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ORIGINAL RESEARCH

Health risk assessment of textile effluent reuses as irrigation water in leafy vegetable *Basella alba*

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Abstract
Purpose The aim of this research was to assess the health risk of textile wastewater reuse as irrigation water on leafy vegetable (*Basella alba*) by comparing variable growth rate in different ration of wastewater and freshwater irrigation and assess their soil-to-plant transfer factor (TF) and health risk index (HRI).
Methods Pot experiments were laid out with five treatments including control with three replications with different irrigation schemes with textile wastewater collected from the untreated point source. The irrigation scheme was, 100 % groundwater as control with four treatments as 75 % groundwater: 25 % wastewater, 50 % groundwater: 50 % wastewater, 25 % groundwater: 75 % wastewater and 100 % wastewater.
Results Soil-to-plant TF in different treatments including control were in the order of Pb (1.0–1.7) > Cu (1.3–1.5) > Cd (0.8–1.0) > Zn (0.1–1.1). TF values of Pb and Cu in the range from 1 to 1.7 indicating their accumulation in *B. alba* plants and their potential health risk by dietary exposure. The HRI for individual metal as well as cumulative HRI of the metals was less than unity (0.33) which indicated the consumption of the vegetables was considered to be safe for one harvest.
Conclusion Over many seasons of irrigation with wastewater, level of salinity and heavy metals can accumulate on the agriculture land and their long term consumption may link to a chronic health risk. Hence, consumption of these vegetables on regular basis should be avoided.

Keywords Textile wastewater reuses · Irrigation · Transfer factor (TF) · Health risk index (HRI) · *Basella alba*

Introduction

Water, the vital material in all aspects of life on earth, plays an extremely important role for human being, socio-economic development and the existence of ecosystems (An et al. 2014). The quality and quantity of any water supply planning is highly important, especially when considering for irrigation purposes. However, the productive use of wastewater has also increased, as millions of small-scale farmers in urban and peri-urban areas of developing countries have no alternative sources of irrigation water (Qadir et al. 2010).

Textile and dyeing factories in the world pose major environmental threats because of large amount of water and dyes involved in manufacturing process (Ranganathan et al. 2007; El-Rahim et al. 2008). Textile wastewater contains substantial pollution loads in terms of pH, temperature, color, chemical oxygen demand (COD), biochemical oxygen demand (BOD), total suspended solid (TSS), total dissolved solids (TDS), electrical conductivity

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(EC) and heavy metals. The value of these parameters has been reported to be very high in many literature compared to the values in Bangladesh Environment Conservation Rules (BECR’ 1997) (MOEF/DOE/GOB 1997) standards set by the government of Bangladesh (Shammi et al. 2014; Khan et al. 2011; Ahmed et al. 2007; Mahfuz et al. 2004; Kabir et al. 2002). Two of the main concerns for wastewater reuse in agricultural irrigation are environmental and human security (Ganoulis 2012). The main positive effects of using wastewater are improved soil fertility, and as a result improved crop production through increased organic matter (OM) and macro- and micro-nutrient content (Pereira et al. 2011a), and environmental benefits such as reduced groundwater uptake and reduced direct discharge of residual waters (Muyen et al. 2011; Toze 2006).

However, soil pollution with heavy metals due to discharge of untreated urban and industrial wastewater is a major threat to ecological integrity and human well-being (Mahmood and Malik 2014). A high sodium adsorption ratio (SAR) of the wastewater implies a hazard of sodium (Alkali) replacing Ca^{2+} and Mg^{2+} in the soil through a cation exchange process that damages soil structure mainly permeability, and which ultimately affects the fertility status of the soil and reduce crop yield (Gupta 2005), and buildup of salinity in the soil (Klay et al. 2010). While wastewater irrigation builds exchangeable Na^{+} up, the excessive Na^{+} was leached out of the soil profile after a rainy summer season (>400 mm) (Pereira et al. 2011b). Long term irrigation of farm lands with wastewater leads to contamination of soil and plant system with heavy metals (Salakinkop and Hunshal 2014). The soil and plant samples show higher values due to accumulation (Gupta et al. 2010). Bioaccumulation factors of heavy metals were significantly higher for leafy than for non-leafy vegetable (Zhuang et al. 2009). Dietary exposure to heavy metals, namely cadmium (Cd), lead (Pb), zinc (Zn) and copper (Cu), has been identified as a risk to human health through the consumption of leafy vegetable grown on contaminated sites with wastewater irrigation (Zhuang et al. 2009; Hu et al. 2013; Hu and Ding 2009; Nabulo et al. 2010; Intawongse and Dean 2006).

Millions of small-scale farmers in urban and peri-urban areas of developing countries like Bangladesh have no alternative sources of irrigation water for agriculture other than reuse of wastewater discharged from textile and dyeing factories. The textile wastewaters in Savar, Dhaka (Bangladesh) have been in use for irrigation since last many years. Although reuse of wastewater could be a potential method for reducing irrigation cost, improving crop production and reducing ecological damage by direct discharge, polluting soil directly while ground water and food crops indirectly. Soil pollution with heavy metals can be a major threat to ecological integrity and human well-being. However, very few reports have been found in Bangladesh related to the dietary exposure of heavy metals by consuming leafy vegetables (Jolly et al. 2013; Alam et al. 2003; Al-Rmalli et al. 2012). Therefore, the aim of this research is to assess the health risk of textile wastewater reuse as irrigation water on leafy vegetable (*Basella alba*) production by comparing variable growth rate in different ration of wastewater and fresh water irrigation and to assess their health risk from consumption.

