Hydraulic Discontinuity on SWAP model

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1. Introduction

Salinization is one of the most important issues to be solved at the agricultural land, which has high groundwater table. Salinization would occur the place where water connection between groundwater and surface water. Therefore the countermeasure to cope with it is 1) reduce of groundwater level, 2) cutting off the connection of surface and groundwater, 3) flushing the saline of ground surface. Here we focused on the hydraulic discontinuity of liquid phase water in gravel and sand layer to control saline movement. Hydraulic continuity is the condition of that soil water in liquid phase transmit pressure in any direction, i.e., soil water shows hydrostatic pressure profile in static.

Kawakami (1997) suggested that coarse soil has threshold height of capillarity. Gurr, et al (1952) and Nakano (1972) showed threshold water content to control the movement of solute in coarse soils. They considered that, in some dry condition, nor has enough liquid water to connect with each pore, water moves accompanied with phase transition, hence solute stayed out even in thermo-gradient condition.

Here we investigated the importance of gravel layer to reduce evaporation. As a first step, we studied on liquid water movement in unsaturated condition, and consider the application of hydraulic discontinuity onto saline problematic area (see **Figure 1**).

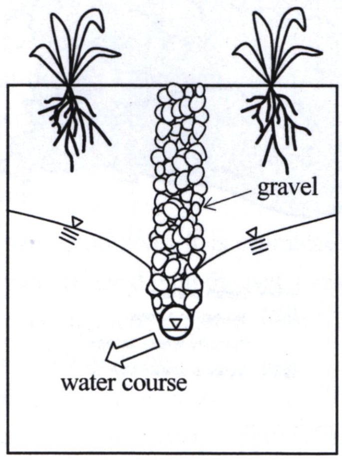

Figure 1 Vertical cross section of pipe-gravel drain

2. Material and method

Experimental apparatus are show in **Figure 2**. The materials of these experiments were the glass beads in 24 mm diameter (named pinpoint pressure measurement, PPM). Column experiment had carried out under various water level, in thermo controlled Laboratory (=20°C). Density of the glass beads was 2.50 g cm^{-3}. The unique point of these experiments was direct measurement of water pressure of pendular ring using hypodermic needle.

The initial condition was fully saturated. The top boundary condition was air pressure and covered plastic film to minimize evaporation. Lower boundary one was defined by water level controller.

3. Result and discussion

Figure 3 shows the time series of pressure head of liquid water under the various water levels. In every measured point, pressure head indicated groundwater level, in which water pressure was hydrostatic profile, until threshold point under the drying condition. In

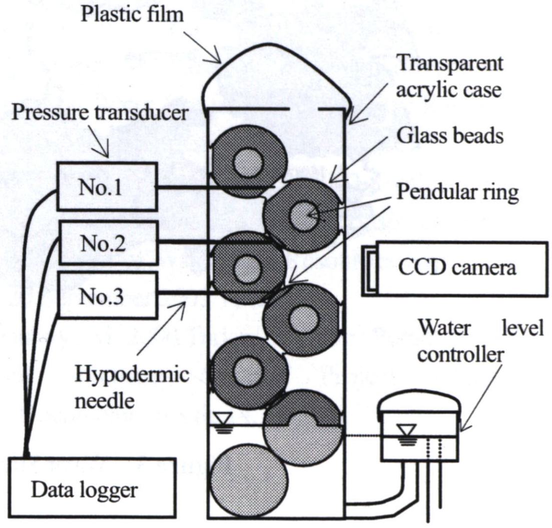

Figure 2 Schematic diagram of pinpoint pressure measurement (PPM) device

each measured points, pressure head showed almost constant value (= -1.5cm). In this condition, liquid water remained at contact points of glass beads, and formed catenoid shaped pendular ring. Pressure of pendular rings are not depends on groundwater level, nor to transmit any water pressure (Bear and Bachmat, 1991). We define independent condition as hydraulic discontinuity (Aoda, 2004). Therefore, water pressure p_c was written as:

$$p_c = \sigma\left(\frac{1}{r_1} + \frac{1}{r_2}\right) \neq \rho g h . \qquad (1)$$

Where σ is surface tension of liquid water (=72.75 $\times 10^{-3}$ N m^{-1}), r_1 and r_2 are principle radii of curvature of air-water interface of pendular ring (positive convex, and negative concave; r_1= 2.87 $\times 10^{-3}$ m, r_2= -0.44 $\times 10^{-3}$ m, respectively), ρ is density of liquid water, g is acceleration due to gravity and h is height from free water surface (positive upward).

4. Numerical Approach

Water flow in unsaturated soil-root system would be described as:

$$C(\psi)\frac{\partial \psi}{\partial t} = \frac{\partial}{\partial z}\left[K(\psi)\left(\frac{\partial \psi}{\partial z} + 1\right)\right] - S(\psi) . \qquad (2)$$

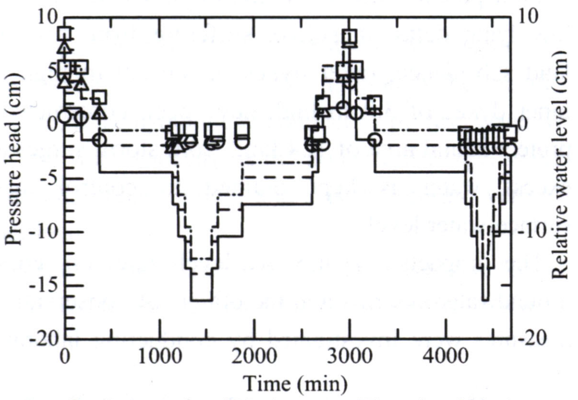

Figure 3 Time series of pressure head of liquid water under various water levels

where C (=dθ/dψ) is specific water capacity and is a differential soil water characteristic curve, t is time (day) and S is macroscopic soil water extraction rate by plant roots (cm^3 cm^{-3} d^{-1}), ψ is pressure head (= $p/\rho g$)(cm) and K is unsaturated hydraulic conductivity (cm d^{-1}).

For the numerical simulation, especially in unsaturated condition, relationship between soil and water is the most important. Effective saturation is represented as (van Genuchten, 1980):

$$Se = \frac{\theta - \theta_r}{\theta_S - \theta_r} = \left[1 + (\alpha\psi)^n\right]^{-m} . \qquad (3)$$

Where Se is effective saturation, θ is volumetric water content (cm^3 cm^{-3}), θ_C is critical water content at the condition of hydraulic discontinuity, and consists of pendular rings and adsorbed water films, and α, n, m are the parameters. If one used equation (3), one is not able to present hydraulic discontinuity. Therefore effective saturation would be as:

$$Se = \frac{\theta - \theta_C}{\theta_S - \theta_C} = \left[1 + (\alpha\psi)^n\right]^{-m} . \qquad (4)$$

Equation (4) would able to represent the domain where water moves in liquid phase, and able to classify the water phases, liquid or vapor. SWAP model has several options to select as lower boundary condition (Dam, et al., 2000). The hydraulic discontinuity would be applicable to simulate water and solute movement onto problematic area to control salinity.

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