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Research Article
Accumulation of Heavy Metals in Soil and Sweet Potato (*Ipomoea batatas*) Irrigated with Treated and Untreated Textile Effluents

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Abstract
Background and Objectives: Accumulation of heavy metals in soil and plant tissue is one of the most pressing threats to the growth and development of plants, as well as human health. The purpose of the investigation was to evaluate the impact of using treated and untreated industrial effluent on the amount and type of heavy metals accumulated in soil and plant tissue and its impact on growth and yield of sweet potato (*Ipomoea batatas*) va. Kulfo. **Material and Methods:** The experiment was conducted at Hawassa College of agriculture using pot at field condition during January-June, of 2016. A completely randomized experimental design with 4 treatments (3 replicates each) were used. The effluent samples were collected from; untreated lagoon, semi treated lagoon, treated lagoon and Lake Hawassa water and used as treatments. Plant growth and physiological parameters were collected during the vegetative growth period and during harvesting time (150 DAP). **Results:** The result indicated that sweet potato irrigated with untreated textile wastewater significantly reduced vine length as compared to control. Plant irrigated with semi treated wastewater gave maximum photosynthesis and transpiration rate than untreated, treated and water from Lake Hawassa (Control). The bioaccumulation concentration factor (BCF) value of Cu in untreated wastewater was 1.4-2 fold higher than the translocation value Cu in lake water, semi treated and treated treatments. Copper (Cu) has higher capacity to accumulate in edible parts of sweet potato tuber than Cd, Cr and Zn metals. However, Zn had stronger potential to accumulate in soil than Cu and Cr. **Conclusion:** It is concluded that both Zn and Cu were found potential metals to accumulate both in soil and plant tissue and likely threat for human health than Cr if inhabitants of study area experience the consumption of sweet potato irrigated with untreated textile effluent.

Key words: Bioaccumulation, heavy metals, photosynthesis, textile effluent, sweet potato

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Textile processing operations are considered as an important part of the industrial sector in both developed and developing countries like Ethiopia[1-2]. However, the wastewater discharged from the factory have adverse effect on the environments and human life. The textile industrial discharges are mainly associated with concentration of heavy metals like Lead (Pb), Cadmium (Cd), Mercury (Hg), Copper (Cu), Nickel (Ni), Zinc (Zn), Arsenic (Ar) and others[3]. Heavy metals are commonly defined as those metals having 5 times (5 g cm^{-3}) higher specific density than waters[3]. Such metals are hazardous to ecosystems or human health based on the threshold level present in soils and plants[4]. They may causes carcinogenic disease, mutation and genetic damage if their threshold is above what the human body is requiring per body mass[1-2,5-7].

Plants, which are sessile by nature, are the most vulnerable and sensitive to pollution than other organisms. Cho-Ruk *et al*.[8], Pahlsson[9] and Toth *et al*.[10] indicated that toxic materials in water, soil and air could harm the fine structures of vital plant organs such as leaves and root systems. However, the amount of heavy metal removed from soil by plant depends on plant species, plant age, growth condition of plants, pH of the soil, organic matter content of the soil and cation exchange capacity of the soil1[11-14]. In addition, report indicated that, the absorbed heavy metal from the soil can also be stored in roots (Lead) or both in the root and shoot region of the plants (copper and zinc)[15-16].

While it is accumulated in different parts of plant organs, it inhibit metabolic processes by inhibiting the action of enzymes and this may be the most important cause in the reduction of chlorophyll content. However, the response of sweet potato to heavy metals not well addressed. Sweet potato [*Ipomoea batatas* L. (Lam.)] is one of the food security root and tuber crop which is cultivated in most of the developing countries. In Ethiopia it is cultivated in moisture stressed area by small-scale farmers of Eastern, Southwestern and Southern parts of the country[17]. However, drought is often a major environmental constraint for sweet potato production in areas where moisture is a limiting factor for production[18-19]. Under such condition farmers are encourage to use treated industrial wastewater. However, industrial wastewater driven food chain contamination by heavy metals has become a burning issue in recent years because of their potential accumulation in bio systems.

This is therefore, the objective of this study was to evaluate the amount and type of heavy metal accumulated in soil and plant tissue through irrigation of untreated, semi treated, treated and lake Hawassa water and its impact on growth performance and productivity of sweet potato. Therefore, a better understanding of heavy metal sources, their accumulation in the soil and plant system seem to be practically important issue in future research and risk assessment.

