Asian Journal of Chemistry Vol. 20, No. 1 (2008), 563-570

Effects of Sewage Sludge Applications on the Yield and Trace Element and Heavy Metal Accumulation in Peanut (*Arachis hypogaea* L.)

SEZAI DELIBACAK*, BÜLENT OKUR, BÜLENT YAGMUR and ALI RIZA ONGUN
Department of Soil Science, Faculty of Agriculture, Ege University, 35100 Izmir, Turkey
E-mail: sezai.delibacak@ege.edu.tr

In this research, effects of different sewage sludge (biosolid) levels on the yield and trace element and heavy metal acumulation in peanut were investigated. The experiment was conducted using a randomized block design with 4 replicates in Menemen Plain, in the Western Anatolia region of Turkey in year 2003 and 2004. Wet sewage sludge was added to the soil at the rates of 0, 30, 60, 90 t ha^{-1}. The results showed that increasing sewage sludge application to Typic Xerofluvent soil significantly increased peanut yield, Fe, Cu and Ni content of edible part of peanut in 2003 and 2004, but did not significantly affect Mn, Zn, Cd, Cr, Pb contents of peanut in same years. Meanwhile, trace elements and heavy metals (Fe, Cu, Mn, Zn, Co, Cd, Cr, Ni, Pb) concentrations of peanut were found under threshould values.

Key Words: Peanut, Yield, Sewage sludge, Trace elements, Heavy metals.

INTRODUCTION

Sludge is defined as the residual material removed from wastewater treatment facilities. A new term, biosolids, suggests the beneficial usage of sludge. The definition of biosolids is now accepted as those primarily organic solid products produced by wastewater treatment processes that can be beneficially recycled.

Treatment of sludge is its preparation for final use or disposal including, but not limited to, thickening, stabilization, and dewatering of sludge. Sludge treatment does not relate to storage of wastewater sludge[1].

The application of sewage sludge (biosolid) to agricultural land has become a common practice over the past several decades. This practice is inexpensive, logical and easy to carry out. Since sewage sludge contains plant nutrients and organic matter, it may be used to supplement or replace commercial fertilizers for crop production. The beneficial effects of using sludge on agricultural soils have been proven by numerous researchers. It has been shown that sewage sludge application improves the physical, chemical and biological properties of soil[2-4].

Nutrients content of sludge increase plant biomass and yield[5,6]. Pedreno *et al.*[7] found that tomato yield was clearly favoured by sewage sludge fertilization and no difference was observed from other organic fertilizer treatments. Awad *et al.*[8] stated that sewage sludge application significantly increased the growth of apple seedlings. The Pb and Ni contents of fruits and leaves were slightly increased and Hg and Cd remained almost unaffected. Pinamonti *et al.*[9] tested sewage sludge compost in 14 apple orchards. The resulting data demonstrated that sewage sludge compost did not cause any significant increase in heavy metal levels in plants. Researchers found that sewage sludge can be used to fertilize the soil with no danger in the short/medium term either to the environment or to crops.

However, sewage sludge application may lead to the accumulation of a number of potentially harmful components such as heavy metals in soil and crops. The presence of heavy metals in the applied sludge can cause phytotoxic effects, soil and water contamination and accumulation of heavy metal in food supplies[10,11].

In Turkey, the application of sewage sludge to vegetable and fruit production has been limited by Ministry of the Environment regulations. After the analysis of sewage sludge and soil, permission to apply sludge must be obtained from the relevant officials[12].

Accumulation and availability to plants of heavy metals in agricultural soils largely depend on the composition of the sludge, rate of sludge application, soil properties and crop species and cultivar. Increased Zn and Cu concentrations have often been observed in soil and plants with sludge applications[13,14] while only very slight variations in Cr, Pb, Ni, Cd, Hg and B concentrations have generally been determined[13,4].

In the long term, the use of sewage sludge can also cause a significant accumulation of heavy metals in soil and plants. Sloan *et al.*[15] stated that after sludge applications the relative bioavailability of sludge applied with heavy metals was Cd > Zn > Ni > Cu > Cr > Pb.

