CHARACTERISTICS OF PHOSPHOROUS SORPTION BY SOME NATURAL SEDIMENTS OF SAUDI ARABIA

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ABSTRACT

The adsorption of phosphate is a process wherein phosphate ions in solution react with atoms on the surface of soil particles. This is an important property affecting both the fate of phosphate fertilizer and the availability of phosphate to plants. In order to understand this phenomena, two natural (gray and red) clay sediments which numerously present in Saudi Arabia, were selected to investigate the behavior of phosphorus sorption as a function of equilibrium P concentration (0, 10.0, 20.0, 40.0, 80.0 and 100 μg p/ml). The used sediments were dominated by smectite clay with relatively small amounts of calcite and kaokinite. The average clay content in the used sediments ranged from 64 to 73%, while the $CaCO_3$ ranged from 16 to 22 g. kg^{-1}, EC_e (20.19 to 37.31 dSm^{-1}), and pH (7.02 to 7.14). Clay fractions were separated from sediment samples have CEC (C mole kg^{-1}) range between 56 and 71.5 and surface area of 128 -690 m^2 gm^{-1}. Results indicated that the phosphorus sorption followed the Langmuir adsorption isotherm. Moreover, the Freundlich adsorption isotherm was also, applicable over the entire P concentration range (0 to 100 μg p/ml). Data pertaining the Langmuir adsorption isotherm show that, the binding energy (K_d) reached 51.34 and 2.30 l/gm for the 1st and the 2nd steps of P sorbed by the gray clay sediment, respectively. While the respective values for the red clay reached 33.76 and 2.63 l/gm. Meanwhile, for the Freundlich adsorption isotherm, the binding energy (n) reached 0.58 and 0.53 l/gm for the gray and red clay sediments, respectively. However, the b values (maximum adsorption capacity) reached 47.04 and 130.59 mg/g with correlation coefficient (r^2) 0.98 and 0.95 for the gray and red sediments, respectively. Desorption data indicated that nearly half of the adsorbed P was extracted in the two extractions which followed the adsorption. In conclusion, the study emphasized the high impacts of the used natural clay deposits in phosphorus retention and such deposits can be successfully used to provide the growing plants with available phosphorus through p fertilizations.

Key words: clay deposits, langmuir and freundlich adsorption isotherms, phosphorous adsorption.

1. INTRODUCTION

From the lecture it is well known that soils have a defined capacity to adsorb phosphorus and there will be a great possibility to release excess P into the surface or ground water when a critical P sorption saturation level is attained (Paulter and Sim, 2000 and Bohn *et al*., 2011). Moreover, phosphate sorption plays an important role in environmental aspects of P management. The capacity of soil to retain added P is often described by simple adsorption equations, which relate P concentration in solution to the amount of P retained by the soil (Jalali and Peikam, 2012). The most popular mathematical models used to describe P sorption are the Langmuir and Freundlich equations (Afsar *et al*., 2012). Many studies indicated that the most soil properties affecting the P adsorption capacity are soil texture (Leclerc *et al.,* 2001) organic matter (Daly *et al.,* 2001), oxides of iron and aluminium (Toor *et al.,* 1997), soil pH and $CaCO_3$ content (Bertrand *et al*.,2003).

As the soil solution contains low concentration of P as compared to plant requirements, many trials have been done for predicting the quantity of phosphate fertilizer required to bring soil to various levels of adequacy for crop production. An approach to this problem is to measure adsorbed phosphate at standard supernatant concentrations of P as an

estimate of phosphate needs of soils. Phosphate adsorption isotherms have been used as basis for evaluating the P requirements of soils (Fox and Malat 1993). However, investigations of phosphate adsorption have been centered on two major areas, namely the mechanism of phosphate adsorption and the identification of phosphate reactive sites (Yuan and Wu, 2007). Understanding P adsorption mechanism is vital for improving efficiency of phosphate fertilizer use while the latter is essential to evaluate intensity of adsorption and understanding the various processes associated with the phenomenon.

