*Bangladesh J. Agric. and Environ.* 3(1): 63-73, June 2007

# SEWAGE SLUDGE AS SOIL AMELIORATOR

**Tanushyam Sikder, J C Joardar and S M Imamul Huq**

Department of Soil, Water and Environment
University of Dhaka
Dhaka-1000, Bangladesh

## Abstract

A field experiment was conducted with sewage sludge to study the possible use of it as a soil ameliorator *vis-à-vis* its effect on amaranthus (*Amaranthus gangeticus* L) growth. The experiment was randomly arranged in three separate blocks. In one block only sewage sludge at the rates of 1, 2.5, 5 and 10 t/ha was applied; in the second block, sewage sludge along with fertilizer was applied while in the third block only fertilizer was applied at ½, 1 and 1½ rates of the requirement for *Amaranthus gangeticus* L. The plants were grown for up to 45 days. Treatment responses were evaluated in terms of soil organic matter, plant yield and concentrations of N, P, K, Fe, Zn, Mn, Pb and Cd in soil and plant. It was found that sewage sludge significantly increased the content of soil organic matter. Application of sewage sludge @ 10 t/ha raised the soil organic matter by about 42%. The yield of the plant was also increased significantly ($p=0.005$ and 0.011 for sewage sludge and sewage sludge plus fertilizer). The soil pH decreased. The N, P, Fe, Zn, Pb and Cd content in soil and plant was increased but the content of K and Mn was unaffected. The heavy metals, except Pb, both in soil and plants were, however, below toxic levels. The effect of sewage sludge mixed with fertilizer was found better than sewage sludge alone.

**Key words: Sewage sludge; Amaranthus; Yield; Nutrient element; Heavy metals**

## Introduction

To keep the soil sustainable for crop production ameliorative measures are necessary and various sources of organic matter could be used as soil ameliorator. The sewage sludge could be a good source of such a one. Huge amount of sewage sludge is being generated everyday in Dhaka city as well as in other cities and towns in Bangladesh and there is no proper plan to use it. The authority is facing problem with the disposal of this sewage sludge, as they cannot be dumped ubiquitously because of sanitary and aesthetic reasons. The treated sludge in the sewage treatment plant is left unutilized due to lack of appropriate technical know-how. Use of sewage sludge in agriculture is not a new phenomenon. Sewage sludge has been extensively used in many countries of the world, especially Europe, America, Japan, Mexico and some parts of Asia. Agricultural use of sewage sludge is desirable on environmental and economical grounds.

They provide organic material, improve soil's physical conditions and have the potential for recycling the plant nutrients (Jeevan and Shantaram 1999). Successful management and judicious application of sewage sludge to agricultural land might be a cheap source of organic matter (Adani and Tambone 2005), nitrogen, phosphorus etc. (Pilevski and Mull 1999). This waste material could also improve soil physical properties (Chua 1999).

Toxic heavy metals are the long-term hazard in land application of sewage sludge (Adriano 1986, Pilevski and Mull 1999). The elevated concentrations of heavy metals on land receiving sludge are of public concern for possible phytotoxicity or increased movement of these metals into the food-chain (Heckman *et al.* 1987). To minimize the threat of food-chain contamination, accurate estimation of movement and potential for plant accumulation and food-chain cycling of sludge-borne heavy metals is important (Yingming and Corey 1993). Either the metal contents in the sludge or the application should be reduced below quantities accepted by given prescriptions. A judicial application of sludge as fertilizer under the given presumptions will have economical advantages for farmers and for those who run the sewage plants.

The study was conducted with a leafy plant amaranthus (*Amaranthus gangeticus* L.) using various treatments of sewage sludge with a view to: evaluating the possibility of using the sewage sludge as soil ameliorator; seeing the effect of sewage sludge as a source of plant nutrient and at the same time its effect on plant growth and assessing the heavy metal contaminants behavior in the soil and their mobility and bioavailability.

