

## Impact of textile sludge on the growth of red amaranth (*Amaranthus gangeticus*)

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### Abstract

**Purpose** In Bangladesh, the sludge of textile effluent treatment plant has been considered as a potential environmental threat due to its huge volume and chemical content. Thus, the present study was carried out to assess the reuse possibility/potentiality of textile sludge in agricultural applications.

**Method** Textile sludge was applied at different loading ratios (0–100 % sludge) with soil for the pot cultivation of red amaranth (*Amaranthus gangeticus*); subsequently, chemical analyses were carried out on the harvested plants.

**Results** The results showed that the content of plant nutrients nitrogen (N), phosphorus (P), potassium (K) and iron (Fe) in sludge was significant compared to organic manure along with a high content of total organic carbon (TOC). The growth parameters (height, number of leaves, leaf area and root length) of red amaranth were affected by the application of textile sludge. Maximum plant growth

was observed in the 100 % sludge treatment group, maybe because of the high content of plant nutrients. However, the root length and number of leaves were not significantly affected by the sludge. The plant analyses implied that addition of textile sludge did not increase the content of copper (Cu), cobalt (Co), cadmium (Cd), nickel (Ni) and manganese (Mn), but lead (Pb), chromium (Cr), zinc (Zn) and iron (Fe) content crossed the maximum permissible limit set by FAO/WHO.

**Conclusion** Textile sludge can improve the nutrient contents of pot soil and growth of red amaranth, which is revealed by pot experiments. Therefore, it can be used as soil improver if Pb, Cr, Zn and Fe content can be controlled in the textile sludge.

**Keywords** Fertilizer · Heavy metals · Nutrients · Plant growth · Red amaranth · Solidification · Textile sludge

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## Introduction

The textile and dyeing industries are now viewed as a major environmental threat in Bangladesh because of the presence of highly toxic dyes, salts, acids, alkalis bleaching agents and heavy metals such as Cd, Cu, Zn, Cr and Fe (Islam et al. 2009; Mathur et al. 2005). This industrial sector is one of the largest consumers of water as well as the biggest producers of wastewater. In Bangladesh, different industries have emerged in the last decade producing huge volumes of effluents and about 28 % are textile and dyeing industries (Shammi et al. 2014). According to the Bangladesh government rules, every industry has an effluent treatment plant. The plants are not generally operated because of the high cost involved in treating effluents, as a result they discharge the untreated effluent to the outside environment which ultimately negatively affects human beings (Hossain et al. 2010, 2015).

During the past two decades, the reuse of treated or untreated wastewater in irrigation has been quite common in Europe, the USA, Mexico, Australia, China, India and the Near East and, to a lesser extent, in Chile, Peru, Argentina, the Sudan and South Africa (Bartone and Arlosoroff 1987). Industrial wastewater has also been considered as a threat to the environment in Bangladesh. Researchers are looking for suitable management options for industrial wastewater, such as reuse of gamma-irradiated textile wastewater for the growth of plants (Parvin et al. 2015). Hossain et al. (2015) used untreated industrial effluent as irrigation water for rice production, and the accumulation of heavy metals into rice plants with subsequent reduction of plant growth/yield parameters was confirmed. Another scientist applied filtered municipal wastewater for the irrigation of red amaranth to assess the feasibility of its use for agricultural purposes (Biswas et al. 2015).

However, another new problem was created, that is, along with wastewater there is another vital portion of waste, i.e., sludge. In conventional wastewater treatment processes, sludge is inevitable. The volume characteristics and contaminant loading of textile sludge varies with the treatment processes as well as raw materials used in the production processes (Islam et al. 2009). In addition, some studies have reported that the textile sludge is rich in organic compounds and plant nutrients (Teixeira et al. 2007; Hue 1995) and has the potentiality to improve soil properties, as it contains many plant nutrients such as N, P and K and could be an alternative to chemical fertilizers in agriculture (Luostarian et al. 2008; Gupta and Garg 2008; Casado-Vela et al. 2006). Although the production of textile sludge in Bangladesh is very high, there are very few sludge treatment plants. According to the Waste Concern report in (2009), the

production of sludge was 36.39 million metric tons/year in 2012 in Bangladesh. Waste Concern and ADB 2009 also performed a future projection, which indicated that the amount of sludge will continue to increase with increasing industrialization in Bangladesh in the near future. Moreover, untreated sludge contains harmful elements which can easily accumulate into the plants and ultimately enter into the food chain. Thus, sludge management is becoming an unavoidable problem and in the near future the situation will be much more critical in developing countries like Bangladesh. Considering the above circumstances, the reuse potentiality of nutrient containing textile sludge (i.e., TOC, N, P, K, Br, Mn, Cu and Zn) is becoming an emerging field of study. The present study was conducted aiming to investigate the possibility and potentiality of textile sludge as a soil conditioner/fertilizer to cultivate a very popular leafy vegetable, red amaranth, in Bangladesh.

