EVALUATION OF SURFACE SEAL THICKNESS AND HYDRAULIC CONDUCTIVITY OF FOUR SOILS AS AFFECTED BY SAR AND IONIC STRENGTH OF THE SOIL SOLUTION

S. M. Aly, A. M Amer, W. M. Omran and E. M. Salem
Department of Soil Science, Faculty of Agriculture, Menoufiya University, Egypt.

(Received: Sep. 3, 2012)

ABSTRACT: *A surface seal is defined as a top layer of soil with hydraulic properties significantly lower than that of the subsurface layer. The surface seal could be a very thin layer or a diffused layer several centimeters thick. The thickness (L_1) and hydraulic properties of the seal are a function of many factors such as the presence of fine materials (mineral or organic), electrolyte concentration, SAR value and others. The objectives of this study were to evaluate seal thickness and hydraulic conductivity of four soils as influenced by two electrolyte concentrations (5 and 50 meql^{-1}) of six SAR values (0, 5, 10, 30, 50 and ∞) and to evaluate the effect of SAR and clay content on the seal thickness and hydraulic conductivity. Four soil types from Menoufiya governorate in Egypt were chosen (Quesna, El-Bghour, Shebin El-Kom and Berket El-Saba). The two electrolyte solutions represent ionic strengths of 0.005N and 0.05N) and used soil were of different classes of soil texture. The method suggested was applied to evaluate seal thickness and hydraulic conductivity in soil columns considering the surface seal as a top layer in a two layers soil system. Results indicted a sharp decrease of hydraulic conductivity of a sealed soil (K_e) with SAR values up to SAR(10) then continued to decrease at a much smaller rate for all soils. Ke values were high in the sandy soil of Quesna and decreased with increasing clay content where the lowest values were observed with the clay soil of Berket El-Saba. Seal thickness in the sandy soil was slightly increased with increasing SAR values while decreased only up to SAR(10) and then increased with increasing SAR and was the highest in the clay soil. Hydraulic conductivity of the seal K_1 generally decreased with increasing the SAR ratio at 5meq l^{-1} whereas it was increased up to SAR(30) and then decreased with increasing SAR at 50meq l^{-1}. Results of P_x indicate that negative values of P_x imply a tendency of holding water in soil while the positive values indicate water movement outside the point of interest in soil.*

Key words: *Surface seal, seal thickness, hydraulic conductivity.*

INTRODUCTION

A surface seal is defined in this work as a top layer of soil with hydraulic properties significantly lower than that of the subsurface layer. The surface seal could be a very thin layer or a diffused layer of several centimeters thick.

The relationship between seal thickness (L_1) and hydraulic conductivity values (Ks) is a complicated one. It depends on the way of arrangement of soil particles and their size and the nature of the soil particles included in the surface seal. Many other factors have clear effect on surface seal such as the electrolyte concentration, the content of sodium ion, and the organic matter type and content (Aly and Letey, 1988).

In the studies of soil moisture dynamics in the root zone, surface seal thickness and hydraulic conductivity are important factors in deciding the hydraulic properties of the whole soil, and affect the intake rate of the soil surface.

Augeard *et al.* (2007) observed that, the seal hydraulic conductivity decreases with time, the water infiltrating from the surface also decreased with time at different values of SAR /or salt concentrations.

Reduced hydraulic conductivity can greatly increase the amount of runoff and soil erosion. Quantitative description of seal development has focused on the mathematical description of the process (Römkens and Wang, 1985).

Abu-Sharar *et al.* (1987) mentioned that the cause of the Ksat reduction is often loss of macropores from aggregate slaking (Lebron *et al.,* 2002; Levy and Mamedov, 2002).

During water application, and due to the formation of surface seal layer, a negative pressure suction is developed. This negative pressure increases the forces that pull water into the soil during the next flow period and should increase the infiltration rate (Samani *et al*. 1985). However, the development of negative pressure in the soil surface reduces the hydraulic conductivity of this surface layer. Thus, this thin layer can have a significant effect of reducing water infiltration in succeeding irrigation events (Izuno *et al*., 1985, Moore and Singer, 1990, Jalali – Farahani *et al*., 1993 and Samani *et al*. 1985). All experiments were aimed to evaluate seal thickness and hydraulic conductivity values as influenced by the different SAR values and electrolyte concentrations of studied soils.

The aim of this study is to evaluate the thickness and hydraulic conductivity of the formed surface seal in four soils with different soil texture. Moreover, is to evaluate the effect of two electrolyte concentration (5 and 50meq l^{-1}) of different SAR values (0, 5, 10, 30, 50 and ∞) on the hydraulic properties of the soil and the thickness and hydraulic conductivity of the surface seal.

MATERIALS AND METHODS

To achieve the aims of the study, four soils were chosen at different locations representing Minoufiya governorate (Quesna, El-Bghour, Shibin El-Kom and Berket El-Saba). Disturbed and undisturbed soil samples were collected at depth of 0–30 cm. The disturbed samples were air dried, gently crushed and sieved through a 2 mm sieve. Fine fractions (below 2 mm) were subjected to chemical and mechanical analysis. The undisturbed samples were used to determine bulk density and Hydraulic conductivity. Soil physical and chemical analyses were carried out according to Black *et al*., (1965) and presented in Tables 1 and 2.

