EFFECT OF WATER TABLE ON SALINITY OF DRAINAGE WATER AND MIXING REGION UNDER DRAIN

EFFET DE LA SURFACE DE NAPPE PHREATIQUE SUR LA SALINITE DE L'EAU DE DRAINAGE ET DU MELANGE DE L'EAU D'IRRIGATION ET DE L'EAU SOUTERRAINE AU DESSUS DE LA CANALISATION

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ABSTRACT

In spite of recent developments in drainage, the main concern remains on subsurface water quality and its harmful impacts on environment and water quality reduction in downstream. In general, water inflows to subsurface drain vertically and horizontally caused by deep percolation losses and subsurface radial flow which is a mixture of drainage water and subsurface water. Part of water inflow to the drain is from under the drain. Salinity of water, under the drain is more than the salinity of the water above the drain. Especially in arid regions, to design subsurface drain and to manage the irrigation and drainage system, the salinity of drainage outflow should be reduced to the lower value. In this paper the mixed depth will be introduced which can be an important parameter to design and to manage the drainage system. The effect of water table depth on mixing depth and drainage water quality were investigated in a physical model. The mixing depth is presented as a function of drain outflow rate, the hydraulic conductivity, depth of impervious layer and the head causing the flow. It is advised to reduce installation depth of drains to decline water table and mixing water depth and prevent outflow of salinity of lower depths.

Key words: *Drainage effluent, Water table, Effluent quality, Mixing region, Physical model, Environmental impact.*

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RÉSUMÉ ET CONCLUSIONS

La saleté haute de l'eau pénétrée dans les canalisations souterraines engendre beaucoup de problèmes en vue de l'environnement, de la diminution de la qualité des sources d'eau et de la consommation des lieux bas. Il faut viser les dimensions environnementales des plans ou des schémas de l'arrosage et l'assèchement à fin de bien utiliser les sources naturelles et de façon résistante. En général les écoulements entrés dans la canalisation du sous-sol, concernant l'écoulement vertical et horizontal, sont les résultats des pertes de la pénétration en profondeur de l'eau à l'arrosage et des écoulements en rayon du sous-sol résultants du mélange de l'eau d'irrigation et de l'eau du sous-sol vers les canalisations. Une partie de l'eau entrée dans la canalisation et au dessous de la canalisation, est résultat du mélange de l'eau d'irrigation et celui de souterraine qui est plus salé dans les régions sèches. Dans cette étude on a fabriqué un modèle physique en Placsi Glasse à fin de vérifier l'influence du niveau de la statique d'eau sur la saleté du suintement d'eau et la profondeur du mélange de l'eau d'irrigation et de celui de souterraine au dessous de la canalisation. Pour examiner les épreuves, à l'eau dans la source souterraine on a d'abord ajouté du Permanganate de Potasse et NaCl jusqu'à ce que l'EC de l'eau arrive à 20 dm. Pour élaborer l'eau d'irrigation dans la partie haute du modèle on a utilisé le système de l'irrigation et l'eau à l'irrigation avec EC de 1 dm. En utilisant le rouleau nourri de l'eau souterraine, le niveau de l'eau souterraine est devenu stable jusqu'au dessous de la canalisation tellement que la distance de dessous de la canalisation au plancher devienne colorée. Ensuite par mise en œuvre de l'eau d'irrigation en débit précis et stable par au dessous de la boîte, le niveau statique de l'eau a été stabilisé au dessus du niveau de la canalisation et dans les profondeurs précis par rapport au niveau du sol. Avec la prise des photos de la stabilisation du niveau de la statique d'eau dans les distances temporelles très courtes, les traits d'écoulement vers la canalisation se déterminaient. Ces traits représentent l'étendue de l'épaisseur de la couche de l'écoulement résultant de la profondeur égale à la couche d'obstacle. Avec le changement du débit, on a stabilisé le niveau de la statique d'eau dans une autre profondeur et on mesurait dans les nouvelles conditions, la profondeur du lavage de la matière colorée. A chaque épreuve on a étudié les différentes informations comme la situation du niveau de la statique d'eau en rapport au niveau de la canalisation et les traits du déroulement et la saleté de l'eau sorti de la canalisation. Les résultats ont montré que le fardeau hydraulique sur la canalisation par rapport à la distance horizontale entre deux canalisations suive une équation de quatrième degré. Avec l'augmentation du débit entré et en conséquence celle de l'hauteur du niveau de la statique d'eau par rapport à la situation de la canalisation, le profondeur du mélange augmente et en conséquence augmente la saleté de l'eau sorti. En fin, des résultats acquis on a obtenu la profondeur du mélange comme une équation et en forme de dépendance, de la distance des canalisations et le charge d'eau au milieu de la canalisation. En avoir cette relation, le lieu du mélange et le part de l'eau souterraine dans la qualité de l'eau est estimable. Les résultats montrent que dans la direction de la gestion de la qualité de l'eau sortie, on vise moins la profondeur de l'installation et la distance des canalisations pour que l'hauteur du niveau de la statique de l'eau et la profondeur du mélange se diminuent et en conséquence on évite de la sortie des sels des profondeurs plus basses.