MATERIALS AND METHODS

Description of the study area: The pot experiment was conducted in Horticultural Science field, at Hawassa University, college of Agriculture, Hawassa, Ethiopia from January-June, 2016. The site is located in Hawassa city which is 273 km away from the capital city known as Addis Ababa. The site is located at 7°3'17'' N latitude and 38°28'21''E longitude and at an altitude of 1700 masl. The soil type of the area is sandy loamy with pH of 7.9. The average rainfall of the area is 800-1100 mm annually, while the average annual maximum, minimum and mean temperature of 27, 12 and 20, respectively.

Plant materials, pre-treatment conditions and experimental design: For this study sweet potato cultivars (Kulfo) which was obtained from Southern Agricultural Research Institute (SARI), Hawassa, Southern Nation Nationality People Regional State (SNNPRS) and Ethiopia was used. The experiment was conducted in pot (pot size of 50 cm wide and 20 cm depth) filled with mixture of top soil, compost and sand (2:1:1: v/v ratio). In each treatments 6 pots were used and replicated three times. During the pre-treatment growth period (4 weeks), plants were watered with tape water to enhance root and shoot establishment. The pre-treatment cultivation ended when plants had 4-5 adventitious roots and about 3-4 well developed leaves. The experiment had 4 treatments of irrigation water; untreated wastewater, semi treated wastewater, treated wastewater and control. The experiment was laid out in complete randomized design (CRD) using pots at field condition.

Wastewater sample collection: Three wastewater samples were collected from 3 Hawassa textile wastewater treatment lagoon (Site 1, 2 and 3) and another water sample from Lake Hawassa and used as control (Fig. 1). The wastewater were sampled from each lagoon only once to keep the uniformity of the wastewater concentration uniform throughout the experiment period. During the experimental period, one litter of wastewater was applied to each pot in addition to the irrigation water used as treatments. The wastewater collected before entering the treatment lagoon

Fig. 1: Sample collection site (Modified from[20-21])

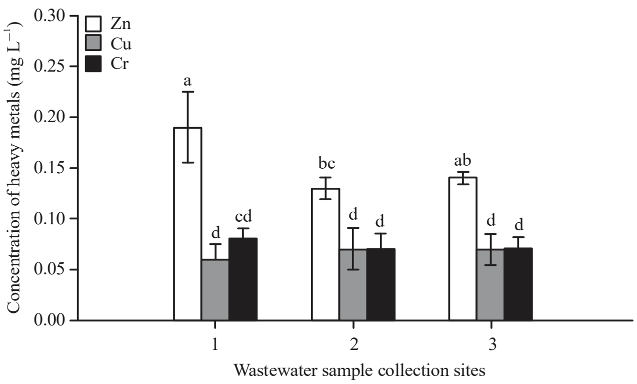

Fig. 2: Concentration of different type of heavy metals in untreated (Site 1), Semi treated (site 2) and treated (site 3) wastewater collected from Hawassa textile effluents

All values sharing the same letter in each element are statistically non-significant at $p \leq 0.05$

(Site 1: untreated), hereafter called Site-1, wastewater collected from semi treatment lagoon (Site 2: semi treated), hearafter called Site 2, wastewater collected from the treatment (Site 3: treated) lagoon, hereafter called Site 3 and from Hawassa Lake, hereafter called control.

Determination of heavy metals in water, textile effluent, soil and plant tissue: Heavy metals (Cr, Cu, Zn, Cd,) accumulated in plant tissue and soil medium was analyzed at JIJE Analytical testing service laboratory, Addis Ababa, Ethiopia using Atomic absorption spectrometry based on the methodology of AOAC Official Method 985.35.Similarly, the concentration of each element in wastewater and tuber sample were calculated following the methodology developed by APHA 3111C[22] and AOAC 923.03, respectively. Moreover, the concentration of element in soil also calculated following the methodology used by Aqua-Regia Digestion[23]. However, the concentration of Cd recorded in each sample was found below the detection level and therefore the statistical analysis did not include Cd (Fig. 2).

Plant growth analysis: Non-destructive growth data such as vine length, branch number, leaf number, leaf thickness, stomatal conductance, leaf surface temperature and chlorophyll fluorescence measurement was collected from three plants during the vegetative stage. The destructive measurement data like, collection of total leaf area, imprints of leaf epidermis, fresh weight of leaf, stem, individual tubers, total tuber fresh weight/plant and dry weight of leaf, stem, individual tubers and total dry weight of tuber/plant were collected during harvesting period (at 150 days after planting).

