Zagazig J.Agric. Res., Vol. 29 No.(5) 2002 1649-1663

EFFECT OF SEWAGE SLUDGE ON SOME PHYSICAL PROPERTIES OF CULTIVATED SILTY CLAY SOIL

Ghali, M.H.A.

Soil Dept. Institute of Efficient productivity, Zagazig Univ., Egypt.

Received 30 / 7 / 2002 *Accepted 18 / 8 / 2002*

ABSTRACT: Laboratory experiment was carried out in soil columns. Surface soil sample (0-40 cm depth) was collected from El-Sowa (Abu Hamade), Sharkia Governorate. Air-dried sewage sludge (from El-Gabal El-Asfar) was used in the present study. The sludge-treated samples were prepared by mixing sludge: soil portions (wt/wt) equivalent to 1.5, 3 and 6%. The moistened mixtures were incubated in the laboratory for 4 months then the samples were air-dried and ground to pass trough a 2 mm sieve.

The objectives aimed to investigate the effect of sewage sludge treatments on plastic limit of silty clay soil, as well as, to evaluate aggregate stability in response to sewage sludge application by measuring optical transmission (O.T,%) of two size fractions (<2 μm and < 5 μm) dispersed in different solutions $NaCl/CaCl_2$ at constant SAR of 4, 8, 16 and 20. Furthermore, the hydraulic conductivity (HC) was also measured.

Values of plastic limit for silty clay soil column samples increased by increasing organic carbon %. Therefore, the changes is plastic limit of the soil indicate relative amounts of organic gel materials present. The data of dry aggregate size distribution for the different samples showed a substantial reduction of half the values of coarse aggregates % (1.6-20 and 1.0-1.6 mm) for the sludge-treated soil samples compared to the initial or control samples. Such a reduction ultimately in a corresponds the increase in the percentage of fine (<0.25 mm) aggregates. This response was greater at 1.4 g cm^{-3} than 1.29 g cm^{-3} soil bulk density.

O.T, % for the < 2 and 5 μm size fractions of the soil suspensions increased linearly with increasing electrolyte concentration beyond a certain limiting value depending on the solution SAR and sludge application rate. HC values of the 6% sludge-treated samples were greater than the corresponding values of the other samples. This was mainly attributed to the enhancement of aggregate stability, clay dispersion and subsequent clogging in the conducting macropores.

INTRODUCTION

Soils of arid and semi-arid regions are generally characterized by poor aggregate stability which is associated with crust formation at the soil surface and fragile structure in the subsurface (Shainberg and Letey, 1984). Effect of sewage sludge on soil physical properties is well established by so many workers, but no much emphasis has been done on plastic limits and aggregate stability.

The plastic limits of silty surface soils have been found to increase water due to the presence of coarse soil particles which rolled over each other with compacted portions of fine silt/clay matrix in between (Emerson, 1995).

Aggregate slaking and the subsequent clay dispersion may even be observed when irrigating such silt with water of low sodium adsorption ratio (SAR) and/or low salinity (Abu-Sharar, 1988). Increasing aggregate stability can be achieved by increasing soil organic matter. This may be accomplished by the addition of municipal sewage sludge (Glauser, *et al.*, 1988). However, when sludge products are used judiciously, the risk to human health and the environment is negligible. According to (Jacobs, 1981) when the levels of C_d and P_b are lower than 25 and 100 mg kg^{-1}, respectively, is considered to be of good quality sewage sludge and recommended for agricultural land application.

Biological processes can also contribute substantially to short-term changes in macro-aggregation through binding effect on soil particles and accordingly better aggregates (Haynes and Francis, 1993).

However, the aims of the present work are to study the effect of sewage sludge treatments on plastic limit of silty clay soil, as well as, to evaluate aggregate stability in response to sewage sludge application by measuring optical transmission (O.T, %) of soil suspensions and hydraulic conductivity (HC) of soil columns pre-treated with Nacl/Cacl$_2$ solutions of decreasing electrolyte concentration at constant SAR values.

MATERIALS AND METHODS

Samples of surface silty clay soil (0-40 cm depth) were collected from El-Sowa, (Abu Hammad), Sharkiya Governorate. Air-dried sewage sludge was obtained (from El-Gabal El-Asfar) was used in the present study. The main physical and chemical characteristics of soil and sludge samples are set-up in Table (1). The samples were dried and ground to pass through a 2.0 mm sieve. A sludge sample was suspended in distilled water at a ratio of 1:3 wt/wt. Shaken for 5 hr and filtered. EC, pH, soluble Ca, Mg, Na, K and P were determined in the filtrate according to standard methods of analysis (Page, 1982). Trace elements were determined by DTPA-extractable (Lindsay and Norvell, 1978) using atomic absorption

Table (1 a): Some physical and chemical properties of the investigated soil

Particle size distribution				CEC meq/ 100g	pH (1:2.5) n.H_2O	ECe dS m-1	D_b	D_p	Porosity	O.C	O.M	$CaCO_3$	Moisture content %			
Sand		Silt	Clay										Plastic limit	F.C.	P.W.P	A.M.
F.	C.						g cm^{-3}		(%)							
(%)																
4.6	4.0	41.6	49.8	48.2	7.8	2.4	1.29	2.61	50.58	0.36	0.62	1.5	22.6	28.5	13.7	14.8

Table (1 b) : Chemical properties of the studied sewage sludge.