Mots clés : *Effluent de drainage, nappe phréatique, qualité d'effluent, région de mélange, modèle physique, impact sur l'environnement.*

(Traduction française telle que fournie par les auteurs)

1. INTRODUCTION

The soil and water salinities are the main limiting factors in production of crop in arid and semi-arid region. About 23.5 million hectares which is about 14.2% of the total area of Iran, or 30% of the total plains and flat – sloping lands suffer from salinity. In these regions, the main cause of salt accumulation in the soil is water scarcity. Low amount of annual precipitation is inadequate to leach out the soil salts. Another factor that contributes the soil salinities is the shallow depth of saline ground water. The drainage system is most needed for salt leaching at reclamation stage in these regions. The main concern is salt concentration of drainage outflow and its harmful impacts on environment. For perfect management of drainage out flow, it is necessary to know the constituents and the source of the drainage outflow. The successful performance of a drainage system depends on optimal design of drain depth and drain space. Therefore, the design of subsurface drain spacing and depths should ensure that the salinity of drainage outflow is reduced. To achieve this purpose, the flow net of water to drain should be analyzed and the transmission path of the saline water through the soil should be determined.

Drainage equation provides a rational basis for the design of land-drainage installation. Many models are developed to design and to manage the irrigation and drainage system. The main efforts in design drain spacing and depths are focused on equivalent depth. Equivalent depth is a function of the depth to the impervious layer, the radius of the drain, and the spacing between drains. The irrigation and drainage management models use equivalent depth as the depth below the drain installation situation which encompasses the horizontal and radial flow in to drains. In the present paper the mixed depth is introduced for drainage system management. Mixing depth is the outer flow path under the tile drain and the depth where deep percolation and subsurface water are mixed and flow into drains. It will be shown that the mixed depth is an important parameter which affects the quality of drainage outflow.

Nozari's rechearch in Khuzestan (1388[4]) illustrated that drainage outflow discharge and its salinity are related. The increase in drainage outflow discharge causes increased salinity of the drainage outflow. The salinity of drainage outflow was more than the salinity of irrigation water and ground water in adjacent to the and below the drain. Nozari reported that radial flow into the tile drain mixed with saline groundwater increase the salinity of the drainage outflow. Ayars (1987) demonstrated the quality of drainage outflow from the drains installed in deeper layer was lower than those installed at shallow depth. Grismer (1993) and Hornbuckel (2007) found that by increasing in the depth and space of installation of drains, the quality of drainage outflow decreased.

