

*Original Research Article*

# Solubility and Movement of Calcium Phosphate Minerals in Some Calcareous Soils as Influenced by Application of Phosphate Fertilizer and Water Potential

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## Abstract

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Immobilization and mobilization reactions of soil phosphorus depend on chemical, physical, and biological properties of soil and these soil properties strongly depend on soil water content and rate of phosphate application. Laboratory study was conducted at 30°C for one week on two calcareous soils from southern part of Iraq, Hartha soil (silty clay) and Zubair soil (loamy sand) to study the effect of superphosphate application (0, 60, and 120 mgPkg<sup>-1</sup> soil) and water potential (field capacity, 3/2 field capacity, and 1/2 field capacity) on solubility and vertical movement of phosphate for four soil depth (0-5), (5-10), (10-20), and (20-40) cm. Results showed that increasing P-rates application increased soluble P and it was decreased with decreasing of soil moisture content as follow: FC > 3/2FC > 1/2 FC. Formation of calcium phosphate minerals in the studied soils according to saturation index (SI) values showed that Ca-P minerals were MCP, OCP, and HA which their values were above 1 (SI > 1), the degree of saturation index was related mainly to the differences between studied soils and soil moisture, rate of application. Calcium phosphate minerals didn't change with changing of soils depth.

**Keywords:** Calcium phosphate, P-Solubility, SI, Field capacity

## INTRODUCTION

Phosphorus (P) is an essential macronutrient, being required by plants in relatively large quantities (~0.2 to 0.8%) (Mengel and Kirkby, 1987) and it is in general one of the most limiting for agricultural production in tropical soils (Mills and Jones, 1996). In calcareous soils, phosphorus retention and mobilization take place due to precipitation and adsorption; however, it is not always easy to distinguish between the two mechanisms. Water Soluble P fertilizers applied to soil react with soil constituents to form less soluble phosphates, when added to soil containing large amount of calcium, soluble P is usually precipitated as dicalcium phosphate (DCP) or octacalcium phosphate (OCP) (Bell and Black, 1970). Delgado and Torrent (2000) showed that, at relatively low concentrations, phosphate was adsorbed on the surface of calcium carbonate crystals. At higher concentrations

there was apparently chemical precipitation of calcium phosphate. In calcareous soils, P is mainly bound to adsorption surface at low (<10<sup>-4.5</sup>M) concentrations of orthophosphate in solution (Tunisi et al., 1999), whereas it is mainly precipitated as calcium phosphates at higher concentrations (Lindsay, 1979).

It is the general opinion of soil scientists that there is little downward movement of phosphorus when phosphate fertilizers were applied to the surface of most soils. A review of the literature (Jalali, 2009; Robbins and Smith, 1977) supports this opinion, and they found that the distance of diffusion of phosphorus from various soluble phosphate fertilizers varied with time, rate of phosphorus application, moisture content of the soil, and soil texture. As fertilizer P reacts in calcareous soils, it is converted to less soluble compounds such as dicalcium

phosphate dehydrate (DCPD) or octacalcium phosphate (Wandruszka, 2006).

The objectives of this study were: (1) to measure the effect of rate of P fertilizer: (2) soil moisture content (3) soil texture on calcium phosphate solubility and precipitation of Ca-P minerals and vertical movement in two calcareous soils.

## MATERIALS AND METHODS

Soil samples (0-30cm) were collected from two sites in southern part of Iraq. One was silty clay alluvial soil collected from Hartha, and the other was a loamy sand desert soil collected from Zubair. Before use, each sample was air dried and ground to pass a 2 mm screen. They were characterized for some properties in table (1) as the methods mentioned by Black (1965) and Page et al. (1982).

Plastics columns with length of 50cm and diameter were prepared, steel clasp was placed at the end of the column, gravel layer and coarse of sand were put on them, then 700 gm and 850g of silty clay soil and loamy sand soil were loaded in the columns respectively. Soils were fertilized with concentrated superphosphate at three rates (0, 60, and 120 mg P kg<sup>-1</sup> soil) (ppm), at the surface of the soils, and moisten to (field capacity, 3/2 field capacity and 1/2 field capacity) which were (30% for silt clay soil and 20% for loamy sand soil). Soil were incubated at 30°C for one week in an Incubator. After incubation, columns were cut horizontally for four depths (0-5), (5-10), (10-20), and (20-40)cm. Soils were analyzed for pH, electrical conductivity (E.C), soluble calcium and phosphate according to methods mentioned in Page et al. (1982).

