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Research Article

Evaluation of Sewage Sludge in Sudan as soil improver for crop production

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Abstract

The aim of the present work was to study the effects of sewage sludge application on growth, and minerals accumulation in selected crop tissues, as well as to investigate its effect on soil characteristics. Field experiments of growing sorghum (sorghum bicolor), sunflower (Helianthus annuus), maize (Zea mays) crops under five loading of sewage sludge, (0, 5, 10, 15 and 20 ton/hec), were carried out at the experimental farm of Soba sewage treatment plant, south Khartoum during growing season of 2014 / 2015. The experiment was conducted using a completely randomized design with 3 replicates. Plant height, leaves number, fresh weight and dry weight were measured after 30 and 60 days of growth. Also chemical, physical and biological properties of the investigated sludge and soil of the experiment were evaluated. The concentration of lead, cadmium and chromium were determined in crop tissues. The results indicated that sewage sludge contained significant concentration of total coliform and parasite eggs, also the development of sorghum, maize and sunflower crops was significantly affected by the application of sewage sludge, with significant change in soil properties. However, the effect of sewage sludge on soil characteristics was of no consistent pattern.

Keywords: *Sewage sludge, treatment plant, soil properties, heavy metals, Plant growth, Plant tissues*

1. Introduction

Sewage sludge, also known as bio-solid, is a residue resulting from the treatment of wastewater released from various sources (Edwards *et al*, 2017) It is a concentrated suspension of solids, largely composed of organic matter and nutrient-laden organic solids, and its consistency can range in form from slurry to dry solids, depending on the type of sludge treatment (Mehta *et al*., 2015). Recycling of sewage sludge on cropland has been considered as one of the possible solutions to the complex problem of sewage sludge disposal (Defra, 2007). The growing preference for land application of organic wastes, including sewage sludge, to agricultural land has received attention in recent years to reduce cost, environmental problems and regulatory constraints associated with alternative disposal methods of sludge. Sewage sludge is high in organic content and plant nutrients and, in theory, makes good fertilizer. (Du *et al*, 2012). It was reported that supplying nutrients (N, P, secondary nutrients, and micronutrients) to the crops improving soil physical properties, increasing soil organic matter content, and several advantages of land application of municipal sewage sludge can be achieved (Katanda *et al*, 2007). But, pathogenic organisms and heavy metal contents limit their usage (Cabañas-Vargas *et al*., 2013; Nogueira *et al*., 2009).

Moreover, some researchers warn about their high contents in organic compounds and phenols as well as its salts and their high pH value (Bolz *et al*., 2001). Several studies have been conducted to understand the effects of applying sludge to agricultural products, yet many unanswered questions remain. The unique composition of sludge and many factors in the soil-plant system, that influence the chemical composition and plant uptake of these metals add complexity to solving the problem. However, beneficial effect of using sludge on agriculture has been proven by many workers (Sukreeyapongse *et al*, 2002). It has shown that sewage sludge application increase plant biomass, and yield as well as improving the physical, chemical and biological properties of soil (White *et al* 1997; Bozkurt, 2003; Akdeniz *et al*.; 2006; Ahmed *et al*., 2010 and Yagmur *et al*., 2017).

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In Sudan so many tones of sewage sludge from domestic sewage water is accumulated daily in ponds of soba sewage treatment plant. Usually sewage sludge is used as fertilizer in many countries after many treatments to ensure its safety, However it may be used by some farmers without safety measures as source of macro and micronutrients for fruits production. Sewage sludge application may lead to accumulation of heavy metals in soil and crops, This accumulation is largely depend on the composition of the sludge , the rate of sludge application , soil properties and crop species (Bozkurt, 2003). The objective of the present work were to study the effects of sewage sludge application on growth, accumulation of minerals in sorghum, sunflower, and maize tissues as well as to investigate its effect on soil properties.

2. Materials and Methods

2.1. Materials

The sewage sludge used in this study was collected from anaerobic dried ponds of Soba wastewater treatment plant, south Khartoum. Part of this sludge was kept for physical, chemical and biological analysis, and the rest of it was used for soil treatment in the field experiments. For both experimental and analytical purposes (physical and chemical), the sewage sludge was subjected to drying under the sun for 5 days then ground into very small particles and kept in polyethylene bags. However, for biological analysis raw and fresh sludge was used immediately.