Table (1): Particle size distribution of the studied soil profiles

Profile No. and location	C. Sand (%)	F. Sand (%)	Silt (%)	Clay (%)	Texture grade
1, Quesna	50.50	20.50	17.10	11.90	Sandy
2, El-Baghour	1.98	16.42	41.78	39.82	Silty clay loam
3, Shebin El-Kom	6.18	14.40	40.86	38.56	Clay loam
4, Berket El-Saba	6.89	21.71	28.54	42.86	Clay

Table (2): Chemical analysis of the studied soils

Chemical properties	1, Quesna	2, El-Baghour	3, Shebin El-Kom	4, Berket El-Saba
pH	8.40	7.24	6.91	8.22
EC	0.43	1.10	1.96	1.88
Ca^{2+}	1.35	4.80	6.24	5.88
Mg^{2+}	1.40	1.92	2.88	3.93
Na^{+}	1.42	3.98	9.24	8.72
K^{+}	0.13	0.48	1.48	0.34
CO_3^{2-}	-	-	-	-
HCO_3^{-}	3.40	3.25	3.85	4.75
Cl^{-}	0.75	6.00	13.52	11.60
SO_4^{2-}	0.15	1.93	2.47	2.52
SAR	1.21	2.17	4.32	3.93
$CaCO_3$ (%)	1.12	0.43	0.34	2.10
OM. (%)	0.21	1.72	1.79	2.06

Two electrolyte solutions (5 and 50 meq l^{-1}) representing ionic strength of 0.005N and 0.05N of Six SAR values (0, 5, 10, 30, 50 and ∞) were prepared to be used in studying their effects on hydraulic conductivity and surface seal thickness of the four soils. The soils were saturated and washed several times with the two solutions, then were dried and kept to be used for the study.

Plastic soil columns (5.20 cm inside diameter) were used divided in two sections (5cm each) that can be separated easily to remove the top layer containing the surface seal.

Saturated Hydraulic conductivity was determined for the whole column (K_e). The top sections of the columns were removed after drying the soils and the saturated hydraulic conductivity was determined for the lower section (k_2).

Saturated hydraulic conductivity was determined using undisturbed soil samples according to Klut's method according to Kult & Dirkson (1986). The hydraulic gradient was kept constant during the experiments with a constant head device.

The method used by Aly, S.M. and M.E., Abdullah (2002) was applied for calculation of seal thickness and hydraulic conductivity from a simple experiment in the lab. The experiment involved measurements of soil hydraulic conductivity before and after the removal of the top layer of the soil column, which was considered as a two layers soil system. The computer program MathCAD was used for solving simultaneously a number of equations equal to the number of unknowns. The unknowns were L_1, K_1, L_2, and P_x. Where $L_1$and K_1 are the surface seal thickness (cm) and the hydraulic conductivity of the surface seal, respectively. While L_2 is the thickness of the soil layer underneath the surface seal and P_x is the pressure head at the interface between the two layers of the soil column.

To obtain the four equations to be solved simultaneously, the following was considered: To calculate water flow in layered saturated soils, the following equation is applied:

$$Ke = \frac{L}{\frac{L_1}{K_1} + \frac{L_2}{K_2}} \qquad (1)$$

where K_e is the effective hydraulic conductivity of the whole column (cm hr^{-1}), L is the soil length of the whole column (cm) ($L = L_1 + L_2$), L_1 is the seal thickness (cm), L_2 is the thickness of the lower layer in soil column (cm) and K_1 and K_2 are the hydraulic conductivity of the seal and subsoil layer (cm hr^{-1}) respectively.

Darcy's equation can be written across the surface seal as:

$$Je = K_1 (h + L_1)/ L_1 \qquad (2)$$

To calculate The pressure potential between layers within a soil column (P_x) (cm), the Darcy's equation was applied as follows:

$$Je = -(\frac{K_2}{L_2}). \quad (L_2 + P_x) \qquad (3)$$

where J_e is the steady water flux through the soil column (cm/hr).

The fourth equation can be either $L = L_1 + L_2$ or a regression equation relating the two unknowns K1 and L1.

The soil parameters, L_1, K_1, L_2, K_2, J_e and P_x were computed at different values of SAR (0, 5, 10, 30, 50 and ∞) at 5 and 50meq l^{-1} electrolyte concentration of soil solution and were listed in Tables (3-6).

RESULTS AND DISCUSSION:

Data in Table (2) indicated that both the sandy and the clay soils have high pH values (8.2-8.4) where the HCO_3^- was the dominant anion in the sandy soil also its value was not higher than the other soils. Organic matter increased with clay content where it was only 0.2% in the sandy soil and was 2% in the clay soil. SAR of the soils ranged between 1.2-4.3, where the highest value was observed in Shebin El-Kom soil followed by the clay soil of Berket El-Saba.

Hydraulic conductivity:

The results of L_1, K_1, L_2, K_2 and P_x were computed at different values of SAR (0, 5, 10, 30, 50 and ∞) as well as at 5 and 50meq

l^{-1} electrolyte concentrations and presented for studied soils in Tables (3, 4, 5 and 6). Generally in all soils, hydraulic conductivity (K_e) in the presence of the surface seal (top soil layer present) was significantly lower than the hydraulic conductivity of soil layer underneath the surface seal (K_2 after removal of the surface layer). Figure (1) indicated the sharp decrease of K_e with SAR values up to SAR(10) then continued to decrease at a much smaller rate for all soils. K_e values were high in the sandy soil of Quesna and decreased with increasing clay content where the lowest values were observed with the clay soil of Berket El-Saba.

Hydraulic conductivity of the surface seal K_1, shown in Figure (3) revealed that at low electrolyte concentration (5meq l^{-1}), the value followed a gradual decrease with increasing SAR for all soils. Highest values of K_1 were found in the clay soil. Values of K_1 in the loamy and silty loam soils were relatively lower than that of the sandy or clay soils. At high electrolyte concentration (50meq l^{-1}), K_1 was undulating with SAR only for the sandy soil and was generally decreased for all other soils. This may be due to increasing clay dispersion with SAR, especially for the clay soil, while the irregular increase in the sandy soil is attributed to the lack of dispersible materials.