Methods

Species selection

Malabar spinach (*B. alba*) is a fast-growing, soft-stemmed vine is a very popular vegetable in Bangladesh (Table 1) which was selected for the experiment.

Experimental design

The pot experiment was laid out with five treatments including control with three replications (Table 2). During the investigation, morphological parameters (average length of stems, leaf area and wet weight) of plants were noted in with the help of measuring scale and digital balance for two times, i.e., 7 and 40 days of emergence. Two randomly selected plants were used from each treatment pot for collecting physiological data. A germination test

Table 1 Scientific classification

Division:	Magnoliophyta
Class:	Magnoliopsida
Order:	Caryophyllales
Family:	Basellaceae
Genus:	*Basella*
Species:	*B. alba*

Basella alba

Table 2 Irrigation scheme using textile wastewater

	Control	T1	T2	T3	T4
Irrigation scheme	100 % groundwater	75 % groundwater: 25 % wastewater	50 % groundwater: 50 % wastewater	25 % groundwater: 75 % wastewater	100 % wastewater

Table 3 Test report of physic-chemical properties of wastewater sample analysis

Water quality parameters	Sample 1	Sample 2	Ground water	Irrigated land[a]
Chemical oxygen demand (COD) (mg/L)	832	1023	–	400
Biochemical oxygen demand (BOD_5) (mg/L)	380	470	4.50–4.62	100
Dissolved oxygen (DO) (mg/L)	0.08	0.07	4.00–4.15	4.5–8
Total suspended solid (TSS) (mg/L)	42	142	–	200
Total dissolved solid (TDS) (mg/L)	4144	4231	–	2100
pH	8.15	8.35	7.00–7.30	6.5–8.5
EC (μS/cm)	7390	7853	140–170	1200
Total alkalinity (mg/L)	795	750	–	–
Total hardness (mg/L)	175	190	–	–
Na (mg/L)	4026.89	4066.69	–	200
Ca (mg/L)	8.63 ± 0.05	9.54 ± 0.05	–	75
Mg (mg/L)	3.83 ± 0.02	3.72 ± 0.02	–	30–35
Zn (mg/L)	0.13 ± 0.00	0.14 ± 0.00	–	10.0
Cu (mg/L)	0.0096 ± 0.00	0.0036 ± 0.00	–	3.0
Pb (mg/L)	<0.0913	<0.0913	–	0.1
Cd (mg/L)	<0.25	<0.25	–	0.5
SAR	12.76	13.14	–	–

[a] Industrial wastewater quality standard Bangladesh Environment Conservation Rules (MOEF/DOE/GOB 1997)

was done prior to the experiment which indicated 100 % germination in both 100 % wastewater and 100 % fresh water. Four seeds were planted in each pot. The pots were irrigated with groundwater as the source of freshwater, textile wastewater as well as the mixture of the two in different ratios (Table 2). The characteristics of groundwater are given in Table 3.

Collection and characterization of wastewater

Wastewater used in this experiment was raw and untreated point source collected from a textile industry of Savar, Dhaka (Bangladesh) and transported by standard methods as mentioned in APHA (1998). The wastewater sample was a mixture of different procedures such as washing, dying and rinsing, etc. To get the general idea of the characteristics, wastewaters from two different times were collected as sample 1 in the morning and sample 2 in the afternoon and their mixture was used for the experiment purposes. Within collection of half an hour Physic-chemical parameters electrical conductivity (EC), pH, DO was measured on the spot. EC, pH, and DO were measured by EC meter (EC 241, HANNA, Portugal), pH meter (Lab 851, SCHOTT Instruments, Germany), and DO meter (H19143, HANNA), respectively. Total hardness was measured by complexometric titration using EDTA; alkalinity was measured by titration method, total suspended solids (TSS) by gravimetric method, chemical oxygen demand (COD) by the closed reflux titrimetric method and biological oxygen demand (BOD_5) by standard method (APHA 1998).

The sodium adsorption ratio (SAR) was calculated by the equation given by Richards (1954) in $(\mathrm{meq/L})^{0.5}$.

$$\mathrm{SAR} = \frac{\mathrm{Na}^{+}}{\sqrt{\frac{\mathrm{Ca}^{2+}+\mathrm{Mg}^{2+}}{2}}} \quad (1)$$

where, Na^{+}, Ca^{2+}, Mg^{2+} are sodium, calcium and magnesium ion concentrations in meqL^{-1}.

Collection and characterization of soil sample

Soil was collected from the agricultural land near Savar and considered as background soil. The soil belongs to the Madhupur clay formation. The soils are brown and red mottled, strongly acidic, friable clay loam to clay soils over deeply weathered red mottled Madhupur clay. The top soil is 10–15 cm thick (Huq et al. 2013). The clay minerals present in the Madhupur Clay soil of different areas of Savar and Dhaka are kaolinite (52.39 %), illite (36.39 %) and small amount of illite–smectite (11.21 %) (Haque et al. 2013). Cation exchange capacity (CEC) of Madhupur clay is low, pH 6.9 with poor moisture retention capacity (Hoque 1984).

