Journal of Engineering Sciences, Assiut University, Vol. 36, No.5, pp.1061-1070, September 2008

THE ROLE OF EVAPORATION TOWARDS WATER BUDGET IN JORDAN

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(Received May 25, 2008 Accepted June 6, 2008)

Water in Jordan is chronic problem due to the incremental demand and shortage of resources. This effect is so clear not only for drinking, but for domestic, industries, and agriculture uses.
Evaporation considers the major cause of loss of hydrological cycle and stored water, which needs more study and more tools and technology in order to decrease the turn of this parameter within specific place and specific methodology.
Meteorological stations are the suitable places for instillation various equipments of measurement of solar radiation, temperature, humidity, wind, pressure, and precipitation. But, it differs in size, objects, and distance between each other.
Isra station was selected to be used for studying hydrology and metrology parameters at the campus and surround area by researches through available means at the present time and others in the future after it's obtained.

KEY WORDS: *Jordan, Water, evaporation, hydrology, metrology.*

INTRODUCTION

Water exists normally in many forms in the nature. It appears mostly in the oceans (saltwater) and polar ice caps, but also as clouds, rain water, rivers, freshwater aquifers, lakes, and sea ice. Water in these bodies continuously moves through a cycle including evaporation, precipitation, infiltration, and runoff. Clean water is essential substance for human life, but unfortunately it faces a lot of shortage in many parts of the earth.

From a biological standpoint, water has many distinct properties that are critical for the proliferation of life that set it apart from other substances. It carries out this role by allowing organic compounds to react in ways that ultimately allows replication. All known forms of life depend on water. Water is vital both as a solvent in which many of the body's solutes dissolve and as an essential part of many metabolic processes within the body (e.g. significant quantities of water are used during the digestion of food).

Fresh water has its greatest density under normal atmospheric pressure at 4 °C, then becoming less dense as it freezes or heats up from this point—the only reason bodies of water do not freeze all the way through (which would kill all the organisms within it). As a stable, polar molecule prevalent in the atmosphere, it plays an important role as a greenhouse gas absorbing infrared radiation, without which, earth's average surface temperature would be -18 °C.

Water that fit for human consumption is called drinking water or "potable water". Water that is not fit for drinking, but is not harmful for a human when used for food preparation is called safe water.

This natural resource is becoming scarcer in certain places nowadays, and its availability is a major social and economic concern. Also currently, about 1 billion people around the world routinely drink unhealthy water. Most countries have accepted the goal of halving, by 2015, the number of people worldwide who do not have access to safe water and sanitation during the 2003.

Even if this difficult goal is met, it will still leave more than an estimated half billion people without access to safe drinking water supplies and over 1 billion without access to adequate sanitation facilities. Poor water quality and bad sanitation are deadly; about 5 million deaths a year are caused by polluted drinking water.

That is hardly surprising, since that 90% of all wastewater still goes untreated into local rivers and streams in the developing countries. Arround 50 countries, formed fourth of the world's population, suffer from medium or high water stress, and 17 of these countries extract more water annually than their recharged through natural water cycles. The strain affects surface freshwater bodies like rivers and lakes, but it also degrades groundwater resources.

One of the regions which suffers from the water shortage is the the Middle East, which has only 1% of the world's available fresh water and formed 5% of the world's population. Thus, in this region, water is an important strategic resource. By 2025, it is predicted that the countries of the Arabian Peninsula will be using more than double the amount of water naturally available to them. According to a report by the Arab League, two-thirds of Arab countries have less than 1,000 cubic meters water per person per year, which is considered the minimum limit of water amount related to the estimated volume allocated to other regions of the earth.

Jordan as an example of this region is considered one of the poorest ten countries of the world from water point view. This happens due to the shortage of rainfall, minimum number of streams, high population growth, quick changes of life standard, wide area of desert, and high percentage of evaporation.

Based on that, it was necessary to study the situation of various parameters that affect the water budget in this country. One of these factors which attracts the writers of this paper is the evaporation, since it losses more than 95% of annual precipitation over this country, where the average ratio of evaporation was given by United Nations over the whole ground surface around 60%.