Seal thickness:

Regarding the seal thickness in Figure (2) it was observed that at the low electrolyte concentration 5meq l^{-1}, the seal thickness in the sandy soil was almost constant or slightly increased with increasing SAR values. On the contrary, the clay soil have the highest value of the seal thickness and was decreased only up to SAR(10) and then increased with increasing SAR. The loamy soil of Shebin El-Kom, showed an intermediate behavior where thickness was decreased only up to SAR(10) and then slightly decreased with increasing SAR. To explain the behavior at the low electrolyte concentration, in case of sandy soil, which have low dispersible clay, the increase of SAR causes increase of Na^+ which will increase dispersion and form a stable suspension. This will lead to the formation of a diffused thick seal with somewhat high hydraulic properties. As the clay content increases, the increase of SAR causes an increase of the dispersible clay and at a certain point will become unstable and may flocculate or precipitate to produce a relatively thin seal with low hydraulic properties.

At high electrolyte concentration (50 meq l^{-1}), seal thickness increased sharply with SAR increasing in the sandy soil while decreased with increasing SAR in the clay soil. It was increased up to SAR(10) in the loamy soil and then decreased. To explain the behavior at the high electrolyte concentration, large amounts of ions are available, the dispersible materials in sandy soil are low and as the increase of SAR increases Na^+ which causes an increase in dispersion and swelling, and consequently the seal thickness will increase. On the contrary in the soil having high clay content, the dispersion will increase with increasing SAR and Na^+ in turn. Instability of clay will increase and cause some flocculation and the thickness of the seal will decrease with increasing SAR as shown in Figure (2). Similar results on clay flocculation were reported by Sposito (1984) and Aly and Letey (1988 and 1990). These variations on the seal thickness values may be return to many factors. The main factors are the effect of different solutions, soil structure, migration of fine particles to lower layers, clay content and pore size distribution affected by electrolyte concentrations.

Interaction between soil type and SAR value in terms of soil hydraulic properties

Data in Table (3) revealed that presence of the seal in Quesna soil reduced the soil conductivity (k_e/k_2) to 65% of its value without seal at 5meq l^{-1} and to 71% at 50meq l^{-1}. Hydraulic conductivity of the seal K_1 generally decreased with increasing the SAR ratio at 5meq l^{-1}, whereas it was increased up to SAR(30) and then decreased with increasing SAR at 50 meq l^{-1}. The average value of k_1 is only 11.9 and 22.2% of k_2, respectively while the ratio

TABLE 3

TABLE 4

TABLE 5

TABLE 6

FIG 1

FIG 2

FIG 3

(K_1/K_2) increased with increasing SAR except for the highest SAR at 50meq l^{-1}. Average Seal thickness was 0.72 and 1.46 cm, respectively and was slightly decreased and then increased at 5meq l^{-1} whereas the opposite was observed at 50meq l^{-1}, where it was increased up to SAR(50) and then sharply decreased.

Data in Table (4) indicated that presence of the seal in El-Baghour soil reduced the soil conductivity (K_e/K_2) to 40% of its value at 5meq l^{-1} and to 39% at 50meq l^{-1}. Hydraulic conductivity of the seal K_1 sharply decreased with increasing the SAR ratio at both 5 and 50meq l^{-1}. The average value of K_1 is only 8.9 and 9.4 % of k_2, respectively while the ratio (K_1/K_2) was almost constant with increasing SAR except for the highest SAR at 5 and 50meq l^{-1}. Average Seal thickness was 1.9 and 2.3 cm, respectively and was decreased with SAR increase at 5meq l^{-1}. and was fluctuating at 50meq l^{-1}.

Table (5) Presence of the seal in Shebin El-Kom soil reduced the soil conductivity (K_e/K_2) to 58% of its value at 5meq l^{-1} and to 63% at 50meq l^{-1}. Hydraulic conductivity of the seal K_1 decreased with increasing the SAR ratio at 5 and 50meq l^{-1}. The average value of k_1 is only 22 and 21.2 % of K_2, respectively while the ratio (K_1/K_2) generally decreased with increasing SAR. Average Seal thickness was 1.9 and 1.5 cm, respectively and was fluctuating, and was highest at SAR(0).

Table (6) Presence of the seal in Berket El-Saba soil reduced the soil conductivity (K_e/K_2) to 0.51 of its value at 5meq l^{-1} and to 0.55 at 50meq l^{-1}. Hydraulic conductivity of the seal K_1 decreased with increasing the SAR ratio at 5 and 50meq l^{-1}. The average value of K_1 is only 10.5 and 17.7 % of K_2, respectively while the ratio (K_1/K_2) generally decreased with increasing SAR. Average Seal thickness was 1.17 and 1.72 cm, respectively and was fluctuating at 50 meq l^{-1} and was highest at SAR(0).

The pressure head (P_x) at the interface between the surface seal and the underneath layer of soil.

P_x value in Quesna soil increased from a negative value of -1.37 to a positive value of 0.53 cm with the low salt concentration while decreased from a positive value of 2.29 to a negative value of -0.23 cm with the high salt concentration (Table, 3). Similar results were found in Shebin El-Kom soil, where P_x value was increased from a negative value of -1.9 to a positive value of 1.37 cm with the low salt concentration while decreased from a positive value of 2.8 to a negative value of -3.66 cm at 50meq l^{-1} (Table, 5).

P_x value in El-Baghour soil was almost constant or fluctuated around the negative value of -3.9 to -5.2 cm (Table, 4) . P_x value in Berket El-Saba soil decreased from a positive value of 0.09 to a negative value of -0.3.5 cm with the low salt concentration while decreased from a negative value of -0.17 to a positive value of 2.82 cm at 50 meq l^{-1}, (Table, 6).