Background soil before irrigation and that have passed 45 days after irrigation were collected, air-dried, ground by agate mortar and pestle, and sieved through a 150 µm mesh size sieve for metal analyses. For the ease of data interpretation percent change of physic-chemical parameter after 45 days of irrigation was compared using the following formula

$$\%\mathrm{Change} = \frac{\mathrm{N_{Sample}} - \mathrm{N_{background}}}{\mathrm{N_{background}}} \times 100 \qquad (2)$$

$N_{background}$ = background data obtained for different parameters.

N_{sample} = sample data obtained after different treatments with unit expressed in %.

Collection and characterization of vegetable samples

Two randomly selected plants from five treatments with three replication pots were collected after 45 days of maturation. The plants were washed with double distilled water, chopped into smaller pieces, oven dried at 70 °C for 48–72 h, weighed and placed in a dehydrator. The dried samples were then ground and passed through 150 µm sieve.

One gram of dry matter was weighed into 50-mL glass beakers, followed by the addition of 10 mL mixture of analytical grade acids of HNO_3 (concentration 70 %) and $HClO_4$ (concentration 70 %) in the ratio 5:1. The digestion was performed at a water bath (temperature 80 °C) to heat for 72 h until a light color solution was obtained. After cooling, the solution was made up to a final volume of 25 mL with distilled water in a volumetric flask. Triplicate digestion of each sample was carried out together. For soil sample analysis the same procedure was followed. Analysis of heavy metals in water, soil and plant (Cu, Pb and Zn) were carried out by FLAAS (Flame Atomic Absorption Spectrophotometer Model: SHIMADZU AA-6800 series) with the detection limit for Fe (0.5 mg/L) Cu (0.0025 mg/L), Zn (0.01 mg/L), Pb (0.09 mg/L) and Cd (0.25 mg/L) in the Laboratory of Bangladesh Rice Research Institute. Ca and Mg were extracted by ammonium acetate method (Peech et al. 1947) and determined in FLAAS with the detection limit 0.50 and 0.3 mg/L, respectively. Flame Photometer PFP7 was used for the determination of Na (0.20 mg/L).

Total nitrogen content was analyzed by Kjeldahl method (Kjeldahl apparatus, model no. P/N 21284-01, critical value 0.12), percent organic matter (OM) was measured by ashing method (Storer 1984), total organic carbon (TOC) was measured by wet oxidation method as described in Huq and Alam (2005). Soil sulfur was measured turbidimetrically as sulfate (Hunt 1980) (using Tween-80) by UV-Spectrophotometer (Model: SPECORD 222A433, Analytik Jena AG, Germany) at 420 nm wavelength. All the instruments were calibrated before measurement and reagents were of analytical grade (AnalaR). All the glassware, containers and tools were soaked overnight with 20 % (v/v) nitric acid and finally rinsed with deionized water. All samples were filtered through 0.22 µm polycarbonate membrane filter.

Measurement of transfer factor (TF)

Heavy metal concentrations of soils and crops were calculated on the basis of dry weight. The soil-to-plant transfer factor (TF) of heavy metals (Fe, Cu, Pb, Zn, Cd) from soils to vegetables were calculated using the method of Cui et al. (2004) as follows:

$$\text{Transfer Factor (TF)} = P/S \qquad (3)$$

where, P and S is the residual concentration of the trace metal in plant tissues and in soil, respectively (ppm dry wt).

Measurement of daily intake of metal (DIM) and health risk index (HRI)

Health risk index (HRI) was calculated according to the method of Cui et al. (2004). The average daily leafy vegetable intake rate among Bangladeshi people is 0.0361 kg as found from the survey of Bangladesh Bureau of Statistics (BBS 2011). Data on average adult body weight of Bangladesh was 49.50 kg (Walpole et al. 2012). Using daily intake of metals (DIM) and reference oral dose (R_{fD}), the HRI value was obtained using the following equation.

$$\mathrm{HRI} = \mathrm{DIM}/R_{fD} \qquad (4)$$

where, R_{fD} is the reference oral dose (0.7, 0.04, 0.3, 0.004, 0.001 mg/kg BW/day) for Fe, Cu, Pb, Zn, and Cd, respectively (US-EPA IRIS 2006).

If the value of HRI is less than 1 then the exposed population is said to be safe (Zhuang et al. 2009).

The daily intake of metals (DIM) was calculated to averagely estimate the daily metal loading into the body system of a specified body weight of a consumer. This will inform the relative phyto-availability of metal. This does not take into cognizance the possible metabolic ejection of the metals but can easily tell the possible ingestion rate of a particular metal (Cui et al. 2004).

$$\mathrm{DIM} = C_{\mathrm{metalconc.}} \times C_f \times D_{\mathrm{foodintake}}/\mathrm{BW} \quad (5)$$

where, DIM is daily intake of metal mg/kg/day; $C_{\mathrm{metal\ conc.}}$ is heavy metal concentration in plants (mg/kg), C_f is the conversion factor of 0.085 to convert fresh vegetable weight to dry weight, $D_{\mathrm{food\ intake}}$ is daily intake of leafy vegetables, based on average daily vegetable intake of the country (g) and BW = average body weight (kg).