## Materials and Methods

The field experiment was conducted in a field situated in the premises of the Pagla sewage treatment plant, Shyampur, Dhaka, Bangladesh. The georeference of the selected field is 23° 40.986' N, 90° 27.035' E. The landscape of the study area is almost level to gently undulating. The land of the study area belongs to Sonatala soil series (SRDI 1965) belonging to the AEZ-9(e). The soil samples were collected from the experimental site to determine the physical properties and nutritional status of the soil. The soil sample representing 0-15 cm depth from the surface was collected following the method as suggested in USDA (1951). The soil samples were processed (Imamul Huq and Alam, 2005) and sieved through a 0.5 mm sieve and stored for analysis.

The treated sewage sludge samples were collected from the lagoons of Pagla sewage treatment plant. The sewage sludge samples were also air dried, ground and screened through a 0.5 mm sieve and then mixed thoroughly for laboratory analysis. Certified seeds of *Amaranthus gangeticus* L. (BARI Lalshak-1) were collected from Bangladesh Agricultural Research Institute (BARI).

Treatments used were four rates each of sewage sludge and three combinations of sewage sludge + fertilizers and three rates of fertilizer. The treatment combinations are shown in Table 1.

The whole experimental site was divided into three experimental blocks. The first block was used for sewage sludge, second for sewage sludge plus fertilizer, and the third for only fertilizer.

Required numbers of plots for the three experiments were laid in each block. Each set of plots was arranged in a completely randomized way in the respective blocks. There was a control treatment in each the blocks of the experiment. There were three replications for each treatment. Plot sizes were (3m × 3m) with intra plot spacing of 0.5 m and intra block spacing of 1 m. The total area of the experimental field was 646 $m^2$.

**Table 1. The treatments and the corresponding codes used in the field experiment.**

| Treatment | Code |
|---|---|
| Control | $S_0$ |
| Sewage sludge (1 t/ha) | $S_1$ |
| Sewage sludge (2.5 t/ha) | $S_2$ |
| Sewage sludge (5 t/ha) | $S_3$ |
| Sewage sludge (10 t/ha) | $S_4$ |
| Control | $SF_0$ |
| Sewage sludge (5 t/ha) + Fertilizer (0.5 times of the required) | $SF_1$ |
| Sewage sludge (5 t/ha) + Fertilizer (Just the required) | $SF_2$ |
| Sewage sludge (5 t/ha) + Fertilizer (1.5 times of the required) | $SF_3$ |
| Control | $F_0$ |
| Fertilizer (0.5 times of the required) | $F_1$ |
| Fertilizer (Just the required) | $F_2$ |
| Fertilizer (1.5 times of the required) | $F_3$ |

The required nutrients were calculated on the basis of soil test value interpretation (BARC 1997). The amount of nutrients were 113.88 kg N/ha, 34.59 kg P/ha and 24.64 kg K/ha. The total amount of P and K fertilizer (from TSP and MP, respectively) and 1/3 of N fertilizer (from urea) as well as sewage sludge were applied at the time of field preparation. The rest 2/3 of N fertilizer was applied in two installments: the first after 14 days and the second after 21 days of sowing. Seeds of amaranthus were sown in line in the plots one week after application of the treatments and allowed to germinate. Germination started 5 days after sowing.

The water content of the soil was maintained at about field capacity throughout the growing period of the plant through irrigation. Intercultural operations such as thinning, weeding etc. were done manually as and when required. Plants were harvested after 40 days from emergence of seedlings. Ten plants of amaranthus were sampled from the middle of each plot. All plants were uprooted and the roots and shoots were washed with deionized distilled water several times to remove free ions as well as to dislodge any adhering particles on the root surface. The plant samples were first air dried and then oven dried at 70° ± 5°C for 48 hours. The dried plant samples were then ground to pass through a 0.2 mm sieve for chemical analysis. After harvesting, soil samples from each plot were also collected and processed as mentioned earlier.

## Data recorded from the collected samples were:

a) Soil and sewage sludge: Moisture content, texture (only for soil), pH, organic matter, total N, P, K, Fe, Zn, Mn, Pb, Cd. Available N, P and K were also determined.

b) Plant: Yield, N, P, K, Fe, Zn, Mn, Pb and Cd.

Statistical analyses were done by using the software Minitab 13.0.