Stomata anatomy and gas exchange analysis: During the vegetative stage, stomata number and morphology was measured on fully expanded leaves. To evaluate stomata anatomy and features, epidermal imprints was taken between 10:00-11:00 h from the lower surface of fully expanded leaves by coating approximately 1.5×1.5 cm area of the leaf surface with clear nail polish. Epidermal impressions were made by applying a thin pellicle of transparent fingernail polish on the leaf surface and letting it dry for 10 min. The imprints were removed from the leaf with clear adhesive tape and glued on a microscope slide. Stomata aperture, stomata number and stomata opening area were measured using Automated Upright Leica Microscope (LM) DM5000 B, fixed with digital Leica DFC425/DFC425C image processing camera (Leica DFC450, resolution 5 M pixels, 2/3" CCD sensor, pixel size 2560×1920 3.4×3.4 µm).

Moreover, stomata conductance (gs) was estimated during the vegetative growth stage (on 4th and 5th week, days after planting) from fully opened intact leaves (at

5th node) using an open system LCA-4 ADC portable infrared gas analyzer (Analytical Development Company, Hoddeson, England) set to measure under ambient conditions. The measurements were done between 12:00 and 15:00 h while the photosynthetic active radiation (PAR) was ranging from 500- 2000 μmol m^{-2} sec^{-1}.

Bioaccumulation and translocation of heavy metals from soil to tuber: The concentrations of heavy metals in soil and sweet potato tuber samples were determined following the methodology of FAAS APHA 3111C[22] and AOAC 923.03. From each soil and about 0.5-3 g of air-dried soil was mixed with 7 mL of concentrated HNO_3 and 21 mL of concentrated HCl. The mixture was digested and dissolved in 2% HCl solution. Similarly, about 0.5-3 g sweet potato tuber samples was digested in a 5 mL 1 N HNO_3. The copper (Cu), zinc (Zn), chromium (Cr) and cadmium (Cd) concentrations of digestion solutions of soil and tuber samples were determined using flame atomic adsorption spectrophotometer. The translocation of each of the heavy metal from soil to tuber was calculated following the methodology[24].

Estimating daily intake (EDI) and health risk of heavy metals: The estimated daily intake (EDI) of heavy metals was determined based on the metal levels in sweet potato tuber and the amount of consumption of the respective sweet potato tuber. Previous report indicated that, the EDI of metals could be evaluated according to the average concentrations of each metal in food crops and the respective daily consumption rate[25]. The EDI of metals for adult was estimated based on the methodology[26].

Using a short survey the sweet potato intake patterns and cooked by adults at Chefe kotijabesa district (district surrounding the industry and wastewater treatment lagoon) of South Nation and Nationality of peoples region State (SNNPRS), Ethiopia were assessed. In this study, about 90 adults were involved in the survey. The minimum and maximum age and body weight record in the questionnaire survey for adults were 30-86 years and 53-78 kg, respectively.

Moreover, the health risks that is associated with the intake of heavy metals was assessed based on Target Hazard Quotients (THQs). The THQ is a ratio of determined dose of a pollutant to a reference dose level. If the ratio is less than 1.0, the exposed population is unlikely to experience obvious adverse effects. The method to estimate THQ was provided in USEPA Region III Risk Based Concentration Table (USEPA, Integrated Risk Information System-database, Philadelphia PA, Washington 2007)[27-28]. For THQ, an adult person with 70 years old and 65 kg b.wt., were used as average exposure time and body weight of local inhabitants.

Table 1: Contamination categories based on geo-accumulations index (Igeo)

Class	Value	Classifications
0	I-geo<0	Unpolluted
1	0≤I-geo<1	Unpolluted to moderately polluted
2	1≤I-geo<2	Moderately polluted
3	2≤I-geo<3	Moderately to strongly polluted
4	3≤I-geo<4	Strongly polluted
5	4≤I-geo<5	Strongly to very strongly polluted
6	I-geo = 5	Very strongly polluted

Source: Ho *et al.*[31]

Index of geo-accumulation: The intensity of environmental pollution induced by heavy metal contamination was determined based on the index of geo-accumulation of each heavy metal measured during the analysis. The index value of each metal in soil was calculated using the methodology applied by Asaah *et al.*[29] and Mendiola *et al.*[30]. The degree of metal pollution was assessed in terms of 7 contamination classes based on the increasing numerical value of the index[31] as following in Table 1.

Statistical analysis: For each treatment, data was collected in three replication from 3 plants. All statistical tests were performed in Minitab (Minitab 16.1.1, windows version, State College, Pennsylvania, USA). Analysis of variance (ANOVA) was done using one-way ANOVA. Significant differences between treatments (mean separation) was determined using Tukey's test at $p<0.05$.

