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# MUNICIPAL GARBAGE EFFECTS ON THE LEACHING OF SOIL SOLUTES

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## ABSTRACT

Unknown effects of surface/subsurface municipal garbage on interception, subsequent wash-off, and movement of agrochemicals through soils are concerns. Calcium chloride movement as an analogous for a highly movable solute is monitored in a sandy soil collected from the College of Agriculture and Veterinary Medicine King Farm at Al-Qassim province, Kingdom of Saudi Arabia. The sandy soil was packed uniformly in PVC columns at bulk density of 1.65 g/cm$^3$. The height and diameter of soil column were 20.8 cm and 8.6 cm, respectively. The municipal garbage was applied to the soil columns using five strategies: three levels of the municipal garbage at the top of soil column (0.0 g, 40 g and 60 g), and two levels was mixed in the upper 10-cm layer (40 and 60 g). Calcium chloride solution of 96.4 meq/l was applied at the top of each soil column using a 1.5-cm constant water pressure head. An effluent of each column was collected periodically. The effluents were analyzed for the EC which gives the concentration of calcium chloride in meq/l. The concentration distribution of ions in the effluent was described using the computer program of CXTFIT for the first three strategies of garbage applications. The dispersion coefficient, D, and the mean pore water velocity, $\overline{V}$, were calculated using the computer program. In general, The program described more than 98% of the variations in the effluent concentrations of the $CaCl_2$. The variations in D and $\overline{V}$ were not significant at 5 % level for the first three applications strategies. So, there is no effect for the first three application strategies on the movement of $CaCl_2$ in the used soil. The pore volume at 50% effluent $CaCl_2$ concentration was calculated for garbage application strategies. The $CaCl_2$ was moving more slowly when 60 g of the garbage was mixed in the upper 10-cm layer in comparison to either application strategy. There were significant differences in the pore volume between the fifth application (60 g mixed) and either application. But the difference in the pore volume among the first four application strategies was not significant. So, to delay the appearance of the movable solutes in effluent, it is recommended to mix high organic residue in the upper soil layer.

**Keywords**: municipal garbage, application strategies, mean pore water velocity, dispersion coefficient.

## INTRODUCTION

The use of agricultural chemicals (pollutants) is widespread in modern agriculture. A significant portion of these pollutants entering streams, lakes, and ground water results from agricultural fields. Recent reports detail the extent to which drinking water supplies have been affected by nitrate. A study of drinking water quality in the Midwestern United States showed 6% of 599 water samples from 303 shallow wells contained higher $NO_3$ concentrations than the U.S. Environmental Protection Agency maximum contaminant level of 10 mg/L (Kolpin *et al.* 1991). In order to solve the water pollution problem, agrochemical sources should be controlled. Such a good mean to control the agricultural pollution is utilization the best management practices (BMPs). For example, Water Program (RCWP), conducted during the 1980s in the United States of America, demonstrated the importance of using BMP systems to control agricultural nonpoint source (NPS) pollution (Gale *et al.*, 1993). An individual BMP can be performed using tillage type or agricultural chemicals management. Increasing awareness of the potential environmental hazards posed by agricultural chemicals has spurred research in the area of pollutant transport with regards to the tillage type (Kanwar *et al.*, 1985; Hall *et al.*, 1989; and Green *et al.*, 1995). Implementation of no-till can promote the development and preservation of macropores (Kanwar *et al.*, 1985). Several studies have demonstrated that macropores may encourage the preferential transport of both water and solute (White, 1985) while others have observed less chemical leaching (Kanwar *et al.*, 1985). A study by Hall *et al.* (1989) concluded that herbicide transport through a well-drained soil matrix was greatest under a no-till management system. Gish *et al.* (1989) concluded that preferential flow encouraged atrazine movement under no-till system. Conventional tillage practices disturb the upper 10 to 20 cm of soil, and this disturbance often results in reduced leaching of surface applied chemicals when compared with no-till (conservation tillage) management system (Singh and Kanwar, 1991). Indeed, the depth of disturbance need not be deep; Anderson and Bouma (1977) reduced leaching by applying a 0.5-cm layer of gypsum and sand to the surface of the soil to prevent the infiltrating liquid from flowing rapidly through macropores. This crust closed the surface pores to moderate infiltration. Management the timing and method of agricultural chemicals application could lead to improve the quality of our water resources. Green *et al.* (1995) studied the leaching of atrazine in undistributed soil columns using different crop residue ratio at the top of the columns. The columns were classifieds into three groups according to their saturated hydraulic conductivity (high-Ksat, medium-Ksat and low-Ksat). They found that greater amounts of atrazine were recovered with the first 5.0 cm of drainage in the 100%-residue columns than with the zero-residue columns for high and medium-Ksat columns. Zonal soil management allows for the combination of various strategies for preserving macropores to aid infiltration in solute-free zones and for macropores destruction to limit preferential flow through solute placement zones. Management of separate soil zones during chemical application was investigated by Ressler *et al.* (1998) using three strategies (ponded application of solute, unsaturated solute infiltration, a zonal management technique). They reported that solute breakthrough patterns during the first 2.5-cm drainage were influenced by both solute application method and soil column macroporosity.

