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DESCRIPTION OF MAGNESIUM ADSORPTION UNDER THE INFLUENCE OF DIFFERENT TEMPERATURES IN CALCAREOUS SOILS WITH VARIED AGRICULTURAL USES

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ABSTRACT

In order to study the effect of temperature on magnesium adsorption in different calcareous soils, adsorption equations such as the Langmuir, the Freundlich, and the Temkin equations were used to describe the adsorption process. The study was conducted on five different agricultural exploitation sites in Nineveh Governorate - Iraq, and each site was divided into two depths (surface, subsurface). the study was conducted at three temperatures (278, 298, 318 Kelvin), when comparing these equations through the values of (R^2) and (SE), the Langmuir equation outperformed both the Freundlich and Temkin equations in the first place, while the Temkin equation in the last place, some functions derived from the Langmuir equation were studied (maximum adsorption capacity, binding energy, maximum buffering capacity, the results of the study showed that the effect of temperature on the maximum adsorption capacity values was negatively related to the equilibrium temperature (R^2=91), when the temperature increased from 278 to 298 K, it led to a decrease in the maximum adsorption capacity by 18.89%, as for the effect of temperature on the average binding energy values, there was a weak positive correlation between the average binding energy values and the equilibrium temperatures (R^2=0.006), when the temperature increased from 278° to 298° K, it led to an increase in the average binding energy by 74.39%, and increasing the temperature from 278° to 318° K led to an increase in the average binding energy by 6.76%. The effect of temperature on the maximum buffering capacitance values did not have a consistent pattern.

INTRODUCTION

Soil temperature plays an important role in the process of ionic exchange of ions in the soil environment, as well as in the process of their absorption by the plant (Alhadede *et al.,* 2025; Al-Maamori *et al.,* 2015). In general, the speed of any chemical reaction increases with the rise in temperature, as the temperature increases by 10 degrees Celsius (Al-Qattan and Al-Khafagi, 2023). From this standpoint, Al-Obaidi and Al-Zubaidi (2005) see the necessity of studying the reactions of some elements under the influence of different temperatures, especially in Iraqi environmental conditions, due to the large fluctuations in temperature during the seasons of the year and during the day and in one day (Al-Hadede *et al.,* 2022; Razvanchy and Fayyadh, 2023). It is known that the chemical behavior of any ion in a given environment is significantly affected by the temperature of the medium, and that the adsorption process is one of the chemical reactions that generates heat (exothermic) unless it is accompanied by an absorption or diffusion process within the pores of the solid phase (Al-Taie and Khaled, 2023; Al-Hamandi *et al.,* 2024). Therefore, an increase in temperature leads to a decrease in the adsorption capacity (Aljumaily and kashmoola, 2022). From a molecular perspective, increasing the temperature leads to an increase in the kinetic energy of the molecules adsorbed on the adsorbent surface (Mawlood and Essa, 2017), which leads to an increase in the probability of their separation from the adsorbent surface and their return to the solution (Al-hayany and Al-Obaidi, 2018). The adsorption process, accompanied by absorption or diffusion within the pores is endothermic, so increasing the kinetic energy of the adsorbed molecules increases the ability to enter the pores of the solid phase and increases the speed of their diffusion within it, so the adsorption efficiency increases with increasing temperature (Al-Jubory and Al-Khafagi, 2024; Jaafar and Abdulrasool, 2025). Magnesium ions are characterized by behavior and physicochemical properties that distinguish them from other positive ions in the soil, such as the hydrated ionic diameter, diffusion coefficient, polarity, and their position in the composition of primary and secondary minerals (Rasheed, 2022; Sparks, *et al.,* 2022). Its hydrated diameter is larger than these ions, which makes it surrounded by a larger number of water molecules compared to other ions. The difference in the size of the hydrated diameter between Ca^{+2} and Mg^{+2} (dihydrate cation) leads to a difference in the behavior of these two ions and the ionic activity of each of them (Hashim and Hassan, 2023), as the hydrated diameter is a major factor in calculating the activity coefficient using the Debye-Hückel equation. Magnesium has a special diffusion coefficient and diffusion time constant that reflects its movement in the soil, which ranges between (0.69-1.46×10^{-10} $m^2.sec^{-1}$). In this regard, Najafi-Ghiri and Boostani (2020) indicated that increasing the temperature of calcareous soils leads to an increase in the amount of soluble and exchangeable ions, thus increasing their release rate. Due to the lack of studies on the effect of different climatic conditions on magnesium adsorption in the soil environment, this research aims to determine the role of temperature and its effect on magnesium adsorption in calcareous soils by relying on adsorption equations.

MATERIALS AND METHODS

Selection of study sites

The study included five agricultural sites in Nineveh Governorate, Iraq, with soils of different types of use (wheat, vegetables, olives, forests, and unused). Soil samples were collected from the surface layer (0–25 cm) and the subsurface layer (25–30 cm) for routine analysis. The soil samples were air dried and ground using a wooden hammer, then sieved through a 2 mm sieve, the amount of the three components: clay, silt, sand, total calcium carbonate $CaCO_3$, organic matter O.M, cation exchange capacity CEC, pH, and electrical conductivity EC were determined using the methods described (Carter and Gregorich, 2008), as shown in Table (1).