RESULTS

Plant growth and anatomy of stomata: Sweet potato plants irrigated with wastewater collected from Site 1 had significantly ($p\leq 0.05$) shorter vine length than plants irrigated with water collected from Lake Hawassa (control). The presented result indicate that, irrigating sweet potato (Kulfo) plant with untreated (site 1) and semi treated (site 2) wastewater reduced the vine length by about 28.1 and 17.89 cm, respectively compared to plant irrigated with Lake Hawassa water (control) (Table 2). However, branch number, leaf number, total leaf area, stomata aperture, stomata opening area, specific leaf area, total fresh weight/plant, number of tubers/plant and individual tuber fresh weight were not significantly influenced due to treatment effect ($p>0.05$) (Table 2). Moreover, result also showed that, irrigation of sweet potato with untreated, semi treated,

Table 2: Impact of untreated (site 1), semi treated (site 2), treated (site 3) textile effluent and lake Hawassa water (control) irrigation on growth and yield of sweet potato (Kulfo variety during 2015/2016)

Treatments	Vine length (cm)	Branch number	Leaf number	Leaf area (cm^2)	Total fresh weight of tuber (g)	Number of tuber	Individual tuber fresh weight (g)
Control	90.56 ± 4.40^a	33.30 ± 5.7	565.0 ± 148	4229.9 ± 1664	512.0 ± 241	4.0 ± 0.00	128.0 ± 60.3
Site 1	62.44 ± 4.12^b	22.20 ± 2.3	501.8 ± 94.3	3141.7 ± 746	317.0 ± 50.5	5.3 ± 0.90	65.1 ± 17.2
Site 2	72.67 ± 8.41^b	24.55 ± 6.5	823.4 ± 336	6708.7 ± 3248	769.1 ± 416	5.7 ± 1.45	143.6 ± 63.4
Site 3	79.80 ± 3.4^{ab}	29.89 ± 2.3	647.2 ± 143	3593.9 ± 617	295.2 ± 18.0	3.7 ± 0.33	81.0 ± 2.73
p-value	0.035	0.397	0.709	0.573	0.516	0.344	0.577

All values sharing the same letter in a column are statistically non-significant at $p \leq 0.05$, Mean±SE

Table 3: Impact of untreated (site 1), semi treated (site 2), treated (site 3) textile effluent and lake Hawassa water (control) irrigation on stomata distribution, stomata aperture and stomata area/sweet potato leaf (Kulfo cultivar)

Treatments	Stomata count (mm^{-2})	Stomata aperture (m)	Stomata opening area (m^2)	Specific leaf area (cm^2 g^{-1})
Control	20.3 ± 2.2^a	340.1 ± 18.1	681.0 ± 47	90.27 ± 16.2
Site 1	17.3 ± 0.9^{ab}	353.9 ± 23.0	653.0 ± 130	84.60 ± 16.7
Site 2	12.7 ± 2.3^b	314.5 ± 27.2	555.0 ± 88	100.00 ± 23.8
Site 3	19.3 ± 2.96^{ab}	325.0 ± 20.5	800.0 ± 56	86.80 ± 30.2
p-value	0.047	0.639	0.326	0.842

All values sharing the same letter in a column are statistically non-significant at $p \leq 0.05$, Mean±SE

Table 4: Impact of untreated (site 1), semi treated (site 2), treated (site 3) textile effluent and lake Hawassa water (control) irrigation on leaf temperature, gas exchange, transpiration rate and photosynthesis/leaf of sweet potato (Kulfo cultivar) plant

Treatments	Leaf surface temperature (°C)	Stomata conductance (gs) (mmol m^{-2} sec^{-1})	Transpiration rate (mmol m^{-2} sec^{-1})	Photosynthesis (mol m^{-2} sec^{-1})
Control	36.13 ± 1.4^b	90 ± 0.02	3.17 ± 0.62^b	10.0 ± 3.1^{ab}
Site 1	39.00 ± 1.4^{ab}	56 ± 0.01	2.78 ± 0.46^b	9.7 ± 2.0^{ab}
Site 2	36.98 ± 0.5^b	90 ± 0.02	4.90 ± 0.53^a	15.3 ± 3.04^a
Site 3	43.00 ± 1.13^a	40 ± 0.02	3.16 ± 0.5^b	3.8 ± 0.98^b
p-value	0.002	0.289	0.042	0.028

All values sharing the same letter in a column are statistically non-significant at $p \leq 0.05$, Mean±SE

treated and lake Hawassa water significantly ($p \leq 0.05$) influenced number of stomata/mm^2. Sweet potato plant irrigated with Lake Hawassa water had seven more stomata number/mm^2 than plant irrigated with semi treated textile effluent (Table 3).