From the previous results of P_x, it can be concluded that the negative value indicates a tendency of keeping water in soil while the positive value indicates water movement outside the point of interest in soil (Samani *et al*., 1985). This indicates that the negative pressure increases the forces that pull water into the soil during the next flow period, and should increase the infiltration rate. However, the development of negative pressure in the soil surface reduces the hydraulic conductivity of this surface layer. Thus, this thin layer can have a significant effect of reducing water infiltration in succeeding irrigation events.

Considering the important equation for layered soils $L/K_e=L_1/K_1 + L_2/K_2$ we notice that generally the ratio L_1/K_1 increases with SAR and its value at 5meq always greater than at 50meq l^{-1}. For Quesna and Shebin El-Kom $L_1/K_1 < L_2/K_2$ at 5meq l^{-1} while the opposite is true at 50meq l^{-1}. While for El-Baghour and Berket El-Saba soils $L_1/K_1 > L_2/K_2$ at 5 and 50 meq l^{-1}.

The variations of the seal thickness may return to the effect of soil structure change after treatment with different electrolytes. Moreover, the migration of fine particles to lower layers in soil, high clay content and the electrolyte concentrations all have influence on pore size distribution. The plugging or deposition of fine particles may dominate the action of sealing which will have a big influence on seal thickness and hydraulic conductivity values (Zejun *et al*., 2002). The obtained results are in agreement with those of Mamedov *et al*. (2001), Ben-Hur and Lado (2008), Luza and Heermann (2005) and Brakensiek and Rawls (1983).

Conclusion:

Surface seal is defined as the orientation and packing of dispersed soil particles which have disintegrated from the soil aggregates due to the impact of rain drops. By definition surface seals are formed at the very surface of the soil, rendering it relatively impermeable to water. Crusts are thin soil surface layers more compact and hard, when dry, than the material directly beneath. They hamper seedling emergence, reduce infiltration and favor runoff and erosion. Seal is generally the term given to a wet crust. Generally in all soils, equivalent hydraulic conductivity (K_e) in the presence of the surface seal in top soil layer present was significantly lower than the hydraulic conductivity of soil layer underneath the surface seal (K_2). The method suggested by Aly, S.M. and M.E., Abdullah (2002) for evaluation of seal thickness and hydraulic conductivity in soil columns consider the surface seal as a top layer in a two layers soil system. Results indicted a sharp decrease of hydraulic conductivity of a sealed soil (K_e) with SAR values up to SAR(10) then continued to decrease at a much smaller rate for all soils. Ke values were high in the sandy soil of Quesna and decreased with increasing clay content where the lowest values were observed with the clay soil of Berket El-Saba. The development of negative pressure in the soil surface reduces the hydraulic conductivity of surface layer. Thus, this thin layer can have a significant effect of reducing water infiltration in succeeding irrigation events.

REFERENCES

Abu-Sharar, T.M., F.T. Bingham and J.D. Rhoades (1987). Reduction in hydraulic conductivity in relation to clay dispersion and disaggregation. Soil Sci. Soc. Am. J. 51: 342-346.

Aly, S.M. and Letey (1988). Polymer and water quality effects on flocculation of monomorillonite. Soil Sci. Soc. Am. J. 52:1452-1458.

Aly, S.M. and Letey (1990). Physical properties of sodium treated soil as affected by two polymers. Soil Sci. Soc. Am. J. 54:501-1504.

Aly, S.M. and M.E. Abdullah (2002). Evaluation of thickness and hydraulic conductivity of soil surface seal in PAM treated soils. Minia J. Agric. Res. & Dev. Proc. Minia 1st Conf. for Agric. & Environ. Sci. Minia, Egypt, March 25-28, 2002.

Augeard, B., S. Assouline, A. Fonty, C. Kao and M. Vauclin (2007). Estimating hydraulic properties of rainfall-induced soil surface seals from infiltration experiments and X-ray bulk density measurements. Journal of Hydrology. Vol. 341, issue 1-2: 12– 26.

Ben-Hur, M. and M. Lado (2008). Effect of soil wetting conditions on seal formation, runoff, and soil loss in arid and semiarid soils. Soil Research 46(3): 191–202.

Black, G.A., D.D. Evans, J.L. White, L.E. Ensminger and F.E. Clerk (1965). Methods of soil analysis. Parts, 1 and 2. Am. Soc. Agron. Madison, USA.

Brakensiek, D.L. and W.J. Rawls (1983). Agricultural management effects on soil water processes. Part II: Green and Atnpt parameters for crusting soils. Transactions of the ASAE 26(6): 1753-1757.

Jalali-Farahani, H. R., D. F. Heermann and H. R. Duke (1993). Physics of surge irrigation, II, Relationship between soil physical and hydraulic parameters, Trans. ASAE, 36(1): 37–44.

Izuno, F.T., T.H. Podmore and H.R. Duke (1985). Infiltration under surge irrigation. Trans. ASAE 28 (2): 517–521.

Klute, A. and C. Dirksen (1986). Conductivities and diffusivities of unsaturated soils. P 687- 734. In A. Klute (ed) Methods soil analysis. Part 1. 2nd ed. Agron. Monoger. 9 ASA and SSA, Madison, WI.

Lebron, L., D.L. Suares and T. Yoshida (2002). Gypsum effects on the aggregate size and geometry of three sodic soils under reclamation. Soil Sci. Soc. Am. J. 66:92-98.

Levy, G.J. and A.I. Mamedov (2002). High-Energy-Moisture-Characteristics aggregate stability as a predictor for seal formation. Soil Sci. Soc. Am. J. 66:1603-1609.

Luza, P. B. and D. Heermann (2005). A statistical approach to estimating runoff in center pivot irrigation with crust conditions. Agricultural Water Management 72: 33–46.