Calculations: First, the ionic strength (I=mole L<sup>-1</sup>) of each soil filtrate was calculated from the electrical conductivity (E.C=dSm<sup>-1</sup>) by the equation (Griffin and Jurinak, 1973).

$$I=0.013 E.C$$

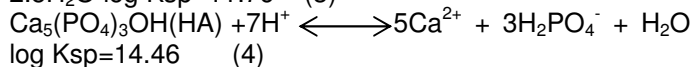
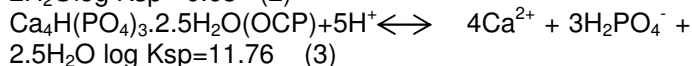
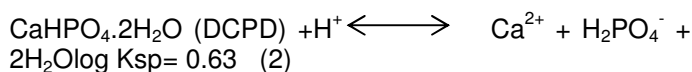
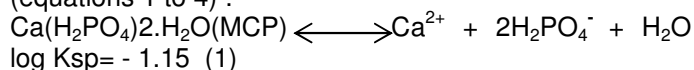
Next the activity coefficients,  $f_i$ , were calculated by using Davies equation (Davies, 1962).

$$-\log f_i = 0.509 Z_i (I^{0.5}/1 + I^{0.5}) - 0.3I$$

Where  $Z_i$  stands for the charge on the ion (i). The activity,  $a_i$  of the ion was calculated from the corresponding concentration,  $C_i$ , by the equation:

$$a_i = f_i C_i$$

Diagnosis of calcium phosphate minerals formation [Monocalcium phosphate (Ca(H<sub>2</sub>PO<sub>4</sub>)<sub>2</sub>·H<sub>2</sub>O, Dicalcium phosphate dehydrate (CaHPO<sub>4</sub>·2H<sub>2</sub>O, Octacalcium phosphate (Ca<sub>8</sub>H(PO<sub>4</sub>)<sub>3</sub>·2.5H<sub>2</sub>O, and Hydroxyapatite (Ca<sub>5</sub>(PO<sub>4</sub>)<sub>3</sub>OH)] were calculated from solubility products ( $K_{sp}$ ) and ion activity Products (IAP) depending on equations mentioned in Lindsay (1979) (equations 1 to 4) :-



A saturation index (SI) is a value to denote the saturation of solution with respect to a particular mineral phase:

$$SI = \log IAP / \log K_{sp}$$

A positive SI value indicates that soil is supersaturated with respect to a given phase according to standard equilibria values for that mineral and properties of the soil.

## RESULTS AND DISCUSSION

Results in tables 2 and 3 showed the effect of phosphate rates application, and field capacity on solubility and movement of phosphate according to activity of phosphate, calcium ions in solution and ionic of Hartha and Zubair calcareous soils. It is showed that increasing of phosphate rates (0, 60, and 120 mg kg<sup>-1</sup>) application to the studied soils increased its activity in soil solutions of both soils. Inorganic P in soil solution at level of 0.2 to 0.3 mg l<sup>-1</sup> can be critical for plant growth (USAD, 2003).

From the results of our study we can show that the activity of phosphate in soil solutions raised from (5.73E<sup>-6</sup>, 3.95 E<sup>-6</sup> and 2.08E<sup>-6</sup>) M equal to (0.177, 0.121, and 0.062) mg l<sup>-1</sup> for control treatment of P at (FC, 3/2FC, and 1/2FC) of Hartha soil respectively to reach at 60 and 120 mgP kg<sup>-1</sup> to (0.388, 0.121, 0.177 mg l<sup>-1</sup>) and (0.685, 0.112, and 0.201 mg l<sup>-1</sup>) respectively. While the activity of phosphate in Zubair soil solution at the same treatment was (1.06E<sup>-6</sup>, 0.74E<sup>-6</sup>, and 0.63E<sup>-6</sup>) equal to (0.031, 0.022, and 0.019 mg l<sup>-1</sup>) for control treatment were reached at 60 and 120 mg l<sup>-1</sup> at (FC, 3/2FC, and 1/2FC) to (0.068, 0.053, and 0.028 mg l<sup>-1</sup>) and (0.257, 0.174, and 0.12 mg l<sup>-1</sup>) respectively.