The movement of solute in soils depends on the geometry of the soils and physical and chemicals interaction of the solute and media during flowing (Biggar and Nielsen, 1962). Rao *et al.* (1980) studied the breakthrough curves (BTC's) for $^{36}Cl^-$ and $^3H_2O$ in water-saturated columns of aggregated and non-aggregated porous media at pore-water velocities ranged from 2 to 96 cm/hr. Theses BTC's were used to verify that convective-depressive solute transport occurs in the inter-aggregate pore-water region, while the intra-aggregate pore-water to behave as a diffusion sink/source for solute.

Equations describing the movement of a solute through a porous medium such as soil have been derived and investigated by many researchers. Theses equations use both analytical and numerical techniques to describe non-interacting as interacting solute transport. For example, van Genuchten and Alves (1982) introduced analytical solutions for the one-dimensional convective-dispersive solute transport equation. Parker and van Genuchten (1984) introduced a computer program based on the analytical solution of solute transport equation. The program is called CXTFIT that describes a non-linear least-squares inversion method. The program can be useful to identify several parameters in a number of theoretical one-dimensional solute transport models.

The comparative effects of garbage application strategies on both water and solute transports during miscible displacement of electrolytes are limited in the literature. So, five application strategies of municipal garbage under 0.015-m pressure head are used for monitoring the solute and water transport in a sandy soil. Calcium chloride solution is used for leaching the soil and The CXTFIT program is used for calculating the electrolytes transport parameters.

## MATERIALS AND METHODS

### I-Experiment

Municipal garbage was collected from Hail Province, the Kingdom of Saudi Arabia. The stones and metals were removed then the rest portion of the collected garbage was fermented partially. Sandy soil used in this study was sampled from a surface layer (0.0-30.0 cm depth) from the farm of the Agriculture and Veterinary Medicine College, King Saud University, Al-Qassim. The soil sample was prepared by air-drying, crushing and sieving to pass through a 2-mm screen.

For studying solute leaching, the sieved sandy soil was packed in PVC columns (8.6-cm I.D. and 20.8-cm long). Five application strategies of the municipal garbage to the soil columns were used: No garbage, 40 g at the top of soil column, 40 g was mixed in the upper 10-cm layer of soil column and 60 g on the top of soil column, and 60 g was mixed in the upper 10.-cm layer of the soil column. These application strategies were referred as bare soil, 40 g-top layer, 40 g-mixed layer, 60 g-top layer and 60-g mixed layer, respectively. The bulk density of soil column was 1.65 g/cm$^3$. The soil columns were saturated using the tap water then 1.5-cm constant water pressure head was maintained at the inlet of each soil column for leaching the soil columns. Calcium chloride solution with 96.4 meq/l was used for leaching the soil columns. Three replicates were assigned for each application strategies. Effluents were collected at fixed times from each soil column separately and analyzed for EC. The chloride concentration was obtained from knowledge of the EC.

## II- Theory

Transport of a linearly exchangeable solute is described with the one-dimensional advection-dispersion equation (ADE) (Parker and van Genuchten, 1984):

$$R\frac{\partial C}{\partial t} = D\frac{\partial^2 C}{\partial x^2} - v\frac{\partial C}{\partial x} \qquad t > 0 \qquad (1)$$

where $R = 1+\rho\zeta/\theta$, is the retardation coefficient which is equated to unit for chloride ions, C is the resident concentration expressed in mass of solute per volume of solution $[M/L^3]$, t is time [T], D is the dispersion coefficient $[L^2/T]$, $v = q/\theta$, is the mean pore-water velocity [L/T], $\rho$ is the porous medium bulk density $[M/L^3]$, $\zeta$ is an empirical distribution constant $[L^3/M]$, and $\theta$ is the volumetric water content $[L^3/ L^3]$ and x is the distance in direction of flow [L]. Equation [1] describes the temporal and spatial solute concentration in a homogeneous porous medium.