The use of sewage sludge in agriculture depends on soil pH, lime content, soil cation exchange capacity and soil organic material. Liming is a common practice in agriculture to maintain optimal soil pH and has also been used to reduce the solubility of trace element and heavy metals. Investigations have been performed on the effect of lime addition to reduce trace element and heavy metal solubility[16-18]. Peles *et al.*[19] found that Zn, Cu, Cd and Pb concentrations in various field plant species were significantly lower in plants collected from limed compared to unlimed sludge treated plots. Agricultural land in Turkey is generally rich in lime and is low in organic matter and available P, Fe and Zn concentrations and soil pH is mostly neutral and alkaline. The mobility of trace element and heavy metals depends on soil pH and lime content. Therefore, the physical and chemical properties of soils of Turkey can be improved by using sewage sludge which has sufficient organic matter, available P and micronutrients.

The objective of the present study was to investigate the effects of sewage sludge application on the yield and trace element and heavy metal concentrations of edible part of peanut grown in Typic Xerofluvent soil.

EXPERIMENTAL

The field study was carried out in the experimental fields of Agriculture Faculty's Research Farm of Ege University in Menemen, Izmir, Turkey. Research area is in the Western Anatolia region of Turkey. The experiment was carried out on a sandy-loam soil, which was clasified as a Typic Xerofluvent[20].

Sewage sludge was taken from sewage sludge treatment plant of metropolitan region of Izmir city may produce around 600 tons (moist basis) of sewage sludge per day. Ferric chloride and calcium oxide were added to raise the efficiency of the dewatering process of sewage sludge. The sewage sludge produced presented a pH varying between 10 and 12, which increased the pathogen control and decreased the heavy metal availability.

Three different levels of wet sewage sludge (30, 60 and 90 t ha^{-1}) were applied to experimental soil on May 1st. Gravimetric water content of wet sewage sludge was 79.82 %. 25 kg ha^{-1} N; 55 kg ha^{-1} P_2O_5; 30 kg ha^{-1} K_2O were also applied to experimental soil as basic fertilization at the same time mixed with soil to 10 cm depth. The experiment was designed according to randomized blocks with four replications. There were 16 plots in the experiment (3 sewage sludge treatments and control). Dimensions of plots were 3 × 6 m (18 m^2).

The sowing of peanut seeds (*Arachis hypogaea* L.) were done by sowing machine on May 5th, 2003 and June 4th, 2004 to 5 cm of soil depth, in rows 70 cm apart. Irrigation was provided when required. Harvest were made by plough and peanuts collected manually (November 14, 2003 and October 15, 2004). Fresh yield of peanuts were weighed. Peanut samples from each parcel were collected for heavy metal analysis. Samples were dried in a forced air oven at 70 ºC for 48 h and digested in a nitric-perchloric acid mixture. Fe, Cu, Mn, Zn, Co, Cd, Cr, Pb and Ni contents in the extracts were determined using atomic absorbtion spectrophotometry[21].

The following measurements were made on the experimental soil and sewage sludge: Gravimetric water content of wet sewage sludge[22], pH[23], water soluble total salt[24], $CaCO_3$[25], organic matter[26], total N[27], total P[28]. Total K, Ca, Mg, Na and trace elements (Fe, Cu, Zn, Mn) and heavy metals

(Co, Cd, Cr, Ni and Pb) were analyzed with 3HCl + $1HNO_3$ extraction solution[29] and measured by AAS[21]. Texture of experimental soil was determined using the hydrometer method[30]. Data were analyzed using the SPSS statistical software package[31]. The least significance difference test was used to establish if differences in the treatments were significant at P = 0.01, 0.05.

Some physical and chemical properties of the soil and sewage sludge used in the experiment are given in Table-1.

TABLE-1
SOME PHYSICAL AND CHEMICAL PROPERTIES OF THE EXPERIMENTAL SOIL AND SEWAGE SLUDGE

Parameters	pH	Salt (%)	Organic matter (%)	N (%)	Available mg kg $^{-1}$				
					P	K	Ca	Mg	Na
Soil	7.70	0.032	1.26	0.07	5.40	341	2836	273	72
					Total mg kg $^{-1}$				
Sew. sludge	7.34	3.640	46.39	3.06	13300	6800	37400	6800	5900
	Total mg kg $^{-1}$								
	Fe	Cu	Zn	Mn	Co	Cd	Cr	Ni	Pb
Soil	1.88	13.65	37.88	316.08	10.75	0.34	48.09	48.15	12.51
Sew. sludge	11400	258.40	94.60	298.60	14.20	3.64	144.60	69.60	153.90