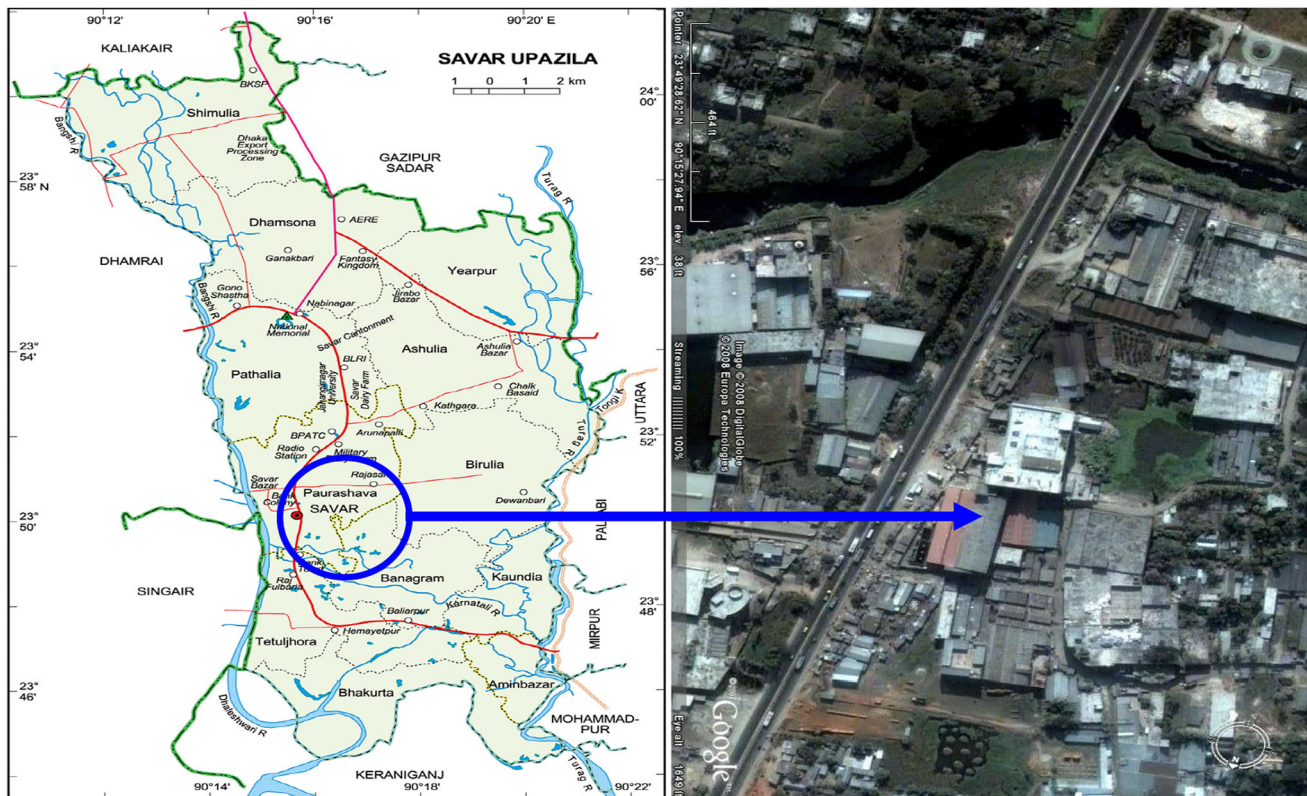
## Materials and methods

### Sample collection

The sample sludge was collected from Halimur Rahman (H.R.) Textiles Mills Ltd., which is located at Kornapara, Savar upazilla, Dhaka, Bangladesh (23°49'31" N and 90°15'27.72" E) (Fig. 1). This textile mill has effluent treatment plants where the wastewater is treated chemically and partially biologically, but they do not have a sludge treatment facility. The sludge was kept for several days/months for sun drying and finally throw into a landfill site or any low land.

