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MOVEMENT OF EFFLUENT DISCHARGE TOWARDS LATERAL DRAIN UNDER DIFFERENT IMPERVIOUS LAYERS AND WATER TABLE DEPTHS

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ABSTRACT

An experiment was conducted in a permeability tank constructed at the Laboratory of Department of Land and Water Management. Two soils with different textures collected from Khesana Mori and Nasarpur were used in the experiment. Soils were analyzed for the textural class and hydraulic conductivity. The soil collected from Khesana mori was sandy with hydraulic conductivity of 6.9 m/day, while the soil brought from Nasarpur was clay loam with hydraulic conductivity of 0.0564 m/day. Three impervious layers were imposed at 100, 200, and 300mm depths and four water table depths were maintained from soil surface at 0.0, 30.0, 60.0, 90.0 mm depths above the lateral. The effluent discharge was measured by volumetric method and same was calculated using Hooghoudt's formula. The results showed that the effluent discharge from laterals was maximum when the water table depth was maintained at soil surface under both sandy and clay loam soils. The effluent discharge decreased with the increase in the depth of impervious layer. Hydraulic head above the lateral influenced the effluent discharge. When the hydraulic head increased the effluent discharge also increased. The study also found that the sandy soil with higher value of hydraulic conductivity collected from Kesana Mori had more effluent discharge compared to that of clay loam soil with lower value of hydraulic conductivity collected from Nasarpur. Therefore the drain spacing must be decided on the basis of water table depth, location of impervious layer, soil texture and hydraulic conductivity.

Keywords: effluent discharge, impervious layer, hydraulic conductivity, constant head permeameter

INTRODUCTION

Inappropriate irrigation is one of the root causes of waterlogging in the Indus Basin Irrigations (IBI) (Zaman and Ahmad, 2009). According to the reports of Indus Basin irrigation System (IBIS) in 1880s the water table was between

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30-45 m without any provision of drainage (WAPDA, 1981), but due to seepage from canal and poor irrigation methods in the IBIS over a period of 100 years, the water table depth has reached to less than 3 m in Sindh. Hence approximately 81% of area in Sindh is waterlogged (Zaman and Ahmad, 2009). This is consistent with Anonymous (2007), who reported that Sindh has been severely affected by waterlogging due to the accretion of river beds, inadequate salt exist and traditional watering of crops. According to Lashari and Mahesar (2012) about 2.2 Mha of land was under the water table depth of 0 to 1.6 m in 1999, which drastically reduced to about 0.26 Mha due to drought conditions in 2001. Then it rose to 2.7 Mha in 2003. From 2004 to 2009 water table has again raised and continuously rising.

The waterlogging has greatly contributed to the salinization of the land. Salinity forms a far most serious threat than waterlogging and reduces soil productivity. Salts are accumulated in the upper layers of the soil profile due to capillary rise; hence the continuous capillary rise of shallow water table brings salts to surface (FAO, 1997). This is consistent with Alam *et al*. (2000), who attributed that every year; approximately 120 million tons of salts are added to the land from canal and underground water. The salt leftover buildup in the soil and affects the growth and survival of crops. The effluent discharge carries salts from vadoze zone through drains, which create the problem of soil salinization. According to Flowers (2004), soil salinity has exceeded up to a noticeable level, it warns the sustainability of agriculture over a vast level in the world.

Therefore a study was carried out in a permeability tank at a laboratory of Department of Land and Water Management, Faculty of Agricultural Engineering, Sindh Agriculture University, Tandojam using different lateral drains and water table depths with an aim to investigate the effect of impervious layers and water table depths on the movement of effluent discharge.

