مجلة العلوم البحثة والتطبيقية
Journal of Pure & Applied Sciences
www.Suj.sebhau.edu.ly ISSN 2521-9200
Received 21/04/2019 Revised 29/08/2019 Published online 17/11/2019

Fractionation of Organic and Inorganic Phosphorus in Sandy Soils irrigated by Treated Wastewater Cultivated by Hordeum vulgre & Vicia faba

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Abstract Changes in inorganic and organic phosphorus fractions resulting from wastewater application on sandy soil were studied using sequential extraction technique. Plant phosphorus content was determined in a pots study using Hordeum vulgre and Vicia faba. Five levels of wastewater addition, (0, 25, 50, 75 and 100 %) were used for irrigation. Several parameters like pH, EC, CEC, OM and $CaCO_3$ were assessed. The findings showed that wastewater treatments increased the pH, EC, CEC, $CaCO_3$ and OM in treated soil. The highest values recorded with 100% wastewater treatment. Wastewater irrigation influenced soil phosphorus concentrations, the higher values recorded using 100% treatment. Total phosphorus content of the cultivated soil was higher compared to uncultivated soil. Inorganic phosphorus was dominant compound of total phosphorus. Wastewater enhancing organic phosphorus composition of tested soil. The distribution of phosphorus quantities across different fractions (inorganic and organic) in uncultivated soil were Ca-P > Water-P > Organic-P > Read –P >Fe-P > Al-P. While in Vicia faba cultivated soil, were Ca-P > Organic-P > Water-P > Read –P > Fe-P = Al-P. The trend in oil cultivated with Hordeum vulgre were Organic-P > Ca-P > Water-P > Read –P > Fe-P >Al-P. In general, Ca-P is the largest fraction of phosphorus. Which affect phosphorus availability. The Organic-P is important source of phosphorus in soil irrigated with wastewater. Recycling of wastewater enhancing phosphorus concentrations and increasing its content in Hordeum vulgre in comparison with Vicia faba.

Keywords: Hordeum vulgre, Inorganic-P, Organic –P, Sandy Soil, Vicia faba.

تجزئة الفسفور العضوي وغير العضوي في الترب الرملية المعاملة بالمياه العادمة المعالجة المنزرعة بنباتي Hordeum vulgre & Vicia faba

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الملخص أجريت هذه الدراسة بهدف تقييم التغيرات في صور الفسفور العضوي وغير العضوي الناتجة عن استخدام المياه العادمة على التربة الرملية باستخدام تقنية الاستخلاص المتسلسل. تم تحديد محتوى الفسفور بزراعة نباتي Hordeum vulgre ، Vicia faba في اصص بلاستيكية. استخدمت خمس مستويات من إضافة مياه الصرف الصحي (0 ، 25 ، 50 ، 75 ، 100٪) للري. تم تقييم العديد من المعلمات مثل pH ، EC ، CEC ، OM ، $CaCO_3$. وقد أظهرت النتائج أن اضافة مياه الصرف الصحي رفعت قراءات كل من pH ، EC ، CEC، CaCO3 ، OM في التربة المعاملة. أعلى القيم المسجلة كانت مع معاملة مياه الصرف الصحي بنسبة 100٪. أثر الري في مياه الصرف الصحي على تركيزات الفسفور في التربة ، وكانت القيم الأعلى المسجلة باستخدام المعاملة 100٪. وكان إجمالي محتوى الفوسفور في التربة المزروعة أعلى مقارنة بالتربة غير المزروعة. وكانت تراكيز الفسفور غير العضوي سائدة من بين صور الفسفور. ان إضافة المياه العادمة تعزز تركيبة الفسفور العضوي للترب المختبرة. وكان توزيع كميات الفسفور عبر الأجزاء المختلفة (العضوية وغير العضوية) في التربة غير المزروعة Ca-P> Water-P> Organic-P> Read –P> Fe-P> Al-P. أثناء تواجدك في Vicia faba ، كانت Ca-P> Organic-P> Water-P> Read –P> Fe-P = Al-P. الاتجاه السائد في الزيت المزروع باستخدام Hordeum vulgre كان Organic-P> Ca-P> Water-P> Read –P> Fe-P> Al-P. وبشكل عام ، كان Ca-P هو أكبر جزء من الفسفور والذي يؤثر على توافر الفوسفور. وكان الفسفور العضوي مصدرا مهما للفوسفور في التربة المروية بمياه الصرف. ان إعادة تدوير مياه الصرف الصحي تعزز تراكيز الفوسفور وزيادة محتواه في Hordeum vulgre بالمقارنة مع Vicia faba.

