

**SELECTED HEAVY METALS CONCENTRATION IN SOME
VEGETABLES CULTIVATED USING INDUSTRIAL WASTEWATER
IRRIGATION**

M. Sc. THESIS

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Haramaya University

**Selected Heavy Metals Concentration in Some Vegetables Cultivated Using
Industrial Wastewater Irrigation**

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Science in Biology**

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DEDICATION

I dedicate this piece of thesis work to my wife Haymanot Ayalew and my two daughters Danawit Teshome and Yordanos Teshome for their encouragement in this thesis activity.

STATEMENTS OF THE AUTHOR

By my signature below, I declare and affirm that this Thesis is my own work. I have followed all ethical and technical principles of scholarship in the preparation, data collection, data analysis and compilation of this Thesis. Any scholarly matter that is included in the Thesis has been given recognition through citation.

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ACRONYMS AND ABBREVIATIONS

APHA	American Public Health Association
BOD	Biological Oxygen Demand
COD	Chemical Oxygen Demand
GPS	Global Positioning System
ISO	International Organization for Standardization
MOH	Ministry of Health
MOWE	Ministry of Water and Energy
MOWR	Ministry of Water Resources
SPSS	Statistical Package for Social Sciences
TOC	Total organic carbon
TSS	Total suspended solids
WHO	World Health Organization
USEPA	US Environmental Protection Agency
USDA	United States Department of Agriculture
FAO	Food and Agriculture Organization

TABLE OF CONTENTS

Page

<u>STATEMENTS OF THE AUTHOR</u>	v
<u>BIOGRAPHICAL SKETCH</u>	vi
<u>ACKNOWLEDGMENTS</u>	vii
<u>ACRONYMS AND ABBREVIATIONS</u>	viii
<u>TABLE OF CONTENTS</u>	ix
<u>LIST OF TABLES</u>	xi
<u>LIST OF FIGURE</u>	xii
<u>ABSTRACT</u>	xiii
<u>1. INTRODUCTION</u>	0
<u>1.2 General Objective</u>	4
<u>1.2. 1. Specific objectives of the study</u>	4
<u>2. LITERATURE REVIEW</u>	5
<u>2.1 The Contamination of Vegetables with Heavy Metals</u>	5
<u>2.2. Irrigation Water and Characteristics of Wastewater</u>	6
<u>2.3 Effect of Industrial Wastewater on Vegetables</u>	7
<u>2.4 Features and Effects of Major Chemicals and Heavy Metals</u>	9
<u>2.5. Wastewater Management Agreed international Agendas and Policies</u>	10
<u>2.6. Wastewater Treatment System at Wonji Sugar Factory</u>	12
<u>3. MATERIALS AND METHODS</u>	14

<u>3.1. Description of the Study Area</u>	14
<u>3.2. Study Design</u>	16
<u>3.3. Sources of Data</u>	16
<u>3.4. Water Sample Collection</u>	16
<u>3.5. Vegetable Sample Collection</u>	17
<u>3.6 Analyses of Water Samples</u>	17
<u>3.7 Analysis of Vegetable Samples</u>	17
<u>3.8. Data Analysis</u>	18
<u>4. RESULTS AND DISCUSIONS</u>	19
<u>4.1. Heavy metal concentration in vegetables sampled from different irrigation sites</u>	19
<u>4.2. Heavy metal concentrations (mg/kg) of the vegetables sampled from the three irrigation sites</u>	23
<u>4.2.1. Heavy metal concentration (mg/kg) in tomato</u>	23
<u>4.2.2. Heavy metal concentration (mg/kg) in cabbage</u>	24
<u>4.2.3. Heavy metal concentration (mg/kg) in onion</u>	25
<u>4.3. Heavy metal concentrations in irrigation water</u>	26
<u>5. SUMMARY, CONCLUSION AND RECOMMENDATIONS</u>	27
<u>5.1. Summary and Conclusions</u>	27
<u>5.1.1. Summary</u>	27
<u>5.1.2. Conclusion</u>	28
<u>5.2. Recommendations</u>	29
<u>6. REFERENCES</u>	30
<u>7. APPENDEXES</u>	37
<u>Appendix- 1</u>	37
<u>Appendix- 2</u>	38
<u>Appende-3</u>	39
<u>Appendix4</u>	40

LIST OF TABLES

Tables

Page

<u>1. Heavy metal concentration (mg/kg) determined from different vegetables sampled from Kuriftu site (values are mean \pmSE, n=</u>	
21	
<u>2. Heavy metal concentration (mg/kg) determined from different vegetables sampled from Melkahida site (values are mean \pmSE, n=3</u>	
22	
<u>3. Heavy metal concentration (mg/kg) determined from different vegetables sampled from Awash Melkassa site (values are mean \pmSE, n=3)</u>	
23	
<u>4. Comparison between the different heavy metal concentrations (mg/kg) of tomato sampled from different cultivation sites (values are mean \pmSE, n=3)</u>	25
<u>5. Comparison between the different heavy metal concentrations (mg/kg) of cabbage sampled from different cultivation sites (values are mean \pmSE, n=3)</u>	26
<u>6. Comparison between the different heavy metal concentrations (mg/kg) of onion sampled from different cultivation sites (values are mean \pmSE, n=3)</u>	27
<u>7. Concentration (mg/L) of the different heavy metals in wastewater sampled from different points (values are mean \pmSEM, n=3)</u>	
28	

LIST OF FIGURE

Figures	Page
Figure 1. Map of the study area (source Google map)	16

Selected Heavy Metals Concentration in Some Vegetables Cultivated Using Industrial Wastewater Irrigation

