Chapter 16: Evaporation Process

Introduction

Evaporation is a fundamental process in the hydrological cycle, playing a critical role in the redistribution of water on the Earth's surface. In hydrology and water resources engineering, understanding evaporation is essential for estimating water losses from reservoirs, lakes, irrigation systems, and other open water bodies. Evaporation also impacts agricultural planning, dam design, and catchment area management. This chapter deals with the principles, factors affecting, measurement, and estimation methods of evaporation in detail.

16.1 Definition of Evaporation

Evaporation is the process by which water changes from liquid to vapor phase due to the absorption of energy (usually from solar radiation). It primarily occurs at the surface of water bodies and moist soils. The rate of evaporation depends on climatic conditions and surface characteristics.

16.2 Factors Affecting Evaporation

Several factors influence the rate of evaporation:

16.2.1 Solar Radiation

- **Primary energy source** for evaporation.
- Directly proportional to evaporation rate.
- Greater solar radiation increases the energy available for converting water to vapor.

16.2.2 Temperature

- Higher air and water temperatures accelerate evaporation.
- Warm air holds more moisture, enhancing the gradient for vapor movement.

16.2.3 Humidity

- Inversely related to evaporation.

- High relative humidity reduces the vapor pressure gradient between water surface and air.

16.2.4 Wind Speed

- Wind removes the saturated air layer near the water surface, maintaining a high vapor pressure gradient.
- Increases evaporation rate significantly in open water bodies.

16.2.5 Atmospheric Pressure

- Lower atmospheric pressure reduces the boiling point of water, thereby increasing evaporation.

16.2.6 Water Quality

- Impurities and dissolved salts can alter evaporation rates.
- Saline water evaporates slower due to reduced vapor pressure.

16.2.7 Surface Area

- A larger exposed surface area leads to higher total evaporation.

16.3 Measurement of Evaporation

Evaporation can be measured using direct or indirect methods.

16.3.1 Class A Evaporation Pan

- **Standard instrument** used in hydrological studies.
- Made of galvanized iron (diameter = 1207 mm, depth = 255 mm).
- Installed in an open area above ground surface.
- Daily evaporation is measured by change in water level.

Limitations:

- Evaporation from a pan is generally more than from a natural water body due to greater exposure and heating.

16.3.2 ISI Standard Pan (Modified Class A Pan)

- Used in India; similar to Class A pan but placed within a square enclosure of bricks with grass.

16.3.3 Floating Pan

- Placed directly on the water surface of a reservoir.
- More accurate representation of actual conditions.

16.3.4 Lysimeter

- Measures evaporation from soil and plants (evapotranspiration).

- Used for agricultural and watershed hydrology studies.

16.3.5 Atmometer

- Also called an **evaporimeter**.
- Measures evaporation from a wet porous surface (porous cup or disc).

16.4 Estimation of Evaporation

When direct measurement is not feasible, evaporation is estimated using empirical or analytical formulas.

16.4.1 Water Budget Method

Based on the continuity equation:

$E = I + P - O - \Delta S$ Where,

- **E** = Evaporation
- **I** = Inflow
- **P** = Precipitation
- **O** = Outflow
- **ΔS** = Change in storage

Used for large lakes or reservoirs where inflow, outflow, and storage can be monitored.

16.4.2 Energy Budget Method

- Based on the principle of conservation of energy.
- Calculates evaporation from net radiation input and energy used for other processes.

$E = (R_n - H - G)/\lambda$ Where,

- **E** = Evaporation
- **Rn** = Net radiation
- **H** = Sensible heat transfer
- **G** = Ground heat flux
- **λ** = Latent heat of vaporization

16.4.3 Penman Equation

A combination method that includes both energy and aerodynamic components:

$$E = \frac{\Delta R_n + \gamma f(u)(e_s - e_a)}{\Delta + \gamma}$$

Where:

- **Δ** = Slope of vapor pressure curve
- **Rn** = Net radiation
- **γ** = Psychrometric constant
- **f(u)** = Wind function
- **(es - ea)** = Vapor pressure deficit

16.4.4 Empirical Formulas

a) Mayer's Formula:

$$E = K(e_w - e_a)(1 + u_9/16)$$

Where:

- **E** = Evaporation (mm/day)
- **e_w** = Saturated vapor pressure at water temperature
- **e_a** = Actual vapor pressure of air
- **u_9** = Wind speed at 9 m height
- **K** = Coefficient (depends on location and season)

b) Rohwer's Equation:

$$E = 0.771(e_w - e_a)(1 + 0.536u)$$

Used where wind speed and vapor pressure data are available.

16.5 Evaporation Reduction Techniques

In regions with water scarcity, it is crucial to reduce evaporation losses, especially from reservoirs and canals.

16.5.1 Physical Methods

- **Floating covers**: Using plastic sheets or hexagonal modular covers.
- **Shading**: Trees or artificial covers near small tanks.

16.5.2 Chemical Methods

- **Monomolecular films**: Use of long-chain alcohols like hexadecanol to form a thin layer on the water surface.
- Reduces evaporation by suppressing surface turbulence.

16.5.3 Structural Measures

- **Deepening of tanks**: Reduces surface area.
- **Reservoir lining**: Minimizes seepage and evaporation losses.
- **Wind breaks**: Planting rows of trees to reduce wind velocity.

16.6 Evapotranspiration

Though related, evapotranspiration differs from pure evaporation.

16.6.1 Definition

Evapotranspiration is the combined loss of water from soil (evaporation) and vegetation (transpiration).

16.6.2 Potential Evapotranspiration (PET)

Maximum possible evapotranspiration under adequate water supply.

16.6.3 Actual Evapotranspiration (AET)

Actual observed evapotranspiration under field conditions.

16.6.4 Estimation Methods

- **Blaney–Criddle method**
- **Thornthwaite method**
- **Hargreaves method**
- **Penman–Monteith method**

These methods use climatic data such as temperature, radiation, and humidity.

16.7 Application in Water Resources Engineering

Evaporation studies are essential for:

- **Reservoir design**: To assess annual losses.
- **Irrigation planning**: To estimate crop water requirement.
- **Catchment modeling**: For accurate water balance computation.
- **Drought analysis**: To understand losses during dry periods.
- **Climate impact studies**: To model future water availability.
