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ASSESSMENT OF USING SEWAGE WATER EFFLUENT ON SOME SOIL CHARACTERISTICS

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ABSTRACT

The major goal of this study was to evaluate the impact of using sewage water effluent as a sole source of irrigation for different periods of application on some physical and chemical properties of soil. Therefore, three sites representing different periods of sewage effluent utilization were chosen at Abou – Rawash Farm, Giza Governorate.

The first site was uncultivated and assumed to be as a background reference of the studied area (0-Yr); the second and the third site were selected to represent area, which has been irrigated continuously with sewage effluent for 7 years (7-Yr) and 14- years (14-yr), respectively. Disturbed and undisturbed surface soil samples (0-20 cm) were taken from the three sites.

The results revealed that amending soil with sewage water had no influence on soil texture class even after (14-Yr) of the application; the texture still sandy textured soil. Total calcium carbonate decreased from 3.46% in the control to 1.84 and 1.50 % in the (7-Yr) and (14-Yr) amending soil, respectively. Organic matter content, increased due to the sludge amending. The magnitude of the increase was as the years of application increased.

The results also indicated that the values of soil bulk density (B.D) was decreased with increasing the years of sludge application. This is may be attributed to the binding effects of organic matter exist, producing a more structured soil, consequently decreasing bulk density. The available water (AW) increased as the years of application increased. After (7-Yr) of sludge application, the data showed that available water was percentage increased by 2.46 folds as much as in control soil and by 4.76 fold after (14-Yr) .

Results also, revealed that the reaction of the soil was alkali in the beginning (7.48 in the control) and changed to slightly acidic after consecutive use of sludge application. The data showed that the EC value was increased by nearly 33% due to the sludge application. The availability of N, P and K increased progressively as the years of application increased. In (7–Yr) soil and (14-Yr) soil, N content was increased by 23 and 29 folds, respectively, the corresponding data were (15 and 23 folds) for K and (2 and 3 folds) for P.

Results showed that drastic increase in the contents of heavy metals of the soil being irrigated with sewage effluents. As the period of irrigation increase, the total contents of heavy metals progressively increased.

The fractionation results of the tested heavy metals showed that, on average basis, the residual form was amounted to be 30% for Cd, 40% for Cu, 35% for Pb and 48% for Zn were associated with residual form. The rest of the extracted fraction, as shown from the data, could be arranged in descending order as follows: organic form >oxide – bounded > carbonate - form >exchangeable – form.

In this connection, using swage effluent for irrigation sustained soil physical properties, but chemical properties must be considered.

Keywords: Sewage Sludge, Effluents, irrigation, Sandy soil, Bulk density, Moisture constants, Fractionation of heavy metals.

INTRODUCTION

In arid and semi arid region, disposal of sewage sludge and/ or using sewage effluents in irrigation has become an important element in water resources planning. Application of sewage effluent can enhance soil chemical and physical properties and serve as valuable nutrient source and consequently, hancing agricultural productivity. ; Higgins , 1984) .These materials also contain toxic heavy metals and organic contaminates, which when applied to soil accumulate and potentially leading to phytotoxicity or entry into food chain. (Aboulroos *et al..,* 1991 and Eman, 2005).

Disposal of sewage effluent supplies a high content of organic matter with favorable effects on soil physical properties (Feigen *et al*.; 1991). Sadek and Sawy (1989) found that, utilizing sewage water effluent for irrigation resulted in soil textural changes where the fine particles increased in the surface layers. The change in soil texture and the increase in organic matter content are mainly attributed to the suspended matter in the sewage water, especially, before the development of purification technique at Abou-Rawash. This suspended material was measured and found to be in the range of 2.8 to 8.6 g/L. This material is reach in organic matter, which deposit mainly on the soil surface. (EL – Amir *et al..,*1997). Considerable information is available concerning the effects of organic matter, such as sewage sludge on soil bulk density. Long-term studies (Gupta *et al*.., 1977; Webber, 1978; Weil and Krooontje, 1979) indicate a decrease in soil bulk density with sewage sludge applications. Mathan (1994) explained that, organic matter improves soil structure, soil bulk density gradually decreased from one year to another. Among the various soil types, Powers et al.., (1975) reported that the effect of disposal sewage effluent on soil bulk density appears to be more pronounced for coarse - textured soil. Generally, the sewage effluent application increases the soil capacity to retain water. The organic carbon of sludge may affect water retention as direct effect of sludge organic particles themselves or through its indirect effect on other soil physical properties such as soil bulk density or soil porosity. Moreover, the available water was increased with increasing the period of sewage effluents utilization. (Metzger and Yaron, 1987)