RESULTS AND DISCUSSION

The fresh weights of peanuts with shell were given in Table-2. The highest yield (8943.5 kg ha^{-1}) of peanut was found at the first year (2003) harvest with the highest dose of sewage sludge aplication (90 t ha^{-1}) to soil (Table-2). It was followed by 60 and 30 t ha^{-1} sewage sludge aplications. The lowest yield was found at the control (Table-2). At the second year (2004), the highest yield (6783.0 kg ha^{-1}) of peanut was determined at 60 t ha^{-1} sewage sludge aplication. Peanut yields of second year were under the first year yields at all doses of sewage sludge. This means that second year effect of sewage sludge is very low. Sewage sludge can be decomposed

TABLE-2
EFFECTS OF SEWAGE SLUDGE APPLICATIONS ON FRESH PEANUT (WITH SHELL) YIELD

Sludge (ton ha^{-1})	Fresh peanut with shell (kg ha^{-1})		
	2003	2004	Total
90	8943.5 a	6774.1 a	15717.6 a
60	8623.6 b	6783.0 a	15406.6 a
30	8151.6 c	6612.7 ab	14764.3 b
0	7631.2 d	6404.0 b	14035.2 c
LSD	250.18‡	250.18‡	404.09‡

‡Statistically significant at $p \leq 0.01$ level.

very fast because of high temperature and high microorganism activity in the experimental soil. The highest total yield of peanut was found at the highest dose of sewage sludge (90 t ha^{-1}). It was followed by 60, 30 and 0 t ha^{-1} doses of sewage sludge aplications, respectively.

According to these results, it can be suggested that peanut yield significantly increased with increasing sewage sludge doses. This result may be explained to the high organic matter and macro and micronutrient content of applied sewage sludge. Sewage sludge applications increased yield in various plant species[7,4,11].

Trace element and heavy metal composition in edible part of peanut in 2003 and 2004 were given in Tables 3 and 4.

TABLE-3
EFFECTS OF SEWAGE SLUDGE APPLICATIONS ON Fe, Cu, Mn, Zn, Co, Cd, Cr, Pb AND Ni CONCENTRATION OF EDIBLE PART OF PEANUT IN 2003

Sludge (ton ha^{-1})	2003-Edible part of peanut (mg kg^{-1})								
	Fe	Cu	Mn	Zn	Co	Cd	Cr	Pb	Ni
90	17.50 a	7.44a	17.14	39.12	0.40b	0.08	0.31	1.05	2.13a
60	17.06ab	6.57ab	16.90	38.07	0.67ab	0.08	0.31	0.90	2.04a
30	15.03ab	6.12ab	17.80	38.07	0.67ab	0.08	0.31	1.05	1.94ab
0	14.61b	5.948b	17.67	37.36	0.81a	0.08	0.31	0.90	1.67b
LSD	2.724‡	1.267†	ns	ns	0.314‡	ns	ns	ns	0.278‡

†,‡Statistically significant at $p \leq 0.05$ and $p \leq 0.01$ level, respectively; ns: not significant.

Increasing sewage sludge application to peanut plant significantly increased Fe and Cu content of edible part of peanut in 2003 and 2004, but did not significantly affect Mn and Zn contents of peanut in same years (Tables 3 and 4).

TABLE-4
EFFECTS OF SEWAGE SLUDGE APPLICATIONS ON Fe, Cu, Mn, Zn, Co, Cd, Cr, Pb AND Ni CONCENTRATION OF EDIBLE PART OF PEANUT IN 2004

Sludge (ton ha^{-1})	2003-Edible part of peanut (mg kg^{-1})								
	Fe	Cu	Mn	Zn	Co	Cd	Cr	Pb	Ni
90	18.20a	7.30a	17.68	38.88	0.45b	0.11a	0.31ab	1.08	2.19a
60	18.14a	6.14ab	17.24	37.72	0.80a	0.10ab	0.33 a	1.01	2.07a
30	16.32ab	6.69ab	17.52	37.22	0.75ab	0.08ab	0.33 a	0.94	1.97ab
0	15.78b	5.98b	17.23	36.50	0.91a	0.07ab	0.30 b	0.91	1.70b
LSD	2.002†	1.267†	ns	ns	0.314‡	0.031†	0.022‡	ns	0.278‡

†,‡Statistically significant at $p \leq 0.05$ and $p \leq 0.01$ level, respectively; ns: not significant.

