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KANZARI S et al, The Experiment, 2014., Vol. 29(2), 1952-1956



LABORATORY METHOD FOR CHARACTERIZATION OF SOIL/WATER ADSORPTION COEFFICIENT

Abstract

The study of solute transport processes in the soil requires the determination of the adsorption coefficient. A laboratory experiment based on Batch equilibrium method was developed. This method involves contacting a chosen soil with water solutions with different concentrations and adjusted the obtained isotherms on analytical models. The method was applied to three soils and the results have demonstrated its validity. **Keywords:** Adsorption coefficient - Batch equilibrium method – Linear adjustment - Soil

Introduction

Sorption characterizes the physicochemical process by which molecules or ions are fixed (adsorption) or released (desorption) by the solid phase of the soil. These interactions depend on the concentration and characteristics of the solute (Yuan et *al.*, 2013), soil properties (Chabaux et *al.*, 2008), the physico-chemical environment of the soil (pH, temperature, water content, etc.) (Ressio et *al.*, 1999), as well as the interaction with other dissolved elements (Sánchez-Jiménez et *al.*, 2012). Sorption strongly affects the behavior of the solute in the soil, in particular their susceptibility to degradation processes (Lennartz, 1999), volatilization (Naseri et *al.*, 2014), photodecomposition and transport potential in the soil to the atmosphere and surface waters (Seeger et *al.*, 2013). The relationship between the concentrations in the solid phase (C_S) or adsorbed phase to the soil solution concentration (C_L), at an equilibrium state, is called sorption isotherm. Isotherm depends on the temperature, the soil, the solute and at a given initial state. The adsorption isotherms are characterized by their analytical expression that can be a function more or less elaborate: linear, exponential, etc. Batch equilibrium method can provide adsorption isotherms on soil suspensions. In this paper we present a simple laboratory method to estimate the adsorption coefficients of three soils with contrasted texture.

Materiel and Methods

Batch equilibrium method

Three soils presented in Table 1 were sampled from a land parcel $(35^{\circ}15'47.58''N; 10^{\circ}4'17.16''E$ in the region of Bouhajla (Central Tunisia). Irrigation water comes from a surface well with a water quality corresponding to a TDS of 6.5 g.l⁻¹, an ECi 7.5 dS.m⁻¹.

Soil	Clay (g kg ⁻¹)	Silt (g kg ⁻¹)	Sand (g kg ⁻¹)	Texture (USDA [*])
1	9.5	4.5	85	Sand
2	12.5	30	57	Loam
3	35	5	60	Clay

Table 1. Soil particle size analysis of the three soils.

* Scheme: United States Dept. of Agriculture

The soil samples were washed, crushed and dried. 5 g of each soil were put in the following solutions:

- Sol 1 (Ci₁,V₁) : 5 g of each soil + 50 ml water from the well
- Sol 2 (Ci_2, V_2) : 5 g of each soil + 100 ml water from the well

KANZARI S et al, The Experiment, 2014., Vol. 29(2), 1952-1956



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- Sol 3 (Ci_3, V_3) : 5 g of each soil + 150 ml water from the well
- Sol 4 (Ci_4, V_4) : 5 g of each soil + 200 ml water from the well
- Sol 5 (Ci₅,V₅) : 5 g of each soil + 250 ml water from the well

The solution was stirred until equilibrium is reached to measure the final concentration of the soil solution C_L . In most cases, the equilibrium was reached after 24 hours. Any decrease in the concentration is attributed to the adsorption. The concentration of the adsorbed phase is C_S calculated as:

$$C_s = \frac{(C_i - C_L) \times V}{M} \tag{1}$$

Where C_i : the initial concentration, C_L : the final concentration of the soil solution, V: Volume of the solution and M: soil mass.

Adsorption isotherm modeling

The measured values were adjusted on the linear sorption model and the models of Freundlich and Langmuir using their linear discretization.

According to El Ass et al. (2006), the equations are:

- linear sorption model : $C_S = K_d.C_L$, where, C_S : concentration of the adsorbed phase (kg.kg⁻¹), C_L : soil solution concentration (kg.m⁻³) and K_d : adsorption coefficient (m³.kg⁻¹).
- Freundlich model : log $C_S = \log K_F + (\log C_L)/n$, where K_F is the adsorption capacity and n is the adsorption intensity.
- Langmuir model : $C_L/C_S = 1/(\beta K_L) + C/\beta$, où β is the maximal adsorbed concentration and K_L is the Langmuir coefficient.

Results and Discussion

The linear, Freundlich and Langmuir adsorption isotherms of each soil are illustrated in Figure 1. The sandy soil has the highest slope, loamy soil has an average slope and the clay soil slope has the lowest. This distinction in texture classes is more visible in the case of the linear model than in the case of the Freundlich model and even less in the case of Langmuir model. This indicates heterogeneity in the adsorption of solute according to the texture of each soil.



RESEARCH ARTICLE

KANZARI S et al, The Experiment, 2014., Vol. 29(2), 1952-1956





Figure 1. Adsorption isotherms of the soils.

The adsorption isotherms fit better on the linear model which is confirmed by the determination of specific coefficients for each model (Table 1). In the linear case, the correlation coefficient R^2 is greater than 0.9 for the three soils. Also, the adjustment of the Freundlich model is acceptable. However, the Langmuir model does not appear adequate in the case of the sandy and loamy soils.

KANZARI S et al, The Experiment, 2014., Vol. 29(2), 1952-1956



Model	Linear		Freundlich			Langmuir		
	K _d	R ²	n	K _F	R ²	β	KL	R ²
Sand	0.1	0.99	1012	1	0.98	638	1.5	0.65
Loam	0.2	0.83	561.1	0.08	0.62	638.16	1.57	0.65
Clay	0.9	0.97	1195	1.14	0.95	-11.2	-88.4	0.88

Table 2. Adsorption coefficients values for each model and soil.

Based on K_d values, the sandy soil has the lowest value and promotes the solute transport. On the other hand, the clay soil has the highest value which indicates that 90 % of the solute is retained by the solid phase. These results are confirmed by several studies like Fruhstorfer et *al.* (1993); Gonçalves et *al.* (2006); Roulier et *al.* (2006).

Conclusion

The characterization of the adsorption coefficient is essential to simulate solute transport in unsaturated soils. The proposed method, based on the Batch equilibrium method, is simple and can be used for all types of soils and waters. The results are in agreement with the literature which confirms the validity of the method.

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KANZARI S et al, The Experiment, 2014., Vol. 29(2), 1952-1956

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