academicJournals

Vol. 7(8), pp. 179-185, August, 2015
DOI: 10.5897/JHF2015.0385
Article Number: 530474D55053
ISSN 2006-9782

http://www.academicjournals.org/JHF

Journal of Horticulture and Forestry

Full Length Research Paper

Nutrient status of potato (*Solanum tuberosum* L.) tubers and lettuce (*Lactuca sativa* L.) leaves produced along the bank of River Beressa

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Received 1 January, 2015; Accepted 8 July, 2015

The discharge of untreated solid and liquid wastes containing toxic heavy metals (Cr, Pd, Ni, Hg and As) from municipal and industrial activities has deteriorate the potential of Beressa River water mainly for irrigation purpose and affect the chemical property of soils and vegetables grown along the bank. Thus, this work was conducted to assess the concentrations of both essential nutrients (Ca, Mg, K, P, N, Mn, Fe, Cu and Zn) and heavy metals (Cd, Cr, Pd, Ni, Hg and As) in potato tubers and lettuce leaves produced along the bank of river using irrigation. Depending on their position and extent of water pollution, three different farms were identified and representative plant samples were collected from each farm for laboratory analysis. The vegetables from the non-irrigated farm were characterized by their lower contents of Ca, Mg, K, P, N, Mn, Fe, Zn and Cu. There was no detection of heavy metals in the potato tubers collected from farms 1 and 2, and except Cd, the lettuces of farm 3 had the highest concentration of toxic heavy metals. Apart from the lettuce leaves harvested from the irrigated farms, all the vegetables were safe for consumption and had a good essential nutrient content than the non-irrigated farm. Eventually, it is important to protect and mitigate the quality of the environment through creating awareness and conducting different studies of natural resources pollution remediation and controlling.

Key words: Potato, lettuce, nutrients, heavy metals, water pollution, Beressa River.

INTRODUCTION

Most developmental activities have a desirable role in developing countries like Ethiopia as they seen from the perspective of socioeconomic advancements. However, a wrong implementation and poor management of urbanization and industrialization activities deplete the natural resources (Jande, 2005), produce large amounts

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of toxic wastes that deteriorate the quality of the ecosystem (Fisseha et al., 2008) and cause ill health on human, aquatic life and other living things (Ashraf et al., 2010) and cause loss of crop productivity (Gbehe, 2004). For instance, Cadmium has adverse effects on the kidneys and bones. Even up on a long-term consumption it replaces Zn in the body and leads to body disorders. Arsenic is known to be carcinogenic and toxic but there is little direct evidence of toxicity related to the ingestion of nickel. Lead can cause a variety of neurological disorders. In children, it inhibits brain cell development and prevents the uptake of iron. So people ingesting lead often exhibit symptoms of anemia including pale skin, fatigue, irritability and headaches. (http://www.lenntech.com/processes/heavy/heavy-metals/heavymetals.htm#ixzz1torQPuv7).

Utilization of water consisting industrial effluents, agricultural discharges and household sewages affect the quality of soils and vegetations by introducing toxic heavy metals (Carter, 1985; Morera et al., 2001; Bridge, 2004). For instance, excessive entrance of inorganic pollutants into the soil system reduce its fertility status and natural filtering/ buffering capacity (Blum, 1996), influence activity and abundance of most soil microbes (Gasper et al., 2005) and deteriorate the quality of plants by affecting their growth and metabolism (Baccouch et al., 1998), photosynthesis, respiration, stomata functioning and biomass production (Larcher, 1984; Pierzeynski and Schwab, 1993).

According to Bigdell and Seilsepour (2008), the quality the Firoozabad River in Shahre Rey, Iran was deteriorated by the emissions from tannery, painting factory, soap factory, melting industry and wastes from domestic uses, garages, gas stations and hospitals which fortunately pollute the soils under irrigation and the produced vegetables with Cd, Pb, Cu and Zn. The Ona River in Ibadan, Nigeria deposited most of industrial wastes on farms of its flood plain and increased the level of N, P and K in the soils which inhibited the toxic absorption of Pb. Cu, Zn, Cr, Fe and Cd by arable crops like maize and vegetables (Ande, 2014).