Table (1): Some physicochemical properties of the study soils

Depth Cm	pH	EC	$CaCO_3$	O.M	CEC	Soil Separates($gm.kg^{-1}$)			Texture
		$dS.m^{-1}$	$gm.kg^{-1}$		$Cmol.kg^{-1}$	Sand	Silt	Clay	
First Site (Wheat)									
0 – 25	7.20	0.44	360	16.50	21.73	185.5	582.5	232.0	Si.L
25 – 50	7.10	0.43	255	13.75	20.00	635.5	57.50	307.0	SCL
Second Site (Vegetable)									
0 – 25	7.40	0.71	330	15.11	20.86	110.5	357.5	532.0	C
25 – 50	7.20	0.53	270	14.77	22.60	385.5	157.5	457.0	C
Third Site (Fruit)									
0 – 25	7.50	0.44	360	16.84	20.00	160.5	532.5	307.0	SCLo.
25 – 50	7.20	0.34	385	10.99	23.47	460.5	157.5	382.0	SC
Fourth Site (Forests)									
0 – 25	7.80	0.28	240	13.75	19.13	425.5	457.5	117.0	L
25 – 50	7.50	0.20	230	9.27	20.86	550.5	282.5	167.0	Sa.L
Fifth Site (Uncultivated)									
0 – 25	7.30	0.60	400	13.06	22.60	160.5	557.5	282.0	SCL
25 – 50	7.10	0.27	330	10.30	24.34	435.5	182.5	382.0	CL

SiL: Silt Loam SCL: Sandy Clay Loam C: Clay SCLo.: Silty Clay Loam SC: Sandy Clay L: Loam Sa.L: Sandy Loam

Magnesium adsorption at three temperatures (278, 298, 318 K)

Transparent plastic containers with a volume of 100 ml and a tight seal were used to study this adsorption. The containers were prepared with a number of magnesium concentrations prepared from magnesium chloride ($MgCl_2$) added as follows: (0, 0.1, 0.2, 0.4, 0.6, 0.8, 1, 2, 5) mmol l^{-1}. each container contained 2.5 g of the study soil, these concentrations were added in volume and the volume was made up to 50 ml with distilled water. The plastic bottles were then shaken with a shaker for 2 hours and left to equilibrate for 48 hours at three temperatures (278, 298, 318 K). The suspension in the bottles was then filtered to obtain the equilibrium solution in which calcium, magnesium, pH, and EC were determined. The amount of magnesium adsorbed on the exchange surface was calculated in mmole kg^{-1} from the following relationship:

$$Mg.ad = (Mgin - Mgfin) \times (V/S) \;\ldots\ldots\ldots.(1)$$

Mg.ad: adsorbed amount, Mg_{in} : added-Mg , Mg_{fin}: balanced-Mg, V: volume of solution, S: soil mass.

Equations describing the adsorption and exchange of magnesium at the surface of the solid phase:

1) Langmuir equation: The linear form of this equation states:

$$1/X = 1/Kb \times 1/c + 1/b \quad \ldots\ldots\ldots.(2)$$

X: Concentration of the adsorbed element on the exchange surface of the soil mmole kg^{-1}
C: Concentration of the element in the equilibrium solution mmole l^{-1}
K: Binding energy of the element to the adsorption sites kg l^{-1}
b: adsorption capacity mmole.kg^{-1}

2) Freundlich equation: The logarithmic form of the equation states:

$$Log\,X = log\,K + b\,log\,C \quad \ldots\ldots\ldots.(3)$$

X: Concentration of the adsorbed element on the exchange surface of the soil mmole kg^{-1}
C: Concentration of the element in the equilibrium solution mmole l^{-1}
K: Binding energy of the element to the adsorption sites kg l^{-1}
b: adsorption capacity mmole.kg^{-1}

3) Temkin equation

$$X = K1\,ln\,Ce + K2 \quad \ldots\ldots\ldots..(4)$$

X: Concentration of the adsorbed element on the exchange surface of the soil mmole kg^{-1}
K_1: adsorption capacity mmole.kg^{-1}
InC_e: Natural logarithm solution concentration mmole l^{-1}.
K_2: Binding energy of the element to the adsorption sites L. kg^{-1}.

