LAND DEGRADATION IN ADDIS ABABA DUE TO INDUSTRIAL AND URBAN DEVELOPMENT

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Abstract: Addis Ababa *is currently facing land degradation due to urbanization and industrialization resulting in physical sealing of soils, and contamination of ecosystems with pollutants such as heavy metals. The physical sealing of soils occurs due to increasing construction of industrial and residence buildings, roads, play grounds, etc. Municipal and industrial wastes are constantly added into river water or farmlands, with little or no treatment. Consequently, heavy metals build up in river water, soils and vegetables. Consumption of contaminated vegetables may have negative health implications and hence it is very imperative to increase public awareness at all levels. Treatment of effluents and bio-reclamation of degraded soils could ameliorate the current situation.*

INTRODUCTION

Addis Ababa is the capital of Ethiopia that lies at the geographical coordinate of 9^0N and $38^045'$ E, covering a total area of over 51, 000 hectares. The altitude of Addis Ababa ranges between 2000-3100 masl and the average minimum and maximum temperatures are about 9.9 ^{0}C and 24.6 ^{0}C, respectively. The mean annual rainfall is about 1196 mm (EPB 2001). Human population in the capital is currently estimated to be about 3.5 million. Most of the rivers in Addis Ababa originate from the "Entoto" mountain. They flow through the city from the north to the south.

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The major rivers in the city are Kolfe; Bulbula and Kebena. Bulbula and Kebena rivers join each other at the Peacock Park and later enter into Akaki River. City dwellers use these rivers to bath themselves, wash their clothes, and irrigate urban farms. Some others use them for providing drinking water for domestic animals while others use the banks as sanitary grounds. In former times, the river water was used as potable water for human drinking. Different industrial and municipal wastes such as industrial effluents, organic wastes, house and town refuses enter into these rivers.

Hitherto studies in land degradation in Ethiopia focused on physical soil loss and the respective impoverishment of plant nutrients and gave little emphasis on land degradation through industrial and urban activities.

Soil degradation through industrial and urban development is described as sealing and physical, chemical and biological degradation. Sealing of soils occurs through the construction of roads, industrial premises, houses, sporting facilities, and the use of soils as dumping grounds for different kinds of refuse (Blum 1998). Agricultural lands which otherwise could be used for cereal, fruit or vegetable production, or serve as rangelands are converted into roads and housing grounds through sealing. Reduction of farmlands in urban and peri-urban centers in this manner will consequently result in commensurate crop losses.

Chemical and biological degradation are caused by contamination with inorganic compounds such as heavy metals, as well as organic compounds such as polycyclic aromatic hydrocarbons (PAHs). The physico-chemical and biological degradation resulting from industrial activities is more concentrated and intense than that from urban activities. These urban and industrial activities in many cases irreversibly reduce the multi-functionality of soils (Blum 1998).

Under natural conditions, plants, animals and human beings are adapted to the local natural heavy metal concentrations (Blum 1996). Increased extraction of heavy metals and use of raw materials and fossil energy since the mid-eighteenth century however, are now leading to global pollution through atmospheric and water contamination (Blum 1988). Agricultural and municipal activities such as: dumping of wastes including sewage and sludge, use of fertilizers and pesticides, additives in animal feeds and contaminated manure, etc. are also increasing the amount of heavy metals in ecosystems (Bidwell and Dowdy 1987: McBride 1995).

Excess entrance of heavy metals into the soil reduces the natural filtering and buffering capacity of the soil. Its major effects in the ecosystem include intoxication of soil organisms, pollution of the food chain and deterioration of the groundwater quality and hence a risk to human health (Blum 1996: Ma and Rao 1997). Since this process is continuous, the pollution of soils and the atmosphere in this manner is of a great concern.

Very little information is so far available on the extent of contamination of soils, irrigation water and vegetables grown in urban Ethiopia. Moreover, there are no water, soil or air quality guidelines currently in use as to how these resources should be utilized. The objective of this study is therefore to assess the extent of degradation of the soils, water and crops in Addis Ababa, as a result of increasing human population and industrialization.

METHODS OF STUDY

Site Description

The experiments were undertaken at four vegetable growing farms in Addis Ababa (Bulbula, Kera, Kolfe, and Akaki). The city of Addis Ababa is located right in the center of the country at 9° 3' North latitude and 38° 43' East longitude (Ethiopian Mapping Authority 1988).

