Evaporation

Evaporation is the process in which a liquid changes to the gaseous state at the free surface, below the boiling point through the transfer of heat energy.

The rate of evaporation is depended on the following :

(i)Vapour Pressure

$$E_L = C\,(e_w - e_a)$$

Where E_L = rate of evaporation (mm/day)

C = a constant

e_w = the saturation vapour pressure at the water temperature in mm of mercury

e_a = the actual vapour pressure in the air in mm of mercury

This equation is known as Dalton's law of evaporation after John Dalton (1802) Who first recognized this law. Evaporation continuous till $e_w = e_a$. If $e_w > e_a$ Condensation takes place

(ii) Temperature

The rate of evaporation increases with an increase in the water temperature.

(iii) Wind

The rate of evaporation increases with the wind speed up to a critical speed beyond which any further increase in the wind speed has no influence on the evaporation rate.

(iv) Atmospheric Pressure

A decrease in the barometric pressure , as in high altitudes, increases evaporation.

(v) Soluble Salts

When a solute is dissolved in water, the vapour pressure of the solution is less than that of pure water and hence causes reduction in the rate of evaporation. For example, under identical condition evaporation from sea water is about 2 – 3% less than the fresh water.

(vi) Heat Storage in Water Bodies

Deep water bodies have more heat storage than shallow ones.

Evaporimeters

The amount of water evaporated from a water Surface is estimated by the Following methods :