RESULTS AND DISCUSSION

Equations used to describe magnesium adsorption at different temperatures

In order to study the effect of adding different levels of Mg^{+2} concentrations to the study soils and to describe the adsorption process, the adsorption equations were used, such as the Langmuir equation, the Freundlich equation, and the Temkin equation. The formulas of these equations were applied according to the data on Mg^{+2} adsorption in these soils, as shown in Figures (1, 2, and 3) as models for applying these equations, by using a non-linear regression analysis program for the actual (estimated) and expected absorption values for each soil model of the studied soils, with reference to the use of the special program for non-linear regression analysis using the least squares method when calculating the constants of the Langmuir equation as described by (Holfrod *et al.,* 1974; Muhammad, *et al.,* 2024), then, the standard error (SE) of this analysis was calculated, the values of the adsorbed amount of Mg^{+2} were adopted as a function of the state of the dissolved magnesium ion in equilibrium with it in describing the Mg^{+2} adsorption reactions when applying the Langmuir, Freundlich, and Temkin equations, when comparing these equations through the values of the coefficient of determination (R^2) and the standard error (SE), we note that the two equations (Langmuir and Freundlich) showed a good description in expressing Mg^{+2} adsorption compared to the Temkin equation, which showed a weak description of Mg^{+2} adsorption, from Table (1), we note that the Langmuir equation is superior to both the Freundlich and Temkin equations, and the Freundlich equation comes in second place in describing the adsorption process, then the Temkin equation comes in last place, as the Langmuir equation gave a value for the coefficient of determination R^2 as an average (0.83, 0.86 and 0.84) and a value for the standard error SE as an average (0.163, 0.147 and 0.139) for each of the temperatures 278, 298 and 318 Kelvin, respectively.

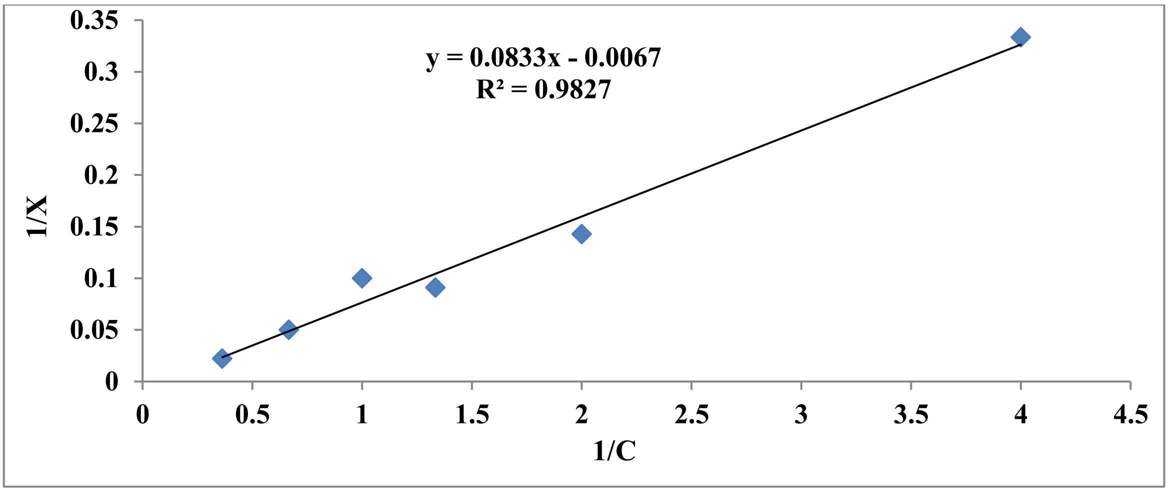

Figure (1): Relationship between the reciprocal of the Mg^{+2} concentration versus the reciprocal of the amount adsorbed at the surface depth of the fourth site as a model of the Langmuir equation (298 K)

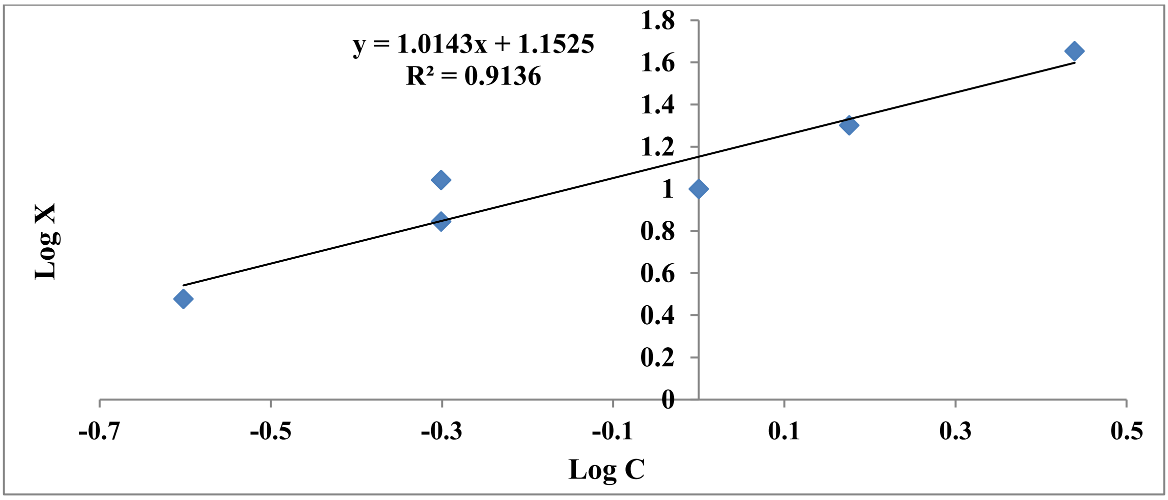

Figure (2) Relationship between the logarithm Mg^{+2} concentration versus the logarithm of the amount of it adsorbed at the surface depth of the fourth site as a model of the Freundlich equation (298 Kelvin)