2. MATERIALS AND METHODS

In this study a physical model made of Plexiglas was used to investigate the effect of the water table depth on mixing depth and drainage water quality. The model was 1.86 meter in length, 0.2 meter in width and 0.9 meter in height. To observe the outer flow path, the model was filled with clay which had bright color. The experiments were done for two cases. In the first case a pipe drain was installed at a depth 0.46 m below the ground surface and in the

4 Years starting with 13 are according to Iran calendar. To get the corresponding English calendar year, add 621.

second case the depth of drain installation was changed to 0.32 m below the ground surface. The bottom of the model was assumed to be the impervious layer. In order to measure the water table, ten piezometers were installed on one side of the model. Saline water prepared by dissolving K_2MnO_4 and NaCL was added to subsurface reservoir to simulate a ground water with 20 dS/m salinity. In the upper part of model a drip irrigation system was installed to apply water with salinity of 1 dS/m. Ground water (aquifer) under the drain was fed by colored liquid through a pipe installed at the side near the bottom of physical model, in order to create a color zone under the drain. Then, water table was fixed by application of constant rate of water through irrigation system. The outer flow path was recorded on the Plexiglas side in photograph. Soft ware Grapher 7 used to digitise the photograph. In Figure 1 the mixing depth can be observed in the experimental model. The drainage out flow discharge was measured by the volumetric method. This experiment was repeated for other water table depths, by increasing irrigation rate. Water table depths, flownet, salinity of drainage water were evaluated.

Fig. 1. The schematic of experimental model and mixing depth

3. RESULTS AND DISCUSSION

3.1 The effect of Water Table Head on Mixing Depth

The hydraulic head distribution and the outer flow path for different discharges in two cases are shown in Figures 2 and 3. In general, the outer flow path is affected by the hydraulic head. When the inflow discharge increases, the hydraulic head and the mixing depth also increase. Mixing depth was obtained as a parabolic equation.

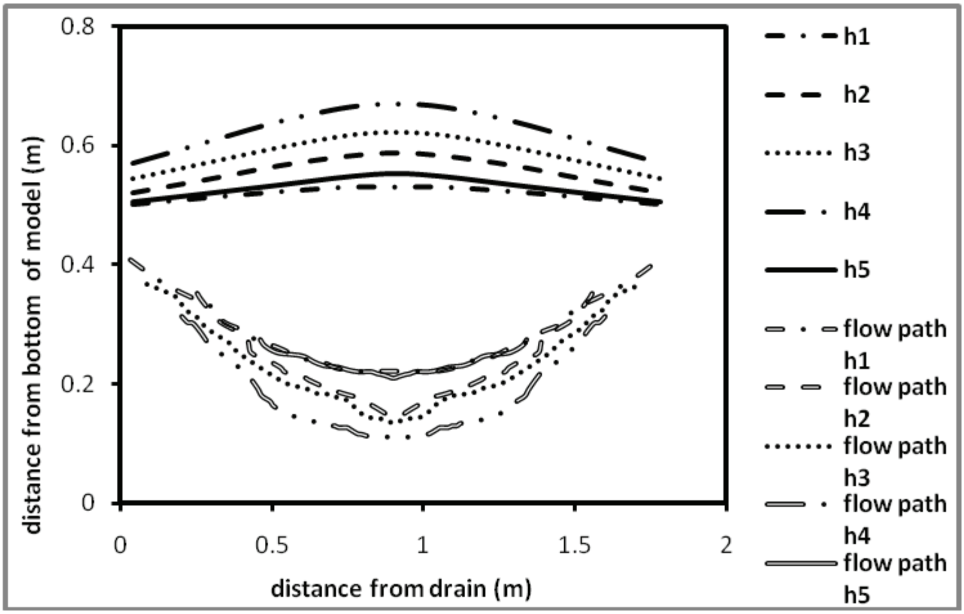

Fig. 2. The diagram of water table head and mixing depth in different discharge (La graphique du niveau de la statique de l'eau et le trait d'écoulement dans les débits différents par rapport à l'installation des canalisations)