### Sludge characterization

The effluent treatment plant of H.R Textile Mills Ltd. is operated by a chemical treatment method, which is followed by activated sludge process. The processes of treatment are homogenization, bar screening, equalization, chemical reaction, neutralization, aeration and finally round head clarifying. The clarifier is the main source of sludge that is collected in sludge pits; then it is allowed to mechanically/sun dry before disposal. The sludge used for this study was collected from the sludge drying bed after complete dewatering. The collected sludge is taken to a laboratory to analyze the physical and chemical properties. TOC, total nitrogen (TN), nitrate-nitrogen (NO<sub>3</sub>-N), phosphate-phosphorus (PO<sub>4</sub>-P), K, Na, Mg, Ca and heavy metal concentrations were measured by following the standard methods described in APHA-AWWA-WEF (1998). The percent of sodium and sodium absorption ratio (SAR) were calculated using the following equations:



**Fig. 1** Location of the H.R Textile Mills Ltd. at Savar upazilla, Dhaka, Bangladesh

$$\text{Percentage of Na} = \frac{[\text{Na}] \times 100}{[\text{Na}] + [\text{K}] + [\text{Ca}] + [\text{Mg}]}, \quad (1)$$

$$\text{Sodium absorption ratio (SAR)} = \frac{[\text{Na}] \times 100}{\sqrt{\frac{[\text{Ca}] + [\text{Mg}]}{2}}}, \quad (2)$$

where the concentrations of the ions are expressed in meq/L (Suaraz 1981). All the used chemicals were of analytical grade.

pH and electric conductivity (EC) of the textile sludge sample were determined with a glass electrode (Hanna pH meter, USA) and conductivity instruments EC meter (Model: HANNA, EC 241, Conductivity meter). Collected sludge samples were dried in an oven at about 100 °C for 8 h and then repeatedly ground and dried until a constant weight was obtained. The dried samples were powdered and sieved through a 0.5 mm sieve. The samples were carefully labeled in a ziplocked polybag and kept for analysis at room temperature.

Total organic carbon (TOC) was measured by titrimetric method according to Walkley and Black (1934), and the wet oxidation method as described by Jackson (1973). Kjeldahl distillation method was employed for measurement of total nitrogen. Nitrate-nitrogen and phosphorus were determined by UV-spectrophotometer (Model: UV-1800, SHIMADZU).

K, Na, Ca, Mg and extractable heavy metals (Ni, Zn, Cu, Pb, Cd, Cr, Hg, Mn, Fe) were measured by flame atomic absorption spectrometer (FAAS) (Model: Varian AA240FS) after microwave digestion.

### Plant selection and pot preparation

Red amaranth (*Amaranthus gangeticus*) is a popular leafy vegetable in Bangladesh and widely consumed for its nutritional value. In addition, it has a short harvest time with very fast growth. The sun-dried sludge was ground and mixed with soil at four ratios (0, 50, 75 and 100 %) of sludge with soil and each pot was loaded with a total of 4 kg soil/soil–sludge mixture. The 0 % sludge containing pot, i.e., pot filled with only soil, was also used as positive control to compare the impact of different ratios of sludge on red amaranth. The three replications were prepared for each treatment and a total of 12 pots were placed inside a transparent shade to protect the plants from rain and ensure proper sunlight at the Department of Environmental Sciences, Jahangirnagar University, Dhaka, Bangladesh. For irrigation, an equal volume (0.5 L per day) of freshwater was applied to each pot in the morning. Under these controlled conditions, plants were grown for 50 days until their harvest. During this period, no additional sludge was

applied and the height, number of leaves and leaf area were counted at every 10 days interval. After 50 days, the plants were harvested carefully and taken to the laboratory for further analyses. Then the plants were washed with water and dried in an oven at 100 °C temperature and weighed carefully. The method of measurement of plant morphology was carried out according to the method used by Dolgen et al. (2004).

Statistical analyses were done using one-way ANOVA followed by Turkey's post hoc test at a 0.05 significant level to understand the effects of different sludge loading on the height, number of leaves, leaf area and root length. The R version 3.2.2 software was used to perform all the statistical analyses.