الكلمات المفتاحية: تربة رملية، فسفور عضوي ،فسفور لاعضوي، نبات الفول Vicia faba ، نبات الشعير Hordeum vulgre

Introduction:

With increasing demand of agricultural production and as the peak in global production will occur in the next decades, phosphorus (P) is receiving more attention as a non-renewable resource. One unique characteristic of P is its low availability due to slow diffusion and high fixation in soils [1]. The geochemical processes dominate P cycling in semiarid soils when calcium carbonate ($CaCO_3$) is abundant in the soil profile. Ligand exchange between P and carbonate minerals limits P availability in desert soils, and the precipitation of phosphate with calcium establishes the upper limit for the availability of P [2]. Soil phosphorus can be organic or inorganic in combination with Fe, Al, Ca and other elements. The organic P composition of semi-arid soils is generally unknown, but such information is fundamental to understanding P dynamics in irrigated agriculture. Use of a sequential extraction procedure allowed soil P to be separated and characterized as P released to an anion exchange resin, and P soluble in alkali and acid of varying strengths. The fractionation procedure gives separate soil P fractions which vary in the extent of their availability to growing plants. Also, the sequential fractionation procedure can be used to record small changes in soil P. Desert soils lack noticeable levels of organic matter. Thus, treated municipal wastewaters are usually applied as a source of irrigation water and plant nutrients. Typically, treated municipal wastewaters contain 10 - 40 mg l^{-1} nitrogen and from a few to 30 mg l^{-1} phosphorus, wastewater has a high nutritive value that might improve plant growth [3]. However, the principal object sewage treatment is to allow human and industrial effluents to be disposed of without danger to human health or unacceptable damage to the natural environment. Therefore, the most appropriate wastewater treatment to be used for irrigation is that which will produce an effluent which meets the recommended chemical and microbiological quality guidelines. The demand for water is continuously increasing in semi-arid and arid regions. Therefore, water of higher quality is preserved for drinking purposes while that of lower quality is recommended for irrigation. Treated municipal wastewater is less expensive and considered an attractive source of irrigation water in these countries. Moreover, irrigation with municipal wastewater is considered an environmentally sound wastewater disposal practice that helps in minimizing the pollution of the ecosystem [4]. The reused of treated domestic wastewater in the soil-plant system is an attractive method, which allows increasing the available water supply and improve the agricultural development of drought-affected regions. This practice is also beneficial from the environmental point of view, reused wastewater reduces the negative impacts of the excessive discharge of nutrients and contaminants caused by the disposal of these effluents in surface waters [5]. Regions recycling of water in arid and semi-arid may have a greater impact on future usable water supply than any of the other technologies used for increasing water supply like water harvesting, desalting of sea water. Currently, Saudi Arabia reuses 16 % with a goal to increase reuse to 65 % by 2016, Singapore reuses 30 % and 29% of wastewater reuse in agriculture in California. Different regions and governmental agencies, both in the United States and globally, have adopted a variety of standards for use of reclaimed water for irrigation of crops [6]. The majority of the research conducted on wastewater reuse in agriculture focuses mainly on its effect on plant growth and development with little attention to the changes induced in the soil fertility and chemistry parameters. The objectives of this study were to evaluate the changes in soil phosphorus that occur due to reused treated wastewater, and to evaluate the response of *Hordeum vulgre* and *Vicia faba* to irrigation with treated wastewater.

Materials and Methods

Treated municipal wastewater: the wastewater obtained from the Municipal Wastewater Treatment Plant in Sebha city- Libya. The resources of this wastewater originate from mainly household activities; as very limited industrial activities exist.

Soil: tested soil was collected from the depth 0-15 cm for uncultivated area in sebha city. Plants: Barley *(Hordeum vulgre)* and Beans *(Vicia faba)* were used as the test plants

The study was conducted under controlled conditions in laboratory, where, 45 pots were filled with desert soil classified as sandy soil, collected in the 0-15 cm soil layer for uncultivated area in sebha city. After that, the pots divided to three groups :15 unplanted pots served as a control, 15 pots cultivated with Barley *(Hordeum vulgre)* and another 15 pots cultivated with Beans (*Vicia faba).* Five irrigation solutions were applied to both tested plants, which included T1 –control 0 % (distilled water), T2=25%, T3=50%, T4=75% and T5 100% wastewater. 100 ml from each treatment was used for irrigation. This was done to ensure that leaching did not occur. After 45 days planting, tested plants and soil samples were collected from each pot and subjected to chemical characterization at the laboratory.