2.1.1 Crop seeds

Seeds of sorghum (Sorghum bicolor), maize (Zea mays) and sun flower (Helianthus annuus) used in this study were purchased from Khartoum north local market.

2.2. Methods

Field experiments of growing sorghum (sorghum bicolor), sunflower (Helianthus annuus), maize (Zea mays) crops under five different concentration of sewage sludge, (0, 5, 10, 15 and 20) ton/hec, mixed well with the upper layer of soil, were carried out at the experimental farm of Soba sewage treatment plant, south Khartoum during growing seasons (2014 – 2015). Chemical, physical and biological properties of the investigated sludge were carried out. A bench pH meter (WAP–CD 80) was used to measure the pH of sewage sludge samples as described by Ryan (2000), while electric conductivity (EC) was recorded using a calibrated EC meter (Jenway, 4310). Organic carbon (OC) and Organic matter were estimated using chromic acid wet oxidation method as described by Sleutel *et al*., (2007).Total N and P were determined in according to the method described by Perez *et al*, (2001) and Sikora *et al*, (2005) respectively. The concentrations of Na, K, Fe, Cu, Mn, Cr, Cd, and Pb were determined by the method described by Walinga *et al*. (1989) using the Atomic Absorption Spectrophotometer (Pye Unicam Model). The total count of bacteria was enumerated using the pour plate method, while the Most Probable Number (MPN) method was used to determine faecal coliforms in sewage sludge (Clesceri, *et al*., 2012). Parasites egg was estimated using methods described by Wang *et al*. (1997). The experiment was carried out in a randomized complete block design with three replicates. All experimental plots were regularly irrigated with tap water. In this experiment, seedlings were harvested from the field plots after 30 and 60 days of growth for each experiment. Ten seedlings of the three crops were harvested randomly from each replicate to study the impact of sewage sludge treatment on crop development; the performance of each crop was estimated in terms of shoot length, leaves number per plant, fresh weight and dry weight. The plant height of ten seedlings was measured with meter scale. At the same time, fresh weight and dry weight of each seedling were measured independently. Dry biomass was determined after oven drying for 48 h at 80°C (Mokhtarpour *et al*., 2010). The obtained results were subjected to appropriate statistical analysis according to Gomez and Gomez (1984). The least significant difference (LSD) test was used to compare the means at 5% level of probability.

3. Results and discussions

Table 1 shows the result of the analysis of sludge samples collected from the Soba wastewater treatment plants. The pH value of the sludge under study (6.68) was neutral and agreed with many previous studies (Gawdzik, *et al*., 2014). It was reported that the pH value of sewage sludge samples analyzed from different sources in different times ranged between (5-8) (Pathak *et al*., 2009). In case of nitrogen, phosphorus and potassium the results revealed that the nitrogen content (3.64%) agreed with that reported by the same above authors, while both the potassium (1390 mg/kg) and phosphorus (0.875 mg/Kg) are out of their range. Analysis of biological parameters namely, plate count, total coliform (1.5), E.coli and parasite eggs (2.0) summarized in Table 1 showed that the sludge contain significant amount which hinder the use of wastewater in restricted irrigation (1/100 WHO) and allowed the use in unrestricted irrigation(1000/100ml). Table 2 illustrate the results of sodium, Copper, Zinc, Manganese, iron, Lead, and Chromium, The results of trace and heavy metals indicated that among all trace and elements, sodium concentration was highest followed by zinc, manganese, copper, and iron. While for heavy metals very low concentration of lead, Chromium, and Cadmuim were reported. For biological parameters the results confirmed presence of E. coli and parasite eggs in sludge under study.

Table1. pH, EC, organic carbon, organic matter, and trace and macro elements in sewage sludge obtained from Soba plant.

Parameter tested	pH	EC (mS/cm)	OC (%)	OM (%)	N (%)	P(mg/kg)	K(mg/kg)
Values	6.68	3.20	16.51	28.48	3.64	0.875	1390

Parameter tested	Na (mg/kg)	Cu (mg/kg)	Zn (mg/kg)	Mn (mg/kg)	Fe (mg/kg)	Cr (mg/kg)	Pb (mg/kg)	Cd (mg/kg)
Values	3259	14.25	56	30.25	11.75	4.25	0.725	7.25

Parameter tested	Plate Count Bacteria (per 100 ml)	Total coliform Bacteria	*E Coli* Bcreaia	Parasite eggs
Values	$2.7 \times 10^{8-}$	1.5	+ ve	2.0