The dispersion coefficient D in Eq. [1] reflects two mechanisms responsible for solute spreading, molecular diffusion and mechanical dispersion. A common expression for the dispersion coefficient is

$$D = \lambda D_0 + \alpha|v| \qquad (2)$$

Where $D_0$ is the ionic or molecular diffusion coefficient in free water $[L^2/T]$, $\lambda$ is a tortuosity factor ($0 < \lambda < 1$), and $\alpha$ is the dispersivity, [L]. Equation [2] assumes that, macroscopically, the active process of diffusion can be combined with the more passive process of mechanical dispersion.

For solving Eq. [1] numerically or analytically the initial concentration of solute and the boundary conditions are required. The initial solute concentration for the present study is:

$$C(x,0) = C_i \qquad (3)$$

The values of $C_i$ is the solute concentration in the soil solution prior the calcium chloride application at the inlet of a soil column. The following top-boundary condition is used in combination with Eq. [1]:

$$C(0,t) = C_0 , \quad 0 \ ? \ t \qquad (4)$$

The concentrations of electrolytes at the top-boundary are the concentration of leaching calcium chloride solution which was 96.4 meq/l.

The presence of semi-infinite medium could be invoked by imposing the condition:

$$?C/?x|_{x=\infty} = 0.0 \quad t>0 \qquad (5)$$

Based upon equations [1] through [5], Parker and van Genuchten (1984) introduced an analytical solution and the program of CXTFIT for Equation [1]. For obtaining the solute transport parameters (v, and D), the program of CXTFIT was fitted to the concentrations of chloride determined in the effluent of each soil column in the present study.

## RESULTS AND DISCUSSION

The CXTFIT program was fitted to the effluent concentration of chloride for obtaining the mean pore-water velocity, v and dispersion coefficient, D, for the application strategies of bare soil, 40 g-top layer, and 60 g-top layer. The soil columns of these applications strategies are uniform that required by the program of CXTFIT. Table [1] shows the mean pore-water velocity and dispersion coefficient for 0.0 , 40-g-top, and 60-g-top application strategies. Since the chloride is a non-reactive solute, its retardation coefficient, R, is considered to be a unit. It is obvious from Table [1] that D of the chloride anion increases as the municipal garbage rate increases under the above mentioned application strategies. Green *et al.* (1995) used wide range for covering undistributed soil column using crop residue (0.0 to 100 %) then monitored the chloride concentration in the effluent of undisturbed soil column. They found that the zero level of crop possessed the lowest dispersion coefficient and at 100 % level gave the greatest dispersion coefficient. These increases are due to the mechanical dispersion that is a function of the pore-water velocity (Leij *et al.*, 1991). All D values (0.005844 – 0.007398 $m^2/h$) are considerably larger than the effective molecular diffusion coefficients in soils, which vary, depending on the soil type and water content, from 0.00007 to < 0.00001 $m^2/d$ (Vanderborght *et al.*, 1997). However, the differences among those application strategies are not significant at 5 %. There is no obvious trend for the pore -water velocity. Their values are close together and the differences among them are not significant. Figures [1] - [3] show the predicted and experimental effluent concentration of chloride as a function of time for those application strategies. In general, the predicted concentration of chloride agreed reasonably with the experimental values. The program described 98 % of the variations in the effluent concentrations of chloride under pressure head used in the study for the three application strategies. Results of these study indicate that program of CXTFIT is a useful tool for estimating the pore- water velocity and the dispersion of a solute in soils. Knowledge of these coefficients is required for describing the transport and fate of such solute in soils. Their values can be used for chemical waste sites, sewage water sites and fertilizer managements.