For that, the study of this parameter needs certain methods and tools in order to estimate it and to find its relationship with meteorological and hydrological processes. Based on that, Jordan established a number of meteorological stations through out the country in order to collect data about evaporation and other parameters of climate and hydrology. One of these stations was established at Isra university campus for helping instructors, researchers, and local community pioneers to study the evaporation assessment towards water budget, especially around the site of the university. The scope of this paper is to investigate the collecting data from this station through different days, months, and years, then clarify the role of evaporation towards water budget at the campus and surrounded area.

EVAPORATION CONCEPT

Evaporation is considered the stage of loss within the hydrological cycle due to its high percentage of missing water which reaches 95% in Jordan. This situation leads to minimize green areas and increase arid areas. So, in order to understand its role we need knowledge about the process and mathematical equations used for that.

Keeping in mind that maximum evaporation and evaporation plus transpiration is known as potential evaporation and potential evapotranspiration (PE) respectively, and it constitutes the maximum possible rate due to the prevailing meteorological conditions, while actual evaporation is the real amount of water which is evaporated from wet land and water bodies.

One of the most used methods of measuring potential evaporation is the lysimeter and the standardised US Class A pan (Fig.1 and 2 respectively); the former deals with green land and the later with open water body.

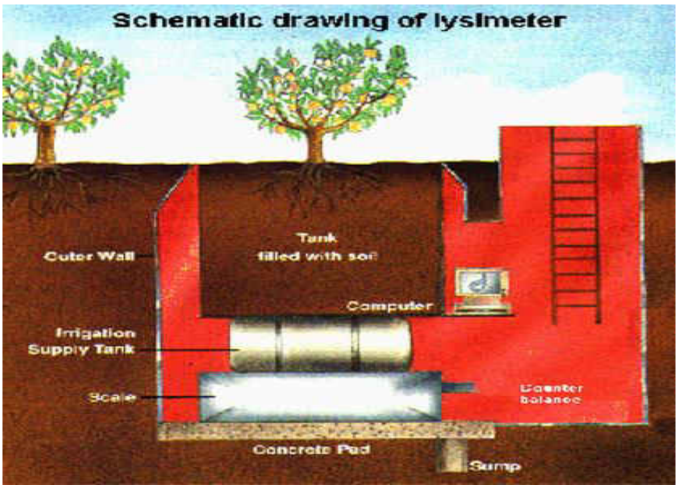

Fig. (1) Schematic drawing of lysimeter

As shown in Fig. (1), field capacity is assured by maintaining continuous percolation from the bottom of the tank. Thus the vegetation cover is allowed to transpire freely, and the total evaporation loss is dependent entirely on the ability of the air to absorb the water vapour. Then, potential evaporation (PE) is given by:

PE = Rainfall + Irrigation - Percolation

But one of the disadvantages of these gauges is that the soil sample is disturbed, and in winter seasons certain difficulties in operating the gauges are encountered due to snow and freezing.

So, measured values of PE using these irrigated gauges can be exaggerated in very dry periods and hot climates. Surrounding parches ground heating and drying the air above tends to cause increased evaporation from the continuously watered and transpiring vegetation of the gauge. (Show, 1994)