The procedure described by [7] for the analysis of wastewater was adopted for this work. The pH and EC of the samples was measured upon arrival to the laboratory, the concentaions of Total dissolved solids (TDS), Biochemical Oxygen Demand (BOD), Magnesium (Mg) Calcium (Ca), Chloride(Cl), Sulphate (SO_4) Organic Phosphate (Organic– P), (Hydrolyzable-Phosphate (Hydrolyzable-P) and Total-P (Total-P) were following standard methods [7].

All of the chemical and physical determinations were made by generally accepted methods. The soil pH and EC were determined according to the methodology proposed by [8]. Cation exchange capacity(CEC) was determined using saturated method [9]. Soil organic matter (OM) was determined using potassium dichromate volumetric method [10]. Calcium carbonates ($CaCO_3$) was determined using titration method described by [11]. Pipette method was used to determine soil texture [12].

Fractionation of soil phosphorus: Modified sequential fractionation of soil Inorganic -P was done according to the procedure of [13]. First, the water soluble phosphate (Water-P) was extracted using deionized water. Second, Aluminium bound phosphate (Al-P) was extracted via 1M NH_4F pH 8.5. Subsequently, iron bound phosphate (Fe-P) was removed in 0.1 N NaOH. Then, 0.5 M H_2SO_4 used to extract Calcium phosphate (Ca-P). Sodium

citrate solution 0.3M $Na_3C_6H_5O_7$ with $Na_2S_2O_4$ was used to extracted the reductant phosphate (Red-P). Total phosphate (Total-P) was determined by extraction of ignited soil sample with 1 N H_2SO_4. Organic Phosphorous: O-P content was calculated as the difference between P in ignited and non-ignited samples. Phosphorus concentrations in all the solutions were measured on a spectrophotometer at 882 nm [14].
After drying, all the plants were dried and digested in 2 mL HNO_3 in a block digester at 90 °C for one hour. 2ml of 4:1 solution of $HNO_3$and HCl was added after which the samples were placed in a digester for 12 hours at 110 °C. The concentrations of P in the solutions were measured on a spectrophotometer at 882 nm ([14].

Results and dissection

i. **Treated wastewater characteristics**

In arid and semi-arid countries water is becoming limited resource and planners are forced to reuse any sources of water that could be used effectively and economically. Treated municipal wastewater quality was considered for reuse in irrigation. Treated municipal wastewater is mainly comprised of water (99.9%) together with relatively small concentrations of suspended and dissolved organic and inorganic solids. As result in Table 1 show, wastewater used have pH 6.93 and this value were found to be within the permissible level suggested by [15]. (pH = 6 – 8). Salinity is a key parameter in determining the suitability of the water to be used for irrigation. The EC of tested wastewater was 2.50 dS m^{-1} and TDS 858 $mgl^{-1.}$ this within the limits suggested by FAO (1985) (EC > 3.0 dS m^{-1} and TDS > 2000). Besides, tested wastewater have 2.40 mgl^{-1} BOD, this value is within the permissible of [15].and [6] (BOD> 30 mgl^{-1}). The BOD is the quantity of oxygen needed to stabilize organic matter using microorganisms, unpolluted water has typical BOD values of 2 mgl^{-1} or less (FAO, 1985). The concentrations of Ca, Cl and SO_4 in tested wastewater were 51.20, 205.30 and 1.60 mgl^{-1} respectively. These values are in the acceptable range based on FAO standards [15]. Phosphorus in wastewater may be either inorganic or organic forms, although the greatest single source of inorganic phosphorus is synthetic detergents. Organic phosphorus is found in food and human waste as well. The Finding showed that the wastewater studied contain 1.45 mgl^{-1} Organic-P, 1.05 mgl^{-1} mgl^{-1}hydrolyzable –P and 2.02 mgl^{-1} Total –P. these values were within the limits suggested for treated wastewater [16]. In general, our results inducted that the chemical composition of wastewater studied is within the standards limits. The treated wastewater can be suitable to be reused in irrigation.