The Cd, Cr and Pb concentrations of peanut in 2003 and Pb concentration of peanut in 2004 did not significantly change with sewage sludge treatments. Meanwhile, the highest Co concentrations of peanut were at control in 2003 and 2004. Increasing sewage sludge application to peanut plant significantly decreased Co content of edible part of peanut in same years. Co contents of experimental soil and sewage sludge were nearly same (10.75-14.20 mg kg^{-1}, respectively). Sewage sludge is an organic matter source and increase organic matter content of soil. Humus and other organic compounds can chelate metals and form stable complexes. Humic fractions with lower molecular weights are more effective for complexation with metallic ions, since they contain phenolic and carboxylic groups in higher concentrations[32]. For this reason, Co content of edible part of peanut may be decreased by increasing sewage sludge aplications. Sewage sludge aplications caused significant increases Ni content of peanut in 2003 and 2004. The aplication of 60 and 90 t ha^{-1} sewage sludge significantly increased Cd concentration of peanut in comparison to 30 t ha^{-1} sewage sludge and control in 2004. The highest Cr contents were found with 30 and 60 t ha^{-1} sewage sludge treatments in 2004 (Tables 3 and 4).

According to the Food Standards Agency and Institute of Food Research[33], threshold values of Fe, Cu, and Mn in edible part of peanut are 25.0; 10.2 and 21.0 mg kg^{-1}, respectively. Approximate Zn content of peanut is 50.0 mg kg^{-1} as reported by Baker *et al.*[34]. Recommended upper level of Co is 1.0 mg kg^{-1} in apple, plum, peach, bean and cowpea[35] Permitted level of Cd is 0.11 mg kg^{-1} in tomato[35]. Critical level of Cr content of tomato is 1 mg kg^{-1}. Permitted level of Ni is 3.7 in bean as suggested by Schacklette[36].

Threshold values of all these heavy metals show that edible part of peanut has heavy metal concentrations under recommended upper levels.

Frost and Ketchum[37] indicated that the Zn, Cu, Cd and Cr concentrations of plant tissues increased with sludge application. In addition to this, López-Mosquera *et al.*[38] did not find significant correlation between the total metal concentrations in the soil and plant tissues. This can be explained by the low heavy metal concentrations in the sludge and the high pH and lime content of the experimental soil. Peles *et al.*[19] found that heavy metal concentrations (Cu, Zn, Cd and Pb) were significantly lower in plants collected from limed soils compared to unlimed soils treated with sludge. Also the soils in Turkey and the research area (Menemen-Izmir) are generally calcareous and have a pH value above 7.0. This is an advantage for preventing against the toxic effects of trace elements and heavy metals, the trace element and heavy metal contents of soil and plants to which sewage sludge is applied. However, long-term sewage sludge application may cause the accumulation of some trace elements and heavy metals in the soil and their entry into plants in quantities above the maximum permitted concentrations. That's why, use of sewage slugge in agriculture have to be always controlled for public health.

ACKNOWLEDGEMENT

The authors would like to thank the Ege University Scientific Research Found for providing financial supporting for project number 2003 ZRF 018.