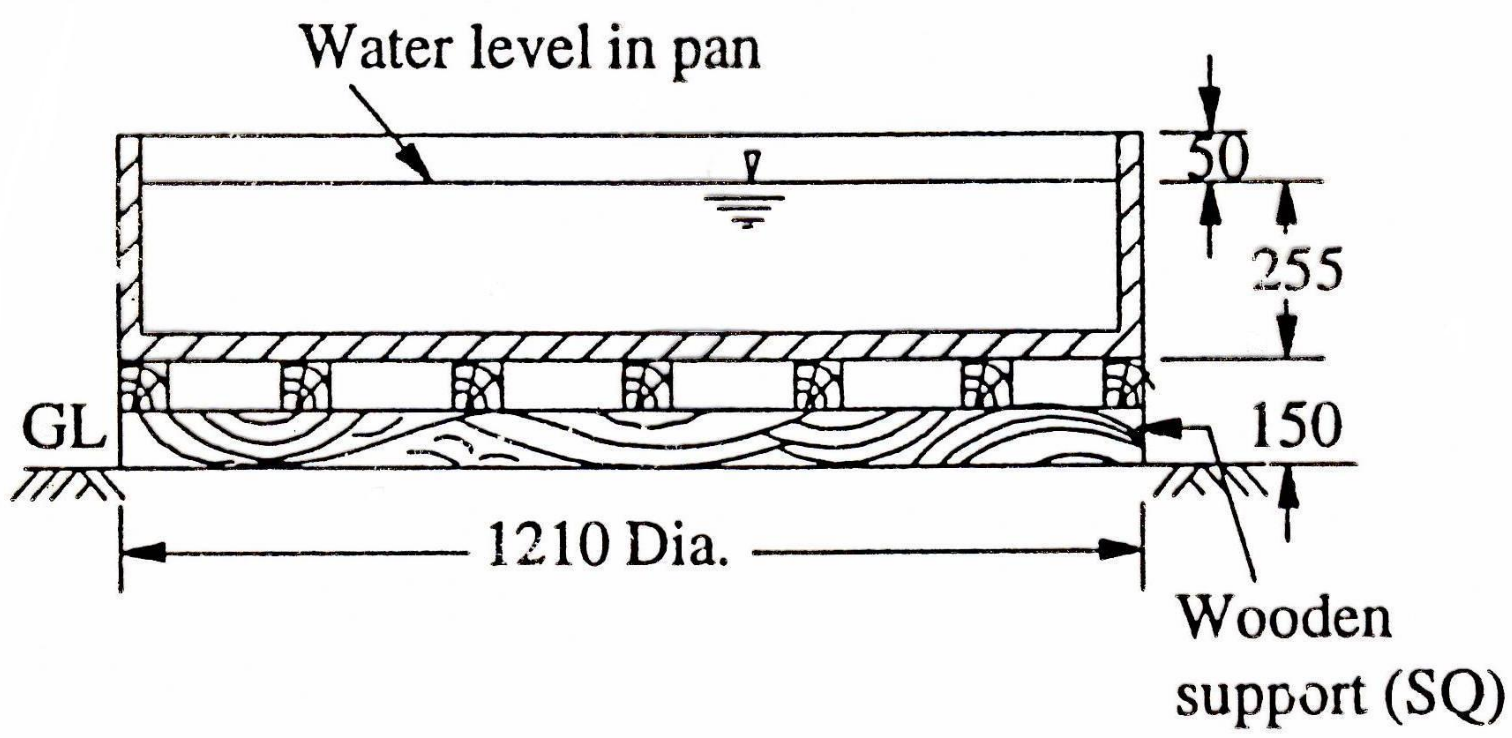
(i) using evaporimeter

(ii) empirical evaporation equations and

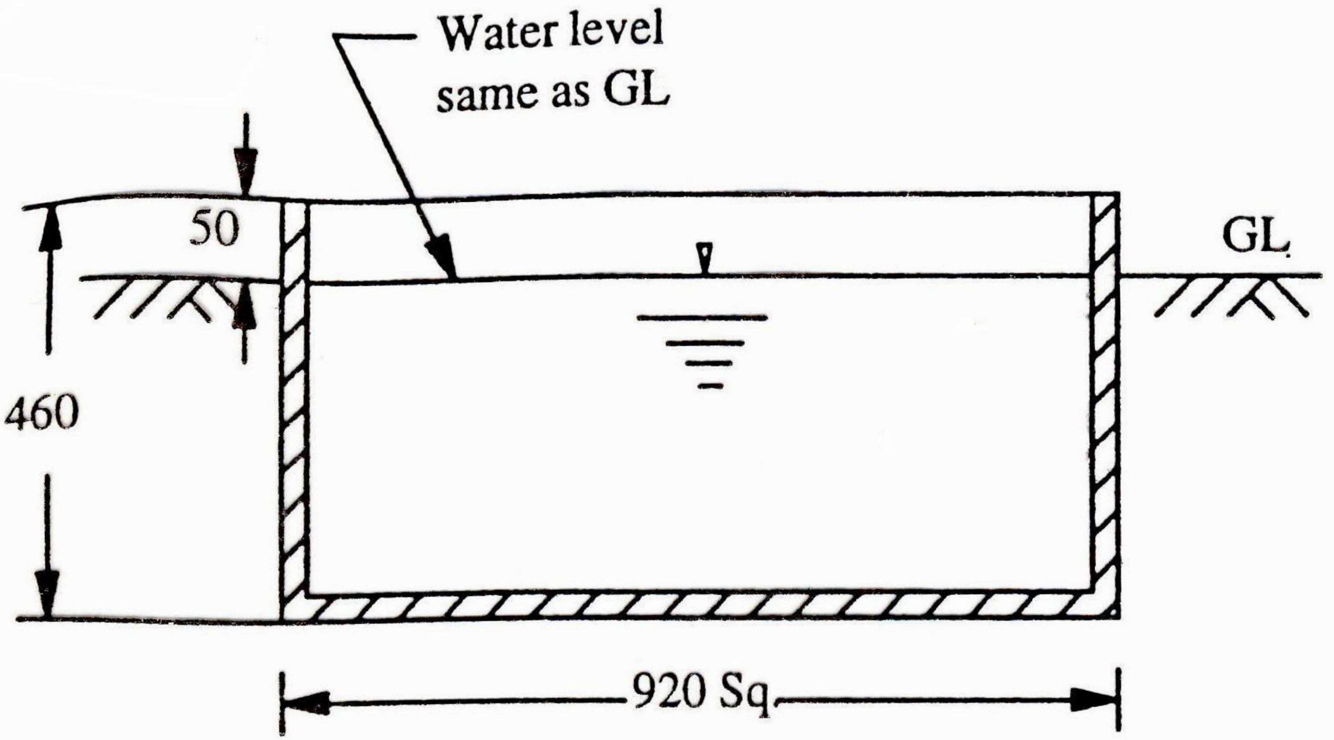
(iii) analytical methods

Types of Evaporimeters

Class A Evaporation Pan



Colorado Sunken Pan



US Geological Survey Floating Pan

Square pan 900 mm side and 450 mm depth supported by drum floats in the middle of a raft (4.25 m x 4.87 m) is set a float in a lake. The water level in the pan is kept at the same level as the lake leaving a rim of 75 mm.

Pan Coefficient Cp

Evaporation pan are not exact models of large reservoirs and have the following principle drawbacks :

1. They differ in the heat storing capacity and heat transfer from the sides and bottom. The sunken pan and floating pan aim to reduce this deficiency. As a result of this factor the evaporation from a pan depends to a certain extent on its size.
2. The height of the rim in an evaporation pan affects the wind action over the surface.
3. The heat transfer characteristics of the pan material is different from that of the reservoir.

Thus a coefficient is introduced as

Lake evaporation = C_p x pan evaporation

In which C_p = pan coefficient. The values of C_p in use for different pans are given in the following Table

VALUES OF PAN COEFFICIENT C_P

Sl. No.	Types of pan	Average value	Range
1.	Class A Land Pan	0.70	0.60-0.80
2.	Colorado Sunken Pan	0.78	0.75-0.86
3.	USGS Floating Pan	0.80	0.70-0.82

Evaporation Stations

The WMO recommends the minimum network of evaporimeter stations as Below.