Mamedov, A.I., G.J. Levy, I. Shainberg and J. Letey (2001). Wetting rate, sodicity, and soil texture effects on infiltration rate and runoff. Aust. J. Soil Res. 39:1293-1305.

Moore, D.C. and M.J. Singer (1990). Crust formation effects on soil erosion processes. Soil Science Society American Journal, 54: 1117-1123.

Römkens, M.J.M. and J.Y. Wang (1985). Soil translocation by rainfall. J. Miss. Acad. Sci. 9:21-30.

Samani, Z.A., W.R. Walker and L.S. Willardsen (1985). Infiltration under surge flow irrigation. Trans. ASAE 28:1539-1542.

Sposito, G. (1984). The Surface Chemistry of Soils: Oxford University Press, NY, pp. 154-161.

Zejun, T., L. Tingwu, Z. Qingwen and Z. Jun (2002). The sealing process and crust formation at soil surface under the impacts of raindrops and polyacrylamide. Proc. 12th Conf. ISCO, May 26-31, Beijing, China.

تقدير سمك القشور السطحية والتوصيل الهيدروليكي لأربعة أراضي وتأثرها بنسبة إدمصاص الصوديوم والقوة الأيونية للمحلول الأرضي

صالح محمد على ، عبد المنعم محمد محمد عامر ، وائل محمد عمران ، إبراهيم محمد سالم

قسم علوم الأراضي، كلية الزراعة، جامعة المنوفية، مصر

الملخص العربي

تعريف القشور السطحية في هذا العمل بأنها عبارة عن الطبقة العليا من التربة ذات خواص هيدروليكية تقل عن الطبقات المتواجدة تحتها. القشور السطحية عبارة عن طبقة رقيقة جدا أو طبقة منتشرة في عدة سنتيمترات من الأرض. ان سمك القشور وخواصها الهيدروليكية دالة لعديد من العوامل مثل وجود الحبيبات الناعمة (معدنية وعضوية)، تركيز الإلكتروليت، نسبة إدمصاص الصوديوم وعوامل أخرى. الهدف من هذه الدراسة هو تقدير سمك القشور السطحية والتوصيل الهيدروليكي لأربعة أراضي وتأثرها بنسبة إدمصاص الصوديوم (صفر، 5، 10، 30، 50 ومالانهاية) والقوة الأيونية للمحلول الأرضي (5 و50 ملليمكافئ/لتر) وتقدير تأثير كل من نسبة إدمصاص الصوديوم ومحتوى الطين على كل من سمك القشور والتوصيل الهيدروليكي. تم اختيار أربعة أراضي من محافظة المنوفية – مصر بمناطق (قويسنا، الباجور، شبين الكوم وبركة السبع). تم تطبيق الطريقة المقترحة لتقدير سمك السيل والتوصيل الهيدروليكي لأعمدة التربة متخذا في الاعتبار أن القشور السطحية هي الطبقة العليا لطبقتين في النظام المقترح للقياس. أوضحت النتائج أن هناك نقص واضح في التوصيل الهيدروليكي للأراضي المحتوية على هذه القشور في وجود قيم لنسبة إدمصاص الصوديوم حتى (10) ثم استمر النقص حتى وصل إلى معدلات منخفضة جدا للأراضي الأربعة. قيم التوصيل الهيدروليكي كانت مرتفعة في أراضي قويسنا الرملية وتقل مع زيادة محتوي الطين حيث وجد أن أقل القيم لأراضي بركة السبع الطينية. سمك القشور السطحية للأرض الرملية زادت زيادة طفيفة مع زيادة نسبة إدمصاص الصوديوم ولكنها تناقصت حتى (10) وكانت أعلي قيم للسمك في الأراضي الطينية.

Table (3): Computed results of seal parameters for Quesna area

Electrolyte conc. Meq. l^{-1}	SAR	L_1	L_2	K_1	K_2	Ke	Px	L_1/K_1	Ke/K_2	K_1/K_2	L/Ke
5	0	0.72814	9.2719	1.0587	12.124	6.8845	-1.3742	0.687768	0.567841	0.087323	1.453
	5	0.64538	9.3546	0.93683	8.5365	5.6031	-0.14455	0.688898	0.656370	0.109744	1.785
	10	0.58729	9.4127	0.62983	6.5042	4.2023	-0.29044	0.932458	0.646090	0.096834	2.380
	30	0.71689	9.2831	0.5075	4.1156	2.7262	-0.05951	1.412591	0.662406	0.123311	3.668
	50	0.91541	9.0846	0.49898	2.773	1.9567	0.53094	1.834563	0.705626	0.179942	5.111
	∞	2.119	7.881	0.45146	1.3314	0.94222	0.48524	4.693661	0.707691	0.339087	10.613
50	0	0.15176	9.8482	1.4951	22.868	18.791	2.2906	0.101505	0.821716	0.065380	0.532
	5	0.54433	9.4557	1.5239	13.907	9.6421	0.37797	0.357195	0.693327	0.109578	1.037
	10	0.46117	9.5388	1.0552	8.9521	6.6552	1.0984	0.437045	0.743423	0.117872	1.503
	30	2.4929	7.5071	2.4879	6.784	4.7425	0.36493	1.00201	0.699071	0.366731	2.109
	50	3.6259	6.3741	1.9162	4.8506	3.1188	-0.2265	1.892235	0.642972	0.395044	3.206
	∞	0.20427	9.7957	0.17849	2.8012	2.1545	1.5058	1.144434	0.769135	0.063719	4.641

