

Studying the kinetics of sodium and chloride ion in salt soils (Sabakh and Shura) by using two different qualities of salinity water

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ABSTRACT

The study was conducted on two soils, Al-Kifl city, the sixth district, Al-Mouradia located in the coordinates (443178 east and 3573606 north), where the study included taking normal columns with a depth of (0 cm to 60 cm) by the hammering method. The experiment was conducted in the graduate laboratory at the College of Agriculture, Al-Qasim Green University using two soils with two levels of salinity which is symbolized by (S), where the first level is Shura soil which is symbolized by (S1), the second level is Sabakh soil which is symbolized by (S2), and two qualities of water which are symbolized by (W), where the river water with EC (1.5 dS.m^{-1}) symbolized by (W1) and the drainage water with EC (12.1 dS.m^{-1}) symbolized by (W2) and with two levels of gypsum addition symbolized by (G), the first level is gypsum addition (zero g.kg^{-1}) which is symbolized by (G1) and the second level is 6.58 g.kg^{-1} gypsum for Shura soil and 2.63 g.kg^{-1} gypsum for Sabakh soil which are symbolized by (G2) according to the gypsum needs based on access to $\text{ESP} = 10$. The columns were leached using a continuous immersion method with a water compressor of 10 cm, where the mixture displacement solution (river water and drainage water) was added with a volume equal to 0.5, 1.0, 1.5, 2.0, 2.5, 3.0 of the total pore volume. The kinetic behavior for adsorbing sodium and chloride ions from the Shura and Sabakh soil was described by the following equations (zero-order equation, first-order equation, diffusion equation, power function equation, and Elovichand equation) using the STATISTICA program. The results showed that the power function equation has excelled on all equations in describing the adsorption of sodium and chloride ions where the average for both the correlation coefficient R^2 and the standard error SE and the K-adsorption coefficient (Kd) for the power function equation to describe the adsorption of sodium amounted to (0.86, 0.14, and $0.47 \text{ cmol.kg}^{-1}\text{day}^{-1}$). As for the chloride ion, it was (0.91, 0.09, and $0.39 \text{ cmol.kg}^{-1}\text{day}^{-1}$), respectively.

Keywords: kinetics, chloride, sodium, Shura, Sabakh, river water, drainage water.

*Research paper from the thesis for the first author.

دراسة حركيات ايوني الصوديوم والكلورايد في الترب الملحية الشورة والسبخة باستخدام نوعيتي مياه مختلفة الملوحة

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الخلاصة

أجريت الدراسة على تربتين من ناحية الكفل مقاطعة 6 المرادية الواقعة ضمن الاحداثي شرقا 443178 والاحداثي شمالا 3573606 حيث شملت الدراسة اخذ أعمدة طبيعية بعمق 0 cm الى 60 cm بطريقة الطرق، نفذت التجربة في مختبر الدراسات

العليا في كلية الزراعة /جامعة القاسم الخضراء باستعمال تربتين بمستويين من الملوحة ويرمز لها بالحرف S حيث المستوى الأول تربة الشورة بالرمز S1 والمستوى الثاني تربة السبخة بالرمز S2 ونوعيتين من المياه ويرمز لها بالحرف W وهي مياه نهر W1 ذات $EC\ 1.5\ dSm^{-1}$ ومياه بزل W2 ذات $EC\ 12.1\ dSm^{-1}$ وبمستويين من الإضافة الجبسية ويرمز لها بالحرف G المستوى الأول G1 صفر gm/kg والمستوى الثاني G2 $6.58\ gm/kg$ جبس للتربة الشورة و $2.63\ gm/kg$ جبس للتربة السبخة وذلك حسب الاحتياجات الجبسية على أساس الوصول الى $ESP=10$ ، غسلت الاعمدة بطريقة الغمر المستمر وبضاغط مائي قدره $10\ cm$ حيث اضيف محلول الازاحة الامتزاجية (مياه النهر ومياه البزل) بحجم يعادل $0.5, 1.0, 1.5, 2.0, 2.5, 3.0$ من الحجم المسامي الكلي. تم وصف السلوك الحركي لتحرر ايونات الصوديوم والكلورايد من تربتي الشورة والسبخة بالمعادلات التالية (معادلة الرتبة صفر، معادلة الرتبة الأولى، معادلة الانتشار، معادلة دالة القوة ومعادلة ايلوفيج) وباستعمال برنامج STATISTICA حيث أظهرت النتائج تفوق معادلة دالة القوة على جميع المعادلات في وصف تحرر ايونات الصوديوم والكلورايد حيث كان المعدل لكل من معامل الارتباط R^2 والخطأ القياسي SE ومعامل سرعة التحرر Kd لمعادلة دالة القوة لوصف تحرر الصوديوم هو 0.86 و 0.14 و $0.47\ cmolkg^{-1}day^{-1}$ اما بالنسبة لأيون الكلورايد كانت 0.91 و 0.09 و $0.39\ cmolkg^{-1}day^{-1}$ على التتابع .

الكلمات المفتاحية: حركيات، الكلورايد، الصوديوم، شورة، سبخة، مياه نهر، مياه بزل.