Physical, chemical and physiochemical properties of the soil and sewage sludge were determined following procedures as described by Imamul Huq and Alam (2005). Total Fe, Zn, Mn, Pb, and Cd contents of soil, sewage sludge and plant were extracted by digesting with the ternary acid mixture ($HNO_3$:$HClO_4$:$H_2SO_4$ at 5:2:1 ratio) and the content of these samples were estimated by Atomic Absorption Spectrometer (AAS). Selected properties of the soil and sewage sludge are presented in Table 2.

**Table 2. Some important properties of the selected soil and sewage sludge.**

| Parameters | Values | |
|---|---|---|
| | **Soil** | **Sludge** |
| Moisture (%) | 9.0 | 66.0 |
| Organic matter (%) | 1.30 | 7.97 |
| Texture | Loam | - |
| pH | 5.17 | 5.94 |
| Total N (%) | 0.13 | 0.80 |
| Total P (%) | 0.07 | 0.54 |
| Total K (%) | 0.14 | 0.22 |
| Available N (ppm) | 107.60 | 662.12 |
| Available P (ppm) | 1.44 | 316.80 |
| Available K (ppm) | 19.00 | 96.82 |
| Fe (%) | 3.06 | 2.40 |
| Zn (%) | 0.009 | 0.941 |
| Mn (%) | 0.06 | 0.08 |
| Pb (ppm) | <0.002 | 17.69 |
| Cd (ppm) | 0.68 | 2.20 |

## Results and Discussion

### Effect of sewage sludge on soil properties

Application of sewage sludge increased organic matter content in soil (Table 3). Treatment of sewage sludge alone showed a significant (p=0.034) increase of organic matter, which was 42% higher at 10 t/ha sewage sludge over control. When sewage sludge was applied along with fertilizer, the increase was only 16% higher (p=not significant). However, no change in organic matter content in soil was observed when fertilizer was applied alone.

**Table 3. Effect of sewage sludge on soil properties.**

| Treatment | OM (%) | pH | N | | P | | K | |
|---|---|---|---|---|---|---|---|---|
| | | | Total (%) | Available (ppm) | Total (%) | Available (ppm) | Total ( %) | Available (ppm) |
| $S_0$ | 1.50 | 4.87 | 0.139 | 134.47 | 0.053 | 0.72 | 0.129 | 31 |
| $S_1$ | 1.94 | 4.88 | 0.134 | 147.92 | 0.056 | 2.16 | 0.127 | 33 |
| $S_2$ | 1.79 | 5.38 | 0.121 | 188.26 | 0.065 | 5.03 | 0.131 | 26 |
| $S_3$ | 1.82 | 4.80 | 0.134 | 215.15 | 0.056 | 1.44 | 0.135 | 35 |
| $S_4$ | 2.13 | 4.76 | 0.175 | 94.13 | 0.066 | 4.31 | 0.130 | 28 |
| $SF_0$ | 1.50 | 4.87 | 0.139 | 134.47 | 0.053 | 0.72 | 0.129 | 31 |
| $SF_1$ | 1.38 | 4.91 | 0.148 | 161.36 | 0.061 | 6.47 | 0.111 | 23 |
| $SF_2$ | 1.40 | 5.16 | 0.094 | 107.58 | 0.072 | 2.16 | 0.116 | 16 |
| $SF_3$ | 1.74 | 4.88 | 0.121 | 174.81 | 0.098 | 7.04 | 0.125 | 21 |
| $F_0$ | 1.50 | 4.87 | 0.139 | 134.47 | 0.053 | 0.72 | 0.129 | 31 |
| $F_1$ | 1.55 | 4.52 | 0.175 | 147.92 | 0.051 | 6.47 | 0.127 | 21 |
| $F_2$ | 1.50 | 5.14 | 0.134 | 188.26 | 0.064 | 33.06 | 0.132 | 22 |
| $F_3$ | 1.53 | 5.29 | 0.202 | 215.15 | 0.072 | 50.32 | 0.129 | 44 |

Soil pH was not significantly affected by application of sewage sludge. However, it showed a decreasing trend (Table 3) with sewage sludge treatment although a slight increase in pH was observed at higher fertilizer application.