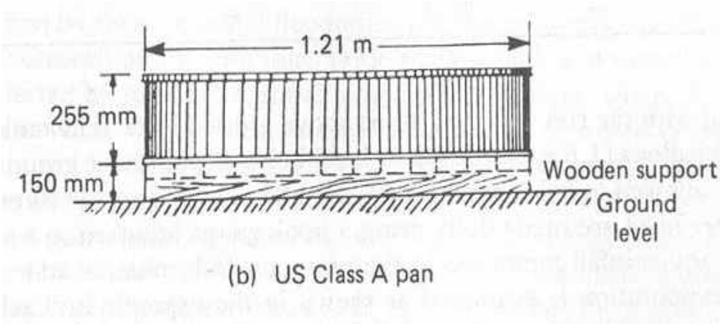

Fig. (2) US Class A pan

With respect to pans, there are a lot of standardized pans for measuring evaporation, and the US Class A pan (Fig. 2) is probably the most used one. The pan is circular with a diameter of 1.21 m and depth of 0.255 m. The basin is put on a 0.15 m high wooden frame due to the need of air circulation around the basin. The water level is kept about 0.05 m below the rim of the pan to prevent air entrainment. The water level is measured every day, either you measure the difference between the present and the origin water level or if you have chosen to obtain the water level in the pan, you measure the amount of water you've put into the pan. Due to that the sun hits the sides of the pan; the temperature gets higher which means that the evaporation gets higher than the actual evaporation. To correct this value you multiply your evaporation value from the pan with a coefficient, called pan coefficient and its value depends on what climate region your test have been taken.

EVAPORATION CALCULATION:

A value of the actual evapotranspiration (E_t) over a catchment area is more often obtained by first calculating the potential evapotranspiration (PE), assuming an unrestricted availability of water, and then modifying the answer by accounting for the actual soil moisture content. Fore that, there are several formulas for calculating potential evaporation (based on theoretical or empirical models), but the most commonly used is the Penman equation:

$$PE = \left(\frac{\Delta}{\Delta+\gamma}\right) * Q_{ET} + \left(\frac{\gamma}{\Delta+\gamma}\right) * E_{at} \text{ (mm/day)}$$

Where:

$Q_{ET} = Q_S*(1 - r) - Q_l$

$Q_l=0.95*[8.64*10^7/(\rho*\lambda)]*\sigma*(273.16+T_a)^4*(0.53+0.065*(e_d-1.0)^{1/2})*(0.10+0.90*(n/N))$

$E_{at} = 0.3*(1+0.5*u_2)*(e_a-e_d)$

Δ: is the slope of the saturation vapour pressure curve with respect to temperature (mb/C).

γ: is the hygrometric constant (=0.65 mb/C).

Q_l: is long wave radiation from the water body.

r: is a coefficient relating to vegetation cover (r = 0.25 for a short grassed surface).

T_a: is air temperature (C).

n/N: is the ratio of actual/possible sunshine hours of bright sunshine.

ρ: is the density of water (kg/m^3).

λ: is the latent heat of vaporization of water (J/kg).

σ: is Stefan Bolzman's constant (= $5.7*10^{-8}$ W/ (m^2*grad^4)).

u_2: is wind velocity (m/s).

e_a: is the saturation vapour pressure for the measured air temperature (mb).

e_d: is the actual vapour pressure of the air (mb).

Q_{ET}, Q_s, Q_l, E_{at} are all expressed in mm/day.

This equation is resulted directly from basic formulae of open water surface and it joints water budget and energy budget.

Another equation is Blaney-Criddle formula:

$$PE = p(0.46T + 8) \text{ mm/day}$$

Where p is the mean daily percentage (for the month) of total annual daytime hours.

In addition to that, evapotranspiration can be estimated from satellite data, based on the fact that evaporation looses energy from surfaces due to radiation of infrared heat from earth to distinguish cool surfaces from warm surfaces. In other words, very dry and desert areas will be hotter than their surroundings, therefore the objects of the researchers how to determine the amount of evapotranspiration that occurs at given location.

The calculation of potential evaporation (PE) from readily available meteorological data is seen to be much simpler operation than the computation or measurement of actual evapotranspiration (E_t) from a vegetated surface. However, water loss from a catchment area does not always proceed at the potential rate, since this is dependent on a continuous water supply. When the vegetation is unable to abstract water from the soil, then the actual evaporation becomes less than potential. Thus the relationship between E_t and PE depends upon the soil moisture content.