1. INTRODUCTION

Soils with high salinity levels present in some regions of Iraq were divided into two basic groups, which are Shura soils and Sabakh soils. From the morphological aspect, the shura soil is characterized by a dry white salt crust, due to the accumulation of large quantities of sodium chlorides, sodium sulfate, and magnesium, while the Sabakh soils are characterized by a dark color surface layer with moisture and viscosity, where it contains large quantities of salts of calcium and magnesium chlorides (2). When leaching salt soils, the displacement of the soil solution with another solution (differs from it in density and concentration), this process is known as immiscible displacement (15) as mentioned in (12). The processes of dissolving and displacing the salts from the soil are the leaching stages, where the salts are dissolved when the water enters the pores of the soil, and the displacement occurs when the leaching water is drained. There have been many attempts to describe and formulate equations that describe the reactions that occur in the soil because they have great importance that helps us in predicting the changes that take place inside the soil as these equations take into account the time factor in the reaction to determine the K-adsorption coefficient (Kd)

(17). Recent studies also have tended to use the quiet flow, or what is called the miscible displacement, since it is closer to the reality of the field, and this agrees with (18, 14, 15). The best way to study adsorbing ions in the soil is to use the concept of chemical kinetics and the theoretical basis for studying the adsorbing ions from the soil by applying rate laws and the goal of which is the calculation of the adsorption coefficient and these equations include (zero-order equation, first-order equation, diffusion equation, power function equation, and Elovichand equation) where the time factor with the liberated quantity is entered with mathematical equations where the best equation in describing the adsorption of elements and their liberation is determined by a comparison between the values of the correlation coefficient (R^2) and the standard error (SE) as a measure of the preference between them (8). The current study aims to know the rate and kinetics of sodium and chloride ions in the soils of Shura and Sabakh and their influence by adding gypsum by applying kinetic equations during continuous leaching using river water and drainage water and eliciting the best equation to describe rate by adopting the lowest standard error SE and the highest correlation coefficient R^2 (19).

2. MATERIALS AND METHODS

- 1- Al-Mouradia region in Al-Kifl district belonging to Hilla city was chosen to taking the study soil, where a salty soil of Sabakh and Shura with a silty clay loam texture was obtained. The soil samples were collected from a depth of (0-60 cm), dried aially, then ground with a plastic hammer and passed through a sieve with a diameter of 2 mm, and some of their chemical and physical properties were estimated, as shown in Table (1).
- 2- A wooden stand was manufactured to raise the plastic columns of the PVC type with an inner diameter of 10 cm and a length of 75 cm and at the bottom of the column a perforated plastic plug was placed with a filter paper placed at the bottom of the column for the purpose of preventing the exit of soil particles with the leachate and on top of it put a filter paper for the purpose of preventing the soil being raised when adding water. The soil columns were taken naturally by the hammering method where the bottom end of the plastic column was honed for the purpose of facilitating the penetration of

the soil. A thick wooden board was placed on the upper end for the purpose of hammering on it and a large hammer was used for the purpose of applying great pressure to push the column.

- 3- The river water with electrical conductivity (1.5 dS.m^{-1}) and drainage water with electrical conductivity (12.1 dS.m^{-1}) were used as a displacement solution by installing a solution depth of 0.1 m above the soil surface through inverted plastic bottles. Some chemical traits of the used leaching water were estimated as shown in Table (2). The leachates of leaching were then collected after the displacement solution volume equal to 0.5, 1.0, 1.5, 2.0, 2.5, and 3.0 passed from the pore volume of soil, and the pore volume PV of the Shura soil amounted to (2130.49 cm^3) and the Sabakh soils (2084.17 cm^3). After finishing the leaching process, the soil was separated from the column, then the soil column was cut into three parts, the thickness of each part is approximately 20 cm. The soil was air-dried and ground then passed through a 2 mm diameter sieve, and filled with plastic bags for later analysis.

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Table 1: Some of the chemical and physical traits for Shura and Sabakh soil before leaching.

Trait		Shura soil	Sabakh soil	Unit
Electrical conductivity for saturated paste (ECe)		146.21	184.11	dSm ⁻¹
Degree of reaction (pH)		7.10	7.11	---
Sodium (Na ⁺¹)		811.60	520.00	mmol.L ⁻¹
Potassium (K ₊₁)		11.07	13.75	
Calcium (Ca ⁺²)		70.00	170.00	
Magnesium (Mg ⁺²)		251.50	485.50	
Chloride (Cl ⁻¹)		1401.00	1796.00	
sulfate (SO ₄ ⁻²)		20.25	12.20	
Bicarbonate (HCO ₃ ⁻¹)		14.10	14.30	
Carbonate (CO ₃ ⁻²)		NIL	NIL	
Sodium adsorption ratio (SAR)		45.26	20.31	mmol.L ^{-0.5}
Exchangeable sodium percentage (ESP)		39.57	22.29	According to the American Salinity Laboratory
Cation exchange capacity (CEC)		26.20	25.04	cmol.kg ⁻¹
Lime (CaCO ₃)		23.53	25.71	gmkg ⁻¹
Gypsum (CaSO ₄ .2H ₂ O)		2.65	2.72	
Organic matter (OM)		10.60	16.20	
Bulk density (pb)		1.42	1.45	mg.m ⁻³
Soil separates	Sand	153	152	g.kg ⁻¹
	Silt	557	563	
	Clay	290	285	
Texture		Silt Clay Loam		

Table 2: Some chemical traits for water used for leaching.