A significant increase in the total N content of the soil (Table 3) due to application of sewage sludge and fertilizer alone were observed (p=0.000 and 0.002 for sewage sludge and fertilizer, respectively). The total nitrogen in soil was 26% and 45% higher due to the highest rates of sewage sludge and fertilizer applications alone, respectively over their controls (LSD values for sewage sludge and fertilizer at 5% level are 0.01 and 0.03, respectively). Treatment with sewage sludge mixed with fertilizer also increased the total N content in soil but the increase was not statistically significant.

The available N content of the soil increased due to treatments of sewage sludge or sludge plus fertilizer and fertilizer alone (Table 3). The increased available nitrogen was found to be significant (p=0.000 for all the cases) for all treatments. The increase in available nitrogen was as high as about 60% compared to control when the soil was treated with sewage sludge and fertilizer alone but it was only 30% when sewage sludge was applied along with fertilizer (The LSD values at 5% level for sewage sludge, sewage sludge plus fertilizer and fertilizer were 16.10, 2.68 and 8.67, respectively).

Total P showed an increasing trend with sewage sludge application (Table 3). When applied at a rate of 10 t/ha, the sewage sludge was effective in increasing the total P content to about 25% over control; however, the overall increase in P was not found to be significant. On the other hand, application of sewage sludge along with fertilizer and fertilizer alone had a positive significant (p=0.007 and 0.046 for sewage sludge plus fertilizer and fertilizer alone, respectively) effect on total P in soil. Treatment $SF_3$ and $F_3$ showed about 85 and 36% higher P content over control, respectively. Phosphatic fertilizer could be the contributor to this significant effect (LSD value at 5% level was 0.02 for sewage sludge plus fertilizer as well as fertilizer alone also). The application of sewage sludge alone or in combination with fertilizer showed highly significant (p=0.000 for both the cases) effect on the available P content of soil. The maximum increase was observed for treatment $SF_3$. Fertilizer alone also showed similar effect (The LSD values at 5% level for sewage sludge, sewage sludge plus fertilizer and fertilizer alone were 0.54, 5.15 and 3.13, respectively).

Application of sewage sludge had no significant effect on the total K content in soil. This might be due to the fact that the sludge did not contain much K to enrich the pool of K in soil. The available K content of the soil increased significantly due to various treatments (Table 3). The application of sewage sludge and fertilizer alone increased the available K content in soil significantly (p=0.000 for both the cases). Treatment $S_3$ and $F_3$ showed the maximum increase (12.9 and 41.9% for sewage sludge and fertilizer alone, respectively) over control. On the other hand, the available K was tended to decrease with application of sewage sludge along with fertilizer (The LSD values at 5% level for sewage sludge and fertilizer alone was 3.11 and 4.07 respectively).

Iron content in the soil showed an increasing trend when sewage was applied alone or in combination with fertilizer (Table 4). However, the increase was not significant in either case.

On the other hand, application of fertilizer alone showed significant (p=0.001) decrease in the content of iron in the soil. Application of sewage sludge increased the Zn content in soil (Table 4). Zinc content was as high as about 63% when sewage sludge was applied alone and it was more than 93% when sewage sludge was applied in combination with fertilizer. The increase in Zn content due to application of sewage is plausible because sewage contains huge amount of the element. But surprisingly enough, fertilizers applied also contributed substantial amount of Zn to soil. Fertilizer alone increased the Zn content to as high as 22%. The increase in Zn content of soil was significant (p=0.001 and 0.038 for sewage sludge and sewage sludge plus fertilizer, respectively; the LSD values at 5% level were 0.0024 and 0.0052 for sewage sludge and sewage sludge plus fertilizer, respectively).