MATERIALS AND METHODS

The experiments were conducted in a permeability tank (2m × 1m × 0.1m) developed at the Department of Land and Water Management, Faculty of Agricultural Engineering, Sindh Agriculture University, Tandojam. It is consisted of iron sheets on its left, right and back sides while front side is constructed by 10 mm thick transparent perspex plastic sheet to monitor the movement of water. Three iron sheets and one perspex sheet were fixed using angle iron at its corners as can be seen in Figure 1. Piezometers were installed to monitor water table depths in the tank. An over flow pipe was installed to carry out excess water and pipe drains were installed at three different locations. The water table depths were controlled using a Mariotte bottle.

Two soils of different texture and hydraulic conductivities collected from Khesana Mori and Nasarpur were used in this experiment. The soils were then ground and thoroughly mixed to obtain homogeneity. The textural class of soil was determined by hydrometer method (Bouyoucos, 1927), dry bulk density was determined using the method described by Blake and Hartz (1986) and hydraulic conductivity was determined using Babu and Vasudevan (2008) relation equations:

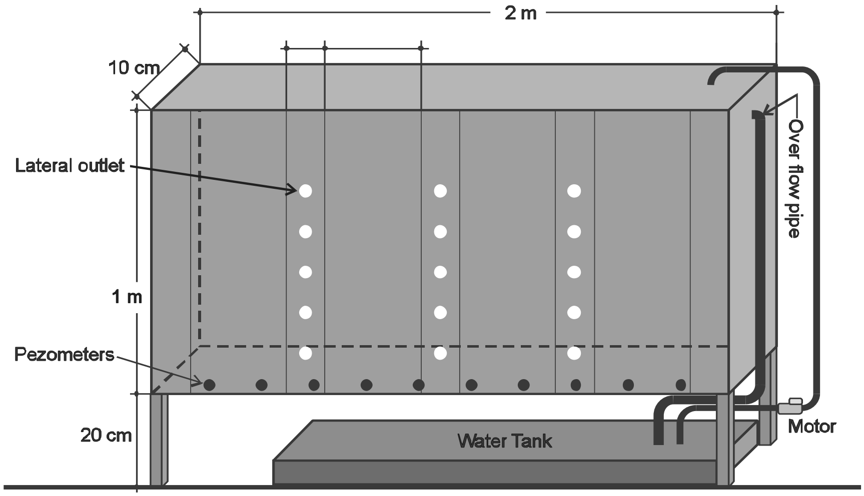

Figure 1. Three dimensional view of permeability tank

$$K = \frac{QL}{Ah}$$

where,
K = coefficient of permeability
Q = quantity of water discharged (cm^3 min^{-1})
L = quantity of water discharged (cm)
A = cross-sectional area of specimen (cm^2)
h = difference in head on manometers (cm)

Table 1. Hydraulic conductivity of sandy soil collected from Khesana Mori

Diameter (cm)	Area (cm^2)	Time (Min)	V (cm^3)	Q (cm^3 min^{-1})	Length (cm)	H_1 (cm)	H_2 (cm)	h= H_1-H_2, (cm)	K=QL/ Ah(cm min^{-1})	Average K
13.8	149.5712	3	288	96.00	30	76	36	40	0.48138	6.9 m/day
13.8	149.5712	3	289	96.33	30	75	35	40	0.4830	
13.8	149.5712	3	286	95.33	30	75	35	40	0.478	

Table 2. Hydraulic conductivity of clay loam soil from Nasarpur

Diameter (cm)	Area (cm^2)	Time (Min)	V (cm^3)	Q (cm^3 min^{-1})	Length (cm)	H_1 (cm)	H_2 (cm)	h= H_1-H_2, (cm)	K=QL/ Ah (cm min^{-1})	Average K
13.8	149.5712	4	16	4	10	90	25	65	0.004114	0.0564 m/day
13.8	149.5712	4	16	4	10	90	25	65	0.004114	
13.8	149.5712	4	14	3.5	10	90	23	67	0.003493	

The physical properties of soils are depicted in Table 3. Soil collected from Khesana Mori was classified as sandy soil and that collected from Nasarpur was classified as clay loam soil.

