Impact of Sewage Sludge on Water Movement in Calcareous Sandy Soils

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أثر حمأة الصرف الصحي على حركة المياه داخل تربة رملية كلسية

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خلاصة: أجريت هذه الدراسة لاستقصاء التغييرات الناتجة في خواص التربة الفيزيائية، وأثرها على حركة المياه تحت ظروف الري بالغمر حيث تمت إضافة حمأة الصرف الصحي حتى عمق ١٠ سنتيمترات، بمعدلات ٠، ٢٥، ٧٥ و ١٠٠ ميجاجرام للهكتار، لنوعين من التربة المفككة تحتويان على كميات مختلفة من كربونات الكالسيوم. ودلت النتائج على نقص التسرب التراكمي (I) بزيادة معدلات حمأة الصرف الصحي. وكان التسرب الأساسي للتربة الرملية خفيفة الكلسية أعلى منه في التربة الرملية متوسطة الكلسية. ولقد أوضحت التحاليل المعملية انخفاضا أسيا في التوصيل الهيدرولكي المشبع وزيادة في قدرة تخزين الماء الميسر، بزيادة معدلات الحمأة. كما نقصت انتشارية المياه D(θ) بزيادة معدلات الحمأة لكلا التربتين. قيم D(θ) للتربة الرملية خفيفة الكلسية كانت أعلى منه في التربة الرملية متوسطة الكلسية.

ABSTRACT : The present study was undertaken to investigate the changes in soil physical properties and their effect on water movement under ponded irrigation. Sewage sludge was applied to 10 cm soil depth at rates of 0, 25, 75, and 100 Mg•ha^{-1} to two disturbed soils differing in $CaCO_3$ content. The results showed that cumulative infiltration (I) decreased with an increase in sewage sludge rates. Basic infiltration for slightly calcareous sandy soil was higher than that of moderately calcareous sandy soil. Laboratory measurements showed an exponential decrease in saturated hydraulic conductivity and an increase in available water capacity with an increase in sewage sludge rates. For both soils, water diffusivity ($D(\Theta)$) decreased with an increase in sewage sludge rates. The ($D(\Theta)$) values of slightly calcareous sandy soils were higher than those of moderately calcareous sandy soils.

Most agricultural soils in Saudi Arabia are sandy. These soils are characterized by low water holding capacities, high infiltration rates, high evaporation rates, low fertility levels and very low organic matter content (Bashour et al., 1983). The productivity of these soils is thus limited. These limitations become very important under arid and semi-arid climatic conditions. The use of organic amendments may improve the chemical and physical properties of soils and supply plant nutrients to achieve long term productivity. Sewage sludge along with other organic wastes are commonly used as soil amendments.

Epstein et al.(1976) in their study on the effect of sludge and sewage compost on physical properties of a silt loam soil, reported that the addition of sewage sludge shifted the water retention curve of soils and resulted in a higher water content at any specific water potential. However, the available water capacity (i.e. amount of water between -33 and -1500 kPa) essentially remained the same as that of the original soil. In contrast, Vigerust (1983) in his study on clay soils found that the addition of sewage sludge at an annual rate of 15 Mg•ha^{-1} (i.e. 15 x 10^6 g•ha^{-1}) for three years increased the available water capacity. A similar conclusion was obtained by Giusquiani et al. (1995).

Soil water movement depends on several factors including organic matter content, soil texture, and quality of irrigation water. In this respect, Eps (1975) reported an increase in saturated hydra conductivity of a silt loam soil following slu treatment. Furthermore, Wei et al. (1985) found low sludge application rates of 11.2 and 22.4 Mg did not significantly affect the saturated hydra conductivity of a silty clay loam soil. However, hydraulic conductivities of saturated soil cores at sludge treatments of 44.8 and 112.0 Mg•ha^{-1} as we an annual treatment of 22.4 (134.4 total) Mg•ha sludge were significantly higher than that of the con

The effect of sewage sludge on infiltration ra silty clay loam soil was reported by Wei et al. (19 They indicated that both 112.0 and 134.4 Mg sludge treatments increased the infiltration rate.

Due to inconsistent reports on the effect of sev sludge on soil physical properties, the present study undertaken to investigate the effect of sewage slu rates on infiltration, saturated and unsaturated hydr conductivities, and soil water diffusivity of two with different total $CaCO_3$ levels.