**Table (1): Pore -water velocity and dispersion coefficient for the soil column covered with organic residue during the saturated $Cl^-$ breakthrough experiment.**

| Organic residue (g on column top) | Mean pore water velocity, m/h | Dispersion coefficient, $m^2/h$ |
|---|---|---|
| 0.0 | 0.2982 | 0.005844 |
| 40.0 | 0.3066 | 0.006234 |
| 60.0 | 0.2790 | 0.007398 |
| $LSD_{(0.05)}$ | 0.1701 | 0.006121 |

Figure [4] shows the relative pore volume under all application strategies. It is obvious that the relative concentration of chlorides increases as the pore volume increases. It is worth noting that the 60.0 g on soil column top and 60.0 g mixed in the upper 10-cm layer possessed the greatest pore volume to reach 1 relative concentration. One relative concentration occurred after 1.5 pore volume for 0.0, 40 g on top and 40 g mixed while it occurred

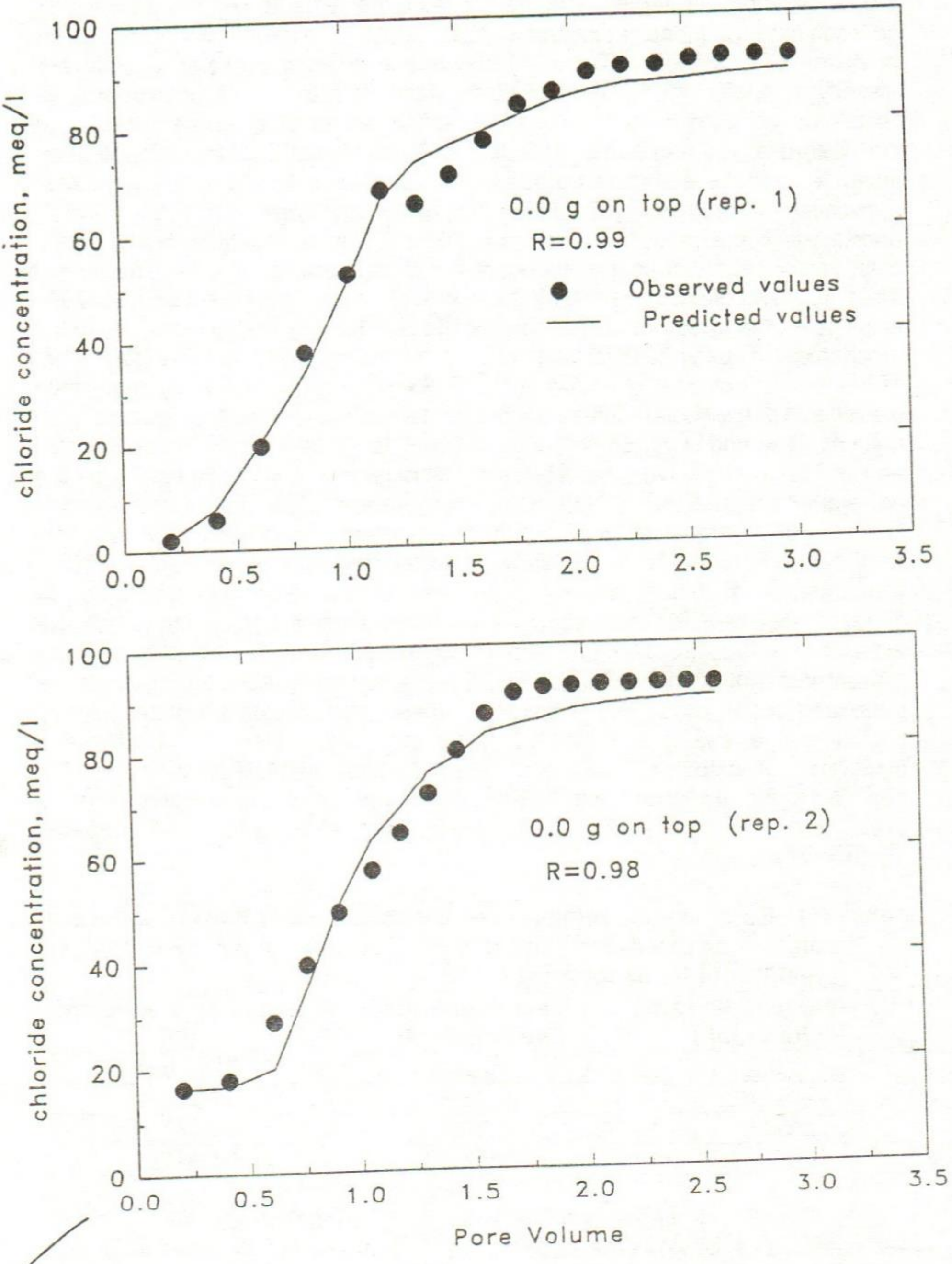

Fig 1 : The predicted and observed chloride breakthrough curve for bare soil columns.