Generally, P-concentration in soil solutions increased with increasing of P-rate application but its concentration decreased with decreasing of soil moisture content (FC > 3/2FC > 1/2FC) because of differences of super phosphate solubility in soil solution and these differences were clear in Zubair loamy sand soil as compared with Hartha silty clay soil. The observations of this study are similar to the finding of Sinigani and Mahohi (2009).

Increasing of P-rate decreased of soil pH values (increasing of H<sup>+</sup> ion activity) because of acidity effect of concentrated super phosphate (Lindsay, 1979), and increasing phosphate activity in soil solutions and ionic strength. In surface layer, the impact of P-fertilizer application on soil pH was most likely associated with the amount of water Field capacity (tables 2 and 3).

The vertical distribution of phosphate in soil solutions of the studied soil showed decreasing of P activity with

**Table 1.** Some chemical and physical properties of the studied soils

Soils	pH	E.Ce (dSm <sup>-1</sup> )	CaCO <sub>3</sub> (gm kg <sup>-1</sup> )	CEC (Cmolkg <sup>-1</sup> )	Organic Matter (gm kg <sup>-1</sup> )	P-NaHCO <sub>3</sub> (mg kg <sup>-1</sup> )	Texture
Hartha	7.80	7.50	285.5	17.97	10.60	21.70	Silty clay
Zubair	8.1	2.60	79.20	3.20	0.80	5.50	Loamy sand

**Table 2.** Effect of Phosphate rate application and field capacity on pH, Ionic Strength, and activity of phosphate and calcium in Hartha soil

P-Rate (mgkg <sup>-1</sup> )	P-depth (cm)	pH	I (M) Field capacity	H <sub>2</sub> PO <sub>4</sub> <sup>-</sup> (M)E <sup>-6</sup>	Ca <sup>2+</sup> (M)E <sup>-2</sup>
0	0-5	7.53	0.164	7.30	1.33
	5-10	7.63	0.153	6.20	1.36
	10-20	7.66	0.149	4.99	1.41
	20-40	7.73	0.147	4.41	1.27
<b>mean</b>		<b>7.64</b>	<b>0.153</b>	<b>5.73</b>	<b>1.34</b>
60	0-5	7.30	0.168	17.80	1.37
	5-10	7.53	0.158	12.90	1.40
	10-20	7.56	0.152	11.20	1.43
	20-40	7.63	0.149	8.34	1.38
<b>mean</b>		<b>7.51</b>	<b>0.157</b>	<b>12.56</b>	<b>1.40</b>
120	5-10	7.20	0.178	31.90	1.40
	10-20	7.36	0.176	24.80	1.41
	20-40	7.53	0.170	17.00	1.41
	5-10	7.56	0.166	15.00	1.38
<b>mean</b>		<b>7.41</b>	<b>0.173</b>	<b>22.18</b>	<b>1.40</b>
<b>3/2 field capacity</b>					
0	0-5	7.66	0.143	5.93	1.32
	5-10	7.76	0.133	4.20	1.36
	10-20	7.86	0.130	2.83	1.39
	20-40	7.86	0.127	2.84	1.27
<b>mean</b>		<b>7.79</b>	<b>0.133</b>	<b>3.95</b>	<b>1.34</b>
60	0-5	7.46	0.146	1.36	1.35
	5-10	7.56	0.139	1.10	1.37
	10-20	7.76	0.135	7.34	1.45
	20-40	7.80	0.131	5.90	1.37
<b>mean</b>		<b>7.79</b>	<b>0.133</b>	<b>3.94</b>	<b>1.39</b>
120	5-10	7.36	0.164	2.30	1.37
	10-20	7.53	0.162	1.70	1.39
	20-40	7.66	0.157	1.18	1.44
	5-10	7.70	0.153	9.24	1.33
<b>mean</b>		<b>7.56</b>	<b>0.159</b>	<b>3.61</b>	<b>1.38</b>
<b>1/2 Field capacity</b>					
0	0-5	7.80	0.136	2.13	1.16
	5-10	7.86	0.132	2.83	1.19
	10-20	7.86	0.128	2.15	1.23
	20-40	7.93	0.122	1.22	1.20
<b>mean</b>		<b>7.86</b>	<b>0.130</b>	<b>2.08</b>	<b>1.20</b>
60	0-5	7.66	0.141	8.77	1.22
	5-10	7.96	0.136	4.58	1.21
	10-20	7.76	0.131	5.36	1.28
	20-40	7.83	0.128	4.45	1.24
<b>mean</b>		<b>7.80</b>	<b>0.134</b>	<b>5.79</b>	<b>1.24</b>
120	0-5	7.53	0.158	1.73	1.24
	5-10	7.83	0.154	9.47	1.31
	10-20	7.80	0.151	8.50	1.34
	20-40	7.76	0.146	6.61	1.27
<b>mean</b>		<b>7.73</b>	<b>0.152</b>	<b>6.58</b>	<b>1.29</b>