ABSTRACT

This study was conducted to assessing of selected heavy metals (Cr., Cd, Zn, Hg and Pb) accumulation in the edible portions of cabbage, tomato and onion cultivated around Wonji in eastern part of Ethiopia. The concentrations of the same heavy metals were determined in water samples collected directly from industry discharge and also three irrigation sites Varied between sampling points. Vegetable Samples were first optimized through wet digestion procedure and contents of heavy metals were analyzed using atomic absorption spectrometry (AAS). In Kuriftu samples, value of Chromium (Cr) in descending order was that concentration in cabbage > onion > tomato, Cadmium (Cd) concentration in Cabbage > tomato > onion, Lead (Pb) concentration in onion > tomato > cabbage, mercury (Hg) in tomato > onion > cabbage and Zinc (Zn) concentration in tomato > cabbage > onion. In Melkahida samples, concentration of Chromium (Cr) in onion > cabbage > tomato. Cadmium (Cd) concentration in Cabbage > onion > tomato, Lead (Pb) concentration in onion > tomato > cabbage, mercury (Hg) in tomato > onion > cabbage and Zinc (Zn) concentration in

cabbage > onion > tomato. In Awash Melkassa samples, concentration of Chromium (Cr) in onion > cabbage > tomato. Cadmium (Cd) concentration in onion > cabbage > tomato, Lead (Pb) concentration in cabbage > onion > tomato, mercury (Hg) in tomato > onion > cabbage and Zinc (Zn) concentration in cabbage > tomato > onion. Concentrations of heavy metal in each vegetable showed significant difference between the three farming sites. In tomato, for example :Chromium (Cr) concentration ranged from 0.27 mg / kg in Awash Melkassa to 0.65 mg /kg in Kuriftu Cadmium (Cd) ranged from 0.26 mg / kg Awashmelkassa to 0.97mg/kg in Kuriftu Lead (Pb) ranged from 0.14 mg / kg in Awashmelkassa to 0.34mg/kg, in Kuriftu Zinc (Zn) ranged from 7.94 mg / kg in Awashmelkassa to 12.41 mg / kg in Kuriftu Similar trend was also observed when cabbage and onion are considered. In water samples values of the tested heavy metals also varied between sampling points. Overall, results of this study showed that heavy metal concentrations measured in irrigation water and vegetables were above the limit

Key words : Bioaccumulation, Heavy metal, Irrigation water, vegetable, Wonji

1. INTRODUCTION

The world's population is growing rapidly and concentrating in urban centers. This trend is particularly intense in developing countries, where an additional 2.1 billion people are expected to be living in cities by 2030 (FAO, 2012). However, sanitation coverage is not keeping pace with urban growth and, as a result, most wastewater enters water courses untreated (FAO, 2012). Many farmers in developing countries grow crops, especially vegetables, in urban and semi-urban environments using this wastewater to irrigate their crops. Such wastewater is often heavily contaminated with disease-causing organisms and chemical agents that can seriously harm the health of the farmers, the traders who handle crops and the people who consume them.

The volume of wastewater generated by industrial and other sources has increased with population size, urbanization, and industrial development (Qadir, *et al.*, 2008). In urban areas of many developing countries, agriculture depends, at least to some extent, on wastewater as a source of irrigation water. The quality of the water and the conditions under which this water is used vary greatly (Huibers *et al.*, 2004). However, the quality of wastewater used and the nature of its use vary enormously, both between and within countries. In many low-income countries such as in Africa, Asia, and Latin America, the wastewater is mostly used untreated (Ullah, H., I. Khan and I. Ullah. 2011; and Gosh A., Bhatt M. and Agrawal H. 2012).

As argued by Drechsel and Keratin (2014), 85% of wastewater generated from industries and urban centers worldwide ends up in the environment in its untreated form. They further described that, with increasing global population, the gap between the supply and demand for water is widening and is reaching such alarming levels that, in some parts of the world it is posing a threat to human existence. In developed countries where environmental standards are applied, much of the wastewaters are treated prior to use for irrigation of fodder, fiber, and seed crops and, to a limited extent, for the irrigation of orchards, vineyards, and other crops. In developing countries, though standards are set, these are not always strictly adhered to

(Hussain et al. , 2002) Wastewaters are basically contaminated with trace elements like lead (Pb), copper (Cu), zinc (Zn), boron (B), cobalt (Co)

chromium (Cr), arsenic (As), molybdenum (Mo), manganese (Mn), etc. many of which are non-essential and over time toxic to plants, animals and human beings (Kanwar and Sandha, 2000). Long-term application of untreated wastewater results in significant buildup of heavy metals in soil (Ullah *et al.*, 2008 ; Khan and Ullah *et al* 2011; and Gosh *et al.* , 2012) and vegetables and subsequently transfer to food chain and cause potential health risk to consumers (Singh *et al* ., 2010; Gupta *et al.*, 2011).

Particularly, concentrations of heavy metals in plants grown in wastewater-irrigated soils are significantly higher than in plants grown in the soil (Khan *et al.* , 2008 : Singh *et al.* , 2010 Gupta *et al.* , 2011). Sharma *et al.*, (2006) concluded that the use of untreated wastewater for irrigation increases the contamination of plants by Cd, Pb, and Ni in edible portion of vegetables causing potential health risk in the long term. Sachan *et al.* (2007) found that bio-accumulation of Pb and Cr in vegetables was above the critical concentrations for plant growth while Pb and Cd were above the prescribed limit in the diet of animals. Chary *et al.*, (2008), assessed Zn, Cr, Cu, Ni, Co and Pb in soils, forage grass, milk from cattle, leafy and non-leafy vegetables. Human risk was assessed in people known to consume these contaminated foods by analyzing metals concentrations in venous blood and urine. In general, the above findings of researches showed that, vegetables irrigated by industrial wastewater pose serious hazards to plants and eventually to human health. Moreover, wastewater from various industries contains heavy metals that accumulate in vegetables and has negative impacts on vegetables grown.

Rapid urbanization and industrialization in many parts of the world would be the main reasons for contamination by metals in the terrestrial environment. This can influence the natural geochemical cycling of the ecosystem. Important sources for heavy metals contamination include: irrigation by sewage water and industrial effluents sewage sludge , organic manures and composts, vehicular emissions, incinerators , industrial waste, atmospheric deposition of heavy metals from point sources such as metalliferous mining, smelting and industrial activities . Factors which influence the concentration of heavy metals in plants include climate, atmospheric deposition, the nature of the soil on which the plant is grown and the degree of maturity of the plant at the time of harvesting. Repeated use of wastewater can overcome the

capacity of the soil to retain heavy metals therefore; soil can release heavy metals into the ground water or soil solution available for plant uptake. Airborne heavy metal contamination is becoming a great concern in different countries. The major source for airborne Pb is automobile exhausts and for Cd and zinc are smelting, fossil fuel combustion and waste incineration. As most of vegetable growing areas are situated in, or near sources of atmospheric deposits, the risk of potential contamination of them is high. Contamination with metal is of great concern, particularly in agricultural production systems. Contamination with heavy metals which comes from the industries and vehicles may be deposited on the vegetable surfaces during their production, transport and marketing. It has been shown that contamination of vegetables is mainly by Pb, Cd, Cr and Zn.