According to Bergström, (1992) the relationship between PE and E_t can be expressed as following:

$$E_t = PE \qquad \text{when } h \geq h_{FC}$$

$$E_t = PE.\left[\frac{h - h_{WP}}{h_{FC} - h_{WP}}\right] \qquad \text{When } h_{WP} < h < h_{FC}$$

$$E_t = 0 \qquad \text{when } h \leq h_{WP}$$

Where:

h: is the amount of soil moisture (mm).

h_{FC}: is the amount of soil moisture corresponding to field capacity (mm).

h_{WP}: is the amount of soil moisture corresponding to the wilting point (mm).

and this relationship can be shown graphically according to Veihmeyer and Hendrickson on line A, Thornthwaite on line B and Penman on curve C (Ward, 1999), Fig. (3).

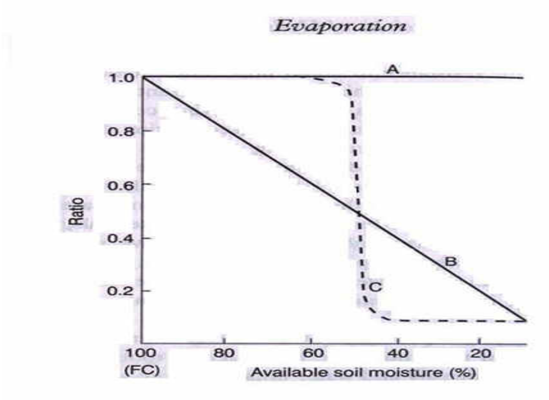

Fig. (3): relationship between PE and E_t

DESCRIPTION OF ISRA EVAPORATION STATION:

As shown in Fig. 4, the dimensions of the station site are (15 m ×15 m) and the floor is compacted sand soil to prevent grass growth. The site is surrounded with a fence to secure the various equipments of the station. Available tools are only three pans class A; each one has 125cm diameter and 25 cm depth. Underneath the pan there is wooden plate located above the ground to promote the circulation of air under the pan and to check any pan leakage.

The station still need a number of tools and instruments related to the study of hydrology and meteorology such as radiometer, barometer, anemometer, instruments Shelter, rain gauge, and humidity device.

For five years, measurements and readings of temperature and evaporation were taken for at 8 O'clock, 10 O'clock, 12 O'clock, 14 O'clock, 16 O'clock on various days and months of different seasons of these years.

ANALYSIS

As shown in Fig. 5, measurements of temperature and evaporation within month 4 of year 2004 are plotted graphically and the resultant showed that there is a fluctuation of both parameters according to the variation of the weather in one hand and there is different in the magnitudes of these parameters in other hand.

Figure 6 dictated that there is a variation of temperature and evaporation among winter season months of year 2004. From that, both parameters increased from January towards May. But, variation of temperature is less than that of evaporation. Also, variation of temperature look like constant between February and May, while a mount of evaporation during April is less than February due to change of climate or other reasons.

Figure 7 represented variation of evaporation among months 4 and 5 of year 2004. It showed that fluctuation evaporation in May more than that of April. Also, its magnitude is more. This variation matched with such months and such place in one year.