Mineral deposits in Saudi Arabia are widespread and of many types, all conditions favorable for the formation and accumulation of clay deposits were combined during the Phanerozoic in Saudi Arabia (Laurent, 1993). In most cases, the clay occurrences in such deposits contain a predominant proportion of kaolinite. Exceptions are the distinctly marine deposits of the early Paleozoic (Jauf and Tauk formations) and the Tertiary littoral marine deposits of the east coast (Hadrukh and Dam formations) in which illite predominates. Certain lagoon or lacustrine environments generated deposits of attapulgite clay (Aruma and Dammam formations) or montmorillonitic clay (Tertiary formations of the Red Sea coast) (Laurent, 1993). Natural clays such as clay stone or mudstone comprise several clay minerals with one or more impurities. The most common impurities are free iron oxide minerals, amorphous silica and alumina, quartz grain, limestone, gypsum and other more soluble salts. These impurities affect largely clay characteristics and may affect adversely its use in specific applications (Al-Omran *et al.,* 2004 and Al-Omran *et al.,* 2005). In their study Fox and Malat, (1993) pointed out that a kinetic study, of phosphate adsorption showed an initial fast step followed by a slower process affecting by pH, phosphate concentration, rate of shaking and temperature, they added that desorption of phosphate also revealed two consecutive kinetic stages. In addition, clay minerals, such as kaolinite, illite, beidellite, and montmorillonite which constitute the fine-grained part of the ore, have a tendency to fix large proportions of the extractor, depending upon their surface properties (Zhou and Li,2011). It is interesting to note that the natural sediments were found in a huge quantities and have been used for long times to sustain agricultural productivity in

Saudi Arabia (Al-Omran *et al.,* 2005and Sheta *et al.,* 2006). Therefore, the objective of this study was to investigate the kinetics of phosphorus adsorption / desorption by such natural sediments to establish a good management practice for P fertilizer under Saudi Arabian conditions.

2. MATERIALS AND METHODS
2.1. Sediment collections

Two natural clay sediments (gray and red) were collected from the South Western Regions of Saudi Arabia. The gray sediments were collected from Jeddah-Al- Madinah Al-Munawwarah road which located at (39º 13' 53.1" E, 22º 13' 53" N), meanwhile the red sediments were collected from Khulays Governorate located at (39º 2' 31.6" E, 22º 9' 9.2" N).

The collected sediments were prepared for mineralogical, physical and chemical analyses following the standard procedures described by Gee and Bauder,(1996) for particle size distribution; Rhoades, (1996) and Thomas, (1996) for soluble salts and pH determination in the saturation paste extract; Loeobert and Suarez (1996) for the determination of calcium carbonate content. Cation exchange capacity in each soil sample was determined with the method for arid zone soils described by Sumner *et al.* (1996). Surface area was measured according to Soil Survey Laboratory Methods Manual, (1992). Tables (1 and 2) depict some of the physico– chemical and mineralogical properties of the studied deposits collected from different locations.

The clay fraction (< 2 um) was separated from the collected sedements according to (Soukup *et al.,* 2008). Sub samples of clay fraction were Mg^{2+} or K^+ saturated using 1M $MgCl_2$ or 1M KCl, respectively, then slides were prepared as oriented mounts. X-ray diffractograms were obtained using Cu-Kα radiation at 40kV and 25mA. K-saturated samples were scanned after air drying and following heat treatment at 550^oC for 2 h. Mg-saturated samples were scanned following air drying and ethylene glycol solvation. Identification of clay minerals and accessory minerals was carried out according to (Dixon and Weed, 1989). Free iron and manganese oxides (Fe_d & Mn_d) were extracted using sodium citrate bicarbonate- dithionate method (CBD) according to (Mehra and Jackson, 1960). Amorphous silica and alumina (Si $_{am}$ & Al_{am}) were dissolved in boiled NaOH (1N) for 2.5 minutes

according to Alexiades & Jackson (1966) then Al and Si in the extracts were measured by Atomic Absorption.