As heavy metals are non-biodegradable and non-thermo degradable and they have long biological half-lives, they will accumulate in the food chains which have significant effects on human health in the long term. One of the most important aspects of food quality assurance is heavy metal contamination of the food items. As awareness of the risk of heavy metal contamination in food chain increases national and international regulations on food quality have lowered the maximum acceptable levels of toxic heavy metals in food items. A number of studies have shown heavy metals as important contaminants of the vegetables. It has been shown that accumulation of heavy metals in the kidney and liver of humans may occur after prolonged exposure to unsafe concentrations of heavy metals through foodstuffs. Pregnant women or very young children are more vulnerable to heavy metal toxicity.

Some of the important effects of heavy metal poisoning are neurological disorders, central nervous system destruction, and cancers of various body organs. They may cause disruption of several biochemical processes, leading to cardiovascular, nervous, kidneys and bone diseases. Also, there are some reports showing low birth weight and severe mental retardation of newborn children where during pregnancy mother exposed to toxic amounts of a heavy metal through direct or indirect consumption of vegetables

Vegetables are becoming important part of Ethiopian people's diet specifically when Bayonet a variety of vegetables are put on Injera (Injera, is a staple food in Ethiopia, which is made from a tiny grain called Teff) is prepared. This fact shows the importance of evaluating the safety of

vegetables in aspect of heavy metal contamination. The aim of the present study was to determine the concentrations of heavy metals (Cd, Cr, Zn ,and Pb) in some vegetables (tomatoes, cabbage, onions,) grown with irrigation water tapped from Awash river locally at Kuriftu, Melkahida, Melkasa places near Awash river and sold in the urban markets.

With the ever increasing demand on irrigation water supply, farmlands are frequently faced with utilization of poor quality irrigation water. In many parts of Ethiopia, wastewater, which are disposed to wells, ponds, streams and treatment plants, are used as a source of irrigation water as well as for drinking (Eskinder *et al.*, 2010) Direct discharge of waste materials from industrial sources to rivers and the leakage of industrial wastes from poorly designed septic tanks to the ground water, and sewage effluents can change the quality of water that will be used for irrigation in the country. For example, studies have indicated that among the industries located in Addis Ababa, 90 to 96 percent discharge their waste without any form of treatment to nearby water bodies and open spaces (EPA, 2005; Freezer, 2012). These indicate the existence of some studies that have been carried out in Ethiopia regarding wastewater utilization for irrigation. However, almost all of these researches were concentrated around Addis Ababa, particularly around Akaki River.

However, as far as the knowledge of the researcher is concerned there is no study conducted regarding the impact of industrial wastewater and on vegetables irrigated in and around Wonji area. But, as stated by Lemma (2002) and Edessa (2014), since the start of vegetable production in Ethiopia, a lot major vegetable production packages have been developed in the Central Rift Valley region the country, including Wonji area. They confirmed that, commercial irrigated agriculture was started in the Rift Valley corridor of the country. With the course of time, the semi-pastoral households inhabiting the region adopted cultivation of high value vegetables using various sources of irrigation water. Nowadays, vegetable production as a business has reached a climax in the area in which hundreds of thousands of farmers (households, cooperatives, and investors), brokers, and various forms of traders are involved (Edossa, 2014).

Wonji is one of the few industrial areas in Ethiopia, including Wonji Sugar Factory. The existing industries have been discharging their wastes into the surrounding environment, in particular to the nearby Awash River. According to the information obtained from Adama District Agriculture

Office, many farmers are diverting the effluent contaminated river water to irrigate their farmlands to grow vegetables. In addition, the local agricultural office explains that, despite the fact that many cooperative vegetable farm enterprises have used the river for irrigation since long time ago; no study has been conducted yet on the suitability of the water for vegetable irrigation in the area.

In general, industrial wastewater and its nutrient content can be used extensively for irrigation and other ecosystem services. Its reuse may deliver positive benefits to the farming community, society, and municipalities. However, wastewater reuse for irrigation of vegetables also exacts negative externality effects on humans and ecological systems, which need to be identified and assessed (Hussein *et al.* , 2002) In view of the foregoing, the basic intent of conducting this study is, therefore, to provide reliable information on the magnitude of the industrial wastewater and the concentration of heavy metals in water used for vegetable irrigation; which will help farmers and policy makers to take appropriate measures on time.

1.2 General Objective

The general objective of this study is to assess heavy metals concentration of industrial wastewater and the concentration of those heavy metals in some vegetables irrigated around Wonji sugar factory including their effects on human health in consuming those vegetables.

1.2. 1. Specific objectives of the study

- To assess the extent of heavy metals in water used for irrigation around the study area.
- To explore the concentration of heavy metals in some vegetables irrigated in the study area (tomatoes, cabbage, onions,) against standards.

Moreover, in achieving the objectives of this study, emphasis has made for heavy metals concentration of irrigation water (average concentrations of Cadmium (Cd), Lead (Pb), Chromium (Cr), and Zinc (Zn) and, Mercury (Hg) in the water samples and vegetable samples.

2. LITERATURE REVIEW

2.1 The Contamination of Vegetables with Heavy Metals

The contamination of vegetables with heavy metals due to soil and atmospheric contamination poses a threat to its quality and safety. Dietary intake of heavy metals also poses risk to animals and human health. Heavy metals such as Cd and Pb have been shown to have carcinogenic effects

(Trichopoulos, 1997). High concentrations of heavy metals (Cu, Cd and Pb) in fruits and vegetables were related to high prevalence of upper gastrointestinal cancer (Turkdogan *et al.*, 2002). For most of the people, the main route of exposure to heavy metals is through the diet except occupational exposures at related industries. Regulations have been set up in many countries and for different industrial set up to control the emission of heavy metals. The uptake and bioaccumulation of heavy metals in vegetables depend on the concentrations of heavy metals in soil, the nature of soil on which the vegetables are grown and the degree of maturity of the plants at the time of harvest (Lake *et al.* 1984; Scott *et al.*, 1996; Voutsas *et al.*, 1996).