Traits	River water	Drainage water	Unit
Electrical conductivity (EC)	1.5	12.1	dS.m ⁻¹
Degree of reaction (pH)	8.2	8.1	-----
Sodium (Na ⁺)	4.18	29.28	mmol.L ⁻¹
Potassium (K ⁺)	0.88	1.10	
Calcium (Ca ²⁺)	1.25	16.75	
Magnesium (Mg ²⁺)	3.75	28.75	
Chloride (Cl ⁻)	11.40	77.50	
sulfate (SO ₄ ²⁻)	1.20	20.75	
Bicarbonate (HCO ₃ ⁻)	2.10	8.50	
Carbonate (CO ₃ ²⁻)	Nil	Nil	Nil
Sodium adsorption ratio (SAR)	1.86	4.34	mmol.L ⁻⁵
Total dissolved salts (TDS) (it is mathematically calculated)	0.96	7.74	g.kg ⁻¹

5- calculations

A- The pore volume was calculated from the total porosity according to (9):

$$f = 1 - \left(\frac{\rho_b}{\rho_s} \right) \dots\dots\dots(1)$$

where

ρ_b = bulk density (mg.m^{-3})

ρ_s = true density (mg.m^{-3})

f = total porosity

B- The mathematical formulas for these equations have been adopted according to (4) to assess the cumulative ionic concentration:

$C_t = C_0 - K_t \dots\dots\dots(2)$ The zero-order equation

$\text{Ln}C_t = \text{Ln}C_0 - K_t \dots\dots\dots(3)$ first-order equation

$C_t = C_0 + K_t^{0.5} \dots\dots\dots(4)$ diffusion equation

$C_t = C_0 + K \text{Ln}t \dots\dots\dots(5)$ Elovichand equation

$\text{Ln}C_t = \text{Ln}C_0 + K \text{Ln}t \dots\dots\dots(6)$ The power function equation

where:

C_0 : zero ion concentration at zero time.

C_t : concentration of the adsorbed ion at time t.

$\text{Ln}C_0$: the natural logarithm of the zero-ion concentration at zero time.

$\text{Ln}C_t$: natural logarithm of the adsorbed ion concentration at time t.

K: Coefficient of adsorbed rate for each equation.

t = time

C- To determines the best mathematical equation describing the ion adsorption process and the rate of its adsorption (K_d) from the soil. This is done by calculating the R^2 coefficient between the amount of adsorbed ion and time and calculating the standard error SE which represents the difference between the experimental results and the calculated results from the linear kinetic equation from an equation according to (20):

$$SE = \left[\frac{\sum (C_t - C_t^*)^2}{n - 2} \right]^{0.5}$$

$\dots\dots\dots(7)$

where

C_t : concentration of magnesium measured by solution at time t.

C_t^* : concentration of magnesium calculated from the equation at time t.

n: number of measurements in the experiment.

D- Gypsum requirements are estimated according to (5) from the following equation:

$$\text{Gypsum (Meq.100 g}^{-1} \text{ soil)} = \frac{\text{required ESP} - \text{original ESP}}{\text{CEC}} \times 100 \dots\dots\dots(8)$$

6- Chemical and physical traits

A- Total Dissolved ions were estimated in the saturated paste extract where calcium and magnesium were estimated by titration with Fresnite 0.01 N and chloride by titration with silver nitrate

- AgNO₃ (0.01 N) according to (16) and the amount of sodium and potassium using the flame photometer system.
- B- Electrical conductivity (EC) and degree of reaction (pH) were estimated using a WTW device.
 - C- Cation exchange capacity (CEC) was estimated by saturation with sodium and displacing it with ammonium acetate (1N) according to (16).
 - D- Lime was estimated by calculating the weight loss in CO₂ when treating the soil with 1N HCl (16).
 - E- Gypsum was estimated by depositing it in a suspension 1:10 according to (16).
 - F- The organic matter was estimated by wet digestion according to (11).
 - G- The soil separates were estimated to extract the texture using the Hydrometer method (11).
 - H- The bulk density was estimated by the mass method proposed by (10).

3. RESULTS AND DISCUSSION

Curves of adsorbing sodium ion

Table (3) shows the values of the cumulative leaching time and the cumulative concentrations for the sodium ion and for the Shura and Sabakh soil columns. where the results indicate that there is a difference in the cumulative time and the cumulative concentrations of adsorbing sodium ion, where the soils of leached shura with river water without adding gypsum took a longer period of time which amounted to (56 days) for the S1W1G1 treatment and the cumulative concentration for sodium ion amounted to (213.4 cmol.kg⁻¹day⁻¹) for the treatment S1W2G1 which was leached with drainage water, where it lasted 48 days and the cumulative sodium concentration amounted to

(207.6 cmol.kg⁻¹day⁻¹) as shown in Figure (1). This reflects the effect of water salinity on the rate of leaching and displacement of sodium ions from the soil, and this agrees with (6). Table (3) also shows when comparing between the treatments for which gypsum was added and without adding gypsum, it was found that the treatments for which gypsum was added, which included the S1W1G2 treatment and the S1W2G2 treatment, were leached with a lesser period of time, which amounted to (37 days) for both treatments. while the S1W2G2 treatment gave the highest value for the cumulative concentration of the Sodium ion amounted to (239.1 cmol.kg⁻¹day⁻¹) compared to the S1W1G2 treatment which amounted to (215.5 cmol.kg⁻¹day⁻¹). This reflects on the role of gypsum in influencing the rate of leaching and displacement of sodium ions from the soil, and this agrees with (9, 7, 21, 13), this in relation to the columns of Shura. As for Sabakh columns, Table (3) indicates to the superiority of the S2W2G1 treatment that leached with drainage water and without adding gypsum in the displacement of sodium ions over the rest of the treatments where the cumulative concentration of sodium ions amounted to (245.6 cmol.kg⁻¹day⁻¹) as shown in Figure (1). While the S2W2G2 treatment took less time for all pore volumes to descend, where the cumulative time for them amounted to (45 days), and this agrees with (6). Figure (1) shows the graphical relationship for the cumulative concentrations of sodium ion as a function for the pore volumes passing through the soil columns where a difference is observed in the cumulative values for the concentrations of sodium ion according to soil salinity, the salinity of leaching water, and the level of gypsum addition, where it is observed from the curve that there are two adsorbing stages: the first rapid and high during the first periods and

