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Assessment of the irrigation feasibility of low-cost filtered municipal wastewater for red amaranth (*Amaranthus tricolor* L cv. Surma)

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Abstract

Because of the scarcity of clean water, treated wastewater potentially provides an alternative source for irrigation. In the present experiment, the feasibility of using low-cost filtered municipal wastewater in the irrigation of red amaranth (*Amaranthus tricolor* L cv. Surma) cultivation was assessed. The collected municipal wastewater from fish markets, hospitals, clinics, sewage, and kitchens of households in Sylhet City, Bangladesh were mixed and filtered with nylon mesh. Six filtration methods were applied using the following materials: sand (T_1); sand and wood charcoal consecutively (T_2); sand, wood charcoal and rice husks consecutively (T_3); sand, wood charcoal, rice husks and sawdust consecutively (T_4); sand, wood charcoal, rice husks, sawdust and brick chips consecutively (T_5); and sand, wood charcoal, rice husks, sawdust, brick chips and gravel consecutively (T_6). The water from ponds and rivers was considered as the control treatment (T_o). The chemical properties and heavy metals content of the water were determined before and after the low cost filtering, and the effects of the wastewater on seed germination, plant growth and the accumulation rate of heavy metals by plants were assessed. After filtration, the pH, EC and TDS ranged from 5.87 to 9.17, 292 to 691 $\mu S\ cm^{-1}$ and 267 to 729 $mg\ L^{-1}$, respectively. The EC and TDS were in an acceptable level for use in irrigation, satisfying the recommendations of the FAO. However, select pH values were unsuitable for irrigation. The metal concentrations decreased after applying each treatment. The reduction of Fe, Mn, Pb, Cu, As and Zn were 73.23%, 92.69%, 45.51%, 69.57%, 75.47% and 95.06%, respectively. When we considered the individual filtering material, the maximum amount of As and Pb was absorbed by sawdust; Cu and Zn by wood charcoal; Mn and Cu by sand and Fe by gravel. Among the six filtration treatments, T_5 showed the highest seed germination (67.14%), similar to the control T_0 (77.14%). The healthy plants/pot ratio (93.62%) was significantly higher for T_5, even higher than the control (85.19%). Additionally, the average plant height for T_5 (8.097 in.) was statistically identical to the control (8.633 in.). The average number of leaves for T_5 (10) was near to the control (12). Finally, the minimum amount of heavy metals accumulated in the plants of T_5, whereas the maximum accumulation rate varied among treatments. The accumulated levels of Fe, Mn, Cu, and Zn were within the safe limit; however, the concentrations of Pb and As exceeded their safe

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limits. The results showed that the low-cost filtration method potentially allows municipal wastewater to be used in irrigation for agricultural production.

Keywords: Heavy metals; Irrigation feasibility; Low cost filtration; Municipal wastewater; Red amaranth

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1. Introduction

During this century, and notably within the past two decades, the use of municipal wastewater in the irrigation of agricultural crops has become more widespread, notably in arid and semiarid areas of both developed and developing countries. The controlled use of untreated and treated wastewater in irrigation is now quite common in Europe, the United States, Mexico, Australia, China, India and the Near East and, to a lesser extent, in Chile, Peru, Argentina, the Sudan and South Africa (Bartone & Arlosoroff, 1987). The earliest documented experiment of wastewater reuse was the large scale application of municipal wastewater on croplands in Western Europe and North America during the early 1900s, when flush toilets and sewer systems were being introduced (Asano, 2002; Asano & Levine, 1996). The use of domestic wastewater for crop production has been practiced for several centuries. The impetus of "sewage farms" was to minimize or prevent pollution in rivers and to conserve water and nutrients to improve agriculture (Shuval, 1991). Over the past 20 years, a strong revival of interest in the controlled use of wastewater for crop irrigation has occurred to increase local food production (Witt et al., 1991). A substantial amount of wastewater is discharged from different cities in Bangladesh, potentially causing different fatal diseases in humans, animals and plants. This municipal wastewater could be filtrated using low-cost filtrating materials such as sand, coal, brick, sawdust, rice husks, and gravel to reduce different chemicals and metal contents to allow the use of the water in irrigation and other homestead purposes. Heavy metals such as Cd, Cu, Ni, Pb, As, Cr, and Zn represent potential hazards to plants and animals (Burchill, Hayes, Greenland, Greenland, & Hayes, 1981). Trace quantities of heavy metals such as Ni, Mn, Pb, Cr, Cd, Zn, Cu, Fe and many others are important constituents of most industrial wastewaters. The chemical analysis of municipal wastewater is essential to assess the degree of environmental pollution or toxicity caused by the effluents.