The prolonged use of these effluents for irrigation could increase the organic matter content of irrigated soils (Ben-Hur, 2004). It is inevitable that sludge application to soils, especially at high rate or with repeated frequency, will result in elevated concentrations of many potentially toxic elements. (El–gendi, 2003).

Therefore, the understanding of the beneficial and the potential adverse effects of using these materials in soils is of ultimate goal.

The purpose of this study is to evaluate the effects of using sewage effluent water as a sole source of irrigation and years of application on some physical and chemical properties of soil.

MATERIALS AND METHODS

This study was carried out on Abou - Rawash farm, Giza, Egypt. This area is well characterized by using sludge and sewage effluent water as a sole source of irrigation. Three sites were chosen to represent different periods of sewage water utilization in the studied area. The first site had not been irrigated and assumed uncontaminated (0- Yr). The second and third sites were selected to represent area, which irrigated continuously with sewage effluent water for 7–years (7 –Yr) and 14 – years (14 –Yr), respectively.

The disturbed and undisturbed surface soil samples (0- 20 cm) were collected from these sites. The disturbed soil samples air-dried and ground to pass through a 2 mm screen and kept for determine some chemical properties of the studied soil. In addition, samples of sewage effluent water were collected from irrigation source. Soils and water samples were subjected to the following analyses:

1- Sewage effluent water analyses:

A sample of sewage effluent water, which was used for irrigation, was filtrated for chemical analyses, which, were carried out according to Page *et al...* (1982) and for Cd, Cu, pb and Zn determination using Atomic Absorption Spectrophotometer. Some characteristics of water are presented in Table (1).

2- Soil Analysis

- General characteristics of the tested soil were carried out, i.e. Particle size distribution was carried out by pipette method by Gee Bander (1986), Organic matter (OM %) and calcium carbonate ($CaCO_3$ %) were described by Jackson (1973).
- Soil chemical analyses were carried out according to Page *et al...* (1982).
- The undisturbed soil samples were used to determine some soil physical properties. Soil bulk density was determined using the core method technique according to Black (1982). Soil moisture constants i.e. field capacity, wilting point and available water were determined according to Stakman (1966).
- Total Metal Content: One-gram (dry weight) soil samples was digested using 12 ml of a mixture of HCLO4 and HF (5:1 v1v) in platinum crucible. The crucible was brought to near dryness, before a further 12 ml of the acid mixture added and again bringing to near dryness. Finally, 1ml of HClO4 was added and the sample was evaporated until the appearance of white fumes.
- The residue was then dissolved in 5 ml of conc, HCl before making up to 25 ml with deionised water. (Tessier *et al*.., 1979). Cd, Cu, Pb and Zn were determined using Atomic Absorption Spectrophotometer.
- DTPA –Extractable metals : Available Cd ,Cu ,Pb and Zn were determined for all soil samples using 0.005 m DTPA (Diethylene Triamine Penta Acidic) as outlined by Lindsay and Norvell (1978).

- **Fractionation of the tested heavy metals :**

The tested heavy metals were extracted sequentially as described by Tessier *et al..,* (1979) into the following five fraction;

1- Exchangeable (1M NaOAc, pH8.2).
1- Bound to carbonate (1MNaOAC, pH5).
2- Bound to Fe & Mn oxides (0.4M $nH_2OH.Hcl$ in 25%acidicacid v\v).
3- Organically bounded (0.02 M HNO_3 +30% H_2O_2, pH2).
4- Residual (HF + $HClO_4$).

Extractions were carried out on1.0.gm. sub samples in 50 ml polyethylene centrifuge tube.

