RAMA UNIVERSITY

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FACULTY OF MEDICAL SCIENCES

SOIL WATER MOVEMENT

Water is a highly dynamic component in soil system. It moves in all three phases : solid, liquid and vapour. In saturated or flooded situation, water moves in liquid phase, while in a partially dry or unsaturated soil, it moves in both liquid and vapour phases. Movement in solid phase as commonly occur in frozen soil is also believed to take place closer to clay surface.

The flow of liquid water is due to a gradient in matric potential from one soil zone to another. The direction of flow is from a zone of higher matric potential to one of lower matric moisture potential. Saturated flow takes place when the soil pores are completely filled with water. Unsaturated flow occurs when the pores even in the wettest soil zones are only partially filled with water. In each case, moisture flow is due to energy - soil relationships.

Concept of Flow

Water movement through soil is proportional to the product of the driving force and the conductivity of soil for water.

$$Q = c\,DK$$

Q = Flow velocity C = Proportional factor

D = Driving force K = Conductivity of the medium.

This relation holds true for heat transfer and for flow of electricity as well as for water movement.

The driving force in case of water is a pressure gradient. Water moves from a position of high pressure to a position of low pressure in both saturated and unsaturated conditions, including in vapour state.

$$Q = cKAP / L$$

Where Q = Flow velocity ($L^3 T^{-1}$)

C = Dimensionless proportionality

constant K = Hydraulic conductivity

($M^{-1}L^3T$)

A = Cross sectional area (L^2) of the porous

medium P = Pressure gradient ($ML^{-1}T^{-2}$).

Unsaturated Flow

Through large and continuous pores rapid water movement occurs under saturated condition. But in unsaturated condition, only micro pores would accommodate water and allow the water to move slowly. The relationship between matric potential and hydraulic conductivity governs the water movement under unsaturated condition.

Saturation flow occurs at or near zero potential, while most of the unsaturated flow occurs at a potential of -0.1 bar or below. Zero potential, the hydraulic conductivity is 1000 times greater, as compared to the potential that characterize the typical unsaturated flow.

Under saturated condition (high potential levels) hydraulic conductivity is higher in sand than in clay. Under unsaturated condition (less potential values) hydraulic conductivity is higher in clay than in sand.

In both saturated and unsaturated conditions, flow is majorily governed by hydraulic conductivity of the soil and the diving force. But the diving force in unsaturated condition is primarily the matric potential gradient or the difference in matric potential of the moist soil areas and the drier areas in to which the water is moving. Movement will be from a zone of thick moisture films (higher matric potential e.g. -0.001 MPa) to one of the films (lower matric potential e.g. -0.1MPa).

SATURATED FLOW	UNSATURATED FLOW
Most of the pores are filled with water	Many pores are not filled with water
Soil water will be at zero bar tension	Soil water will be at higher tension
Driving force is positive pressure potential	Driving force is negative pressure potential
Flux is in the direction & proportional to gradient $K = \frac{\Delta H}{\Delta X} X \frac{At}{Q}$	Flux is in the direction & proportional to gradient - $K = \frac{\Delta H}{\Delta X} X \frac{At}{Q}$
Most water is not available to plants under saturated condition	Plant will take water mostly held under unsaturated condition

Vapour movement in soils

Two types of water movement occur in soils, internal and external. Internal movement takes place within the soil i.e., in soil pores. External movement occurs at the land surface and the water vapour is lost by evaporation.

Water vapour moves from one point to another within the soil in response to difference in vapour pressure. Thus, water vapor moves from high vapour pressure (under saturated condition where in air is nearly 100% saturated with water vapour) zone to lower vapor pressure zone (dry soil). Similarly, if the temperature of one part of the uniformly moist soil is lowered, the vapor pressure will decrease and water vapor will tend to move toward t he cooler part). Heating will have the opposite effect.

As the quantity of water vapor is small, its movement in soil is not of much practical significance. However, in drought situation, its movement may be of considerable significance especially in supplying moisture to drought resistant desert plants.

The permeability of soil for water vapour is proportional to the volume of water free pore space, regardless of size of pores. Free path plays significant role rather than size of pores.

Saturated flow: Following heavy rain or irrigation application, pores of soil are often filled entirely with water. This is said to be the saturated condition of the soil.

The flow of water under saturated condition is determined by hydraulic force driving the water through the soil (commonly gravity) and the hydra ulic conductivity, or the ease with which the soil pores permit water movement.

$$V = Kf$$

V = Volume of water move per unit time. f = water moving force K = Hydraulic conductivity.

The driving force, known as hydraulic gradient, is the difference in height of water above and below the soil column.

Besides, downward flow of water in saturated condition, hydraulic force also will cause horizontal and upward flow. This flow is usually not quite rapid, because the force of gravity does not assist horizontal flow and hinders upward flow. Downward flow is more in coarse textured soils, whereas horizontal move is equally significant in fine textured soils. The law of "poiseuille" express the f low of water

$$Q = PpR^4 / SLZ$$

Where Q = Volume of flow cc/sec; P = Pressure difference dynes/cm ^{2}

R = Radius of the tube, cm ? = Length of

tube Z = Viscosity of liquid dynes – Sec/cm ^{2}

(poises)

According to Poiseuille'S law, the rate of flow of a liquid through a narrow tube is proportional to the fourth power of the radius of the tube and to the pressure; and inversely proportional to the viscosity of the liquid and the length of the tube. The rate of saturated flow in soils of various texture is in the sequence :

Sand > Loam > Clay

Viscosity of water increases more than one percent with each one degree – centigrade drop in the temperature.

The law of "Darcy" states that the velocity of flow of a liquid through a porous medium is proportional to the force causing the flow and to the hydraulic conductivity of the medium.

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Infiltration : Infiltration is the entry of water at the soil air interface due to sorption and vertical flow of water though the soil profile.

This process is of gr eat practical significance, as it determines how much of rain storm or irrigation water enters the soil and how much over flows the land surface as run -off.

Irrespective of soil texture, the infiltration rate in a dry soil would be high, initially and the infiltration rate reduces exponentially with time and attains a steady rate after a long lapse of time. It is expressed as millimeters per hour. Infiltrate rate is high and constant in non- swelling clay soil i.e., laterite soils.

Percolation : The down ward movement of water through soil. Percolation occurs when the water is under pressure or when the tension is smaller than about ½ atmosphere or when the hydraulic gradient of the order of 1.0 or less