B.Sc. Botany 3rd Year
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Water potential

Water potential term was coined by Slatyer and Taylor (1960). It is modern term which is used in place of DPD. The movement of water in plants cannot be accurately explained in terms of difference in concentration or in other linear expression.

The best way to express spontaneous movement of water from one region to another is in terms of the difference of free energy of water between two regions (from higher free energy level to lower free energy level).

According to principles of thermodynamics, every components of system is having definite amount of free energy which is measure of potential work which the system can do. Water Potential is the difference in the free energy or chemical potential per unit molar volume of water in system and that of pure water at the same temperature and pressure.

It is represented by Greek letter or the value of is measured in bars, pascals or atmospheres. Water always moves from the area of high water potential to the area of low water potential. Water potential of pure water at normal temperature and pressure is zero. This value is considered to be the highest. The presence of solid particles reduces the free energy of water and decreases the water potential. Therefore, water potential of a solution is always less than zero or it has negative value.

Water potential is the potential energy of water per unit volume relative to pure water in reference conditions. Water potential combines various water movement-related potential forces which may work in parallel or opposition to one another. Many different elements might be active at once in complicated biological systems. For instance, the potential (negative vector) is decreased when solutes are added, and the potential (positive vector) is increased when pressure is increased.

Water potential is defined as the potential energy of water in the system to pure water when the pressure and temperature are held constant. The ability of water molecules to flow freely inside a given environment or system can also be measured using water potential. It is represented by the Greek letter Psi (Ψ) and is calculated in kilopascals (kPa).

Water potential is always negative and rises as high as pure water at atmospheric pressure, which equals zero. The more solutes there are in dirty water or water that contains solutes, the more negative Psi (Ψ) gets because the solute particles would attract the molecules of water and limit their ability to move freely.

Water Potential Gradient

The difference between the water potentials of two liquids is known as the water potential gradient. Water potential is the ability of water to travel between two locations because of variations in pressure, dissolved solutes, and other factors. The rate of osmosis is directly influenced by the water potential gradient between two solutions; the greater the difference, the faster osmosis advances from higher to lower water potential.

Water Potential Formula and Components

The following formula is used to calculate water potential:

$$\mathbf{\Psi = \Psi_s + \Psi_p + \Psi_g + \Psi_m}$$

However, it is usually shortened into the following formula:

$$\mathbf{\Psi = \Psi_s + \Psi_p}$$

Here, Ψ_s represents solute potential, Ψ_p represents pressure potential, Ψ_g represents gravitational potential, and Ψ_m represents the matrix potential or matric potential.

Solute Potential (Ψ_s)

Osmotic potential, also known as solute potential, is the amount by which the presence of a solute in pure water reduces the water potential. The free mobility of the water molecules decreases when solutes are introduced to pure water.

Since pure water has a zero solute potential, the potential of solute is either negative or less than zero. It is shown by the symbol Ψ_s. At atmospheric pressure, $\Psi_w = \Psi_s$.

Pressure Potential (Ψ_p)

The water potential increases when a pressure greater than atmospheric pressure is exerted on the solution. A cell becomes turgid when its internal pressure increases, which also increases its turgor pressure. The symbol for this is (Ψ_p). It is almost zero in plasmolysed cells. It can be harmful in the xylem vessels, where water is drawn by an open system and creates a tension of roughly –2 MPa on the surface of a plant leaf.

Gravitational Potential (Ψ_g)

It results from the gravitational force of attraction on the water potential. It is dependent on the acceleration brought on by gravity, the height of the water above the fixed value, and the density of the water. Since this gravitational potential is so small, it is usually ignored.

Matrix Potential (Ψ_m)

Matrix represents things that are on the surface, such as soil particles, cell walls, and protoplasm. Matrix potential results from the intermolecular interactions and H-bonds assisting in the bonding of water to the cytoplasm and cell wall. The matrix potential is usually ignored in plant cells and tissues because it has little effect on osmosis. The matrix potential always has a negative value. It is written as Ψ_m.

Dry seeds have significant matrix potential. If it is considered, the equation would be $\Psi_w = \Psi_s + \Psi_p + \Psi_m$.

Significance of Water Potential

One method for describing the transport of water from a region with high to low water free energy is water potential. This idea helps in the explanation of how water is capable of defying gravity and moving freely. Water potential explains how water travels via osmosis, capillary action, and against gravity throughout the body of plants.

Life, as we know, would not exist without the continuous movement of water. Plants can carry out photosynthesis due to the water. The food chains that are sustained by metabolism at the base would not exist without water potential. There would also be no known biodiversity without water potential.

Factors Affecting Water Potential

In plants, the main factors which influence the water potential are pressure, concentration and gravity. The sum of these components is as follows –

$\Psi = \Psi_s + \Psi_p + \Psi_g$

Ψ_s denotes the effects of solutes, Ψ_p denotes the effects of pressure and Ψ_g denotes the effects of gravity on the free energy of water.

Effect of solutes on water potential

The solute potential or the osmotic potential indicates the effect of the dissolved solutes on water potential. The solutes reduce the free energy of water by the dilution of water, which mainly is an entropy effect. In other words, combining solutes and water causes an increase

in the entropy or disorder of the system and hence decreases the free energy. This indicates that the osmotic potential is independent of the particular nature of the solute.

Effect of pressure on water potential

The pressure potential is the effect of the hydrostatic pressure on water's free energy. The positive pressure increases the water potential, while the negative pressure decreases it. Both negative and positive pressure take place in plants. In the cells, the positive hydrostatic pressure is called turgor pressure. The negative hydrostatic pressure that develops in the xylem conduits frequently is tension.

Effect of Gravity on water potential

The factor of gravity causes water to move downwards till the gravitational force is conflicted by an equal antagonistic force. This gravitational potential relies on the height of water over the reference state water, the water density and the acceleration due to gravity. Symbolically, it is as follows –

$\Psi_g = \rho_w$ gh (value of ρ_wg is 0.01 MPa m^{-1})

The gravitational factor (Ψ_g) generally is left out in criteria of water transport at the level of cells, as variations in this factor among adjacent cells are negligible in comparison with differences in the pressure potential and osmotic potential.