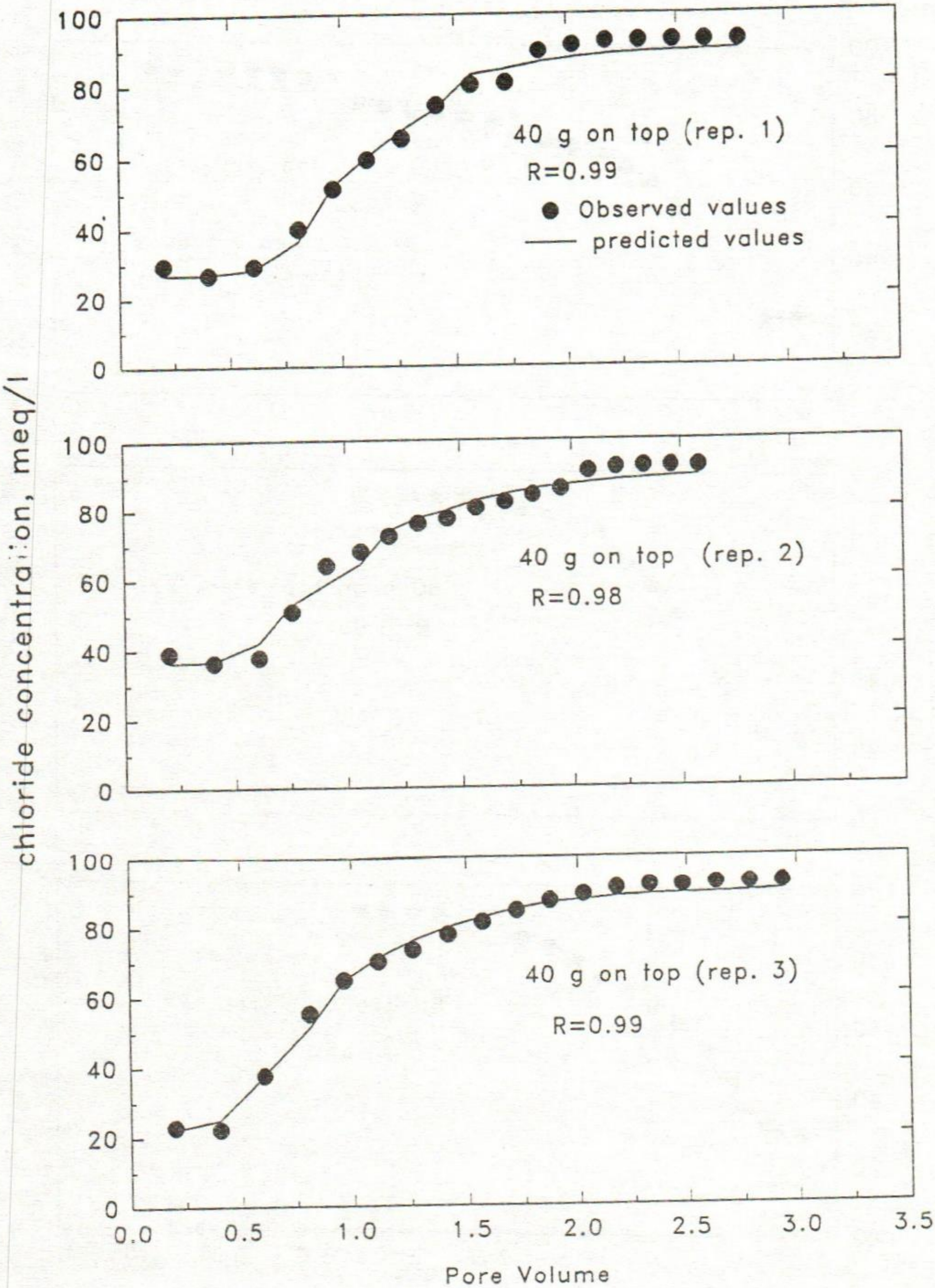

Fig 2 : The predicted and observed chloride breakthrough curve using 40 g of municipal garbage at the top of soil column.