Extract of suspended sludge in water								DTPA extract (mg/kg) sludge						
O.C	N	EC dS m^{-1}	pH	Ca	Mg	Na	K	Cu	Fe	Zn	Mn	Ca	Pb	Ni
(%)				meq/L										
20.4	5.1	3.56	5.6	6.7	2.1	11.6	12.1	6.84	23.4	9.5	27.9	0.03	6.6	0.48

spectrophotometry. Sludge content of O.C and total N were determined by Walkely, Black and Kjeldahl methods, respectively (Page, 1982).

Soil/sludge mixture preparation and its measurement:

I- Stability of soil aggregates:

Soil and sludge samples were mixed to obtain mixtures with municipal sludge percentage of 1.5, 3 and 6% by weight. The greater values of sludge % were applied mainly to establish basic concept of sludge effect in this regard. PVC columns (30 cm length and 5 cm diameter) with a funnel shape bottom were packed with the homogeneous soil/sludge mixtures to obtain two bulk densities (i.e 1.29 and 1.4 g cm^{-3}).

The sludge-amended soil columns were wetted from below then placed vertically in a plastic tray filled with distilled water in a manner such that the lowest 1 cm of each column was submerged with water. Thenafter, the columns were incubated for 4 months during which once a week, each soil column was rewetted from below, then excessive water was allowed to drain. This process was employed to redistribute soluble constituents that may have accumulated at the soil surface along with the upward-moving water by Capillarity. At the end of incubation period, the columns were air-dried and gently ground to pass through a 2 mm sieve. Sub-samples were employed in the determination of O.C% and dry aggregate size distribution using 4 sieves having openings of 1.6, 1.0, 0.5 and 0.25 mm, according to Klute, (1986).

Stability of soil aggregates was determined by measuring optical transmission % of soil suspensions (OT %) using a spectrophotometer at wavelength of 420 nm (Abu-Sharar, 1988). 8 ml of NaCl/$CaCl_2$ solutions of increasing electrolyte concentration but constant SAR values of 4, 8, 12, 16 or 20 were gently pipetted into triplicate 0.2 g soil samples placed in test tubes of identical optical transmission. Each tube was stopered by thumb then slowly inverted and returned to an upright position. The test tubes were left standing for the time required for settling of >5 or >2 μm fractions under definit depth.

II. Plastic limit of silty clay loam soil:

Different soil/sludge mixture columns at an average bulk density of 1.29 g cm^{-3} were air-dried and gently ground to pass a through 2 mm sieve. The samples are mixed with sufficient water so that it can be made homogeneous by kneading. It is then shaped into a ball. Next a sub-sample is rolled out on a glass plate applying minimum finger pressure. The ball is then allowed to dry until a sub-sample can be just rolled out as a 3 mm diameter thread without breaking. The soil is then in the plastic limit condition and its gravimetric water content is considered as the plastic limit. (Haines, 1930).

III. Measurement of hydraulic conductivity (HC):

The initial and sludge-amended duplicate samples were mixed with equal portions of 0.1 M HCl- washed sand (<1.6 mm size fractions) and packed in PVC cylinders (30 cm length, 5.0 cm diameter) with a funnel-like bottom, to a depth of 17.0 cm at an average bulk density of 1.29 Mg m^{-3}. A sand layer of 2.0 cm was first packed in the bottom of each cylinder to prevent the movement of fine soil aggregates with effluent solutions. Each soil column was then wetted from below using 50 meq/L NaCl/$CaCl_2$ electrolyte solution of constant SAR values of 4, 8, 12, 16 and 20. The initial sample used in the HC measurements at SAR 20 was first wetted with 100 meq/L solution. For each soil column, HC was first measured using the most concentrated solution, then the solution was successively replaced with diluted solutions of 25, 20, 10, 8, 5, 2 meq/L and distilled water) for constant SAR. Hydraulic conductivity was measured by a constant hydraulic head of 10 cm. Effluent solutions of each soil column discharged to a siphon device of 2 ml volume and, in turn, into a fraction collector glass tubes in 8 ml increments. The discharge time of the 8 ml volumes was reported and, subsequently, the corresponding HC was calculated.

For each treatment solution, leaching of the soil columns continued as long as stead state H.C. was not reached. Because of the difficultly in obtaining reproducible result from duplicate columns, HC was expressed on relative basis, i.e., relative to the maximum HC reported when employing the most concentrated solution of the same SAR.