specifically during the first and second pore volume and The second is for the treatments related to Shura soil, while this exceeds to the third pore volume for the treatments related to the Sabakh soils, and then gradually decreases

during the last stages of the experiment, thus the adsorbing sodium curves obtained can be considered an actual expression of what happens to the sodium ion inside the soil during the continuous leaching processes.

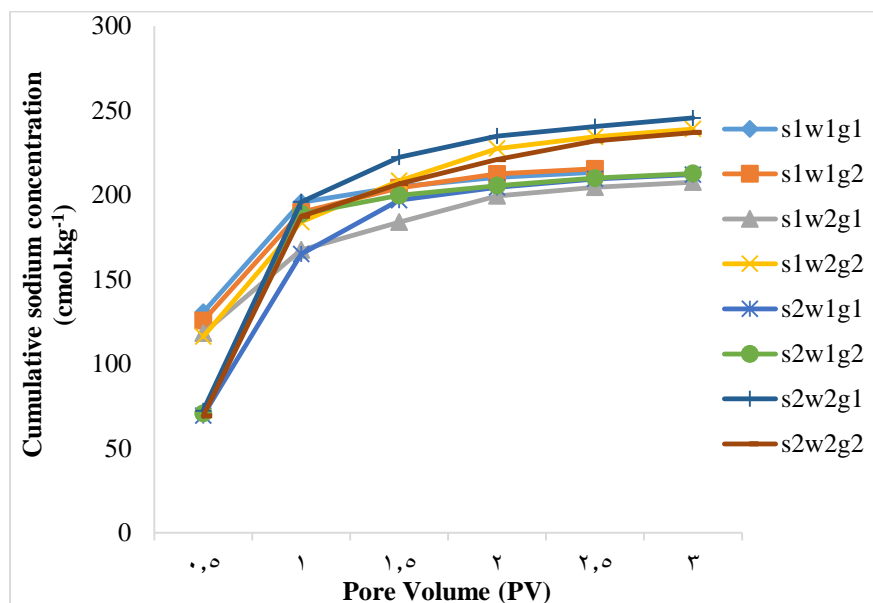


Figure 1: Adsorption curves of Cumulative sodium ions with pore volumes for all treatments.

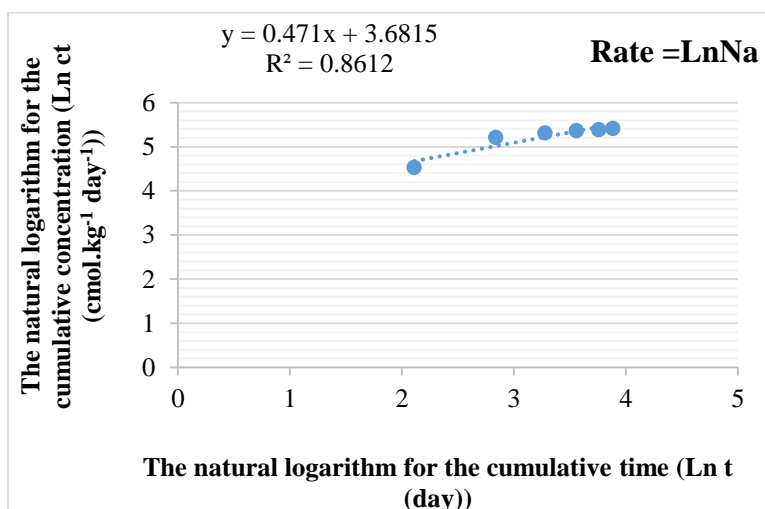
Mathematical description for the adsorbing sodium ion based on chemical kinetics

Table (4) shows that the power function equation, the diffusion equation, and the Elovichand equation were with highly significant correlation coefficient (R^2), therefore relied on the lowest standard error (SE) and based on the above, it was shown that the power function equation has excelled on the rest of the equations in describing the adsorbing sodium ion, Where the rate of the correlation coefficient for all treatments according to the

power function equation amounted to (0.86) as shown in Figure (2) where the correlation coefficient ranged from 0.77 to 0.95 as shown in Table (4), the lowest correlation coefficient value was at the S2W1G2 treatment while the highest value was at the treatments (S1W2G1 and S1W2G2), and this agrees with (3) when leaching calcareous soils from northern Iraq to the validity of all equations and arranged the preference to the following: first-order equation> diffusion equation> power function equation> zero order equation> Elovichand equation.

Table 3: cumulative time and cumulative concentration for sodium ions.