Materials and Methods

Two bulk surface soil samples (0 - 30 cm) two different locations were used for this study. The soils were similar in the textural class, but varied in $CaCO_3$ content. The first soil sample (Soil 1) was collected from Haradh (24°13 N, 47°40 E), 150 Km east of Riyadh. This sample represented a slightly calcareous sandy soil (Typic Torripsamments). The second soil sample (Soil 2) was collected from the College Experimental and Research Station at Dierab (24°25 N, 46°34 E), 40 Km southwest of Riyadh. This sample represented a moderately calcareous sandy soil. Some physical and chemical characteristics of the studied soil samples and sewage sludge are presented in Table 1. Particle size distribution was carried out by the pipette method (Day, 1965). Soil organic matter was determined by the Walkley and Black procedure (Jackson, 1973) and total $CaCO_3$ was measured by Collin's calcimeter (Allison and Moodie, 1965). Electrical conductivity (EC) was determined from a 1 to 2 soil extract (Bower and Wilcox,1965). The pH of soil and sewage sludge material was determined from the 1 to 2 soil extract using a pH-meter (Peech, 1965). The cation exchange capacity (CEC) of soils and sewage sludge material was determined by NaOAC (sodium acetate) (Chapman, 1965).

For the infiltration experiment, soil samples were packed at 1.5 g cm^{-3} bulk density in transparent sectioned lucite cylinders (5 cm internal diameter, 60 cm long). The five rates of sewage sludge used in this study were 0, 25, 50, 75 and 100 Mg • ha^{-1} (on dry weight basis) and applied to the upper layer (0-10 cm) of the soil cylinders. A flooding apparatus (El-Shafei and Al-Darby, 1991) was used to obtain infiltration data as a function of time throughout the experiment, and to maintain a constant head (2.5 cm) above the soil surface by means of a bubbler tube. Observations made during the infiltration included change in the bubbler tube reading and the visible wetting front advance. When the wetting front reached approximately a 40 cm depth below the soil surf infiltration was terminated and the distribution of w content was determined gravimetrically. Soil sam were dried at 105°C in 5-cm increments with exception of the first and the last 5 cm where w content was determined at 2.5 cm increment. E treatment was replicated three times.

TABLE 1

Physical and chemical properties of soils and sewage sludge

Component	Soil 1	Soil 2	Sludge
Sand (2.00-0.02mm), %[a]	90	92	76
Silt (0.02-0.002m), %[a]	5	5	5
Clay (< 0.002 mm), %[a]	5	3	19
Total $CaCO_3$ %	8.9	26.7	12.7
CEC,[b] mol • kg^{-1}	2.8	2.7	25.7
pH (1:2)[c]	7.5	8.0	6.8
EC (1:2)[cd], dS • m^{-1}	4.7	1.3	8.4
Organic matter, %	0.5	0.2	38.2

[a] Including $CaCO_3$.

[b] CEC cation exchange capacity.

[c] In water extract.

[d] EC, electrical conductivity.

The saturated hydraulic conductivity determined by the constant head method (2 cm) us a glass cylindrical permeameter 6 cm in diameter 12 in height. The soil samples were packed in cylinder to a 9 cm height at 1.5 g • cm^{-3} bulk density both soils. The rates of sewage sludge applied to b soils were: 0, 25, 50, 75 and 100 Mg • ha^{-1}. T corresponding amounts of sewage-sludge material w hand-mixed thoroughly with air-dried soil. Then, soil in the cylinder was saturated by capillary r through the perforated bottom for 24 h. Tap water v percolated from soil for two hours for all treatmen The time was sufficient to achieve equilibrium. T saturated hydraulic conductivity was an average of t determinations.

The soil-water retention curves were obtained using a pressure plate apparatus (Richards, 1954) matrix potential ranging from -6 to -1500 kPa. The s samples for the treated and untreated samples of bo soils were packed in brass rings, 5 cm in diameter a 3 cm in height, at 1.5 g • cm^{-3} bulk density for treatments. The soil samples were saturated for 24 before the pressure plate experiment.

Results and Discussions

CUMULATIVE INFILTRATION: The results of cumulati infiltration of slightly and moderately calcareous san soils as affected by the sewage sludge rates of 0, 2 50, 75 and 100 Mg • ha^{-1} are illustrated in Figure The relationships between cumulative infiltrati depth, of either treated or untreated soils and time, m be demonstrated by fitting the Kostiakov equati (1932). This equation is expressed as:

$$I = A t^{B} \qquad (1)$$

where I is the cumulative infiltration depth (cm) in tin t (minutes) and A and B are infiltration parameters th depend upon soil properties and initial condition

The data in Table 2 and Figure 1 reveal th cumulative infiltration of all treatments tended increase with time with a correlation coefficient (r) 0.983. Nevertheless, the infiltration paramete appreciably varied with respect to the rate of sewa sludge and $CaCO_3$ content of the soi

Generally, the results indicated that cumulati infiltration depth (I) decreased with increasing sewa