Photosynthesis, transpiration rate and stomatal conductance: Result in Table 4 indicated that, except leaf stomata conductance, leaf temperature, transpiration rate and photosynthesis rate were significantly influenced by type of irrigation water used ($p \leq 0.05$). Plant irrigated with semi treated textile wastewater gave significantly higher transpiration rate (4.9 mmol m^{-2} sec^{-1}) and photosynthesis (15.3 mol m^{-2} sec^{-1}) as compared to plant irrigated with untreated, treated and lake Hawassa water (Table 4). Moreover, it was observed that plant irrigated with treated wastewater had significantly larger leaf surface temperature (43.0) than those irrigated with untreated (39), semi treated (36.98) and control (36.13) (Table 4).

Accumulation of heavy metals in soil media: The pollutant intensity of the heavy metals also evaluated based on the geo accumulation range and pollutant classification value of heavy metals. Result from geo accumulation classification analysis indicated that, Zn had stronger geo accumulation potential than Cu and Cr (Table 5). From the background heavy metal concentration of upper crust and agricultural soil and geo accumulation estimation point of view, Zn might be categorized as potentially a moderately pollutant ($Igeo \geq 1$) element, whereas, Cu and Cr might be categorized as unpolutant to moderately pollutant (Igeo = 0.1-0.4) (Table 5). Moreover, value for Cd was not indicated due to the concentration was below the instrument detection level.

Moreover, the soil analysis result indicated that irrigation of sweet potato with untreated, semi treated, treated textile effluent and Lake Hawassa water significantly ($p \leq 0.05$) influenced the concentrations of the heavy metals in growing media. Growing media irrigated with treated textile effluent had higher concentration of Cu (29.08 mg kg^{-1} soil) than media irrigated with untreated, semi treated textile effluent and Lake Hawassa water. However, the concentration of Cr was significantly higher in untreated (16.8 mg kg^{-1} soil) and control (15.9 mg kg^{-1} soil) as, growing media irrigated with untreated textile effluent and lake Hawassa water, respectively (Table 6). However, there was no significant difference ($p > 0.05$) on the concentration of Zn in growing media due to the type of irrigation water used (Table 6).

Table 5: Average, calculated igeo index, background concentration of upper crust, Igeo grade of pollution intensity of heave metals in soil sample irrigated with lake Hawassa water (control), untreated (site1), semi-treated (site 2) and treated (site 3) of Hawassa textile wastewater

Treatments	Elements	Background concentration of upper crust (Bn) (mg kg^{-1} soil)	Geo-accumulation index (Igeo = Log2(Cn/1.5Bn)	Pollution intensity
Control	Zn	52.0	1.0	Moderately polluted
Site 1	Zn	52.0	1.0	Moderately polluted
Site 2	Zn	52.0	1.0	Moderately polluted
Site 3	Zn	52.0	1.0	Moderately polluted
Control	Cu	14.3	0.4	Unpolluted to moderately polluted
Site 1	Cu	14.3	0.2	Unpolluted to moderately polluted
Site 2	Cu	14.3	0.3	Unpolluted to moderately polluted
Site 3	Cu	14.3	0.4	Unpolluted to moderately polluted
Control	Cr	35.0	0.1	Unpolluted to moderately polluted
Site 1	Cr	35.0	0.1	Unpolluted to moderately polluted
Site 2	Cr	35.0	0.1	Unpolluted to moderately polluted
Site 3	Cr	35.0	0.1	Unpolluted to moderately polluted
Control	Cd	-	ND	-
Site 1	Cd	-	ND	-
Site 2	Cd	-	ND	-
Site 3	Cd	-	ND	-

ND: Not detected, Bn: Background concentration of metal upper crust, Cn: Concentration metal

Table 6: Concentration of heavy metal in sweet potato (Kulfo variety) growing media irrigated with treated, semi treated, untreated textile effluent and lake Hawassa water (control) during January-June 2016

Treatments	pH	Cu	Cd	Cr	Zn
		(mg kg^{-1})			
Control	7.89	26.02 ± 1.2^{a}	ND	15.9 ± 1.3^{a}	186.40 ± 3.4
Site 1	7.90	14.72 ± 1.2^{b}	ND	16.8 ± 1.6^{a}	178.85 ± 9.0
Site 2	7.99	21.64 ± 4.1^{ab}	ND	8.2 ± 3.2^{b}	183.07 ± 5.5
Site 3	8.00	29.08 ± 2.3^{a}	ND	13.3 ± 0.9^{ab}	175.77 ± 10.3
p-value		0.016	ND	0.05	0.747