## Results and discussion

### Physico-chemical properties of textile sludge and pot soil

The important physico-chemical properties of textile sludge and pot soil were analyzed to assess the status of sludge compared to the pot soil (Table 1). The pH is very important for soil fertility, as it can affect the bioavailability of soil nutrients. Most of the essential plant nutrients are soluble at pH 6.5–6.8 and the optimum pH for normal plant growth is 6.9 (Hussain et al. 1995). In the present study, for both soil (6.3) and sludge (6.9), the pH was in tolerable range and acidic in nature. The standard pH of irrigation water recommended by the FAO is 6.5–8.4 (Ayers and Westcott 1985).

Another important physical property is soil moisture content; according to the Ministry of Agriculture of

Bangladesh the minimum range of moisture content in organic fertilizer should be 15 % (BARC 1997). The average moisture content in the studied raw textile sludge was 80 %.

The concentration of total N (TN) in textile sludge and soil was 0.47 and 0.002 %, respectively. The very high concentration of TN in textile sludge may be due to the use of azo dyes in textile production processes. Other than TN, P is one of the most important nutrient elements for agricultural production in most of the agricultural regions of the world (Holford 1997; Kogbe and Adedirán 2003). P-deficient plants, therefore, are stunted with a limited root system and thin stems (0.63 % in sludge), and K ( $4066 \pm 4.1$  mg/kg) is needed in large quantities by many crops as indicated by Hua et al. (2008). The visual K deficiency symptom is the scorching or firing along leaf tips and margins (Bergmann 1992; Perrenoud 1993; Singh and Trehan 1998).

The content of TOC (35 %) in textile sludge was higher than that in pot soil (Table 1). The Na concentration of textile sludge did not seem far above the tolerance limit. If Na concentration was higher in textile sludge, it can be minimized by mixing with soil to avoid its effect on plant (Dolgen et al. 2004). In Bangladesh, textile sludge has been studied for its reuse potentiality. For example, Islam et al. (2009) have already studied the plant nutrient and organic matter contents in textile sludge in Gazipur, Bangladesh, and he concluded that textile sludge can supply small, but significant amount of plant nutrients. In addition, Biswas et al. (2015) used filtered municipal wastewater for irrigation purposes and found that plant treated with filtered municipal water (sand, wood, charcoal and rice husk brick chips) showed significantly higher growth with regard to height and number of leaves, as well as heavy metal

**Table 1** The physico-chemical properties of textile sludge and soil

Parameters	Textile sludge (average)	Soil (average)
pH	6.9	6.3
Electric conductivity	0.04 (after 1:100 dilution)	0.08
Moisture content	80 %	50 %
Total organic carbon (TOC)	35 %	0.94 %
Total nitrogen (TN)	0.47 %	0.002 %
Nitrate-nitrogen	2532.9 (mg/kg)	4140.7 (mg/kg)
Total phosphorus	0.63 %	0.40 %
Sulfur (S)	0.0013 %	0.10 %
Sodium (Na)	$3634.1 \pm 10.9$ mg/kg	$565.5 \pm 11.4$ mg/kg
Potassium (K)	$4066 \pm 4.1$ mg/kg	$1780.3 \pm 32.1$ mg/kg
Calcium (Ca)	$20565.3 \pm 246.1$ mg/kg	$3478.6 \pm 80.1$ mg/kg
Magnesium(Mg)	$4634 \pm 9.3$ mg/kg	$6353 \pm 31.8$ mg/kg
SAR	5.9 meq/L	1.3 meq/L
% Sodium (Na)	11.1 %	4.6 %

SAR sodium absorption ratio

**Table 2** Comparison of macronutrients composition of some commonly used chemical fertilizers (BARC 1997) and textile sludge (%)

Name of the organic manure and chemical fertilizer	N (%)	P (%)	K (%)	S (%)
Cow dung	0.5–1.5	0.4–0.8	0.5–1.9	–
Poultry manure	1.6	1.5	0.85	–
Farmyard manure	0.5–1.5	0.4–0.8	0.50–1.9	–
Compost	0.4–0.8	0.3–0.6	0.70–1.0	–
Urea	46	–	–	–
Ammonium sulfate	21	–	–	24
Triple superphosphate	–	20	–	1.3
Muriate of potash	–	–	50	–
Potassium sulfate	–	–	42	18
Gypsum	–	–	–	18
Superphosphate	–	8	–	–
Diammonium phosphate	18–21	20	–	1
Textile sludge	0.47	0.63	0.40	0.001

BARC Bangladesh Agricultural Research Council

accumulation rate was also within allowable limits. However, Pb and As exceeded their allowable limits.