Table 2. Plant height, leaf numbers, fresh weight and dry for sorghum plant in 30 and 60 days of harvesting as affected by application of sewage sludge

	30 days				60 days			
Treatments	Plant height	Number of leaves	Fresh weight	Dry weight	Plant height	Number of leaves	Fresh weight	Dry weight
0 kg	14.37^{b}	3.07^{a}	3.12^{c}	1.13^{c}	30.30^{b}	5.07^{a}	2.23^{c}	1.20^{b}
5 kg	26.50^{a}	4.33^{a}	16.77^{b}	5.33^{a}	43.53^{a}	5.53^{a}	10.03^{b}	4.27^{a}
10 kg	25.73^{a}	4.30^{a}	9.00^{c}	3.43^{b}	35.97^{a}	5.07^{a}	5.00^{c}	2.07^{b}
15 kg	26.53^{a}	4.17^{a}	16.93^{b}	5.13^{a}	37.73^{a}	5.50^{a}	8.00^{c}	3.57^{a}
20 kg	38.30^{a}	5.07^{a}	23.63^{a}	7.50^{a}	48.53^{a}	5.73^{a}	24.67^{a}	3.13^{a}

Means in the same column with different letter (s) are significantly different ($p \leq 0.05\%$)

Table 3. Plant height, leaf numbers, fresh weight and dry for sunflower plant in 30 and 60 days of harvesting as affected by application of sewage sludge

	30 days				60 days			
sludge treatments	Plant height	Number of leaves	Fresh weight	Dry weight	Plant height	Number of leaves	Fresh weight	Dry weight
0 kg	17.40b	9.50c	3.23d	0.84c	25.40c	8.87a	10.60b	2.80b
5 kg	31.43ab	14.30abc	11.87c	2.97b	47.77b	10.97a	33.83a	9.10a
10 kg	45.80a	18.27a	38.50a	6.70a	65.10a	14.77a	53.07a	13.17a
15 kg	40.83a	12.50bc	25.13b	4.37a	52.70ab	11.63a	36.63a	9.33a
20 kg	45.30a	15.77ab	21.07b	5.17a	54.87ab	12.40a	37.27a	9.93a

Means in the same column with different letter (s) are significantly different ($p \leq 0.05\%$)

Table 4. Plant height, leaf numbers, fresh weight and dry for Maize plants in 30 days of harvesting as affected by application of sewage sludge

	30 days				60 days			
sludge treatments	Plant height	Number of leaves	Fresh weight	Dry weight	Plant height	Number of leaves	Fresh weight	Dry weight
0 kg	14.77^{b}	3.77^{b}	2.27^{c}	0.51^{c}	16.93^{c}	5.37^{a}	6.41^{c}	1.50^{c}
5 kg	25.07^{a}	4.63^{a}	8.00^{b}	1.12^{b}	44.73^{a}	7.07^{a}	51.93^{b}	12.73^{b}
10 kg	23.30^{a}	4.83^{a}	7.37^{b}	1.10^{b}	31.67^{b}	5.40^{a}	35.08^{b}	7.23^{b}
15 kg	20.07^{a}	4.40^{a}	5.23^{b}	0.99^{b}	26.70^{b}	6.07^{a}	15.67^{c}	3.50^{c}
20 kg	33.87^{a}	4.77^{a}	17.37^{a}	2.47^{a}	47.97^{a}	7.93^{a}	89.33^{a}	17.47^{a}

Means in the same column with different letter (s) are significantly different ($p \leq 0.05\%$)

As shown in Table 2, 3 and 4, the values of plant height, number of leaf, fresh weight and dry weight of the three crops under investigation, increased significantly as compared to control due to sewage sludge application. The highest values of all biomass parameters were observed in the treatment of highest concentration of sludge in soil (20 kg). The same finding were reported by many authors, Wang *et al* (2008) stated that the biomass of Z. japonila was increased by 64-316% in the sludge treatments compared with the control. Increase in biomass due to sewage sludge application may be attributed to the fact that the nutrients amount were significantly increase in soil after sewage sludge application, furthermore, it is well known that, sewage sludge can improve the soil physical characteristics since it usually contains high proportion of organic matter (Pakhnenkoa, *et al*.,2009).