Once dispersed clay appeared in the effluent solutions, (O.T, %) of 8 ml portions of these solutions were reported. The amount of dispersed clay in the effluent solutions was determined gravimetrically. The dispersed clay was first flocculated in a given volume using $CaCl_2$ then over-dry weights of difinit volume samples from each of clay suspension (clay + salt) and clear supernatant (salt content) were determined. Clay is determined by difference oven-dry weight (Klute, 1986).

RESULTS AND DISCUSSION

El-Gabal El-Asfar sewage sludge is slightly acidic with a relatively mild salinity (EC = 3.5 dS m^{-1}) the concentration of DTPA-extractable heavy metals were generally low. Some chemical properties of the sewage sludge and some physical and chemical properties of the investigated soil are presented in Table (1 a & b).

The plastic limit values from the zero, 1.5, 3.0 and 6% sludge treated soil column samples, after incubation period, were 22.6, 23.5, 25.1 and 27.4 %) and the organic carbon values were (.36, 0.55, 0.64 and 0.95 %), respectively. The data reveal that the plastic limit for silty clay soil column increased by increasing). O.C %. The plastic limit is increased because of water sorbed by organic gel materials in additional to 1-3 μm sized pores between the compacted portions which is created by the process of measuring the plastic limit. The presence of such pores should have little effect on the matrix suction since this is determined by the size of the largest water-filled pores present. Also, water sorbed is proportional to carbon content. This allows changes in the plastic limit of a soil to be used to indicate relative amounts of organic gel materials present. However, several years after cropping which has been changed from grass to arable, more gel material was present compared to the *same* soil under continuous arable. This argument are consistent with those of Chenu, (1993), Emerson, *et al.* (1994); and Emerson, (1995).

The values of dry aggregate size distribution are presented in Table (2). The effect of extensive physical desterption due to mixing and grinding of the sludge treated soil, was impacted on aggregates formation. This is noticed by comparing dry aggregate size distribution of these samples with the initial or control samples under two bulk densities. The data of dry aggregate size distribution for the different samples, also, show a substantial reduction of half the values of coarse aggregate % (1.6-2.0 and 1.0-1.6 mm) for the sludge treated soil compared to the initial or control samples. Such a reduction resulted, in turn, in a corresponding increase in the percentage of the fine (<0.25 mm) aggregates. This response was greater at 1.4 than 1.29 g cm^{-3} soil bulk density. Tisdall *et al.* (1978) and Gupta *et al.* (1984) argued that physical distripution of soil aggregates causes a greater decrease in their stability in absence than in presence of microbial activity. In addition to the aggregate stabilizing effect of organic matter. The greater sludge application rate may increase microbial activity and, subsequently, promotes the establishment of binding substances strong enough to effect slaking of the fine aggregates and ultimately clay dispersion. Increasing stability and size of soil aggregates lead to a reduction in clay dispersion. Glauster, *et al.* (1988).

Optical transmission values (O.T. %) for <2μm clay suspensions from 1.5 to 6% sludge treated samples which have been obtained with solutions of increasing electrolyte concentration at different constant SAR (i.e. 4, 8, 12, 16 and 20) are presented in Fig. 1. The data indicate that (O.T, %) values were increased linearly with increasing electrolyte concentration, and maximum clay dispersion was obtained at OT % ≤ 10 (except for the 6% sludge-amended samples treated with solutions of SAR 4 or 8). For the low SAR values the 6% treatment seems to be effective in limiting clay dispersion, Abu-Sharar, (1988) termed electrolyte concentration corresponding to (O.T, %) of 10 a

Table (2): Dry aggregate size distribution for sludge-treated soil samples under different bulk densities.

Sludge application rate (%)	Soil bulk density 1.29 g cm^{-3}				
	Dry aggregate diameter (mm)				
	1.6-2.0	1.0-1.0	0.5-1.0	0.25-0.5	<0.25
* IS	20.5	16.2	15.1	27.4	20.8
** CS	18.7	15.7	14.9	29.3	21.4
1.5	15.3	14.1	13.7	21.4	35.5
3.0	14.7	13.2	14.2	19.6	38.3
6.0	17.4	12.5	13.4	17.8	38.9
	Soil bulk density 1.4 g cm^{-3}				
IS	27.7	17.7	14.9	14.1	25.6
CS	25.2	16.3	14.5	15.2	27.8
1.5	13.2	13.6	12.9	18.9	41.4
3.0	12.3	11.9	13.4	17.3	44.7
6.0	14.1	11.6	12.1	16.5	45.7

* The initial sample (IS) was neither treated with sludge, nor other subsequent procedures.

** The control sample (CS), without sewage sludge treatment, but subjected to other subsequent procedures.

Table (3): Critical concentrations (meq/L) for the initial and sludge-treated soil samples at different SAR values. .