2.2. Phosphorus adsorption experiments

Two grams from each of the clay deposits were placed in 100ml polypropylene centrifuge tubes and solutions (20ml) containing varying amounts of P (0, 10.0, 20.0, 40.0, 80.0 and 100.0 µg P /ml in P - free 0.03 M potassium nitrate (KNO_3) at pH7.0, were added and the resulting suspensions were allowed to attain equilibrium for 24 h at 25^oC in an incubator with occasional shaking followed by centrifugation (15000 rpm for 15 min, at 25^oC), then decantation, and filtration. The filtrate was analyzed for P following the methods of Olsen and Sommers, (1982). The equilibrium solution was prepared by dissolving potassium dihydrogen phosphate (KH_2PO_4). Dilute KNO_3 solution was used instead of de ionized water or dilute calcium chloride solution to avoid a positive error due to presence of yellowish color in the water extract or a possible P retention in presence of high contents of soluble calcium in the form of Ca – Phosphate minerals. P sorbed by the studied clay deposits was calculated as the difference between the initial P and equilibrium P concentrations. The amount of native adsorbed P initially present in the deposits was estimated by extrapolating the adsorption isotherms derived from higher to zero concentration of soluble P and from the amount of P extracted with P– free 0.01 M $CaCl_2$ solution. The native P so estimated was taken into account to establish the corrected adsorption isotherm. The data of P sorption were first calculated according to Langmuir adsorption isotherm. The linear form of the isotherm used was: (c)/(X/m) = 1/ b (c) +1 / kb, Where (c) = equilibrium concentration (µ g p/ml), (x/m) = adsorbed p(µ g p /g soil), b = adsorption maximum (µ g p /g soil), and k = a constant related to bonding energy (ml /µ g). The data were also described by the Freundlich adsorption isotherm. The linear form of the isotherm used was: log (X/m) = 1/ n log (c) + log k, where 1/ n is the slope of the regression line, and k and n are empirical constants.

2.3. Phosphorus desorption experiments

Each of the previously used deposit samples in the adsorption experiments was treated two more successfully times with 10ml of P- free 0.5 M NH_4HCO_3 DTPA solution, and shoked for 24 h followed by centrifugation for 15 min at 3000 rpm. The supernatants were collected for the P

determination using the method described by Olsen and Sommers (1982). Desorbed P was calculated as the difference between the equilibrium P concentrations at each desorption step and the equilibrium P concentrations of the previous step, divided by two (dilution factor). A statistical analysis including simple and multiple correlation coefficients were made to determine if any relationship existed between various deposit properties and some P adsorption / desorption parameters among the studied clay deposits.

3. RESULTS AND DISCUSSION
3.1. Properties of the used sediments

The studied clay deposits are exposed on gentle slopes beneath the stony layers. Table (1) showed that the studied sediment has clay content ranges from 64 to 73 %, very high clay content was recorded in the first site (Gray sediments). $CaCO_3$ contents range from 16 to 22 g kg^{-1}. Salinity levels are quite high and range from 20.19 – 37.31 dS m^{-1}. Values of sediment's pH ranged from 7.02 to 7.14, which corresponded to most of the arid soils. The studied sediments have relatively high contents of total Fe particularly in the sediment samples from Al-Madinah (Nos. 41 and 42) 132.5 gkg^{-1} where the sediments were formed from the basaltic lava of the Harrat. Total contents of P in the studied sediments are variable between 1.8 and 2.7mg kg^{-1} (Table 2). On the other hand, the available P ranges from 1.5 – 2 mg kg^{-1}.

The results presented in Table (2) indicated that free Fe oxides ranged from 19399 – 25986 mg kg^{-1}. The highest contents were observed in the second samples (Khulays Governorate). Free Mn oxides showed relatively high quantities which ranged from 131-139 mg kg^{-1} which could reflect the mineralogical composition of the dominant igneous and metamorphic rocks from which these deposits were formed.

The Cation exchange capacity was quite high for the studied samples and ranged from 56 to 71.5 C mole kg^{-1} (Table 2). The studied clays have high surface area; it ranges from 128.4- 371.4 m^2.gm^{-1} which was quite high. X- ray diffract grams showed, the dominance of smectite followed by kaolinite, illite, and interstratified minerals.

3.2. Phosphorus adsorption

The P sorption by the studied clay sediments generally, conformed to the Langmuir sorption isotherm but over limited concentration ranges.

Table (1): Location, sample description and some characteristics of the collected sediment samples.