The total annual rainfall in Addis Ababa for the year 2000 (year of experiment) was 1049.1 mm. The average annual maximum air temperature was 22.9 °C, while the average annual minimum air temperature was 9 °C.

The major soil type of the vegetable farms at Bulbula, Kera, and Kolfe is Fluvisol while the soil types of the vegetable farm at Akaki are Vertisol on upper terraces and Fluvisol on bottomland. The soils of the farms at

Bulbula, Kera, and Kolfe are medium acidic to neutral while the pH of the soil at Akaki farm is stongly basic.

Population and Industrial Growth in Ethiopia

Population size and number of industrial establishments in major cities/towns of Ethiopia were obtained from reports of the Central Statistical Authority (CSA 1991; 1994; 1999a; 1999b; 1999c; 2001). Sealing effect of the urban soils was discussed based on the increment of housing units and industrial establishments in the capital over a given period.

Water Sampling and Analysis

In February 2000, composite surface water samples were taken at locations where the rivers are diverted to major vegetable farms. The samples during this period represent relatively the least diluted metal concentrations, since this is a dry period, just before the small rainy season begins in Ethiopia. The amount of rainfall in February 2000 was 0 mm. The water sample from the Kolfe River was taken near the Kolfe Comprehensive High School, while the samples from Bulbula and Kebena Rivers were taken at two different spots near the Peacock Park. The sample from Kera River was taken near the Kera vegetable farm. The industrial liquid waste from Akaki Textile Factory was sampled as it entered the Fanta Vegetable Producing Farmers' Association, and the Akaki River sample was also taken close to this farm.

About 5ml of HNO_3 acid was added to clean 250ml polyethylene bottles before adding about 100 ml samples of river water or industrial liquid waste. The chemical composition of the water from various sources was determined using a PE Elan 5000 ICP-MS (inductively coupled plasma - mass spectrometer) equipped with a regular nebulizer. The metals determined include: Cd, Co, Cr, Cu, Hg, Mo, Ni, Pb, and Zn; the metalloids include As, B and Se.

Soil Sampling and Analysis

A composite soil sample from the surface (0-20 cm) was collected from each vegetable farm at Kolfe, Peacock Park, Kera and from Akaki Fanta Vegetable Producing farm. After air drying and sieving, the pH of the soil samples was measured from a 1:2 soil/water solution with a pH meter. Soil organic carbon was measured using a LECO CR-12 carbon analyzer and texture was determined by pipette method involving wet sieving, after the carbonates and organic matter were removed.

Finely ground soil samples each weighing 0.5 g were placed separately in a Teflon digestion vessel and digested with 8 ml HNO_3 and 4 ml HF in a microwave digestion system, for total metal analyses. Total soil metals were then determined using a PE Elan 5000 ICP-MS. The metals determined included Cd, Co, Cr, Cu, Hg, Mo, Ni, Pb, and Zn; the metalloids included As, B and Se.

Vegetable Sampling and Analysis

Twenty-five recently matured leaves (composite sample) from each of lettuce (*Lactuca sativa* L.), Swiss chard (*Beta vulgaris* L. var. *cicla*), cabbage (*Brassica oleracea* L. var. *capitata*), red beet (*Beta vulgaris* L. var. *vulgaris*), Ethiopian kale (*Brassica carinata* A. Br.), and potato (*Solanum tuberosum* L.) were sampled at early maturity from the different farms in Addis Ababa, irrigated with industrial and municipal wastes. The samples were then cleaned with de-ionized water repeatedly. These were later dried in an oven at 65 ^{0}C for about 2 days, and were ground using a Cross-beater grinding mill.

Samples underwent pressurized digestion with HNO_3/H_2O_2 in a microwave digester and most of the metals in the extract were later determined with ICP-MS. Zinc, iron and manganese were measured by ICP-OES (Inductively coupled plasma - optical emission spectrometer). Arsenic was measured with HG-AAS (heated graphite furnace attached to an atomic absorption spectrophotometer).

RESULTS AND DISCUSSION

Population Growth and Impact on the Environment

Among the twelve highly populated towns and cities of Ethiopia, six of them (Bahir Dar, Jijiga, Awassa, Dire Dawa, Nazret, and Mekelle) had population increase of over 50 percent from 1984 to 1994. At Bahir Dar and Jijiga the growth was over 100 percent (Table 1). From 1994 to 2001, population increased in Nazaret, Jimma, Debre Zeit, and Awassa, in the range of 41-43 percent, slightly higher than most of the other cities.