Statistical Analysis

Data were put in Excel. Average of three replications and their standard error was calculated. Preparation of graphs and statistical analysis correlation coefficient and one way ANOVA with post hoc Tukey test was calculated in Origin 9.0 (OriginLab, USA). A 0.05 level of probability was used to calculate the critical value of *F*. If F falls below a fixed threshold, it can be concluded that all the sets of samples have equal averages. Pearson's correlation coefficient with 95 % confidence interval of metal values between soil sample and plant samples were analyzed.

Results and discussion

Irrigation wastewater characteristics

The textile industry consumes large quantities of water and produces large volumes of wastewater through various steps in dyeing and finishing processes (Brown and Laboureur 1983). The textile wastewater is a complex and contains variable mixture of polluting substances in terms of high pH, temperature, color, chemical oxygen demand (COD), biochemical oxygen demand (BOD), total suspended solid (TSS), total dissolved solids (TDS), electrical conductivity (EC) and heavy metals. The value of these parameters has been reported to be very high compared to the values in Bangladesh Environmental Conservation Rules (BECR' 1997), set by the government of Bangladesh (Table 3). The sodium hazard or SAR is expressed in terms of classification of irrigation water as low (S1: <10), medium (S2: 10–18), high (S3: 18–26) and very high (S4: >26) (Richards 1954). The wastewater of the sampled industry falls into medium SAR hazard. A high SAR value implies a hazard of sodium (Alkali) replacing Ca^{2+} and Mg^{2+} in the soil through a cation exchange process that damages soil structure mainly permeability and which ultimately affects the fertility status of the soil and reduce crop field (Gupta 2005).

Morphological changes in plant growth

Vegetables grown in wastewater-irrigated soil had normal appearance lacking any external visible symptoms. The wet weight versus dry weight of the plant samples indicated that compared to the control, all the treatments had less wet weight as well as dry weight. This indicates although stem and number of leaf is higher, weight (both wet and dry weight) of the plant was being affected by the irrigation scheme to some extent. For plant growth in each treatment, the length of the stem of every individual (Fig. 1a) was measured by a scale, and its number of leaves (Fig. 1b) was counted. It is observed that average length of stem and number of leaf was higher in Treatment 1 compared to the control and other treatments. However, the one way ANOVA did not indicate the presence of any significant variances among the treatments (Table 4). Although approximately 83 % variance exists for T1 in terms of stem length, however, since the *p* value is 0.186 greater than 0.05, indicating the null hypothesis is rejected. In terms of wet weight and dry weight, it was observed that compared to control all the treatments had lower wet weight and dry weight (Fig. 1c).

Changes in irrigated soil

The pH values of textile wastewater samples were 8.15 and 8.35. On the other hand, soil pH measured in background soil was 7.12 ± 0.0352. With the change of wastewater and fresh water ratio soil pH was turning to basic. Wastewater irrigation has the potential to add large amounts of salt to the soil (Fig. 2). The increase in electrical conductivity due to sodium content of wastewater may potentially reduce crop yield (Tripler et al. 2011; Rusan et al. 2007). The values of salinity of wastewater samples were 7390 and 7853 µS/cm. Percent increase or decrease for soil salinity as measured was positive in all the pots with the range from 46.34 to 246.34 %. Moreover, it has been also observed that irrigation with reclaimed wastewater also decreased soil acidity, which is beneficial to the acidic tropical soil (Pereira et al. 2011b). To add here, since Madhupur clay has low CEC (Hoque 1984) and SAR value of wastewater fell into medium SAR hazard, the soil has low SAR hazard.

%Total N was found to decrease negatively in all the pots which indicate utilization of nitrogen from the pot soil by the plants and it also indicated no addition of nitrogen from the wastewater. %Organic Carbon was increased in all the pots which indicated addition of organic carbon in the soil. The most increase was found in pot 2 with the value of 37.50 % changes which had the irrigation ratio of 25 % wastewater with 75 % fresh water. On the other