Sample	Location	Color		pH	EC dS m⁻¹
		Dry	**Moist**		
Gray deposits	Jeddah-Al-Madinah Al-Munawwarah Road 39º 13' 53.1" E, 22º 13' 53" N	Light gray (2.5Y7/2)	Pale yellow (2.5Y 7/4)	7.02	37.31
Red deposits	Khulays Governorate 39º 2' 31.6" E, 22º 9' 9.2" N	Yellowish red(5YR5/6)	Red(2.5YR4/6)	7.14	20.19

Sample	CaCO₃ (g/kg)	Clay (%)	Silt (%)	Sand (%)	Description
Gray deposits	22	73	17	10	Clayey clods, gray, compacted
Red deposits	16	64	23	13	Clayey clods, red, compacted

Table (2): Amorphous Si and Al, Free Fe and Mn oxides, surface area, cation exchange capacity (CEC), and semi quantitative analysis of X-ray diffract grams obtained for clay fraction separated from sediment samples.

Sample	CEC Cmole kg⁻¹	Mn_d	Fe_d	Si_am	Al_am	Surface Area m² gm⁻¹
		mg kg-1				
Gray deposits	71.5	139.2	19399	1630	980	690
Red deposits	56.0	131.3	25986	1341	976	128.4

Where: Al_{am}: amorphous alumina, Si_{am} amorphous silica, Fe_d free Fe oxides, Mn_d Free Mn oxides

Sample	Smectite	Kaolinit	Interstratified	Illite	Quartz	Feldspars
Gray deposits	++++	++	+	+	+	+
Red deposits	+++	+++	+	+	++	+

Where: ++++ means (>70%), +++ (50-70%), ++ (35-50%), + (10-35%)

However, at high equilibrium solution data deviated from the Langmuir model. Such deviations from the Langmuir model indicated that there were different reactions may be occur at higher P concentrations (Table, 3 and Figs. 1 &2). The obtained K values reflected the large difference between the two studied sediments in their C.E.C and their specific surface area (Tables, 1 & 2).

The gray sediments with relatively high clay and CaCO₃ contents had adsorbed more phosphate. Such behavior could be either owing to large surface area of gray sediment or stronger reactive sites (Tables,1 & 2). In this respect, Leclerc *et al.,* (2001) recorded higher adsorption maxima with greater clay contents of soils, while Bertrand *et al.* (2003) supported that calcium carbonate enhanced phosphate adsorption.

Using the R^2 values as a test for goodness of fit

gray as well as red sediments (R^2 = 99) appeared to conform relatively well to Langmuir equation especially in the 1ˢᵗ and the 2ⁿᵈ stages of adsorption (Table 3 and Fig. 1). This indicating that phosphate adsorption did not occur by a single process in these sediments. Thus, Langmuir equation can be used to characterize the p adsorption. In this respect, some workers suggested that adsorption follows Langmuir isotherm in the range of 25-100 ug g⁻¹ of adsorbed P (Paulter and Sim, 2000; Bohn *et al.,* 2011). Afsar *et al.* (2012) considered the effect of adsorbed ions in the equilibrium solution as the cause of the commonly reported curvilinear nature of the simple Langmuir isotherm.

Freundlich equation was applied to the same P adsorption data by plotting logarithmic values of x/m (the adsorbed P) against values of log C_n (the

equilibrium P concentration). Also, due to R^2 value Freundlich equation described adequately phosphate retention by the studied sediments (Table 4). Freundlich equation showed another characteristic that the adsorption points were compressed at the top end, which might have disguised the poor linearity. In this respect, Barrow (1978) reported gentle curves when Freundlich equation was applied to soil phosphate adsorption data.

3.3. Amounts of desorbed Phosphorus

Studying phosphorus desorption may be helpful for better understanding the role of the studied sediments in providing the adsorbed phosphorus fertilizers to the growing plants. This is because the availability of both applied and native phosphorus is largely controlled by sorption and desorption characteristics of the soil. Therefore, a proper understanding of the mechanism of P release from the used sediments is very important to establish good management practices for P fertilizations.

Higher amounts of extracted P were obtained in the second extraction from the two studied sediments; Also, Gray clay sediments gave the higher amounts of extracted P. This behavior may be due to the nature of adsorbing sites in such deposits, which may differ from those of the other red clay one. By calculating the desorbed P as a percentage from the adsorbed P, one can conclude that, the studying clay deposits were greatly differ from each other, especially at low concentration of applied P. Furthermore, the relatively higher percentages of desorbed P were obtained in the 1st extraction which followed the adsorption. The differences in such percentages were (35.48- 32.18); (43.03 – 38.73) ; (37.71 – 30.308); (41.49- 27.97) and (44.49 – 33.51) for the gray sediments, while the respective values for the red deposits reached (28.26- 25.27); (33.97- 30.43); (34.32- 29.23); (47.07- 35.20) and (45.39- 34.23), respectively.