With increase in population, degradation of the ecosystems takes place at a more rapid rate. Soil degradation through urban activities is mainly due to the enormous consumption of air, water and other goods within towns. Consumption of these products results in the release of huge amounts of solid and liquid wastes in cities. In Addis Ababa, in 1998 about 150,720 m^3 d^{-1} of water was consumed, and the resultant municipal, industrial and domestic wastes were 29,200, 7,120 and 110,000 m^3 d^{-1}, respectively (Dierig 1998).

The other problem manifested in Addis Ababa over the last two decades because of population increase is the sealing of soils because of construction of many houses for residence, business, and industrial purposes and also construction of roads. Number of housing units in Addis Ababa increased by 44 percent in ten years, i.e., from 259,555 in 1984 to 374,742 in 1994 (CSA 1991; 1999b). The number of households during the same period increased by 53 percent, from 267,765 in 1984 to 410,443 in 1994 (CSA 1999b). This has led to the abandonment of productive farmlands in the periphery of the city and eviction of farmers to the countryside. Most of the farmers had also to change their profession and remain in the city.

Abandonment of productive farmlands entails crop losses. According to a recent study, yield of teff in Ethiopia is on the average about 9 quintals per hectare, while wheat and barley yields are about 12 quintals per hectare (FAO 1998). Any reduction in productive farmlands around Addis Ababa has resulted in losses by as many quintals of such cereals multiplied by the area of land converted to housing premises, roads, or playgrounds, etc., through sealing. The current scenario of conversion of teff growing farmlands into industrial premises, along the roadside between Addis Ababa and Modjo, is a living witness of what could have happened around Addis Ababa, in a similar manner.

Industrialization and Impact on the Environment

Private and public manufacturing industries are mushrooming each year in urban centers like Addis Ababa (Table 1). The increase in the number of industrial establishments results in sealing of soils similar to sealing of soils due to urbanization as discussed above. In the context of soil degradation by urbanization and industrialization, there exists competition between the use of soil for infrastructure, as a source of raw materials, as geogenic and cultural heritage, for agriculture and forestry uses, filtering, buffering and transformation on the one hand, and as gene reserve and biodiversity on the other hand (Blum 1998).

Percentage growth in industrial establishments over the last decade was much higher compared to percentage of population growth (CSA 1999c). In addition to the sealing effect, the volume of industrial effluent discharged into rivers is assumed to have increased (Fig. 2). This in turn results in more intensive contamination of the ecosystems with heavy metals and other pollutants.

Vegetable Production and Consumption in Addis Ababa

Very intensive vegetable production takes place in Addis Ababa compared to rural Ethiopia. This is primarily because city dwellers consume more vegetables in their diet. Moreover, because of the rivers flowing through Addis Ababa, there is a year round possibility of growing vegetables. At Akaki, industrial liquid waste is directly drained into one of the farmlands there to irrigate vegetables especially during the off-season.

Over 11,100 tons of greater than 14 different vegetables are produced annually on more than 400 ha of land, by about 7 different farmers' associations in Addis Ababa (AARAB 2001). The figure does not include vegetables produced at the backyards of private houses and smaller plots of other farmers' associations. Potato (*Solanum tuberosum* L.), carrot (*Daucus carota* L.), Swiss chard (*Beta vulgaris* L. var. *cicla*), cabbage (*Brassica oleracea* L. var. *capitata*) and lettuce (*Lactuca sativa* L.) are the vegetables that are grown on largest area (Fig. 3). Potato production is the highest, while pepper is among the least produced vegetables.

Vegetables did not constitute major food dishes in the Ethiopian household in the past, except the long fasting season before Easter or on the fasting days Wednesdays and Fridays. However, since recent years, the production and consumption of vegetables is increasing gradually, especially among the urban community, after people became more aware of the importance of vegetables in a balanced diet.

Heavy Metal Pollution of Rivers, Soils and Vegetables in Addis Ababa

Municipal and industrial wastes in Addis Ababa are first and foremost dumped in to the rivers thus making water the first substrate to be contaminated. Soil and vegetables are contaminated at the second and third stages respectively, as the contaminated river water is applied on vegetable farmlands. Extent of their pollution is discussed below.