Red amaranth (*Amaranthus tricolor* L cv. Surma) belongs to the family Amaranthaceae that originated in Asia. This crop is grown commonly as a food or an ornamental crop throughout the tropics. This crop is also known as 'Lalshak' and is a popular leafy vegetable grown both in the winter and summer seasons in Bangladesh. For the economic production of red amaranth, a good seed germination percentage and high plant growth requires frequent and proper irrigation. In Bangladesh, freshwater is abundant and is not considered a limited natural resource. However, the global environment is changing (Frederick, 2001), and this natural resource is becoming increasingly important for ecological stability (Ajmal & Khan, 1983). Over the past century, freshwater availability has become a limiting factor in agricultural development because of the exponential growth of population, rapid industrialization and urbanization, higher cultivation intensities and poor water management practices (Ray & Gül, 1999). In addition, the options for increasing the supply of fresh water have become expensive and often damaging the environment (Frederick, 2001). The scientific evidence regarding the filtration of municipal wastewater to obtain quality water for irrigation purposes is limited. The majority of the studies cover filtering for drinking water. The filtration method in this study was designed from filtering and purification techniques applied for drinking water. Spellman (2013) reported that common examples of filter media are filter paper, filter cloths, and wire mesh. Activated charcoal filtration is a physical process that removes dissolved chemicals and heavy metals from wastewater (Monser & Adhoum, 2002) and controls odor (Burgess, Parsons, & Stuetz, 2001). Healy, Rodgers, and Mulqueen (2007) also reported that sand filtration is an alternative treatment mechanism for agricultural wastewater. Slow sand filtration involves removing material in suspension or dissolved in water via percolation at a slow speed (Ellis & Wood, 1985). Rapid sand filtration is performed either in open gravitational flow filters or in closed pressure filters, allowing higher effective loadings (James, 1940). The tertiary effluent from rapid sand filtration consistently satisfied the water quality requirements for irrigation (Hamoda, Al-Ghusain, & Al-Mutairi, 2004). Stone filtration is also an effective pathway for wastewater treatment (Herrera Melian, Araña, González Díaz, Aguiar Bujalance, & Doña Rodríguez,

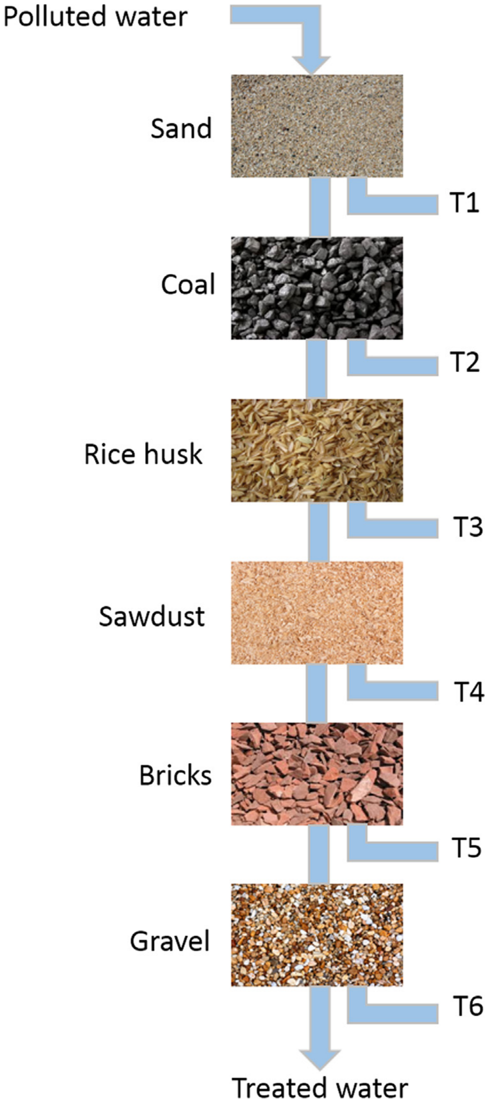

Fig. 1. Experimental setup.

2009). Hegazy, El-Khateeb, Amira, and Kamel (2007) mentioned that the combination of cement kiln dust and rice straw as a filter was an efficient and low-cost technology for wastewater treatment and reuse. A biological sand filter consisting of sand, gravel and microorganisms is able to provide clean drinking through its bioremediation activities (Lea, 2008). Natural lava stones can be successfully used for low-cost aerobic biofiltration of municipal wastewater (Gonzalez-Martinez, Millan, & Gonzalez-Barcelo, 2007). Simple sari cloth filtration is sustainable and continues to protect villagers from cholera in Matlab, Bangladesh (Huq et al., 2010). Hussam and Munir (2007) reported that a two-bucket system filter (one bucket filled with coarse and fine sand and the other with wood charcoal and brick chips) produced arsenic-free safe drinking water approved by the Bangladesh Government. Therefore, the low-cost filtering process for municipal wastewater in the current study was constructed using the filtering materials of sand, wood charcoal, sawdust, rice husks, brick and gravel.

Although the proper use of municipal wastewater is a critical issue for crop production in Bangladesh, few studies are available to access the effects of its application. This experiment was designed mainly using the low cost filtration of municipal wastewater to analyze the effects on seed germination, growth parameters and heavy metal uptake of red amaranth.

2. Materials and methods

2.1. Wastewater collection and processing

The municipal wastewater samples were collected in properly labeled plastic bottles from the effluents of different sites: a fish market, hospitals, clinics, sewerage and kitchens of Sylhet, Bangladesh. Samples were collected from the upper 2–4 cm of effluents to minimize hazards. The collected samples were preserved in plastic bottles in the laboratory at control temperatures of 20 ± 2 °C without any chemical treatment. The four different samples were mixed together to produce the main working sample (S) and filtered with 1 mm nylon mesh to remove debris.

2.2. Low cost filtration of municipal wastewater

Six different filtration techniques that varied the low-cost filtering materials were designed to filter the working samples. These methods employed consecutive applications of materials: sand (T_1); sand and wood charcoal (T_2); sand, wood charcoal and rice husks (T_3); sand, wood charcoal, rice husks and sawdust (T_4); sand, wood charcoal, rice husks, sawdust and brick chips (T_5); and sand, wood charcoal, rice husks, sawdust, brick chips and gravel (T_6). The water from ponds and rivers was considered as the control treatment (Fig. 1). The filtering materials were collected from nearby households and road sides and washed prior to use.