**Table 4. Effect of sewage sludge on heavy metal content in soil.**

| Treatment | Fe (%) | Zn (%) | Mn (%) | Pb (ppm) | Cd (ppm) |
|---|---|---|---|---|---|
| $S_0$ | 3.27 | 0.009 | 0.071 | <0.002 | 1.15 |
| $S_1$ | 3.37 | 0.008 | 0.072 | 1.36 | 1.89 |
| $S_2$ | 2.48 | 0.008 | 0.057 | 2.75 | 1.85 |
| $S_3$ | 3.25 | 0.014 | 0.030 | 1.97 | 1.81 |
| $S_4$ | 3.71 | 0.011 | 0.061 | 1.84 | 2.25 |
| $SF_0$ | 3.27 | 0.009 | 0.071 | <0.002 | 1.15 |
| $SF_1$ | 2.99 | 0.011 | 0.060 | 2.48 | 0.79 |
| $SF_2$ | 3.25 | 0.011 | 0.063 | 2.50 | 0.68 |
| $SF_3$ | 3.19 | 0.017 | 0.070 | 4.97 | 1.05 |
| $F_0$ | 3.27 | 0.009 | 0.071 | <0.002 | 1.15 |
| $F_1$ | 3.10 | 0.010 | 0.068 | 3.42 | 1.04 |
| $F_2$ | 2.16 | 0.008 | 0.044 | 1.97 | 1.05 |
| $F_3$ | 2.43 | 0.010 | 0.078 | 4.07 | 1.41 |

The application of sewage sludge did not have any significant effect on the changes in the content of soil Mn. There have been inconsistent changes in Mn content; in some cases the contents showed increase while in others cases it decreased. The application of sewage sludge alone showed significant (p=0.020) decrease in the content of manganese in the soil. This could be due to chelation of the metal with the organic molecules in the sludge. Besides, the sewage sludge contained a small amount of Mn. But in the case of sewage sludge plus fertilizer and fertilizer alone the change in Mn content in soil was not significant (The LSD value at 5% level was 0.024 for sewage sludge). Lead content in soil increased with the application of sewage sludge (Table 4). Lead was found to have accumulated more in soils treated with sewage sludge plus fertilizer than sewage sludge alone. This could be related to the high Pb in fertilizer (TSP – 73 ppm, MP – 27.5 ppm and Urea – 21 ppm). Moreover, sewage sludge itself contained quite high amount of Pb. Increased lead content was found to be positively significant (p=0.000 for all the cases) for all treatments (The LSD values at 5% level were 0.51, 1.19 and 0.47 for sewage sludge, sewage sludge plus fertilizer and fertilizer, respectively). Though the background level of soil cadmium was within the acceptable limit of less than 1 mg/kg, application of sewage sludge however, enriched the soil with Cd. Application of sewage sludge and sewage sludge plus fertilizer showed significant (p=0.000 and 0.006 for sewage sludge and sewage sludge plus fertilizer, respectively) increase in the content of cadmium in soil.

Application of fertilizer alone also increased the Cd content in soil but in this case the treatment effect was not significant. The contribution of fertilizer in Cd ( Cd in fertilizers: TSP- 2.18 ppm, MP – 1.75 ppm and Urea – 0.53 ppm) accumulation in soil again indicated that the fertilizer sold in the market are contaminated (The LSD values at 5% level were 0.37 and 0.24 for sewage sludge and sewage sludge plus fertilizer, respectively).

From the above observations, it is clear that the application of sewage sludge in the soil as soil ameliorator changed the nutritional status of the soil. The organic matter was also increased with the treatment of sewage sludge alone as well as mixed with fertilizer. As the fertilizer did not show any effect on organic matter the increase was obviously due to application of sewage sludge. The soil pH tended to decrease due to the application of sewage sludge. Total N and P were increased due to the application of sewage sludge but it performed better when sewage sludge was applied along with fertilizer. There was no effect on the total K in soil. However, the available N, P and K in soil were increased with the application of sewage sludge alone as well as in combination with fertilizer. Moreover, the application of sewage sludge significantly changed the content of zinc, manganese, lead and cadmium content in soil. The accumulation of Pb and Cd in soil is considered a negative aspect of the use of sewage sludge in soil. However, the inorganic fertilizers that were used also contributed to these heavy metals in the soil. Thus, sewage sludge cannot be singled out as the only contributor to addition of these heavy metals in soil. The sewage sludge thus, could be used as an effective soil ameliorator.

However, the increase of Pb and Cd in soil, albeit not highly elevated, needs to be assessed in relation to their entry into the crop grown on sewage ameliorated soil, as it might become a concern for food chain contamination.