Table 1. Wastewater properties

Parameter	Units	Values
pH		6.93
EC	dS m^{-1}	2.50
TDS	mgl^{-1}	858
BOD	mgl^{-1}	2.40
Mg	mgl^{-1}	18.24
Ca	mgl^{-1}	51.20
Cl	mgl^{-1}	205.30
SO_4	mgl^{-1}	1.60
Organic - P	mgl^{-1}	1.45
Hydrolyzable-P	mgl^{-1}	1.05
Total-P	mgl^{-1}	2.02

ii. Soil physio-chemical characterization

Some of physio-chemical characterization of tested soil are shown in Table 2. Slightly alkaline pH (7.83) was observed in the soil studied, which are very common in semiarid and arid regions.

Table 2. Physio-chemical characterization of the tested soil

Parameter	Unit	Values	
pH		7.83	
EC	dS m^{-1}	0.99	
CEC	cmol kg^{-1}	2.38	
OM	%	0.20	
CaCO3	%	0.26	
Clay	%	3.20	**Sandy Soil**
Silt	%	2.69	
Sand	%	94.11	

The results showed the low OM level (0.20%) in this soil. Low OM% is typical of arid desert regions. Generally, tested soil is sandy (94.11% sand) and it has low $CaCO_3$ (0.26%) and CEC (2.38 (cmol kg^{-1}) due to remarkable contribution of clay and organic amounts (0.20 % OM and 3.20 % Clay).) Soil texture is a fundamental physical property of soils [17].

iii. Effect of wastewater addition on soil chemical characterization

The results indicated that the evaluated chemical soil parameters were changed by the application of wastewater (Table 3 fige.1). Generally, wastewater treatments increased the pH, EC, CEC, $CaCO_3$ and OM in tested soil. Soils irrigated with 100% treatments had a higher value than other treatments especially 0% wastewater (distilled water). For unplanted soil, pH was found to increase following wastewater application due to the high content of basic cations such as Na, Ca, and Mg in the wastewater applied. this in line with [4]. Wastewater irrigation resulted in higher values for EC of the soil 1.67 dS m^{-1}, the increase in EC is mainly attributed to the original high level of TDS of the wastewater that would accumulate in the soil with continuous wastewater application, which lead to accumulation of less soluble salts in the soil. The mean levels of CEC increased in treated soils. This implies soils accumulation of nutrients as a result of used wastewater, where the higher value was recorded 3.91 cmol kg^{-1} for 100% wastewater treatment, indicating a direct impact of wastewater irrigation on chemical characterization of soil studied. Likewise, the quantities of OM were affected by wastewater irrigation treatments. The higher rate of wastewater application (100%) resulted in higher amount of OM (2.67 %). Soil organic matter can be enhancing the structural properties of a soil by binding together soil particles into aggregates. However, $CaCO_3$% values did not significant differ from each other, but the higher rate of wastewater used (100%) resulted in higher value of $CaCO_3$ (0.30%).

In planted soils, temporal increase in soil pH due to the addition of wastewater. Such increase in the soil pH would affect solubility and availability of certain nutrients in treated soils. Generally, the findings showed the low levels of CE, CEC, OM in planted soils compered to unplanted soil. The results showed the direct effects of wastewater irrigation on of CE, CEC, OM and $CaCO_3$ in planted soils. The values of CE, CEC, OM and $CaCO_3$ were increased following wastewater application during the growing season, application of wastewater could enrich the soil with necessary nutrients that enhance plant growth. The above views are supported by some authors, who showed that irrigation with wastewater had a positive effect on soils characters [18]. However, the finding showed temporal decrease in OM in planted soils compered to unplanted soil, which can be partially attributed to the possible decomposition and oxidation of the soil carbon toward the end of the growing season by the introduced microorganisms by wastewater [4]. However, the increase $CaCO_3$% following wastewater addition could affect availability of nutrients such as phosphate. The abundance of Ca^{2+} in the soil solution limits P-solubility by forming sparingly soluble Ca-P compounds [19]. In this study, at alkaline soil pH values, phosphate ions may tend to react quickly with calcium form less soluble compounds.