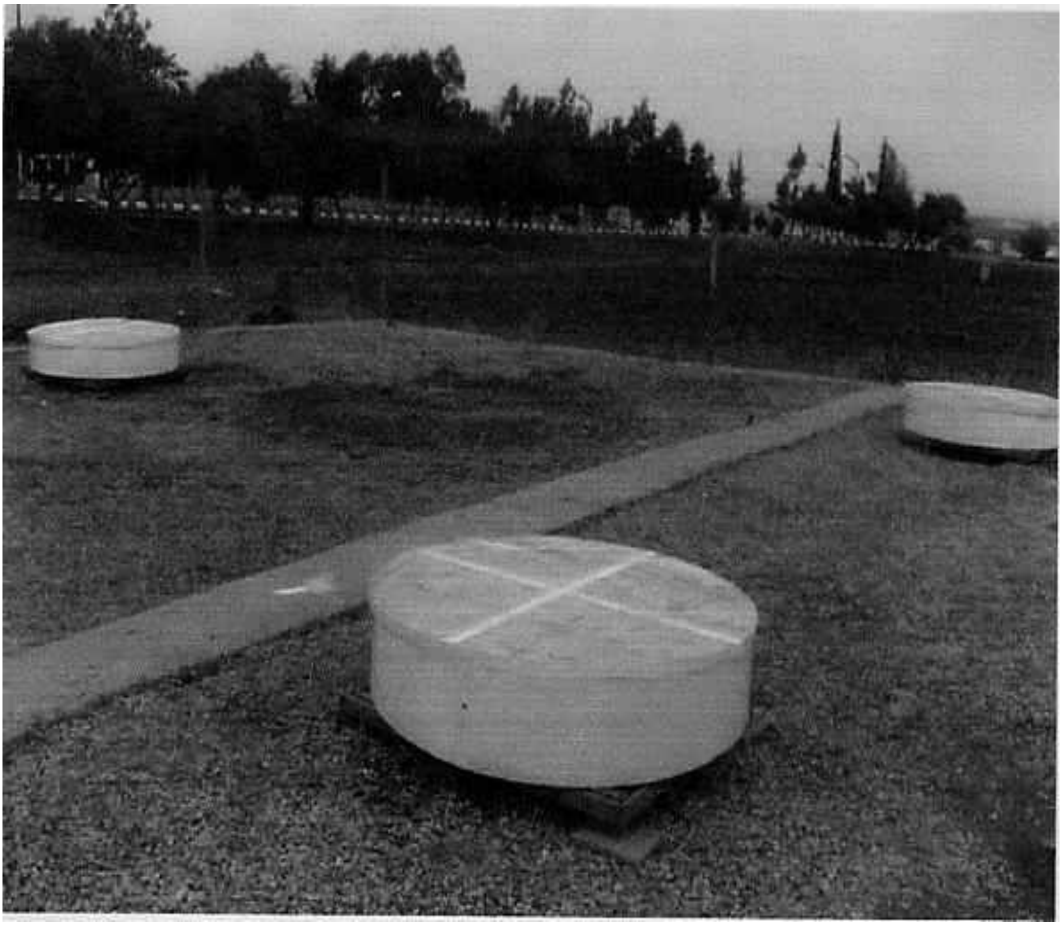

Fig. (4): Isra Evaporation station

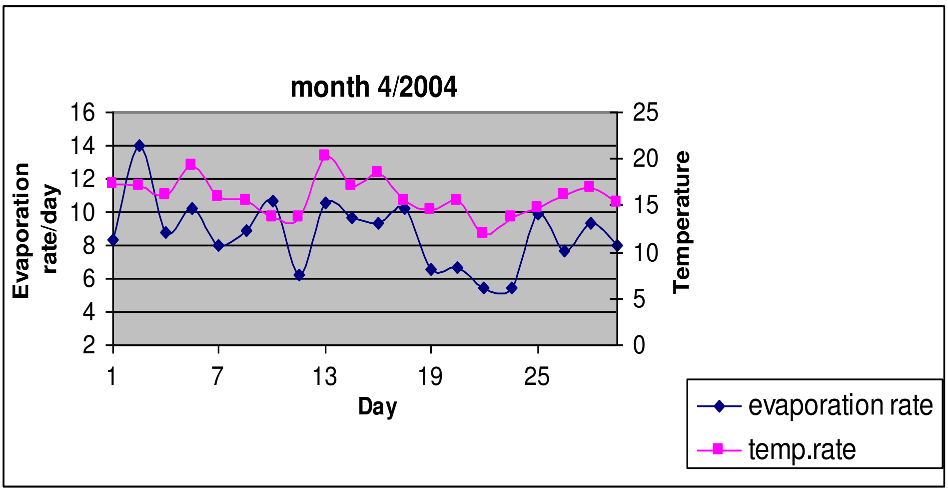

Fig. 5 Variation of evaporation &Temp. In April 2004

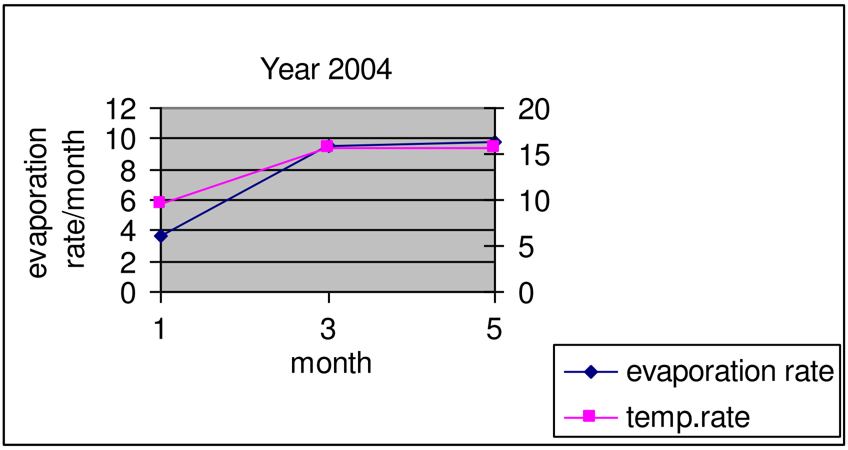

Fig. 6 Variation of evaporation &Temp. Through months of 2004

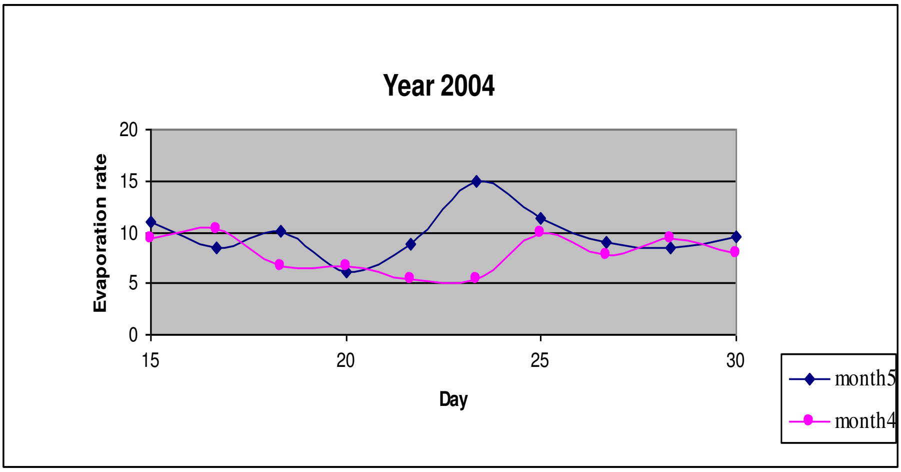

Fig. 7 Variation of evaporation through April &May of 2004

In addition to that, average of evaporation rate among number of months in year 2002 was plotted in Fig. 8. It was shown that evaporation was maximum in August and fewer in December. This situation represented the real conditions of the surround area in specific and the country in overall.

Besides that, variations of evaporation and temperature within one day (2/5/2002) were plotted graphically in Fig. 9. It was shown that maximum of magnitude of both parameters was at 2 pm, but the minimum of temperature was at 8 am according to the received solar radiation by pan water. But, minimum magnitude of evaporation was at 10 am instead of 8 am due to the addition of evaporation of water during previous night over reading of 8 o'clock.