It was reported that the average concentration of organic matter in sewage sludge from 12 wastewater plants in seven cities in developing countries was about 33.18%., also the averages of the main nutrients of sewage sludge (nitrogen, phosphorus, potassium) were 2.53, 1.05 and 0.74% respectively (Antolin *et al*., 2010), they concluded that under application of sewage sludge treatment, plant grew better than untreated plant. However this condition is highly dependent on water availability.

The analysis of lead, cadmium and chromium in sorghum, maize and sunflower tissues as affected by different concentration of sewage sludge, as shown in Tables 5, 6 and 7 indicated that there was no any significant difference noticed with increase of sewage sludge concentration. This finding revealed that no significant increase in heavy metals was recorded as consequence of sewage sludge application. This may be attributed to the low concentration of these metals in sludge (4.25, 0.725 and 7.25 mg/ kg) for chromium, lead and cadmium respectively.

Also may be related to heavy metal bioavailability. It was reported that the total concentrations of metals in soil does not provide information about its bioavailability (Oyeyiola *et al*., 2010).

Tables 8, 9 and 10 shows how the soil properties affected by application of sewage sludge, its indicated that, in all crop experiments increase of sewage sludge loading lead to change in most of attributes of soil characteristics with non- consistent pattern, However, as compared to soil before application of sewage sludge, all values of the soil tested parameters, with exception of potassium in sorghum experiment and sodium in maize experiment, were less than that of soil before application of sewage sludge. Fluctuation in results of the most attributes, as increase in sewage sludge may attributed to that samples of soil mixed with sewage sludge may not represented the whole soil of the experiment, since practically sludge was not well mixed with experimental soil (practically it is difficult to mix sludge totally with soil experiment) so some samples may contain large portion of soil and some may contain large portion of sewage sludge and vice versa.

In conclusion, sewage sludge from Soba treatment plant, contained significant concentration of total coliform and parasite eggs. Generally, application of sewage sludge in sorghum, maize and sunflower, improve growth and crop biomass productivity, with significant change in soil properties.

Table 5. Heavy metals concentration (mg/Kg) in sorghum plant tissues as affected by sewage sludge treatment of two period of harvesting

Sludge treatment	30 days			60 days		
	Pb	Cd	Cr	Pb	Cd	Cr
0 kg	3.88[a]	0.28[a]	5.21[a]	4.45[a]	0.07[a]	0.45[a]
5 kg	1.83[a]	0.20[a]	0.25[b]	4.52[a]	0.22[a]	0.38[a]
10 kg	2.03[a]	0.17[a]	0.32[b]	3.70[a]	0.52[a]	0.45[a]
15 kg	3.15[a]	0.13[a]	0.28[b]	3.92[a]	0.25[a]	0.62[a]
20 kg	2.30[a]	0.15[a]	0.27[b]	1.27[a]	0.20[a]	0.35[a]

Means in the same column with different letter (s) are significantly different (p ≤0.05%)

Table 6. Heavy metals concentration (mg/Kg) in Sunflower plant tissues as affected by sewage sludge treatment (two period of harvesting)

Sludge treatment	30 days			60 days		
	Pb	Cd	Cr	Pb	Cd	Cr
0 kg	6.77[a]	0.45[a]	0.35[a]	4.87[a]	0.45[a]	0.73[a]
5 kg	5.92[a]	0.38[a]	0.23[a]	1.37[a]	0.38[a]	0.62[a]
10 kg	5.30[a]	0.43[a]	0.40[a]	2.10[a]	0.43[a]	0.50[a]
15 kg	4.57[a]	0.32[a]	0.62[a]	9.98[a]	0.32[a]	0.50[a]
20 kg	3.82[a]	0.18[a]	0.45[a]	5.77[a]	0.18[a]	0.78[a]

Means in the same column with different letter (s) are significantly different (p ≤0.05%)

Table 7. Heavy metals concentration (mg/Kg) in Maize plant tissues as affected by sewage sludge treatment (two period of harvesting)

Sludge treatment	30 days			60 days		
	Pb	Cd	Cr	Pb	Cd	Cr
0 kg	4.50a	0.45 a	0.68 a	0.07 a	0.01 a	0.13 a
5 kg	3.32abc	0.38 a	0.63 a	0.68 a	0.01 a	0.12 a
10 kg	3.88ab	0.43 a	0.43 a	0.07 a	0.01 a	0.08 a
15 kg	2.07abc	0.32 a	0.52 a	0.07 a	0.01 a	0.13 a
20 kg	1.12c	0.18 a	0.77 a	0.68 a	0.01 a	0.12 a