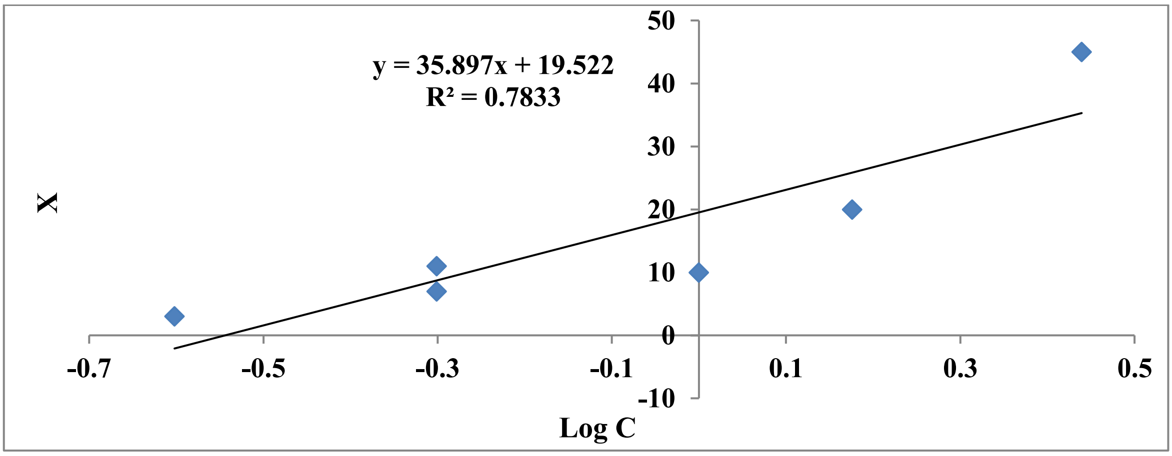

Figure (3): Relationship between the logarithm of Mg^{+2} concentration versus the amount of it adsorbed at the surface depth of the fourth site as a model for the Temkin equation (298 K)

Table (2): Coefficient of determination (R^2) and standard error (SE) for Mg^{+2} adsorption using the Langmuir, Freundlich, and Temkin equations

Site No.	Land Use	Depth cm	Langmuir		Freundlich		Temkin	
			R^2	SE	R^2	SE	R^2	SE
At 278° Kelvin								
First	Wheat	0 – 25	0.91	0.122	0.95	0.228	0.89	10.74
		25 - 50	0.89	0.129	0.84	0.384	0.88	9.10
Second	Vegetable	0 – 25	0.51	0.321	0.78	0.501	0.62	17.79
		25 - 50	0.84	0.163	0.87	0.306	0.71	15.29
Third	Fruit	0 – 25	0.76	0.212	0.80	0.536	0.79	18.52
		25 - 50	0.83	0.179	0.89	0.259	0.84	11.77
Fourth	Forests	0 – 25	0.92	0.221	0.97	0.197	0.79	15.02
		25 - 50	0.87	0.151	0.93	0.320	0.79	25.01
Fifth	Uncultivated	0 – 25	0.87	0.014	0.91	0.314	0.78	14.94
		25 - 50	0.91	0.122	0.91	0.364	0.78	21.64
Average			0.83	0.163	0.88	0.340	0.78	15.98
At 298° Kelvin								
First	Wheat	0 – 25	0.81	0.167	0.80	0.471	0.95	7.83
		25 - 50	0.97	0.054	0.81	0.644	0.83	16.58
Second	Vegetable	0 – 25	0.80	0.010	0.88	0.304	0.81	13.64
		25 - 50	0.80	0.438	0.94	0.336	0.78	17.15
Third	Fruit	0 – 25	0.80	0.010	0.94	0.141	0.89	9.93
		25 - 50	0.87	0.134	0.88	0.382	0.92	11.36
Fourth	Forests	0 – 25	0.98	0.031	0.91	0.279	0.78	15.90
		25 - 50	0.90	0.011	0.89	0.317	0.69	19.68
Fifth	Uncultivated	0 – 25	0.80	0.176	0.85	0.393	0.95	7.53
		25 - 50	0.89	0.442	0.95	0.334	0.97	6.27
Average			0.86	0.147	0.88	0.360	0.85	12.58
At 318° Kelvin								
First	Wheat	0 – 25	0.90	0.118	0.94	0.242	0.95	7.06
		25 - 50	0.91	0.114	0.96	0.214	0.92	9.76
Second	Vegetable	0 – 25	0.79	0.173	0.82	0.444	0.92	9.35
		25 - 50	0.78	0.221	0.92	1.601	0.82	18.59
Third	Fruit	0 – 25	0.89	0.118	0.88	0.347	0.89	9.99
		25 - 50	0.80	0.109	0.50	0.100	0.79	18.98
Fourth	Forests	0 – 25	0.78	0.173	0.92	0.275	0.87	12.46
		25 - 50	0.85	0.173	0.85	0.453	0.58	29.23
Fifth	Uncultivated	0 – 25	0.81	0.167	0.86	0.402	0.93	9.65
		25 - 50	0.92	0.031	0.45	0.415	0.53	33.98
Average			0.84	0.139	0.81	0.449	0.82	15.90