2.3. Determination of pH, electrical conductivity (EC), total dissolved solid (TDS) and heavy metals in the wastewater

The pH values of the wastewater samples were measured by taking 50 mL of sample water in a 100-mL beaker and immersing the electrode of the digital pH meter (Corning pH meter 320) into the sample, as stated by Ghosh, Bajaj, Hassan, and Singh (1983). The EC of the municipal wastewater samples was measured by taking a 100-mL water sample in a 500 mL beaker. The conductivity cell was rinsed with distilled water and then placed into the wastewater sample. The sample temperature was adjusted to 25 °C. The electrical conductivity was calculated using a conductivity meter (Model WPA CM 35) according to Tandon (1993). To determine the TDS, 100 mL of sample was taken and filtered through double-layered filter paper (Whatman No 42), and the filtrate was collected in a dry glass beaker. The TDS was then measured using a TDS meter. The concentrations of heavy metals such as Fe, Zn, Cu, Mn, As and Pb in wastewater samples were analyzed on a UV-light and atomic absorption spectrophotometer (Model UNICAM 969) using the method described in the standard methods for the examination of water and wastewater by Gilcreas (1966). Each analysis was performed in triplicate.

2.4. Pot preparation and growing of red amaranth

Different fertilizers, such as urea, TSP, MOP and cow dung, were applied at the time of pot (2000 cm and a 1-L volume) preparation with loamy soil (500 g/pot) and during other practices according to the fertilizer recommendation guide-2005 of Bangladesh (BARC, 2005). Low-cost filtered wastewater (75 mL) was regularly applied in each pot.

Healthy red amaranth cv. Surma seeds were purchased from the Bangladesh Agricultural Development Corporation (BADC) in Sylhet, Bangladesh. The seed germination test was performed on the identical pots in which plants would be maintained to observe their growth and yield parameters. Collected seeds were washed and soaked for 24 h and mixed with sand for broadcasting over the soil of each pot (including the control pot). In total, 70 seeds were broadcasted per pot. We counted the maximum height or growth on the third week after sowing and because the red amaranth can be consumed as fresh leafy vegetable when it gains the maximum height after three weeks of growth. The plant height was also measured on a weekly basis. Throughout the growing period, the days to germination of the seed, the percentage of seed germination, the healthy plant/pot ratio, the number of leaf/plant, and the plant growth were calculated.

$$\%\ \text{Germination} = \frac{\text{Number of seeds germinated}}{\text{Total number of seeds sown}} \times 100$$

Table 1
Changes in the chemical properties (pH, EC and TDS) of municipal wastewater after low cost filtration.

Treatments	pH			EC (μS cm^{-1})			TDS (mg L^{-1})		
	Before filtering	*After filtering*	*Recommended pH value for irrigation purpose by FAO*	*Before filtering*	*After filtering*	*Recommended EC value for irrigation purpose by FAO*	*Before filtering*	*After filtering*	*Recommended TDS value for irrigation purpose by FAO*
T_1	7.88 ± 0.21	6.19 ± 0.24 e	6.5–8.4 Ayers and Westcot, (1985)	763 ± 3.56	292 ± 2.21 f	200–700 (Pescod, 1992)	852 ± 3.22	267 ± 1.14 f	450–2000 Ayers and Westcot (1985)
T_2		6.93 ± 0.16 d			348 ± 1.98 e			530 ± 2.24 c	
T_3		5.87 ± 0.19 e			488 ± 3.21 d			729 ± 3.32 a	
T_4		7.41 ± 0.98 c			691 ± 2.26 a			377 ± 1.57 e	
T_5		8.29 ± 1.12 b			544 ± 2.25 c			442 ± 3.58 d	
T_6		9.17 ± 1.17 a			643 ± 2.87 b			652 ± 4.12 b	
LSD$_{(0.05)}$		0.3857			6.661			7.421	
CV (%)		3.16			0.85			0.97	
Level of significance	**			**			**		

Similar letter indicates identical and different letter means they are not same.
**Significant at 1% level of probability.

$$\%\ \text{Healthy plant} = \frac{\text{Number of healthy plants}}{\text{Total number of plants}} \times 100$$

2.5. Determining the heavy metal content in red amaranth after harvesting

At harvest, the plant samples were immediately oven dried at 80 °C until fully dry and ground to produce a fine powder. Samples were then digested using a tri-acid digestion process to extract the heavy metals. The resulting solutions were analyzed to determine the heavy metal concentrations on an atomic absorption spectrophotometer (Model UNICAM 969) using the standard method described for the examination of water and wastewater by Gilcreas (1966).

2.6. Statistical analyses

Prior to commencing statistical analyses, all data were checked for normality, and an equal variance was confirmed using Levene's test. All data are presented as the mean ± SD ($n=3$). The effects of the low cost filtration on the percent germination, the healthy plants per pot, the number of leaves/plant, the average plant height and the heavy metal concentrations (Mn, Cu, Zn, Fe, As and Pb) in the water and plants were analyzed using a one-way ANOVA followed by Tukey's post-hoc test at a 0.05 significant level. Correlations between parameters were judged by Pearson's correlation coefficient at the 0.05 significant level. All statistical analyses were performed using SPSS for Windows (Version 13.0, SPSS, Inc., Chicago, IL, USA).