Water Pollution

Chemical composition of Bulbula, Kebena, Kera, Kolfe, and Akaki Rivers and Àkaki industrial liquid waste are considered in this study because they are applied on the major vegetable farmlands in Addis Ababa (Table 2).

A recent work on the heavy metal composition of these rivers at a point upstream (Abraha G/Kidan 2000) indicates that they have generally much lower concentrations than the samples in this study which are sampled at lower positions downstream. This manifests that the relatively good quality rivers emanating from the Entoto Mountain in North Addis Ababa get contaminated as they flow southwards through the densely populated city, from pollutants resulting from urbanization and industrialization.

Water analyses results show that most of the heavy metals/metalloids are either not detectable or found in trace concentrations in the irrigation water sources in Addis Ababa. As exception to this, Cr, Cu and Pb happen to be available in concentrations of environmental concern. Chromium is found in excessively high concentrations in Kera River, close to 300 times the maximum permitted concentration, CMC (16μg/L) according to recent United States Environment Protection Agency (USEPA) standards (USEPA 1999). Cu in Bulbula River is close to the CMC (13 μg/L), while in Kera it is about 3 times and in Akaki effluent about 2 times as much as the CMC. Pb in all rivers and Akaki effluent are below the CMC (65 μg/L) but above the continuous concentration, CCC (2.5 μg/L).

The high Cr concentration in Kolfe River was due to the input from Cr containing wastewater from the adjoining tannery (BCEOM and GKW 1993). Effluents entering from garages, fuel stations or from the nearby oil industries could also bring some chromium into the river. The Kera River later joins the mainstream of Akaki River. Cu in Bulbula and Kera Rivers in Addis Ababa is added from effluents of metal industries there, while that in the Akaki effluent comes out of the textile factory there. All except Kebena seem to have anthropogenic additions of lead from garages and fuel stations, paint and ceramic industries.

According to this study, at this stage the water from Bulbula and Kebena Rivers is found to be safe for livestock drinking. Kolfe River is not safe for animal drinking water because of the toxic levels of Cr according to guidelines indicated in Ayers and Westcot (1985).

It is reported that human communities and domestic animals living around Addis Ababa use these rivers as sources of drinking water (Yesehak et al. 1999). The same study reveals that the Cr, Cd, Pb, and Fe concentrations are about or greater than twice the World Health Organization (WHO) recommended rates, and hence are hazardous for human and livestock health if used for drinking purposes.

Soil Pollution

According to central European toxicity limits (Ewers, 1991), the vegetable farms at Addis Ababa are contaminated to toxic levels with 7 out of 12 metals and metalloids studied (Table 3). These include: Co (Akaki), Cr (Kera and Kolfe), Fe (all), Mn (Peacock Park, Kolfe and Akaki), Ni (all), Pb (Kera), and Zn (Peacock Park, Kolfe and Akaki). This occurred on Fluvisols. In an earlier report, it was found that the Vertisols at Akaki consisted of toxic levels of Cr and Ni (Fisseha Itanna 1998).

Besides heavy metal contamination by river water, the farmlands are also contaminated with solid wastes and gas emissions. With increase in industrialization and urbanization, environmental problems related to heavy metal build up correspondingly increase. In addition to this, there exists little awareness of the environmental consequences of application of such wastes on farmlands. Most of the industrial plants also gave very little consideration to decontaminate the effluents discharged from their industries. More emphasis is laid only to the economic return from the industries.

High Co concentration in Akaki resulted from incremental additions from Kolfe and Kera Rivers, which finally enter into Akaki River. The high chromium concentration in Kolfe, Kera and Akaki farms is largely due to the effluent from the tanneries in the capital. Wastes from garages and fuel stations or other municipal sources could have also contributed. Chromium compounds enter the ecosystem through products like pigments - as anti-corrosives in oil industries dyeing components in textile industries, tanneries, etc. (Gauglhofer and Bianchi 1991).

Nickel was also found in high concentrations in most of these farms. It originates most likely from gas emissions. Nickel enters the atmosphere from combustion of fossil fuels by stationary and mobile power sources, from emissions of nickel mining and refining operations, from metal consumption in industrial processes, and from incineration of wastes (Sunderman and Oskarsson 1991).

At Akaki, lots of lead is applied in the metal factory. Wastes from garages and fuel stations, paint and ceramic industries entering into Kolfe-Kera-Akaki Rivers could also contribute to high concentrations of Pb in soils. Lead can be added into the environment through industrial products like batteries, as anti-knock agent in gasoline, pigments, in glassware and ceramic industries, etc. (Ewers and Schlipkoeter 1991).