Air pollution may pose a threat to post-harvest vegetables during transportation and marketing, causing elevated levels of heavy metals in vegetables (Agrawal, 2003). Elevated levels of heavy metals in vegetables are reported from the areas having long-term uses of treated or untreated wastewater (Singh *et al.*, 2004; Sinha *et al.*, 2005; Sharma *et al.*, 2006; Sharma *et al.* 2007). Other anthropogenic sources of heavy metals include the addition of manures, sewage sludge, fertilizers and pesticides, which may affect the uptake of heavy metals by modifying the physico-chemical properties of the soil such as pH, organic matter and bioavailability of heavy metals in the soil. What muff (2002) and McBride (2003) found that increasing concentrations of heavy metals in soil increased the crop uptake.

Cultivation areas near highways are also exposed to atmospheric pollution in the form of metal containing aerosols. These aerosols can be deposited on soil and are absorbed by vegetables, or alternatively deposited on leaves and fruits and then absorbed. Voutsas D A, Grimanis A & Samara C. (1996) have reported high accumulation of Pb, Cr and Cd in leafy vegetables due to atmospheric depositions. Field studies have found positive relationships between atmospheric metal deposition and elevated concentrations of heavy metals in plants and top soil (Larsen *et al.*, 1992; Sanchez-Camazano *et al.*, 1994). The levels of heavy metals in vegetables collected from peri-urban areas of New Delhi were found to be high due to atmospheric deposition as well as due to use of contaminated water. The magnitude of heavy metal deposition on vegetable surfaces varied with morpho-physiological nature of the vegetables (Singh and Kusmar, 2006). Jassir *et al.*, (2005) have shown that unwashed leafy vegetables sold on roadside of Riyadh city, Saudi Arabia had higher levels of heavy metals as compared to washed leafy

vegetables. Demirezen and Aksoy (2006) have reported higher concentrations of Pb, Cd and Cu in *Abelmoschus esculentus* collected from urban areas of Kayseri, Turkey as compared to those from rural areas. The partitioning of heavy metals is well known, with accumulation of greater concentrations in the edible portions of leafy or root crops than the storage organs or fruits (Jinadasa *et al.* , 1997 : Lehoczky *et al.* , 1998 : Sharma and Agrawal, 2006 .

2.2. Irrigation Water and Characteristics of Wastewater

The importance of vegetables in nutritious and healthy diets is well recognized, and in recent years consumers have been encouraged to eat more of these products. For many countries, particularly developing countries, these products have become a valuable commodity. At the same time, food safety problems linked to the consumption of fresh vegetables are increasing (WHO, 2012).

On the other hand, the use of wastewater poses some risks to human health and the environment. Because of these risks, the prevailing scientific approach to wastewater irrigation advocates treatment before use. But the reality is that many developing countries lacked to maintain treatment facilities and activities. Many farmers, therefore, consider wastewater a valuable resource; and wastewater irrigation becomes an individual or community activity (FAO. Eskinder Zinabu, Eyassu Yazew and Mitiku Haile, 2010).

As stated by FAO (2012) and WHO (2012), water contaminated with dangerous microorganisms and industrial wastes are the major source of human illness when consumed directly or used in food production and preparation. Improving water quality is a primary public intervention needed to improve human health. When supplies are limited, use of water for basic human needs take precedence over all others, including agriculture uses. In this regards, WHO recommended that, if water of poor or uncontrolled quality is used in the growing field, a Sanitation Safety Plan should be adopted to minimize risks to farm workers, local communities and vegetable crop contamination. As a result, WHO (2006) and others have specified requirements to promote the safe use of wastewater and excreta in agriculture, including a risk management approach that can be established at a level that is realistic under local conditions. However, the practice of using wastewater for irrigation of vegetables is still continued in urban and semi-urban areas of most counties, particularly in developing nations, resulting negative consequences. With regards to this

a recent study finding confirmed that 85% of wastewater generated from industries and urban centers worldwide ends up in the environment in its untreated form (Drechsel and Keraita, 2014). With increasing global population, the gap between the supply and demand for water is widening and is reaching such alarming levels that in some parts of the world it is posing a threat to human existence. Even, in developed countries where environmental standards are applied, much of the wastewater is treated prior to use for irrigation of vegetable and other crops and, to a limited extent, for other purposes (Hussein et al . , 2002; Singh, et al . , 2010; and Gupta et al . ,2011).

Industrial wastewater flows, closely follow the processing pattern of local industries, which depend on the processes involved, the number of shifts operated, and the water requirement of the industry. Variations from established patterns are minimal and occur during shift changes or stoppages. Flow variations may also occur due to processing of seasonal products. Therefore, seasonal fluctuations in the industrial wastewater discharges are more significant. In cities where, industrial wastewater constitutes a major component of the total wastewater flow in the area, fluctuations in industrial wastewater discharges are likely to be of significant importance in water cycle management (Hussein et al . , 2002; and Gosh et al . , 2012).

Though the actual composition of wastewater may differ from community to community, wastewaters usually contain the following broad groupings of constituents: Organic matter, Nutrients (Nitrogen, Phosphorus, and Potassium), Inorganic matter (dissolved minerals), Toxic chemicals, Pathogens, and Heavy metals (Sharma and Prasad, 2009).