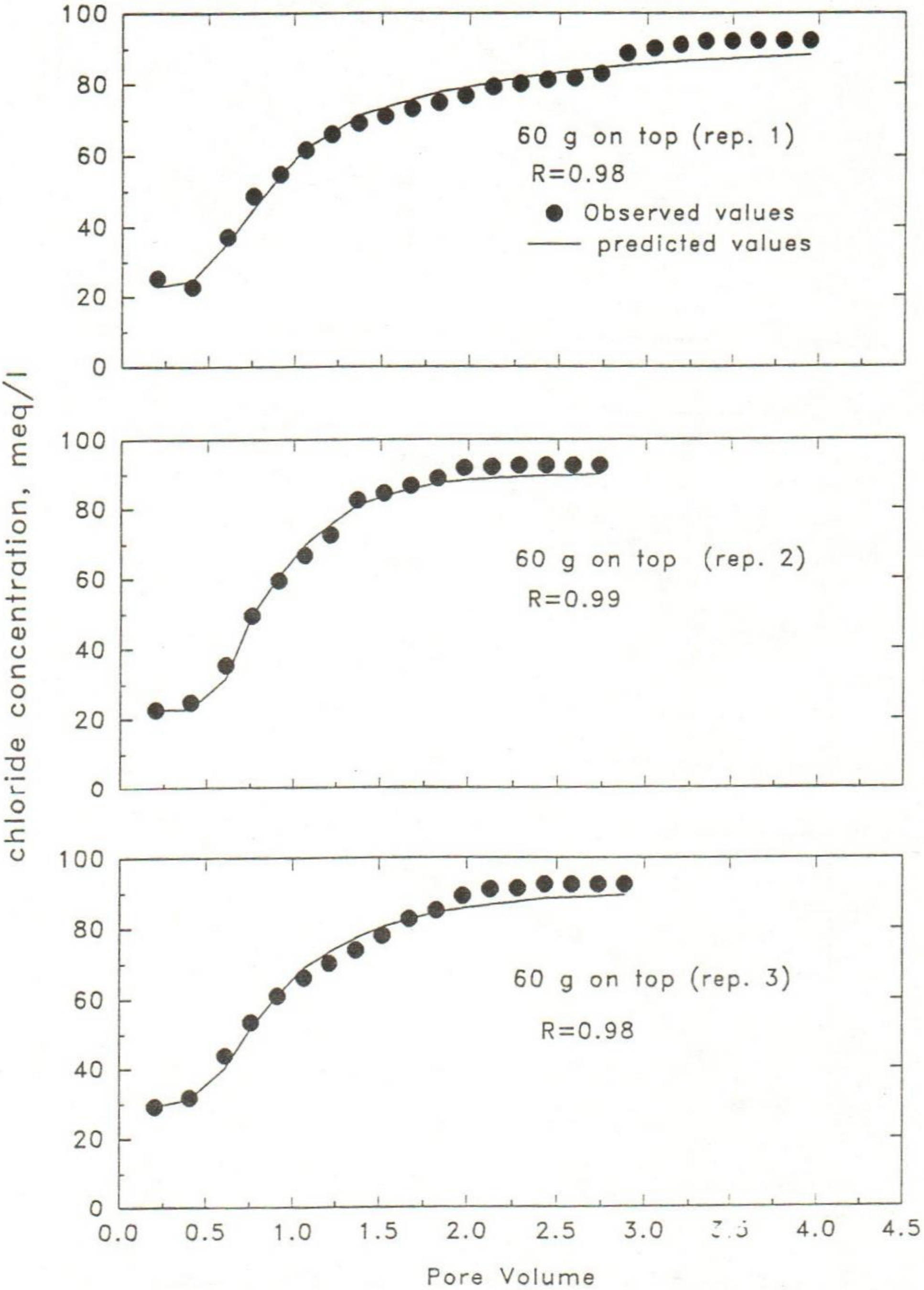

Fig 3 : The predicted and observed chloride breakthrough curve using 60 g of municipal garbage at the top of soil column.