The obtained results lead to the conclusion that the amount of adsorbed Phosphate ions increase as the rate of applied phosphate increased from 0 to 100mg/l in the two tested sediment samples. Data agreed very well with the Langmuir and Freundlich equation, as the correlation coefficient was almost near 1.0 for the two studied sediments. In the

Table (3): Maximum adsorption capacity (MAC) and binding energy (BE) for the adsorbed Phosphorus on the studying sediments according to Langmuir equation.

Deposit	Step	Equation	R^2	(MAC) b (mg/g)	(BE) K (l/gm)
Gray clay	1st	C/(x/m) =6.0683X +0.1182	0.99	0.165	51.339
	2nd	C/(x/m) =1.4268X+0.6212	0.99	0.701	2.297
Red clay	1st	C/(x/m) =5.5264X +0.1637	0.99	0.181	33.759
	2nd	C/(x/m) =1.5803X+0.6005	0.99	0.633	2.632

Table (4): Maximum adsorption capacity (MAC) and binding energy (BE) for the adsorbed Phosphorous on the studying sediments according to Frundlish equation.

Deposit	Equation	R^2	(BE) n l/gm	(M AC) K mg/g
Gray clay	Log (x/m)= 1.7197x - 1.6725	0.98	0.5814	47.04354
Red clay	Log(x/m) = 1.887x - 2.1159	0.95	0.5299	130.587

Langmuir adsorption the K_d values for the used sediments reached 51.34 and 2.30 l/gm for the 1st and the 2nd steps of gray clay, respectively. While for the red clay reached 33.76 and 2.63 l/gm. However, the maximum adsorption capacity reached 0.165 and 0.53 mg/g with correlation coefficient (r^2) 0.99 and 99, respectively. Meanwhile, for the Freundlich adsorption isotherm, the binding energy (n) reached 0.58 and 0.53 l/gm for the gray and red clay sediments, respectively. However, the b values (maximum adsorption capacity) reached 47.04 and 130.59 mg/g with correlation coefficient (r^2) 0.98 and 0.95 for the gray and red sediments, respectively.

Desorption data indicated that nearly half of the adsorbed P was extracted in the two extractions which followed the adsorption. In conclusion, the ability of the used clay sediments to retain P was high and there were differences between the studied sediments in sorption and desorption characteristics of P. This indicates the profitability of using both studied natural sediments as ion exchangers for phosphorus sorption as well as, providing the growing plants with available phosphorus through p fertilizations.
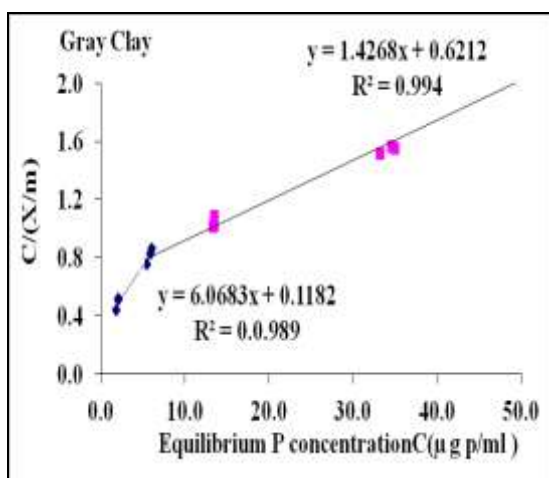

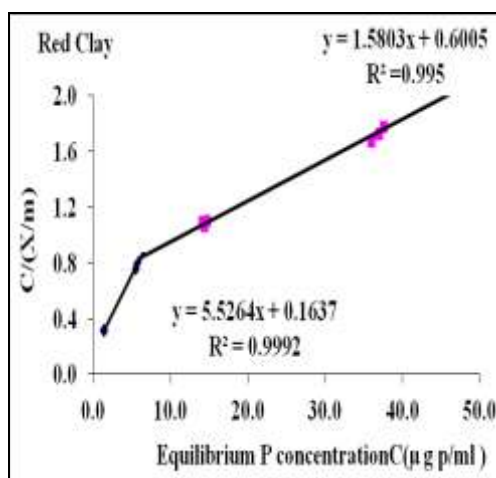**Fig. (1): Langmuir adsorption isotherm of P in the studying Gray Sediments.**

