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# Concentration levels of metals in vegetables grown in soils irrigated with river water in Addis Ababa, Ethiopia

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ABSTRACT

Samples of vegetables, water and soil were collected from four vegetable farms in Addis Ababa to evaluate the extent and trend of metal accumulation in these systems and health risk concerns to consumers. Vegetable samples were digested in $HNO_3$ and $HClO_4$, soil samples in Aqua Regia and water samples were pre-concentrated with methyl isobutyl ketone (MIBK) using the chelating agent ammonium pyrrolidine dithiocarbamate (APDC). All the samples were analyzed for Co, Cr, Cu, Mn, Ni, Zn, Cd and Pb with flame atomic absorption spectrophotometer. The concentrations of Cd (0.12–1.13 mg kg$^{-1}$) and Pb (0.11–0.89 mg kg$^{-1}$) in the vegetables surpassed the maximum recommended levels. The total metal concentrations in soils were (mg kg$^{-1}$): Cr, 9.9–22.8; Co, 28.0–47.3; Cu, 25.1–51.4, Mn, 1000–1054; Ni, 16.4–55.8; Zn, 146–149; Cd, 1.4–1.8 and Pb, 22.0–50.7. The trace metals Cd, Co, Cu, Mn and Ni in most of the water samples collected from Goffa, Kera and Akaki farms also surpassed irrigation water guideline limits, which might be a case for high accumulation of metals in the soils. However, the soil pH (6.5–7.6) and high cation exchange capacity (CEC), 38.41–50.18, coupled with high clay content, 37–51%, of the soil seemed to limit metal uptake by the vegetables. The physical parameters, pH (7.43–7.89) and electrical conductivity (0.33–1.54 dS/m) of irrigation waters measured at 25 °C were found within the acceptable range.



## 1. Introduction

In developing countries, industrial activities such as metal workshops, garages, tanneries, pharmaceuticals and factories produce huge volumes of effluents that contain heavy metals and other toxicants, which affect the quality of rivers and streams (Tiwari et al., 2008). Heavy metals are non-degradable and thus readily accumulate in the soil at toxic levels due to long term application of wastewater. Plants grown in these soils also accumulate metals in their tissues. Their metal uptake and accumulation depend on the concentrations of available metals in soils, solubility sequences and the plant species growing on these soils (Andersson, 1977).

Addis Ababa is one of the fast expanding cities in Ethiopia, which currently covers an area of 530 km$^2$ harbors a number of industries and other activities including urban farming that may generate waste products containing heavy metals at potentially harmful concentrations. The streams and rivers in the city, which are consumed by livestock and also used for other purposes such as irrigating vegetables and crops and washing cattle, receive major part of the waste produced by the residents and industries (Alemayehu, 2001; Itanna, 2002). Among the streams and rivers, the Little Akaki River receives major portion of the waste released in the west-central part of Addis Ababa from metal workshops, garages, tanneries, slaughterhouse and others that possibly affect its water quality (Worku et al., 1999). Irrigating farms with these streams and rivers could contaminate the soil with heavy metals such as Cd, Co, Cr, Cu, Mn, Ni, Pb and Zn and hence the plants grown on these soils (Itanna, 1998a; Chary et al., 2008; Kashif et al., 2009). Ironically a growing trend is discernible in the use of these waters for irrigating vegetable farms, especially during dry seasons, while domestic and industrial waste disposal appears to pose increasing threat to the city's water bodies.

Excess amounts of heavy metals from anthropogenic sources that gain access in to the ecosystem may lead to geo-accumulation and bioaccumulation, which in turn pollute the environment and also affect the food chain and ultimately risk the human health at the apex of the food chain (Brar et al., 2000; Dosumu et al., 2003).

The association of metal concentrations in vegetables to that in soils and waters may indicate extent of vegetable contamination by metals and reveal the key contaminant source and potential health risk to consumers of the vegetables. The present study was

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undertaken to assess the status of heavy metals contamination of Addis Ababa Rivers and streams, farm soils irrigated with these waters, and vegetables grown in these farms with the view to addressing potential health risk implications to consumers. To achieve the set forth objectives, samples of five types of vegetables, namely; Swiss chard (*Beta vulgaris L. var. cicla*), Ethiopian kale (*Brassica carinata A. Br.*), lettuce (*Lactuca sativa L.*), cauliflower (*Brassica oleracea L var. botrytis*) and cabbage (*Brassica oleracea L. var. capitata*) grown in four vegetable farms (Peacock, Kera, Goffa and Akaki farms) along the river courses, farm soils and irrigation waters were collected and analyzed for their Cd, Cr, Co, Cu, Pb, Mn, Ni and Zn concentrations.

## 2. Materials and methods

### 2.1. Description and location of the vegetable farms

Four vegetable farms, namely; Peacock, Kera, Gofa and Akaki irrigated with either Big Akaki River or Little Akaki River or their streams were selected to study the level of trace metal contamination (Fig. 1). Peacock farm (also called Bulbula farm) is located on the east side of the road to Bole International Airport. This farm is irrigated with Kebena and Bulbula Rivers, which together form the Big Akaki River. Kera and Goffa farms are found in the southern part of the city. Kera farm is nearer to Kera abattoir and is irrigated with the Little Akaki River (also called Kera River). Goffa farm, which lies downstream of Kera area, is irrigated with Kera River and the merged Kera and Kore Rivers, which flow in the south westerly direction to form the Little Akaki River. Akaki farm is located in the south western part of Addis Ababa near Lake Aba Samuel in Sakelo village. Being in the downstream of the Little Akaki River, this farm receives no direct industrial discharges.