**Table 3.** Effect of Phosphate rate application and field capacity on pH, Ionic Strength, and activity of phosphate and calcium in Zubair soil

P-Rate (mgkg <sup>-1</sup> )	P-depth (cm)	pH	I (M)	H <sub>2</sub> PO <sub>4</sub> <sup>-</sup> (M)E <sup>-6</sup>	Ca <sup>2+</sup> (M)E <sup>-2</sup>
0	0-5	7.96	0.049	1.38	0.83
	5-10	8.00	0.049	1.29	0.87
	10-20	8.13	0.048	0.97	0.93
	20-40	8.23	0.047	0.58	0.77
<b>mean</b>		<b>8.08</b>	<b>0.048</b>	<b>1.06</b>	<b>0.85</b>
60	0-5	7.93	0.053	3.27	0.85
	5-10	8.03	0.052	2.70	0.92
	10-20	8.06	0.051	2.05	0.98
	20-40	8.16	0.050	0.82	0.84
<b>mean</b>		<b>8.05</b>	<b>0.052</b>	<b>2.21</b>	<b>0.90</b>
120	0-5	7.63	0.063	12.20	0.96
	5-10	7.80	0.062	8.25	1.05
	10-20	7.83	0.060	7.05	1.18
	20-40	7.86	0.057	5.94	0.97
<b>mean</b>		<b>7.78</b>	<b>0.061</b>	<b>8.36</b>	<b>1.04</b>
<b>3/2 field capacity</b>					
0	0-5	8.16	0.048	0.99	0.81
	5-10	8.23	0.047	0.78	0.85
	10-20	8.26	0.046	0.74	0.93
	20-40	8.36	0.045	0.44	0.75
<b>mean</b>		<b>8.25</b>	<b>0.047</b>	<b>0.72</b>	<b>0.74</b>
60	0-5	8.03	0.051	2.70	0.83
	5-10	8.13	0.049	1.80	0.91
	10-20	8.16	0.048	1.65	0.96
	20-40	8.23	0.047	0.72	0.84
<b>mean</b>		<b>8.14</b>	<b>0.049</b>	<b>1.72</b>	<b>0.89</b>
120	0-5	7.86	0.061	8.10	0.93
	5-10	7.96	0.060	5.51	0.96
	10-20	8.03	0.058	4.71	1.10
	20-40	8.06	0.055	4.08	0.89
<b>mean</b>		<b>7.98</b>	<b>0.059</b>	<b>5.60</b>	<b>0.97</b>
<b>½ Field capacity</b>					
0	0-5	8.26	0.047	0.74	0.74
	5-10	8.33	0.046	0.66	0.83
	10-20	8.33	0.044	0.66	0.92
	20-40	8.36	0.044	0.44	0.71
<b>mean</b>		<b>8.32</b>	<b>0.045</b>	<b>0.63</b>	<b>0.80</b>
60	0-5	8.13	0.049	1.80	0.82
	5-10	8.23	0.048	0.72	0.88
	10-20	8.23	0.047	0.72	0.95
	20-40	8.30	0.046	0.62	0.81
<b>mean</b>		<b>8.22</b>	<b>0.048</b>	<b>0.97</b>	<b>0.87</b>
120	0-5	8.00	0.059	5.68	0.93
	5-10	8.13	0.058	3.82	0.95
	10-20	8.16	0.056	3.58	1.07
	20-40	8.20	0.054	3.02	0.81
<b>mean</b>		<b>8.12</b>	<b>0.057</b>	<b>4.03</b>	<b>0.94</b>

increasing of soil depth from (0-5cm) to (20-40cm) with corresponding with increasing of calcium activity and soil pH. Eissa et al. (2003) attributed increasing of Vertical phosphate movement in sandy calcareous soil to soil moisture and calcium concentration of soil.

