Determination of Selected Heavy Metals Content and Health Risk Assessment of Cabbage Cultivated in Elalla Farmland, Mekelle, Ethiopia

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Abstract

Like other countries in Ethiopia vegetables are vital edible plants which are a crucial part of the human food. One from these vegetables cabbage is a leafy green biennial plant grown as an annual vegetable for its dense leaved heads. The heavy metal content of cabbage may vary on the composition of the water and nature of soil. The study was aimed to determine concentration of selected heavy metals like Cadmium (Cd), Chromium (Cr), Cupper (Cu), Lead (Pb), Iron (Fe) and Zinc (Zn) were measured in edible portion of cabbage and soils around four sites of cabbage production area in Elalla farmland Mekelle, Tigray, Ethiopia, and the potential health risk of heavy metal contamination to the local population via vegetable consumption, Transfer factor and daily intake of metal was also evaluated. The level of heavy metals in soil and Cabbage vegetable were determined by flame atomic absorption spectrophotometer (FAAS) that uses acetylene as fuel with air. The concentration of Cd (17.15 ± 1.26 to 17.52 ± 0.24) mg/Kg and Zn (325.10 ± 6.00 to 512.86 ± 3.13) mg/Kg in the soil sample exceeds from the limit the guideline of agricultural soil and the mean concentrations of Fe, Cu, Pb and Cr is below the guideline of agricultural soil. The mean concentration of Pb(3.060 ± 0.18 to 5.982 ± 0.11), Zn(144.662 ± 3.16 to 173.660 ± 2.18), Cr(11.825 ± 0.18 to 13.482 ± 0.37) and Cd(0.309 ± 0.01 - 0.712 ± 0.06) in all study sites of cabbage samples were exceeded the permissible limits set by FAO but Pb and Fe are below the permissible limit. The TF calculated were also investigated lower for all metals and for the value of HRI is below 1, according to the present study the result indicates that exposed population is assumed to be safe. As the results show that HRI of contamination in cabbage has less health risk to the consumers.
Keywords: - Cabbage, Heavy metals, Health Risk, Health Risk Assessment, Daily Intake Metal
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1. Introduction

Vegetables are vital edible plants which are a crucial part of the human food. Feeding of vegetables like cabbage, potato, carrot or beans plays important roles in human nutrition and health, particularly as sources of vitamins, thiamine, niacin, pyridoxine, folic acid, minerals, and dietary fiber and used to convert the fats and carbohydrates in to energy [1, 21].

Cabbage (Brassica oleracea) is a leafy green biennial plant grown as an annual vegetable for its dense leaved heads. Cabbage has lower levels of saturated fat and cholesterol and has been recognized as a good source of thiamine, calcium, iron, magnesium, phosphorus, potassium, dietary fiber and manganese [2, 19].

Leafy vegetables like cabbage have the tendency of good absorption of heavy metals from soil. Soils may become contaminated by the accumulation of heavy metals through emissions from the rapidly expanding industrial areas, mine tailings, disposal of high metal wastes, leaded gasoline and paints, land application of fertilizers, animal manures, sewage sludge, pesticides, wastewater irrigation, coal combustion residues, spillage of petrochemicals, and atmospheric deposition [3].Some potentially toxic metals and trace elements like lead, cadmium, chromium, iron, copper and zinc present in agricultural soils enter the human body through the food chain and this could become a significant source of cumulative poisons following continued absorption and bio-accumulation. This contamination of cabbage has been linked to cases of food-borne illness in humans [4, 18].

At Elalla which is the river that passes through Mekelle city different municipal wastes are being disposed, cars are being washed, mostly children are using on it for showering and drink from the river and many people are consuming the Cabbage and Spinach vegetables mostly cultivated around that area. However, there were no other studies conducted regarding levels of heavy metals in Cabbage vegetable grown on this study area. Therefore, the study aims to generate baseline information on the level of selected heavy metals (Cd, Cr, Pb, Cu, Fe and Zn) concentration in soil and edible part of Cabbage vegetables [5, 17].

2.   Materials and Methods
2.1. Description of the Study Area
The study was carried out at around Elalla River farmland which is found to the Northern side of Mekelle city, Tigray, Ethiopia. The city was located 780 kilometers north of the capital city of Ethiopia, Addis Ababa, at a latitude and longitude of 13°29′N 39°28′E and 13°29′N 39°28′E, with an elevation of 2084 meters above sea level. According to Ethiopia 2011 Central Statistical Agency, Mekelle city has an estimated population of 261,200 with density of 86.15 people per square kilometre. The temperature in Mekelle ranges from 11.5 to 30.65 °C and annual rainfall varies from 24.0 to 486.0 mm/month [6].