Pore Volume (PV)	S1W1G1		S1W1G2		S1W2G1		S1W2G2		S2W1G1		S2W1G2		S2W2G1		S2W2G2	
	Cumulative time (day)	Cumulative Na concentration (cmol.kg ⁻¹ day ⁻¹)	Cumulative time (day)	Cumulative Na concentration (cmol.kg ⁻¹ day ⁻¹)	Cumulative time (day)	Cumulative Na concentration (cmol.kg ⁻¹ day ⁻¹)	Cumulative time (day)	Cumulative Na concentration (cmol.kg ⁻¹ day ⁻¹)	Cumulative time (day)	Cumulative Na concentration (cmol.kg ⁻¹ day ⁻¹)	Cumulative time (day)	Cumulative Na concentration (cmol.kg ⁻¹ day ⁻¹)	Cumulative time (day)	Cumulative Na concentration (cmol.kg ⁻¹ day ⁻¹)	Cumulative time (day)	Cumulative Na concentration (cmol.kg ⁻¹ day ⁻¹)
0.5	14	130.5	7	125.6	8	118.2	5	116.1	8	69.4	14	70.7	6	72.2	8	69.1
1.0	26	195.6	15	189.8	17	167.5	12	184.0	16	165.0	27	188.9	14	195.9	15	187.4
1.5	35	204.9	24	204.2	26	183.9	19	208.4	25	196.9	42	199.8	25	222.4	22	206.7
2.0	47	210.5	31	212.5	36	199.5	25	227.5	31	204.5	54	205.6	36	234.9	29	221.0
2.5	56	213.4	37	215.5	43	204.6	32	234.5	37	209.5	62	210.0	46	240.5	37	232.1
3.0					48	207.6	37	239.1	45	212.1	70	212.8	52	245.6	45	237.0

**Figure 2:** The relationship between the natural logarithm of the cumulative time and the natural logarithm of the cumulative concentration for sodium-ion according to the power function equation.

Coefficient of rate for adsorbing sodium ion

Table (4) shows the values of the coefficient of rate for adsorbing sodium ion, where the coefficient of rate for adsorbing sodium ion calculated by the power function has been adopted for its preference in describing the adsorbing sodium ion over the rest of the equations, where the average of the coefficient

of rate for adsorbing sodium ion amounted to ($0.47 \text{ cmol.kg}^{-1}\text{day}^{-1}$) as shown in Figure (3), where the S1W2G1 treatment gave the lowest value for the coefficient of Kd which amounted to ($0.30 \text{ cmol.kg}^{-1}\text{day}^{-1}$) while the S2W2G2 treatment gave the highest value to the coefficient of Kd amounted to ($0.66 \text{ cmol.kg}^{-1}\text{day}^{-1}$) as shown in Table (4).

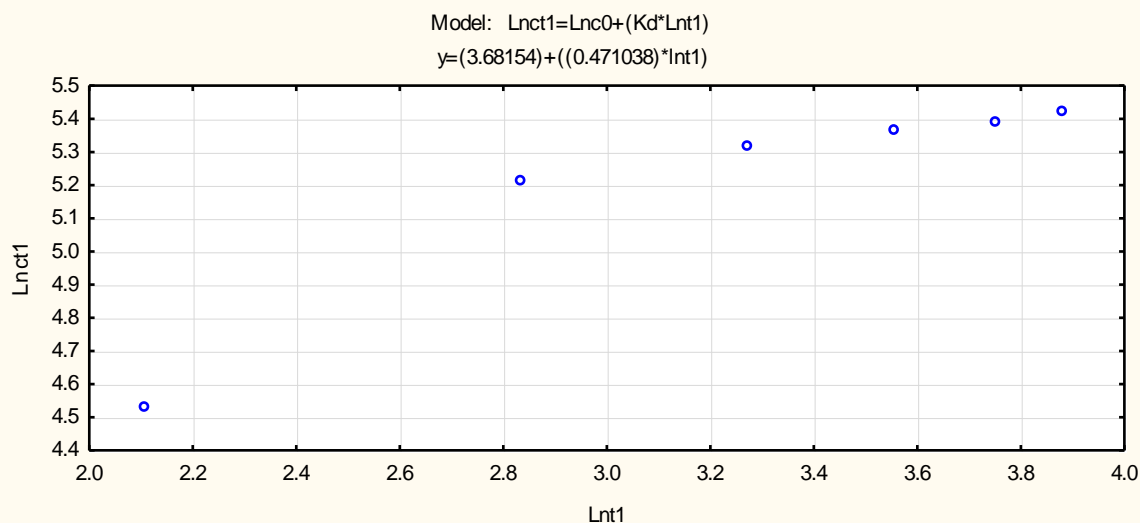


Figure 3: The values of the coefficient of rate for adsorbing sodium ion (kd) according to the statistical relationship between the natural logarithm of the cumulative time and the natural logarithm of the cumulative concentration for sodium-ion according to the power function equation.

Table 4: values of coefficient of adsorbing rate (kd), correlation coefficient (R^2), and standard error (SE) used to describe Na kinetic.