## Response of plant

### Growth and yield

The growth of amaranthus as affected by different treatments of sewage sludge was observed during the experimental period. The plants responded positively to all the treatments compared to the control. The poor growth of the plant in the control plots confirmed the poor nutritional status of the soil. Application of sewage sludge increased the yield of amaranthus (Table 5). Maximum yield was obtained in $S_3$ treatment where the increase was more than 3.52 times over control. However, when sewage sludge was mixed with fertilizer, the yield increase was much higher in all the treatments. At $SF_3$, the yield showed 18.49 fold increases over control. Thus the effect of sewage sludge mixed with fertilizer performed the best in producing yield of amaranthus whereas the fertilizer alone performed better than the sewage sludge alone. The effect of all the treatments on the growth of amaranthus was significant ($p=0.005$, 0.011 and 0.001 for sludge, sludge plus fertilizer and fertilizer alone, respectively; the LSD values at 5% level were 4.36, 22.28 and 13.77 for sewage sludge, sewage sludge plus fertilizer and fertilizer alone, respectively, on the production of yield).

## Plant nutrient and heavy metal concentration

Plant nitrogen content was increased with the application of sewage sludge (Table 5). The sewage sludge mixed with fertilizer performed the best than sewage sludge and fertilizer alone. With sewage sludge plus fertilizer, N content in plants was the highest in treatment $SF_2$, (35% higher than control). The increased N content was significant (p=0.036 for sewage sludge and p=0.00 for sludge plus fertilizer and fertilizer alone) for all the cases (The LSD values at 5% level were 0.45, 0.18 and 0.19 for sewage sludge, sewage sludge plus fertilizer and fertilizer alone, respectively). It has been reported that nitrogen uptake increased with increasing rates of sewage sludge in rice plants (Tamura *et al.* 1988), in wheat straw and grains (Gupta *et al.* 1989, 1993). Application of sewage sludge showed a significant positive effect on the phosphorus content of the plant (Table 5).

**Table 5. Effect of sewage sludge on yield and NPK content of amaranthus.**

| Treatment | Yield (t/ha) | N (%) | P (%) | K (%) |
|---|---|---|---|---|
| $S_0$ | 2.36 | 3.33 | 0.35 | 3.88 |
| $S_1$ | 3.33 | 3.04 | 0.30 | 3.84 |
| $S_2$ | 2.73 | 3.62 | 0.44 | 3.79 |
| $S_3$ | 10.67 | 3.46 | 0.44 | 3.43 |
| $S_4$ | 8.00 | 3.77 | 0.52 | 3.84 |
| $SF_0$ | 2.36 | 3.33 | 0.35 | 3.88 |
| $SF_1$ | 31.33 | 3.39 | 0.56 | 4.37 |
| $SF_2$ | 34.67 | 4.5 | 0.58 | 3.60 |
| $SF_3$ | 46.00 | 4.33 | 0.68 | 3.21 |
| $F_0$ | 2.36 | 3.33 | 0.35 | 3.88 |
| $F_1$ | 19.33 | 3.40 | 0.49 | 3.31 |
| $F_2$ | 32.67 | 4.10 | 0.57 | 3.95 |
| $F_3$ | 38.67 | 4.17 | 0.65 | 3.16 |

The effect was best for sludge plus fertilizer which caused 92.37% increase in the plant P at $SF_3$ as compared to control. However, the application of sewage sludge at the rate of 10t/ha contributed to 45.48% increase in P at $S_4$, whereas the application of fertilizer alone in $F_3$ showed 84.18% increase of plant P as compared to control (The LSD values at 5% level were 0.13, 0.12 and 0.11 for sewage sludge, sewage sludge plus fertilizer and fertilizer, respectively). Application of sewage sludge had no significant effect on plant potassium. There was no significant effect of sewage sludge on Fe content in the plant. In some cases the Fe content in the plants decreased and in some cases it increased (Table 6). Some work indicated that sewage sludge increased iron accumulation in corn (Hinesly *et al.* 1972) and in various vegetables (Paulraj and Ramulu 1994). Zinc content in plant increased with application of sewage sludge (Table 6). With increasing treatments of sewage sludge and sewage sludge plus fertilizer, the content of zinc increased in most of the cases though not significant for any of the cases. It has been reported that the application of sewage sludge increased Zn uptake in vegetables (Chu and Wong 1987, Paulraj and Ramulu 1994) and in corn (Hinesly *et al.* 1972, Mullins *et al.* 1986).