Over 33 industrial effluents from Addis Ababa are said to enter into the Akaki river, making it the most highly polluted river in the country. Consequently, the vegetable farms at Akaki consist of the highest concentrations of most of these metals and metalloids comparatively (Table 3).

Status of Vegetables Grown on Contaminated Farms

Vegetables grown at Kera apparently are more contaminated with heavy metals than those from Peacock Park, possibly because of more industrial effluents entering into Kera River and the farm. Potato, Swiss chard, carrot and cabbage from Akaki generally contained more of these toxic elements compared to those from Kera and Peacock Park farms (Table 4).

Vegetables from Akaki contained higher concentrations of the toxic elements than those from the other farms in Addis Ababa, because this farm is predominantly irrigated with industrial liquid waste from the textile factory there, which receives little or no treatment at all. In addition to it, the Akaki River receives municipal and industrial wastes from several tributaries including the Kera River. Consequently, there is a higher load of toxic metals/metalloids entering the river from various sources.

Differences in Metals Accumulated in Vegetables

From the six vegetables grown with industrial and municipal wastes, highest concentrations of cobalt were observed in potato from Akaki, lettuce and Swiss chard from Kera, respectively. Lettuce from Kera accumulated the highest concentrations of Cr and Fe; whereas kale from the same place accumulated highest amounts of Cu, Ni, and Zn. Swiss chard and carrot from Akaki contained the highest Mn and Pb, respectively. Hence, lettuce, Swiss chard and kale seem to be major metal accumulating vegetables in Addis Ababa. Lettuce and Swiss chard are reported to be high accumulators of metals elsewhere too (Bower 1994).

Metal Status in Vegetables and Associated Health Risk

In all vegetables studied, the micronutrients (Cu, Fe, Mn and Zn) and Ni, and Pb are found in concentrations exceeding maximum concentrations, according to metal standards set for similar vegetables by USEPA (United States Environmental Protection Agency) (USEPA 2000). In addition to this, Cd in carrot at Akaki and Potato in all sites also surpass such maximum limits. Arsenic in lettuce at Kera and in potato at all sites is also a point of concern.

On the average the cobalt content of plants varies between 0.05 and 0.30 mg kg^{-1} (Marschner 1996). Swiss chard from contaminated farms in Addis Ababa and Akaki, kale and lettuce from Kera and potato from Akaki contain cobalt in concentrations above normal in vegetables. Toxic level of Co could have carcinogenic effect (Schrauzer 1991). Although soil Cr concentrations nearly at all sites are in high concentrations, this does not seem to be reflected in the vegetables. This may be due to Cr exclusion by plant roots. Plants usually contain 0.02-14 mg kg^{-1} Cr on dry weight basis (Gauglhofer and Bianchi 1991).

Considering the FAO/WHO guidelines (FAO/WHO 2001), Cd in all vegetables but cabbage, and Pb in all vegetables from all sites contain concentrations higher than the maximum limits in vegetables. Exceptions were Cd in carrot and Swiss chard at Peacock Park.

Concentration of these metals in the vegetables alone would not suffice to show exposure of consumers to metals. A recent study on vegetable consumption of low income communities in Addis Ababa shows that on the average a household of this category in Addis Ababa consumes about 5g of vegetables per day (ENDA 2002). Based on this figure, the theoretical maximum daily intake (TMDI) or weekly intake (TMWI) of metals is quite low. Obviously vegetable producers and communities with better income consume definitely more than the amount specified above. However, the average consumption in Addis Ababa is still less than the required 200g per day. Hence, risk of eating vegetables grown at these places gets acute, whenever the community changes its food habit and increases vegetable consumption.

Generally, soil metal contents correlate fairly well with those in vegetables, which signifies that the higher the contamination by an element, the greater its concentration in plant tissue.

CONCLUSIONS AND RECOMMENDATIONS

Fifty percent of the highly populated cities in Ethiopia had population increase of over 50 percent between the years 1984-94, and with some towns like Bahir Dar and Jijiga the growth was over 100 percent. With increase in human population and increase in more residential houses, sealing of soils takes place at a rapid rate.

Percent growth in industrial establishments over the last decade in Ethiopia and particularly Addis Ababa was much higher compared to percent population growth. In addition to the sealing effect, the volume of industrial effluents discharged into rivers can be assumed to have increased. This in turn results in more intensive contamination of the ecosystems with heavy metals and other pollutants.