Among the streams and rivers of Ethiopia, the Beressa River is the one that receives major portion of untreated solid and liquid wastes released from municipal and industrial activities in the town of Debre Berhan (Tebasie) (Negash et al., 2011). This situation has deteriorated of the water quality for irrigation and other domestic uses because of raised levels of chemical oxygen demand (COD), biochemical oxygen demand (BOD), PO_4^{3-}, total suspended solids (TSS), total dissolved solids (TDS), Pb and Hg (Awgchew et al., 2015). According to Negash et al. (2011) and Haymanot (2014), the soils being irrigated from the river have a slightly acidic pH and considerable amount of toxic heavy metals like Co, Cr, Ni, As, Hg, Pb and Cd. Thus, this study was proposed and conducted in order to assess the concentrations of essential nutrients and heavy metals in the potato tubers and lettuce leaves produced using irrigation from the Beressa River water.

MATERIALS AND METHODS

Description of the study area

The study was conducted at Tebasie sub-town of Debre Berhan town which is located at 09° 35' 45'' to 09° 36' 45'' north latitude and from 39° 29' 40'' to 39° 31' 30'' east longitude and found at 125 km north east of Addis Ababa with an elevation ranging between 2800 and 2845 m above sea level. The soil is vertisol type with clay loam texture and slightly acidic characteristics. Moreover, it is vulnerable to erosion and degradation due to overgrazing, poor conservation practice, deforestation and unwise utilization of natural resources. The twenty seven years (1985-2011) data obtained from the Ethiopian National Meteorological Agency indicates that, the area receives a mean annual rainfall of 927.10 mm and characterized by a unimodal rainfall pattern with a maximum (293.02 mm) and minimum (4.72 mm) peaks in August and December, respectively. The mean monthly maximum and minimum temperature range from 18.3 to 21.8°C and from 2.4 to 8.9°C, respectively (Figure 1).

Site selection, sample collection and preparation

In this study, three farms (Farm 1 – Eyerusalem Vegetable Farm; Farm 2 - Debre Berhan University's Research and Demonstration Field; Farm 3 - Tera Vegetable Farm) were selected based on their position and exposure to pollution.

Farm 1 and 3 (Figure 2), located at the upper and down streams of the River on its way through the Tebasie sub-town, were irrigated by the river water during dry season for commercial vegetable crop production; whereas, farm 2 was only irrigated with rainwater and never been irrigated by the river water.

Representative plant tissue samples were collected from each farms by considering the slope gradient (bottom, medium and upper) and agronomic management practices in a zigzag pattern with an interval of five steps and from each experimental plants, undamaged and matured edible parts were collected. A fully grown lettuce leaf samples were taken in the last week of March 2013 from the middle part by discarding the old leaves at the bottom and young rolled leaves at the top part. While, the potato tuber samples were taken in the early week of June 2013 from each plant with a medium/seeding size.

The lettuce leaf samples were cleaned by washing several times with water and 0.2 % detergent solution to remove the dusts and waxy coating, respectively, with no rubbing, and then washed by a 0.1 M HCl and plenty of distilled water. Before soaking the samples with tissue paper, they were washed with double distilled water to carry out micronutrient analysis (FAO, 2008). Moreover, the potato tubers were harvested and washed by water to remove adhering soil and then were cleaned and treated like the lettuce and sliced using a slicer. The tuber and leaf samples were air dried on a clean plastic tray at a room temperature for a week in a dust free atmosphere and oven dried at 60°C for 48 h before being ground in an electric stainless steel mill (the cup and blades were cleaned before each sample) and sieved through a 0.5 mm sieve and stored in glass desiccators until analysis time (Ryan et al., 2001).