Means in the same column with different letter (s) are significantly different (p ≤0.05%)

Table 8. Effect of application of sewage sludge on soil characteristics of sorghum

Physico- chemical Characteristics	Soil before treatment	Soil after application of sewage sludge				
		Control	5%	10%	15%	20%
EC (µS/cm)	532.6	881	983	665	430	410
pH	10.27	10.1	10.13	10.18	10.21	10.3
O.C %	0.108	0.072	1.6008	0.072	0.054	0.018
O.M %	0.186	0.1242	2.7598	0.1242	0.0931	0.031
N %	0.111	0.0336	0.0336	0.0252	0.0392	0.0308
Na (mg/kg)	1642.5	1272.5	1439.7	1875	1439.7	1707.6
K (mg/kg)	79.5	89.27	66.97	66.97	66.97	44.65
P (mg/kg)	0.40	0.1	0.15	0.1	0.15	0.1
Cd (mg/kg)	0.47	0.175	0.10	0.175	0.10	0.175
Pb (mg/kg)	3.27	3.02	1.20	1.67	2.67	2.42
Cr (mg/kg)	7.53	0.175	0.25	0.45	0.67	0.3

Table 9. Effect of application of sewage sludge on soil characteristics of sunflower

Physico- chemical Characteristics	Soil before treatment	Soil after application of sewage sludge				
		Control	5%	10%	15%	20%
EC (µS/cm)	532.6	536	722	783	908	516
pH	10.27	9.64	10.07	10.1	9.91	9.99
O.C %	0.108	0.09	0.036	0.018	0.9	0.1081
O.M %	0.186	0.1552	0.0621	0.031	0.1552	0.1864
N %	0.111	0.0364	0.0392	0.0364	0.0476	0.042
Na (mg/kg)	1642.5	1372.7	1640.5	1238.7	1908.2	1774.2
K (mg/kg)	79.5	66.9	44.65	44.65	44.65	66.97
P (mg/kg)	0.40	0.29	0.25	0.1	0.29	0.25
Cd (mg/kg)	0.47	0.175	0.175	0.1	0.175	0.225
Pb (mg/kg)	3.27	3.02	2.425	1.2	1.67	2.67
Cr (mg/kg)	7.53	0.175	0.3	0.25	0.45	0.67

Table 10. Effect of application of sewage sludge on soil characteristics of Maize

Physico- chemical Characteristics	Soil before treatment	Soil after application of sewage sludge				
		Control	5%	10%	15%	20%
EC (µS/cm)	532.6	536	722	783	908	516
pH	10.27	9.64	10.07	10.1	9.91	9.99
O.C %	0.108	0.09	0.036	0.018	0.9	0.1081
O.M %	0.186	0.1552	0.0621	0.031	0.1552	0.1864
N %	0.111	0.0364	0.0392	0.0364	0.0476	0.042
Na (mg/kg)	1642.5	1372.7	1640.5	1238.7	1908.2	1774.2
K (mg/kg)	79.5	66.9	44.65	44.65	44.65	66.97
P (mg/kg)	0.40	0.29	0.25	0.1	0.29	0.25
Cd (mg/kg)	0.47	0.175	0.175	0.1	0.175	0.225
Pb (mg/kg)	3.27	3.02	2.425	1.2	1.67	2.67
Cr (mg/kg)	7.53	0.175	0.3	0.25	0.45	0.67

Conclusions

The most significant conclusions, which can be derived from this work is that significant variation in values of pH, EC. of treated wastewater of Soba treatment plant was observed throughout the months of year. In spite of variability throughout the year, the values of pH, EC, Concentration of total coliform and nematodes in treated wastewater, of Soba treatment plant, were more than the concentration limit set by WHO, for restricted irrigation, and less than the limit for unrestricted irrigation. The values of pH, EC, organic matter (OM), elemental nutrients, as well as heavy metals encourage utilization of sewage sludge as soil amendment as reuse option. Liquid sewage sludge from Soba treatment plant, contained significant concentration of total coliform and parasite eggs. Generally, application of treated wastewater and sewage sludge in sorghum, maize and sunflower, improve growth and crop biomass productivity. No significant change was observed in soil as a result of application of both, treated wastewater and sewage sludge in crop production, for the two seasons.

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