All values sharing the same letter in a column are statistically non-significant at $p\leq0.05$, ND: Not detected, Mean$\pm$SE

Table 7: Concentration of heavy metal in sweet potato (Kulfo variety) tuber irrigated with treated (site 3), semi treated (site 2), untreated textile effluent (site 1) and lake Hawassa water (control) during January-June 2016

Treatments	Cu	Cd	Cr	Zn
	(µg g^{-1} dw tuber)			
Control	4.99 ± 0.3^{a}	ND	0.00 ± 0.0^{c}	27.17 ± 0.32^{b}
Site 1	5.90 ± 0.7^{a}	ND	0.45 ± 0.03^{b}	30.94 ± 2.08^{a}
Site 2	5.60 ± 0.4^{a}	ND	0.37 ± 0.3^{b}	26.70 ± 0.88^{b}
Site 3	2.80 ± 0.3^{b}	ND	0.57 ± 0.04^{a}	24.80 ± 0.36^{b}
p-value	0.004	ND	0.001	0.03

All values sharing the same letter in a column are statistically non-significant at $p\leq0.05$, ND: Not detected, Mean$\pm$SE

Bioaccumulation and translocation of heavy metals from soil to tuber: Irrigation of sweet potato with untreated, semi treated and treated textile effluent resulted in significant differences ($p\leq0.05$) in copper (Cu), chromium (Cr) and zinc (Zn) content of sweet potato tubers (Table 7). Result indicated that irrigation of sweet potato with treated textile effluent significantly gave minimum (2.8 µg g^{-1}) concentration of Cu in tuber than plant irrigated with lake Hawassa water, untreated and treated textile effluent. Sweet potato irrigated with treated textile effluent and untreated textile effluent significantly accumulated higher concentration of Cr (0.57 µg g^{-1}) and Zn (30.94 µg g^{-1}) per gram of tuber respectively than the other irrigation water used (Table 7). However, the concentration of Cd was not detected in tubers. The result indicated that significantly higher difference ($p\leq0.01$) in translocated amount of Zn, Cu and Cr was observed due to treatment effect. Higher translocated amount of Cu and Zn were found in a sweet potato tuber irrigated with untreated textile effluent than those plant irrigated with Lake Hawassa water, treated and semi treated textile effluent (Fig. 3). Moreover, significantly higher translocated amount of Cr was recorded in a sweet potato irrigated with semi treated textile wastewater (Fig. 3).

Estimated daily intake (EDI) of heavy metals: It was observed that, highly significant difference ($p\leq0.05$) on the level of daily estimated intake of Zn, Cu and Cr metal concentration per the size of tuber ingested. It was observed that significantly higher concentration of Zn (0.53 µg/day) was recorded from Sweet potato irrigated with untreated textile effluent (site 1). However, the estimated daily intake (EDI) for Cu was found significantly higher (0.101 µg/day) with sweet potato plant irrigated with untreated textile effluent than treated, semi treated and control (Table 8). Similarly, it was observed that sweet potato irrigated with treated textile effluent increased the potential of ingesting higher concentration of Cr (0.009 µg kg^{-1}) was

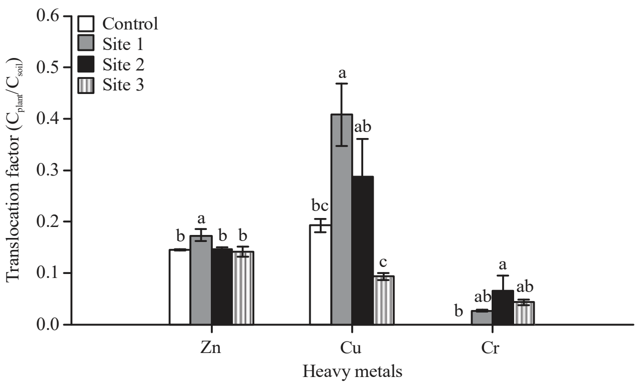

Fig. 3: Estimation of the amount of Cu, Cr and Zn (mg kg^{-1} soil) translocated from soil to sweet potato tuber due to irrigation of sweet potato with untreated (site 1), semi treated(site 2), treated (site 3) textile effluent and lake Hawassa water (control)

All values sharing the same letter in each element are statistically non-significant at $p \leq 0.05$, Mean±SE