Laboratory analysis

The plant sample were wet-digested by a 2:1 ratio of nitric (HNO_3) and perchloric acid ($HClO_4$) and analyzed for the total nitrogen and phosphorus contents by the Kjeldahl and gravimetric ammonium phosphomolybdate method, respectively and the total contents of

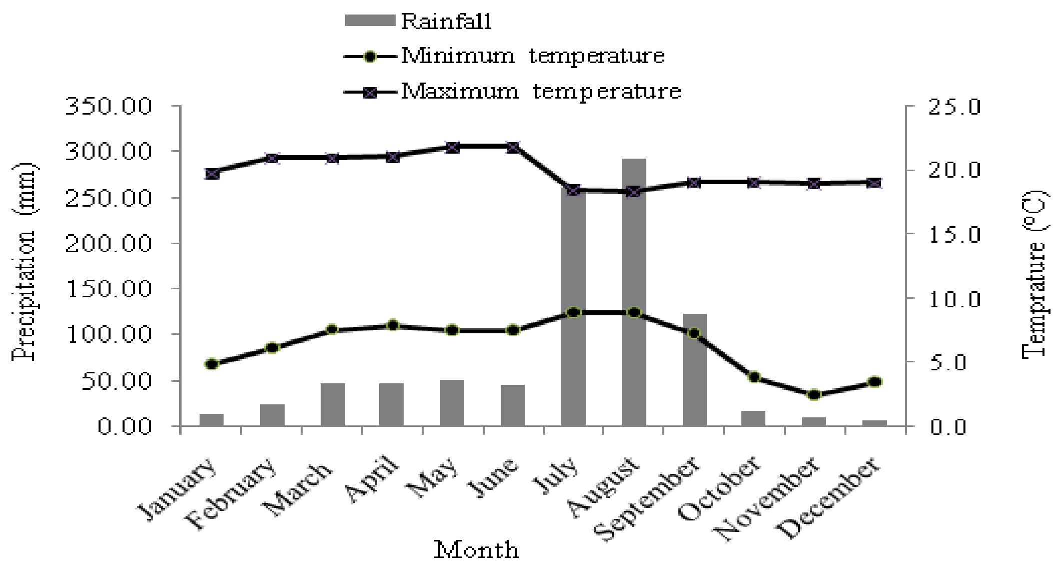

Figure 1. Mean monthly rainfall and minimum and maximum temperatures of the study area.