The sampling points of the study area were taken nearby pollution sources and using the global positioning systems reading (GPS), four selected points which are; Dejat abraha building (S1) above the Mekelle-Adigrat main bridge, bridge of Mekelle-Adigrat road (S2), at 05 kebelle police station (S3) in which Wastes disposes the river and some metal work takes place around it and Place where the river leaves the city (S4).
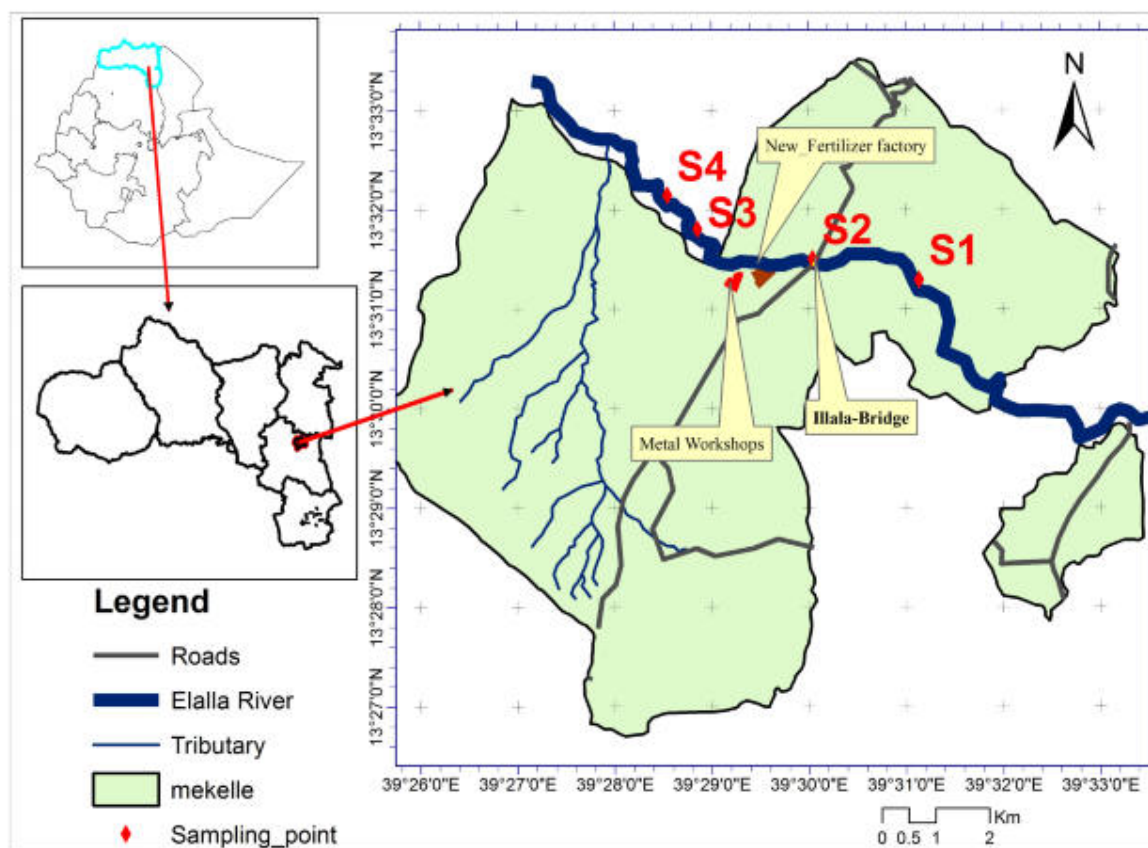

Figure 1. Map of the study area with cabbage and soil sampling sites, Elala farmland, Mekelle [7].

2.2.   Materials and Chemicals
Drying oven, fast sequential atomic absorption spectrophotometer (Varian AA 240 FS, Australia), hot plate (STUART CB162), analytical balance (LARK LA114), and Fume hood (Uethe-Hangsen D31311, Germany); 70% HNO_3 (BDH, England), 98% H_2SO_4 (RSCL Ltd.Com., India), 37% HCl (Riedel-de Häen, Germany) and 30% H_2O_2 (SDSL, Mumbai, India) were used for the analysis. The reagents used were analytical grade and deionized water was used for preparation of solutions [8, 20].