Sewage sludge application rate (%)	SAR				
	4	8	12	16	20
Initial sample	2.8	4.6	5.5	8.3	10.7
1.5	4.4	5.3	6.9	13.4	13.0
3.0	2.3	6.1	7.6	11.3	12.6
6.0	1.9	3.5	8.1	11.2	12.1

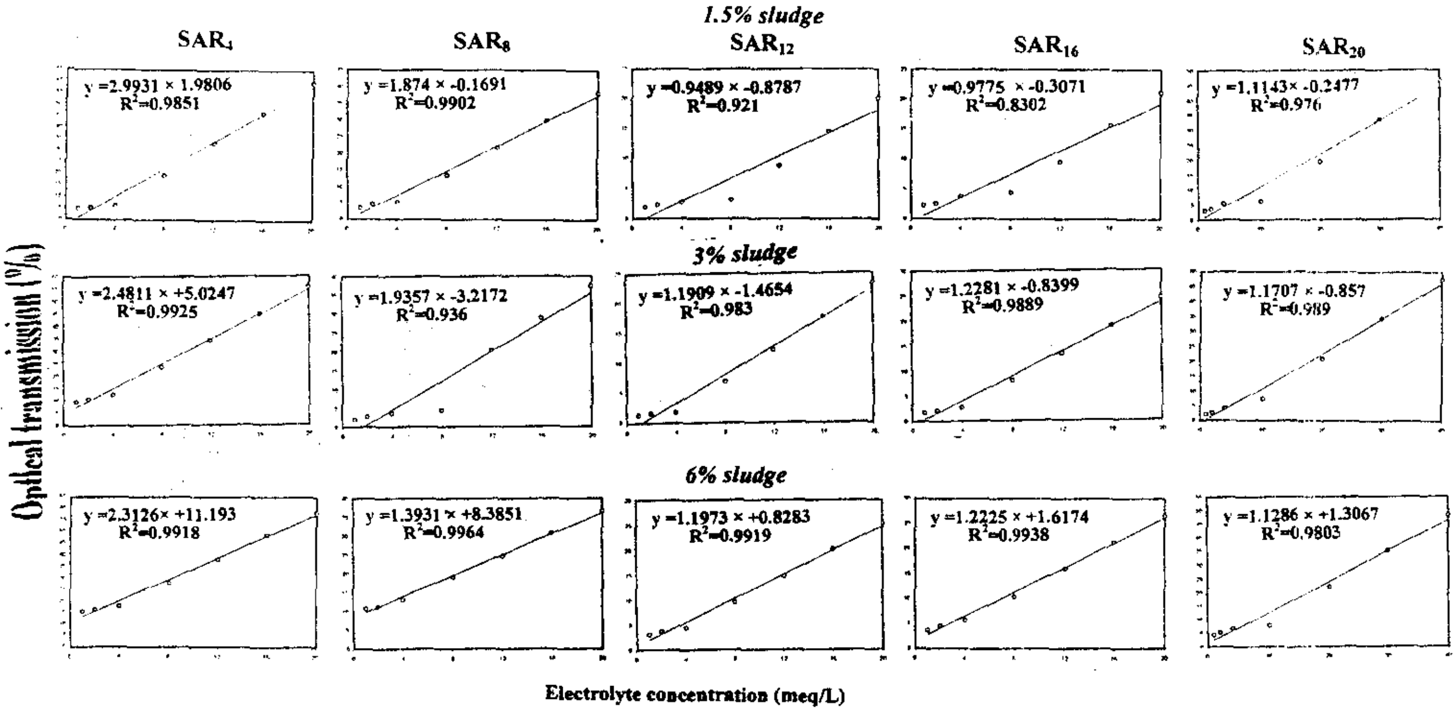

Fig. (1): Scatter diagrams and regression equations of the relationships between optical transmission and electrolyte concentration of <2 µm clay suspensions dispersed from the silty clay soil samples treated by different sludge % and treated with NaCl/$CaCl_2$ solutions of decreasing concentration at constant SAR.

critical concentration. The critical concentration solution of sludge-treated samples were greater than the corresponding values of the initial sample Table (3). At SAR ≥ 8, the critical concentration solution of the 1.5 and 3% sludge treated samples were almost similar, but with decreasing SAR value to 4, critical concentration decreased with increasing sludge application.

