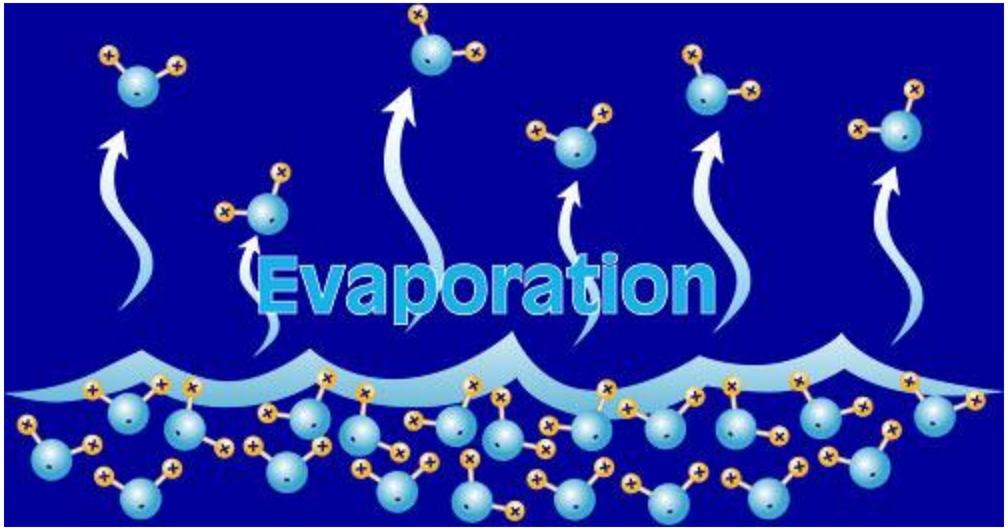
Engineering Hydrology &Irrigation And Drainage Engineering

Evaporation and Evapotranspiration

Ashraf M.Elmoustafa, Ph.D.
Associate Professor, Irrigation and Hydraulics Dept.

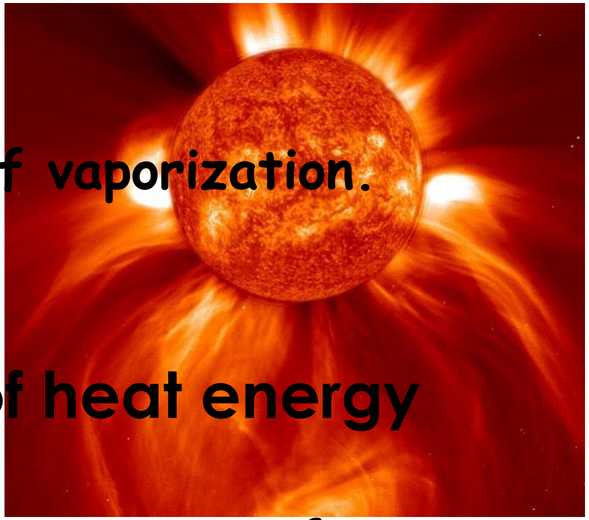
Acknowledgment for my UG and PG students

Evaporation



Can be defined as the process where liquid water is transformed into a gaseous state

THE TWO MAIN FACTORS AFFECTING EVAPORATION:



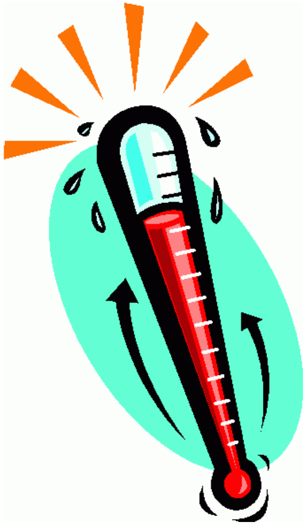
1) The supply of energy to provide latent heat of vaporization.

Solar radiation is the main source of heat energy

2) The ability to transport vapor away from evaporative surface.

depends on: wind velocity over the surface
specific humidity gradient in the air above it

FACTORS AFFECTING EVAPORATION



1- Temperature

When the temperature of water is increased, the water molecules gain more energy, move faster and escape at a faster rate. so we can conclude that “the higher the temperature the higher the rate of evaporation”.