Table 3. Physical properties of soils used in the experiment

Soil	**Sampling locations**	
	Khesana Mori	**Nasarpur**
Sand (%)	90.1	22.80
Silt (%)	2.3	37.30
Clay (%)	7.6	39.90
Textural Class	Sandyl	Clay loam
Bulk Density (g/cm^3)	1.59	1.27

Three impervious layers were imposed at 100, 200, and 300mm depths and four water table depths were maintained from soil surface at 0.0, 30.0, 60.0, 90.0 mm depths above the lateral (Figure 2). Effluent discharge was measured when water table approached to steady state conditions at respective depths. The effluent discharge was measured by volumetric method and same was calculated using Hooghoudt's formula as can be seen in Tables 5-10.

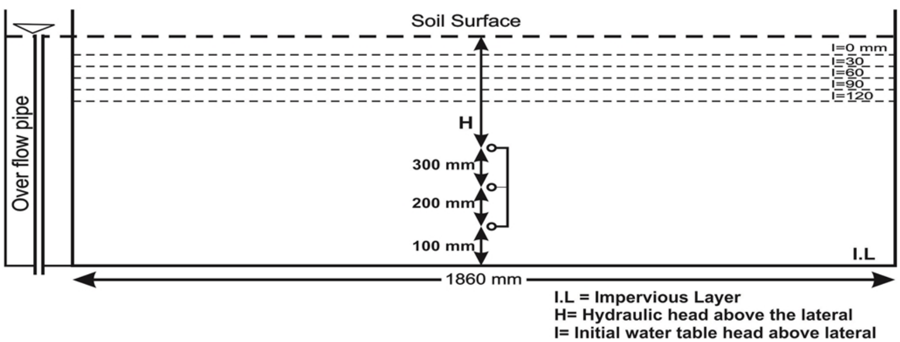

Figure 2. Schematic diagram showing the drain depths and water table levels

Lateral

The lateral (having 8 mm diameter) as shown in Figure 3 was used to collect the effluent discharge. The lateral was wrapped properly with synthetic nylon filter material. The steady state condition was maintained by continuous recharge to the water table using a mariotte bottle. The soils having identical hydraulic conductivity and texture were used as drainage medium.

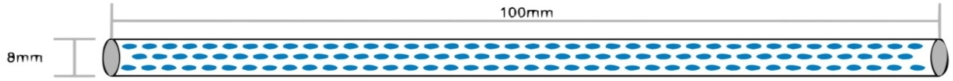

Figure 3. Perforated iron pipe used as Lateral

Drain spacing

The drain spacing is the function of recharge rate (qe) from the soil, and soil texture including water table depth. It was calculated using Hooghoudt's formula (Wesseling, 1972):

$$qL^2 = 8\ Kdh + 4\ Khr^2$$

Where,

q = effluent discharge
L = length between the laterals/ drain spacing
K = hydraulic conductivity
d = diameter of lateral
h = difference in head

RESULTS AND DISCUSSION

The results of effluents discharges are depicted in Tables 5-10. The effluent discharge from laterals was maximum when the water table depth was maintained at soil surface under both sandy and clay loam soils (Table 4). At 100 mm lateral depth, the effluent discharge was 1.5329, 0.0131 m/day; while it reduced to 1.37, 0.0111 m/day; 1.1845, 0.009522m/day; 1.006, 0.00774 and 0.843, 0.00696 m/day, when the water table depth was maintained at surface, level, 30 mm, 60 mm, 90 mm and 120 mm for sandy and clay loam soils, respectively. At 200mm the effluent discharge was 1.323, 0.0111 m/day; while it reduced to 1.145, 0.00929 m/day, 0.9909, 0.00789 m/day, 0.836, 0.0068 m/day, 0.627, 0.00541 m/day when the water table depth was maintained at the surface level 0.00mm, 30mm, 60mm, 90mm, and 120mm for sandy and clay loam soils respectively. At 300 mm depth the effluent discharge was 0.967, 0.0077 m/day; while it reduced to 0.882, 0.00619 m/day, 0.665, 0.00464 m/day, 0.4335, 0.00309 m/day, 0.24, 0.002322 m/day, when water table depth was maintained at the surface level 0.00mm, 30mm, 60mm, 90mm and 120mm for sandy and clay loam soils, respectively.