2.3 Effect of Industrial Wastewater on Vegetables

Many researchers predicted that at high concentration of numerous effluents along with high osmotic pressure, result in decreased seed germination (Ramana *et al.* 2002; Nagada *et al* 2006). Study findings noticed that some crops had reduced germination percentage in the presence of industrial effluent. However, there was no hazardous effect in the presence of treated waste effluent (Ramana *et al.*, 2009). Wins and Murugan (2010) studied the effect industrial effluent on germination and growth of fruits and vegetables, and found that under lower concentration of effluent the germination and seedling growth was higher than the control but in higher concentration there is a gradual decrease in both germination and growth. Best germination

and seedling growth was observed in 25% concentration so they concluded that industrial effluents can be safely used for irrigation after proper treatment and dilution at 25%. Similarly, other study findings stated that, at 75-100% concentrated effluents from industries had harmful effects on germination of fruit and vegetable seeds while there was no consequence up to 50% concentration of the same effluent (Basher and Ali, 2013)

Regarding growth of vegetables irrigated by wastewater, many researchers documented that under different concentrations of industrial effluents; there is an improved seedling length of various crops (Akbar et al., 2007; and Diana, 2009). But it has been stated that high amounts of heavy metals in soils hinder plant growth, physiological, metabolic processes and nutrient uptake. Moreover, in higher plants, gymnosperms toxic metal comes into contact with roots. As a root tip is a site of injury, when it comes to contact with toxic metals results in inhibition of root growth, reduced yield due to less uptake of water and nutrients and a stunted root system (Yusuf, I., Ali, S., and Yasmin, A., 2010). Besides, Ramana *et al.* , (2009) conducted an experiment to check physico-chemical characteristics of the treated and un-treated industrial waste and their effects on three vegetables viz. turnip, radish and brassica. They reported that the untreated industrial wastewater when applied in the rooting medium decreased fresh and dry biomass of root and shoot of all three vegetables but on addition of treated industrial wastewater, there was slightly decreased shoot and root length; so they concluded that industrial wastewater can be used safely for irrigation to vegetables but after proper processing.

In general, Hussein *et al.* , ., (2002) reviewed selected literature on the potential impacts of wastewater use for irrigation/agriculture and identified major potential impacts, which includes: Public health, Vegetable and Crops, Soil resources, Groundwater resources, Property values, Ecological impacts, and Social impacts. Particularly, the use of untreated wastewater for irrigation, no doubt, poses a high risk to human health in all age groups. However, the degree of risk may vary among the various age groups.

2.4 Features and Effects of Major Chemicals and Heavy Metals

The chemical properties of both surface and groundwater include nutrients like Nitrate and phosphate. Nitrates are essential nutrients of green plants for growth and reproduction. The

naturally occurring nitrifying bacteria fix the free nitrogen from the atmosphere into nitrate and make it usable by photosynthetic plants. However, high concentration of Nitrates in the water bodies is responsible to cause many health problems (WHO, 2006).

Next to nitrates, phosphate is also another important nutrient for the growth of green plants. Phosphates are present in sewage, industrial wastes, storm runoff and in consumer products. Excessive loads of phosphate on the surface water speed up Eutrophication, which is a reduction in dissolved oxygen in the water bodies due to addition of minerals and organic nutrients (FAO, 2012). This is one of the problems at many river contaminated with industrial wastewater. As a result, human are exposed to toxic heavy metals either by the ingestion of contaminated food or by drinking water.

Heavy metals most often found in vegetables include As, Cd, Cu, Co, Mo, Zn, Mn and Pb. In vegetables, these heavy metals accumulate in edible parts (leaves and roots). When in trace quantities, some of these heavy metals are micronutrients. However, in elevated concentrations or after prolonged dietary intake, they can pose a significant health risk to humans, leading to various chronic diseases (Drechsel and Keraita, 2014). As a result, Scientists around the globe are working on new ways of conserving water. It is an opportune time, to refocus on one of the ways to recycle water-through the reuse of urban wastewater for irrigation and other purposes. This could release clean water for use in other sectors that need fresh water and provide water to sectors that can utilize wastewater; including for irrigation and other ecosystem services (Basher and Ali, 2013).

Mapanda *et al.*, (2005) on their part argued that, land polluted with heavy metals is becoming a matter of health, planning, economic and environmental concern in Pakistan now a day. Industrial processes produce wastewater that contains heavy metal contaminants. There is an increase in the heavy metal contents when soil irrigated with wastewater. If these effluents are continuously used for irrigation for long periods of time then it may result in toxic levels for plants and animal health. Heavy metals persist in soil which then leaches down into the groundwater and may induce enhanced antioxidant enzymatic activities in plants or become adsorbed with solid soil particles (Gosh *et al.* , 2012).

Bioaccumulation of metal contaminants in the food chain leads to disastrous effects on human health (Basher and Ali, 2013). It was observed that continuous intake of Cadmium (Cd) from food and water results in accumulation of Cd in the kidneys and causes many kidney diseases. Nickel (Ni) becomes hazardous if its concentration exceeds more than the recommended limit of 12 mg per person per day in food. Heavy metal accumulation in plants results in degradation of basal ganglia of liver and brain and mental retardation in human and animals (Singh *et al.* , 2010; Gupta *et al.* , 2011; and Gosh *et al.* .. , 2012)

Therefore, it is important to analyze and determine the metal contents of vegetables from health, and food nutrition perspective. Metal accumulation in edible portions of plants varies and depends on both soil composition and rate of uptake by each plant. For good health and optimum human performance, adequate intake of essential elements and nutrients is crucial.

2.5. Wastewater Management Agreed international Agendas and Policies

In the 1970s and 1980s the human health and environmental impacts of chemicals and waste led to the creation of a number of key international agreements. These, along with other related goal-based international agreements and declarations such as those emanating from the 2002 World Summit on Sustainable Development (WSSD) in Johannesburg, constitute a framework for organizing and implementing specific goals for the environmentally sound design, production, consumption and recycling or disposal of chemicals and hazardous waste (Berra, R., Portals, P, and Watkinson, R., 2012). These goals are also considered against the background of the Millennium Development Goals (MDGs), specifically MDG 1 for eradicating extreme poverty and hunger, and MDG 7 for ensuring environmental sustainability; including specific targets for ozone-depleting substances, as well as for improved access to safe drinking water and sanitation facilities.

The broad set of principles pivotal to the development of international agreements comprises prior informed consent for the Trans boundary movement of hazardous waste and certain hazardous chemicals; transparency through national reporting; the environmentally sound management of chemicals and waste; waste prevention; the precautionary approach; and the polluter pays principle. These are addressed through specific obligations such as the implementation of control measures, monitoring of the state of the environment, and compliance regimes with supportive

delivery mechanisms including capacity building and training, international cooperation, synergies and partnerships.