Concerning aggregate slaking values of (O.T, %) for soil suspensions of < 5 size fractions dispersed from different sludge-treated samples with solution of increasing electrolyte concentration at 4, 8, 12, 16 and 20 SAR are presented in Fig. (2). Results show a linear increase in (O.T, %) with increasing electrolyte concentration in a manner analogous to that clay dispersion. According to Abu-Sharar *et al.* (1987_b) clay does not disperse from the peripheries of intact soil aggregates, but clay disperses at ultimate stage of aggregate slaking. The obtained results reveal that clay dispersion to < 2 μm fractions was more susceptible to increasing SAR in comparison to aggregate slaking to < 5 μm fractions. Metzger and Robert, (1985) indicated that the application of sewage sludge extract to Na-montmorillonite can bring about the formation of microaggregates of approximately 10 μm size. Once such aggregates are destroyed. Extensive clay dispersion may take place. Quirk (1978) pointed out that the intergrowth of clay crystals is mainly dependent on the fine clay particles but not on organic matter or any other cementing agent. This was attributed to pliability of the fine clay particles which act as the binding agent at the clay domain level-organic matter was thought to be important only in strengthening coarse soil aggregates with an equivalent pore size range of 15-50 μm.

Data of relative HC for the zero and sludge treated soil columns Fig. (3) indicated that for solution series having SAR 4, 8 and 12, HC decreased with decreasing electrolyte concentration below 50 meq/L for zero, 1.5 and 3% sludge-treatments and below 20 and 25 meq/L for the 6% sludge-treated samples, respectively. At SAR 16 or 20 all samples showed a reduction in HC with decreasing electrolyte concentration below 50 meq/L and, indicate a decreasing in aggregate stability with increasing SAR. The HC values for the 1.5 and 3% sludge-treated samples were similar but greater than the respective values of zero when permeating solutions of electrolyte concentration > 5 meq/L at any level of SAR. Maintenance of the studied HC can be achieved by the application of a relatively rate of sewage sludge (6%). This was mainly attributed to the enhancement of aggregate stability, clay dispersion and subsequent clogging of the conducting macropores seem to contribute very little to the decreasing HC values the zero and low sludge applications subjected to leaching electrolyte concentration content.

The (O.T, %) of effluent solutions related to clay dispersion falls to a minimum value after permeation of about 130 ml of these solution. Fig. (4) reveals that (O.T, %) of the water