Table 8: Possible estimate of dietary intake (EDI) for individual heavy metals can be consumed for sweet potato tuber grown under treated (site 3), semi treated (site 2), untreated Hawassa textile effluent (site 1) and Lake Hawassa water (control)

	Zn	Cu	Cr	Cd
Treatments	(µg/day)			
Control	0.47±0.00^{b}	0.086±0.00^{a}	0.000±0.00^{c}	ND
Site 1	0.53±0.04^{a}	0.101±0.01^{a}	0.008±0.0^{b}	ND
Site 2	0.46±0.02^{b}	0.096±0.00^{a}	0.006±0.0^{b}	ND
Site 3	0.43±0.00^{b}	0.048±0.00^{b}	0.009±0.0^{a}	ND
p-value	0.031	0.004	0.001	

All values sharing the same letter in a column are statistically non-significant at $p \leq 0.05$, ND: Not detected

Table 9: Target hazard quotient (THQ) for individual heavy metals through the consumption of sweet potato tuber grown on wastewater-irrigated soils

Treatments	Zn	Cu	Cr	Cd
Control	1.53±0.02^{b}	2.11±0.12^{a}	0.0000±0.0^{c}	ND
Site 1	1.75±0.12^{a}	2.48±0.29^{a}	0.0050±0.0^{b}	ND
Site 2	1.50±0.05^{b}	2.37±0.15^{a}	0.0040±0.0^{b}	ND
Site 3	1.39±0.02^{b}	1.17±0.14^{b}	0.0064±0.0^{a}	ND
p-value	0.031	0.004	0.000	-

All values sharing the same letter in a column are statistically non-significant at $p \leq 0.05$, ND: Not detected

found from sweet potato irrigated with treated textile effluent than untreated, semi treated and Lake Hawassa water (Table 8).

Target hazard quotient (THQ): The analysis for THQ indicated (Table 9) that, application of untreated, semi treated, treated textile effluent and lake Hawassa water significantly ($p \leq 0.05$) influenced the level of THQ. Sweet potato irrigated with untreated wastewater (Site 1) had 1.75 times health risk than plant irrigated with, lake Hawassa water, treated and semi treated textile effluent. Among those three elements (Zn, Cu and Cr), the THQ of Cu and Zn was found 2 folds higher than the threshold dose set for minimum health risk (THQ<1).

DISCUSSION

In this study the response of sweet potato (Kulfo) cultivar to treated and untreated textile wastewater was evaluated in terms of growth, physiology and yield on pot experiment at field condition. From the analysis it was observed that sweet potato irrigated with untreated, semi treated and treated textile effluent strongly reduced the vine length as compared to the control (Lake Hawassa water). The reduction in vine length might be related to the higher concentration of heavy metals like Cu, Cr and Zn in untreated wastewater (Table 4). Similar repot from Rivelli *et al.*[32], Singh and Nayyar[33], Ambo-Rappe *et al.*[34], Taylor[35] and Kim *et al.*[36] indicated that higher concentration of Zn, Cu and Cr resulted in growth inhibition, structural damage, reduced cell elongation, physiological and biochemical activities of different species.

The leaf impressions analysis also indicated that sweet potato plant grown under different irrigation water type significantly influenced number and anatomy of stomata. Accumulation of higher concentration of heavy metals in plant tissue significantly influenced cytoskeleton organization, microtubule orientation, differentiation of guard cell and number of stomata in different plant species[22,37-38]. This has been reflected in this study that lower number of stomata was observed in sweet potato plants irrigated with semi treated textile effluent which might be due to the presence of higher concentration of Cr metal in the plant tissue (Fig. 3). In contrary to this investigation, different plant species including *Helianthus annuus* and *Beta vulgaris* exposed to Pb, Cd, Cu and Zn were produced more stomata number/mm^2 than control[39,40].

During the experimental period it was observed that leaf surface temperature, transpiration rate and photosynthesis rate of sweet potato (Kulfo) variety were significantly influenced by the type of irrigation water used. Sweet potato plant irrigated with semi treated irrigation water (site 2) had 1.73 mmol m^{-2} sec^{-1} more transpiration rate than control. Such difference might be due to larger in stomata number, higher stomata conductance and lower leaf temperature (Table 3 and 4). The reduction rate in photosynthesis recorded under site 3 (treated textile effluent) of this study might be related with the lower concentration of Cu in plant (Table 7). Similar, result also reported from that plant with higher concentration of heavy metals like Cu and Zn showed significant increase in leaf photosynthesis than plant with lower Cu and Zn content in tissue[5,41]. In contrary to this investigation report from Gross *et al.*[42], Yuan *et al.*[43], Corradi *et al.*[44], Rai *et al.*[45], Bhati and Singh[46], Kaushik *et al.*[47] and Najam-us-Sahar *et al.*[48] indicated that excessive concentration of Cu, Cr and Zn showed significant reduction in physiological parameters and Photosynthetic pigments of different plant species. Such difference might be related with genetic difference and concentration of heavy metals in the growing media.