Table 3: effect of wastewater treatments on chemical characterization of the treated soil

Wastewater additin	Cultivar	pH	EC	CEC	OM	$CaCO_3$
			dS m^{-1}	cmol kg^{-1}	%	%
0 %	Control	7.83	0.86	2.45	1.90	0.25
	Beans	7.78	0.80	2.08	0.80	0.26
	Barley	7.82	0.84	1.81	0.84	0.24
25%	Control	8.04	1.12	2.59	2.12	0.27
	Beans	7.91	0.91	2.11	0.91	0.26
	Barley	8.03	0.93	1.88	0.93	0.28
50%	Control	8.05	1.23	3.14	2.23	0.29
	Beans	8.00	0.99	2.29	0.99	0.28
	Barley	8.09	1.05	1.99	1.05	0.27
75%	Control	8.07	1.52	3.65	2.52	0.27
	Beans	8.02	1.09	3.11	1.09	0.28
	Barley	8.20	1.18	2.78	1.18	0.29
100%	Control	8.07	1.67	3.91	2.67	0.30
	Beans	8.04	1.15	3.52	1.15	0.29
	Barley	8.23	1.30	3.04	1.30	0.31

iv. Concentrations of organic and inorganic phosphorus fractions in tested soils

Mean soil phosphorus concentrations fraction in soils listed as µg P g soil-1 (Table 4). Evidence is provided for wastewater playing a major role in redistributing P into different forms in the teared soil. In general, Inorganic-P contents in tested were higher than Organic-P. the largest fraction of Inorganic-P is the $CaCO_3$-boun (Ca-P), phosphorous readily precipitates with metal ions and becomes deficient in many soils [2]. The availability of P in most ecosystems depends on soil properties such as mineralogy of the parent material, leaching rates, and soil texture. Generally, bioavailability of P in sandy soils is considered to be low. Data in Table 4 illustrate the differences between the Inorganic-P forms. The distribution of Inorganic-P fractions in uncultivated soil were Ca-P > Water-P> Read –P >Fe-P > Al-P. while in soil cultivated with *Vicia faba*, P quantities were Ca-P > Water-P > Read –P > Fe-P = Al-P. In soil cultivated with *Hordeum vulgre,* P quantities were Ca-P > Water-P > Read –P > Fe-P >Al-P. Thus, Ca-P and Water-P appear to be the major fractions contributing to Inorganic-P.

Table 4: The concentrations of phosphorus fractions in tested soils (µg g^{-1})

Parameters		Inorganic-P					OP	TP
		W-P	Al-P	Fe-P	Ca-P	Red-P		
0 %	Control	17.82	N.D	2.62	40.07	2.16	6.69	93.34
	Beans	12.67	N.D	N.D	37.97	4.00	22.03	105.00
	Barley	12.59	N.D	2.63	28.78	1.88	28.75	100.00
25%	Control	23.54	N.D	2.72	39.34	7.00	8.75	95.42
	Beans	18.04	N.D	N.D	36.88	4.57	30.42	115.21
	Barley	14.13	N.D	2.70	28.38	6.59	35.04	109.58
50%	Control	24.70	N.D	2.97	42.29	8.50	9.17	98.59
	Beans	18.70	N.D	N.D	38.97	4.79	37.92	118.88
	Barley	15.00	N.D	3.38	30.56	5.56	35.04	110.24
75%	Control	25.63	N.D	3.50	44.69	8.75	9.58	98.70
	Beans	20.59	N.D	N.D	43.63	4.82	37.92	114.58
	Barley	15.75	N.D	2.06	32.29	9.22	35.04	111.14
100%	Control	32.50	N.D	4.00	49.72	11.23	10.00	111.87
	Beans	21.75	N.D	N.D	44.72	2.07	37.92	121.88
	Barley	17.53	N.D	1.10	32.94	6.34	40.00	112.12

The most available fraction is Water-P and Organic-P, while Read-P and Ca-P are the most unavailable fractions. Often, Fe-, Al- and Ca-phosphates control the solubility of P in soils. The high base status and pH of soils render P solubility due to the formation of metal complexes such as Ca-P and Mg-P. With increasing soil pH, solubility of Fe-P and Al-P increases but solubility of Ca-P decreases, except for pH values above 8. However, the Inorganic-P content would be more strongly linked to plant P availability [20]. Our results showed the effect of cultivating practices on phosphorus fractions. Preliminary estimates of P losses caused by plants is the major factor indicate that elimination of soil P. The differences in the P fractions of the unplanted and planted soils can be equated to changes induced by cultivation practices.