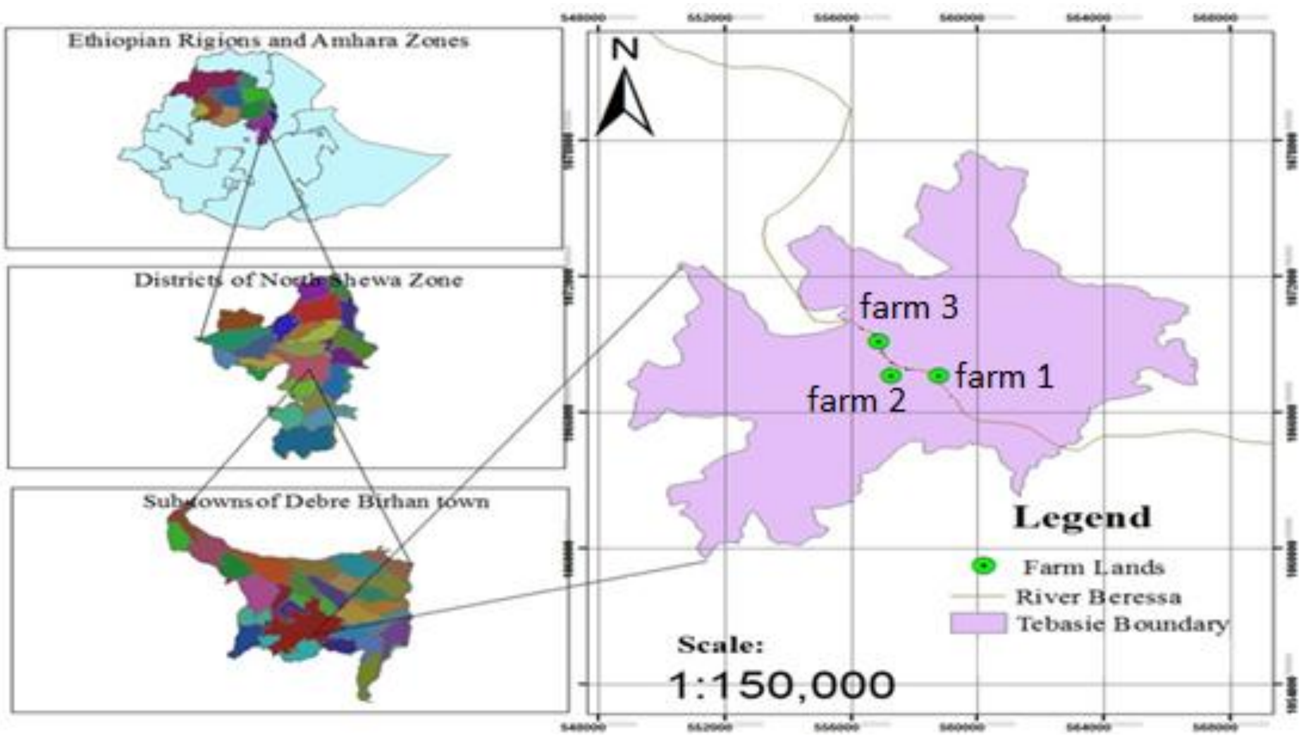

Figure 2. Location map of the study area.

K, Ca, Mg, Fe, Zn, Mn, Cu, Cd, Cr, Pb, As, Ni and Hg were determined by flame atomic absorption spectrophotometer (AAS) (Ryan et al., 2001; FAO, 2008).

RESULTS AND DISCUSSION

The mean essential nutrients and heavy metals composition of potato tuber and lettuce leaf samples collected from three different farms found in Debre Berhan (Tebasie sub town), Ethiopia is presented in Table 1.

The amounts of Ca were 128.3, 120.24 and 141.35 mg kg^{-1} in the potato tubers and 4200, 2042 and 3685 mg kg^{-1} in the lettuce leaves of farms 1, 2 and 3, respectively (Figure 2). The vegetables produced from farm 2 had the lowest content (Table 1) which could imply something to

Table 1. The mean essential nutrients and heavy metals composition in the potato tuber and lettuce leaf tissues.

Content (mg kg^{-1})	Potato tuber			Lettuce leaf		
	Farm 1	Farm 2	Farm 3	Farm 1	Farm 2	Farm 3
Calcium	128.3	120.24	141.35	4200.0	2042.0	3685.0
Magnesium	350.0	292.0	900.0	1675.0	806.0	1500.0
Potassium	20500	8071	17000	52500	20100	61500
Phosphorus	606.0	393.0	547.0	4825.0	2969.0	3688.0
Nitrogen	7200	6700	8100	36300	31800	34900
Manganese	13.0	19.35	34.75	190.25	105.35	122.25
Iron	258.0	214.45	286.75	919.5	487.5	463.75
Copper	3.15	2.02	2.70	9.55	3.15	3.80
Zinc	19.1	34.7	74.4	50.45	30.3	37.1
Cadmium	ND	ND	ND	ND	ND	ND
Chromium	ND	ND	0.01	0.03	ND	0.05
Lead	ND	ND	ND	0.02	ND	0.06
Nickel	ND	ND	0.01	ND	ND	0.05
Arsenic	ND	ND	0.02	0.04	ND	0.07
Mercury	ND	ND	0.01	ND	ND	0.02

ND = Not detected.

suspect the River water. However, the concentrations of Ca in the harvested vegetables were below and in the permissible ranges of safe consumption, 1000 to 10000 mg kg^{-1} (FAO, 2008); because its level in the river water was below the maximum permissible limit (Awgchew et al, 2015) and all the soils had no problem of calcium deficiency (Haymanot, 2014).