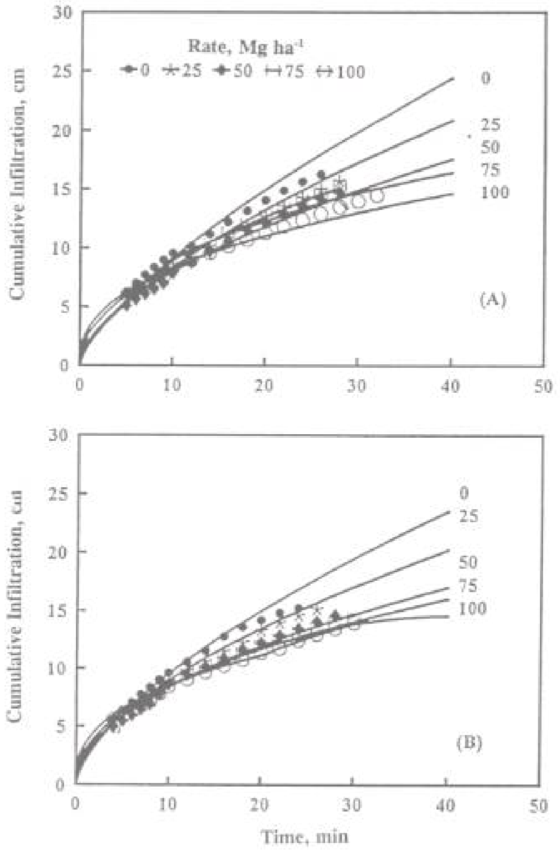

Figure 1. The effect of sewage sludge on cumulative infiltration of slightly (A) and moderately (B) calcareous sandy soils

sludge rates Figure 1. The results revealed a marked reduction in I between the treated soils and the control. This decrease in I values of slightly and moderately calcareous sandy soils by sewage sludge addition could be attributed to the formation and stabilization of soil aggregates which consequently affected the pore size distribution (Epstein, 1975). Another contributing effect of sludge on I values, may be attributed to the migration of micelles to the points of contact between soil particles. This may result in a reduction of size of macropores as well as the clogging of some pores causing a reduction in cumulative infiltration (Johnson, 1975).

The effect of sewage sludge on the infiltration parameters of the Kostiakov equation is demonstrated in Table 2. The A parameter increased with an increase in sewage sludge rates. This increase could be attributed to the absorbance of water by the sewage sludge. The observed increase in the parameter is consistent with what has been reported in the literature (Epstein et al., 1976; Giusquiani et al., 1995; and Mays et al.,1973). The B parameter of treated so lower than that of untreated soils. Moreover, ther gradual decrease in B with an increase in se sludge rates. This may be attributed to improveme soil structure and an increase in aggregate stabili sandy soil due to the addition of sewage sludge (Ep et al., 1976).

INFILTRATION RATE: The effects of sewage sl rates on the infiltration rate of both soils are show Figure 2. The infiltration rate was calculated by ta the derivatives of cumulative infiltration (Equation with respect to time. This results in :

$$dI/dt = i = 60\,AB\,t^{B-1} \qquad (2$$

where i is the infiltration rate (cm • h^{-1}), t is (minutes), and A and B are the infiltration param as defined in Equation (1) and 60 is for unit conver The predicted infiltration rate of slightly and moder calcareous sandy soils decreased by increasing se sludge rates (Figure 2).

The basic infiltration rate represents infiltration rate after a long period when steady conditions prevail. Also, the basic infiltration ra slightly calcareous sandy soil was higher than th moderately calcareous sandy soil as depicted in Fi 2. This may be attributed to the presence of Ca

TABLE 2

The infiltration parameters A and B and correl coefficient (r) for the computed formulae of the cumul infiltration(I)^{a} for the slightly and moderately calcar sandy soil as affected by sewage sludge rates

Rate, Mg • ha^{-1}	Infiltration parameters		Correlation coefficient, r
	A	B	
	Slightly calcareous sandy soil		
0	1.78	0.73	0.986
25	1.82	0.66	0.995
50	2.14	0.57	0.998
75	2.73	0.49	0.997
100	3.27	0.41	0.996
	Moderately calcareous sandy soil		
0	2.12	0.65	0.987
25	2.32	0.59	0.983
50	2.58	0.51	0.997
75	2.96	0.46	0.995
100	3.51	0.39	0.999