RESULTS AND DISCUSSION

1-Characteristics of sewage effluent:

The results refer that the sewage effluent water which used as a sole source of irrigation in the tested area is characterized with slightly acidic reaction (pH=6.95); essential nutrients present in a highly content; NO3 (1.53 ppm), P (3.13 ppm and K (0.20). Also, the data showed that the concentration of heavy metals in the effluent water were within the normal ranges acceptable of sewage effluent water for irrigation purposes ;(Cd = 0. 1; Cu = 0.2, Pb = 5.00 and Zn 2.00 ppm). as mentioned by Aboulroos and El-Falacky (2005).

Table (1): General characteristics and some heavy metals concentrations of sewage effluent water at Abou- Rawash area.

Variable	pH	Ec dS/m	Essential nutrient (ppm)			Heavy metals (ppm)			
			N	P	K	Cd	Cu	Pb	Zn
Sewage effluent water	6.95	3.75	2.05	2.46	0.20	0.04	0.02	0.35	0.16

2- Impacts of sewage effluents on some physical properties of tested soils

2-1 Soil texture:

Data in Table (2) refer that the amending soil with sludge had no influence on soil texture even after 14- years of sludge application; the texture still sandy textured soil. At the same time, the data indicate that the percentage of fine particles increased from 1.33% in the control soil to 8.62% and 19.75% in 7-years amending soil and 14- years amending soil, respectively attributed to the fine particles and sediments existed in the sewage effluent water, as well as, to the effects of years of sludge application. (EL – Amir et al.., 1997)

2-2 Total Calcium Carbonate:

Data also refer that the total calcium carbonate decreased from 3.46% in the control (0-Yr) to 1.84 and 1.50% in the (7-Yr) and (14-Yr) amending soil, respectively. These results may be due to low pH value and the dissolution action of organic acids presented in sewage effluent water.

Table (2): Influence of the amending with sewage effluent on some of soil physical properties.

Variables	control	7 –Yr	14 Yr
Soil Fraction (%)			
Coarse f.(C.S + F.S)	98.67	91.38	81.25
Fine f. (Silt + clay)	1.33	8.62	19.75
Total calcium carbonate%	3.46	1.84	1.50
Organic matter (%)	0.07	3.35	5.79
B.D (g/cm^3)	1.54	1.25	1.23
Soil moisture content (v/v)			
SP	15.13	23.73	32.03
FC	6.23	12.90	22.49
WP	2.55	3.83	4.99
AW	3.68	9.07	17.50

2-3 Organic matter content

Data in Table (2) showed that the initial organic matter content of the control soil (0-Yr) was very low (0.07%) and increased continuously with years of sewage effluent application till it reached to 3.35% and 5.79% in (7-Yr) and (14-Yr) soil samples, respectively.

2-4 Bulk Density

The obtained results of soil bulk density are presented in Table (2), it is obvious that the soil bulk density decreases with sewage effluent utilization. The magnitude of decrease depends on the duration of sewage water utilization. The longer the period the less is the soil bulk density (EL – Amir et al.., 1997). The Bulk density (BD) values (in g/cm^3) were ;(1.54, 1.25 and 1.23) for the control, (7-Yr) and (14- Yr). The decrease in soil bulk density is more related to the increase in soil organic matter content. Sewage effluent applications also, led to a dilution effect resulting from the mixing of the added organic matter with the more dense mineral fraction of the soil. Furthermore, this is may be attributed to the binding effects of organic matter exist, producing a more structured soil, consequently decreasing soil bulk density (Powers et al.., 1975). Similar results were also obtained by McBride (1995) who mentioned that the application of organic substances facilitates the formation of soil aggregation, resulting in decreasing the mass of unit volume.

2-5 Available water content

It well known that, the available water (AW) calculated as the difference between soil moisture at field capacity (F.C) and that at wilting point (W.P). It is obvious from the results in Table (2) and illustrated Fig. (2) that, available water increased as the years of application increased. After (7-Yr) of sludge application, the data showed that the available water percentage was increased by 2.46 folds as much as that in the control soil and by 4.76 folds after (14-Yr) of application. That is referring to the bright side of using sewage effluent on irrigation purpose and its influences on improving some of physical properties of coarse soil texture. Where, sandy soils have much less surface area than clayey soils and thus, retain much less water at higher tensions. However, with addition of organic matter, specific surface area increases resulting in increased moisture at higher tensions (Gupta *et al*.., 1979). Similar conclusions were also obtained by Abd El-Naim *et al*. .,(1982) who mentioned that amending soil with sludge was not effective on increasing of the water holding capacity only ,but also on the pore size distribution. Fine capillary pores were increased on the expense of quickly and slowly drainable pores due to use of sewage water for irrigation. This is may be due to the clogging of larger pores by the suspended solids settled therein the treated soils. Organic matter increases the moisture retention capacity in the soil, which, is due to the reduction of soil bulk density, increases soil porosity and the specific surface area of the treated soil particles. (Tarchitzky *et al*.; 1999).