The Freundlich equation gave a value for the coefficient of determination R^2 as an average of (0.88, 0.88, and 0.81) and a value for the standard error SE as an average of (0.340, 0.360, and 0.449) for each of the temperatures 278, 298, and 318

Kelvin, respectively. In contrast, the Temkin equation gave a value for the coefficient of determination R^2 as an average of (0.78, 0.85, and 0.82) and a value for the standard error SE as an average of (15.98, 12.58, and 15.90) for each of the temperatures 278, 298, and 318 Kelvin, respectively, from the above results, we note that there is a clear indication that both equations (Langmuir and Freundlich) can be used, but the surface Langmuir equation showed the best mathematical description of Mg^{+2} adsorption through the values of the coefficient of determination and standard error compared to the Freundlich equation.

Functions derived from the Langmuir equation

Effect of temperature on the maximum adsorption capacity (Xm) of magnesium in the study soils

One of the most important chemical reactions that occur in the soil environment is adsorption reactions, as these reactions affect the movement of nutrients present in the soil system. Soils differ in their ability to adsorb elements depending on the characteristics of each soil and the conditions of the medium in which adsorption occurs (Al-Mashhdany and Al-Hadethi, 2023). From the results indicated in Table (3), we note that the values of the maximum adsorption capacity when the study soil samples were incubated at a temperature of 278 Kelvin ranged between (6.90) in the surface depth of the second site to (86.20) in the subsurface depth of the fourth site, with an average of (39.49) mmole kg^{-1}. As for when the sample incubation temperature rose to 298 Kelvin, the values ranged between (3.51) in the subsurface depth of the second site to (149.25) in the surface depth of the fourth site, with an average of (32.03) mmole kg^{-1}, while when the samples were incubated at a temperature of 318 Kelvin, the lowest value was in the subsurface depth of the third site and reached (4.56) and the highest value was recorded in the surface depth of the same site (15.74) and at an average of (8.73) mmole kg^{-1}. The variation in the values of adsorption capacity between soils reflects the extent of the influence of organic matter and the soil content of the clay separator and the extent of the strength of the association of the studied element with humic and fulvic acid in the soil, as shown by (Al-Janabi and Al-Obaidi, 2017; Kashmoola *et al*., 2025). The association of divalent positive ions with carbonate minerals is in complex forms within the structure of the electrical double layer. The nature of the existing ones depends on the pH of the equilibrium medium to form different groups in acidic, neutral, and basic solutions, as evidenced by the compression of the electrical double layer, which gives a greater opportunity to adsorb larger quantities of ions present in the equilibrium medium (Pokrovsky and Schott, 2002; Aday *et al.,* 2017). The increased proportion of impurities in the precipitated carbonates from various ions contributes to an increase in the number of active sites on the carbonate surfaces, which leads to an increase in their ability to adsorb various ions, including Mg^{+2}. The emphasis on the role of carbonate minerals when discussing the capacity of soils to adsorb magnesium is due to the high capacity and significant role of these minerals in the adsorption process, as indicated by Wheib *et al. (*2025). Regarding the effect of temperature on the rate of maximum adsorption capacity values, as is clear from the linear regression relationship (Figure 4), we note that there is a negative correlation between the rate of maximum adsorption capacity and equilibrium temperatures (R^2=91). When expressing this relationship statistically, we note that increasing the temperature from 278 K to 298 K led to a decrease in the maximum adsorption capacity rate by 18.89%, and increasing the temperature from 278 K to 318 K led to a decrease in the maximum adsorption capacity rate by 77.89%.