3. Results

3.1. Chemical properties of the municipal wastewater (pH, EC and TDS) after filtering using different treatments

The pH ranged from 5.87 ± 0.19 to 9.17 ± 1.17 after filtering the municipal wastewater samples; prior to filtration, the pH was 7.88 ± 0.21 (Table 1). The electrical conductivity (EC) of the municipal wastewater samples ranged within the limit of $292 \pm 2.21691 \pm 2.26$ μS cm^{-1}; before treatment, the EC was 763 ± 3.56 μS cm^{-1} (Table 1). The total dissolved solids (TDS) values of all treated wastewater samples varied from 267 ± 1.14 mg L^{-1} to

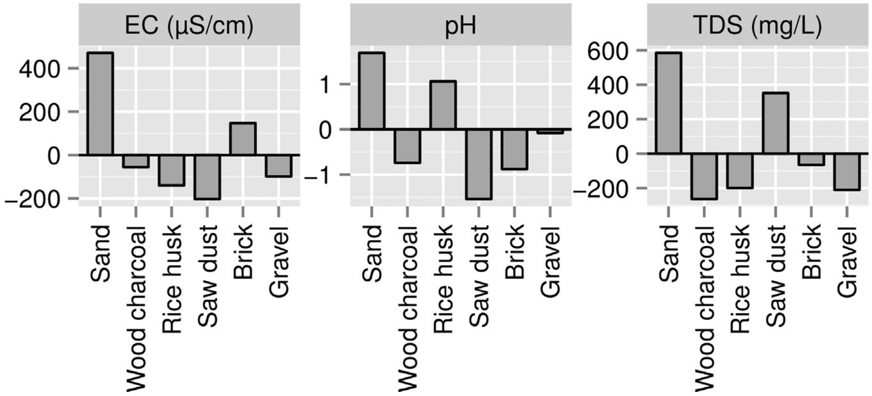

Fig. 2. Efficiency of the experimental materials in altering the water quality parameters. Upward bars indicate the removal amount/increment unit (for pH) and vice-versa.

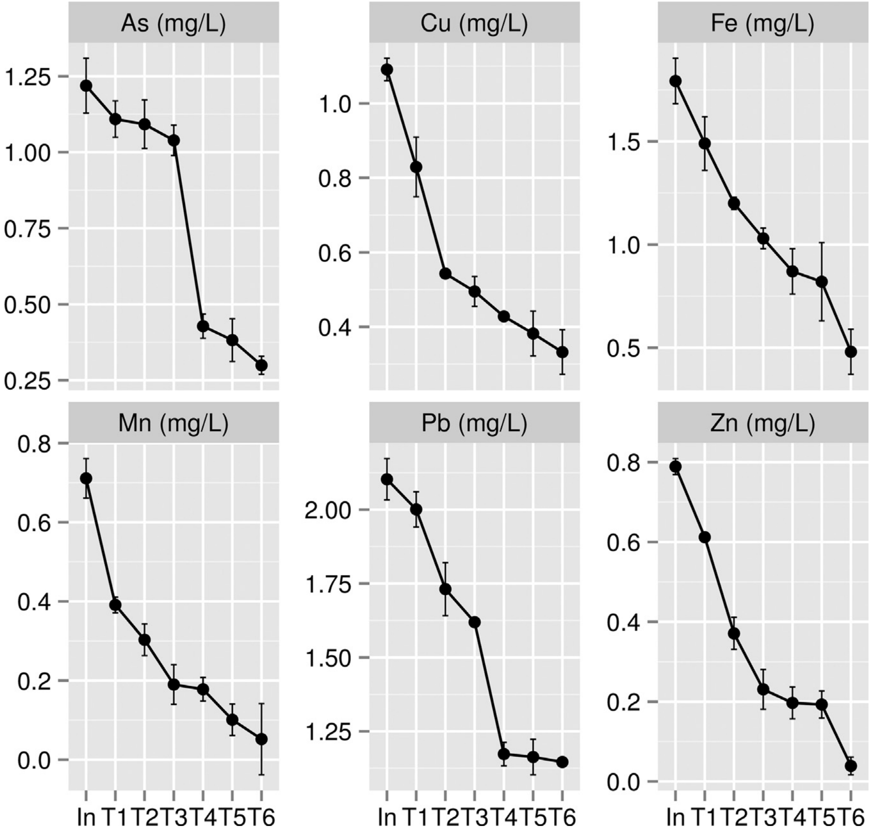

Fig. 3. Cumulative removal of heavy metals from wastewater by the experimental setup.

729 ± 3.32 mg L^{-1} (Table 1); the TDS of the unfiltered sample was 852 ± 3.22 mg L^{-1}. Considering the individual treatments, the maximum reduction in the pH, EC and TDS was found in the sand treatment (Fig. 2)

3.2. Heavy metals reduction

The metals content decreased after each treatment (Fig. 3). The reduction ranges of Fe, Mn, Pb, Cu, As and Zn were 0.30–1.31, 0.32–0.66, 0.10–0.96, 0.26–0.075, 0.11–0.92 and 0.18–0.75 mg L^{-1} from the initial value,

Table 2
Percentage of heavy metals removed by different treatments.

Treatments	Fe	Mn	Pb	Cu	As	Zn
T_1	16.90	45.01	4.85	24.01	9.02	22.43
T_2	33.07	57.36	17.69	50.23	10.42	52.98
T_3	42.55	73.28	23.01	54.63	14.77	70.72
T_4	51.48	74.96	44.22	60.77	64.89	75.03
T_5	54.27	85.79	44.70	64.99	68.66	75.54
T_6	73.23	92.69	45.51	69.57	75.47	95.06