Goals relevant to the sound management of chemicals and waste aim to protect human health and the environment while improving resource efficiency. They can be grouped into six themes:

- Sound management of chemicals throughout their life cycle, including persistent organic pollutants and heavy metals, and of waste;
- Control of the trans boundary movement of hazardous wastes as well as responsible trade in hazardous chemicals;
- Transparent science-based risk assessment and risk management procedures, as well as monitoring systems at the national, regional and global levels;
- Support for countries to strengthen their capacity for the sound management of chemicals and waste;
- Protection and preservation of the marine environment from all sources of pollution;
- Safe radioactive and nuclear waste management.

As explained in WHO Guidelines Safe Use of Wastewater Greywater and Excreta, in May 16, 2012; WHO, together with FAO and UNEP, adopted a multiple-barrier approach to reducing health risks to farmers and consumers from using wastewater in agriculture. This opened the way to targeting a variety of entry points where health risks occur or can best be mitigated before the food is consumed (WHO, 2006; and FAO, 2012:18).

In Ethiopia, the management of water supply and sewage disposal is the responsibility of Regional State and City Administrations, particularly Water Supply and Sewerage Authority. Ministry of Water and Energy (MOWE), Ministry of Health (MOH) and Environmental Protection Authority (EPA) are also responsible for quality control and regulatory aspects of pollution protection of water bodies. In addition, Ministry of Agriculture (MOA) is responsible for provision of agricultural extension services free from contamination and pollution (Gebre and Van Rooijen, 2009).

As stated in Ethiopian Water Resources Management Policy, the area of irrigated agriculture cultivated so far is insignificant compared to the irrigable potential. Sufficient food has to be produced to meet the requirements of the fast growing population and ensure food security for eventualities at household level. Furthermore, small, medium and large scale irrigation schemes will have to be developed in order to enhance reliable agricultural development in Ethiopia to cater for externally marketable surplus that would earn the country foreign exchange and at the same time provide raw material inputs for industries (MOWR, 2004).

Ethiopian Water Resources Management Policy document also stated that, the overall objective of irrigation policy is to develop the huge irrigated agriculture potential for the production of food crops and raw materials needed for agro industries, on efficient and sustainable basis and without degrading the fertility of the production fields and water resources base. Particularly, as stated in specific policy issue number eight of the document, it emphasized to ensure the prevention and mitigation of degradation of irrigated water and maintain acceptable water quality standards for irrigation.

However, as investigated by Edwards (2010) the policy and other relevant guidelines for the safe use of wastewater are not implemented. Moreover, there is no published policy for urban agriculture and semi-urban agriculture extension and marketing approach to meet the demands of the urban community, both producers and consumers (Sisay, 2012).

2.6. Wastewater Treatment System at Wonji Sugar Factory

Wastewater from the factory is discharged through a main drain. The drained water is led through the fields to a pumping system. Two pumps are provided to lift the wastewater from the open channel to aeration ponds. Three aeration ponds are available for treatment of wastewater. Wastewater is filled in the aeration ponds one after the other. When one pond is being filled the first one will discharge water to irrigation while the second pond is being aerated. These aeration ponds are having natural aeration and no mechanical aeration equipment is provided. It had been observed that all the three ponds are covered with hydrated cover. From the above observation it can be concluded that practically no wastewater treatment is taking place in these ponds.

As short term measure the aeration ponds shall be cleaned by weeding out hyacinth and dredging operation is to be done in the ponds to make adequate depth in the pond for improving the water

holding capacity. Each pond shall be provided with minimum six to eight aerators for forced air intake to treat wastewater. This will help in reducing BOD and COD of effluent water. For long term, effluent treatment plant consisting of oil separator, neutralization tank, primary classification with aeration, clarification and dilution tank, shall be provided to bring down BOD value of wastewater 250 ppm to allow water to be used for irrigation purpose.

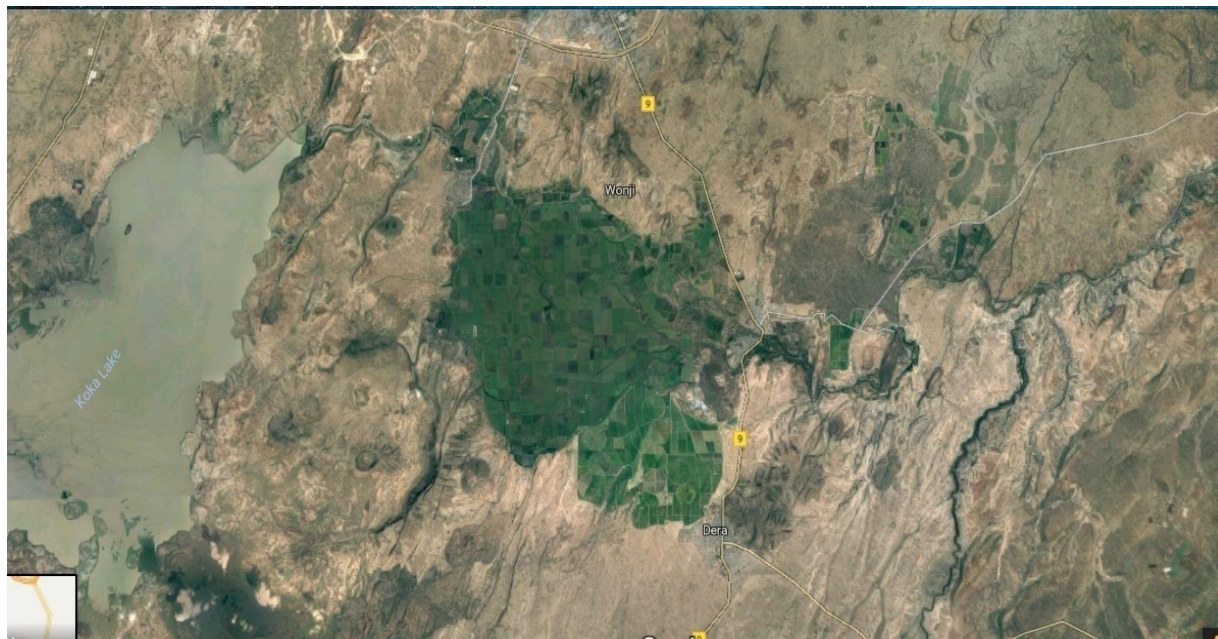
3. MATERIALS AND METHODS

3.1. Description of the Study Area

This study was conducted around Wonji sugar factory, where wastewater irrigated vegetable farms are available. Wonji is located in Adama District, East Showa Zone, Oromia Region, nearby Adama Town, which is 107km away from Addis Ababa and located at a latitude of 8° 26' 59" North and longitude of 39° 16' 48" East at an elevation of 1588m above sea level. Its annual temperature and rainfall are 23°C and 500-800mm, respectively.