On other hand, Organic- P influences availability of P by contributing to Inorganic-P fractions, which is important to net primary production in many ecosystems [2]. The results showed that Organic-P concentrations were greatest in soil irrigated with 100% wastewater, also it is important to note that planted soils content high organic- P concentrations (40.00 µg P g $soil^{-1}$) than unplanted soil. Organic-P in soil is mineralized to Inorganic-P through the action of phosphatases primarily produced by microorganisms, and then Inorganic - P is taken up by plants. Organic-P may be mineralized to Inorganic-P by simple autolysis or enzymatic phosphorylation, and become plant-available. Mineralization of Organic-P provides a large portion of the plant-available P in most soils. Where plant residues are returned to the soil, an increase in P availability may occur by decreasing the adsorption of P to mineral surfaces [19]. As depicted from the current results water soluble and Organic-P were high in wastewater irrigated soil. It is accepted that the availability of phosphors was increased after treatment applied.

Increasing the wastewater application rate increased Total-P in all treatments. In unplanted soil, Total-P level increased from 93.34 to 111.87 µg g^{-1}, while in soil cultivated with *Vicia faba*, Total-P increased from 105.00 to 121.88 µg g^{-1}. in soil cultivated with *Hordeum vulgre*, increased from 100.00 to 112.12 µg g^{-1}. The highest values were in 100% wastewater treatment. This implies soil accumulation of Total-P as a result of their high concentration in the used wastewater. Similar finding was reported by [18]. While the total amount of P in the soil may be high, it is often present in unavailable forms such as Ca-P.

v. Effect of wastewater addition on plants phosphorus concentrations

Data in Table 5 clarify the differences between the P content in *Vicia faba* and *Hordeum vulgre*. As the finding show, tested plants irrigated with treated wastewater had different phosphorus content, the irrigation with treated wastewater led to a significant increase of P content in the tested plants. Each treatment contained different concentrations of plant nutrients and concentrations of P, which should have affected the phosphors content in tissue of tested plants. The P concentrations in *Hordeum vulgre* were high compared to it concentrations in *Vicia faba*.

Table 5. Mean phosphorus concentrations in tested plants (µg g-1)

Treatments	P in *Vicia faba*	P in *Hordeum vulgre*
0 %	3687.50	5812.50
25%	4039.70	7687.50
50%	4218.70	13916.30
75%	5281.30	14645.8
100%	7374.80	16187.50

The highest values at 100% wastewater treatments 16187.50 and 7374.80 µg P g^{-1} for *Hordeum vulgre* and *Vicia faba* respectively. The variation in P concentrations in tested plants are mainly controlled by their physiological activities, and also related to plant root growth, P dynamics in the rhizosphere are mainly controlled by plant root growth. According to our results, the wastewater effluent has the potential to be used as a source of water and nutrients in irrigated plants. Phosphorus is present in several inorganic and organic forms. Plants absorb mainly Inorganic-P but the Organic–P is also an important reservoir for plant nutrition. By releasing organic acids (e.g., oxalate) from roots and mycorrhizae, plants can increase the rate at which phosphorus is derived from soil minerals by chemical weathering. Treated wastewater is a valuable source for plant nutrients and organic matter needed for maintaining fertility and productivity of arid soils [4]. It was found that irrigating wheat and alfalfa with wastewater increased their yield by approximately 11% and 23%, respectively [21].

Consolation:

Reuse of treatment wastewater has a positive impact in terms of enhancement of soil fertility, Phosphorus availability and P content in the tested plants. On the other hand, its high salinity could impose negative effect on soil properties, this obstacle of salinity could be overcome either by implanting more salt-tolerant crops. According to our study, applied of treatments of wastewater gave the highest phosphorus concentration values, with the difference between the two tested plants Applied of treatments of wastewater gave the highest phosphorus concentration values, with the difference between the two tested plants. Also, phosphorus forms and their distribution were different in unplanted and planted soils. The greatest portion of extractable Inorganic-P was present in the Ca fractions. The greatest portion of extractable Inorganic-P was present in the Ca fractions. It is accepted that the availability of phosphors was increased after treatment applied. significant increase in P in tested plants tissue noted due to used treated wastewater. The P concentrations in *Hordeum vulgre* were high compared to it concentrations in *Vicia faba*. In general, this study demonstrated that diluted wastewater can be used to for irrigation poor soils to overcome water scarcity, enhancing phosphors availably and soil nutrients. On other hand future studies should investigate methods to reduce the build-up of salt in the soil when treated wastewater is used to irrigate such soils.

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