Results in tables (4, 5, 6 and 7) showed that the native form of calcium phosphate in Hartha and Zubair soils

according to Saturation index (SI) were super saturated with monocalcium phosphate(MCP), octacalcium phosphate (OCP), and Hydroxy apatite (HA) , and under saturated with monocalcium phosphate dehydrate (MCPD). The solubility of several calcium phosphates in soils are controlled by the activities of phosphate, calcium, pH, and CO<sub>2(g)</sub> (Lindsay, 1979). The Results

**Table 4.** Effect of Phosphate rate application and field capacity on Saturation index(SI) of MCP and DCPD in Hartha soils

P-rate (mg kg <sup>-1</sup> )	Depth (cm)	Field Capacity		3/2 Field Capacity		½ Field Capacity	
		MCP					
		Log IAP	SI	Log IAP	SI	Log IAP	SI
0	0-5	-12.15	10.56	-12.33	10.72	-12.94	11.25
	5-10	-12.28	10.68	-12.62	10.97	-13.02	11.32
	10-20	-12.45	10.82	-12.95	11.26	-13.25	11.52
	20-40	-12.61	10.96	-12.99	11.29	-13.75	11.96
60	0-5	-11.36	9.88	-11.60	10.09	-12.03	10.46
	5-10	-11.63	10.11	-11.78	10.24	-12.60	10.96
	10-20	-11.75	10.22	-12.11	10.53	-12.43	10.81
	20-40	-12.02	10.45	-12.32	10.71	-12.61	10.96
120	0-5	-10.84	9.45	-11.14	9.69	-11.43	9.94
	5-10	-11.06	9.62	-11.39	9.90	-11.93	10.37
	10-20	-11.39	9.90	-11.69	10.17	-12.01	10.45
	20-40	-11.51	10.01	-11.94	10.38	-12.26	10.66
DCPD							
		Log IAP	SI	Log IAP	SI	Log IAP	SI
0	0-5	0.78	1.24	0.55	0.88	0.09	0.15
	5-10	0.78	1.24	0.52	0.82	0.16	0.25
	10-20	0.70	1.11	0.46	0.72	0.08	0.13
	20-40	0.68	1.08	0.41	0.66	-0.10	-0.16
60	0-5	1.05	1.66	0.73	1.15	0.33	0.52
	5-10	1.22	1.93	0.74	1.17	0.27	0.44
	10-20	0.97	1.53	0.79	1.25	0.40	0.63
	20-40	0.89	1.42	0.71	1.13	0.37	0.59
120	0-5	1.03	1.64	0.86	1.36	0.53	0.84
	5-10	1.38	2.18	0.90	1.44	0.45	0.72
	10-20	1.18	1.88	0.89	1.42	0.59	0.93
	20-40	1.08	1.71	0.80	1.27	0.49	0.77

**Table 5.** Effect of Phosphate rate application and field capacity on Saturation index(SI) of OCP and HA in Hartha soils

P-rate (mg kg <sup>-1</sup> )	Depth (cm)	Field Capacity		3/2 Field Capacity		½ Field Capacity	
		OCP					
		Log IAP	SI	Log IAP	SI	Log IAP	SI
0	0-5	16.09	1.37	15.11	1.28	13.40	1.14
	5-10	16.21	1.38	15.21	1.29	13.81	1.17
	10-20	15.99	1.36	15.26	1.30	13.66	1.16
	20-40	15.01	1.36	15.06	1.28	13.23	1.13
60	0-5	16.61	1.41	15.23	1.30	13.67	1.16
	5-10	17.73	1.51	15.47	1.32	13.96	1.19
	10-20	16.58	1.41	16.05	1.36	14.42	1.23
	20-40	16.49	1.40	15.86	1.35	14.47	1.23
120	0-5	16.75	1.42	15.43	1.31	14.09	1.20
	5-10	17.94	1.53	15.91	1.35	14.20	1.21
	10-20	17.29	1.47	16.16	1.37	14.95	1.27
	20-40	16.90	1.44	15.90	1.35	14.68	1.25
HA							
		Log IAP	SI	Log IAP	SI	Log IAP	SI
0	0-5	29.82	2.06	28.55	1.97	26.52	1.83
	5-10	30.07	2.08	28.87	1.99	27.16	1.88
	10-20	29.86	2.07	29.10	2.01	27.08	1.87
	20-40	29.97	2.07	28.89	1.99	26.77	1.85
60	0-5	30.06	2.08	28.28	1.96	26.36	1.82
	5-10	31.80	2.20	28.73	1.99	27.10	1.87
	10-20	30.26	2.09	29.74	2.06	27.65	1.91
	20-40	30.29	2.09	29.60	2.05	27.84	1.93
120	0-5	29.95	2.07	28.29	1.96	24.82	1.72