1. Arid zones – one station for every 30,000 Km^2
2. Humid temperate climates – one station for every 50,000 Km^2, and
3. Cold regions – one station for every 100,000 Km^2.

Empirical evaporation Equations

Meyer's Formula (1915)

$$E_L = K_M (e_w - e_a) (1 + u_9/16)$$

In which, u_9 = monthly mean wind velocity in km/h at bout 9 m above ground and

K_M = coefficient accounting for various other factors with a value of 0.36 for large deep and 0.50 for small shallow waters.

Rohwer's Formula (1931)

$E_L = 0.771(1.465 - 0.000732\, P_a)\,(0.44 + 0.0733\, u_o)(e_w - e_a)$

P_a = mean barometric reading in mm of mercury

U_o = mean wind velocity in km/h at ground level, which can be taken to be the velocity at 0.6 m height above ground.

The wind velocity can be assumed to follow the 1/7 power law

$$U_h = C\, h^{1/7}$$

Where, U_h = wind velocity at a height h above the ground and

C = constant.

This equation can be used to determine the velocity at any desired level.

Example : A reservoir with a surface area of 250hectares had the following average values of parameters during a week : water temperature = 20^{o} C, relative humidity = 40% wind velocity at 1.0 m above ground = 16km/h. Estimate the average daily evaporation from the lake and volume of water Evaporated from the lake during that one week.

Solution :

e_w = 17.54 mm of Hg

e_a = 0.40 x 17.54 = 7.02 mm of Hg

u_9 = wind velocity at a height of 9.0 m above ground

u_1 = 16 km/h $\qquad$ u_9 = ?