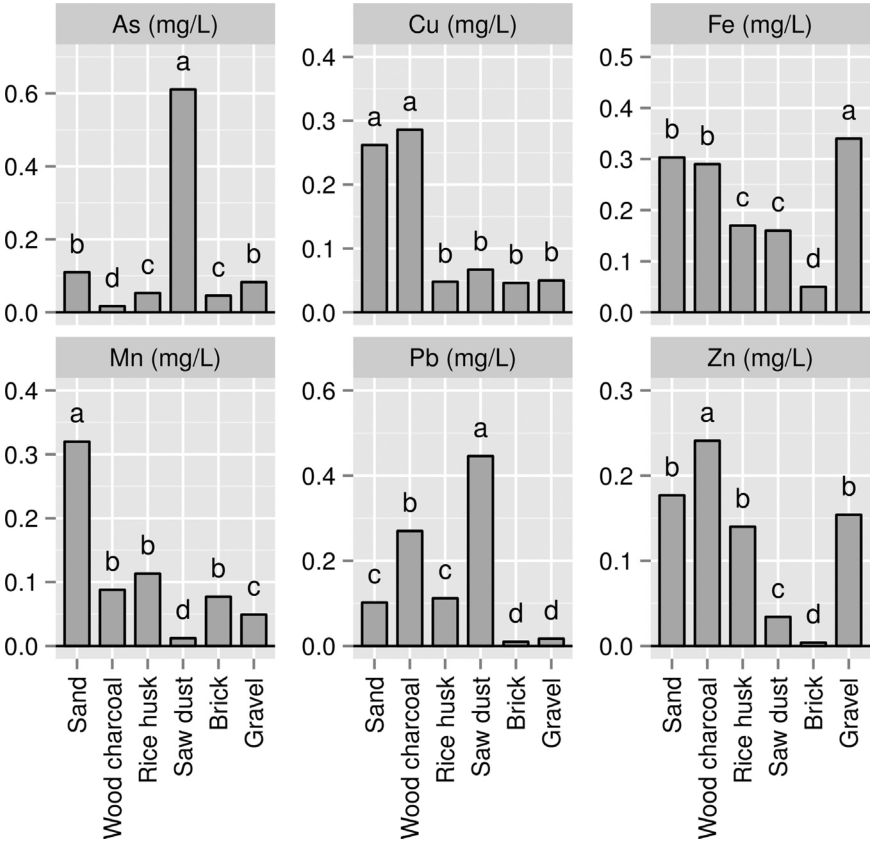

Fig. 4. Efficiency of the filtering materials in removing heavy metals from wastewater. Different letters indicate significant differences at $P=0.05$ according to Tukey's post-hoc test.

respectively, after applying T_1–T_6 (Fig. 3). The percent reduction of Fe, Mn, Pb, Cu, As and Zn were 73.23%, 92.69%, 45.51%, 69.57%, 75.47% and 95.06%, respectively, after applying cumulative treatment (Table 2). For the individual treatments, sawdust absorbed the maximum amount of As and Pb (Fig. 4); wood charcoal and sand accumulated the maximum amount of Cu; wood charcoal absorbed the most amount of Zn, followed by sand, rice husks and gravel; sand absorbed the maximum amount of Mn; gravel absorbed the maximum amount of Fe, followed by sand and wood charcoal (Fig. 4).

3.3. Effect of different filtration treatments on the germination and growth of the plant

The control treatment, T_0, and T_2 required the least number of days (3 days) for the germination of the red amaranth seeds, followed by T_4, T_5 and T_6 (4 days). T_1 and T_3 (5 days) required the highest number of days for

Table 3
Effects of different filtration treatments on the germination percent, plant growth, number of leaves, and number of healthy plants.

Treatments	**Days to germination**	**% germination**	**Height at 1st week (in.)**	**Height at 2nd week (in.)**	**Height at 3rd week (in.)**	**% healthy plant/pot**	**No. of leaf/ plant**
T_0	3.0 b	77.14 a	1.37 d	5.07 b	8.63 a	85.19 b	12.00 a
T_1	5.0 a	65.71 bc	1.97 b	4.90 bc	7.77 bc	60.88 e	7.330 d
T_2	3.0 b	41.43 f	2.13 ab	4.47 de	7.63 bc	75.86 c	5.000 f
T_3	5.0 a	55.71 d	1.73 c	4.67 cd	6.33 e	69.23 d	8.000 c
T_4	4.0 b	47.14 e	1.53 cd	4.27 e	6.60 de	84.85 b	8.000 c
T_5	4.0 b	67.14 b	2.33 a	6.20 a	8.10 ab	93.62 a	10.00 b
T_6	4.0 b	64.29 c	1.60 cd	3.93 f	7.097 cd	80.00 bc	6.000 e
$LSD_{(0.05)}$	0.9365	2.584	0.2283	0.2477	0.7005	5.469	0.6016
CV (%)	13.36	2.47	7.18	2.92	5.37	3.98	4.27
Level of sig.	**	**	**	**	**	**	**

Similar letter indicates identical and different letter means they are not same.
**Significant at 1% level of probability.

Table 4
Metal accumulation in red amaranth after the regular irrigation with municipal wastewater.

Treatments	**Heavy metal content (mg kg^{-1})**					
	Fe	**Mn**	**Pb**	**Cu**	**As**	**Zn**
T_0	37.12 ± 2.12	25.32 ± 1.30 cd	0.20 ± 0.12 g	12.75 ± 1.28	0.005 ± 0.00	26.34 ± 0.54 b
T_1	47.85 ± 6.00 a	29.89 ± 2.01 a	5.11 ± 0.20 a	15.83 ± 2.10 a	7.00 ± 0.80 a	31.95 ± 2.00 a
T_2	42.58 ± 2.00 ab	28.44 ± 0.40 ab	4.03 ± 0.13 b	13.56 ± 2.02 ab	6.77 ± 0.59 a	27.76 ± 2.00 b
T_3	40.95 ± 3.00 bc	27.23 ± 2.10 ab	3.06 ± 0.12 c	12.92 ± 0.71 b	6.45 ± 0.40 a	27.10 ± 0.30 b
T_4	39.68 ± 3.00 bc	26.77 ± 1.62 bc	2.44 ± 0.30 d	12.65 ± 1.60 b	4.95 ± 0.36 b	26.51 ± 1.40 b
T_5	35.37 ± 1.99 c	24.87 ± 1.30 cd	1.68 ± 0.02 e	11.25 ± 1.00 bc	4.32 ± 0.20 b	26.33 ± 0.50 b
T_6	37.93 ± 3.01 bc	23.64 ± 0.50 d	1.09 ± 0.10 f	9.027 ± 0.70 c	3.14 ± 0.10 c	21.90 ± 0.61 c
WHO-ML	**425.00**	**500.00**	**0.30**	**73.00**	**0.01**	**100.00**
$LSD_{(0.05)}$	6.119	2.636	0.3030	2.624	0.8382	2.373
CV (%)	8.45	5.53	5.86	11.76	8.66	4.95
Level of sig.	**	**	**	**	**	**