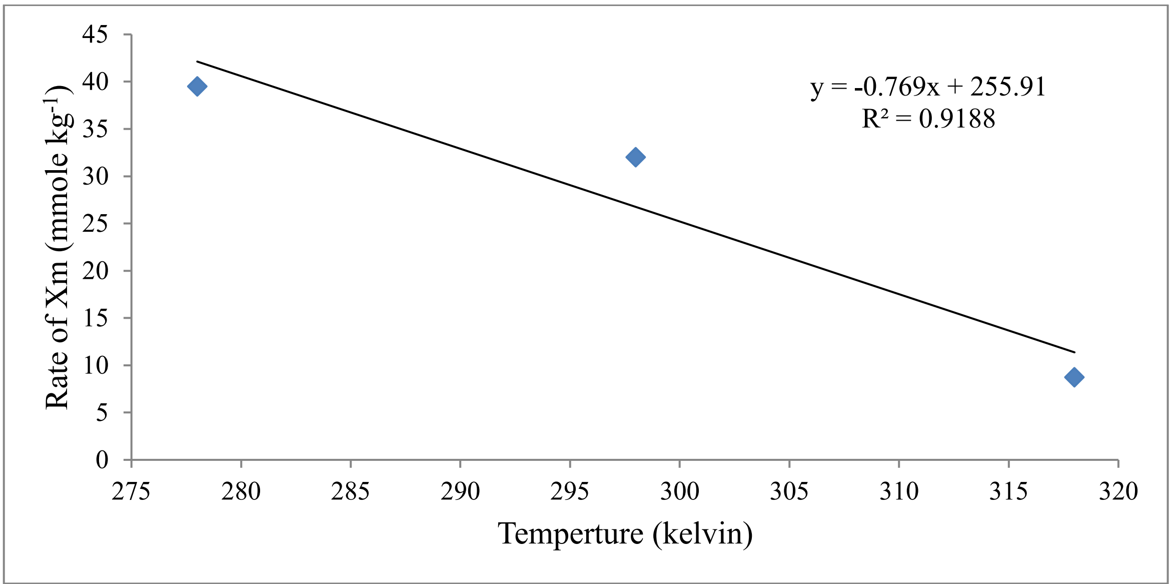

Figure (4): Effect of temperature on the rate of maximum adsorption capacity (Xm) in the study soils.

Effect of temperature on the binding energy (K) of Mg^{+2} in the study soils

Regarding the binding energy (K) of the Langmuir equation, it is an important factor as it is related to the speed of release of the adsorbed element. The binding energy for magnesium gave low values, and as shown in Table (3), there is a slight variation between the studied soils. The values ranged from (0.27) in the surface depth of the second site to (4.56) in the subsurface depth of the fourth site, at a rate of (2.07) L $mmole^{-1}$ at a temperature of 278 Kelvin, when the incubation temperature rose to 298 K, the lowest value was recorded in the surface depth of the first site (1.27) and the highest value was in the surface depth of the fourth site (12.43) at a rate of (3.61) L $mmole^{-1}$, while when the samples were incubated at a temperature of 318 K, the lowest value was in the subsurface depth of the third site (1.45) and the highest value (3.89) was recorded in the subsurface depth of the fourth site at a rate of (2.21) L $mmole^{-1}$. Low values of binding energy indicate that most of the magnesium ions have been adsorbed on non-specialized sites that have low binding energy, which means that magnesium is released into the soil solution due to the weak binding energy, as indicated by Jalali and Moharrami (2007). High values of binding energy may be due to the high clay content of the soil, meaning that adsorption occurs in specialized sites, or it may be due to the association of magnesium ions with humic acid (Albarzanjy *et al.,* 2024). In terms of the effect of temperature on the average binding energy values, as shown by the linear regression relationship (Figure 5), we note that there is a weak positive correlation between the average binding energy values and the equilibrium temperatures (R^2=0.006), when expressing this relationship statistically, we note that increasing the temperature from 278̊ K to 298̊ K led to an increase in the average binding energy by 74.39%, and increasing the temperature from 278° K to 318° K led to an increase in the average binding energy by 6.76%.

Table (3): Maximum adsorption capacity (Xm), binding energy (K), and maximum buffering capacity (MBC) according to the Langmuir equation for the study soils.

Site No.	Land Use	Depth cm	Xm	b	MBC
At 278° Kelvin					
First	Wheat	0 – 25	60.24	3.07	185.44
		25 - 50	59.52	2.80	167.23
Second	Vegetable	0 – 25	6.90	0.27	1.91
		25 - 50	11.65	0.56	6.56
Third	Fruit	0 – 25	51.54	2.52	129.92
		25 – 50	12.50	0.61	7.65
Fourth	Forests	0 – 25	12.09	1.76	21.33
		25 - 50	86.20	4.56	393.87
Fifth	Uncultivated	0 – 25	31.34	1.50	47.16
		25 - 50	62.89	3.10	195.00
Average			39.49	2.07	115.61
At 298° Kelvin					
First	Wheat	0 – 25	7.86	1.27	10.02
		25 - 50	7.78	2.50	19.46
Second	Vegetable	0 – 25	47.61	3.50	167.12
		25 - 50	3.51	2.45	8.64
Third	Fruit	0 – 25	47.39	3.38	160.37
		25 - 50	7.51	1.73	13.04
Fourth	Forests	0 – 25	149.25	12.43	1855.64
		25 - 50	37.45	5.46	204.51
Fifth	Uncultivated	0 – 25	7.99	1.28	10.29
		25 - 50	3.98	2.06	8.23
Average			32.03	3.61	245.73
At 318° Kelvin					
First	Wheat	0 – 25	8.42	2.49	21.02
		25 - 50	7.73	2.34	18.14
Second	Vegetable	0 – 25	5.61	1.63	9.19
		25 - 50	5.93	2.15	12.80
Third	Fruit	0 – 25	15.74	2.47	39.03
		25 - 50	4.56	1.45	6.66
Fourth	Forests	0 – 25	13.15	2.51	33.05
		25 - 50	11.70	3.89	45.63
Fifth	Uncultivated	0 – 25	5.20	1.56	8.14
		25 - 50	9.29	1.57	14.64
Average			8.73	2.21	20.83

