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Residual effects of urban sewage sludge on corn biological yield and chemical composition

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Abstract: A large volume of sewage sludge is produced in the process of urban sewage treatment. The sludge contains relatively large amounts of organic matter, plant nutrients, soluble salts as well as small amounts of some heavy metals. The residual effects of urban sewage sludge on growth and yield of corn and heavy metals and nutrients concentrations in plant were studied in a field trial conducted in one site(Esfahan Agri Res Ctr in Kabutar-abad farm)in central Iran.The treatments included applications of 0, 25, 50 and 100 metric tons of sludge ha^{-1} in a randomized complete block design with three replication. Biological yield of corn increased from 8.6 to 12.3,18 and 16.3 t ha^{-1} for 25, 50 and 100 t ha^{-1} of sludge applications(as compared to the control field) respectively. Concentrations of N, P, K, Fe, Mn, Zn and Cu in plants tissues increased as a result of sludge application.Concentration of Fe, Mo, Zn, Cu and Cr in plant tissues also increased but no toxic symptoms were observed. Concentration of Pb, Cd, Cr, Co and Ni in aerial tissues of corn did not increase as a result of sludge application. The results showed that the average concentration of above elements in all three treatment plants, not exceeded from EPA standards, however, regarding the accumulative property of these elements, in using these sludges in the agricultural soils, the necessary caution and care should be taken. It is concluded that sewage sludge has the potential to be used as an organic fertilizer and soil amendment to improve soil productivity at least for a limited period of time.
keywords: corn, heavy metal,sewage sludge, soil, yield,

Introduction

The use of waste to enhance soil fertility may lead to accumulation of heavy metals in soil and transfer these elements to plants. This situation generally occurs when the industrial sludge to be used (10) or large quantities of organic fertilizers such as compost added to soil (5). Adding a lot of compost leachate, sewage sludge, municipal solid waste compost(5) can increase the soil salinity. The elimination of microelements deficiency by organic matter is due to the complex power of this material. Numerous reports eliminate of micronutrients deficiency by manure, poultry manure and sewage sludge is available (10). In general, sewage is producing from human activities (domestic and agricultural) which is 99.9 percent water and 0.1 percent solids. Sewage sludge as a source of cheap fertilizer and soil conditioner has been of great farmers concern(8).

Low organic matter in arid region soils has caused organic compounds under different names, including sewage sludge, municipal solid waste compost and other organic waste, added to the soil. These compounds have material or useful elements such as carbon, phosphorus, nitrogen, potassium and other elements that are necessary for plant growth, but with harmful substances such as heavy metals(Cd, Pb etc) can combine this polluted environment and cause the entry of these substances into food chains(5).

In a study of heavy metals in soil treated with sewage sludge, leaching, and moved. As in the treatment of 100 tons of sludge per hectare, the available of cadmium more than 12 times of control, the available of zinc was 5.34 times of control, the available of lead was 7.3 times of control and the available copper was 3.42 times of control(7).A study in a samples of sewage sludge showed 121 μg gr^{-1} Pb and in other samples 545-7432 μg gr^{-1} Pb, in USA has been reported(7).

In studying the relationship of organic fertilizers such as sewage sludge and compost with soil available K the changes of K were noted. Increasing K in applying the total organic fertilizers was noted but the intensity of increased K in the soil, by adding sewage sludge, compost and manure, were not the same, so that the lowest increase sewage sludge and cow manure created the greatest increase(10). 30% of sludge organic nitrogen was also mineralized in the first year, 10% in the second year and 5 percent in the third year in mineral soil occurred. Comparison of manure, municipal solid waste compost and sewage sludge showed that sewage sludge is much richer than two other fertilizers, especially in terms of trace elements(8,9).

Bina et al., reported that the mean of heavy metals, parasite eggs and fecal coliform in sewge treatment plant southern Esfahan and Shahin-shahr, were measured ranging from the normal to standard. Statistics mean values of Na, OC and C/N ratio in all three sewage treatment plant and parasite eggs and fecal coliform in the northern sewage treatment plant exceeded the maximum common values and therefore their use is not suitable for different uses and the need to revise the sludge treatment processes and systems were in operation of the treatment plant. Because the average amount of fecal coliform and other plant parasite eggs in the two other treatment plant were located according to the provisions part of 503 CFR40 regulations imposed by the EPA(4) class B pathogen regulations, therefore restrictions in consuming in agriculture in terms of product and harvest time was necessary. Also according to the cumulative properties of heavy metals and the lack of standards necessary protective effects of EPA, the application of sludge for agricultural purposes should be done cautiously and carefully(1).