Among the metals and metalloids studied, the micronutrients (Fe, Cu, Zn and Mn) and Ni, and Pb are of greater health concern in all vegetables at all sites. However, because of relatively low vegetable intake by the community, the daily or weekly maximum theoretical exposure to heavy metals is low. This however could change in the future if food habits change.

To reduce metal/metalloid contamination of the ecosystems, it is advisable to effectively increase treatment of effluents. As a second step it is recommended to reclaim the already contaminated ecosystems through the use of low input technologies such as phytoremediation.

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ACKNOWLEDGEMENTS

The ESTC is acknowledged for providing funding for sample collection. Profs. Anderson, Kerrich and Mermut from the University of Saskatchewan and Prof. Stahr and Dr. J. Breuer from the University of Hohenheim are acknowledged for providing access to their respective laboratories and funding the analyses. Lab staff of the laboratories in Saskatoon and Hohenheim were also very helpful. SIDA/SAREC is acknowledged for covering personal costs during the write up of this manuscript at Uppsala in Sweden.

Table 1: Growth in human population and industrial establishments in some cities/towns of Ethiopia

Town/ City	Human Population			Percent increase in human population		Industrial Establish-hments		% increase in indust. establish.
	1984	1994	2001	1984-1994	1994-2001	1984	1994	1984-1994
Addis A.	1,423,182	2,084,588	2,570,000	46	23	194	501	158
Dire D.	99,980	164,851	227,494	65	38	7	24	243
Nazret	77,256	127,842	180,537	65	41	13	20	53.8
Gondar	80,675	112,249	156,087	39	39	8	9	12.5
Dessie	71,565	97,314	135,529	36	39	1	9	800
Mekele	62,668	96,938	134,996	55	39	4	14	250
Bahir D.	41,138	96,140	134,062	134	39	3	13	333
Jimma	60,218	88,867	125,569	48	41	3	14	367
Debre Z.	55,657	73,372	103,569	32	41	5	15	200
Harar	63,070	76,378	101,000	21	32	4	8	100
Awassa	36,367	69,169	98,917	90	43	5	23	360
Jijiga	24,716	58,360	78,167	136	34	-	4	>400

Source: CSA 1991, 1994, 1999, 2001

Table 2: Concentrations (µg/L) of some toxic elements in the major rivers and in an industrial effluent in **Addis Ababa**

Element	Bulbula	Kebena	Kolfe	Kera	Akaki River	Akaki Eff.
As	1.7	1.16	2.83	0.9	1.19	2.18
B	n.d.	n.d.	217	280	n.d.	n.d.
Cd	0.07	0.08	0.09	0.9	n.d.	0.08
Co	2.69	1.94	5.65	4.95	2.71	2.12
Cr	n.d.	n.d.	3540	7.4	n.d.	118
Cu	12.4	4.35	6.68	39	2.54	27.3
Hg	n.d.	n.d.	n.d.	0.2	n.d.	n.d.
Mo	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Ni	2.26	n.d.	21	8.9	n.d.	n.d.
Pb	14.1	4.16	10.1	33	3.77	5.83
Se	n.d.	n.d.	6.68	0.08	n.d.	1.24
Zn	50.3	30.2	46.2	193	35.1	46.15

n.d.= not detectable

Table 3: Total trace element composition (mg kg-1) of soils of the major vegetable farms in **Addis Ababa**.

Toxic element	Bulbula (Peacock P.)	Kera	Kolfe	Akaki
As	5.2	6.8	4.08	7.76
Cd	0.7	0.4	0.41	0.95
Co	28.0	43.0	26.95	52.95
Cr	81.0	115.0	283	86
Cu	39.0	55.0	45	53
Fe	163860.0	79700.0	181750	128981
Hg	0.23	0.07	0.31	0.16
Mn	6587.0	3598.0	5253	4767
Ni	74.1	115.0	82	154
Pb	46.7	110.0	32.7	48.74
Se	0.09	0.02	0.04	0.13
Zn	2985.5	263.0	2067.5	1767.5

Table 4: Concentrations of trace metals in **leaves** of some vegetables grown-in **Addis Ababa**