Table (4): Computed results of sealing parameters for El-Baghour area

Electrolyte conc. Meq. l^{-1}	SAR	L_1	L_2	K_1	K_2	K_e	P_x	L_1/K_1	Ke/K_2	K_1/K_2	L/Ke
5	0	2.5016	10.498	0.63587	6.3857	2.3305	-4.8986	3.934137	0.364956	0.099577	5.578
	5	2.158	10.842	0.41214	4.8567	1.7406	-5.1628	5.236085	0.358392	0.084860	7.468
	10	1.9778	11.022	0.32665	3.0477	1.3442	-3.9172	6.054799	0.441054	0.107179	9.671
	30	1.7063	11.294	0.16119	1.9221	0.78973	-4.5119	10.58564	0.410868	0.083861	16.462
	50	1.239	11.761	0.087083	1.2386	0.54798	-4.1562	14.22781	0.442419	0.070308	23.723
	∞	0.59335	12.407	0.019042	0.60388	0.25142	-4.8571	31.16007	0.416341	0.031533	51.706
50	0	1.9711	11.029	1.4439	16.775	6.4274	-4.8527	1.365122	0.383154	0.086075	2.023
	5	1.7321	11.268	1.1082	12.283	5.2412	-4.2408	1.562985	0.426704	0.090222	2.480
	10	1.9778	11.022	0.32665	3.0477	1.3442	-3.9172	6.054799	0.441054	0.107179	9.671
	30	1.7063	11.294	0.16119	1.9221	0.78973	-4.5119	10.58564	0.410868	0.083861	16.462
	50	4.0624	8.9376	0.36917	3.5333	0.96057	-5.3864	11.00414	0.271862	0.104483	13.534
	∞	1.0228	11.977	0.057251	1.3542	0.48673	-5.6856	17.86519	0.359423	0.042277	26.710

Table (5): Computed results of sealing parameters for Shebin El-Kom area

Electrolyte conc. Meq. l^{-1}	SAR	L_1	L_2	K_1	K_2	K_e	P_x	L_1/K_1	Ke/K_2	K_1/K_2	L/Ke
5	0	2.9115	7.0885	0.89235	4.1213	2.0069	-1.9107	3.262733	0.486958	0.216521	4.983
	5	1.8648	8.1352	0.50803	3.0161	1.5704	-1.7816	3.670649	0.520672	0.168439	6.368
	10	1.4599	8.5401	0.37806	1.9278	1.206	-0.52593	3.861556	0.625584	0.196110	8.292
	30	1.6757	8.3243	0.18808	1.3314	0.65956	-2.1385	8.909507	0.495388	0.141265	15.162
	50	1.7534	8.2466	0.215	0.56533	0.4397	1.3744	8.155349	0.777776	0.380309	22.743
	∞	1.1188	8.8812	0.3773	0.37877	0.18844	-2.2534	2.96528	0.497505	0.996119	26.413
50	0	2.319	9.7681	0.87201	9.0369	7.4247	2.2702	2.659373	0.821598	0.096494	3.740
	5	0.16771	9.8323	0.54096	5.7749	4.9687	2.8571	0.310023	0.860396	0.093674	2.013
	10	3.5066	6.4934	1.2945	3.9432	2.2959	-0.82234	2.708845	0.582243	0.328287	4.356
	30	1.636	8.364	0.29953	2.3009	1.0993	-2.3701	5.46189	0.477770	0.130179	9.097
	50	0.2522	9.7478	0.028811	1.6282	0.6784	-3.6554	8.753601	0.416656	0.017695	14.740
	∞	3.3661	6.6339	0.16051	0.55968	0.30465	-1.2173	20.97128	0.544329	0.286789	32.824

Table (6): Computed results of sealing parameters for Berket El-Saba area

Electrolyte conc. Meq. l^{-1}	SAR	L_1	L_2	K_1	K_2	K_e	P_x	L_1/K_1	Ke/K_2	K_1/K_2	L/Ke
5	0	1.5826	8.4174	0.53706	3.621	1.897	-1.8026	2.946784	0.523888	0.148318	5.271
	5	1.6222	8.3778	0.31109	2.7419	1.2092	-2.8358	5.214568	0.441008	0.113458	8.270
	10	1.2077	8.7923	0.16299	1.6508	0.78519	-2.5193	7.409657	0.475642	0.098734	12.736
	30	0.92828	9.0717	0.08865	1.1589	0.54649	-2.6551	10.470937	0.471559	0.076495	18.299
	50	0.51048	9.4895	0.05411	0.59925	0.3957	0.08952	9.433941	0.660325	0.090296	25.270
	∞	0.21644	9.7836	0.00605	0.38443	0.16332	-3.5489	35.779938	0.424837	0.015738	61.225
50	0	2.7094	7.2906	2.0055	7.1119	4.2086	-0.8191	1.350985	0.591769	0.281992	2.376
	5	3.7078	6.2992	1.7752	5.1558	3.0214	-0.7605	2.088666	0.586020	0.344311	3.310
	10	3.2518	6.7482	1.1542	4.0478	2.2299	-0.1718	2.817363	0.550892	0.285143	4.484
	30	2.881	7.7119	0.6597	3.0782	1.674	-1.4211	4.367137	0.543824	0.214314	6.872
	50	1.7177	8.2823	0.32267	2.3687	1.1338	-2.3358	5.323395	0.478659	0.136222	8.820
	∞	1.539	8.461	0.08832	0.8056	0.35804	2.8203	17.426258	0.444439	0.109633	27.928