### 2.2. Apparatus and chemicals

Labconco Freeze Dry-3 (Kentucky, USA) was used to freeze-dry the vegetable samples. Digitheat Drying Oven (J.P. Selecta, Barcelona, Spain) was used for drying samples and materials. Buck Scientific 210 VGP Flame Atomic Absorption Spectrophotometer (FAAS) (Norwalk, USA) was used for the determination of metals. The chemicals used were: 70% $HNO_3$ (BDH, England), 70% $HClO_4$ (Aldrich, Germany), 37% HCl (Riedel-deHaën, Germany), methyl isobutyl ketone (MIBK) (BDH, England), ammonium pyrrolidine dithiocarbamate (APDC) (BDH, England) and Buck Scientific Puro Graphic$^{tm}$ calibration standards (Norwalk, USA) for the metals Cd, Co, Cr, Cu, Mn, Ni, Pb and Zn. The accuracy of analytical procedures was checked by analyzing a soil certified reference material (CRM) BM-233 (Gannet Holdings Ltd, South Perth, Australia) obtained from Ezana Mining Development P.L.C. (Mekelle, Ethiopia). All samples and standards were diluted with distilled and deionized water.

### 2.3. Collection, preparation and preservation of samples

Samples of vegetables, soil and water were collected twice from the selected farms, prepared and preserved in the laboratory until analyzed as described below.

#### 2.3.1. Vegetable samples

Composite samples of each of Swiss chard and Ethiopian kale were collected from a minimum of twenty plants per sample from each farm; lettuce samples from a minimum of five plants each. Cauliflower and cabbage samples were collected depending on their availability. Two rounds of six samples each were brought from the vegetables farm to the laboratory in paper bags, cleaned with deionized water in the laboratory to remove dust and extraneous matter (Tiwari et al., 2011). The cleaned vegetables were freeze dried in the Labconco Freeze Dry-3 unit. The dried samples were then ground, homogenized and stored in tightly closed clean sample bottles until analyzed.

#### 2.3.2. Soil samples

Surface soil samples were collected from randomly distributed sampling points within the study farms using plastic spade in the same periods as the vegetable samples. Each soil sample was collected by removing the surface soil and sampling vertically from 0 to 20 cm borehole. During each sampling program, ten–twenty samples were collected and thoroughly mixed in the field, from which three composite samples weighing about 1 kg each brought to the laboratory packed in plastic bags (Stoeppler, 1997; Chary et al., 2008). All samples were well mixed again and quartered in the laboratory and one fourth of each sample was dried in an oven at 105 °C for 12 h. The dried samples were then ground and sieved with 200 mesh (75 μm) sieve and kept packed until analysis. A portion of

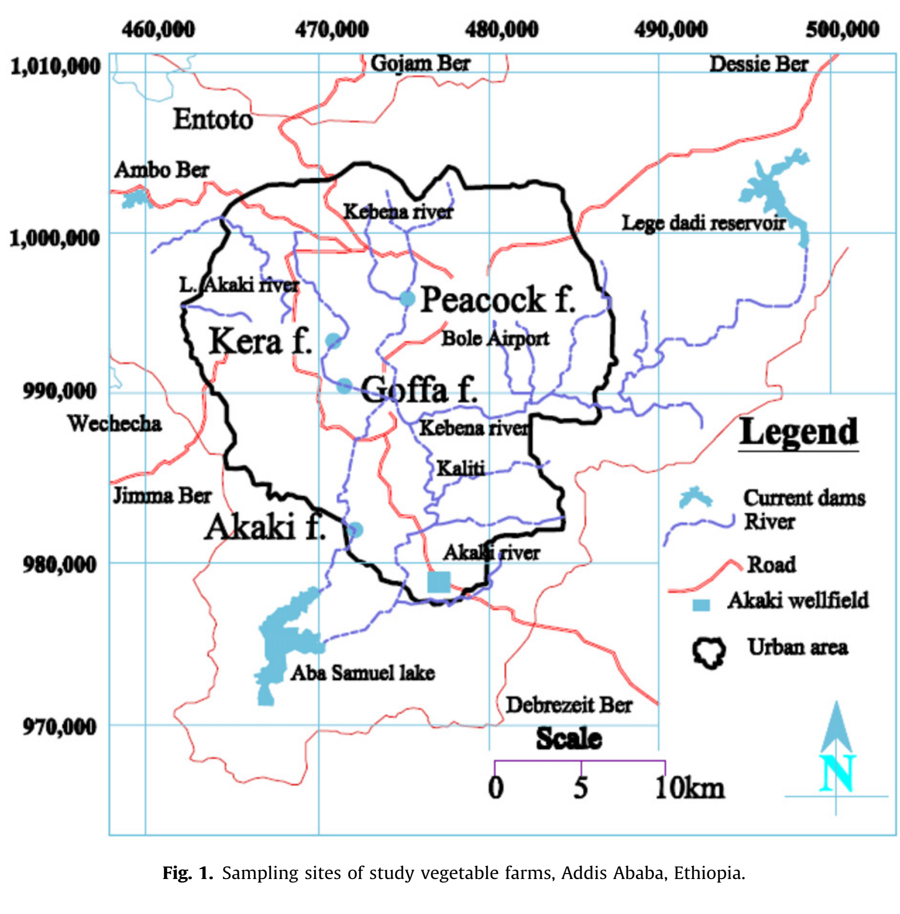


**Fig. 1.** Sampling sites of study vegetable farms, Addis Ababa, Ethiopia.