2- Surface area

The rate of evaporation will be increased by bigger surface area.

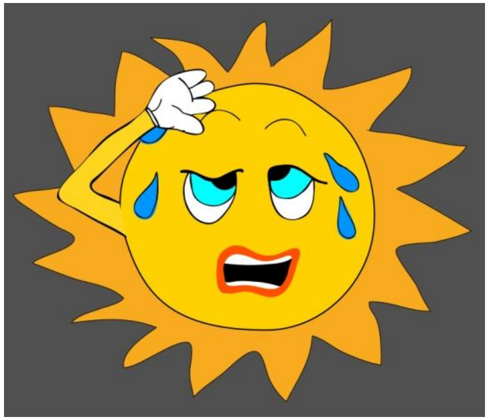
The greater the exposed surface, the faster the evaporation.

3- Wind

When evaporation takes place, the water vapor gathers above the water's surface.

The higher the wind speed, the higher the rate of evaporation.

4- Humidity



If water evaporates in an air-tight container, the space above the water is filled with more and more water vapor.

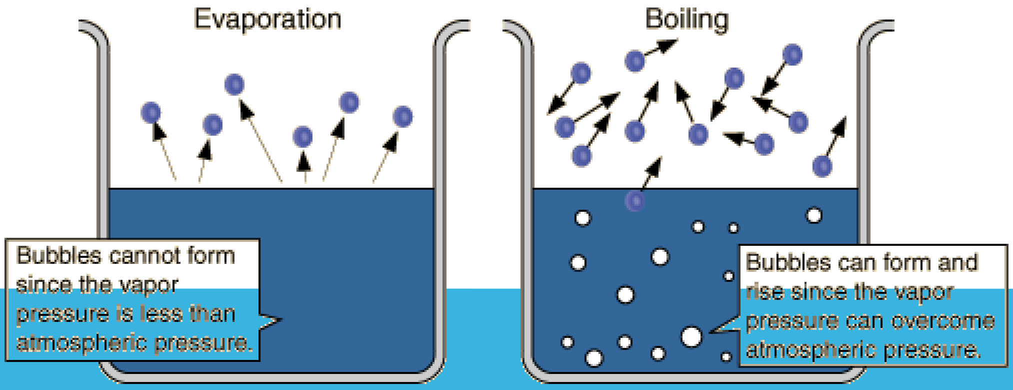
The higher the humidity the lower the rate of evaporation.

5- Density

The higher the density the lower the evaporation rate as the forces which connect the molecules together is stronger.

6- Vapor pressure

The evaporation of a liquid depends upon its vapor pressure, the higher the vapor pressure at a given temperature the faster the evaporation, other condition being equal.



Estimating Evaporation from Free Water Surfaces

1) EMPIRICAL Formulas

A. Meyer's Formula

B. Rohwer's Formula

2)Analytical Methods

A . Water Budget Method

B . Energy Budget Method

C. Mass Transfer (Aerodynamic) Methods

3) Combination of Mass Transfer and Energy Budget Method

4) Use of Evaporation Pans

Empirical Formulas

A large number of empirical equations are available to estimate evaporation using available meteorological data. e.g. USGS and USBR Formula:

$$E = 4.57T + 43.3$$

where:

E in cm/yr;

T is the mean annual temperature in °C.

Most of the available empirical equations for estimating lake evaporation are a Dalton type equation of the general form .e.g. Meyer's Formula, Rohwer's Formula

$$EL = K\, f(u)\,(ew - ea)$$

where:

EL = lake evaporation (mm/day)

ew = saturation vapour pressure at the water surface temperature (mm of mercury)

ea = actual vapour pressure of the overlying air at a specified height (mm of mercury)

f (u) = wind speed correction function

K = coefficient ,

ea is measured at the same height at which wind speed (u) is measured

Empirical Formulas

Mayer Equation;

Monthly evaporation from lakes or reservoirs can be computed using the empirical formula developed by Meyer (1915) but based on Dalton's Law (1802)(Harrold et al., 1986).