From the characterization of textile sludge and soil, it was revealed that the textile sludge contained significant amount of different plant macronutrients (N, P and K). The concentration of NPK in organic manure as evaluated by the Bangladesh Agricultural Research Council (BARC 1997) is nearly similar to the NPK value (0.47, 0.63 and 0.40 %) found in the textile sludge (Table 2).

The most commonly used phosphate fertilizers such as Triple superphosphate (20 %), superphosphate (8 %) and diammonium phosphate (20 %) contain a high concentration of P. Similarly, muriate of potash (50 %) and potassium sulfate (42 %) contained a high concentration of K. The percentage of P and K were 0.63 and 0.40 % in textile sludge which was much lower than the percentages in the respective chemical fertilizers. The amount of S in the textile sludge sample was found to be 0.001 %, lower than the amount of S in chemical fertilizers such as triple superphosphate and diammonium phosphate. Moreover, compared to some commonly used N-containing chemical fertilizers such as urea (46 %), ammonium sulfate (21 %) and diammonium phosphate (18–21 %), which contained extremely higher concentrations of N, textile sludge was found to be low in TN content (0.47 %). Therefore, it can be concluded that according to the comparison of macronutrient content, textile sludge is more similar to organic manure due to the above-mentioned properties.

Heavy metals are very harmful because of their non-biodegradable nature, long biological half-lives and their potentiality to accumulate in different body parts (Manahan 2005; Wilson and Pyatt 2007). Excessive accumulation of heavy metals in agricultural soils through wastewater irrigation may not only result in soil contamination, but also

**Table 3** Heavy metal concentration of textile sludge and soil

Name of heavy metals	Textile sludge, (mg/kg)	Soil (control), (mg/kg)	Maximum allowable limit in soil (mg/kg) (USEPA 1983)
Ni	10.3 ± 1.7	34.1 ± 2.5	40
Zn	367.1 ± 9.2	40.8 ± 0.2	50
Cu	164.1 ± 2.3	22.2 ± 0.1	30
Pb	9.7 ± 0.6	9.3 ± 0.2	10
Cd	0.3 ± 0.0	0	0.06
Cr	17.7 ± 1.40	15.8 ± 1.0	100
Mn	122.9 ± 4.9	382.6 ± 42.1	600
Fe	4245 ± 229.2	19986.9 ± 317.8	–
Co	1 ± 0.5	0	8

affect food quality and safety (Muchuweti et al. 2006). Some researchers have also confirmed that heavy metals such as Cd, Pb, Cu, Zn and Ni have carcinogenic or toxic effects on human beings and environment (Trichopoulos 2001; Turkdogan et al. 2002; Kocasooy and Sahin 2007). The concentration of heavy metals in textile sludge and soil are shown in Table 3. The results revealed that the metal content, except for Zn and Cu, in the textile sludge was lower than the allowable limits stated by the USEPA (United States Environmental Protection Agency) (1983). Dolgen et al. (2004) indicated that a high amount of Zn and Cu has no significant effects on plant growth. Heavy metal concentration in soil was also within the maximum allowable limit and was used for plant growth.

From the results of this study, the tolerable limit of heavy metals as well as the high content of OM, P, Mg and K in textile sludge indicates significant potentiality of its use as a soil quality improver.



### Effects of textile sludge on the growth parameters of red amaranth

The mean value of height, numbers of leaves, leaf area and root length of red amaranth for four treatments are presented in Table 4. The statistical analyses on the growth parameter of plants due to different sludge loadings are given in Table 5.

The average plant height was significantly higher after 50 days in 100 % sludge treatment (18.5 cm) and was statistically identical to 75 % sludge treatment (18 cm). However, both 100 % and 75 % sludge treatments were significantly different from the control or 0 % sludge (16.0 cm) and 50 % sludge (15.5 cm).

Regarding the number of leaves, the average number of leaves was the highest at 100 % sludge (average 9 leaves per pot), but all the treatment were statistically insignificant. The number of leaves in 0, 50 and 75 % sludge were 7.8, 8 and 8.3 leaves (average) per pot.

The significantly maximum leaf area was also found at 100 % sludge treatment (29 cm<sup>2</sup>) after 50 days and was significantly different from the control or 0 and 75 % sludge plant (26 and 21.8 cm<sup>2</sup>, respectively). 50 % sludge (25.5 cm<sup>2</sup>) was significantly identical to the 100 % sludge plant.