The lowest contents of Mg were detected in the potato tubers (292.24 mg kg^{-1}) and lettuce leaves (806.0 mg kg^{-1}) of farm 2 while the maximum was in the potato tubers (900 mg kg^{-1}) of farm 3 and lettuce leaves (1675 mg kg^{-1}) of farm 1 (Table 1). From these findings, the river might condemn for the concentrations in the vegetables of the irrigated farms due to a raised presence of Mg in the water (Awgchew et al., 2015) and concerned soils (Haymanot, 2014). Nevertheless, all the potato tubers were below the minimum permissible limit and except the lettuce leaves of farm 2 (Figure 2), all were in the acceptable range (1000 to 4000 mg kg^{-1}) for safe consumption (FAO, 2008).

The potato tubers and lettuce leaves harvested from the non-irrigated farm (farm 2) had the lowest (8071 and 20100 mg kg^{-1}, respectively) content of K (Table 1) which strengthen the suspicion on the River for its concern. Because, in the river water there was a higher K concentration (Awgchew et al., 2015) and even though all farms had no deficiency of K, the irrigated farms were superior in their K content (Haymanot, 2014). According to FAO (2008), except the potato tubers of farm 2, all were in the permissible range of 10000 to 50000 mg kg^{-1} for safe consumption but the lettuce leaves of the irrigated lands, farms 1 and 3 (Figure 2) were out of the range for safe consumption.

The lowest contents of P were recorded in the potato tubers (393 mg kg^{-1}) and lettuce leaves (2969 mg kg^{-1}) of farm 2 (Table 1). The detected concentrations in the vegetables could imply the presence of some relation between the River water and the soils under irrigation; because phosphate was the one among the pollutants in the Beressa River (Negash et al., 2011; Awgchew et al., 2015) and the two irrigated farms had higher P values than the non-irrigated (Haymanot, 2014). However, the contents in the potato tubers of all farms were below the minimum permissible limit whereas all the lettuce leaves were in the permissible range, 2000 to 5000 mg kg^{-1}, of safe consumption (FAO, 2008).

The concentrations of total nitrogen (TN) in the potato tubers were 7200, 6700 and 8100 mg kg^{-1} and in the lettuce leaves were 36300, 31800 and 34900 mg Kg^{-1} at farms 1, 2 and 3, respectively (Table 1). Despite the differences in fertilization and other farm management practices, the River could blamed for the elevated TN concentrations in the vegetables of farms 1 and 3 (Figure 2) due to the detection of considerable amounts of ammonia and nitrate in the water near the two farms that might have a direct connection with the relative higher amounts of TN in the concerned soils (Awgchew et al., 2015; Haymanot, 2014). According to FAO (2008), the concentrations in all lettuce leaves were in the acceptable range (20000 to 50000 mg kg^{-1}) of safe consumption but the potato tubers were found below the minimum permissible limit.

The amounts of Mn were 13.0, 19.35 and 34.75 mg kg^{-1} in the potato tubers and 190.25, 105.35 and 122.25 mg kg^{-1} in the lettuce leaves collected from farms 1, 2 and 3, respectively (Table 1). Moreover, the contents of Fe in the potato tubers were 258, 214.45 and 286.75 mg kg^{-1} while 919.25, 487.5 and 463.75 mg kg^{-1} in the lettuce leaves of farms 1, 2 and 3, respectively (Table 1). The River water might not blamed as a cause for the contents in the vegetables of the irrigated farms; because the highest amounts of Fe and Mn were found in the soil of non-irrigated farm (Haymanot, 2014) and there was no detection of these elements in the river water sampled near the two irrigated farms (Awgchew et al., 2015). According to FAO (2008), only the potato tubers of farm 3 and lettuce leaves of all farms were in the permissible range of Mn (20-300 mg kg^{-1}) for safe consumption but only the Fe content in the potato tubers of farm 2 (Figure 2) was in the permissible range (50 to 250 mg kg^{-1}) of safe consumption.