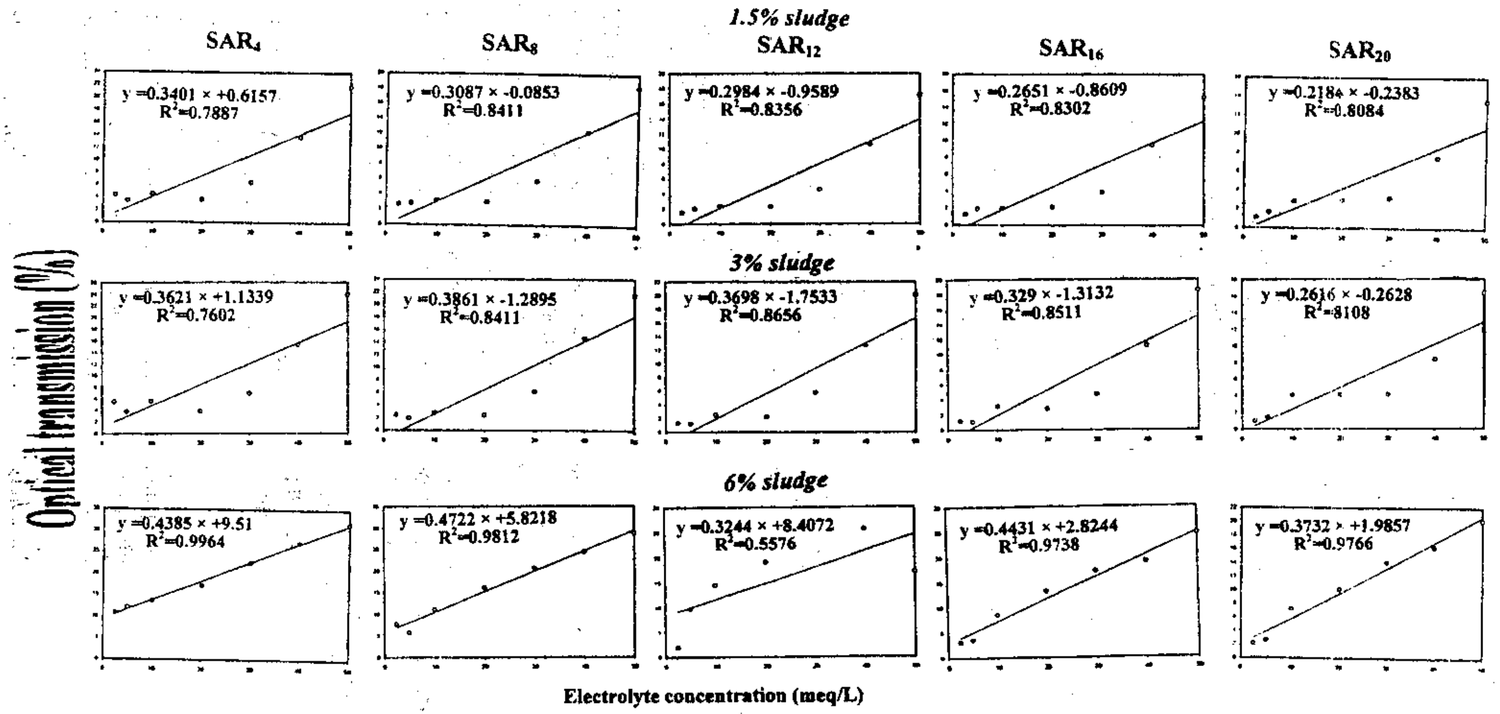

Fig. (2): Scatter diagrams and regression equations of the relationships between optical transmission and electrolyte concentration of <5 µm clay suspensions dispersed from the silty clay soil samples treated by different sludge % and treated with NaCl/$CaCl_2$ solutions of decreasing concentration at constant SAR.

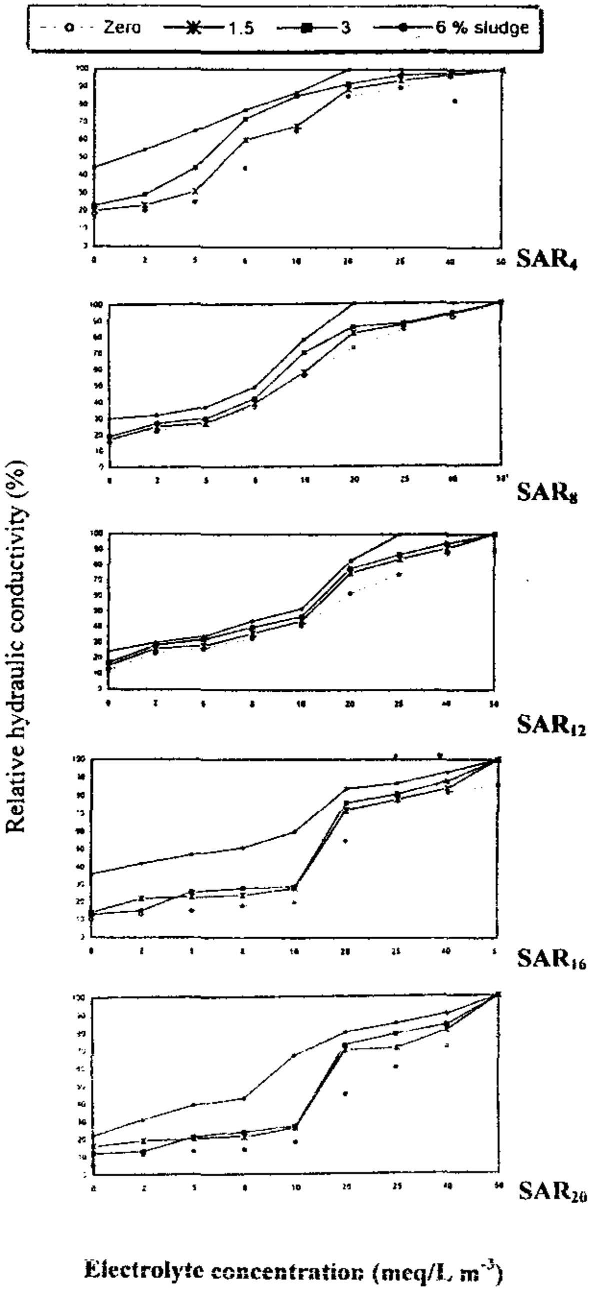

Fig. (3). Effect of decreasing electrolyte concentration of the permeating solutions at constant SAR on the relative hydraulic conductivities of initial and sludge treated soil columns.

effluent from the 6% sludge-treated samples do not drop to 25 (clay dispersion was negligible) and was always greater than the corresponding (O.T, %) of the other samples. Minimum (O.T, %) of the effluent solution decrease (more clay dispersion) with increasing SAR for a given sludge-treated sample and maximum increase (less clay dispersion) with increasing the sludge. application rate at a constant SAR were observed in Table (4). The relatively limited clay dispersion. (especially for the 6% sludge-treated sample permeated with distilled water following SAR 20 solution series, Table 4) indicates that the major cause for HC reduction (≈70%) was mainly due to aggregate slaking rather than to clay dispersion and clogging of the conducting pores as suggested by Shainberg *et al.* (1981). The total amount of clay dispersed from each soil column was small in comparison to the clay content of each column. The total clay dispersed from zero, 1.5, 3 and 6% sludge-treated soil columns permeated with SAR 20 solution series was 0.32, 0.21, 0.20 and 0.04 g, respectively.