No significant differences were found regarding root length among all the treatments (Table 5) However, 100 % sludge treatment showed maximum root growth, i.e., average 5.9 cm root length after 50 days. Comparatively, 50 and 75 % sludge treatment showed minimum growth regarding the root length. The average values of root lengths at 50 and 75 % sludge were 4.1 and 4.8 cm, respectively.

From the growth parameter, it can be confirmed that plant growth rate was influenced by sludge loading; however, some of the parameters remained similar for all of the treatments (number of leaves and root length). Considering a growth rate of 100 % sludge plant, it can be assumed that sludge might have similar potentiality as wastewater in agricultural application. Several studies have already indicated that wastewater from different sources contain considerable amounts of organic matter and plant nutrients (N, P, K, Ca, S, Cu, Mn and Zn) and has been reported to increase the crop yield (Lubello et al. 2004; Nagajyothi et al. 2009; Nath et al. 2009; Pathak et al. 1999; Ramana et al. 2002). Another scientist, Tabassum et al. (2013) reported that wastewater application not only increased the leaf number, leaf area, plant dry matter, photosynthetic rate, total chlorophyll content, 1000 seed weight and seed yield, but also served as an extra dose of fertilizer. Therefore, we can benefit by saving freshwater as well as fertilizer. In this study, it was found that the 100 % sludge treatment group had maximum height, number of leaves, leaf area and root length compared to the control group.

**Table 4** Effects of sludge loading on the height, numbers of leaves, leaf area and root length of red amaranth

Sample	10 days			20 days			30 days			40 days			50 days			
	Height (cm)	No. of leaves (avg.)	Leaf area (cm) <sup>2</sup>	Height (cm)	No. of leaves (avg.)	Leaf area (cm) <sup>2</sup>	Height (cm)	No. of leaves (avg.)	Leaf area (cm) <sup>2</sup>	Height (cm)	No. of leaves (avg.)	Leaf area (cm) <sup>2</sup>	Height (cm)	No. of leaves (avg.)	Leaf area (cm) <sup>2</sup>	Avg. root length (cm/pot)
0 % sludge	3.8	3	1.4	5.3	5.8	10.4	11.1	7.3	15.6	15.4	7.8	20.8	16	7.8	26	5.1
50 % sludge	3.5	2.5	1.2	4.6	5.5	11.2	10.5	7	16.8	14.5	8.0	22.4	15.5	8.0	28	4.1
75 % sludge	3.6	3.0	1.0	5.5	5	8.5	11.6	7	12.8	17	8.2	17	18	8.2	21.8	4.8
100 % sludge	3.8	3	1.5	5.8	6.3	11.6	14.8	8.5	17	17.3	9	23	18.5	9	29	5.9

**Table 5** Statistical results of the growth of red amaranth

Treatment	Height (cm)	No. of leaves	Leaf area (cm <sup>2</sup> )	Root length (cm)
0 % sludge	16d	7.75a	26bc	5.1a
50 % sludge	15.5c	8.0a	28ac	4.1a
75 % sludge	18.0ab	8.2a	21.8b	4.8a
100 % sludge	18.5ab	9.0a	29.0a	5.9a
Level of significance	**	NS	**	NS

NS not significant

\*\* Significance at 1 % level of probability

### Heavy metal uptake by red amaranth

Heavy metal uptake by red amaranth plants was also determined. Metal concentrations in the studied plants are given in the Table 6.

The ranges of Ni, Zn, Cu, Cr, Mn, Fe and Pb accumulation were  $3.6 \pm 3.1$  to  $12.2 \pm 3.1$ ,  $26.6 \pm 7$  to  $241.1 \pm 185.4$ ,  $0.31 \pm 0$  to  $15 \pm 2.5$ ,  $93.9 \pm 2.9$  to  $236.8 \pm 22.2$ ,  $1386.6 \pm 112.9$  to  $3204.2 \pm 253.3$  and  $1.1 \pm 0.9$  to  $2 \pm 0.9$ , respectively. Nowadays, the presence of heavy metals in daily life as well as in wastes is inevitable. The harmful effects of heavy metals to the environment and organisms are well reported and it has been a matter of great concern among the scientific societies. From the result, it was found that the heavy metal concentration in plants was higher than in the control group, except for Ni and Fe. Concentrations of metals such as Ni, Mn, Cd and Cu were found to be within the safe limit; however, Pb, Cr, Zn and Fe exceeded the permitted limit according to FAO (2007). The maximum allowable limits (MLs) of Cd and Pb from FAO/WHO have been used to discuss the results. According to the Codex Alimentarius Commission (2001), 0.2 and 0.3 mg/kg are MLs concentrations of Cd and Pb for leafy vegetables. Red amaranth of any sludge-loaded pot did not contain Cd, maybe because a higher pH value (more than 6.5) does not