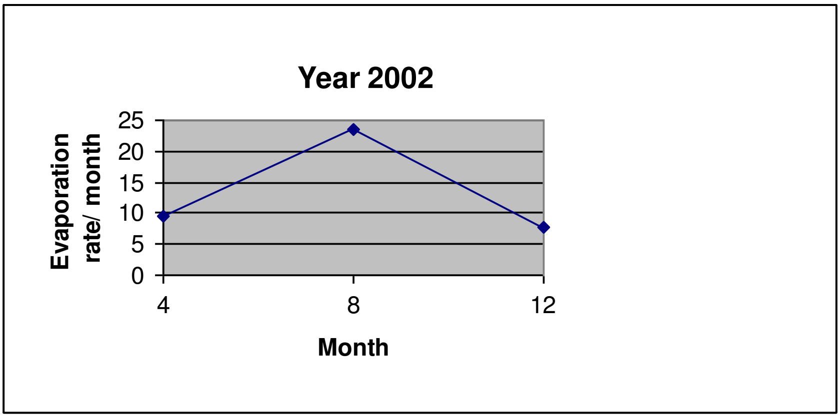

Fig. 8 Variation of evaporation through months of 2004

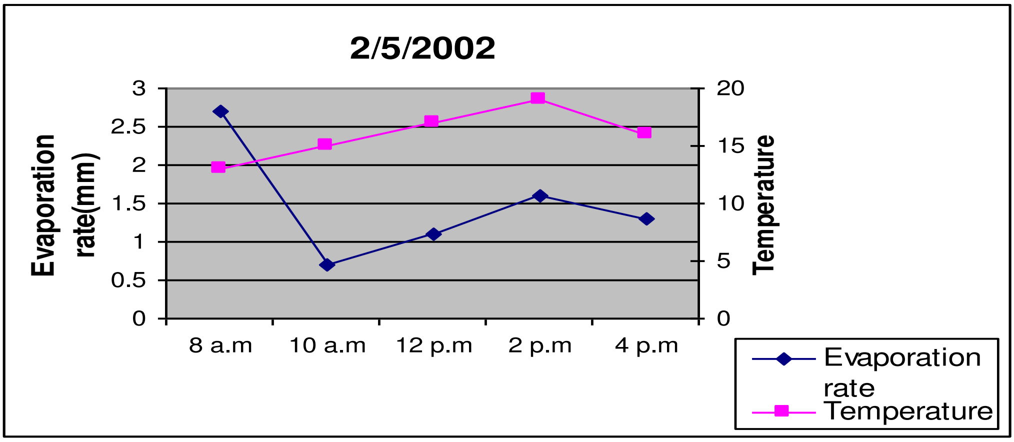

Fig. 9 Variations of evaporation and temperature within one day (2/5/2002)

CONCLUSION

As seen previously, evaporation plays major role in hydrological cycle, since it is the witness of solar radiation turn towards water bodies and wet lands in order to convert water from liquid state into gas state, and allow it to go up into atmosphere layers then forming it later into precipitation after crossing down dew point.

But this sequence becomes great enemy towards water budget in arid and semi arid regions due to its high percentage of the total budget as shown in Jordan.

Based on the results of the present study, it is dictated that evaporation differs from time to time through out the year or from year to year due to the climate change.

For that it is required to obtain advance equipments and new technology to study this phenomenon, in proper way and supply well data for researchers, planners and decision makers to follow the suitable methods in order to decrease the negative side effects of this event in this country.

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دور التبخر في ميزانية المياه في الأردن

تعتبر المياه مشكلة مزمنة في الأردن بسبب زيادة السكان وقلة الموارد المائية، وهذا الأمر أصبح واضحاً في مياه الشرب، الأعمال الإدارية، الصناعة، والزراعة.

يعتبر التبخر أكبر عامل لفقدان مياه الدورة الهيدرولوجية ومخزون المياه ، الأمر الذي يترتب عليه الحاجة لمزيد من الدراسات والأدوات التكنولوجية لتقليل هذا الأثر السلبي.

تعتبر محطات الأرصاد الجوية المكان المناسب لوضع أجهزة قياس الطاقة الشمسية، الحرارة، الرطوبة، الرياح، الضغط والهطال المطري، لكنها تختلف في أحجامها، أهدافها، والمسافات بين بعضها البعض.

تم إنشاء محطة أرصاد جامعة الإسراء لقياس عناصر الهطال المطري وأحوال الطقس من قبل الباحثين ضمن حرم الجامعة والمناطق المحيطة بها في الوقت الحاضر والأيام القادمة.