^{a} $I = At^{B}$

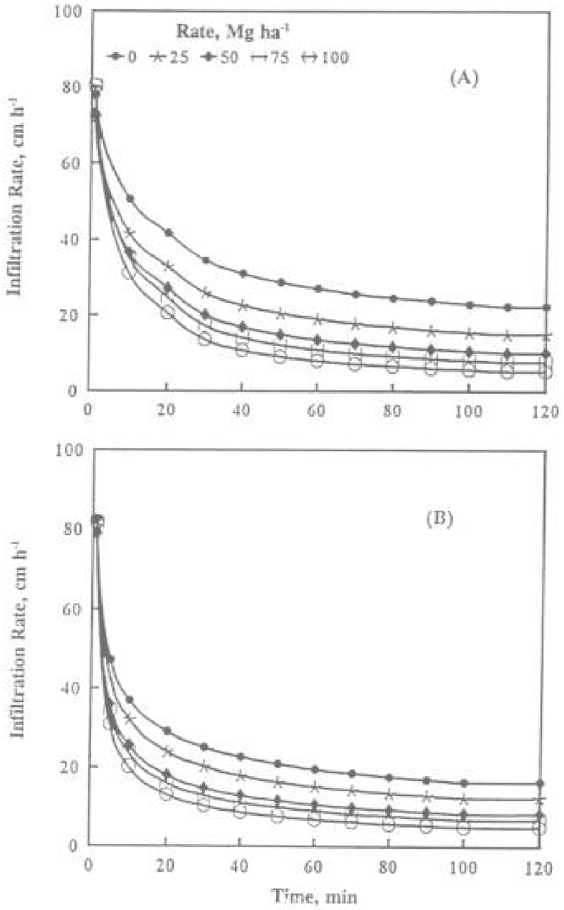

Figure 2. The effect of sewage sludge on infiltration rates of slightly (A) and moderately (B) calcareous sandy soils

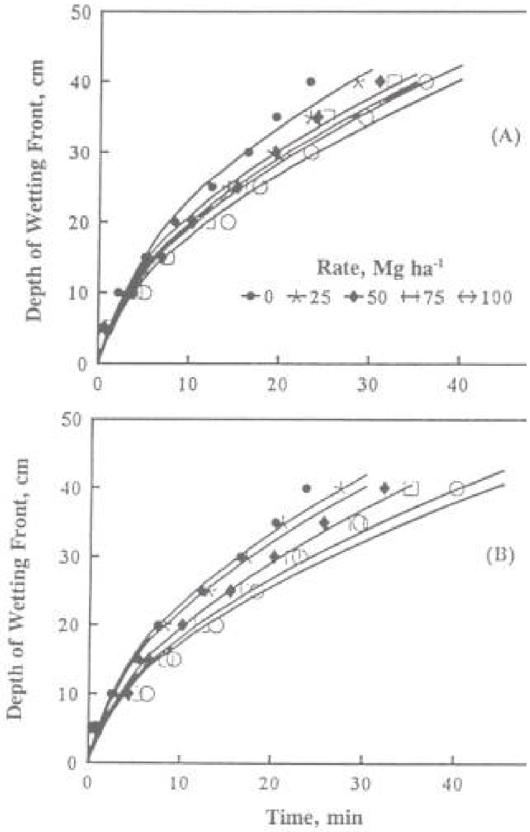

Figure 3. The effect of sewage sludge on advance of t wetting front of slightly (A) and moderately (B) calcareo sandy soils

especially at a level of more than 25% in calcareous soils resulting in a reduction in infiltration rate (FAO, 1973).

ADVANCE OF THE WETTING FRONT: The results in Figure 3 illustrate clearly that the advance of wetting front (Z) of both soils is markedly affected by sewage sludge rates. In general, Z decreased with an increase in sewage sludge rate. Also, the results indicated that the untreated slightly calcareous sandy soil was wetted throughout the complete 40 cm depth within 23.3 min., whereas the soil when treated with 25, 50, 75 and 100 Mg • ha^{-1} sewage sludge rates required 28.5, 31.0, 32.6 and 36.1 minutes to be wetted to the same depth, respectively. The required time to wet the 40 cm soil column of moderately calcareous sandy soil was 23.6, 27.3, 32.1, 35.0 and 36.5 minutes for sewage sludge rates of 0, 25, 50, 75 and 100 Mg • ha^{-1}, respectively.

The relationship between Z and time may be represented by a power function with a correlation coefficient of 0.977. This power function has the fo

$$Z = a\,t^{b} \qquad (3)$$

where Z is the depth to the wetting front in cm, t i minutes, and a and b are two parameters dependent soil type and treatment. Figure 3 and Table 3 indic that the parameter a, generally decreased with increase in sewage sludge rates for both so However, the exponent b was almost constant (0.5) all sewage sludge rates for the two soils.

SATURATED HYDRAULIC CONDUCTIVITY: saturated hydraulic conductivities, K_s, for both soils shown in Table 4. The results indicate that the incre in sewage sludge rate caused a considerable decrease the K_s, for both soils. This reduction could be attribu to the migration of fine particles of sewage slu causing the clogging of some soil macro pores o reduction in the pore size .