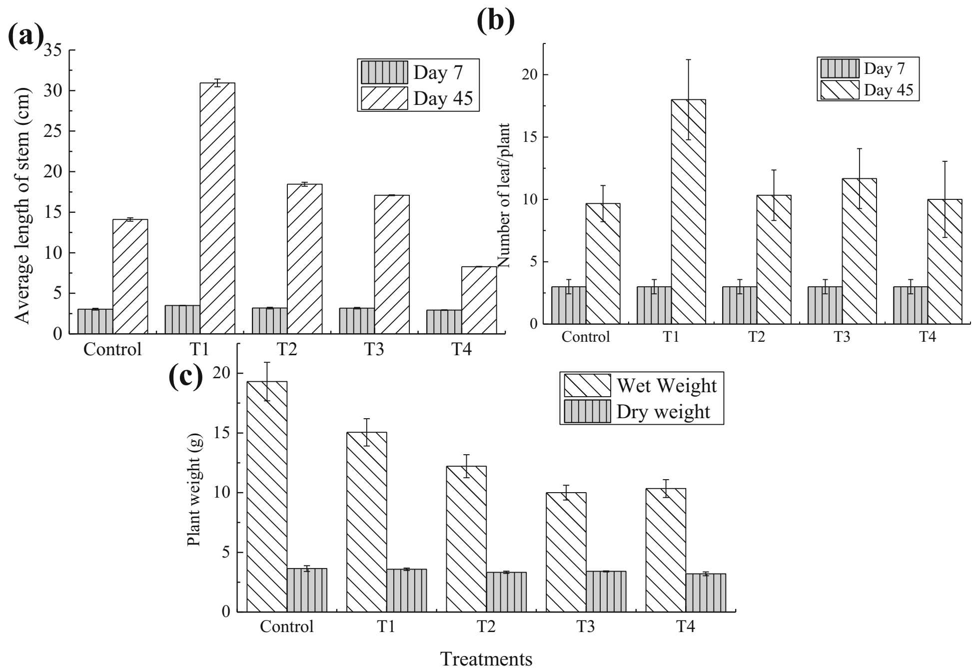


Fig. 1 **a** Average length of stem on the 7th day and 45th day. **b** Average number of leaf per plant on the 7th day and 45th day and **c** wet weight and dry weight after harvest of the vegetable on 45th day. The *capped bars* indicate standard error of three replications

Table 4 Single Factor ANOVA of the plant stem length and number of leaf ($n = 1$)

Source of variation	SS	*df*	MS	*F*	*P* value (0.05)	*F* crit
Between groups	268.926	4	67.23149	2.354369	0.186489	5.192168
Within groups	142.7803	5	28.55606			
Total	411.7063	9				

hand, %OM content and %S and %P was found to decrease negatively in 100 % wastewater plot, while in other pots, it slightly increased (Fig. 3). The increased alkaline pH, salinity and SAR value of the pot soil due to wastewater irrigation might have an impact on the dissolution of the nutrient. In the plant samples %N, %P and %S changed slightly in different treatments compared to the control but the change was not so significant (Fig. 4). Phosphorus (P) is the most important nutrient element (after nitrogen) limiting agricultural production in most regions of the world (Holford 1997; Kogbe and Adediran 2003). The plant available nitrogen and phosphate, and contents of the wastewater-irrigated soil are much lower than the control soil. The lesser nitrogen and potassium content in wastewater- irrigated soil may be also due to wastewater irrigation which reduces the natural microbial activity in the soil, resulting in slower release of plant available nutrients into the soil (Gupta et al. 2010).

It is well known that the biomass uptakes trace metals naturally available to them through soil and stores them in their tissues (Gupta et al. 2010). In the soil sample, the order of metals in terms of highest concentration as recorded were Fe > Cu > Zn > Pb > Cd (Fig. 5). While, in the vegetables highest concentrations of metals detected for Fe > Zn > Cu > Pb > Cd (Fig. 6). A one way ANOVA analysis along with Tukey test indicated the presence of significant variances among the treatments at 0.05 level in both treated soil ($r^2 = 0.9986$ with coefficient of variation 0.082) and plant samples ($r^2 = 0.9997$ with coefficient of variation 0.0247) for heavy metals.

Correlation coefficient is commonly used to test the relationship between two variables. Individual heavy metal in soil and plant samples was measured for control along with treatments. Pearson's correlation at 95 % level of significance (two tailed test) was calculated for soil–plant heavy metals concentration. Although a high concentration of Fe was reported in plant samples, Fe in soil treated with wastewater and Fe in plant samples correlated negatively ($r^2 = -0.36$). The explanation can be given as background soil which is Madhupur clay already contained naturally higher concentration of Fe. Other four heavy metals Cu, Cd, Zn and Pb were positively correlated with r^2 value 0.55, 0.76, 0.57 and 0.46, respectively. In terms of strength of correlation between soil heavy metal and plant heavy metal the order was Zn > Pb > Cu > Cd > Fe.

In general, the presence of high concentrations of Fe and Zn in the vegetables has been previously reported (Abbasi et al. 2013). However, heavy metals Cu, Zn, Pb and Cd