Table 4. Effect of Impervious Layer (IL) and water table level on the effluent discharge

Water Table (mm)	IL at 100 mm qe (m/day)		IL at 200 mm qe (m/day)		IL at 300 mm qe (m/day)	
	Sandy soil	Clay loam soil	Sandy soil	Clay loam soil	Sandy soil	Clay loam soil
0	1.533	0.013	1.324	0.011	0.968	0.008
30	1.370	0.011	1.146	0.009	0.883	0.006
60	1.185	0.010	0.991	0.008	0.666	0.005
90	1.006	0.008	0.836	0.007	0.434	0.003
120	0.844	0.007	0.627	0.005	0.240	0.002

Table 5. Effluent discharge at different heads, compared with values of Hooghoudt's Formula for sandy soil (Impervious Layer = 300 mm)

Initial Head (mm)	H (mm)	Qe (ml/min)	R=d/2 (mm)	K (m/day)	8KDH	4KH2	Hooghoudt's (qe) (m/day)	Observed (qe) (m/day)	Regression coefficient (R2)
0	160	125	4	6.922	2.658	0.709	0.973	0.968	0.981 H
30	130	114	4	6.922	2.160	0.468	0.760	0.883	
60	100	86	4	6.922	1.661	0.277	0.560	0.666	0.981 I
90	70	56	4	6.922	1.163	0.136	0.375	0.434	
120	40	31	4	6.922	0.665	0.044	0.205	0.240	

Drain Spacing L = 1860 mm Drain Depth = 160 mm Lateral Length = 100 mm

Table 6. Effluent discharge at different heads compared with values of Hooghoudt's Formula for sandy soil (Impervious Layer = 200 mm)

Initial Head (mm)	H (mm)	Qe (ml/min)	R=d/2 (mm)	K (m/day)	8KDH	$4KH^2$	Hooghoudt's (qe) (m/day)	Observed (qe) (m/day)	Regression coefficient (R^2)
0	260	171	4	6.922	2.880	1.872	1.373	1.324	0.997 H
30	230	148	4	6.922	2.547	1.465	1.160	1.146	
60	200	128	4	6.922	2.215	1.108	0.960	0.991	0.998 I
90	170	108	4	6.922	1.883	0.800	0.776	0.836	
120	140	81	4	6.922	1.551	0.543	0.605	0.627	

Drain Spacing L = 1860 mm Drain Depth = 260 mm Lateral Length = 100 mm

Table 7. Effluent discharge at different heads compared with values of Hooghoudt's Formula for sandy soil (Impervious Layer = 100 mm)

Initial Head (mm)	H (mm)	Qe (ml/min)	R=d/2 (mm)	K (m/day)	8KDH	4KH2	Hooghoudt's (qe) (m/day)	Observed (qe) (m/day)	Regression coefficient (R^2)
0	360	198	4	6.922	1.994	3.588	1.613	1.533	0.999 H
30	330	177	4	6.922	1.827	3.015	1.400	1.370	
60	300	153	4	6.922	1.661	2.492	1.200	1.185	0.996 I
90	270	130	4	6.922	1.495	2.019	1.016	1.006	
120	240	109	4	6.922	1.329	1.595	0.845	0.844	

Drain Spacing L = 1860 mm Drain Depth = 360 Lateral Length = 100 mm

Table 8. Effluent discharge at different heads compared with values of Hooghoudt's Formula for clay loam soil (Impervious Layer = 300 mm)