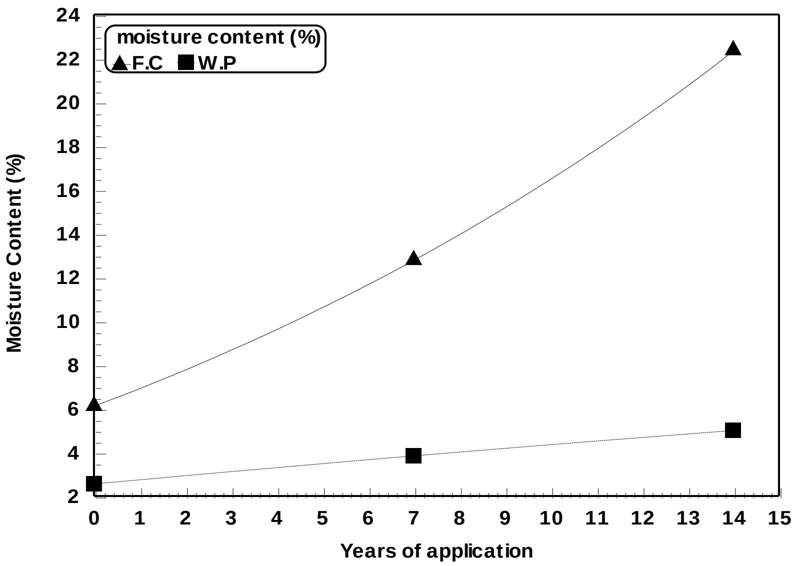

Fig (1) : Effect of disposal of sewage sludge on the studied soil

3 Impacts of sewage effluent on some chemical properties of the tested soils

3-1 Soil- pH

The data in Table (3) reveal that the reaction of the soil was alkali in the beginning (7.48 in the control) and changed to slightly acidic after consecutive use of sludge application. These results were expected since the sewage effluent water characterized with slightly acidic reaction, added to that the low buffering capacity of the tested soil.

3-2 Soil salinity

In the same connection, the data showed that the continuous use of sewage effluent had a little effect on salt accumulation. On an average basis, the data showed that the EC value increased by nearly 33% due to the sludge application

3-3 Available nitrogen, phosphorus and potassium in the tested soils

A glance on Table (3) show that the data of total and available content of N ,P and K in the control soil sample were deficient ,being only 15.61 ,7.21 and 91.10 ppm , respectively. The results indicate that the available N and P is low, while available phosphorous is generally moderate which cited as (10 to 20 ppm) for total soluble N; (2 to 5 ppm) for P and (105 to 350 ppm) for K as the critical levels of that nutrient in soil.

As indicated from the Table (3) the availability of N, P and K increased progressively as the years of application increased. In (7 –Yr) soil and (14-Yr) soil, N content was increased by 23 and 29 folds, respectively, the corresponding data were (15 and 23 folds) for K and (2 and 3 folds) for P. These results may be contributed to microbial activities, which gradually break down the organic matter, particularly low-weight organic acid, which can interact strongly with soil minerals and often reduce metal- sorption. Also, the possible mechanisms responsible for the increased metal efficiency include :

(1) Direct contribution of sludge N ,P and K (see Table 1) .

(2) Competition of sludge – derived organic anions with a given metal for adsorption sites on the soil surface and /or complexion of organic anions with Al^{3+}, $Fe3^{+}$, or Ca^{2+}, thereby lowering the activities of these free cat ions in the soil solution. Thus, in turn, increase the activities of soluble metals in order to satisfy the thermodynamic principle of constant solubility products of those minerals in soil.