The relationship between K_s values of sligh calcareous sandy soil and different sewage sludge ra

TABLE 3

Parameters a and b for computed formulae of advanced wetting front (Z)ª for slightly and moderately calcareous sandy soil as affected by sewage sludge rates

Rate, Mg•ha^{-1}	Parameters		Correlation coefficient, r
	a	b	
	Slightly calcareous sandy soil		
0	6.76	0.54	0.996
25	5.93	0.54	0.993
50	5.49	0.56	0.993
75	5.13	0.57	0.993
100	4.71	0.58	0.997
	Moderately calcareous sandy soil		
0	6.62	0.54	0.995
25	6.27	0.55	0.994
50	5.15	0.58	0.993
75	4.93	0.57	0.988
100	4.78	0.56	0.977

ª $Z = at^b$

TABLE 4

Saturated hydraulic conductivity values (cm h^{-1}) of slightly and moderately calcareous sandy soils as affected by sewage sludge rates

Rate, Mg•ha^{-1}	Saturated hydraulic conductivity, cm•h^{-1}	
	Measured	Computed
	Slightly calcareous sandy soil	
0	24.12	22.46
25	15.06	15.82
50	10.20	11.15
75	8.18	7.85
100	5.68	5.53
	Moderately calcareous sandy soil	
0	19.42	18.19
25	13.00	13.25
50	8.41	9.65
75	7.55	7.03
100	5.22	5.12

(R) was expressed in the following exponential function with an r of 0.992:

$$K_s = 22.46\ e^{-0.014R} \qquad (4)$$

The results in Table 4 reveal that the reduction in computed K_s increased with the increase in sewage sludge rates. The reduction in K_s values amounted to 29.5, 50.4, 65.0 and 75.2 % at 25, 50, 75 and 100 Mg•ha^{-1} sewage sludge rates, respectively.

The relationship between K_s values of moderately calcareous sandy soil and different sewage sludge rates (R) was presented in the following exponential function with an r, of 0.989:

$$K_s = 18.19\ e^{-0.013R} \qquad (5)$$

The results indicate that there is a reduction in K_s values for moderately calcareous sandy soil with an increase in sewage sludge rates. This reduction in K_s values amounted to 27.8, 47.8, 62.3 and 72.7 for sewage sludge rates of 25, 50, 75 and 100 Mg•ha^{-1}, respectively.

Soil Water Retention Curves: Knowledge of the soil water retention curve is essential for water management and agricultural production. The influence of sewage sludge rates on soil water retention curve and water availability for plant growth of slightly and moderately calcareous sandy soils were evaluated. The relationships between soil matrix potential and volumetric soil water content (θ) are presented in Figure 4 for the slightly and moderately calcareous sandy soils at various sewage sludge rates. It is evident that added sewage sludge caused a considerable increase in soil water retention of slightly and moderately calcareous sandy soils. These results are in agreement with those of Epstein et al. (1976) and Giusquiani et al. (1995).

The available water capacity (AWC) of slightly and moderately calcareous sandy soils as affected by sewage sludge rates was calculated as:

$$AWC = \theta_{0.1} - \theta_{15} \qquad (6)$$

Where $\theta_{0.1}$ is the water content at -10kPa, and θ_{15} is the water content at -1500 kPa. The relationships between AWC and sewage sludge rates (R) for slightly and moderately calcareous sandy soils were found to be exponential functions with a slope of 0.0042 for both soils and with an r of 0.970 :

$$AWC = 12.91\ e^{0.0042\,R} \qquad \text{slightly calcareous soil}$$

$$AWC = 11.85\ e^{0.0042\,R} \qquad \text{moderately calcareous soil}$$

The AWC of slightly calcareous sandy soil was 12.9, 14.3, 15.9, 17.7 and 19.7% for 0, 25, 50, 75 and 100 Mg•ha^{-1} sewage sludge rates, respectively. The AWC of moderately calcareous sandy soil was 11.9, 13.2, 14.6, 16.3 and 18.7% for 0, 25, 50, 75 and 100 Mg•ha^{-1} sewage sludge rates, respectively. The percentage increase in AWC of slightly calcareous sandy soil with the increase sewage sludge rates from

