Periodical water supply effect on Zero Flux Plane (ZFP) movement; in unsaturated soil with and without salt

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1. Introduction:

Zero Flux plane ZFP method is one of the promising techniques that can be used in different applications concerning water and solute movement in soil. Two laboratory experiments with simulations have been conducted to study the effect of periodical water supply on ZFP progress in unsaturated soil. First experiment was done to understand and analyze ZFP behavior and movement in Andisol, Tachikawa loam soil, under regular water supply effect. The second experiment was performed to recognize and evaluate the effect of cycling water supply on movement of both ZFP and salt concentrated layer. Analysis of simulation by using Hydrus-1D has been carried out to check the potentiality of detecting of the zero flux plan (ZFP) in unsaturated zone and the possibility of tracing ZFP movement under the condition of periodical water supply.

2. Materials and tools

The soil used in this experiment is Andisol, Tachikawa loam soil, the bulk density was 0.43 g/cm^3.The water content was 128% and 138%. The model used in this study is Hydrus-1D. It is a Microsoft windows based modeling environment for analysis of water flow and solute transport in variably saturated porous media. It includes the two-dimensional finite element model for simulating flow and solute transport in variably saturated media.

3. Method

3.1 Experiments: Two laboratory experiments have been conducted to examine periodical water supply effect on Zero Flux Plane (ZFP) movement; in unsaturated soil with and without salt. For the first experiment, a column with 20 acrylic rings with 4 cm height and 7.5 cm diameter, have been used. The total length is 80cm. Tachikawa loam soil, was packed into the column with initial water content equal to 128%. Seepage face to the bottom and atmospheric face at the top have been implemented. The experiment was carried out for one month .The rate of periodical water supply was 10 mm/3day whereas evaporation rate was estimated by 1.2 mm/day. Total potential and temperature have been measured by tensiometers and thermo couples respectively. Eighth transducers have been fixed to the soil column at distances 2, 6, 14, 22, 30, 38, 54, 74 cm from the soil surface.

The second experiment was performed to recognize and evaluate the effect of cycling water supply on movement of both ZFP and salt concentrated layer. The experiment was done for 5 days. Two columns were used, each of 10 acrylic rings with 4 cm height and 7.5 cm diameter. The total length of each is 40 cm. Tachikawa loam soil, was packed into each column. The lower part of soil column, 10cm height, was mixed with salt, sodium chloride. Salt weight was estimated as 10% of dry 10 cm soil weight, 19 gm. The initial water content was 138%. Seepage face at the bottom whereas the top end is exposed to electric light, 150w, 40 cm apart, as a thermal source, to produce evaporation. A separate experiment was performed to estimate the evaporation rate under the same condition. The evaporation rate was found to be 10 mm/day. Sprinkler periodical water was provided to soil surface. The rate of supplying water was 6 mm/12hours and 12mm/12h for both columns respectively. Both drainage and evaporation occurred simultaneously. Total potential and temperature have been measured by tensiometers and thermo couples respectively. Six transducers have been fixed to the soil column at distances 2, 6, 10, 18, 29, 31cm from the soil surface.

3.2 Simulation: Simulation for the first periodical water supply was performed to evaluate the experimental results. The numerical model used for that was Hydrus-ID. The boundary conditions, nodes distribution, geometry and finite element mesh are shown in Figure 1. The soil type, the evaporation rate, water supply rate and water flow parameters is shown in table 1

Soil Type	E.	Water supply	Total Period	(θr)	(θs)	(n)	(α)	Ks
Andosl, Tachikawa loam soil	1.2 mm/3day	10mm/12h	30 ays	0.62	0.77	0.02	3.6	179.7

Table 1 The features of soils used in simulation(θr) Residual soil water content (θs) Saturated soil water content (E Evaporation.)
(n), (α) Parameters in soil water retention function (K_s cm/day) saturated Hydraulic conductivity

4. Results and discussion

The purpose of periodical water supply experiment is to observe and analyze ZFP movement under regular water providing condition, and to compare the experimental results with numerical ones obtained by Hrdrus-

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1D. Fig. 2 explains total potential lines during for first cycle, 3 days, of the experiment. We can observe ZFP easily. Fig. 3 demonstrates the results of the same cycle but numerically where we can detect ZFP as well. At the end of experiment the soil start to be wet and approach to saturated condition. ZFP can be detected in both figures. A comparison between total potential measured by experiment and simulation can be realized from Fig. 2 and Fig. 3 . There is a good agreement between them. Fig 4 illustrates ZFP movement during the whole experiment time. We can observe that experimental ZFP movement rate is slower than simulated ZFP movement rate. Experimental ZFP reached 30 cm depth after almost 3 days while Simulated ZFP reached same depth after nearly 1 day. The maximum ZFP depth is 30 cm for both experiment and simulation. ZFP vanish suddenly at 30 cm depth and all soil water moves upward.