2.3.   Sample Collection and Preparations
2.3.1. Sample collection
Soil samples were taken once at each sampling day from vegetable gardens with near proximity to the River that crosses the city and once had been using the river water for irrigation purpose. The soil samples were taken from center using stainless steel auger soil sampler at a depth of 0-15 cm after the removal of grassy part. About 1 kilogram of composite soil sample was taken for each site. A total of 4 kilograms of composite soil samples were taken to laboratory in clean and dry polyethylene plastic bags. The collected samples were thoroughly mixed to

give a representative samples and were dried to constant weight, in an oven to remove excess moisture, then grounded and sieved with 200 mesh (75 µm) sieve. The dried samples were kept packed till analysis [9].

About 2 kilograms edible parts of Cabbage vegetable sample were taken from the places in which soil samples were taken and transported to laboratory in clean and dry polyethylene plastic bags. The samples were washed with distilled water to remove dust particles and air dried. The dry vegetable samples were crushed using mortar and pestle. Finally, the powder was packed for heavy metals analysis.

2.3.2. Digestion producers

A triplicate sample of 0.5 g of air-dried ground soil were transferred to the digestive tube; in addition to that 5 ml of concentrated H_2SO_4, 25 ml of concentrated HNO_3 and 5 ml of concentrated HCl were added consequently. The mixture of three acids with the sample was heated at 200 °C for one hour in a fuming hood and then cooled to room temperature. After that 20 ml distilled water added and then filtered. The process of digestion was completed. Finally, the mixture were transferred to a 50 ml volumetric flask, filled to the mark and let to settle for at least 15 hours. The filtrates were analyzed for total Cr, Fe, Cu, Pb, Zn and Cd by using FAAS [9]. Reagent blank was passed between every three measurements of replicate samples so as to check for any eventual contamination or abnormal response of equipment.

A triplicate of approximately 0.5 g of the Cabbage vegetable powder put in to the digestive tube followed by 5 ml of concentrated HNO_3 and 3 ml of concentrated H_2O_2. The mixture was heated at 160 ^{O}C for 1 hour in a fuming hood and then cooled to room temperature. About 20 ml of distilled water were added and the mixtures were filtered filtered through whatman filter paper number 41. Finally, the mixture were transferred to a 50 ml volumetric flask, filled to the mark and let to settle for at least 15 hours. The filtrates were analyzed for total Cr, Fe, Cu, Pb, Zn and Cd by FAAS after the AAS was checked for malfunctioning by passing standard solutions of all the heavy metals to be measured; reagent blank was passed between every three measurements of effluent samples so as to check for any eventual contamination or abnormal response of equipment. Reproducibility of results was regularly checked by carrying out periodic analysis of aliquots collected from one sample and then data were recorded in triplicate [9].

2.4. Heavy Metals Analysis

Heavy metals (Fe, Zn, Cu, Pb, Cr and Cd) in soil and Cabbage vegetable were determined by flame atomic absorption spectrophotometer (FAAS) that uses acetylene as fuel with air as support at Ezana mining laboratory as described in the manufacturer's instruction manual after the digestion procedure completed. Standard reagents and reagent blanks were prepared freshly when needed. All data were recorded in triplicate while conducting the experiments [10].The instrument working condition and detection limits were shown in Table 1.

Table 1. The FAAS Instrument working condition and limit of detection for heavy metal analysis in soil and vegetable samples of Elalla farmland.

Element	Cd	Cr	Cu	Fe	Pb	Zn
Lamp current (mA)	4	7	4	5	5	5
Wave length (nm)	228.8	357.9	324.7	248.3	217.0	213.9
Slit width (nm)	0.5	0.2	0.5	0.2	1.0	1.0
Instrument detection limit	0.002	0.006	0.003	0.006	0.010	0.001
Soil (mg/kg) MDL	1.0	1.0	1.0	1.0	1.0	1.0
Vegetable (Cabbage) (mg/kg) MDL	0.01	0.02	0.01	0.02	0.02	0.05

Risk assessment

Transfer factor is expresses by the bioavailability of a metal at a particular position on a species of plant. It   was calculated based on the total metal content of the leafy part of the plant by using the formula stated as;

$$TF = \frac{concentration\ of\ metal\ in\ edible\ part\ of\ vegetable}{concentration\ of\ metal\ in\ soil}\ [4].$$

The daily intake of metal is the relative phyto-availability of metal and does not take a possible metabolic removal of the metals into account, but indicates the possible ingestion rate of a particular metal.

$$DIM = \frac{CM \times CF \times DIV}{BW}$$

Where CM is the concentration of a heavy metal in plant material (mg/ kg), CF is the Conversion Factor (0.085), DIV is the approximate Daily Intake of Vegetables and BW the average body weight (65 kg) [11].