Wonji is a sugar plantation area where there are several industries at the periphery of the town that predispose its surrounding waters to contamination with heavy metals. Awash river, which originates from west of Addis Ababa flows along the Great Rift Valley into Afar Region State, where it eventually terminates in a salty lake found at the border of Djibouti (Lake Abe). It is an important river in the study area for irrigating vegetables on hectares of land. In its course, Awash River crosses many industries such as Modjo Tannery, Wonji sugar factory, Paper mill, candy factory, and Melkasa Aluminum sulfate factory from west to east, and in these area the main source of water for irrigation in vegetables cultivation is Awash River. The study site comprised of three farms, two are located near the Awash Bridge and the other one at Awash Melkasa.

The irrigation in the study area is carried-out formally by some cooperatives and informally by smallholder farmers without conventional irrigation infrastructure. In most cases farmers take advantage of gravity by blocking waterways upstream and allowing a proportion of the water to flow through temporary channels into a larger system of furrows. The major vegetables irrigated in the area are lettuce, carrot, cabbage, potato, zikuni (cucumber), cauliflower, tomato and onion (Van and Taddesse, 2009).



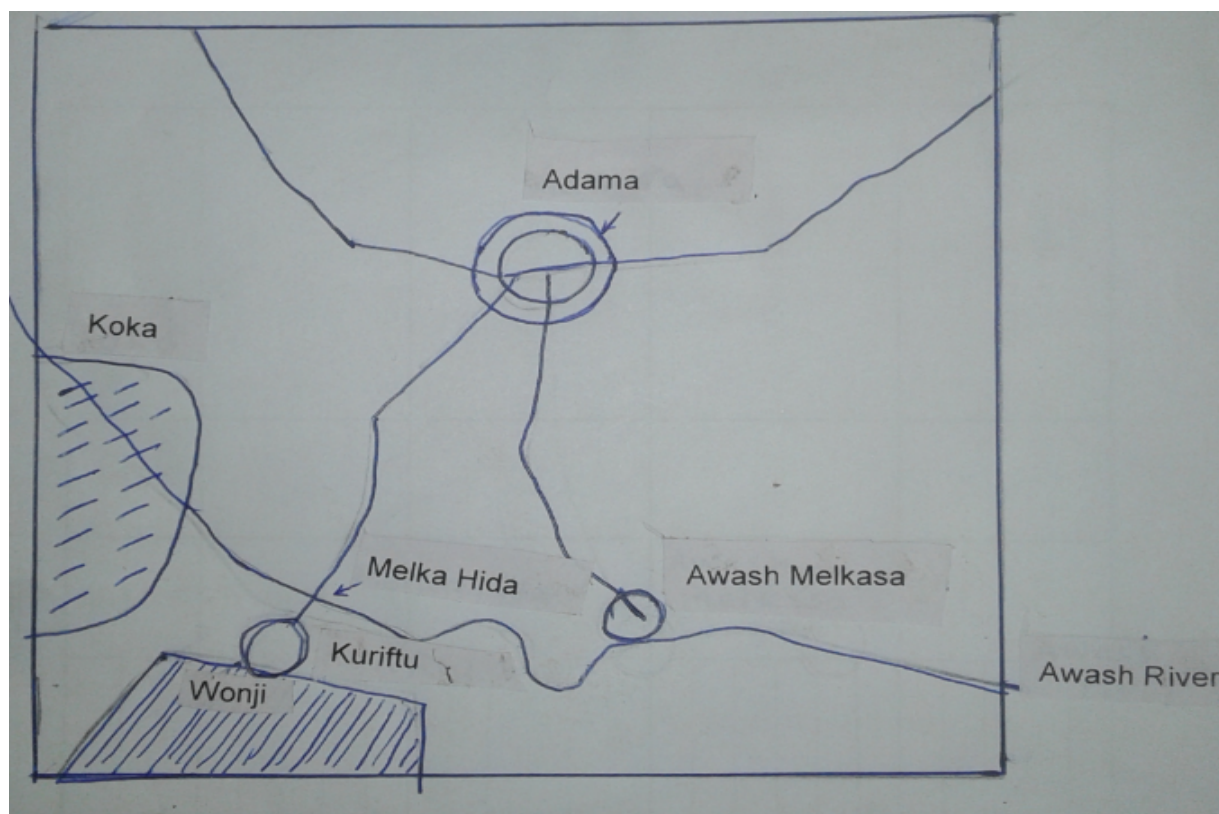


Figure 1. Map of the study area (source Google map)

3.2. Study Design

A laboratory based cross-sectional survey was conducted to assess the level of heavy metals concentration of industrial wastewater and waters used for vegetable irrigations around Wonji Sugar Factory, and the concentration of heavy metals on the edible part of vegetables irrigated with industrial wastewater in the study area. The design includes laboratory investigation which will be carried out by collecting water samples and vegetables from different sources at regularly interval (two-to-three weeks) during November 2016 and February 2017 from the study area. Finally, the results obtained from laboratory investigation were analyzed for comparison against maximum acceptable standards.

3.3. Sources of Data

The sources of data for this study were water samples and vegetables irrigated around the study area. For this, a thorough survey of the outskirts of Wonji area was made and reasonable number of sites, where wastewater was used for irrigation of vegetables was identified for the collection

of water sample and vegetables. The water samples were obtained from two sources: industrial wastewater discharged from factories and water sources used for vegetable irrigation in the study area.

3.4. Water Sample Collection

Water samples were taken from three industrial waste water points while irrigation water was sampled from three locations where irrigation was taking place. At each sampling points and time, one liter of water sample was taken by grab method into a plastic bottle rinsed with the same water prior to sampling. During the collection of water samples about 5ml of HNO₃ was added to the bottles to acidify the water sample so as to be preserved. All the samples were transported in ice box to the laboratory and then stored in refrigerator at less than 4°C until analysis (Goel, 2009).