$u_h = C (h)^{1/7}$

$u_h = C (1)^{1/7}$ = 16 km/h

$u_9/u_1 = C ((9)^{1/7}) / C ((1)^{1/7})$

$u_9 = u_1 (9)^{1/7}$

$= 16 (9)^{1/7}$

$= 21.9$ km/h

By Meyer's formula

$E = 0.36 (17.54 – 7.02) (1 + 21.9/16)$

$= 8.97$ mm/day

Evaporated volume in 7 days

$= 7 \times 8.97/1000 \times 250 \times 10000$

$= 157{,}000\ m^3$

Analytical Methods of Evaporation Estimation

The analytical methods for the determination of Lake evaporation can be broadly classified into three categories as :

1. Water – budget method.
2. Energy – balance method, and
3. Mass – transfer method

Water – Budget Method

$$P + V_{is} + V_{ig} + = V_{os} + V_{og} + E_L + \Delta S + T_L$$

Where,

P = daily evaporation

V_{is} = daily surface inflow into the lake

V_{ig} = daily groundwater inflow

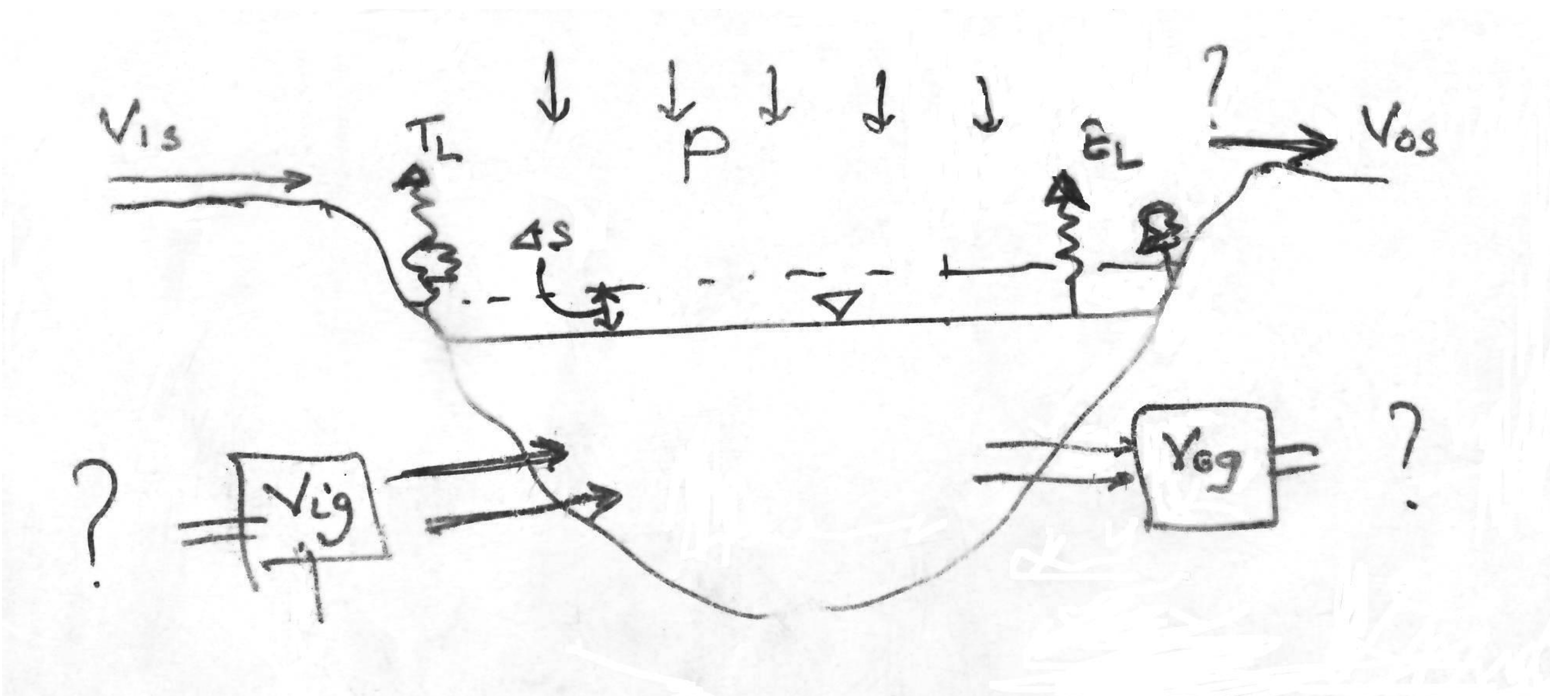
V_{os} = daily surface outflow from the lake