The amounts of Cu in the potato tubers were 3.15, 2.02 and 2.7 mg kg^{-1} while 9.55, 3.15 and 3.8 mg kg^{-1} in the lettuce of farms 1, 2 and 3, respectively (Table 1). The River had a direct relation with the amounts in the vegetables; because the contents in soils the irrigated farms (Figure 2) were higher than the non-irrigated (Haymanot, 2014) and there was a significant detection of Cu in the River water near the two irrigated farms (Awgchew et al., 2015). However, except the lettuce leaves harvested from farm 1, all the vegetables were below the minimum permissible limit (5-20 mg kg^{-1}) of safe consumption (FAO, 2008).

The contents of Zn in the potato tubers and lettuce leaves ranged from 19.1 to 74.4 mg kg^{-1} and from 30.3 to 50.45 mg kg^{-1}, respectively (Table 1). The highest presence of zinc in the River was recorded at water sampling site near farm 3 (Awgchew et al., 2015), and according to Haymanot (2014), the content of Zn in the soils of farm 3, 1 and 2 (Figure 2) was ranked in the order of decrease. Thus, the concentrations in each of the vegetables had no concern with the River water and the irrigated soils. Because, the potatoes harvested from the non-irrigated farm (farm 2) had the highest content than that of farm 1 and the lettuce leaves of farm 1 had the lowest content than farm 3. Except the potato tubers of farm 1, all the harvested vegetables were in the permissible range (20 to 100 mg kg^{-1}) of safe consumption (FAO, 2008).

Cadmium was not detected in the harvested vegetables of all farms (Table 1) and the River water might not be blamed by any means; because Cd was not detected in the River water at the sites around farms 1 and 3 (Figure 2) and in the soils of the irrigated and non-irrigated farms (Awgchew et al., 2015; Haymanot, 2014). Additionally, Cr was not detected in the potato tubers of farms 1 and 2, and in the lettuce leaves of farm 2 but it was 0.01 mg Kg^{-1} in the potato tubers of farm 3 and 0.03 and 0.05 mg kg^{-1} in the lettuce leaves of farms 1 and 3, respectively (Table 1). In this case, the River water might be a reason for the presences of Cr; because relatively there was a higher concentration in the soils of the irrigated farms than the non-irrigated and also there was a considerable amount in the River water around the two irrigated farms that have been expressed in the River water and vegetables in accordance (Awgchew et al., 2015; Haymanot, 2014; Negash et al., 2011). According to FAO (1991), the detected amounts of Cr were below the maximum permissible limit (0.1 mg kg^{-1}) for safe consumption.

The potato tubers harvested from all farms and the lettuce leaves from the non-irrigated farm had no Pb but there were 0.02 and 0.06 mg kg^{-1} in the lettuce leaves of farms 1 and 3, respectively (Table 1) which were below the maximum permissible limit of 0.3 mg kg^{-1} (FAO, 1991) for safe consumption. The River water might be an indirect source of lead in the lettuce leaves of the irrigated lands, farms 1 and 3 (Figure 2); because the contents in the River water at the sites around the irrigated farms were above the maximum permissible limit and were about six times below the maximum permissible limit in the soil of the concerned farms (Awgchew et al., 2015; Haymanot, 2014; Negash et al., 2011).

Nickel was detected only in the potato tubers (0.01 mg kg^{-1}) and lettuce leaves (0.05 mg kg^{-1}) of farm 3 (Table 1) found below the maximum permissible limit of 0.5 mg kg^{-1} (FAO, 1991) for safe consumption. Even though the concentration in the River water was below the maximum permissible limit, there was relatively a higher content of Ni in the soils of farm 3 and in the water at the site near farm 3 and also it was not detected in the soils of farms 1 and 2 (Awgchew et al., 2015; Haymanot, 2014; Negash et al., 2011). Thus, the River water might be a factor for the presences in the vegetables of farm 3 (Figure 2).