Initial Head (mm)	H (mm)	Qe (ml/min)	R=d/2 (mm)	K (m/day)	8KDH	$4KH^2$	Hooghoudt's (qe) (m/day)	Observed (qe) (m/day)	Regression coefficient (R^2)
0	160	1	4	0.056	0.022	0.006	0.008	0.008	0.987 H
30	130	0.8	4	0.056	0.018	0.004	0.006	0.006	
60	100	0.6	4	0.056	0.014	0.002	0.005	0.005	0.987 I
90	70	0.4	4	0.056	0.010	0.001	0.003	0.003	
120	40	0.3	4	0.056	0.005	0.000	0.002	0.002	

Drain Spacing L = 1860 mm Drain Depth = 160 mm Lateral Length = 100 mm

The study showed that the effluent discharge decreased with the increase in the depth of Impervious Layer, which affected the quality of drainage effluent. These results are closely linked to Kamra *et al.* (1994), who reported that the depth of the impervious layer significantly influenced the quality of the drainage effluent. It was found that the hydraulic head above the lateral influenced the effluent discharge are given in the Tables 5 to 10. These lines are in agreement with Shakiba *et al.* (2013), who reported that the hydraulic head affected the effluent discharges. When the hydraulic head increased the effluent discharge also increased. The study also found that the sandy soil with higher value of hydraulic conductivity collected from Kesana Mori had more effluent discharge compared to that of clay loam soil with lower value of hydraulic conductivity collected from Nasarpur. This is consistent with Siyal *et al.* (2010), who concluded that the effluent discharge from coarse textured or sandy soil was much higher than that from fine textured or loam soil. Care must be taken to design a sub-surface drainage system, which may control water table depth. Therefore the drain spacing must be decided on the basis of water table depth, location of impervious layer, soil texture and hydraulic conductivity.

Table 9. Effluent discharge at different heads compared with values of Hooghoudt's Formula for clay loam soil (Impervious Layer = 200 mm)

Initial Head (mm)	H (mm)	Qe (ml/min)	R=d/2 (mm)	K (m/day)	8KDH	$4KH^2$	Hooghoudt's (qe) (m/day)	Observed (qe) (m/day)	Regression coefficient (R^2)
0	260	1.44	4	0.056	0.024	0.015	0.011	0.011	0.998 H
30	230	1.20	4	0.056	0.021	0.012	0.009	0.009	0.998 I
60	200	1.02	4	0.056	0.018	0.009	0.008	0.008	
90	170	0.88	4	0.056	0.015	0.007	0.006	0.007	
120	140	0.7	4	0.056	0.013	0.004	0.005	0.005	

Drain Spacing L = 1860 mm   Drain Depth = 260 mm   Lateral Length = 100 mm

Table 10. Effluent discharge at different heads compared with values of Hooghoudt's Formula for clay loam soil (Impervious Layer = 100 mm)

Initial Head (mm)	H (mm)	Qe (ml/min)	R=d/2 (mm)	K (m/day)	8KDH	$4KH^2$	Hooghoudt's (qe) (m/day)	Observed (qe) (m/day)	Regression coefficient (R^2)
0	360	1.70	4	0.056	0.016	0.029	0.013	0.013	0.981 H
30	330	1.44	4	0.056	0.015	0.025	0.011	0.011	0.998 I
60	300	1.23	4	0.056	0.014	0.020	0.010	0.010	
90	270	1.00	4	0.056	0.012	0.017	0.008	0.008	
120	240	0.9	4	0.056	0.011	0.013	0.007	0.007	

Drain Spacing L = 1860 mm   Drain Depth = 360 mm   Lateral Length = 100 mm

CONCLUSION

The study has shown that the effluent discharge from laterals was maximum when the water table depth was maintained at soil surface under both sandy and clay loam soils. The effluent discharge decreased with the increase in the depth of impervious layer. Hydraulic head above the lateral influenced the effluent discharge. When the hydraulic head increased the effluent discharge also increased. The study also found that the sandy soil with higher value of hydraulic conductivity collected from Khesana Mori had more effluent discharge compared to that of clay loam soil with lower value of hydraulic conductivity collected from Nasarpur.

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