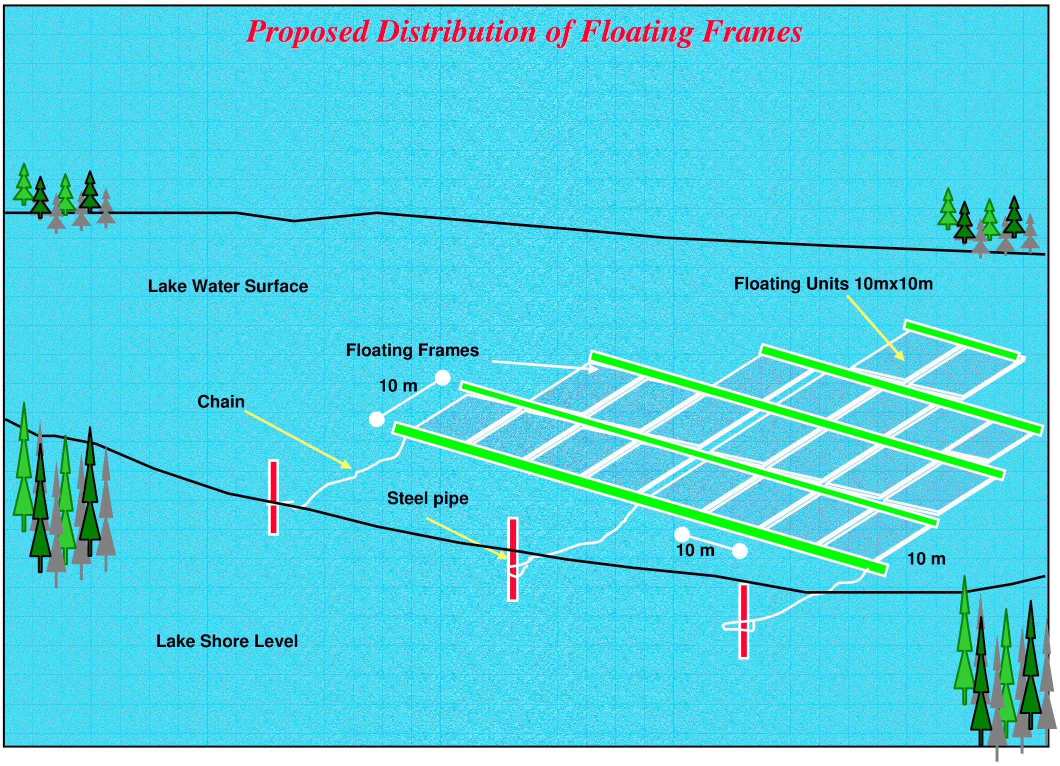

Fig. (8) The Proposed Distribution of Floating Frames (Pontoon) on the Lake Surface