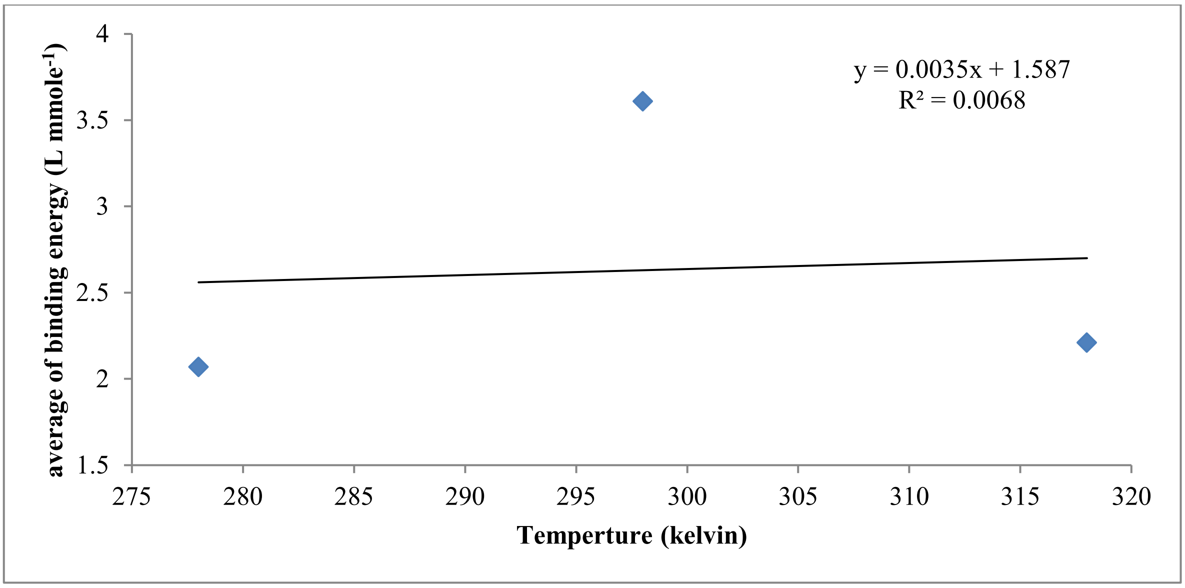

Figure (5): Effect of temperature on the average values of binding energy K in the study soils.

Effect of temperature on the maximum buffering capacity (MBC) of magnesium in the study soils

Maximum buffering capacity is one of the properties of ion adsorption in soil, as it reflects the capacity of the ion adsorbed on the exchange surfaces. This value was obtained mathematically by multiplying the maximum adsorption Xm by the binding energy K of the Langmuir equation, as follows:

$$MBC = Xm \times K$$

The results shown in table (3) indicate that the maximum buffering capacity values of magnesium ranged from (1.91) in the surface depth of the second site to (393.87) in the subsurface depth of the fourth site, at a rate of (115.61) L kg^{-1} at a temperature of 278 K, while when the samples were incubated at a temperature of 298 K, the values ranged from (8.23) in the subsurface depth of the fifth site to (1855.73) in the surface depth of the fourth site, at a rate of (245.73) L kg^{-1}, when the samples were incubated at a temperature of 318 Kelvin, we found that the lowest values were recorded in the subsurface depth of the third site (6.66) and the highest were recorded in the subsurface depth of the fourth site (45.63) and the average was (20.83) L kg^{-1}. The difference in the values of the maximum buffering capacity of magnesium is due to the difference in the behavior of this element towards adsorption due to some factors that affect the nature of adsorption, including the radius of the ion, the valence of the ion, the ionic strength of the solution, and the type of colloidal surface (McBride, 1994; Ashour *et al.,* 2022). Some studies have addressed the factors that control the nature of adsorption of some elements and the accompanying variation in the values of maximum adsorption capacity Xm and binding energy K and the effect of that on the movement and transfer of elements from the adsorption surfaces to the soil solution, which helps increase the spread of the element and then its absorption by the plant (Krishnamurti and Naidu, 2008; Al-Bayati *et al.,* 2021). As for the effect of temperature on the maximum buffering capacity values, as shown by the linear regression relationship (Figure 6), we note that the increase in temperature from 278° K to 298° K was a positive relationship, which led to an increase in the maximum buffering capacity rate by 112.55%, while when the temperature increased from 278 ̊ K to 318 ̊ K, the relationship was negative, which led to a decrease in the maximum buffering capacity rate by 81.98%.