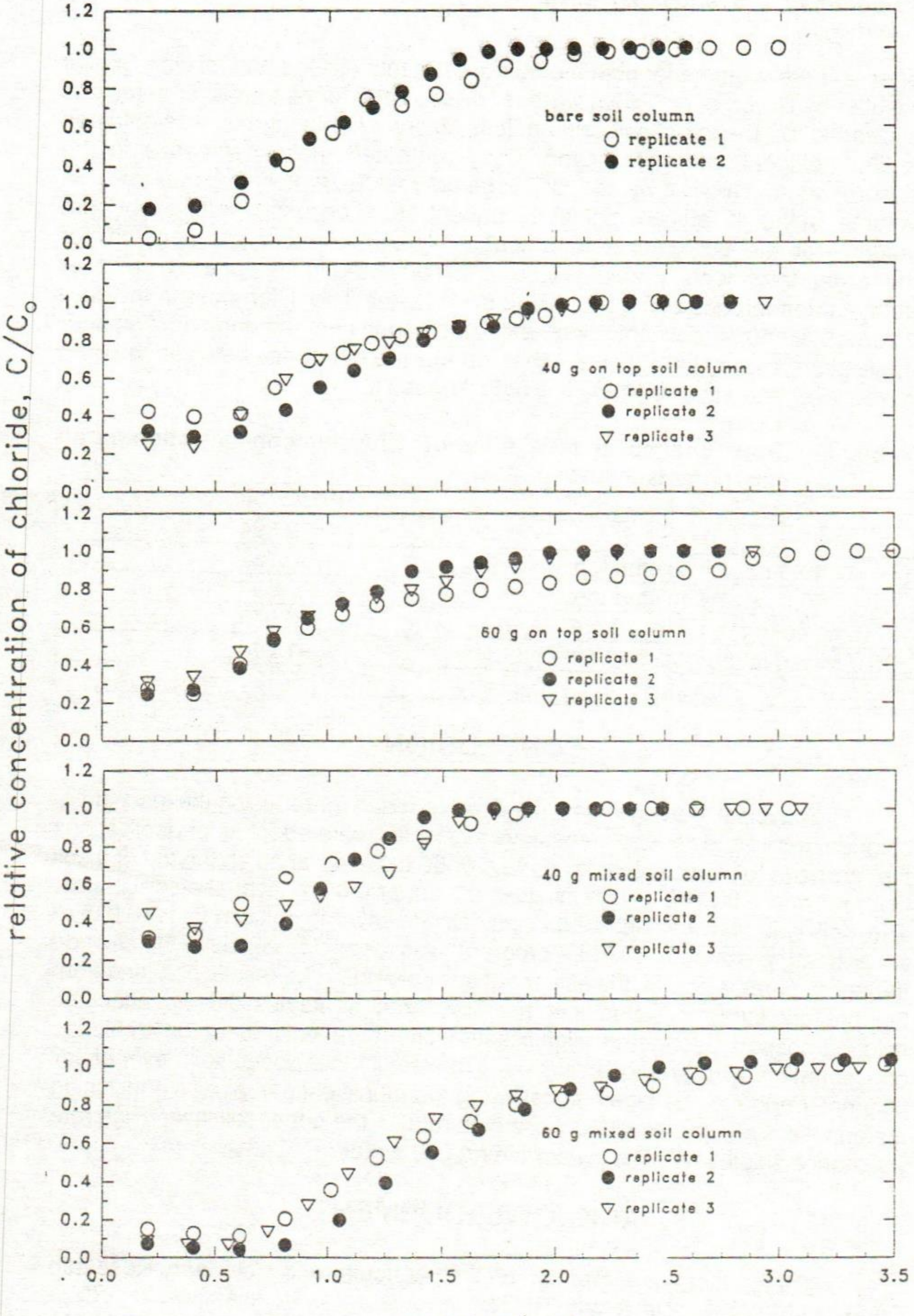

Fig. 4: The chloride breakthrough curve for garbage application aspects

after 3 pore volume for both the 60 g treatments (on top and mixed). Similar results by Green *et al.* (1995) were reported. They found that as crop residue increased at the top of soil column, less chloride concentration was obtained in the effluent of soil column. They attributed these decreases to the absorption of chloride by the dry organic reside. It is noting that the pore volume at 50 % effluent chloride concentration occurred after 1.244 pore volume for the 60 g mixed treatment, while it occurred at less than unity for the other treatments (Table [2]). So, mixing 60 g in the upper 10 cm layer delayed appearance of the chloride in the effluent. The differences in the pore volume at 50% concentration are not significant among the first four application strategies. On the other hand, the difference between the 60-g mixed layer and either strategy is significant at 5%.