$$E = C(e_s - e_d)\left(1 + \frac{u_{25}}{10}\right) \quad (4.17)$$

where
- E = evaporation in inches/month
- e_s = saturation vapor pressure (inches of Hg) of air at the water temperature 1 foot deep
- e_d = actual vapor pressure (inches of Hg) of air = $e_{s\ (\text{air T})} \times \text{RH}$
- u_{25} = average wind velocity (mi/hr) at a height of 25 feet above the lake or surrounding land areas
- C = coefficient that equals 11 for small lakes and reservoirs and 15 for shallow ponds

Evaporation Pan

Class A Pan

Evaporation Pan Method, E = Kp.Ep

E = Evaporation Rate (mm/day)

Kp = Pan Coefficient

Ep = Measured Evaporation (mm/day)

Hook gauge evaporimeter

The Hook gauge evapori-meter measures the rate of evaporation by the change in level from a free water surface in a pan or tank.

The device consists of a sharp hook suspended from a micrometer cylinder, with the body of the device having arms which rest on the rim of a cylinder.

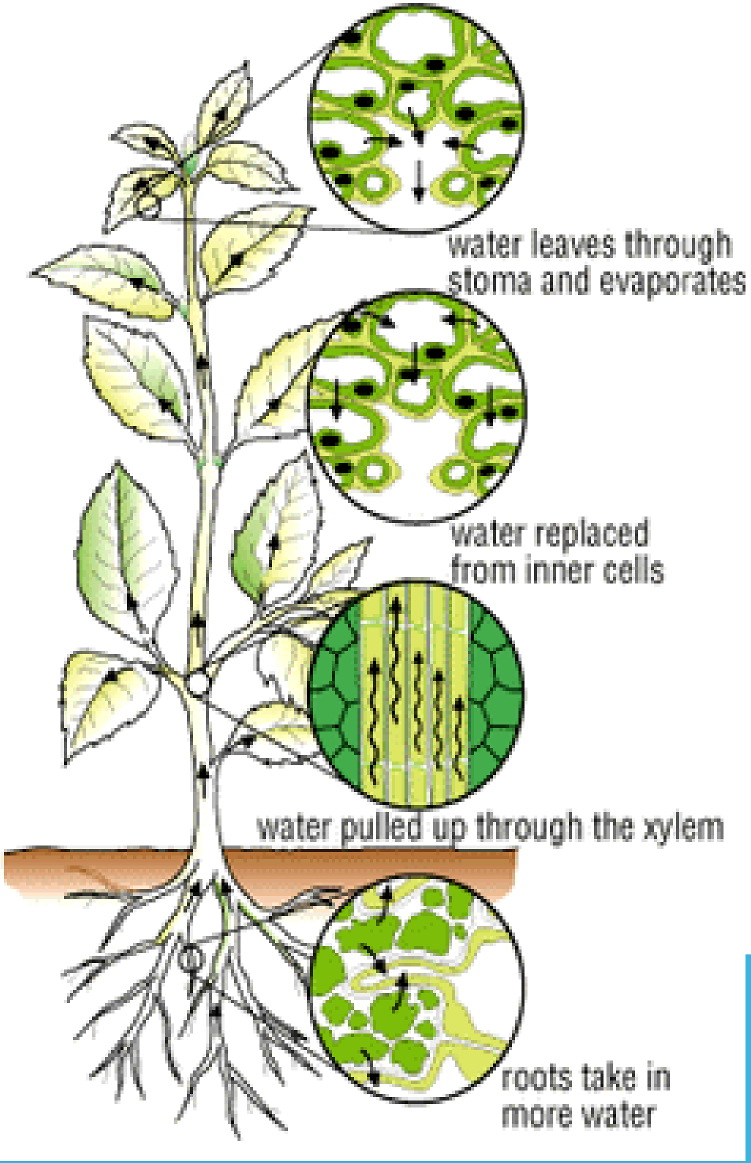
Different ways to measure evaporation :