SD = standard deviation.
Values are mean ± SD.
**Significant at 1% level of probability.

germination. The highest germination percentage (67.14%) was found in T_5, followed by T_1 (65.71%) and T_6 (64.29%); these percentages were statistically identical. However, these germination percentages were significantly lower than the control treatment T_0 (77.14%) that was near the standard (80%) germination percentage. T_2 showed the lowest germination rate (41.43%) (Table 3).

The average plant height was significantly higher in the third week in T_5 (8.10 in.) and was statistically identical to the control sample T_0 (8.63 in.), T_1 (7.77 in.) and T_2 (7.63 in.), whereas the lowest height was found in T_3 (6.33 in.). However, the second week of growth in T_5 (6.20 in.) showed the highest value, marginally higher than the control T_0 (5.07 in.) and was statistically identical to T_1 (4.90 in.) and T_2 (4.47 in.). The lowest growth (3.93 in.) was found in T_6 (Table 3). At the end of the first week, T_5 (2.33 in.) was the tallest, but statistically identical to T_2 (2.13 in.). The plant growth was found to be faster in the second week when compared to the third week.

A significantly higher percent (93.62%) of healthy plant/pot was found in T_5, even significantly better than T_0 (85.19%) and statistically similar to T_4 (84.85%). The lowest percent (60.88%) was observed in T_1 (Table 3). T_5 (10) filtering treatment followed by T_3 (8) and T_4 (8) showed significantly good number of leaves per plant, similar to the control sample T_0 (12). The lowest number of leaves (5) per plant was found for T_2 (Table 3).

3.4. Metal accumulation in red amaranth

The range of Fe, Mn, Pb, Cu, As and Zn accumulation were 35.37 ± 1.99–47.85 ± 6.00, 23.64 ± 0.50–29.89 ± 2.01, 1.089 ± 0.10–5.110 ± 0.20, 9.027 ± 0.70–15.83 ± 2.10, 3.139 ± 0.10–7.002 ± 0.80 and 21.90 ± 0.61–31.95 ± 2.00 mg kg^{-1}, respectively. T_1 showed the maximum accumulation of heavy metals in the red amaranth, and the minimum amount was accumulated in T_6 (Table 4).

4. Discussion

4.1. Changes the pH, EC and heavy metals content of water after filtration

The pH value of municipal wastewater samples ranged from 5.87 ± 0.19 to 9.17 ± 1.17 after filtration; the pH was 7.88 ± 0.21 before filtration. After filtration, the T_5 (8.29 ± 1.12) and T_6 (9.17 ± 1.17) samples were alkaline, and the T_4 (7.41 ± 0.98) sample was slightly basic in nature. However, T_1 (6.19 ± 0.24), T_2 (6.93 ± 0.16) and T_3 (5.87 ± 0.19) were acidic (Table 1). Previous studies, such as Argo and Moutes (1979), documented that the pH value of untreated municipal wastewater was approximately 7.3, and the pH of sewage water used for irrigation around of Quetta, Pakistan varied from 7.24 to 9.21 (Kakar, Yasinzai, Salarzai, Oad, & Siddiqui, 2006). The standard pH of irrigation water recommended by the FAO is 6.5–8.4 (Ayers & Westcot, 1985). Considering the standard value of FAO, filtering treatments T_2, T_4, T_5 and the untreated sample were found to be suitable for irrigation, whereas T_1, T_3 and T_6 were not suitable. The electrical conductivity (EC) of the municipal wastewater samples ranged within the limit of 292 ± 2.21–691 ± 2.26 µS cm^{-1}, whereas before treatment, the EC was 763 ± 3.56 (Table 1), indicating that all the filtration treatments were suited to be irrigation water as recommended by Ayers and Westcot (1985) (200–700 µS cm^{-1}). However, the untreated sample was not suitable for irrigation. The TDS is a critical criterion for judging the water quality for irrigation, drinking and other uses. The TDS values of all treated wastewater samples varied from 267 ± 1.14 mg L^{-1} to 729 ± 3.32 mg L^{-1} (Table 1), and the unfiltered sample was 852 ± 3.22 mg L^{-1}; all were at an acceptable level for use in irrigation, satisfying the FAO standard TDS value (450–2000 mg L^{-1}) (Ayers & Westcot, 1985). Considering individual treatments, sand showed a decreasing trend for pH, TDS and EC and the rice husks for the pH, sawdust for the TDS and brick chips for the EC showed a similar trend as the sand treatment. However, other treatments showed an increasing trend (Fig. 2), and this result agrees with other works (Hamoda et al., 2004; Hegazy et al., 2007).