**Table (2): Pore volume at 50% effluent Chloride concentration for all experimental columns.**

| Organic residue (g) | Pore volume |
|---|---|
| 0.0 | 0.894 |
| 40.0 on soil column top | 0.757 |
| 60.0 on soil column top | 0.698 |
| 40.0 mixed in the upper 10 cm –layer | 0.973 |
| 60.0 mixed in the upper 10 cm-layer | 1.244 |
| LSD $_{(0.05)}$ | 0.193 |

## CONCLUSION

Municipal garbage was used as a mean for reducing the leaching of chloride from sandy soil columns. Five strategies were adapted for applications the garbage to the soil. Zero level, 40 g or 60 g were placed on the top of a soil column, and 40 or 60 g were mixed in the upper 0.01 m-layer of a soil column. The soil columns were leached using calcium chloride solution under 0.015 m as a head pressure. CXTFIT program was used to calculate the chloride transport parameters in the effluent of soil columns. The results obtained from the present study indicated that the first three strategies did not affect the solute transport parameters significantly. The pore volume at 50% chloride concentration was greater using 60 g mixed in the upper soil layer of soil column. For better management for using the municipal garbage as a mulching material, it is recommended to mix a high rate in the upper soil layer. High rate will reduce solute migration toward the ground water resources.

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# تأثير مخلفات المدن على غسيل املاح التربة

**ابراهيم صالح السلامة وإبراهيم نصار نصار**
**قسم االتربة والمياه-كلية الزراعةوالطب البيطري-القصيم -جامعة الملك سعود، المملكة العربية السعودية**

أجريت دراسة لغسيل ارض رملية باستخدام محلول كلوريد الكالسيوم ذو نركيز ٩٦,٤ ملليمكافئ/لتر. تهدف تلك الدراسة إلى تحديد انسب طريقة اضافة للمخلفات العضوية والتي تؤدي الى خفض كمية الكيماويات الزراعية التي تلوث المياه الجوفية خاصة والمصادر المائية عامة. كذلك تهدف الدراسة الى دراسة اثر طريقة الاضافة على قيم معامل الأنتشار للاملاح الذائبة ومتوسط سرعة الماء في فراغات التربة باستخدام برنامج CXTFIT . تم تعبأة التربة في أعمدة PVC حتى كثافة ظاهرية ١,٦٥ جم/سم$^{٣}$. استخدم جهد ثابت من ضغط الماء ٠,٠١٥م عند قمة عمود التربة. تم جمع محلول التربة المار خلال الأعمدة لتقدير الأملاح الكلية الذائبة والتي حسب منه تقدير الكلوريد. استخدم برنامج CXTFIT لوصف تركيز الكلوريد مع حجم المحلول الفراغي (Pore volume) . وصف البرنامج اكثر من ٩٨ % من الاختلافات في تركيز االكلوريد . معامل انتشار الكلور يد المحسوب من البرنامج كان 0.005844 و0.006234 و0.007398 م$^{٢}$/ساعة للمعاملات 0.0 و 40.0 و 60.0 جم مخلفات عضوية على سطح الاعمدة على التوالي. اوضحت النتائج ان معامل الانتشار قد ازداد بزيادة نسبة المخلفات ولكن الاختلافات بين قيم معامل الانتشار للمعاملات المذكورة كانت غير معنوية. قيم سرعة الماء في الفراغات للمعاملات السابق ذكرها لم تتخذ اتجاه ثابت والفروق بين سرعة الماء كانت غير معنوية . نتائج الدراسة تدل علي أن برنامج CXTFIT يعد وسيلة جيدة لتقدير معاملا الانتشار وسرعة الماء في الفراغات . اوضحت الدراسة ان قيم حجم المحلول الفراغي (Pore volume) التي عندها يجمع ٥٠% من تركيز الكلوريد كانت 0.757 و 0.698 و 0.973 و1.244 للمعاملات 0.0 و ٤٠ جم علي السطح و٦٠ جم علي السطح و٤٠ جم مخلوطة و٦٠ جم مخلوطة علي الترتيب. الاختلافات بين المعاملة ٦٠ جم مخلوطة والمعاملات الاخري كانت معنوية في حجم المحلول الفراغي (Pore volume). كما هو ملاحظ ان المعاملة التي تم بها خلط ٦٠ جرام لها اكبر حجم محلول فراغي (Pore volume) وهذا دليل علي تاخير ظهور الكلوريد في محلول الغسيل. وتعد تلك النتيجة جيدة حيث ان استخدام ٦٠ جرام من تلك المخلفات مخلوطة يقلل من فرص انتقال الاملاح الذائبة مثل النترات الي مصادر المياه الجوفية.