The reduction in transpiration rate increases leaf temperature and such effect might be related to lower stomata conductance (Table 3). Under stress condition the leaf temperature increases, however, increase in the rate of transpiration cooling is adaptation mechanism for leaf cells to avoid leaf cell overheating[49].

During the experimental period the effect of irrigating sweet potato with untreated and treated textile wastewater on geo and bioaccumulation was evaluated. The soil analysis result indicated that irrigation of sweet potato with untreated, semi treated, treated textile effluent and Lake Hawassa water significantly ($p \leq 0.05$) influenced the concentration of Cu and Cr in growing media. An increase in the concentration of Cu in geo-accumulation (growing media) in this result might be due to the effect of immobilization of Cu metals by microbial cells accumulated in the original growing media[50]. Moreover, metal accumulation in plant can be strongly influenced by multiple factors, including soil properties, plant factors and other environmental conditions including pollutants[51]. Observation on heavy metal translocation also indicated that irrigating sweet potato with different textile wastewater significantly affected the bio concentration of Copper (CU), Chromium (Cr) and Zinc (Zn). Higher translocation factor of Cu and Zn; were found in a sweet potato tuber irrigated with untreated textile effluent and higher Cr concentration from sweet potato irrigated with semi treated textile wastewater. Different report indicated that, similar effect was observed in different plant species that a greater translocation value indicated a higher accumulation potential of metals in plant tissue and negatively affect the rate of translocation depending on metal mobility, bioavailability and heavy metal root toxicity[52-54].

The daily intake of Heavy metal via sweet potato tuber was evaluated based on the laboratory analysis and short survey and the result is presented in (Table 8). The highest EDI of Zn (0.53 µg/day) and Cu (0.101 µg/day) were recorded from the consumption of sweet potato tuber irrigated with untreated textile effluent (Site 1), whereas, the highest Cr (0.009 µg/day) was obtained from sweet potato irrigated with treated textile effluent (site 3). However, none of the EDIs value exceeded its corresponding provisional tolerable daily intake (PTDI) threshold level, Cr (50-200 µg), Cu (1.5-3.0 mg) and Zn (5-19 mg)[4,9,25,55,56].

The EDIs of Cr, Cu and Zn recorded for the study areas for Cr (0.00-0.009 µg/day), Cu (0.008-0.101 µg/day) and Zn (0.43-0.53 µg/day) were substantially lower than the values reported from other countries[39,55,57]. This discrepancy could be partly attributed to soil and availability of metals types than what was observed in the present study. It is, however, worth considering the contribution of other food groups to Cu, Cr, Zn and Cd or other metals dietary intakes in different location and countries. From the study it was observed that Target Hazard Quotient (THQ) value calculated from the tuber was found higher than 1 compared to the value from leafy vegetables[26]. This result suggested that the inhabitants of the study area might be experienced the potential of getting health risk via the consumption of sweet potato irrigated with treated or untreated textile effluent. This is therefore, irrigating sweet potato with treated and untreated textile wastewater has a potential for health risk due to translocation of heavy metals to the edible part of the crop. Hence, it is recommended to give a public awareness about industrial wastewater management and to limit the consumption of wastewater contaminated crop.

CONCLUSION

Accumulation of heavy metals in soil and plant tissue is one of the most important treat for environment and human health. Irrigation of sweet potato with untreated textile wastewater increased the chance of getting higher level Zn and Cu than Cr. The amount of Zn and Cu accumulated in sweet potato plant via irrigation water could be the main elements contributing to potential health risks for residents in the study area. Therefore, the potential health risks of heavy metals through different types of heavy metal should be the subject of future study.

SIGNIFICANCE STATEMENT

This study discovered the impact of treated and untreated textile wastewater on growth and performance of sweet potato and geo accumulation of heavy metals. The information can be beneficial for growers, researchers, Environmentalists and policy makers. This is therefore this study will help the researchers to uncover the critical areas of industrial wastewater management and utilization in food chain system that many researchers were not able to explore. Thus a new theory on industrial wastewater management and utilization may be arrived at.

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