Table 5. Continue

5-10	31.76	2.20	29.12	2.01	27.07	1.87
10-20	31.05	2.15	29.64	2.05	28.14	1.95
20-40	30.56	2.11	29.43	2.03	27.90	1.93

Table 6. Effect of Phosphate rate application and field capacity on Saturation index(SI) of MCP and DCPD Zubair soils

P-rate (mg kg <sup>-1</sup> )	Depth (cm)	Field Capacity		3/2 Field Capacity		½ Field Capacity	
		MCP					
		Log IAP	SI	Log IAP	SI	Log IAP	SI
0	0-5	-14.80	12.87	-14.10	12.26	-14.39	12.51
	5-10	-13.84	12.03	-14.28	12.42	-14.44	12.56
	10-20	-14.06	12.23	-14.29	12.43	-14.41	12.53
	20-40	-14.59	12.69	-14.84	12.90	-14.87	12.93
60	0-5	-13.04	11.34	-13.22	11.50	-13.58	11.81
	5-10	-13.17	11.45	-13.53	11.77	-14.35	12.48
	10-20	-13.38	11.63	-13.58	11.81	-14.31	12.44
	20-40	-14.25	12.39	-14.36	12.49	-14.51	12.62
120	0-5	-11.85	10.30	-12.21	10.62	-12.52	10.89
	5-10	-12.15	10.56	-12.54	10.90	-12.86	11.18
	10-20	-12.23	10.63	-12.61	10.96	-12.86	11.18
	20-40	-12.47	10.84	-12.83	11.16	-13.13	11.42
DCPD							
		Log IAP	SI	Log IAP	SI	Log IAP	SI
0	0-5	0.32	0.51	0.06	0.09	-0.30	-0.47
	5-10	0.38	0.61	0.05	0.08	-0.26	-0.41
	10-20	0.29	0.45	0.10	0.16	-0.08	-0.13
	20-40	0.01	0.01	-0.12	-0.19	-0.28	-0.44
60	0-5	0.57	0.91	0.38	0.60	0.10	0.16
	5-10	0.63	0.99	0.34	0.55	-0.17	-0.27
	10-20	0.53	0.85	0.36	0.57	-0.11	-0.17
	20-40	0.14	0.22	0.01	0.02	-0.14	-0.22
120	0-5	1.07	1.69	0.74	1.17	0.35	0.56
	5-10	1.07	1.69	-0.31	-0.49	0.36	0.57
	10-20	1.08	1.72	0.74	1.18	0.42	0.66
	20-40	0.96	1.53	0.62	0.99	0.25	0.39

Table 7. Effect of Phosphate rate application and field capacity on Saturation index (SI) of OCP and HA Zubair soils

P-rate (mg kg <sup>-1</sup> )	Depth (cm)	Field Capacity		3/2 Field Capacity		½ Field Capacity	
		OCP					
		Log IAP	SI	Log IAP	SI	Log IAP	SI
0	0-5	15.40	1.31	14.42	1.23	12.90	1.10
	5-10	15.39	1.31	14.55	1.24	13.14	1.12
	10-20	15.49	1.32	14.79	1.26	13.97	1.19
	20-40	14.64	1.24	16.60	1.41	13.49	1.15
60	0-5	15.91	1.35	15.12	1.29	14.08	1.20
	5-10	16.30	1.39	15.25	1.30	13.49	1.15
	10-20	16.05	1.36	15.38	1.31	13.78	1.17
	20-40	14.58	1.24	14.42	1.23	13.81	1.17
120	0-5	17.19	1.46	15.90	1.35	14.29	1.22
	5-10	17.49	1.49	15.96	1.36	14.66	1.25
	10-20	17.64	1.50	16.34	1.39	14.94	1.27
	20-40	17.27	1.47	15.93	1.35	14.37	1.22
HA							
		Log IAP	SI	Log IAP	SI	Log IAP	SI
0	0-5	29.84	2.06	28.64	1.98	26.70	1.85
	5-10	30.34	2.10	28.94	2.00	27.06	1.87
	10-20	30.11	2.08	29.27	2.02	28.19	1.95