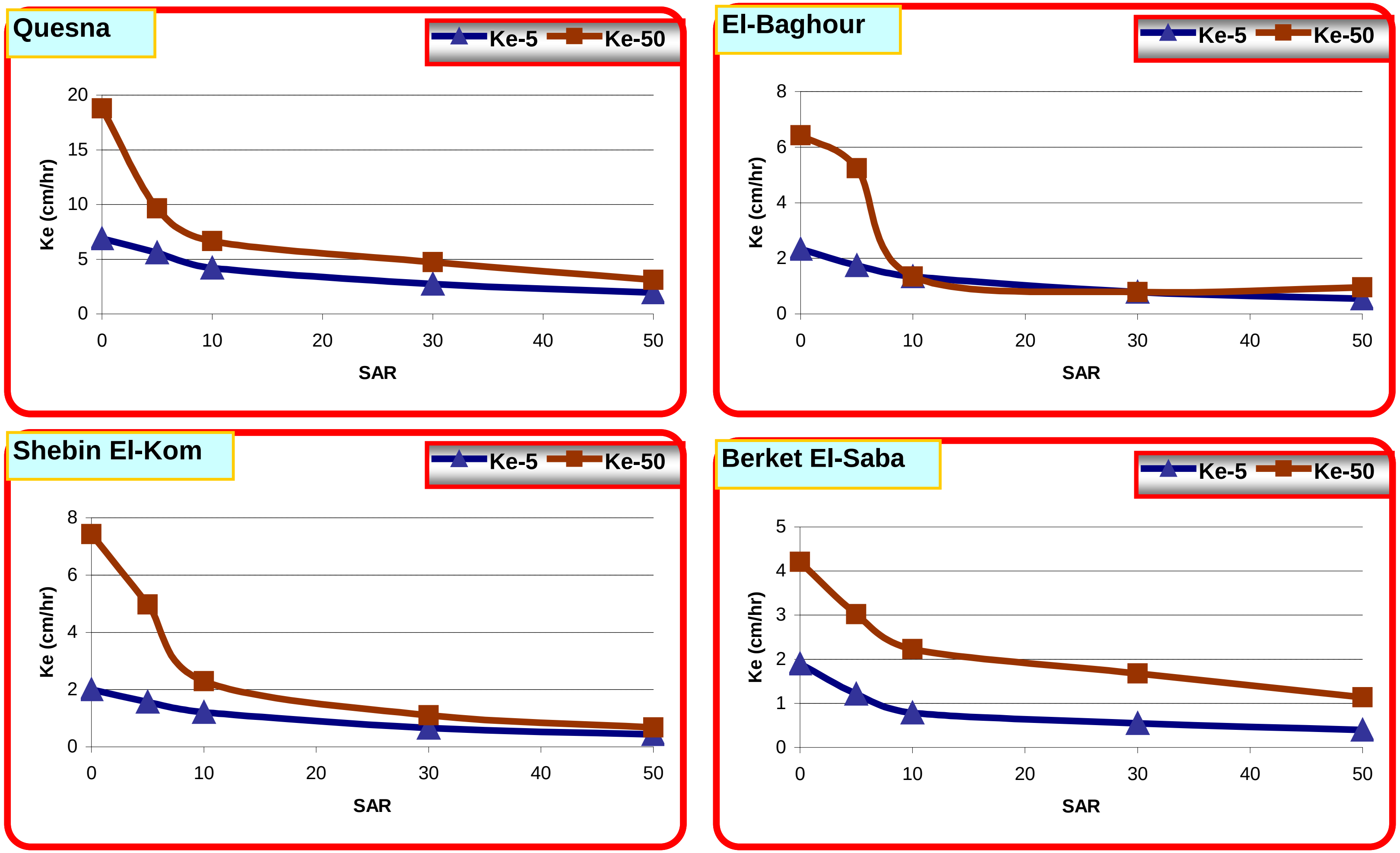

Fig. (1): Effect of SAR values on hydraulic conductivity of sealed soils (cm/h) at 5 and 50meq l^{-1} for all soils under investigation.