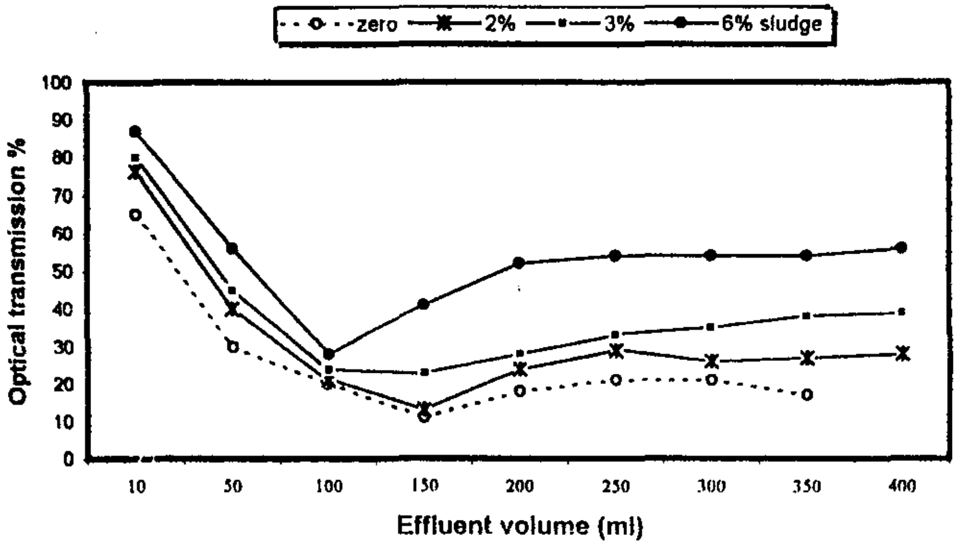

Fig. (4): Optical transmission of the distilled water effluent solutions collected from the initial and sewage sludge treated soil columns previously permeated SAR 20 electrolyte solutions.

Table (4): The minimum (O.T, %) observed in 8 ml portions of the effluent solutions collected from the sludge treated soil columns with solutions of decreasing electrolyte concentration at constant SAR values.

Sewage sludge application rate (%)	**Electrolyte concentration meq/L.**				
	10.0	**8.0**	**4.0**	**2.0**	**0.0**
			SAR 4		
Zero	*NCD	NCD	NCD	49	21
1.5	NCD	NCD	NCD	57	24
3.0	NCD	NCD	84	NCD	29
6.0	NCD	NCD	NCD	NCD	35
			SAR 8		
Zero	NCD	78	55	86	19
1.5	NCD	NCD	63	72	21
3.0	NCD	NCD	NCD	NCD	26
6.0	NCD	NCD	NCD	51	32
			SAR 12		
Zero	NCD	62	47	78	17
1.5	NCD	51	42	65	19
3.0	NCD	NCD	NCD	NCD	22
6.0	NCD	NCD	NCD	40	30
			SAR 16		
Zero	46	58	40	43	14
1.5	42	45	37	55	15
3.0	62	NCD	48	44	18
6.0	NCD	NCD	NCD	NCD	27
			SAR 20		
Zero	38	40	35	36	10
1.5	32	64	31	34	12
3.0	69	NCD	36	35	16
6.0	NCD	NCD	52	44	24

*NCD = No clay dispersion.

REFERENCES

Abu-Sharar, T.M. (1988): stability of soil aggregates as inferred from optical transmission of soil suspension. Soil Sci., Soc., Am. J., 52: 951-954.

Abu-Sharar; F.T. Bingham and J.D. Rhoades (1987_b): Stability of soil aggregates as affected by electrolyte concentration and composition soil Sci., Soc., Am., J., 51: 309-314.

Chenu, C. (1993): Clay-or sand-polysaccharide associations as models for the interface between micro-organisms and soil: water related properties and microstructure. Geoderma 56: 143-56.

Emerson, W.W. (1995): The plastic limit of silty, surface soils in relation to their content of polysaccharide gel. Aust. J. Soil. Res., 33: 1-9.

Emerson, W.W.; R.C. Foster; J.M. Tisdall and D. Weissmann (1994): Carbon content and bulk density of an irrigated natrixeralf in relation to tree root growth and orchard management. Aust. J. Soil Res., 32: 939-51.

Glauser, R.; H.E. Doner and E.A. Paul (1988): Soil aggregate stability as a function of particle size in sludge-treated soils. Soil Sci., 146: 37-43.

Gupta, R.K.; D.K. Bhumbla and I.B. Abrol (1984): Effect of sodicity, pH, organic matter and calcium carbonate on the dispersion behavior of soils. Soil Sci., 137: 245-251.

Haines, W.B. (1930): studies in the properties of soils. (V). The hysteresis effect in capillary properties and the modes of moisture distribution associated therewith. J. Agric. Sci., 15: 178-200.

Haynes, R.J. and G.S. Francis (1993): Changes in microbial biomass C, Soil carbohydrate composition and aggregate stability induced by growth of selected crop and forage species under field conditions J. of Soil Sci., 44: 665-75.

Jacobs, L.W. (1981): Agricultural application of sewage sludge In: J.A. Borchardt *et al.* (eds.) Sludge and Its Ultimate disposal. Ann. Arbor Science Publ, Ann. Arbor, MI.