The initial metals content of the sample before filtering were 1.79, 0.71, 2.10, 1.09, 1.22, and 0.79 mg L^{-1} for Fe, Mn, Pb, Cu, As and Zn, respectively. The metal contents decreased after applying each treatment (Fig. 3). The reduction ranges of Fe, Mn, Pb, Cu, As and Zn were 0.30–1.31, 0.32–0.66, 0.10–0.96, 0.26–0.075, 0.11–0.92 and 0.18–0.75 mg L^{-1} from the initial value, respectively, after applying T_1–T_6 (Fig. 3). The percent reduction of Fe, Mn, Pb, Cu, As and Zn were 73.23%, 92.69%, 45.51%, 69.57%, 75.47% and 95.06%, respectively, after applying the cumulative treatment (Table 2). For the effects of the individual treatments, sawdust absorbed the maximum amount of As and Pb (Fig. 4). Sawdust also played an important role in removing Cu and Zn, although not at the maximum for all materials (Fig. 4). Sawdust, obtained from the wood industry, is an abundant by-product which is easily available in the countryside at a small price. Sawdust contains various organic compounds (lignin, cellulose and hemicellulose) with polyphenolic groups that could bind to heavy metal ions through different mechanisms. A previous study on the adsorption of Pb(II) and Cd(II) onto formaldehyde treated sawdust of *Pinus sylvestris* showed that the two metal ions were successfully removed in less than 20 min at low concentrations (< 10 mg L^{-1}), during which the metal ions could form complexes with the oxygen atom on the carbonyl and hydroxyl groups (Taty-Costodes, Fauduet, Porte, & Delacroix, 2003; Wan Ngah & Hanafiah, 2008). Poplar and fir wood were treated with NaOH and Na_2CO_3 solutions, and equivalent amounts of adsorption capacities were recorded for both types of sawdust for Zn^{2+} and Cu^{2+} ions, although these two adsorbents display different anatomical structures and chemical compositions (Šćiban, Klašnja, & Škrbić, 2006). Li, Zhai, Zhang, Wang, and Zhou (2007) used sawdust and modified peanut husk as absorbents to remove Pb(II), Cr(III) and Cu(II) from aqueous solution; the suitability of the adsorbent was tested by fitting the adsorption data with the Langmuir and Freundlich isotherm, producing good fits for both isotherm. Shukla and Pai (2005) assessed the potential of cheap cellulose-containing natural materials such as groundnut shells and sawdust for Cu(II), Ni(II) and Zn(II) adsorption from aqueous solutions and reported that these materials displayed good adsorption capacities, although the levels differed depending on the combination of adsorbing materials and metal ions. Wood charcoal and sand accumulated the maximum amount of Cu; Zn was absorbed by wood charcoal, followed by sand, rice husks and gravel; the maximum amount of Mn was absorbed by sand; gravel absorbed the maximum amount of Fe, followed by sand and wood charcoal (Fig. 4). Ellis and Wood (1985) mentioned that the removal capacity of slow sand filtration was 30% to 90% for Fe and Mn. Erdem, Karapinar, and Donat (2004) also reported that natural zeolites display a potential to remove cationic heavy metal species from industrial wastewater, supporting our results.

4.2. Effect on seed germination and plant growth

The different filtration treatments and chemical components of municipal wastewater directly or indirectly affected the seed germination rate, plant growth and plant development. The present study showed a comparatively lower rate of germination percentage than the standard, potentially because of the presence of a higher concentration of select heavy metals even after filtration. Begum, Alam, Rahman, and Rahman (2010) and Sarwar, Chowdhury, Biswas, and Sarkar (2011) also reported that the relative germination rate of mustard, stem amaranth, radish and red amaranth is almost inhibited with increasing concentrations of wastewater. Khan et al. (2011) also found that the seed germination was affected in higher concentrations of municipal wastewater. Nagda, Diwan, and Ghole (2006) reported that the seed germination efficiency decreases at higher concentrations of municipal effluent. Khan and Sheikh (1976) reported that the significant reduction and delay in the germination of *Capsium annum* seeds may result from a higher amount of soluble salts in the polluted water. Veliappan, Melchias, and Kasinathan (2002) found that the different concentrations of heavy metals affected the nodule formation and germination of three legume cultivars: *Vignaunguiculata, Vignamungo,* and *Vignaradiata.* Dash (2012) reported that the rate of seed germination for both rice and wheat cultivars increased progressively with increasing concentrations of domestic wastewater up to 50%, thereafter it decreased and was delayed.

Kiziloglu et al. (2007) showed approximately 49% of healthy plants (cauliflower) was found after primary treatment, lower than this in study (93.62% of healthy plants). All growth parameters of the paddy increased by 25% by using the biologically treated municipal wastewater when compared with the control (Jayakumar, Kannan, & Nagarajan, 2013). Begum et al. (2010) reported that the relative shoot elongation ratio of the germinated seeds increased and that the average root length of mustard (*Brassica campestris*), amaranth stem (*Amaranthus gangeticus*) and radish (*Raphanus sativus*) decreased with increasing concentrations of industrial effluent. Wastewater from different sources contains 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, Gori, Nicese, & Ferrini, 2004; Nagajyothi et al., 2009; Nath, Singh, Shyam, & Sharma, 2009; Pathak et al., 1999; Pathak et al., 1998; Ramana, Biswas, Singh, & Yadava, 2002). An increase in the growth of olive (*Olea europaea*) trees due to irrigation with municipal wastewater has been reported by Aghabarati, Hosseini, Esmaili, and Maralian (2008). Stewart, Hopmans, Flinn, and Hillman (1990) also suggested that the addition of municipal wastewater on *Eucalyptus grandis* resulted in a doubling in the growth rate when compared with *E. grandis* grown in a rain fed site over four years. Singh and Agrawal (2010) suggested that wastewater irrigation favorably affected the physiological, biochemical and growth characteristics of plants, but the biomass and yield did not differ significantly for *Beta vulgaris* L. Primary and secondary treated wastewater showed a slightly lower and better crop yield, respectively, for lettuce, radish, carrots, early potatoes, and sugar beets (Zavadil, 2009). Side-shoot lengths of *Thuja orientalis* were greater in plots irrigated with municipal wastewater without significant differences (Sakellariou-Makrantonaki, Tentas, Koliu, Kalfountzos, & Vyrlas, 2003). The growth and yield of stem amaranth were not strongly influenced by textile wastewater irrigation compared with groundwater (Khandaker, Hassan, & Saha, 2013). The growth of alfalfa in the Katta-Elkheel Field was negatively affected by irrigation with wastewater (Zeid, Ghazi, & Nabawy, 2013). The addition of arsenic in irrigation water significantly reduced the yield and yield components of red amaranth (Choudhury et al., 2008). Municipal wastewater application reduced plant vegetative and reproductive growth in addition to adverse effects on the soil health and environment likely because of the high pH, SAR and salinity (Khan et al., 2012). Tabassum, Akhtar, and Inam (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 by giving significantly higher values than groundwater but also served as an extra dose of fertilizer. Therefore, this process fulfills the twin objectives of saving freshwater and saving fertilizers. Mendoza-Espinosa et al. (2008) reported that the number of leaves per shoot and the overall biomass increased and the relative shoot growth rate (RGR) decreased in plants irrigated with wastewater during grape production. Ali, Hoque, Hassan, and Khair (2007) showed that the number of leaves was higher than for other filtration treatments. However, in this study, we found less leaves per plant than the control treatment.