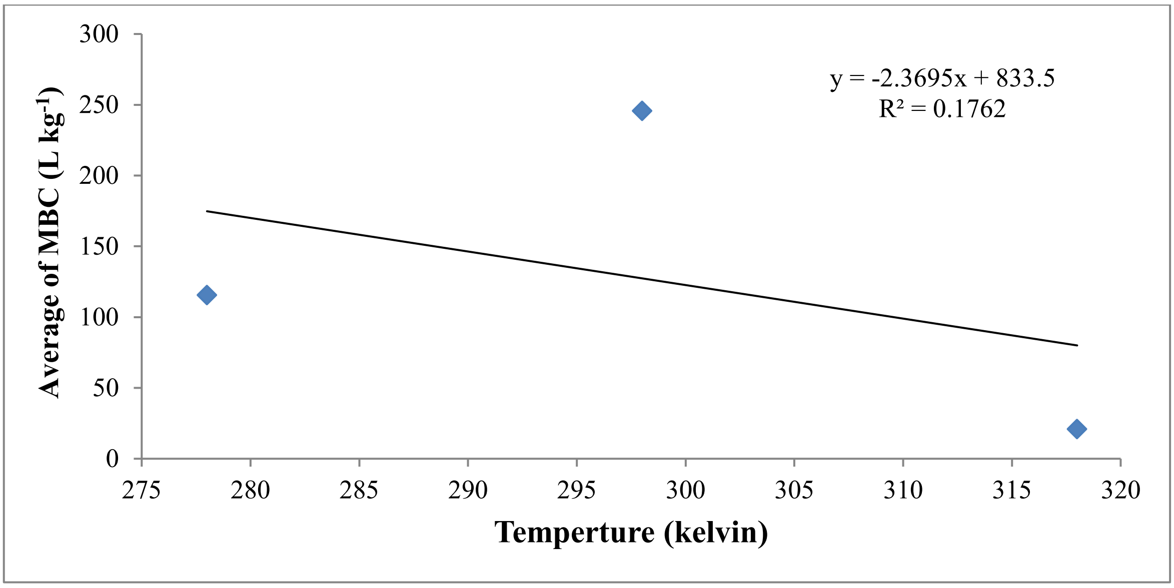

Figure (6): Effect of temperature on the average values of maximum buffering capacity (MBC) in the study soils

CONCLUSIONS

From the above, we conclude that the high or decrease in temperatures during the year seasons affects the ionic exchange processes of magnesium in calcareous soils, and the best equation that describes the reactions of magnesium in such soils is the Langmuir equation compared to the Freundlich and Temkin equations.

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CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest.

وصف امتزاز المغنسيوم تحت تأثير درجات حرارة مختلفة في ترب كلسية مختلفة الاستغلال الزراعي

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الخلاصة

بهدف دراسة تأثير درجات الحرارة على امتزاز المغنسيوم في ترب كلسية مختلفة، فقد استخدمت المعادلات الخاصة بالامتزاز كمعادلة لانكماير ومعادلة فروندلخ ومعادلة تمكن لوصف عملية الامتزاز، أجريت الدراسة على خمسة مواقع مختلفة الاستغلال الزراعية في محافظة نينوى – العراق، وكل موقع مقسم الى عمقين (سطحي، تحت سطحي). تمت الدراسة على ثلاث درجات حرارية (278 , 298 , 318 كلفن). وعند المقارنة

بين هذه المعادلات من خلال قيم معامل التحديد (R^2) والخطأ القياسي (SE) تفوقت معادلة لانكماير بالدرجة الاولى على كل من معادلتي فروندلخ وتمكن, وتأتي معادلة فروندلخ بالمرتبة الثانية في وصف الامتزاز, ثم تأتي معادلة تمكن بالمرتبة الاخيرة, تم دراسة بعض الدوال المشتقة من معادلة لانكماير (أقصى سعة امتزاز, طاقة الربط , السعة التنظيمية العظمى), فقد أظهرت نتائج الدراسة بأن تأثير درجة الحرارة على معدل قيم أقصى سعة امتزاز كانت العلاقة سالبة بين معدل أقصى سعة امتزاز مع درجات حرارة الاتزان (R^2=91), فعند ارتفاع درجة الحرارة من 278° كلفن الى 298° كلفن أدى الى انخفاض معدل أقصى سعة امتزاز بنسبة قدرها 18.89%, أما تأثير درجات الحرارة على معدل قيم طاقة الربط كانت هناك علاقة الارتباط موجبة ضعيفة بين معدل قيم طاقة الربط مع درجات حرارة الاتزان (R^2=00.6), فعند ارتفاع درجة الحرارة من 278° كلفن الى 298° كلفن أدى الى ارتفاع معدل طاقة الربط بنسبة قدرها 74.39%, وارتفاع درجة الحرارة من 278° الى 318° كلفن أدى الى ارتفاع في نسبة معدل طاقة الربط وقدرها 6.76%. في حين تأثير درجات الحرارة على معدل قيم السعة التنظيمية العظمى لم يكن له نمط ثابت.

الكلمات المفتاحية: معادلات الامتزاز ، أقصى سعة امتزاز ، طاقة الربط، السعة التنظيمية العظمى.

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