The health risk index (HRI) was determined as described as follows [12]:

$$HRI = \frac{DIM}{RfDo}$$

Where the Reference oral dose (RfDo) is an estimated exposure of metal to the human body per day that has no

hazardous effect during life time [13]. The value of reference oral doses (RfDo) mg/kg/day for those heavy metals obtained at the present study is summarized in Table 2 below [5].

Table 2. Oral reference doses for heavy metals

Heavy metal	Fe	Zn	Cu	Pb	Cr	Cd
Values RfDo (mg/kg/day)	0.7	0.3	0.04	0.004	1.5	0.001

Method of data analysis and Validation

Statistical analyses were carried out by using Statistical Package for Social Science (SPSS) for Windows version 16.0. The statistical tools used one-way ANOVA. The results obtained in the present study are reported as mean values (obtained from the nine replications) ± standard deviation (SD). As the level of heavy metal contamination might vary with sample collection site, ANOVA was used to test the existence of significant difference between means. The significance differences between mean values were analyzed at 95% confidence level.

3.   Results and Discussion

Table 3. Heavy metals in soil samples

Metal concentration of soil sample in mg/kg, N = 9

Sites	Fe	Zn	Cu	Pb	Cr	Cd
S1	595.124 ± 9.55^b	395.57 ± 8.54^{ab}	41.54 ± 1.15^a	1.57 ± 0.02^a	41.32 ± 1.51^a	17.15 ± 1.26^a
S2	805.78 ± 12.34^a	512.86 ± 3.13^a	42.61 ± 1.42^a	2.23 ± 0.01^a	50.45 ± 2.16^a	17.40 ± 1.19^a
S3	867.74 ± 13.54^a	335.46 ± 7.80^b	40.20 ± 2.15^a	2.21 ± 0.02^a	47.56 ± 1.48^a	17.52 ± 0.24^a
S4	598.11 ± 10.85^b	325.10 ± 6.00^b	40.17 ± 0.36^a	1.51 ± 0.01^b	41.20 ± 2.41^a	17.24 ± 1.33^a
Ewers(1991) standard	5000	300	100	100	100	3.00

At 95 % confidence level the mean concentration of all the studied metals were found to be significantly higher in the site S2 &S3 than site S1 & S4 which could generally mean there was significant metal pollution due to the loads of different anthropogenic activities. The obtained values ranged from 595.124 ± 9.55 to 867.74 ± 13.54 for Fe, 325.10 ± 6.00 to 512.86 ± 3.13 for Zn, 42.61 ± 1.42 to 40.17 ± 0.36 for Cu, 1.51 ± 0.01 to 2.23 for Pb, 41.20 ± 2.41 to 50.45 ± 2.16 for Cr, 17.15 ± 1.26 to 17.52 ± 0.24 for Cd. The mean concentrations of Fe, Cu, Pb and Cr except Cd and Zn considered in the present study were below the guide line value for agricultural soil [4]. As the result from Table 3 shows concentration of Cd was about 6 times higher than the guideline value. The highest concentrations of the Cd in the soil sample could be due to coal, diesel, gasoline, incineration of Cd-containing batteries and plastics, metal alloy production, electroplating, and using of phosphate fertilizers [12]. This excess amount of cadmium accumulation leads health effects like Kidney damage, gastrointestinal effects in form of diarrhoea and vomiting [14].

3.1. Heavy metals in Cabbage

Table 4. Concentration of Heavy metals in Cabbage

Site	**Metal Concentration In Cabbage**					
	Pb	Zn	Cr	Cd	Fe	Cu
Site1	3.242±0.078	173.660±2.18	11.825±0.18	0.395±0.04	183.040±1.31	17.006±0.081
Site2	5.982±0.11	144.662±3.16	12.753±0.47	0.712±0.06	172.700±2.74	13.982±0.14
Site3	3.508±0.23	153.400±1.15	12.212±0.37	0.562±0.53	380.720±3.97	13.083±0.11
Site4	3.060±0.18	164.288±1.10	13.482±0.37	0.309±0.01	313.567±1.01	15.823±0.57
FAO/WHO	0.3 (0.1)	100	2.3	0.1 (0.05)	425	73
Weigert	0.30*	100	2.30	0.20*	425	70.0

Heavy metals are mobile and can easily be taken up by plants in the environment by bioaccumulation and bio magnification. The mean concentration of Pb, Zn, Cr and Cd in all study sites of cabbage samples was higher than the guideline plants set by Weigert but Fe and Cu are below the permissible limit. Singh et al. (2009), Kidu et al. (2015) and Ftsum & Abraha (2018) reported that Cd and Zn concentrations were above the agricultural safe limits of standards in vegetables [4, 5]. The study suggests that accumulation of heavy metals in food stuff causing potential health risks to consumers in the present study.