REFERENCES

1. http://www.usace.army.mil/inet/usace-docs/eng-manuals/em1110-2-501/c-10.pdf.
2. S.M. Aggelides and P.A. Londra, *Bioresour. Technol.*, **71**, 253 (2000).
3. E. Benitez, M. Romero, M. Gomez, F. Gallardolaro and R. Nogales, *Water, Air Soil Pollut.*, **132**, 75 (2001).
4. S.Y. Selivanovskaya, V.Z. Latypova, S.N. Kiyamova and F.K. Alimova, *Agric. Ecosys. Environ.*, **86**, 145 (2001).
5. G. Brofas, P. Michopoulas and D. Alifragis, *J. Environ. Qual.*, **29**, 811 (2000).
6. C.G. Cogger, A.I. Bary, S.C. Fransen and D.M. Sullivan, *J. Environ. Qual.*, **30**, 2188 (2001).
7. J.N. Pedreno, I. Gomez, R. Moral and J. Mataix, *Agric. Ecosys. Environ.*, **58**, 115 (1996).
8. F. Awad, L. Kahl, R. Kluge and J. Abadia, Iron Nutrition in Soil and Plants, Proceedings of the Seventh International Symposium, Zaragoza, pp. 53-62 (1995).
9. F. Pinamonti, G. Stringari, F. Gasperi and G. Zorzi, *Resour. Conserv. Recycl.*, **21**, 129 (1997).
10. L. Yingming and R.B. Corey, *J. Environ. Qual.*, **22**, 1 (1993).
11. C. Keller, S.P. McGrath and S.J. Dunham, *J. Environ. Qual.*, **31**, 1550 (2002).
12. Official Gazette, Legislations of Soil Pollution Control. No: 24609, Ankara (in turkish) (2001).
13. K.A. Barbarick, J.A. Ippolito and D.G. Westfall, *J. Environ. Qual.*, **27**, 801 (1998).
14. J. Nyamangara and J. Mzezewa, *Agric. Ecosys. Environ.*, **73**, 199 (1999).
15. J.J. Sloan, R.H. Dowdy, M.S. Dolan and D.R. Linden, *J. Environ. Qual.*, **26**, 966 (1997).
16. R. Krebs, S.K. Gupta, G. Furrer and R. Schulin, *J. Environ. Qual.*, **27**, 18 (1998).
17. N.T. Basta and J.J. Sloan, *J. Environ. Qual.*, **28**, 633 (1999).
18. M. Fang and J.W.C. Wong, *Environ. Poll.*, **106**, 83 (1999).
19. J.D. Peles, S.R. Brewer and G.W. Barret, *Am. Midl. Nat.*, **140**, 245 (1998).
20. Soil Survey Staff, Keys to Soil Taxonomy, US Govt. Printing Office, Washington DC, USA, edn. 10 (2006).
21. H. Kick, H. Bürger and K. Sommer, *Landwirtsch. Forsch.*, **33**, 12 (1980).
22. W.A. Jury, W.R. Gardner and W.H. Gardner, Soil Physics, John Wiley & Sons Inc., New York, end. 5, p. 327 (1991).
23. M.L. Jackson, Soil Chemical Analysis, Prentice Hall of India Private Limited, New Delhi, India (1967).
24. Soil Survey Staff, Soil Survey Manual, U.S. Dept. Agr. Handbook 18, U.S.Govt. printing Office, Washington DC, USA (1951).
25. E. Schlichting and H.P. Blume, Bodenkundliches Praktikum, Verlag Paul Parey, Hamburg-Berlin (1966).

26. E. Reuterberg and F. Kremkus, Bestimmung von Gesamthumus und Alkalischen Humusstoffen im Boden'. Z. Pflanzenernaehr. Düng. Und Bodenkd. Verlag Cheime GmbH. Weinheim (1951).
27. J.M. Bremner, in ed.: C.A. Black, Total Nitrogen, Methods of Soil Analysis, Part 2, American Society of Agronomy Inc., Madison, Wisconsin-USA, pp. 1149-1178 (1965).
28. W.L. Lott, J.P. Nery, J.R. Galld and J.C. Mercalf, Leaf Analses Technique in Coffee Research, New York, IBEC, Research Ins. Bulletion, No. 9 (1956).
29. G. Hoffmann and I.M. Band, Die Untersuchung von Böden, WDLUFA-Verlag-Darmstadt (1991).
30. G.J. Bouyoucos, *Agronomy J.*, **54**, 464 (1962).
31. SPSS, SPSS 9 for Windows User's Guide, Copyright 1999 by SPSS Inc., SPSS, Chicago, IL (1999).
32. M.L.A. Silveira, L.R.F. Alleoni and L.R.G. Guilherme, *Scien. Agric.*, **60**, 793 (2003).
33. Food Standards Agency and Institute of Food Research, McCance and Widdowson's The Composition of Foods, Sixth summary edition, Printed in The United Kingdom by Bookcraft Ltd. ISBN-0-85404-428-0 (2001).
34. R.D. Baker, R.G. Taylor and F. McAlister, Peanut Production Guide, Guide H-648. Cooperative Extension Service, College of Agriculture and Home Economics, New Mexico State University (1998).
35. A.K. Pendias and H. Pendias, Trace Elements in Soils and Plants, CRC Press Boca Raton, Ann Arbor London, ISBN-0-8493-6643-7, edn. 2, p. 365 (1992).
36. H.T. Schacklette, Elements in Fruits and Vegetable from Areas of Commercial Production in the Conterminous United States, US Geol. Surv. Prol. Pap (1980).
37. H.L. Frost and L.H. Ketchum, *Adv. Environ. Res.*, **4**, 347 (2000).
38. M.E. López-Mosquera, C. Moiron and E. Carral, *Resour. Conserv. Recycl.*, **30**, 95 (2000).

(*Received*: 13 December 2006; *Accepted*: 14 September 2007) AJC-5861