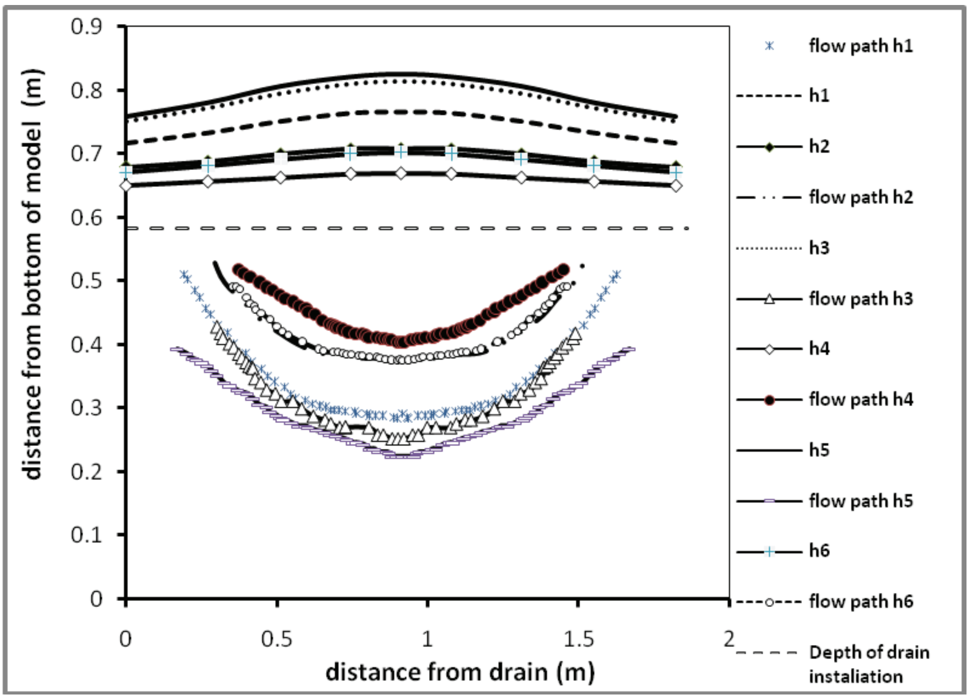

Fig. 3. The diagram of water table head and mixing depth in different discharge inverse the depth of drain installation

3.2 The effect of Water Table Head on drainage outflow discharge

To assess the influence of hydraulic head on drainage outflow discharge, the relationship between q/k and h_m/L are studied (q = drainage outflow rate, k = saturated hydraulic conductivity, h_m = maximum hydraulic head midway between two adjacent drains and L = drain spacing. D in Figs 4 and 5 is the distance between drain and bottom of model. Results indicated that the relationship between q/k and h_m/L was log-linear (of the form: log y = log b + c log x). In Figure 4 it is noticed that when the h_m/L increases, the drainage out flow discharge increases.