allow heavy metals to dissolve in soil (Fisseha 1998). However, the studied textile sludge contained Pb, which is viewed in plants and exceeded the allowable limits. The concentration of Pb in red amaranth was found to exceed the maximum limit (0.3 mg/kg). The 100, 75 and 50 % sludge treatment plants contained almost the same amount of Pb, i.e.,  $1.8 \pm 0.5$ ,  $2 \pm 0.9$  and  $1.9 \pm 0.7$  mg/kg, respectively (Table 6), where 0 % sludge plant contained  $1.1 \pm 0.9$  mg/kg. The Pb concentration was found to be ( $1.587 \pm 0.01$  mg/kg) in red amaranth, ( $1.527 \pm 0.02$  mg/kg) in spinach and ( $1.957 \pm 0.05$  mg/kg) in amaranth by Naser et al. (2012). These values are nearly similar to the Pb content in 0, 50, 75 and 100 % sludge plants. Perhaps, the sources of Pb are dyes used in the textile industry. The concentration of Ni in red amaranth loaded with 0, 50, 75 and 100 % did not exceed the maximum limit (67.9 mg/kg) according to Weigert (1991). The possible sources of Ni in sludge are the dyes, paints and coated steel pipes used in industry. Zn has significant impact on growth and yield of red amaranth. The maximum limits of Zn are 99.4 mg/kg (Weigert 1991). The concentration of Zn was higher in 100 % sludge plants, i.e.,  $241.1 \pm 185.4$  mg/kg than 75 % sludge plants, i.e.,  $168.4 \pm 65$  mg/kg. However, Zn concentration of 50 % sludge plant ( $73.6 \pm 45$  mg/kg) did not exceed the maximum limits. Higher concentrations of Fe were found in 50 % ( $3204.2 \pm 253.3$  mg/kg) and 75 %

**Table 6** Heavy metal concentrations measured in red amaranth plants

Parameter	0 % Sludge (mg/kg)	50 % Sludge (mg/kg)	75 % Sludge (mg/kg)	100 % Sludge (mg/kg)
Ni	$7.8 \pm 3$	$12.2 \pm 3.1$	$6.4 \pm 1.1$	$3.6 \pm 3.1$
Zn	$26.6 \pm 7$	$73.6 \pm 45$	$168.4 \pm 65$	$241.1 \pm 185.4$
Cu	$9.6 \pm 0.7$	$0.3 \pm 0$	$15 \pm 2.5$	$14.3 \pm 0.3$
Cd	0	0	0	0
Cr	$1.9 \pm 0.8$	$5.3 \pm 0.6$	$4 \pm 1$	$1 \pm 0.3$
Mn	$93.9 \pm 2.9$	$160.5 \pm 13.6$	$236.8 \pm 22.2$	$156.8 \pm 1.5$
Fe	$2033 \pm 52.7$	$3204.2 \pm 253.3$	$2487.3 \pm 280.9$	$1386.6 \pm 112.9$
Pb	$1.1 \pm 0.9$	$1.9 \pm 0.7$	$2 \pm 0.9$	$1.8 \pm 0.5$

Values are mean  $\pm$  SD and milligram per kilogram (mg/kg)

SD standard deviation

( $2487.3 \pm 280.9$  mg/kg) sludge plant groups than the control group ( $2033 \pm 52.7$  mg/kg) and 100 % ( $1386.6 \pm 112.9$  mg/kg) sludge group. Other than the control group, the lowest Fe content was found in the 100 % sludge plant. The maximum limit of Fe and Mn are 425.5 and 500 mg/kg, respectively (Ewers 1991; Pendas and Pendas 1992). Among all of three treatment (50, 75 and 100 %) group, the 50 % sludge plants took up a high amount of Fe, which surpassed the maximum limit. Soil pH, soil aeration, reactions with organic matter and some plant adaptations influence Fe availability (Vitosh et al. 1994). Mn is highly accumulated in red amaranth. However, Mn (500 mg/kg) concentration in red amaranth did not exceed the allowable limit even at higher sludge loading. There is a considerable difference of the uptake of Mn among 50, 75 and 100 % sludge plants. 75 % sludge plants take up more Mn than the 50 and 100 % sludge plants. The allowable limit of Cr, Cu, Ni and Zn (2.3, 73.3, 67.9 and 99.4 mg/kg, respectively) has been described by Weigert (1991) and in this study we took it as a reference to express the study results.