As the result indicates the concentration of Cabbage in S2 was almost 2 times higher than the remaining sites sampling sites. This might be due to the discharge from the road sides, the use of wastewater for irrigation from the bridge in which different vehicles were washed, by the improper disposal of municipal as well as domestic waste and sewage from different garages and construction works of the city in to the irrigated soil [5].

Transfer Factor (TF)

Table 5. Transfer Factor of Heavy Metals

	Transfer factor					
sites	**Fe**	**Zn**	**Cu**	**Pb**	**Cr**	**Cd**
S1	0.310	0.438	0.415	2.065	0.293	0.023
S2	0.214	0.281	0.280	2.683	0.260	0.041
S3	0.438	0.457	0.325	1.590	0.255	0.032
S4	0.523	0.505	0.400	2.026	0.317	0.018

Variations in transfer factor among the different sites may be attributed to differences in the concentration of metals in the soil and differences in element uptake by different vegetables. Among all studied metals the transfer factor of Pb was highest for assayed vegetables from the four sampling sites, which showed that Pb is more mobile than the other metals. Consistent with this suggestion, it was reported that Pb was retained less strongly by the soil and hence it is more mobile than other metals [15]. The greater the transfer coefficient value than 0.50, the greater will be the chances of vegetables for metal contamination by anthropogenic activities [4]. When compared with a previous study of Ftsum & Abraha [5], the cabbage transfer factor of current study showed lower than spinach transfer factors.

Table 6. The DIM from Cabbage grown at around the Elalla farmland

	DIM (mg/kg) of Cabbage					
Sites	**Fe**	**Zn**	**Cu**	**Pb**	**Cr**	**Cd**
S1	0.0280	0.0270	0.0026	0.0005	0.0018	0.0001
S2	0.0260	0.0220	0.0021	0.0009	0.0020	0.0001
S3	0.0580	0.0230	0.0020	0.0005	0.0019	0.0001
S4	0.0470	0.0250	0.0024	0.0005	0.0021	0.0001

The daily intake of Cd in all four study sites was estimated as 0.0001 mg/kg, which represents approximately 10 % of the RD, established to 0.001 mg kg of body weight per day. The daily intake was lower than the tolerable daily intake (TDI).

Table 7. Health Risk Index of Heavy metals present in Cabbage.

	HRI of present study heavy metals					
Sites	**Fe**	**Zn**	**Cu**	**Pb**	**Cr**	**Cd**
S1	0.040	0.090	0.065	0.125	0.001	0.100
S2	0.037	0.073	0.052	0.225	0.001	0.100
S3	0.083	0.077	0.050	0.125	0.001	0.100
S4	0.067	0.083	0.060	0.125	0.001	0.100

The HRI for the studied heavy metals presented in Table above Cr < Fe <Cu<Zn <Cd<Pb. But for the value of HRI is below 1, the exposed population is assumed to be safe [4]. As the results show that HRI of contamination in cabbage has less health risk to the consumers.

4. Conclusion

The present study investigates the heavy metal concentration of cabbage and soil sample on which the cabbage cultivated/ irrigated on it around Elalla River. In addition to this the DIM and health risks assessment of the exposed consumers was assessed and reported. According to the investigation the concentration of heavy metals like Cd and Zn in the soil sample exceeds from the limit the guideline of agricultural soil and the mean concentrations of Fe, Cu, Pb and Cr is below the guideline of agricultural soil. The mean concentration of Pb, Zn, Cr and Cd in all study sites of cabbage samples were exceeded the permissible limits set by FAO but Pb and Fe are below the permissible limit. As the results the study shows that HRI of contamination in cabbage has less health risk to the consumers. But because of the presence of high concentration of Cd which exceeds the permissible limit of FAO in cabbage. The consumers should take a great care they should avoid continuous consumption of cabbage from that area and studies must be conducted in different seasons and periods for the future to level concentration of these heavy metals since.

5. References

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