Treatments	Coefficient of adsorbing rate (kd)					Correlation coefficient (R^2)					Standard error (SE)				
	According to the zero-order equation (Cmol.k ⁻¹ g ⁻¹ day ⁻¹)	According to the first-order equation (Cmol.k ⁻¹ g ⁻¹ day ⁻¹)	According to the diffusion equation (Cmol.k ⁻¹ g ⁻¹ day ^{-1/2})	According to the power function equation (Cmol.k ⁻¹ g ⁻¹ day ⁻¹)	According to the Elovich equation (Cmol.k ⁻¹ g ⁻¹ day ⁻¹)	According to the zero-order equation (Cmol.k ⁻¹ g ⁻¹ day ⁻¹)	According to the first-order equation (Cmol.k ⁻¹ g ⁻¹ day ⁻¹)	According to the diffusion equation (Cmol.k ⁻¹ g ⁻¹ day ^{-1/2})	According to the power function equation (Cmol.k ⁻¹ g ⁻¹ day ⁻¹)	According to the Elovich equation (Cmol.k ⁻¹ g ⁻¹ day ⁻¹)	According to the zero-order equation (Cmol.k ⁻¹ g ⁻¹ day ⁻¹)	According to the first-order equation (Cmol.k ⁻¹ g ⁻¹ day ⁻¹)	According to the diffusion equation (Cmol.k ⁻¹ g ⁻¹ day ^{-1/2})	According to the power function equation (Cmol.k ⁻¹ g ⁻¹ day ⁻¹)	According to the Elovich equation (Cmol.k ⁻¹ g ⁻¹ day ⁻¹)
S1 W1 G1	-1.74	-0.01	99.80	0.34	58.83	0.71	0.67	0.83	0.84	0.86	21.39	0.13	16.22	0.09	14.35
S1 W1 G2	-2.72	-0.13	104.70	0.32	53.59	0.78	0.99	0.90	0.90	0.93	19.92	0.13	13.46	0.08	11.14
S1 W2 G1	-2.03	-0.01	92.03	0.30	49.48	0.86	0.81	0.96	0.95	0.98	13.81	0.10	7.42	0.04	5.11
S1 W2 G2	-3.52	-0.01	126.12	0.35	61.99	0.83	0.77	0.95	0.95	0.98	20.83	0.14	10.65	0.06	6.99
S2 W1 G1	-3.45	-0.02	154.33	0.63	82.74	0.73	0.64	0.80	0.85	0.91	31.92	0.28	21.96	0.18	18.33
S2 W1 G2	-2.06	-0.01	133.72	0.62	81.78	0.65	0.59	0.78	0.77	0.82	36.27	0.30	28.59	0.22	25.72
S2 W2 G1	-2.99	-0.01	140.44	0.52	75.36	0.67	0.57	0.83	0.81	0.88	42.31	0.34	29.78	0.22	24.81
S2 W2 G2	-3.76	-0.02	171.05	0.66	92.34	0.68	0.58	0.82	0.79	0.87	39.68	0.34	29.14	0.24	25.17
Rate	-2.69	-0.01	128.54	0.47	69.63	0.75	0.67	0.88	0.86	0.91	26.86	0.21	18.58	0.14	15.39

Curves of adsorbing chloride ion

Table (3) shows the values of the cumulative leaching time and the cumulative concentrations of the chloride ion and for the Shura and Sabakh soil columns, where the soils of leached shura with river water without adding gypsum took a longer period of time which amounted to (56 days) for the S1W1G1 treatment and the cumulative concentration for chloride ion amounted to (213.4 $\text{cmol.kg}^{-1}\text{day}^{-1}$). While the S1W2G1 treatment which was leached with high salinity drainage water where the cumulative time to decrease all porous volumes was 48 days and the cumulative chloride concentration amounted to (343.4 $\text{cmol.kg}^{-1}\text{day}^{-1}$). This reflects the effect of water salinity on the rate of leaching and displacement of chloride ions from the soil, and this agrees with (6). Table (5) also shows when comparing between the treatments for which gypsum was added and without adding gypsum, it was found that the treatments for which gypsum was added, which included the treatments (S1W1G2 and S1W2G2) have leached with a lesser period of time, which amounted to (37 days) for both treatments. while the S1W2G2 treatment gave the highest value for the cumulative concentration of the chloride ion amounted to (384.2 $\text{cmol.kg}^{-1}\text{day}^{-1}$) compared to the S1W1G2 treatment which amounted to (374.0 $\text{cmol.kg}^{-1}\text{day}^{-1}$). This reflects on the role of gypsum in influencing the

rate of leaching and displacement of chloride ions from the soil, this in relation to the columns of Shura. As for Sabakh columns, Table (5) indicates to the superiority of the S2W2G1 treatment that leached with drainage water and without adding gypsum in the displacement of chloride ions over the rest of the treatments where the cumulative concentration of chloride ions amounted to (599 $\text{cmol.kg}^{-1}\text{day}^{-1}$) While the S2W2G2 treatment took less time for all pore volumes to descend, where the cumulative time for them amounted to (45 days), and this agrees with (6). Figure (4) shows the graphical relationship for the cumulative concentrations of chloride ion as a function for the pore volumes passing through the soil columns where a difference is observed in the cumulative values for the concentrations of chloride ion according to soil salinity, the quality of water, and the level of added gypsum, where the S1W2G1 treatment gave the lowest concentration amounted to (343.4 $\text{cmol.kg}^{-1}\text{day}^{-1}$) as shown in Table (5), where it is observed from the curve that there are two adsorbing stages: the first rapid and high during the first periods and specifically during the first and second pore volume and The second is for the treatments related to Shura soil, while this exceeds to the third pore volume for the treatments related to the Sabakh soils, and then gradually decreases during the last stages of the experiment.