		Metal/metalloid concentrations									
Crop	Farm	As	Cd (µg kg-1)	Co	Cr	Cu	Fe	Mn (mg kg-1)	Ni	Pb	Zn
Cabbage	Kera	<1000	<50	62	0.89	3.03	73	29	0.8	0.21	31.8
	Peacock	<1000	<50	133	1.71	3.3	173	25	0.91	0.29	31.81
	Akaki	<1000	<50	131	0.689	2.5	219	30	1.34	0.37	32.49
Swiss C.	Kera	1210	78	681	2.05	8.06	527	37.5	2.1	1.79	56.19
	Peacock	<1000	<50	317	1.04	7.88	461	67	0.89	0.61	48.91
	Akaki	1020	193	532	0.9	14.95	555	218	1.81	1.63	81
Carrot	Mekanisa	<1000	59	130	0.82	7.68	403	53	2.44	0.91	44.87
	Peacock	<1000	<50	84	0.28	7.79	205	29	0.98	0.54	29.9
	Akaki	<1000	84	256	0.82	8.99	469	57	1.66	2.15	59.03
Kale	Kera	<1000	130	308	0.99	9.92	331	126	4.64	0.53	63.71
	Akaki	<1000	<50	187	1.1	3.05	173	30.5	1.31	0.37	35.08
Potato	Kera	<1000	78	256	0.7	9.66	364.5	66	1.4	1.8	28.25
	Akaki	1205	159	882	1.35	13.15	816	69.5	2	2.02	64.7
Lettuce	Kera	1040	126	757	9.47	6.62	1345	106	1.86	1.59	48.63
	Bulbula	<1000	75	167	1.21	6.24	351	54	0.71	0.39	47.8

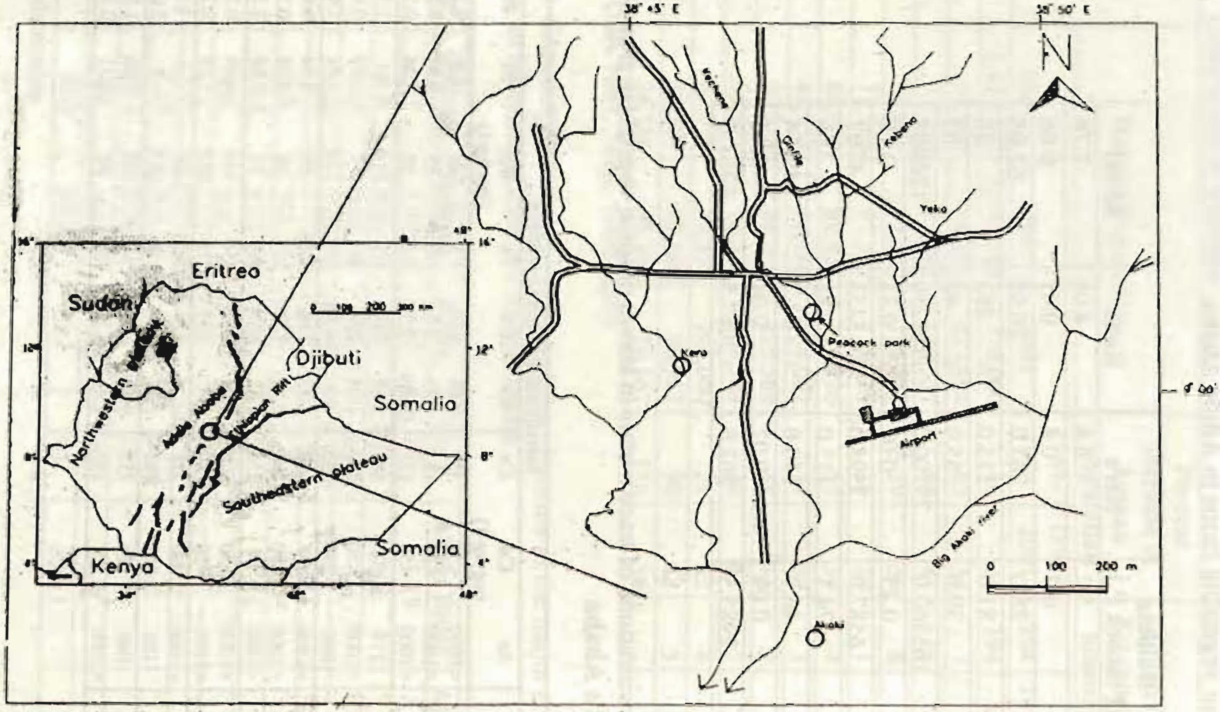

Fig. 1. Water, soil and plant sampling positions at Peacock Park, Akaki and Kera vegetable farms.