4.3. Accumulation of heavy metals

A noticeable amount of heavy mental were accumulated in the red amaranth plant in the maximum growth stage (up to the third week) after the regular irrigation of low-cost filtered municipal wastewater. Fe, Mn, Cu and Zn level were found within the safe limit; however Pb and As exceeded the permitted limit according to FAO (2007). For municipal wastewater, the irrigation of primary and secondary treated wastewater displayed a variation in metal accumulation for Mn (49 and <0.20 mg/L), Fe (0.16 and 0.22 mg/L), Pb (4.3 and 1.4 mg/L), As (1.6 and 1.0 mg/L), Cu (14.6 and 1.7 mg/L) and Zn (260 and 14 mg/L) in lettuce, radishes, carrots, early potatoes, and sugar beets (Zavadil, 2009). The current study agreed with the content of four trace elements (µg/g of dry wt.), Mn (15.5–52.8), Fe (57.2–361), Cu (8.01–18.3) and Zn (27.8–84.4), in four popular vegetables, namely spinach, red amaranth, bottle gourds, and pumpkins (Naser, Sultana, Mahmud, Gomes, & Noor, 2012). The heavy metal contents in red amaranth presented a similar range for Mn (31.1 ± 2.8–48.2 ± 4.56), Cu (9.86 ± 1.04–14.1 ± 2.25) and Zn (31.0 ± 2.19–39.1 ± 3.34), but not for Fe (195 ± 10.9–328 ± 14.8). 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, which showed a distinct Fe content when compared to this study. The previously reported concentrations of Pb in red amaranth (1.58 ± 0.01 mg kg^{-1}), spinach (1.52 ± 0.02 mg kg^{-1}), amaranth (1.95 ± 0.05 mg kg^{-1}) (Naser et al., 2012) were closer to the content of Pb in T_6. Rauf, Parkplan, and Miah (2013) reported the Pb content in the root, stem, leaf of red amaranth (1.91–3.99 mg kg^{-1}), near the range of the Pb content of present study.

Irrigation with wastewater lead to a significant increase in Cu and Fe in sorghum plant in comparison with the control treatment ($P\leq0.01$), but the lead enhancement were not significant (Galavi, Jalali, Ramroodi, Mousavi, & Galavi, 2010). Choudhury et al. (2009) reported that red amaranth can tolerate arsenic up to 15 mg/L, and a drastic yield reduction was obtained with any additional arsenic. The effects of using wastewater in irrigation depend on the filtering materials and tree species. Because of the limited information regarding the low cost filtration of municipal wastewater for irrigation, the seed germination, other growth parameters and heavy metal reduction and accumulation in red amaranth is difficult to compare with the literature. Select studies presented an overall positive trend, revealing that sand, wood charcoal, sawdust, rice husks, brick chips and gravel as a simple filtration method provides a low cost solution for obtaining irrigation water from waste effluents. This simple filtration is applicable in roof gardening or vegetable cultivation at small scales in which a compact dwelling and mechanized lifestyle are united. In this study, the presence and effect of different microorganisms in the wastewater sample and chemical properties of the heavy metal contents in the red amaranth grown in soil were not studied. Future research on the microbial population and the irrigated soil chemical properties and their effect on crops, consumers and growers will address the long term vision regarding the irrigation feasibility of low-cost filtered municipal wastewater.

5. Conclusion

The quality of low-cost filtered municipal wastewater and control water used for irrigation was compared in the present study. The performance on seed germination and the overall plant growth (red amaranth) using the control water was not significantly different than the filtered wastewater. The chemical properties, the pH, EC and TDS, of the filtered wastewater were generally at a satisfactory level. The nutrient concentrations and heavy metals in the treated wastewater appeared to be under the critical limits. The simple filtration method was able to reduce the amount of heavy metals, displaying the irrigation feasibility of low-cost filtered municipal wastewater. Excessive contents of heavy metals in the crops irrigated with municipal wastewater were not noted. A noticeable amount of heavy mental were accumulated in the red amaranth plant during the maximum growth stage (up to the third week) after the regular irrigation with low-cost filtered municipal wastewater. The level of heavy metals Fe, Mn, Cu and Zn were found within the safe limit; however, Pb and As exceeded their limits. T_5 is an effective low-cost filtration method for municipal wastewater for irrigation because it positively influenced the growth parameters, reduced the heavy metal contents and accumulated in red amaranth, except for As and Pb.

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