3-4 DTPA – Extractable heavy metals

Data of the Table (3) showed that DTPA – extractable metals were not detectable in the control soil (0 - Yr). However, these portions increased with time continuously until it reached in (14 – yr) soil and samples to (0.37 ppm, 1.89 ppm, 0.82 ppm and 7.85ppm) for Cd, Cu, Pb, and Zn, respectively. In average, the levels of the tested metals were approximately, 1.5, 1.1, 1.9 and 1.8 times greater than their corresponding values after (7- Yr).

Table (3): Some Chemical properties of the tested soils:

Parameters	Control	7-years	14- years
EC (1:2.5)	1.05	1.40	1.39
pH (Paste)	7.48	6.83	6.80
Available macro- nutrients (ppm):			
N	7.21	169.00	215.00
P	4.10	63.00	96.00
K	110.39	223.48	345.02
Total Heavy metals (ppm)			
Cd	0.18	3.18	7.06
Cu	0.90	37.19	69.04
Pb	5.16	19.58	39.00
Zn	20.80	107.00	306.17
Available Heavy metals (ppm):			
Cd	-	0.26	0.37
Cu	-	1.69	1.89
Pd	-	0.42	0.82
Zn	-	4.31	7.85

3-5 Total heavy metals

Total heavy metals of tested soil samples are listed in Table (3) .The data clearly showed that drastic increase in the heavy metals in the contents of heavy metals of the soil being irrigated with sewage effluents. As the period of irrigation increases, the total contents progressively increased. The data showed that Cd, Cu, Pb and Zn in the (14-yr) soil samples were increased by 2.2, 1.8, 1.9 and 2.8 folds, respectively, compared with their corresponding values in (7-yr) soil sample.

3-6 Fractionations of some heavy metals

The fractionation results of the tested heavy metals are illustrated in Fig (2) the data showed that the residual fraction contained significant amount of the tested heavy metals.

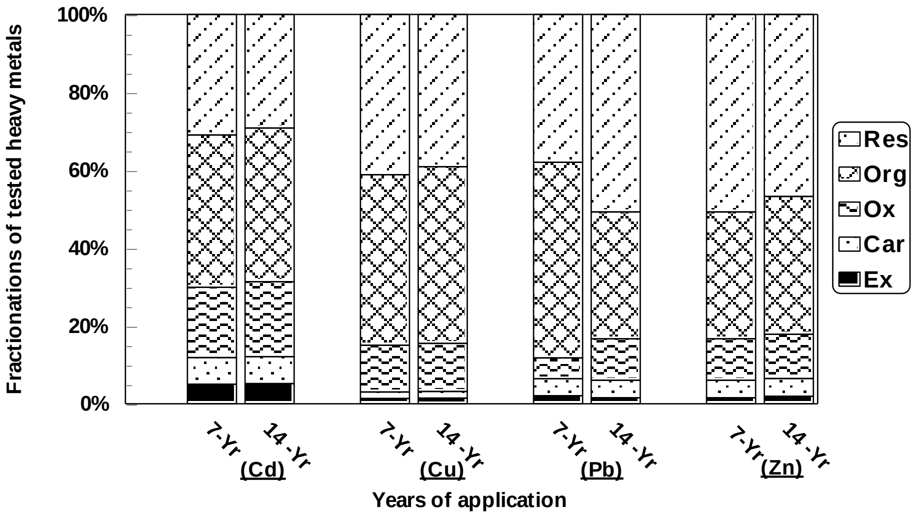

Fig (2) Fractionations of the tested heavy metals in the treated soil

On average basis, it amounted 30% for Cd, 40% for Cu, 35% for Pb and 48% for Zn. throughout the tested heavy metals, the organically bounded forms were considered apart from the residual form, the data showed that it was the most dominant fraction. It constituted about 41% and 31.5% of the sum of the five fractions in (7-yr) and (14-yr) soil samples respectively. In addition, among the tested metals, Pb was manly associated with organic matter (X=50%), followed in decreasing order by Cu(x = 44%), Cd (X=39%) and Zn (x=33%). These results may be attributed to the affinity between organic matter and the metal. The data also showed that the oxide fraction occurred in detected amount, (18% for Cd): and (11% for Zn). Also; the percentages of carbonate and exchangeable forms, as shown from the Fig (2) contributed low percentages. Except of Cd and Pb; the data showed that carbonate and exchangeable fractions are existed in minor portions. As shown from the data; approximately 65% of Cd fraction and 4% of Pb were associated with carbonate portion.