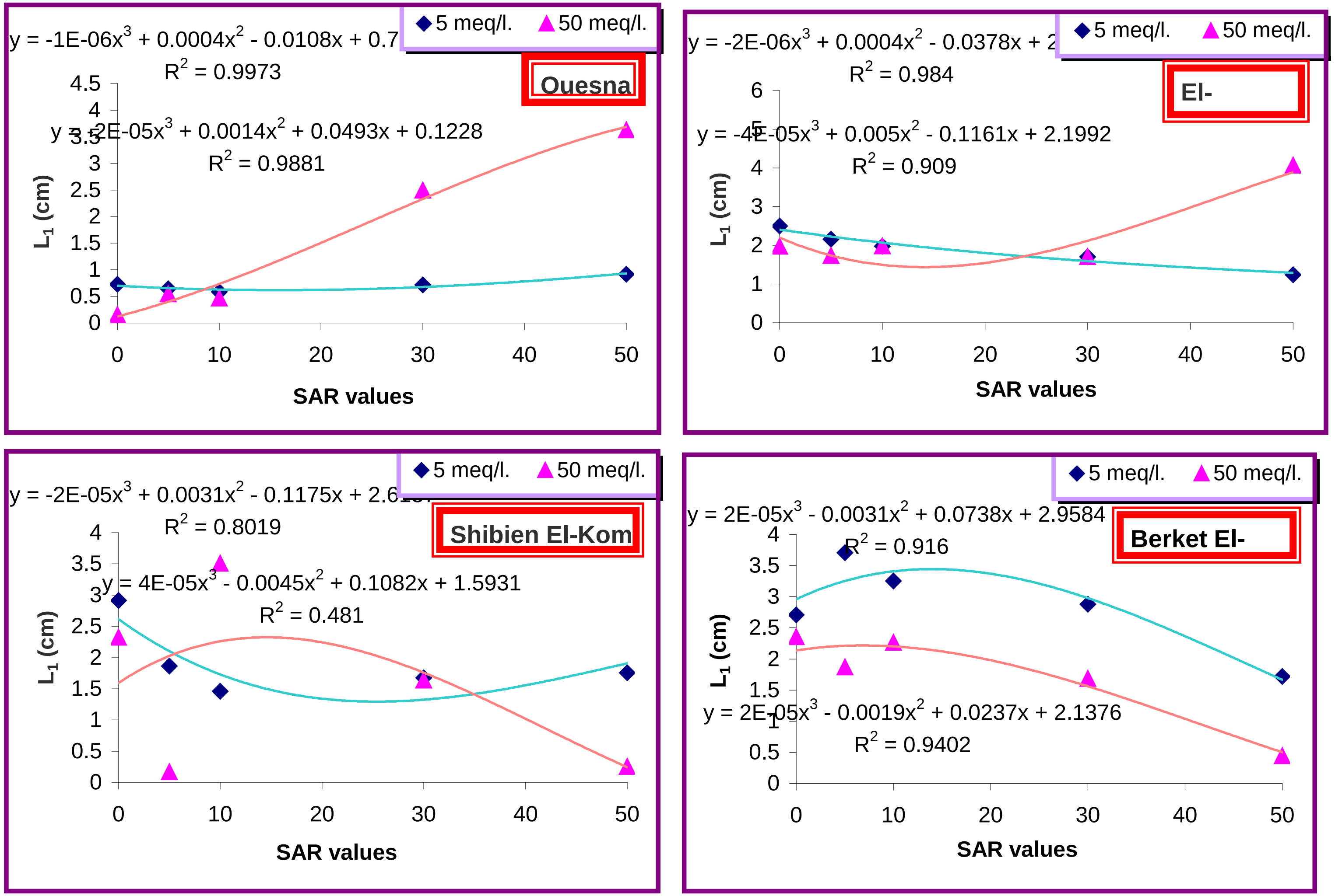

Fig. (2): Effect of SAR values on seal thickness (L_1) at 5 and 50 meq l^{-1} for the soils under investigation.

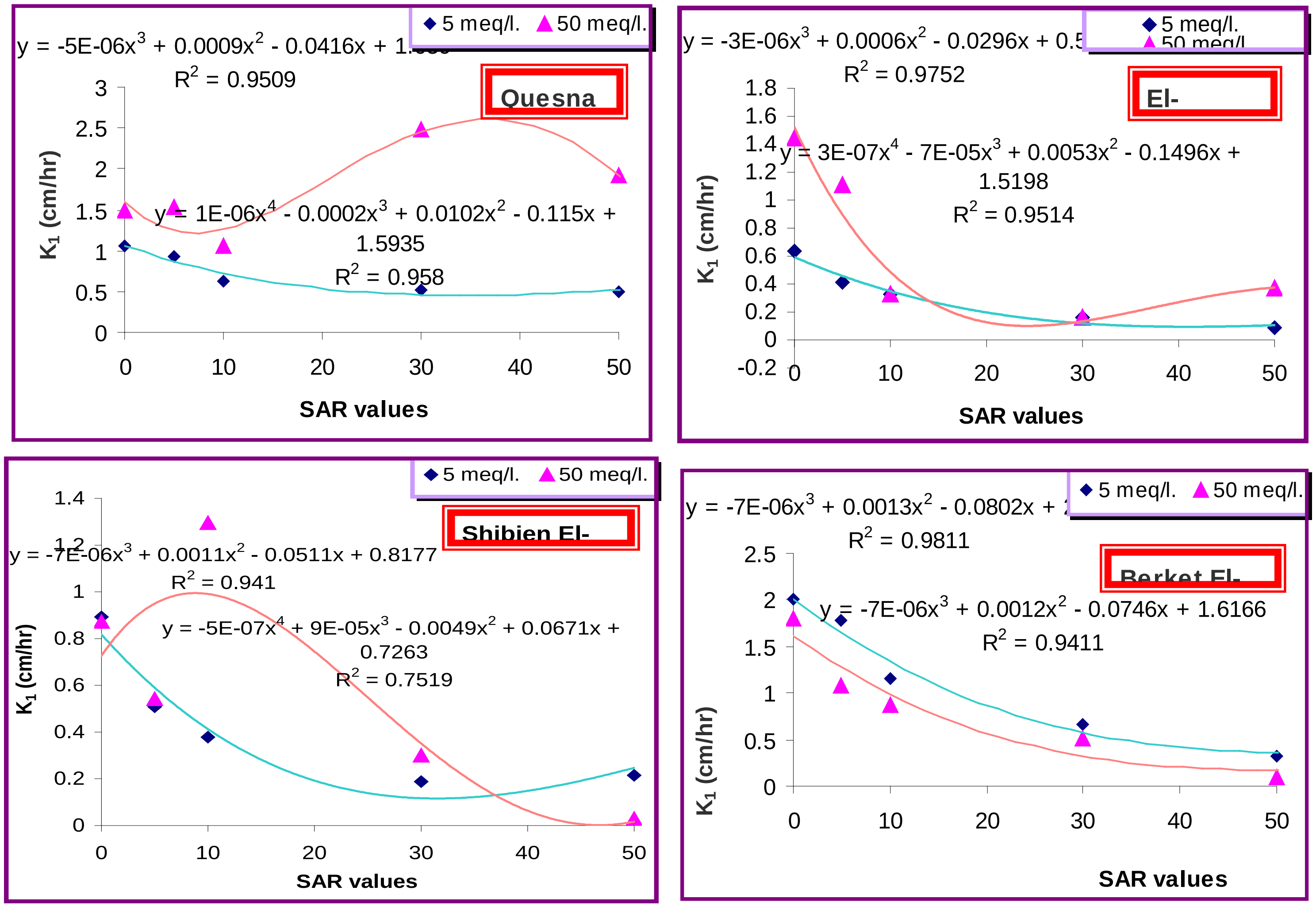

Fig. (3): Effect of SAR values on seal hydraulic conductivity (K_1) at 5 and 50 meq l^{-1}. for the soils under investigation.