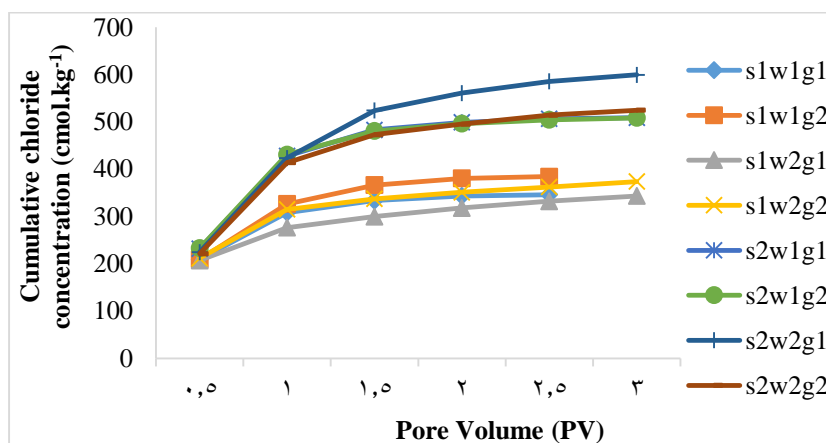


Figure 4: Adsorption curves of Cumulative chloride ions with pore volumes for all treatments.

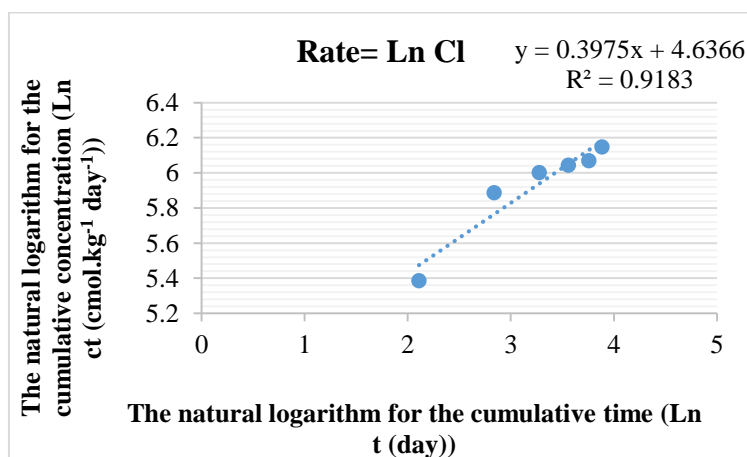
Mathematical description for the adsorbing chloride ion based on chemical kinetics

The kinetic equations that are considered the best methods to predict the adsorption of ions from the studied soils (the power function equation, the diffusion equation, and the Elovichand equation) have been applied, The results of adsorbing chloride ion have been described depending on the highest R^2 and lowest standard error. Table (4) shows that the power function equation, the propagation equation, and the Elovichand equation were with highly significant correlation coefficient (R^2), therefore relied on the lowest value of the standard error (SE). Table (6) shows that the power function equation is excelled on the rest of the equations in describing the adsorption of

chloride ion, where the rate of correlation coefficient (R^2) for all treatments according to the power function equation amounted to (0.91) as shown in Figure (5) where the correlation coefficient ranged between 0.84 to 0.97 as shown in Table (6) where the lowest value for the treatments (S2W1G1 and S2W2G2) while the higher value was for the S1W2G1 treatment. This agrees with (1) when leaching saline soils with a different texture from Baghdad by applying the diffusion equation, the Jurinak equation and the first-order equation to the superiority of the diffusion equation and the Jurinak equation, but the current study was broader where it included applying all kinetic equations, so the result was greater than the power function equation.

Table 3: cumulative time and cumulative concentration for chloride ions.

Pore Volume (PV)	S1W1G1		S1W1G2		S1W2G1		S1W2G2		S2W1G1		S2W1G2		S2W2G1		S2W2G2	
	Cumulative time (day)	Cumulative Cl concentration (cmol.kg ⁻¹ day ⁻¹)	Cumulative time (day)	Cumulative Cl concentration (cmol.kg ⁻¹ day ⁻¹)	Cumulative time (day)	Cumulative Cl concentration (cmol.kg ⁻¹ day ⁻¹)	Cumulative time (day)	Cumulative Cl concentration (cmol.kg ⁻¹ day ⁻¹)	Cumulative time (day)	Cumulative Cl concentration (cmol.kg ⁻¹ day ⁻¹)	Cumulative time (day)	Cumulative Cl concentration (cmol.kg ⁻¹ day ⁻¹)	Cumulative time (day)	Cumulative Cl concentration (cmol.kg ⁻¹ day ⁻¹)	Cumulative time (day)	Cumulative Cl concentration (cmol.kg ⁻¹ day ⁻¹)
0.5	14	209.2	7	209.4	8	207.0	5	211.9	8	232.1	14	233.3	6	224.7	8	221.2
1.0	26	308.2	15	326.4	17	276.3	12	315.1	16	428.0	27	431.1	14	423.7	15	413.8
1.5	35	333.6	24	366.4	26	299.7	19	337.3	25	483.2	42	480.9	25	523.9	22	472.8
2.0	47	343.4	31	380.6	36	318.0	25	351.2	31	498.9	54	496.4	36	561.0	29	495.4
2.5	56	346.1	37	384.2	43	332.1	32	362.5	37	506.3	62	504.5	46	585.5	37	514.1
3.0	—	—	—	—	48	343.4	37	374.0	45	508.8	70	508.6	52	599.5	45	524.6

**Figure 5:** The relationship between the natural logarithm of the cumulative time and the natural logarithm of the cumulative concentration for chloride ion according to the power function equation.