Klute, A. (1986): Methods of Soil Analysis, Part 1. (Ed. A. Klute) (ASA and SSSA Madison, WI).

Lindsay, W.L. and W.A. Norvell (1978): development of a DTPA test for Zinc, iron, manganese, and copper. Soil Sci., Sco., Am., J., 42: 421-428.

Metzger, L. and M. Robert (1985): Ascaning electron microscopy study of the interactions between sludge organic components and clay particles Geolerma, 35: 159-167.

Page, A.L. (Editor) (1982): Methods of soil Analysis Part 2, Agronomy Series, 9. Am. Soc. Agron., Madison, WI.

Quirk, J.P., (1978): some physico-chemical aspects of soil structural stability. A review. In: W.W. Emerson *et al.* (Editors), Modification of soil structure. Wiley, New York, P.P. 3-16.

Shainberg, I.; J.D. Rhoades and R.J. Prather (1981): Effect of low electrolyte concentration on clay dispersion and hydraulic conductivity of a sodic soil. Soil sci. Soc. Am. J., 45: 273-277.

Shainterg, I. And J. Letey (1984): Response of soils to sodic and saline conditions. Hilgardia 52: 1-57.

Tisdall, J.M.; B. Cockroft and N.C. Uren (1978): The stability of soil aggregates as affected by organic materials, microbial activity and physical disruption Aust. J. Soil Res., 16: 19-17.

تأثير حمأة المخلفات الصلبة على بعض الخصائص الطبيعية لأرض سلتية طينية مزروعة

محمد هانى أحمد غالى

قسم علوم الأراضى - معهد الكفاية الإنتاجية- جامعة الزقازيق-ج.م.ع

أجريت تجربة معملية فى أعمدة تربة وجمعت عينات سطحية (٠-٤٠ سم عمق) من الصوة مركز أبو حماد- محافظة الشرقية- واستخدمت فى هذه الدراسة بحمأة المخلفات الصلبة جافة هوائياً من الجبل الأصفر وأعدت عينات الأرض المعاملة حمأة المخلفات الصلبة بخلط أجزاء الحمأة: الأرض بالوزن لتكون المعاملات ١,٥، ٣، ٦٪ وحضنت المخلوطات المرطبة فى ظروف المعمل لمدة أربعة أشهر وبعدها جففت عينات المخلوطات هوائياً.

وتهدف هذه التجربة لدراسة تأثير معاملات حمأة المخلفات الصلبة على حد الليونة لأرض سلتية طينية وأيضاً لتقييم استجابة ثبات التجمعات بإضافة الحمأة وذلك بقياس نسبة النفاذ البصرى للجزئين الحجميين لحبيبات الطين المتفرقة لـ <٢، <٥ ميكروميتر) فى محاليل مختلفة الملوحة من كلوريد الصوديوم والكالسيوم عند ثبات قيمة الـ(SAR) بالقيم التالية(٤، ٨، ١٦، ٢٠) وأيضاً تقدير التوصيل الهيدروليكى لأعمدة الأرض المعاملة بمعدلات حمأة المخلفات الصلبة المختلفة بالإضافة للكونترول وذلك بمرور نفس المحاليل الملحية المختلفة التركيزات فى أعمدة التوصيل وذلك عند قيم ثابته من (SAR).

زاد حد الليونة للأرض السلتية الطينية بزيادة نسبة الكربون العضوى بمعاملات الحمأة المختلفة ولهذا تكون التغيرات فى حد الليونة كدليل نسبى لوجود كميات مواد الغروى العضوى. ووضحت نتائج توزيع التجمعات الجافة لمختلفة العينات أن هناك نقص حقيقى فى نسبة التجمعات الخشنة (١,٦-٢,٠، ١,٥-١,٦ مم) لعينات الأرض المعاملة وصلت للنصف بالمقارنة بالعينات الأولية أو الكونترول وهذا النقص مصحوب بزيادة التجمعات الدقيقة (<٠,٢٥مم) وكانت هذه الاستجابة أكبر تحت كثافة الأرض الظاهرية ١,٤ جرام /سم٣ عن ١,٢٩ جرام /سم٣.

زادت خطياً نسبة النفاذ البصرى (O.T,%) للجزئين الحجمين لمعلقات حبيبات الطين <٢،<٥ ميكروميتر بزيادة تركيز المحاليل الملحية إلى ما بعد قيمة خاصة محددة معتمدة فى ذلك على قيمة النسبة الادمصاصية للصوديوم ومعدل إضافة الحمأة وكان التوصيل الهيدروليكي HC للعينات المعاملة بـ ٦٪ حمأة أكبر من قيم عينات المعاملات الأخرى وهذا يعزى إلى تحسين ثبات التجمعات وتفرقة الطين وما تتبعة من ضيق فى المسام الكبيرة الموصلة.