By considering the results of heavy metal content in studied plants, it was shown that heavy metal concentration did not exceed the allowable limit in plants, except Pb, Cr, Zn and Fe. Among the heavy metals, Pb, Cu and Cd can lead to bioaccumulation (Liao et al. 2013) and may pose a potential health risk for human beings through the food chain. Arora et al. (2008) reported that the range of various metals in wastewater-irrigated different plants was 116–378, 12–69, 5.2–16.8 and 22–46 mg/kg for Fe, Mn, Cu and Zn, respectively. But the present study showed a distinct Fe, Mn and Zn content compared to the study of Arora et al. (2008). Naser et al. (2012) studied red amaranth and reported that concentrations of Pb in red amaranth ( $1.58 \pm 0.1$  mg/kg), spinach ( $1.52 \pm 0.02$  mg/kg) and amaranth ( $1.95 \pm 0.05$  mg/kg) were closer to the content of Pb in different sludge loading plants in this study. In other studies, Rauf et al. (2013) reported the Pb content in the root, stem and leaf of red amaranth (1.91–3.99 mg/kg), which were also very similar to the present study.

According to the results, the textile sludge has no significant influence in increasing the amount of Cu, Ni, Cd and Mn in red amaranth. Nevertheless, the concentration of Pb, Cr, Zn and Fe in red amaranth exceeded the maximum allowable limits. Some elements are essential for plant growth in micro quantities such as Zn, Cu and Mn. Excessive amount of these elements, i.e., more than 300, 150 and 300 mg/kg can cause phytotoxicity in plants (Vitosh et al. 1994). Furthermore, it is also important to consider that the concentration of Zn, Cu, Ni and Mn found in red amaranth are not allowable for human consumption.

However, Ni, Cr, Fe and Pb showed interesting results in this study. The trend of metal accumulation is as follows: Ni ( $50 > 0 > 75 > 100$  % sludge), Zn ( $100 > 75 > 50 > 0$  % sludge), Cu ( $75 > 100 > 0 > 50$  % sludge), Cr ( $50 > 75 > 0 > 100$  % sludge), Mn ( $75 > 50 > 100 > 0$  % sludge), Fe ( $50 > 75 > 0 > 100$  % sludge) and Pb ( $75 > 50 > 100 > 0$  % sludge). In most of the treatments, 75 % sludge-contained pots showed the maximum accumulation than 100 % sludge. There might be two possible reasons: one is the control soils contained metal (though heavy metal concentrations were within allowable limit), but 100 % sludge pot had no soil and therefore there was no chance of metal accumulation by the plant from the soil. Another possible reason could be that the shift of pH toward alkalinity may reduce the bioavailability of the metals. Metals' solubility changes reversely with soil pH, i.e., metal solubility increases with decrease in soil pH and, as a result, metal uptake by plants in calcareous soils is higher than plants in acidic soils (Fisseha 2002). Bingham et al. (1975) found that Cd accumulation was lower in shoots of cereals and legumes than leafy vegetables such as curly cress, lettuce and spinach. All of these factors are very important to do further study in these fields. One of the recent promising methods to remove the heavy metal accumulation in sludge is by using heavy metal-resistant plant growth-promoting bacteria (PGPB) (Ahemad 2014). From this study, we can conclude that the heavy metal uptake (Pb, Cr, Zn and Fe) by red amaranth plants from the soil/soil–sludge mixture was considerably high and may be hazardous to human health.

## Conclusion

The study found that the growth parameters of red amaranth were increased with the applications of textile sludge and/with soil. The textile sludge has a significant level of macronutrients for plants with trace metal content. The metal accumulations in harvested plants were also significantly affected by the application of sludge. However, it can be a potential soil conditioner if the metal can be removed, especially harmful metals, such as Cr and Pb. Further study is needed to clarify the molecular mechanism of plants exposed to textile sludge. In conclusion, the reuse of sludge in agriculture can be one of the potential management options for the sustainable management of textile sludge.

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