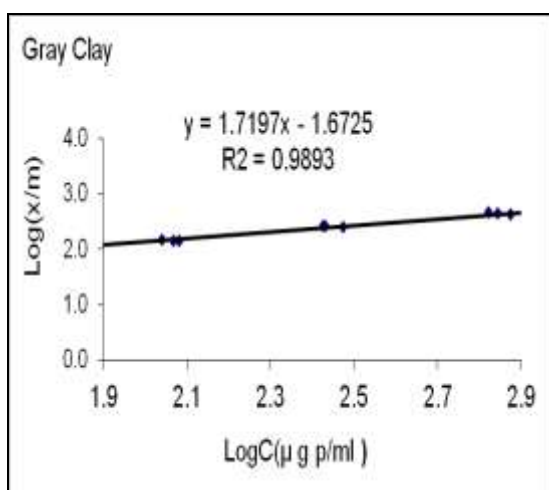**Fig. (2):Langmuir adsorption isotherm of P in the studying Red Sediments.**

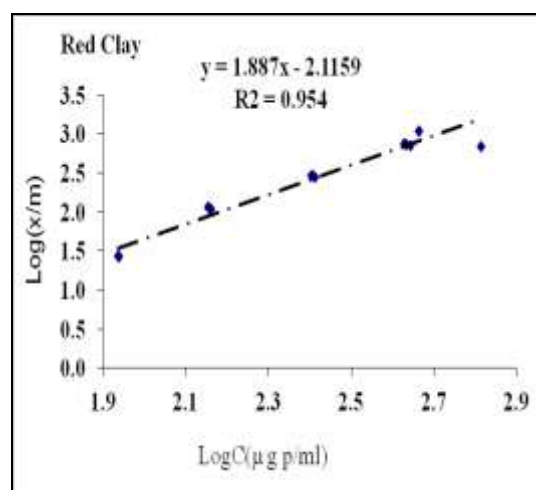**Fig. (3): Freundlich adsorption isotherm of P in the studying Gray Sediments.**

Fig.(4): Freundlich adsorption isotherm of P in the studying Red Sediments.

Table (5): Desorbed P as a percentage from its adsorption on the studied sediments.

Applied P (mg/l)	Ce (mg/l)	X/m (mg/g)	Desorbed P (mg/g)			Desorbed / Adsorbed %		
			D1	D2	Total	D1	D2	Total
Gray Clay Sediments								
0	0.00	0.000	0.013	0.011	0.024	0.000	0.000	0.000
10.0	1.96	0.080	0.041	0.037	0.078	35.478	32.181	67.659
20.0	5.78	0.142	0.074	0.066	0.140	43.030	38.734	81.764
40.0	13.89	0.261	0.111	0.090	0.202	37.713	30.308	68.021
80.0	35.21	0.448	0.199	0.136	0.335	41.490	27.972	69.461
100.0	50.99	0.490	0.231	0.175	0.406	44.490	33.508	77.998
Red Clay Sediments								
0	0.00	0.000	0.009	0.006	0.015	0.000	0.000	0.000
10.0	1.35	0.086	0.033	0.028	0.061	28.262	25.267	53.529
20.0	5.64	0.143	0.058	0.050	0.107	33.974	30.434	64.407
40.0	14.39	0.256	0.097	0.081	0.178	34.315	29.232	63.548
80.0	36.86	0.431	0.212	0.158	0.370	47.074	35.195	82.269
100.0	47.48	0.525	0.247	0.186	0.433	45.393	34.232	79.626

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<h3 style="text-align:center; direction:rtl">خصائص إدمصاص الفوسفور على بعض الرواسب الطبيعية بالمملكة العربية السعودية</h3>

<p style="text-align:center; direction:rtl">عبد الله بن سليمان الفراج - سالم العزب المغربي- عبد العظيم شهوان سلام - محمد بن إبراهيم الوابل</p>