Coefficient of rate for adsorbing chloride ion

Table (6) shows the values of the coefficient of rate for adsorbing chloride ion, where the coefficient of rate for adsorbing chloride ion calculated by the power function has been adopted for its preference in describing the adsorbing chloride ion over the rest of the equations, where the average of the coefficient

of rate for adsorbing chloride ion for all treatments amounted to ($0.39 \text{ cmol.kg}^{-1}\text{day}^{-1}$) as shown in Figure (6), where the S1W2G1 treatment gave the lowest value for the coefficient of K_d which amounted to from (0.26 to $0.47 \text{ cmol.kg}^{-1}\text{day}^{-1}$) while the S2W2G2 treatment gave the highest value to the coefficient of K_d as shown in Table (6).

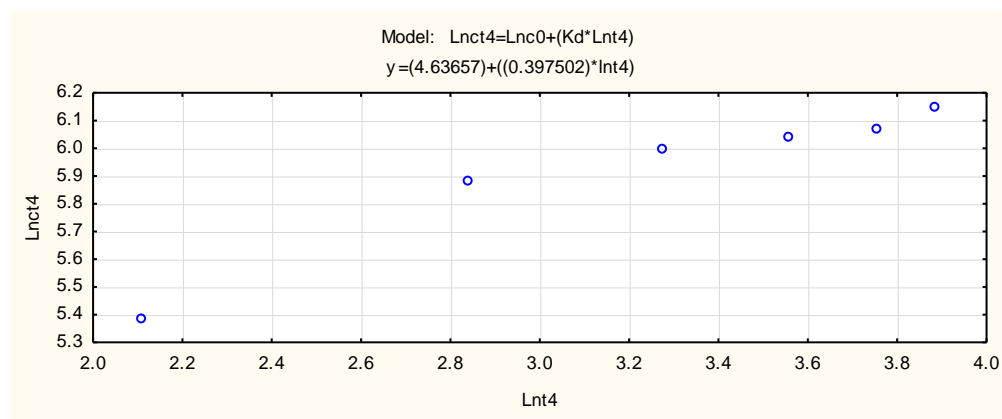


Figure 6: The values of the coefficient of rate for adsorbing sodium ion (k_d) according to the statistical relationship between the natural logarithm of the cumulative time and the natural logarithm of the cumulative concentration for chloride-ion according to the power function equation.

Table 6: values of coefficient of adsorbing rate (kd), correlation coefficient (R^2), and standard error (SE) used to describe CI kinetic.

Treatments	Coefficient of adsorbing rate (kd)					Correlation coefficient (R^2)					Standard error (SE)				
	According to the zero-order equation (Cmol.kg ⁻¹ .day ⁻¹)	According to the first-order equation (Cmol.kg ⁻¹ .day ⁻¹)	According to the diffusion equation (Cmol.kg ⁻¹ .day ^{-1/2})	According to the power function equation (Cmol.kg ⁻¹ .day ⁻¹)	According to the Elovich equation (Cmol.kg ⁻¹ .day ⁻¹)	According to the zero-order equation (Cmol.kg ⁻¹ .day ⁻¹)	According to the first-order equation (Cmol.kg ⁻¹ .day ⁻¹)	According to the diffusion equation (Cmol.kg ⁻¹ .day ^{-1/2})	According to the power function equation (Cmol.kg ⁻¹ .day ⁻¹)	According to the Elovich equation (Cmol.kg ⁻¹ .day ⁻¹)	According to the zero-order equation (Cmol.kg ⁻¹ .day ⁻¹)	According to the first-order equation (Cmol.kg ⁻¹ .day ⁻¹)	According to the diffusion equation (Cmol.kg ⁻¹ .day ^{-1/2})	According to the power function equation (Cmol.kg ⁻¹ .day ⁻¹)	According to the Elovich equation (Cmol.kg ⁻¹ .day ⁻¹)
S1 W1 G1	-2.98	-0.01	169.06	0.36	99.42	0.74	0.71	0.86	0.87	0.90	33.07	0.13	24.08	0.08	20.85
S1 W1 G2	-5.44	-0.01	208.28	0.36	106.43	0.80	0.76	0.92	0.92	0.94	37.01	0.14	23.76	0.08	19.02
S1 W2 G1	-3.05	-0.01	136.07	0.26	72.88	0.90	0.85	0.97	0.97	0.98	17.36	0.07	8.59	0.03	5.82
S1 W2 G2	-4.34	-0.01	157.31	0.27	77.73	0.78	0.72	0.92	0.92	0.95	30.65	0.12	18.68	0.06	14.28
S2 W1 G1	-6.62	-0.01	297.45	0.44	159.83	0.70	0.64	0.85	0.84	0.89	65.50	0.20	46.48	0.13	39.48
S2 W1 G2	-4.26	-0.01	271.83	0.46	165.32	0.73	0.67	0.86	0.85	0.89	60.85	0.19	44.32	0.13	38.22
S2 W2 G1	-7.11	-0.01	322.34	0.43	170.72	0.81	0.71	0.94	0.92	0.97	69.53	0.22	38.81	0.11	27.07
S2 W2 G2	-7.02	-0.01	316.78	0.47	170.59	0.71	0.63	0.86	0.84	0.90	67.86	0.22	47.54	0.14	39.92
Rate	-5.37	-0.01	250.75	0.39	134.89	0.83	0.75	0.93	0.91	0.95	42.39	0.15	27.00	0.09	21.41

CONCLUSIONS

We conclude from the study that the power function equation is excelled on other kinetic equations in describing the adsorption of sodium and chloride ions in saline soils (Shura, Sabakh), and leached with river water and drainage water by continuous leaching method when adding gypsum and without adding it.

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