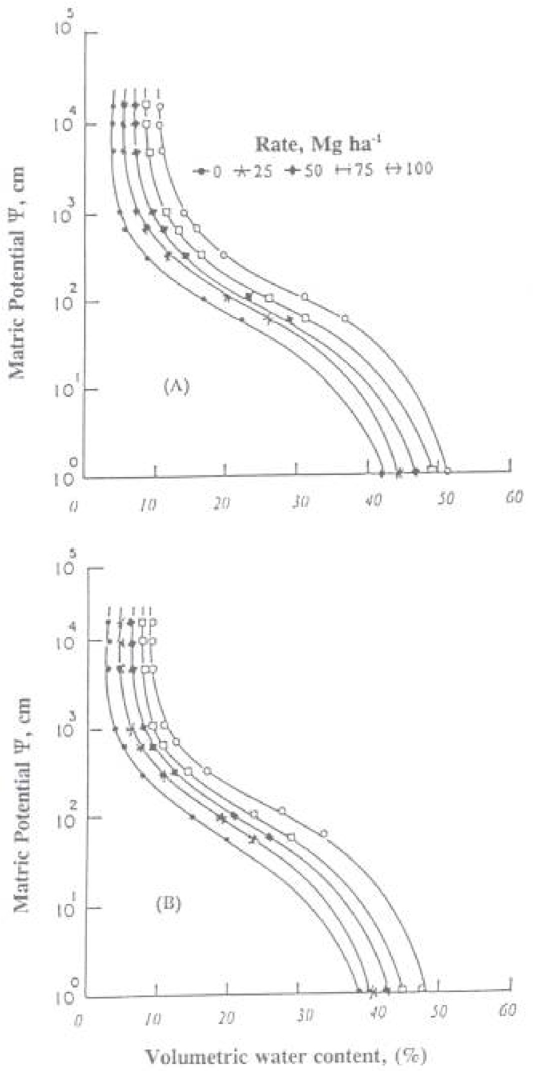

Figure 4. The effect of sewage sludge on water retention curves of slightly (A) and moderately (B) calcareous sandy soils

the control was 10.9, 23.3, 37.2 and 52.7% for 25, 50, 75 and 100 Mg•ha^{-1} sewage sludge rates, respectively. Meanwhile, the percentage increase in AWC of moderately calcareous sandy soil as affected by sewage sludge rates was 10.9, 22.7, 37.0 and 52.1% for 25, 50, 75 and 100 Mg•ha^{-1} sewage sludge rates, respectively.

UNSATURATED HYDRAULIC CONDUCTIVITY: The relationship between unsaturated hydraulic conductivity and soil water content was calculated using the following equation (Campbell, 1974) :

$$K(\theta) = K_s\,(\theta/\theta_s)^{2b+3} \qquad (7)$$

where K(θ) is the unsaturated hydraulic conductivity (cm•h^{-1}) corresponding to the volumetric water content (θ), K_s is the saturated hydraulic conductivity (cm h^{-1}), θ_s is the saturated soil water content, and b is a soil parameter to be calculated from the soil water retention curve.

Data presented in Figure 5 show the values of K(θ) as calculated by Equation (7) for slightly and moderately calcareous sandy soils as affected by the different rates of sewage sludge. Generally, the results indicate that the values of K(θ) increased with an increase in θ for untreated and treated soils. Also, the results show that K(θ) decreased sharply with an increase in sewage sludge.

SOIL WATER DIFFUSIVITY: The obtained soil water retention curves of slightly and moderately calcareous soils as affected by sewage sludge rates can be used to calculate the soil water diffusivity of untreated and treated soils. If the logarithm of the values of matrix

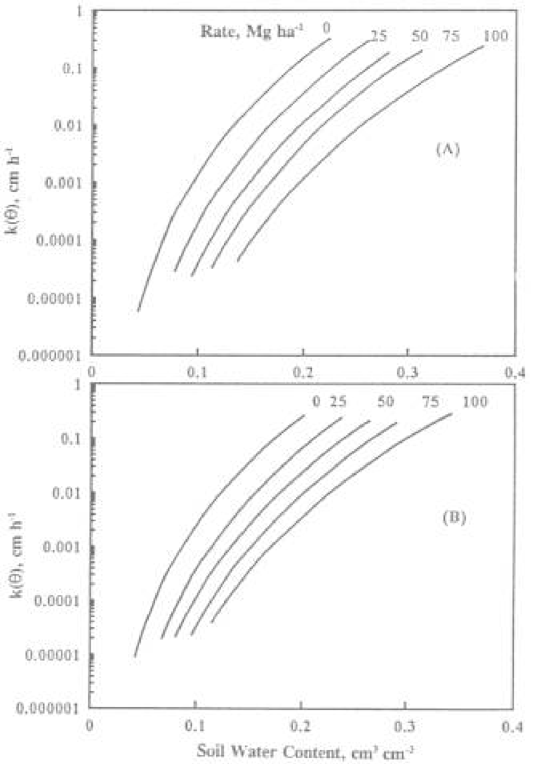

Figure 5. The relationhip between the soil water content (θ) and unsaturated hydraulic conductivity K(θ) as affected by sewage sludge of slightly (A) and moderately (B) calcareous sandy soils

potential (Ψ) are plotted against the logarithm of the relative water content (θ/θ_s), one may expect a straight line within $60 < \Psi < 1000$ cm range of matrix potential as depicted in Figure 6 (Ghost, 1977). Also, this figure shows that the following power function at the above mentioned range of matrix potential can be recommended (Campbell, 1974):