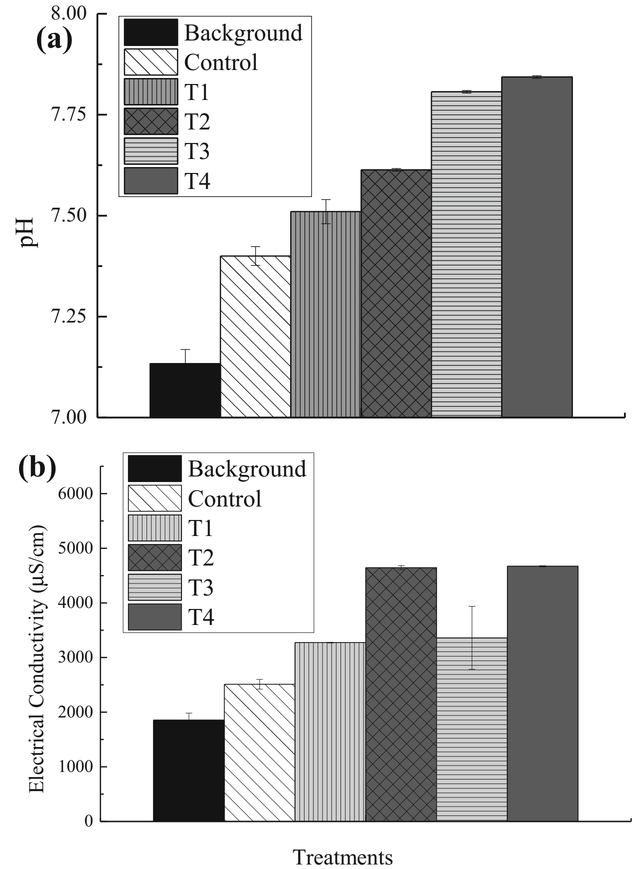


Fig. 2 Changes of soil (**a**) pH and (**b**) electrical conductivity before and after wastewater irrigation. The *capped bars* indicate standard error of three replications

present in the treatments did not comply within the standard limit of 40 mg/kg, 60, 5.0 and 0.2 mg/kg, respectively (FAO/WHO 2011). The accumulation of heavy metals was greater in case of wastewater-irrigated vegetables compared to the control agreeing with previous works (Gupta et al. 2010; Abbasi et al. 2013).

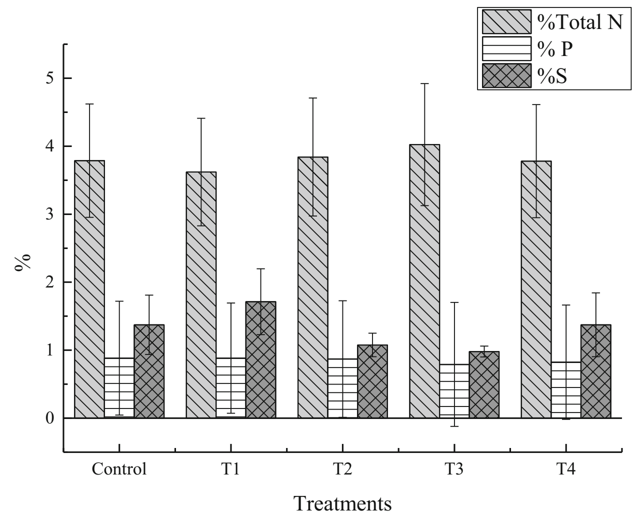
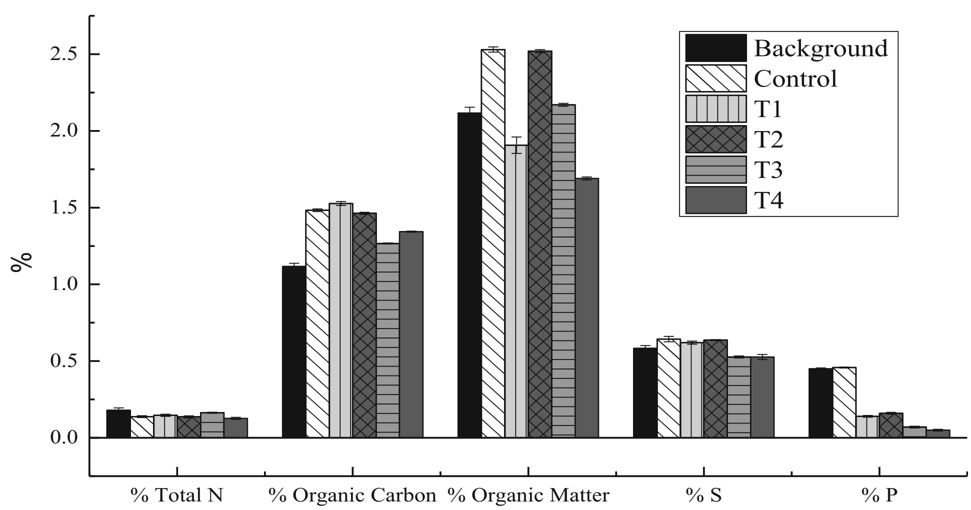


Fig. 4 %Total N, %P and %S Sanalyzed in plant samples. The *capped bars* indicate standard error of three replications

Soil-to-plant transfer factor (TF)

The TF of heavy metal from soil-to-plant was calculated to determine the relative uptake of heavy metal by the plants with respect to soil irrigated with wastewater. It is important to note here that TF value of 0.1 indicates that plant is excluding the element from its tissues, the greater the transfer quotient value than 0.50, the greater will be the chances of vegetables for metal contamination by anthropogenic activities (Khan et al. 2009). A TF value ">1" means higher accumulation of metals in plant parts than in soil (Barman et al. 2000). Soil-to-plant TF is one of the key components of human exposure to metals through food chain (Cui et al. 2004). The higher TF of heavy metal indicates the stronger accumulation of the respective metal by that vegetable (Khan et al. 2009). Therefore, TF of metals is essential to investigate the human HRI (Cui et al.