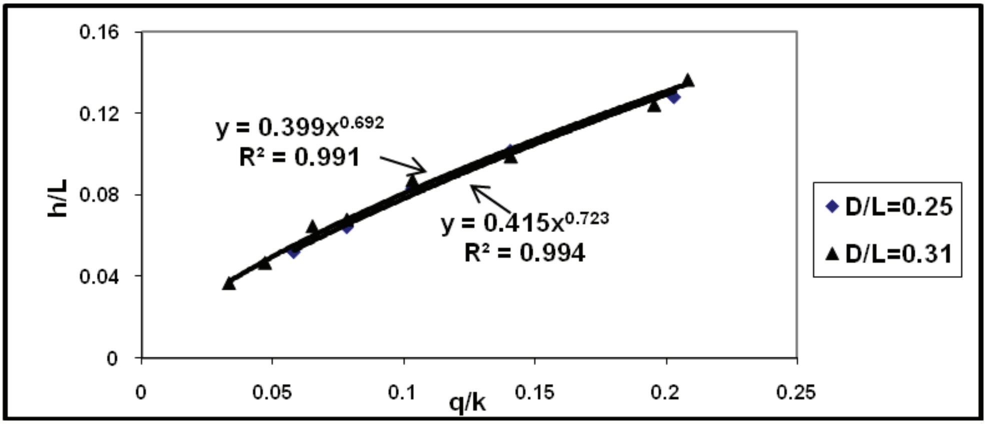

Fig. 4. Relation between dimensionless head and discharge

3.2 The effect of the inflow discharge on the mixing depth

For the effect among the inflow discharge and the mixing depth, the q/k is plotted against d/L, where d is the mixing depth in Figure 5. It is apparent from the Figure that with increasing the inflow discharge the mixing depth increases and the relationship between q/k and d/L is a power equation.

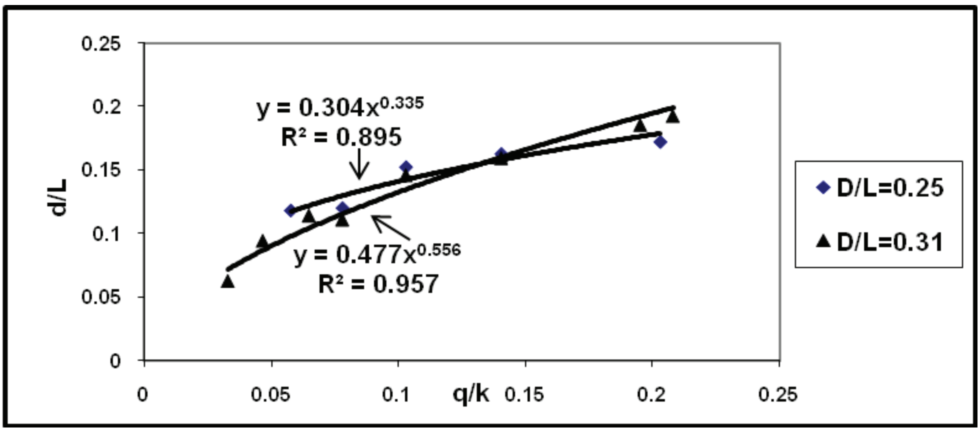

Fig. 5. Relation between dimensionless mixing depth and inflow rate

3.3 Determining the mixing depth in the given distance from the drain installation

Statistical analysis of the data resulted in best fit regression models given below as Equations 1, 2 and 3. The various terms in the three equations have been defined earlier.

$$\frac{h}{D} = 0.0539 - 6.81\left(\frac{X}{L}\right)^4 + 1.83\left(\frac{q}{k}\right) \quad (1)$$

$$\frac{d}{D} = 0.143 - 27.1\left(\frac{X}{L}\right)^4 + 2.34\left(\frac{q}{k}\right) \quad (2)$$

$$d = h\frac{0.143 - 27.1\left(\frac{X}{L}\right)^4 + 2.34\left(\frac{q}{k}\right)}{0.0539 - 6.81\left(\frac{X}{L}\right)^4 + 1.83\left(\frac{q}{k}\right)} \quad (3)$$

3.4 irrigation water discharge and salinity of drainage out flow

The influence of the irrigation water discharge on salinity of drainage outflow is shown in Figure 6. The salinity of drainage out flow is affected by irrigation water discharge. Results indicate that by increasing the irrigation water discharge, the reduction rate of salinity drainage outflow during the time increases. According to the salinity of drainage outflow in comparison with the salinity of irrigation water, this result obtained that a lot of drainage outflow being from the ground water and the concentration of salt in drainage outflow affected by salinity of ground water.