$$\Psi = \Psi_e (\theta/\theta)^{-b} \qquad (8)$$

where Ψ is the soil matrix potential in cm corresponding to the volumetric water content (θ), Ψ_e is the matrix potential in cm, corresponding to air entry value, θ_s is the saturated soil water content, and b is a soil parameter. From the graph in Figure 6 or the best fitting of Equation 8 as $\log \Psi = \log \Psi_e - b \log (\theta/\theta_s)$, Ψ_e and b can be evaluated. The results indicate that Ψ_e for both soils, in general, were not affected by sewage sludge rates. However, the b parameter was affected, where it increased with an increase in sewage sludge rates. The parameter b was also higher for slightly calcareous soil.

The relationship between soil water diffusivity, $D(\theta)$ and soil water content (θ) was defined by Bruce and Klute (1956) as:

$$D(\theta) = -K(\theta)\,(d\Psi/d\theta) \qquad (9)$$

The change in matrix potential with respect to water content ($d\Psi/d\theta$) can be calculated by taking the derivative of Equation (8) with respect to the water content. This results in :

$$d\Psi/d\theta = -b\,\Psi_e\,\theta_s^{b}\,\theta^{-b-1} \qquad (10)$$

Combining Equations (7), (9), and (10) results in

$$D(\theta) = (b\,\Psi_e\,K_s\,\theta^{b+2}) / (\theta_s^{b+3}) \qquad (11)$$

$$\text{for } 60 < \Psi_e < 1000 \text{ cm}$$

Figure 7 shows the $D(\theta)$ as a function of θ for slightly and moderately calcareous sandy soils as affected by different sewage sludge rates. The general shape of $D(\theta)$ curves are in accordance with that obtained by van Genuchten (1980) as predicted from a knowledge of the soil water retention curve and the saturated hydraulic conductivity for $\Psi = 1000$ cm. Generally,

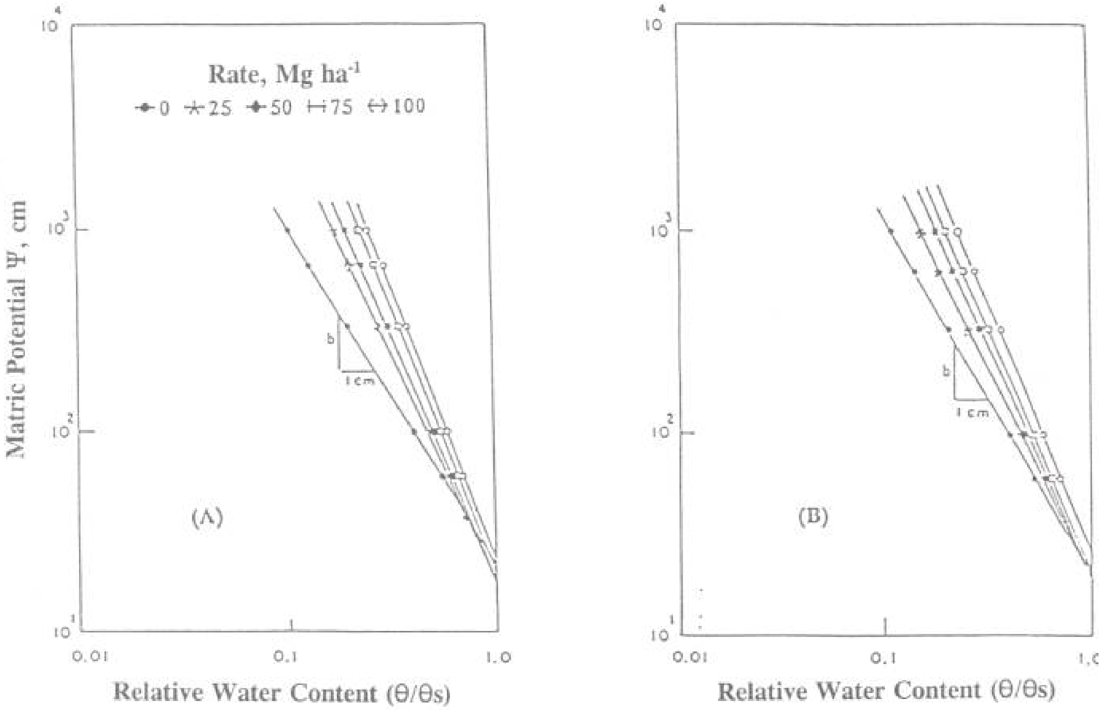

Figure 6. The relationship between the matrix potential and relative water content (θ/θ_s) as affected by sewage sludge o slightly (A) and moderately (B) calcareous sandy soils