There was no As in the potato tubers of farm 1 and 2 and lettuce leaves of farm 2. However, it was 0.02 mg kg^{-1} in the potato tubers of farm 3 and 0.04 and 0.07 mg kg^{-1} in the lettuce of farms 1 and 3, respectively (Table 1). There was no doubt in considering the River as a reason for the detected amount of As in the soils and vegetables of the irrigated farms of 1 and 3 (Figure 2). Because, there was a significant amount of As in the River water (Awgchew et al., 2015; Negash et al., 2011) and relatively higher amount in the soils of the two irrigated farms (Haymanot, 2014). According to FAO (1991), the detected amounts were below the maximum permissible limit (0.2 mg kg^{-1}) for safe consumption.

There was no Hg in the vegetables of farms 1 and 2, but there was in the potato tubers (0.01 mg kg^{-1}) and lettuce leaves (0.02 mg kg^{-1}) of farm 3 (Table 1) which was found below the maximum permissible limit of 0.05 mg kg^{-1} (Bergmann, 1993) for safe consumption. Specifically, it was possible to say that the River was a main cause for the presence of Hg in vegetables of farm 3 (Figure 2). Because, the highest amount of Hg was detected in the water samples collected from the sites near farm 3 and in the soils of this farm (Awgchew et al., 2015; Haymanot, 2014).

SUMMARY AND CONCLUSIONS

The vegetables (potatoes and lettuces) harvested from the non-irrigated farm (farm 2) were the least in their Ca, Mg, K, P and N contents. The highest concentrations of Mn and Fe were recorded in the potato tubers of farm 3 and lettuce leaves of farm 1. The amounts of Cu in the vegetables of farm 1 and the concentrations of Zn in the potato tubers of farm 3 and lettuce leaves of farm 1 were found maximum. According to Mohammed et al. (2014), irrigating the farmlands in selected areas of Vidyaranyapuram, Mysore city of India, with sewage water containing a permissible levels of total N, total P, potassium and heavy metals as proposed by FAO, led to the decrease of soil pH and significant increase of N, P, K, Ca, Mg, Na, Fe, Mn, Cu, Zn and Pb contents in the soils and crops. There was no detection of heavy metals in the potato tubers collected from farms 1 and 2 (Figure 2). The toxic heavy metals like Cd and Pb were not found in the lettuce leaves of farm 2 and in the potato of farm 3. The lettuce leaves of farm 1 were free from Cd, Ni and Hg. Moreover, excluding Cd, the lettuces of farm 3 had highest concentration of the toxic heavy metals. The level of heavy metals (As, Cd, Co, Cu, Fe, Ni, Pb and Zn) in the soils and produced plants of the different farmlands located near waste dumping sites of Lafia, Nigeria was higher, but found below the lower permissible limit of the WHO (Opaluwa et al*.,* 2012).

In conclusion, except the lettuce leaves harvested from the irrigated farms (which was due to its excessive K content), all vegetables were safe for consumption and the vegetables harvested from the irrigated farms (farm 1 and 3) had a good essential nutrient content than the non-irrigated farm. In addition, the lettuce leaves of farm 3 have required extra attentions for frequent uses. However, in the future it is exceedingly important to protect and mitigate the quality of the environment through creating awareness and conducting different studies of natural resources pollution remediation and controlling.

Conflict of Interest

The authors have not declared any conflict of interest.

ACKNOWLEDGMENTS

The authors would like to greatly acknowledge the School of Graduate Studies (Haramaya University) and Debre Berhan University (Ministry of Education) for the financial and overall assistances made so far and they are obliged to extend their deepest gratitude to all individuals and institutions/organizations who in one way or another contributed for the betterment the work starting from the very beginning to the end.

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