The same observation were also repeated by El-Gendi (1997) and (2003).He mentioned that carbonate and oxides were mainly the solid phases when controlling the solubility of Pb and Cd in the soil.

It can be concluded that, soil application of sewage effluent needs to be accompanied by sustainable soil management practices so as to maximize benefits while minimizing harm

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تقييم إستخدام ماء الصرف الصحى على بعض خواص الأرض

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تهدف هذه الدراسة الى تقييم التأثيرات المختلفة لإستخدام مياه مخلفات الصرف الصحى كمصدر وحيد للرى و لمدد مختلفة على بعض الخواص الطبيعية و الكيمائية للأراضى . لهذا تم اختيارثلاث مواقع فى مزرعة ابو رواش بمحافظة الجيزة ممثلة لفترات مختلفة لإستخدام مخلفات الصرف الصحى.

يمثل الموقع الأول المساحة الغير مزروعة للمقارنة بينما أختير الموقعيين الثانى و الثالث ليمثلا المساحة المزروعة والمرويه بمياه مخلفات الصرف الصحى لمدة سبع سنوات و أربعة عشرة سنه على التوالى.وأخذت عينات مثارة وأخرى غير مثارة للطبقة السطحية (صفر – 20 سم) ممثلة للمساحةالمدروسة للمواقع الثلاثة المدروسة.

أوضحت النتائج أن إستخدام مياه مخلفات الصرف الصحى لم يكن لها تأثير على تغيير رتبة القوام بل ظل قوام الأرض رمليا حتى بعد أربعة عشرة سنه من الإستخدام.قلت نسبة كربونات الكالسيوم الى 1.84% و 1.50% وذلك مقارنة بالكنترول3.46 % بعد سبع سنوات و أربعة عشرة سنه على التوالى بينما زاد محتوى الأرض من المادة العضوية كنتيجة إستخدام مياه مخلفات الصرف الصحى بزيادة مدة الإستخدام.

كما أظهرت النتائج إنخفاض قيم الكثافة الظاهرية بزيادة مدة إستخدام مياه مخلفات الصرف الصحى فى الرى ويرجع ذلك لدور المادة العضوية فى تحسين البناء الأرضى و بالتالى إنخفاض قيم الكثافة الظاهرية. زاد محتوى الأرض من الماء الميسربزيادة مدة إضافة مياه مخلفات الصرف الصحى,كما أوضحت النتائج أنه بعد إضافة مياه مخلفات الصرف الصحى لمدة سبع سنوات و أربعة عشرة سنه زاد محتوى الماء الميسر للأرض بمعدل (2.46%) و(4.76 %) على التوالى مقارنة بالكنترول . أوضحت النتائج أيضا أن إنخفاض درجة حموضة الأرض (pH) بعد الإضافات المتعاقبة من مخلفات الصرف الصحى. من ناحية أخرى أظهرت النتائج زيادة ملوحة الأرض بحوالى 33% كما زاد تيسر النتروجين و البوتاسيوم و الفوسفور بزيادة سنوات إستخدام مخلفات الصرف الصحى . زاد محتوى الأرض من النتروجين بمعدل(29,23 %) وكذلك (15,23%) للبوتاسيوم و (2,3 %) للفوسفور على التوالى.

أظهرت النتائج زيادة كبيرة فى المحتوى الكلى للعناصر الثقيلة للأرض المروية بماء مخلفات الصرف الصحى. وكلما زادت فترات الرى زاد المحتوى الكلى زيادة كبيرة. كما دلت النتائج للعناصر الثقيلةالمدروسة أن

عناصر Zn,Pb,Cu ,Cd تمثل بصفة عامة 30% ,40% ,35% ,48% من الصورة المتبقيةعلى التوالى. وتشير نتائج المفصولات الكيميائية للعناصر الثقيلة محل الدراسة الى أن الصورة المتبقية تمثل الصورة السائدة بين المفصولات المختلفة ويمكن ترتيب باقى المفصولات المختلفة ترتيبا تنازليا حسب كمياتها كالأتى: الصورة المرتبطة عضويا > الصورة المرتبطة بالأكاسيد > الصورة المرتبطة بالكربونات > الصورة المتبادلة.