Fig. 3 Changes of soil %Total N, % Organic carbon, % Organic matter, %S and %P. The *capped bars* indicate standard error of three replications



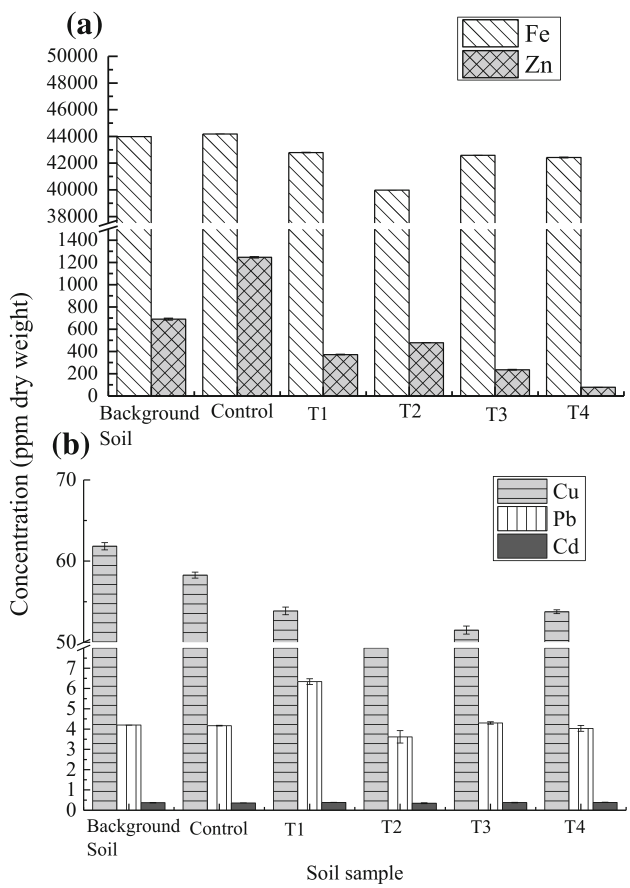


Fig. 5 Concentration of different metal contents in soil sample of different treatments. **a** Fe and Zn concentrations (**b**) Cu, Cd and Pb concentrations. The *capped bars* indicate standard error of three replications

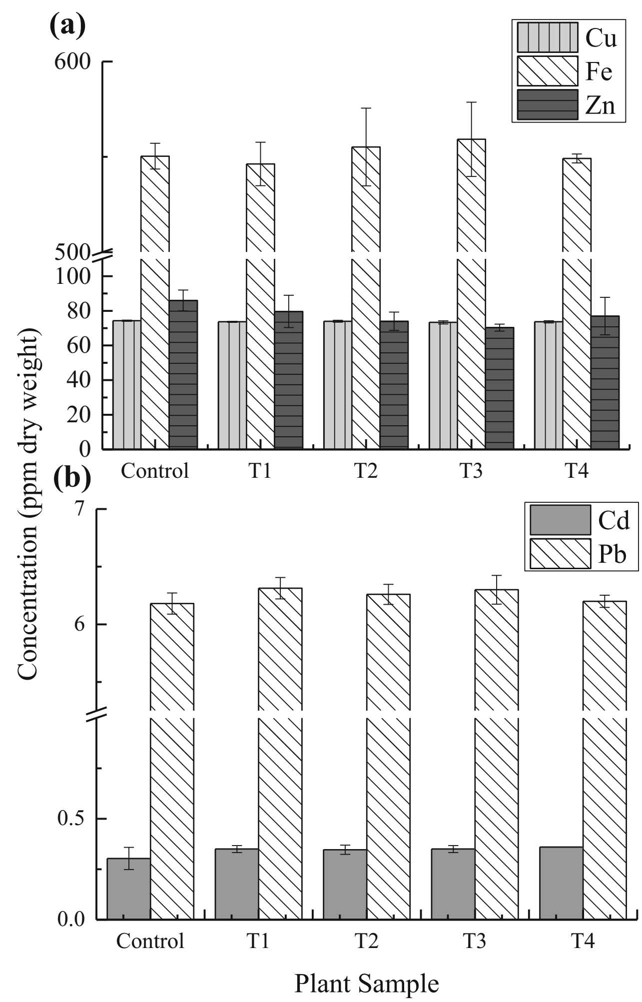


Fig. 6 Selected metal contents analyzed in plant samples (**a**) Cu, Fe and Zn concentrations (**b**) Cd and Pb concentrations. The *capped bars* indicate standard error of three replications

2004). Higher values of TF suggest poor retention of metals in soil and/or more translocation in plants. Leafy vegetables accumulate much higher contents of heavy metals than other vegetables because their higher translocation and transpiration rates (Zhuang et al. 2009; Khan et al. 2009).

Except for Fe, heavy metals Pb, Cu, Cd and Zn showed a higher TF, which is also in agreement with correlation coefficient analysis of concentration of metal in soil and concentration of metal in plants. Soil-to-plant TF in the control irrigation treatment was in the order Pb > Cu > Cd > Zn > Fe. Except T1 and T4, T2 and T3 maintained a similar pattern of TF of the metals as to the control pots (Fig. 7). Soil-to-plant TF in T1 and T4 were Cu > Pb > Cd > Zn > Fe and Pb > Cu > Zn > Cd > Fe. According to data in Fig. 7, Cu and Pb showed mean TF values in the range from 1 to 1.7 indicating their accumulation in *B. alba* plants and then the potential health risk of these two metals by dietary exposure. Metals transfer from soil in plant depends on plant bioavailability and independent of metal and plant type (Intawongse and Dean 2006). However, a complex positive (synergistic) or negative (antagonist) interactions may occur between them, thus increasing or decreasing their availability depending on the type and amount of other metals present in the soil and the soil characteristics, mainly salinity and pH. Figure 7 also indicated where some interactions could be potentially interpreted, for example positive relationship between Cu and Zn, vs. Pb (which decreased) as in T1, or negative between Zn and Pb, Cu and Cd from T2 to T4 when salinity and metal concentration increased. However, to understand this relationship needs more exploration.