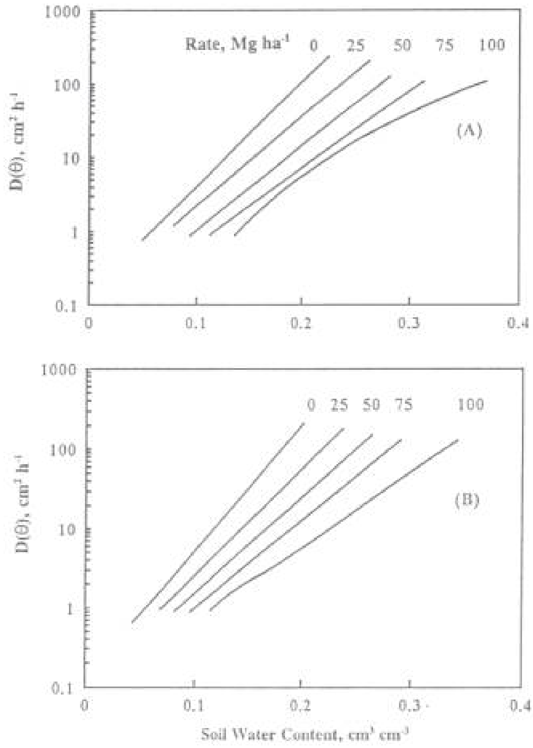

Figure 7. The relationship between the soil water content and computed diffusivity D(Θ) as affected by sewage sludge of slightly (A) and moderately (B) calcareous sandy soils

D(Θ) for both soils increased with an increase in Θ and decreased with an increase in sewage sludge rates. These results can be attributed to the water retention of the sewage sludge. The D(Θ) values of slightly calcareous sandy soil as affected by sewage sludge rates, in general, were higher than those of the moderately calcareous sandy soil. This may be attributed to the effect of total $CaCO_3$ content. The FAO (1973), in their bulletin, stated that increasing the $CaCO_3$ content up to 10 or 15 % increased soil water diffusivity while a further increase up to 20 or 25 % reduced it.

The D(Θ) can be related to soil water content (Θ) by an exponential function Gardner and Mayhugh (1958):

$$D(\Theta) = \alpha e^{\beta\Theta} \qquad (12)$$

where α and β are soil parameters. The parameters α and β for slightly and moderately calcareous sandy soils as affected by sewage sludge rates, R, and the corresponding r are presented in Table 5. The results showed that the values of α and β for the two soils were substantially decreased with increasing sewage sludge rates, which may be attributed to the addition of sewage sludge and the $CaCO_3$ content.

Conclusions

The nutrient and organic matter content of municipal sewage sludge are desirable properties relative to the utilization of sludge on agricultural lands. Sewage sludge can be highly beneficial especially in coarse textured soils, which are usually poor in organic matter and available plant nutrients, and low in water holding capacity. The addition of sewage sludge to sandy calcareous soils caused a reduction in infiltration. Basic infiltration for slightly calcareous sandy soil was higher than that for moderately calcareous sandy soil. The results also showed that the advance of the wetting front of slightly and moderately calcareous sandy soils decreased with an increase in sewage sludge rates.

The effect of sewage sludge on saturated hydraulic conductivity was negative. Available water capacity for slightly calcareous sandy soil was higher than that of moderately calcareous sandy soil. The unsaturated hydraulic conductivity decreased with an increase in sewage sludge rates. The results also revealed that the diffusivity for slightly and moderately calcareous sandy soils increased with an increase in water content and decreased with an increase in sewage sludge rates. The diffusivity values of slightly calcareous sandy soil were higher than those of moderately calcareous sandy soil. This finding showed that the addition of sewage sludge improved the soil physical properties, and thus might increase the productivity of coarse textured soils.

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TABLE 5

The parameters of soil water diffusivity equations for sligthly and moderately calcareous sandy soils as affected by sewage sludge rates

R Mg • ha $^{-1}$	θ_s %	K_s cm • h $^{-1}$	Ψ_s cm	b	α	β	r
Slightly calcareous sandy soil							
0	42.0	22.46	19.0	1.86	0.154	32.78	0.985
25	44.0	15.82	18.0	2.31	0.138	27.90	0.991
50	46.5	11.15	16.0	2.57	0.075	26.41	0.992
75	48.0	7.85	18.0	2.75	0.073	23.93	0.994
100	53.0	5.53	21.0	2.83	0.071	20.40	0.993
Moderately calcareous sandy soil							
0	38.0	18.19	19.0	1.82	0.137	36.53	0.984
25	40.5	13.25	18.0	2.25	0.118	30.96	0.990
50	43.2	9.65	19.0	2.38	0.096	27.89	0.991
75	45.0	7.03	19.0	2.58	0.078	25.58	0.992
100	48.5	5.12	19.0	2.59	0.077	21.79	0.992

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