Mcintosh et al., reported the effects of sewage sludge on the root and aerial Pb and Cd content of fenugreek.The amount of Cd and Pb in all treatments was less than the norm but Pb absorbed higher than Cd (8). The use of sewage sludge can play a role in soil P release. In a study of the cumulative amount of P released during a period of 1,560 hours(65 days) in control soils equal to 0.55- 6.1 mg kg^{-1} and in soils treated with sewage sludge equal to 1.3-15.9 mg kg^{-1} (7). The survey was conducted and articles from the time of construction to the present, sludge generated in urban sewage treatment plants, used by farmers as a fertilizer(is added to the soil every several years)(1). The purpose of this research was to evaluate the residual effects of sewage sludge on the corn chemical characteristics and yield in a field test.

Material and methods

To study the residual effects of sewage sludge on corn chemical composition and yield(single cross 704 variety), after harvesting wheat in the same plot that includes treatments zero (control), 25, 50 and 100 tons of sludge per hectare (based on dry weight) the corn was cultivated. Statistical design was a randomized complete block design with three replication The test region was located at geographic location 51° 51'east longitude and 32° 31' north latitude in the world. The average altitude is 1545m above sea level. The soil in the study area in terms of type of land on the river alluvial terraces and the geomorphological unit formed and evolved on the first river-terrace of Zayandehrood river.

According to the bioclimatic map of Iran(Emberge method) Kabootar-abad station located in arid cold climates. The average annual precipitation has been measured 142.4 mm. The average temperature fluctuation has been reported between 4 to 37.1 °C over the years(6). The sewage sludge provided from Shahin-shahr sewage treatment plant. The way to refine this sewage was secondary aerated lagoons method. Sludge used outdoors and exposed to sunlight for a year. Sludge was added a month before planting into the soil. Due to the amount of nutrients in sludge and soil testing fertilizer needs of corn in the control plot was paid. In the corn milky stage, silage yield measurement, corn plants (biomass) from the crown cut and dried in a ventilator-oven at 75 °C for 48 hours. Analysis of samples was done in the soil and plants laboratory of Esfahan agricultural research center. Sludge dry matter content by placing 10 grams of sludge in the oven(at75 °C) for 24 hours was determined. Total nitrogen was measured by Kjeldahl method(12).

Plant samples digested in a mixture of sulfuric acid and salicylic acid method include wet ash were prepared. Concentration of Ca, Mg, Fe, Mn, Zn, Cu, Pb, Ni, Cr, Cd in plant extracts by atomic absorption with oven graphics were measured in the laboratory of Esfahan university of technology, the accuracy of this method was in the range of micrograms. The resulting data were analyzed of variance using the softwares and the comparison of means was performed at the level of five percent using Duncan's multiple range test.

Results and discussion

The quality of irrigation water in terms of salinity (EC 3.5 ds m^{-1}) and acidity (pH 7.6) was with moderate limitations. The source of irrigation water was a mixture of groun water and the irrigation network of Zayandehrood river. The amount of water entering the plots was controlled by parshalflum. The amount of water used during the growth period was about nine thousand cubic meters per hectare.

The properties and fertilizer value of sludge

Sludge has about 23 percent organic material that can have beneficial effects on the soil properties. Three percent of total N, total P 1.5 percent, total K 0.5 percent and some metal elements. Thus, the treated sludge 50 tons per hectare, 1500 kg N(150 kg solution N), 150 kg K and 450 kg P are added to the soil. Much of N and P are in the form of biological material during mineralization processes are gradually released and available for plants.

Between organic fertilizers, sewage sludge containing higher concentrations of heavy metals(11), in using of sludge as a fertilizer, concentrations of heavy elements, were with greater attention, because long-term use can lead to accumulation of sludge elements and causes water, soil, plants pollution and finally food products pollution. According to the EPA standard(4) the metallic elements in sludge used authorized for use on agricultural land. Ping et al., studied and compared urban waste compost and sewage sludge showed that sewage sludge is much richer than other fertilizers, particularly in terms of heavy metals(10).

Sludge residual effects on chemical properties and corn yield

Biological yield

The effect of different amounts of sludge on the mean values of dry matter, are gathered in table 1. Residual effects of sludge treatment significantly increased the corn biological yield and significant difference between treatments was obtained. The treatment 50 t ha^{-1}, increases the yield and treated 100 t ha^{-1} compared to the previous treatment decreased the corn yield. Thus, the use of more than 50 tons sludge per hectare even in successive cultures is not recommended. Sewage sludge contains organic matter and nutrients required by the plant, and by affecting of the chemical, physical, and biological of soil and can increase crop yield. According to the survey results, these effects remain in the soil for at least two year. Higgins and Rezaei-Nejad et al., reported the positive effects of sewage sludge on corn biological and grain yield (11,7).

Table 1: Mean values of corn biological dry weight *

sludge rate (t ha^{-1})	0	25	50	100
weight (kg m^{-2})	0.86A	1.23B	1.8C	1.63C
% increase	_	39.5	109	89.5

* numbers followed by the same letter are not significantly different($P<0.05$)

The corn leaves chemical composition

The mean values of some elements of corn leaf are gathered in table 2. Elements Co, Pb, Cd were not in atomic absorption system detection limit(μg kg^{-1}). Sludge application significantly increased concentrations of N, Zn, Mn, Fe and Cu of leaf. This increase is very significant, especially for Zn and Mn, due to the effects of the absorption of the positive remaining of sludge. Higgins et al., and Rezaei-nejad et al., reported significant effect of sewage sludge on micro-nutrients increasing uptake in corn leaves (12,7).