The assessment of the effect of periodical water supply on movement of both ZFP and salt concentrated soil layer were examined by second experiment. Fig 5 and Fig 6 illustrate the total potential lines for second cycle, 12 hours period, for both 6mm/12h and 12mm/12h experiments. ZFP can be observed for both column at 10cm and 20 cm depths respectively. The maximum ZFP obtained for both columns was 10 cm and 18cm. correspondingly. The salt concentration distribution is shown in Fig.7 where 19 gm of sodium chloride was mixed with lower part of soil, 10cm, at the beginning of the experiment. It can be observed that salt did not accumulate to soil surface. Slight movement of salt, about 5 cm up, could be seen from the figure. The experiment succeeded to retain high salt concentration lower ZFP and this is turn prohibited the salt accumulation on the soil surface.

5. Conclusions: ZFP depths could be observed and monitored experimentally and numerically, the maximum depth of ZFP calculated for first experiment numerically and experimentally was almost same, about 30 cm. Moreover, the utmost ZFP obtained experimentally and numerically was vanished suddenly after 30 cm depth and as a result, all soil water moved upward. However the other experiment managed to keep high salt concentration below ZFP and this is turn prohibited the salt accumulation on the soil surface. Currently, more careful Experiment and simulation are performing to monitor and control salt accumulation on the soil surface.

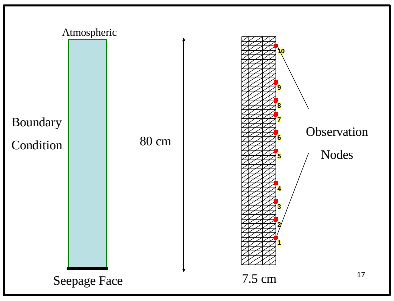


Fig. 1 Sim. Features of periodical water supply

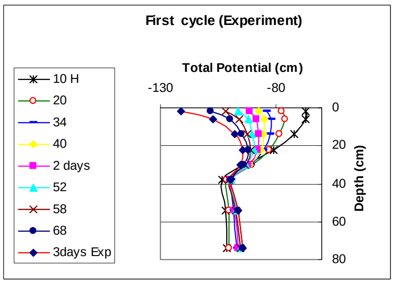


Fig 2 Exp. ZFP movement

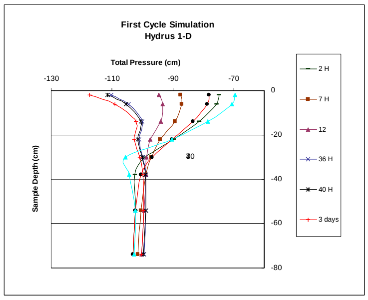
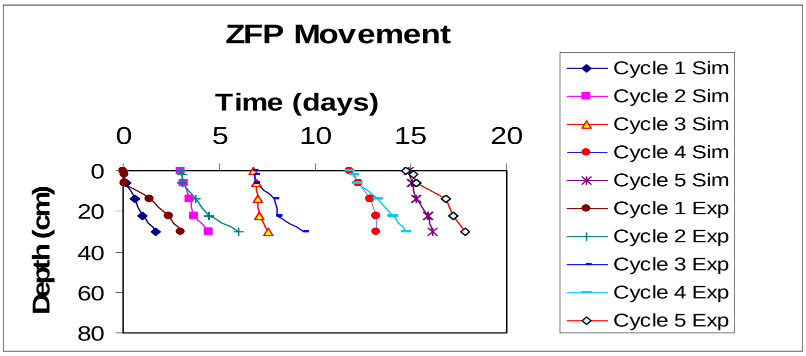
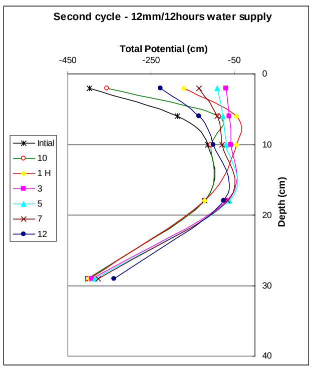
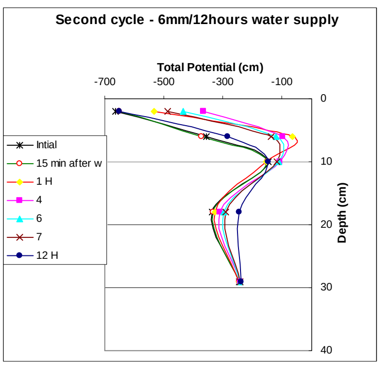


Fig.3 Sim. ZFP movement

Fig 4 Exp and Sim. .ZFP movement







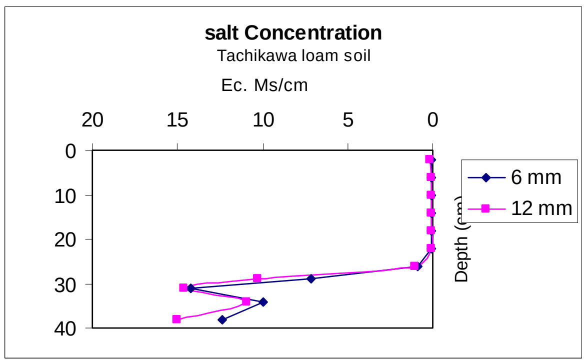


Fig. 5. Exp. ZFP movement of column1 Fig. 6. Exp. ZFP movement of column 2 Fig 7. Salt concentration distribution