Application of sewage sludge also increased the Mn content in plants (Table 6). The treatment effect was only significant (p=0.047) when sludge was applied alone. In the case of sewage sludge plus fertilizer treatment effect was not significant. Uptake of lead by the plants was influenced by the application of sewage sludge as well as fertilizer. The maximum accumulation of Pb has been observed for fertilizer alone substantiating again the presence of Pb in the fertilizer. The accumulation of Pb in plant was lower in case of sludge plus fertilizer compared to sludge or fertilizer alone. The effect of sewage sludge on the accumulation of lead in plants was highly significant (p=0.00 for all the cases). The LSD values at 5% level were 1.10, 1.37 and 9.01 for sewage sludge, sewage sludge plus fertilizer and fertilizer respectively. Increase in lead uptake by crops and vegetables due to application of sewage sludge have been reported by Hinesly *et al.* 1972, and Paulraj and Ramulu 1994. The application of sewage sludge increased significantly the cadmium content in plant (p=0.014). Fertilizer treatment alone also had a significant (p=0.031) effect in the Cd accumulation in plant. Treatment $S_3$, $SF_3$ and $F_3$ showed 64.10, 86.32 and 104.37% increase of Cd content in the plant respectively (The LSD values at 5% level were 0.46 and 0.80 for sewage sludge and fertilizer respectively). In the case of sewage sludge plus fertilizer treatment effect was not significant.

**Table 6. Effect of different treatments on heavy metal content in amaranthus.**

| Treatment | Fe (%) | Zn (%) | Mn (%) | Pb (ppm) | Cd (ppm) |
|---|---|---|---|---|---|
| $S_0$ | 0.21 | 0.028 | 0.015 | <0.002 | 1.17 |
| $S_1$ | 0.26 | 0.027 | 0.015 | 6.00 | 1.22 |
| $S_2$ | 0.14 | 0.033 | 0.012 | 6.85 | 1.81 |
| $S_3$ | 0.11 | 0.041 | 0.027 | 8.42 | 1.92 |
| $S_4$ | 0.09 | 0.038 | 0.021 | 21.43 | 1.52 |
| $SF_0$ | 0.21 | 0.028 | 0.015 | <0.002 | 1.17 |
| $SF_1$ | 0.17 | 0.028 | 0.015 | 5.00 | 1.77 |
| $SF_2$ | 0.20 | 0.022 | 0.014 | 7.73 | 1.93 |
| $SF_3$ | 0.13 | 0.033 | 0.017 | 8.08 | 2.18 |
| $F_0$ | 0.21 | 0.028 | 0.015 | <0.002 | 1.17 |
| $F_1$ | 0.23 | 0.023 | 0.014 | 35.50 | 1.29 |
| $F_2$ | 0.18 | 0.017 | 0.011 | 54.74 | 1.72 |
| $F_3$ | 0.21 | 0.018 | 0.018 | 65.03 | 2.39 |

From the above observations it is clear that the application of sewage sludge significantly increased the yield of amaranthus and the content of nitrogen and phosphorus in plants increasing the nutritional value of the crop. Lead, cadmium and manganese contents were also increased. When sewage sludge was applied along with fertilizer, it showed significant change in the yield of amaranthus and the content of nitrogen, phosphorus and lead. Whereas application of fertilizer alone not only significantly increased the yield of amaranthus but also increased the accumulation of nitrogen, phosphorus, lead, cadmium, zinc and manganese due to the presence of these elements in fertilizer. The contribution of fertilizer in the accumulation of these metals was further substantiated by the accumulation of these elements when fertilizer was applied alone.

Sewage sludge significantly contributed to the accumulation of some heavy metals in plant when it was applied singly but when it was applied along with fertilizer the effect was not significant. Considering the growth of the plant, the yield, nutrient content as well as the heavy metal accumulation in soil and in plant it was observed that sewage sludge produced at Pagla sewage treatment plant is no inferior than the commercial fertilizers used, rather it has an added advantage of supplying organic matter. It appears thus that the sewage sludge from the Pagla sewage treatment plant could be an effective soil ameliorator when supplemented with other inorganic fertilizer. Further research with more crops are needed to make any recommendation on the commercial use of this sludge.