Health risk index (HRI)

There are various possible exposure pathways of pollutants to humans. Principally, the food chain (soil–plant–human) pathway is recognized as one of major pathways for human

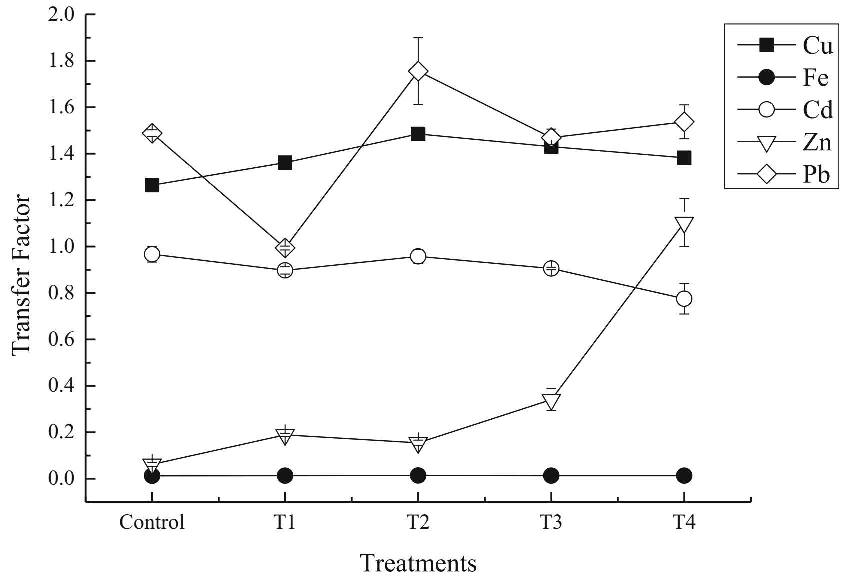


Fig. 7 Soil-to-plant Transfer Factor (TF) of *Basella alba* treated with different treatments in compared to the control. The *capped bars* indicate standard error of three replications

Table 5 Calculation of Health Risk Index (HRI) of *Basella alba*

	Cu	Fe	Zn	Pb	Cd	Cumulative HRI
Control	0.11	0.05	0.02	0.10	0.02	0.30
T1	0.11	0.05	0.02	0.10	0.02	0.30
T2	0.11	0.05	0.02	0.10	0.02	0.30
T3	0.11	0.05	0.01	0.10	0.02	0.30
T4	0.12	0.05	0.02	0.10	0.02	0.31

exposure to soil contamination (Zhuang et al. 2009; Khan et al. 2008). Vegetables are an essential part of diet and are taken both cooked and raw forms by human (Jolly et al. 2013). Leafy vegetables in Bangladesh are normally eaten as cooked form. Although some metals present in vegetables are biochemically essential for humans, concentrations higher than those recommended may cause metabolic disorders (Jolly et al. 2013). The health protection standard of HRI is 1.0 (USEPA 2006). HRI higher than 1 indicates high level of metal exposure from these leafy vegetables. If HRI is lower than 1, the exposed population is said to be safe.

By comparing the estimated dietary intake and target health risk index for Cu, Fe, Zn, Pb and Cd, this study determined that there was no potential health risk for the local inhabitants through consumption of contaminated vegetables. In this study, HRI values of the metals as shown in Table 5 in control and treatments were less than unity. Moreover, the cumulative HRI values for the heavy metals for each treatment were also found to be less than unity. Consequently, the consumption of the vegetables was considered to be safe. Though the background soil collected from the agricultural land near textile industry as well as the wastewater for irrigation with different combination of groundwater do not possess health risk from consumption of these vegetables. However, over many years may be associated with non-carcinogenic health risks (Table 5). As for 0.33 HRI obtained for one harvest and the level of salinity long term consumption of these vegetables may link to a chronic health risk. Although HRI-based risk assessment method does not deliver a quantitative estimation for the likelihood of an exposed population undergoing a reverse health effect, it indeed provides a suggestion of health risk level due to exposure to pollutants (Chary et al. 2008).

Conclusion

The impacts of textile wastewaters on agricultural land and production are now burning issues for the sustainable industrial development of countries like Bangladesh. Application of wastewater as irrigation water for agriculture in urban and peri-urban areas sustainably reuses water resources but threaten the soil quality to be deteriorated, with less microbial activities, high salinity and heavy metals accumulation over time. It also causes vegetable contamination by transfer from soil-to-plant tissues which presume a great chronic health risk to the consumers of these vegetables on regular basis by dietary exposure particularly linked to poor food quality and metal accumulation. Therefore, the consumption of vegetables from the agricultural fields contaminated with continuous exposure of textile wastewater for irrigation should be avoided and consumption of these vegetables on regular basis is not recommended.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no competing interests.

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