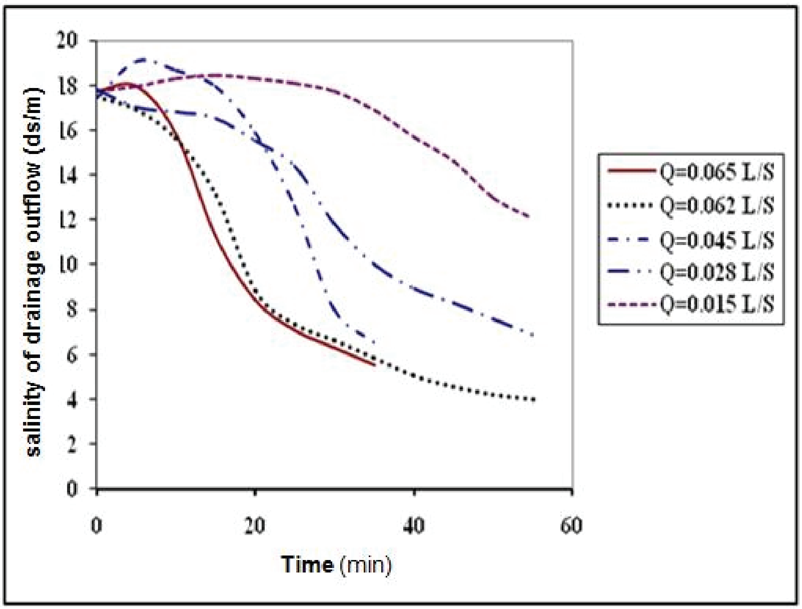

Fig. 6. The quantity of the drainage outflow salinity for different discharge in experiment duration

3.5 The effect of hydraulic head on the salinity of drainage outflow

To assess the effect of hydraulic head on the salinity of drainage outflow, the quantity of the salinity of drainage outflow during the time for different water table head is shown in Figure 7. It is obvious that when the hydraulic head increases the quantity of the salinity of drainage outflow increases. This finding is useful in the regions with shallow and saline ground water table, where as the mixing depth increases the salinity of drainage out flow also increases.

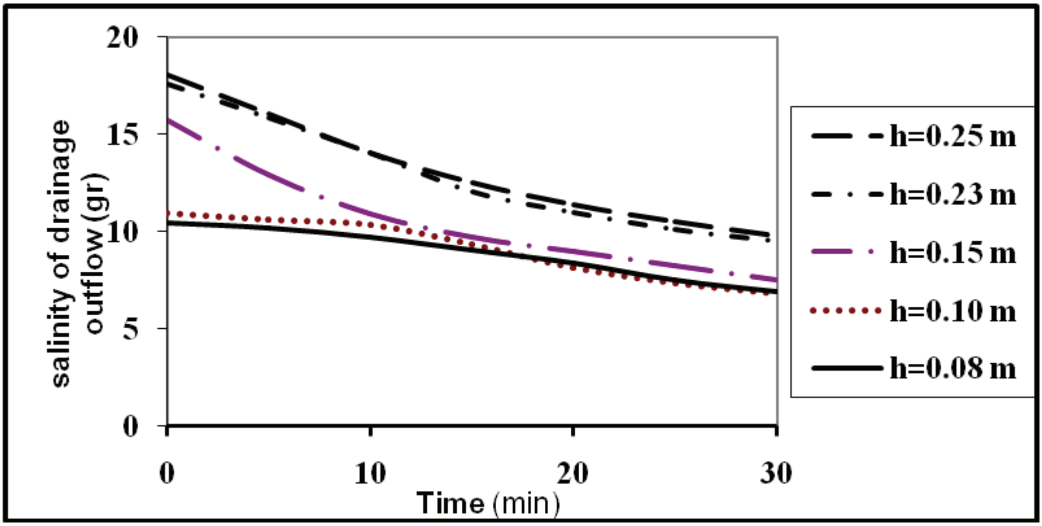

Fig. 7. The quantity of the drainage outflow salinity for different water table head in experiment duration

4. CONCLUSIONS AND RECOMMENDATIONS

In this paper the mixed depth was introduced as an important parameter to design and to manage the drainage system. Mixing depth is effected by the inflow discharge. If the mixing depth decreases the salinity of drainage outflow decreases. So in arid region with saline and shallow water table it is suggested that the drainage space and the depth of drain installation are reduced to decrease the mixing depth and the salinity of drainage outflow.

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