## Acknowledgment

The authors wish to acknowledge the support rendered by the Dhaka WASA authority during the course of this research work.

## References

Adani F and Tambone F. 2005. Long-term effect of sewage sludge application on soil humic acids. ***Chemosphere*. 60(9): 1214-1221.**

Adriano D C 1986. ***Trace elements in the terrestrial environment*,** Springer-Verlag, New York. pp 1-533.

BARC 1997. ***Fertilizer Recommendation Guide-1997.*** (M M Rashid, M Idris Ali, N I Bhuiyan, A K M Hossain, F Huq, A B Talukder, G M Panaullah, M Nuruzzamzn, and M U Miah Eds.) BARC Soil Publication no. 41. Published by the BARC, Dhaka.

Chu L M and Wong M H. 1987. Heavy metal contents of vegetable crops treated with refuse compost and sewage sludge. ***Plant and Soil*. 103: 191-197.**

Chua H. 1999. Overview of water environment properties in Hong Kong (China). ***J. Water Science and Technology*. 40(2): 91-96.**

Gupta A P, Narweal R P and Antil R S. 1989. Effect of different levels of phosphorus and sewage sludge on wheat. ***J. Indian Soc. Soil Sci.* 37: 576-578.**

Gupta A P, Narweal R P and Antil R S. 1993. Effect of different levels of phosphorus and sewage sludge on wheat. ***J. Indian Soc. Soil Sci*. 41(2): 304-307.**

Heckman J R, Angle J S and Chaney R L. 1987. Residual effects of sewage sludge on soybean: Accumulation of heavy metals. ***J. Environ. Qual*. 16: 113-117.**

Hinesly T O, Robert L, Jones and Ziegler E L. 1972. Effects on corn by applications of heated anaerobically digested sludge. ***Compost Sci*. 13: 26-30.**

Imamul Huq S M and Alam M D (Eds.). 2005. ***A Handbook on Analyses of Soil, Plant and Water*.** BACER-DU, University of Dhaka, Bangladesh.

Jeevan Rao K and Shantaram M V. 1999. ***Soil contamination due to urban solid waste.*** In: Aggarwal B S, Dureja P and Dikshit A K. Eds.) Second International Conference on Contaminants in the Soil Environment in the Australia-Pacific Region.12-17 December 1999, New Delhi, India. pp 9-10.

Mullins G L, Sommers L E and Barber S A. 1986. Modeling the plant uptake of cadmium and zinc from soil treated with sewage sludge. ***Soil Sci. Soc. Am. J.*** **50: 1245-1250.**

Paulraj C and Ramulu S. 1994. Effects of soil application of low levels of urban sewage sludge on the uptake of nutrients and yields of certain vegetables. ***J. Indian Soc. Soil Sci.*** **42(3): 485-487.**

Pilevski J and Mull R. 1999. Sustainable use of sewage sledges from sewage plants as fertilizer. ***Z. für Kulturtechnik und Landentnicklung.*** **40(4): 159-162.**

SRDI. 1965. ***Reconnaissance Soil Survey Report: Dhaka District, Soil Resource Development Institute.*** Ministry of Agriculture. Govt. of Bangladesh. pp 72-76.

Tamura Y, Takeuchi M and Seino K. 1988. Effects of application of sewage sludge compost on paddy rice growing in cool regions of Japan. Bulletin of the Tohoku national agricultural experiment station, Japan. ***Tohoku-Nogyo Shikenjo Kenkyu Hokohu.*** **78: 139-153.**

USDA. 1951. ***Soil Survey Manual*** by Soil Survey Staff. Bureau of Plant Industry. Soil and Agricultural Engineering. Handbook No. 80: pp 503.

Yingming L and Corey R B. 1993. Redistribution of Sludge-Borne Cadmium, Copper, and Zinc in a Cultivated Plot. ***J. Environ. Qual.*** **22: 1-8.**