Table 7. Continue

	20-40	29.23	2.02	28.83	1.99	27.80	1.92
	0-5	30.10	2.08	29.10	2.01	27.86	1.93
60	5-10	30.73	2.13	29.48	2.04	27.49	1.90
	10-20	30.51	2.11	29.68	2.05	27.88	1.93
	20-40	29.46	2.04	28.80	1.99	28.04	1.94
	0-5	31.17	2.16	29.59	2.05	27.52	1.90
120	5-10	31.77	2.20	29.86	2.07	28.25	1.95
	10-20	32.02	2.21	30.44	2.11	28.64	1.98
	20-40	31.65	2.19	29.95	2.07	28.00	1.94

obtained in this work are in agreement with the results of Havlin and Westfall (1984); Awad et al. (1985). Soils in southern part of Iraq are alkaline, meaning they have a soil pH above 7.5 (Leytem and Mikkelsen, 2005). Calcareous soils, which are alkaline soils that contain significant amount of calcium carbonate and have a typical pH range 7.8 to 8.5 (Recillas et al., 2012), from the results shown in table 1, the studied soils were calcareous soils with high concentration of calcium and high pH values, that's mean calcium reacts with phosphate ions in soil solutions to form calcium phosphate precipitates, this is generally the most controlling factor for trying up P and reduce its availability for crop uptake.

Jalali (2009) showed that high concentration of calcium in soil solution caused low solubility of Ca-phosphate minerals, suggest that Ca-phosphate minerals are likely control dissolved P concentration (Hanson et al., 2004).

Application of superphosphate [monocalcium phosphate,  $\text{Ca}(\text{H}_2\text{PO}_4)_2$ ] to the studied soils as P-fertilizer is very soluble and would not be expected to be as phase that remain long in the soils. The phosphate released to solution in calcareous soils could form (MCP, DCPD, OCP, and HA) in decreasing order of solubility as well as Ca-phosphates contain other ions (Lindsay, 1979). According to SI values shown in tables (4, 5, 6, and 7) they were decreasing with increasing of P-rate fertilizer application, because of increasing of concentration of phosphate in soil solutions and decreasing of soil pH (tables 2,3).

The highest values of (SI) were for monocalcium phosphate mineral (9.45 to 11.96) as compared to other calcium phosphate minerals [DCPD(-0.16 to 2.18), OCP (1.13 to 1.53), HA(1.72 to 2.20)] for Hartha soil and [MCP(10.64 to 12.87), DCPD(-0.13 to 1.72), OCP(1.10 to 1.5), and HA (1.85 to 2.21)] for Zubair soil. Indicating that MCP is the main dominant calcium phosphate controlling in the studied soils because the incubation period was one week and we can recognized this mineral will be changed to other forms (precipitates) with increasing times. Jalali and Kolach (2008) found that about 21% of ground water samples were saturated with respect to HA in northern Malayer (SI ranged from -12.5 to 5.5), indicating that this mineral is most likely controlling P concentration in ground water.

Increasing of soils depths from (0-5cm) to (20-40cm), were accompanied decreasing values of saturation index (SI) of all calcium phosphate minerals (MCP, DCPD, OCP, and HA), because of decreasing of phosphate and calcium ions in soil solution and increasing of soil pH (Tables 2 and 3), but the minerals stayed as the same form and didn't changed to other calcium phosphate minerals.

Solubility of Ca-phosphate minerals in the studied soils were increased with increasing of soil moisture content as follow ( $\text{FC} > 3/2\text{FC} > 1/2\text{FC}$ ), because of increasing of native and applied phosphate as fertilizer and providing soil solutions with soluble phosphate (Tables 2, 3). Sinegani and Mahohi (2009) found that soluble P was higher in soil incubated in FC as compared to those incubated in other moisture (sat, 0 bar), field capacity (FC, -0.3 bar), and permanent wilting point (PWP, -15 bar).

## CONCLUSIONS

A recent investigation indicates that application of concentrated superphosphate to calcareous soils convert during short time (one week) to calcium phosphate minerals (MCP, OCP, and HA) by precipitation reaction. Increasing of soil moisture content (field capacity) increased solubility of calcium phosphate in soil solution of calcareous soils. Mobility of calcium phosphate minerals and changed in soil depths was limited.

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