<p style="text-align:center; direction:rtl">قسم علوم التربة ـ كلية علوم الأغذية والزراعة ـ جامعة الملك سعودـ المملكة العربية السعودية</p>

<h3 style="text-align:center; direction:rtl">ملخص</h3>

<p style="direction:rtl">إدمصاص الفوسفور هى العملية التي من خلالها ترتبط أيونات الفوسفات الموجودة في المحلول مع المجاميع الفعالة على أسطح حبيبات التربة. وعملية إدمصاص الفوسفور هذه مهمه جدا حيث تؤثر على مصير الأسمدة الفوسفاتية ومدى توفر الفوسفور للنباتات النامية. وفي هذه الدراسة، تم إختيار نوعين من رواسب الطين الطبيعية (الرمادي والأحمر) المنتشرة بكثرة والمستخدمة في الزراعة في المملكة العربية السعودية، وذلك لدراسة سلوك إدمصاص وإنطلاق الفوسفور على هذه الرواسب. تم إستخدام محاليل تحتوي على تركيزات مختلفة من الفوسفور(صفر ،10.0، 20.0،0.0 ، 40.0 ، 80.0 ، 100.0 ميكروجرام فوسفور/مل)، وذلك للتعرف على سلوك إدمصاصها على النوعين المذكورين من الرواسب بتطبيق معادلتي لانجماير وفريندليش للإدمصاص ،</p>

وأيضا تمت دراسة سلوك إنطلاق الفوسفور المدمص بواسطة الرواسب المختارة. أوضحت تحليلات عينات الرواسب المستخدمة في هذه الدراسة إحتوائها على معادن الطين التي تتبع مجموعة الأسمكتيت smectite group مع وجود كميات قليلة نسبيا من معادن الكالسيت والكاؤلينيت. وقد بلغت نسبة الطين في تلك الرواسب ما بين 64 و 73 %، في حين بلغ محتواها من كربونات الكالسيوم $CaCO_3$ من 16 إلى 22 جم/ كجم، وقيم التوصيل الكهربي EC_e لها (20.19 إلى 37.31 dSm^{-1})، ودرجة الحموضة لها (7.02 إلى 7.14). أيضا بلغت السعة التبادلية الكاتيونية CEC لتلك الرواسب (56إلى 71.5 سنتيمول/ كجم) وذات سطح نوعي يتراوح من (128-690 م^2/جم).

أشارت النتائج إلى أن ادمصاص الفوسفوربواسطة تلك الرواسب يمكن وصفها بدقة بكل من معادلة لانجماير، ومعادلة فريندليش للإدمصاص وذلك في وجود تركيزات من الفوسفور في محلول الإتزان تصل إلى(100 g μ/مل). وعند تطبيق معادلة لانجمايرللإدمصاص تبين أن طاقة إرتباط الفوسفور بأسطح رواسب الطين الرمادية المستخدمة بلغت (51.34 و 2.30لتر /جم) لمرحلتى الإدمصاص الأولى والثانية، على التوالي. بالمقارنة ب (33.76 ، 2.63لتر /جم) لمرحلتي الإدمصاص على الطين الأحمر. في حين بلغت السعة الإدمصاصية القصوى للفوسفور (0.165 و 0.53 ملجم فو/ جم رواسب)، وذلك بمعامل إرتباط (R^2) يصل إلى 0.99، 99، على التوالي. في حين أنه عند تطبيق معادلة فريندليش للإدمصاص بلغت السعة الإدمصاصية القصوى (47.04 و 130.59 ملجم فوسفور/جم رواسب) وذلك بمعامل إرتباط R^2 بلغ 0.98 و 0.95للرواسب الرمادية والحمراء، على التوالي.

أشارت النتائج المتعلقة بإنطلاق الفوسفور (desorption) إلى أن ما يقرب من نصف كمية الفوسفور السابق إدمصاصها تم إستخلاصها في مرحلتي الإستخلاص الأولى والثانية التي أعقبت مرحلة الإدمصاص. وقد أكدت الدراسة على القدرة العالية لرواسب الطين المستخدمة في إدمصاص وإنطلاق الفوسفور وهو مايشير إلي إمكانية إستخدامهما بنجاح لتوفير إحتياجات النبات من التسميد الفوسفاتي.