Table 2: Mean values some of the corn leaf elements *

nut/ treat	N %	P	K	Ca	Mg	Zn	Mn mg kg^{-1}	Fe	Cu
1	1.65a	0.19a	1.19a	0.19a	0.05a	26.3a	53.7a	180.3a	5.2a
2	1.87a	0.19a	1.21a	0.21a	0.05a	37.9b	95.5b	218.5b	8.4b
3	1.88a	0.2a	1.24a	0.23a	0.04a	35.0b	92.2b	250.9c	7.6b
4	2.27b	0.24a	1.33a	0.26a	0.05a	47.3b	98.5b	261.7c	8.2b

* numbers followed by the same letter are not significantly different(P<0.05)

The root chemical composition

The mean values of some elements of the root are shown in [Table 3]. Element cobalt, lead, cadmium were not in atomic absorption system detection limit(µg kg^{-1}). Sludge application significantly increased the mean values of zinc, manganese, iron and copper content of the root. In addition to increasing the amount of these elements by adding sludge to soil, development of the plant roots can increase these nutrients uptake. Also the acid in sludge can increase the solubility of elements and increasing their uptake by the roots(3,8). Hemmat et al., reported the increasing of organic matter and soil porosity by using of sewage sludge and appropriate environment for the root to develop.

Table 3: Mean values some of the corn root elements *

nut/treat	N %	P	K	Ca	Mg	Zn	Mn mg kg^{-1}	Fe	Cu	Cr
1	0.913a	0.113a	0.39a	0.61a	0.15a	21.19a	58.3a	95.0a	8.5a	0.933a
2	0.84a	0.143a	0.43a	0.7a	0.15a	26.3b	73.1	155.7b	9.4a	0.67a
3	0.96a	0.177a	0.35a	0.7a	0.2a	27.1b	111.3c	166.7b	10.5b	1.2a
4	1.07a	0.19a	0.56b	0.8a	0.2a	32.2c	103.1c	222.3c	12.5c	0.87a

* numbers followed by the same letter are not significantly different(P<0.05)

The corn seed chemical composition

Applying sludge caused significant increase the mean values of Mn in the corn seed(Table 4). Cr, Co, Pb, Cd in seed were not in atomic absorption system detection limit(µg kg^{-1}). Thereby increasing its nutritional value of seeds will increase the nutritional value of it. Corn grain formation and filling are critical processes in the corn grain production. One of the main problems of corn fields is the lack of complete germination. Sludge treatment significantly increased corn grain yield. Higgins et al., and Rezaei-nejad et al., reported significant sewage sludge effect on increasing nutrients uptake in corn(11,7).

Table 4: Mean values some of the corn seed elements *

nut/treat	N 0%	P	K	Ca	Mg	Zn	Mn mg kg^{-1}	Fe	Cu
1	2.2a	0.33a	0.66a	0.013a	0.03a	28.7a	28.1a	26.3a	9.0a
2	2.1a	0.3a	0.6a	0.01a	0.023a	25.5a	48.1b	22.4b	10.6a

3	2.03a	0.31a	0.6a	0.013a	0.02a	25.3a	57.6b	24.1a	9.2a
4	2.03a	0.36a	0.66a	0.017a	0.023a	26.5a	56.8b	20.9a	8.9a

* numbers followed by the same letter are not significantly different($P<0.05$)

Conclusion

The soil of the testing location is calcareous (45%) and clayey (38%) and has a high buffering capacity to absorb and stabilize heavy elements. Alkaline pH of soil (7.7) can also to deposit and cause non-absorbable metal elements. The above characteristics can prevent the absorption of heavy metals by plants are over. The tested sludge contains considerable quantities of plant nutrients which can be useful in soil fertility and crop needs. The concentration of trace elements and heavy metals in used sludge, according to Iran EPA and USEPA limits are lower than limited level and can be used in agricultural land.

The effects of sludge application significantly increases (5%) soil organic carbon, salinity, and soil available nitrogen, phosphorus, potassium, zinc, manganese, iron and copper. Between the heavy metals only available cobalt was increased significantly but the increase of cobalt in compare with the standard was not poisons to plant. The residual effect of sludge treatments(50 t ha^{-1}) also increased the biological yield of corn significantly. Due to the characteristics of the soil, soil salinity and heavy metals accumulation, 100 t ha^{-1} sludge had negative effects even in the second crop plant. Thus, the use of sludge more than 50 t ha^{-1} even in continuous cultivation is not recommended. According to this study sewage sludge had a good value as a fertilizer. And the purification of human pathogens can be used it as an organic fertilizer on agricultural land limitedly.

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