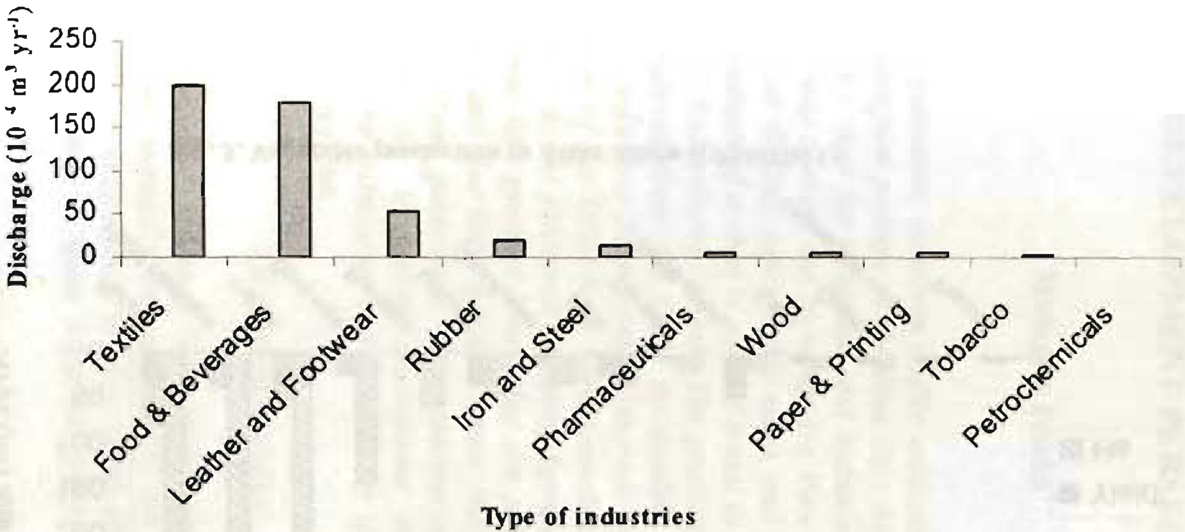

Fig. 2. Volume of discharge of major industries in Addis Ababa

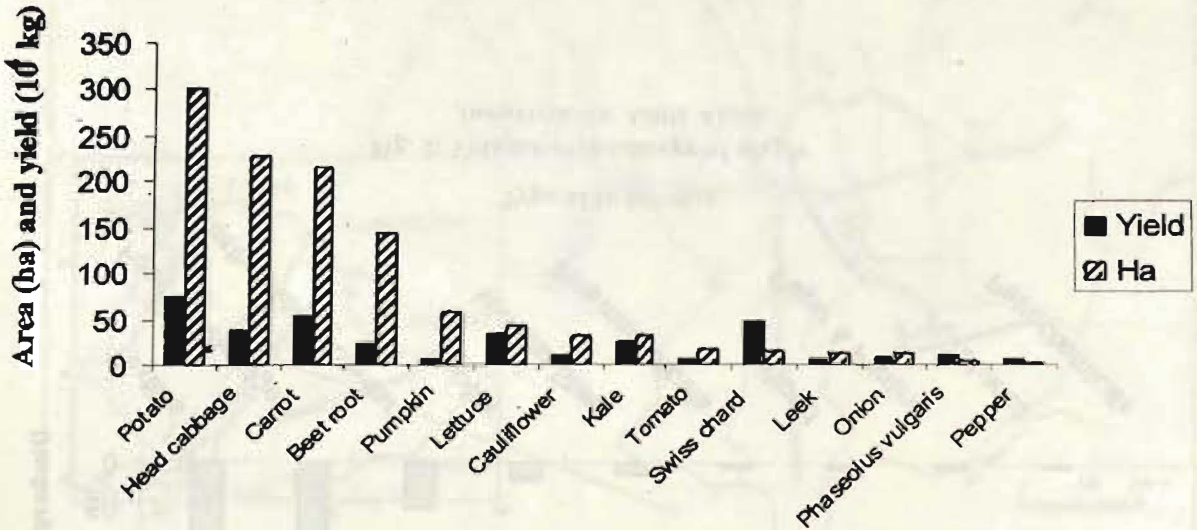

Fig. 3. Vegetable production in Addis Ababa (2000/2001)