V_{og} = daily surface outflow

EL = daily lake evaporation

Δ S = increase in lake storage in a day

TL = daily transpiration loss



Energy – Budget Method

$$H_n = H_a + H_e + H_g + H_s + H_i$$

Where, H_n = net heat energy received by the water surface

$= H_c (1- r) - H_b$

$H_c (1 - r)$ = incoming solar radiation into a surface of reflection coefficient (albedo) r

H_b = back radiation (long wave) from water body

H_a = sensible heat transfer from water surface to air

H_e = heat energy used up in evaporation

$= \rho L E_L$ where ρ = density of water ,

L = latent heat of evaporation and

E_L = evaporation in mm

H_g = heat flux into the ground

H_s = heat stored in water body

H_i = net heat conducted out of the system by water flow (advected energy)

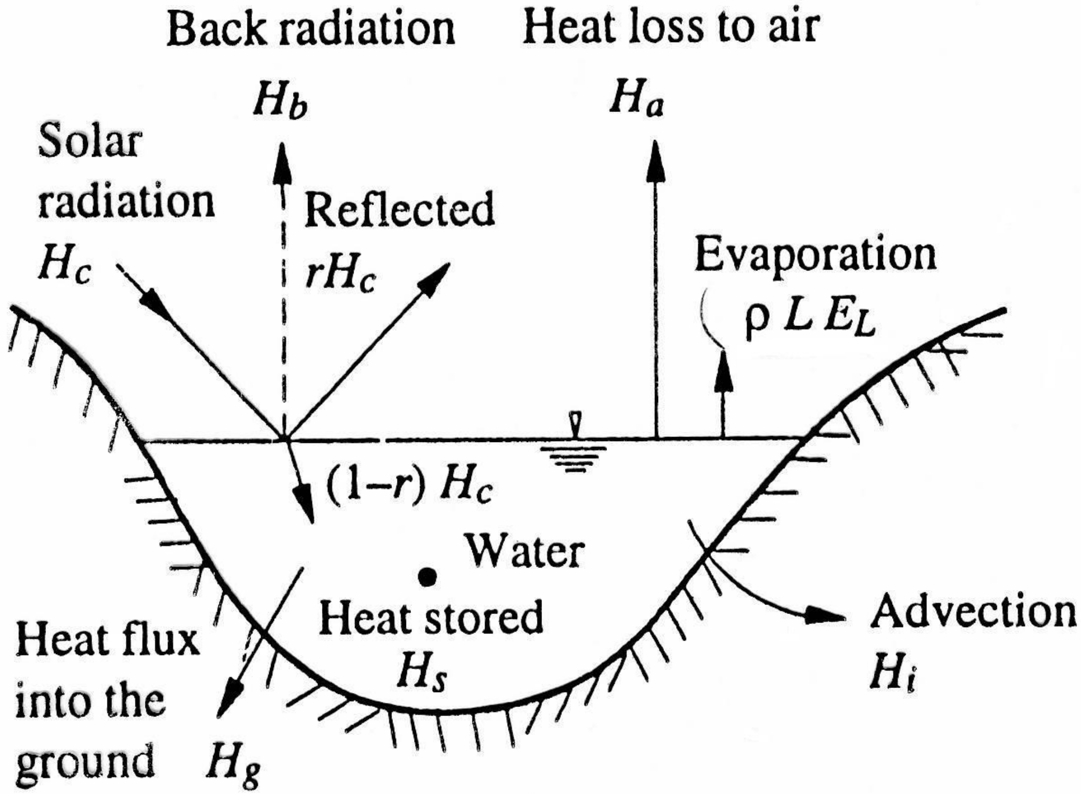


Fig. Energy balance in a water body