Method	Reference	Equation
Combination group		
Priestley–Taylor	Stewart and Rouse (1976)	$E = \alpha \frac{s}{s+\gamma} \frac{Q_n - Q_x}{L\rho} \times 86.4$
deBruin–Keijman	deBruin and Keijman (1979)	$E = \frac{s}{0.85s + 0.63\gamma} \frac{(Q_n - Q_x)}{L\rho} \times 86.4$
Penman	Brutsaert (1982)	$E = \frac{s}{s+\gamma}\left(\frac{Q_n - Q_x}{L\rho}\right) \times 86.4 + \frac{\gamma}{s+\gamma}(0.26(0.5 + 0.54U_2)(e_s - e_a))$
Brutsaert–Stricker	Brutsaert and Stricker (1979)	$E = (2\alpha - 1)\left(\frac{s}{s+\gamma}\right)\left(\frac{Q_n - Q_x}{L\rho}\right) \times 86.4 - \frac{\gamma}{s+\gamma} 0.26(0.5 + 0.54U_2)(e_s - e_a)$
deBruin	deBruin (1978)	$E = 1.192\left(\frac{\alpha}{\alpha - 1}\right)\left(\frac{\gamma}{s+\gamma}\right)\frac{(2.9 + 2.1U_2)(e_s - e_a)}{L\rho} \times 86.4$
Solar radiation, temp. group		
Jensen–Haise	McGuinness and Bordne (1972)	$E = (0.014T_a - 0.37)(Q_s \times 3.523 \times 10^{-2})$
Makkink	McGuinness and Bordne (1972)	$E = \left(\left(52.6 \frac{s}{s+\gamma}\frac{Q_s}{L\rho}\right) - 0.12\right)$
Stephens–Stewart	McGuinness and Bordne (1972)	$E = (0.0082T_a - 0.19)(Q_s \times 3.495 \times 10^{-2})$
Dalton group		
Mass transfer	Harbeck et al. (1958)	$E = (NU_2(e_0 - e_a)) \times 10$
Ryan–Harleman	Rasmussen et al. (1995)	$E = \frac{(2.7(T_0 - T_a)^{0.333} + 3.1U_2)(e_0 - e_a)}{L\rho} \times 86.4$
Temp., day length group		
Blaney–Criddle	McGuinness and Bordne (1972)	$E = (0.0173T_a - 0.314) \times T_a \times (D \div D_{TA}) \times 25.4$
Hamon	Hamon (1961)	$E = 0.55\left(\frac{D}{12}\right)^2 \frac{SVD}{100}(25.4)$
Temperature group		
Papadakis	McGuinness and Bordne (1972)	$E = 0.5625(e_s\max - (e_s\min - 2))\left(\frac{10}{d}\right)$
Thornthwaite	Mather (1978)	$E = \left(1.6\left(\frac{10T_a}{I}\right)^{6.75\times10^{-7}I^3 - 7.71\times10^{-5}I^2 + 1.79\times10^{-2}I + 0.49}\right)\left(\frac{10}{d}\right)$

Transpiration

Is the process of water loss from plants through Stomata plant tissues

(Stomata:small openings found on the underside of leaves that are connected to vascular)



THE FACTORS AFFECTING TRANSPIRATION

1-vapour pressure .

2-temperture .

3-wind.

4-light intensity.

5-Characteristics of the plant.

MEASUREMENT OF EVAPOTRANSPIRATION

Lysimeters

Is a special watertight tank containing a block of soil and set in a field of growing plant .

It is required to measure the evaporation rate from a lake using Meyer equation and with the following data:

Air temperature = 23 ^{0}C

Mean vapor pressure = 10 mbar

Average wind speed at 18 m above the land surface = 18 m/s

Coefficient of speed equation = 0.3

E (mm/day) = 0.5 e_s (1- (R.H./100)) (1 + 0.0625 W_{8m})

e_s Saturated vapor pressure in mmHg

W_{8m} Wind speed in km/h at 8m above the ground

Calculate the evapotranspiration from a field near the in the previous question lake if the soil factor equals 0.70 and the crop factor equals 0.85.

Questions?

THANK YOU!