3.5. Vegetable Sample Collection

A total of 9 recently matured vegetable samples (comprising three types of fresh vegetables: tomatoes, cabbage, onions) were collected from three vegetable farms using a random sampling technique. In order to make the analysis of the sample vegetables comparable, only the edible portion of all those vegetables were considered while selecting and collecting them as a sample.

All the samples were collected aseptically in a sterilized universal container and plastic bags and transported to Regional Laboratory found nearby Adama Science and Technology University for laboratory processing. The samples were cooled during transportation using a cooler box to keep the normal conditions of the micro-flora of vegetables. The analysis was carried out immediately within 24 hours after the samples arrival at the laboratory following Water Quality Monitoring Practical Guide of United Nations Environment Program and the World Health Organization (UNEP/WHO, 1996).

3.6 Analyses of Water Samples

The collected water samples were analyzed for major heavy metals (Cadmium, Lead, Chromium, Mercury, and Zinc) following the Standard methods for the examination of water and wastewater of American Public Health Association (APHA, 2005). Finally, for maximum limit of chemicals in

irrigation water the guide developed by FAO (1985) was used for comparison of laboratory results of the water samples.

3.7 Analysis of Vegetable Samples

In order to detect the concentration of heavy metals in vegetables, the samples were analyzed using wet digestion method as described in the Hand Book number 60 of USDA (USDA, 1954). For this, vegetable samples first cleaned with de-ionized water repeatedly, later dried in an oven at 65⁰C for two days, and ground using a Cross-beater Grinding mill. The samples were then processed and analyzed at laboratory level. The concentrations of heavy metals were determined with Inductively Coupled Plasma-Optical Emission Spectrometer and mass Spectrometer with external calibration (Fisseha, 2009). A comparison of the data with the criterion laid by Pendias and Pendias (1992) for the approximate concentrations of heavy metals in mature vegetable tissue were used during the analysis of laboratory results of vegetable samples (Perveen, S., Samad, A., Nazify, W. and Shah, S., 2012).

3.8. Data Analysis

The data collected for this study were organized and processed using computer programs; Microsoft Excel version 2007 and Statistical Package for the Social Sciences (SPSS V20) Software. Analysis of variance (one-way ANOVA) was used to compare between means and P-values <0.05 were considered as statistically significant.

4. RESULTS AND DISCUSSIONS

4.1. Heavy metal concentration in vegetables sampled from different irrigation sites

Comparison was made between the different vegetables sampled from each sampling site; i.e., Kuriftu, MelkaHidha and Awash Melkassa in terms of the concentrations of the different heavy metals analyzed. Results showed that the concentrations of cadmium, lead, mercury and zinc showed significant ($p < 0.05$) difference between vegetables sampled from Kuriftu irrigation site (Table 1). Values show that cadmium and zinc concentrations were higher in tomato fruit and cabbage than in onion. Whereas the concentration of mercury was higher in tomato than in cabbage and onion. Chromium concentration on the other hand showed no significant difference between the three vegetables. The fact that different vegetables showed variation in concentration of a given heavy metal may show that different vegetables have different capacity to accumulate a given heavy metal. For example, Deribachew et al. (2015) reported that some heavy metals such as Cd are more accumulated in aerial parts of leafy vegetables than in the root and bulbs. Comparison between the permissible heavy metal concentration in vegetables with the observed concentrations showed that concentration of Cd and Pb were beyond the permissible level for consumption (FAO / WHO, 2010).

Table 1. Heavy metal concentration (mg/kg) determined from different vegetables sampled from Kuriftu site (values are mean \pm SE, n=3)

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Heavy metal Type	Heavy metal concentration			Permissible concentration (FAO/ WHO, 2010)
	Tomato	Cabbage	Onion	
Cr	0.65 \pm 0.11 ^a	0.97 \pm 0.01 ^a	0.95 \pm 0.48 ^a	0.57
Cd	0.97 \pm 0.01 ^a	1.62 \pm 0.34 ^a	0.51 \pm 0.01 ^b	0.10
Pb	0.34 \pm 0.01 ^b	0.30 \pm 0.06 ^b	0.50 \pm 0.01 ^a	0.30
Hg	0.22 \pm 0.10 ^a	0.02 \pm 0.01 ^b	0.03 \pm 0.01 ^b	0.34
Zn	12.41 \pm 0.04 ^a	12.13 \pm 0.01 ^a	10.28 \pm 0.04 ^b	12.31

, whereas Note: Values with the same letter superscript in a row represents no significant difference those with different letter superscripts are significantly different.

The concentration of cadmium, lead and mercury each showed significant ($p < 0.05$) difference between vegetables sampled from Melka Hidha irrigation site (Table 2). Values show that cadmium was significantly higher in cabbage and onion than in tomato, which appeared to be opposite to value measured in Kuriftu where its concentration was higher in tomato than in onion.

The concentration of lead was lower in cabbage than in tomato and onion as it was observed in samples from Kuriftu. On the other hand, the concentration of chromium showed no significant difference between vegetables as it was observed in samples from Kuriftu site, suggesting that chromium can equally be sequestered by the fruit of tomato, leaves of cabbage and bulbs of onion. Moreover, concentration of zinc showed no significant difference between vegetables from MelkaHidha site (Table 2). The concentration of mercury was higher in tomato than in cabbage and onion and showed similar pattern to samples from Kuriftu. Comparison between the permissible heavy metal concentrations in vegetables with the observed concentrations showed that concentration of Cd was beyond the permissible level in all of the vegetables tested for consumption (FAO/WHO, 2010). Similarly, concentration of Pb was beyond the safe limit in tomato and onion, but safe in cabbage.

Table 2. Heavy metal concentration (mg/kg) determined from different vegetables sampled from Melkahida site (values are mean±SE, n=3)

Heavy metal Type	Heavy metal concentration			Permissible concentration(FAO / W HO, 2010)
	Tomato	Cabbage	Onion	
Cr	0.51±0.01 a	0.60±0.30 a	0.88±0.19 a	0.57
Cd	0.51±0.01 ^b	0.91±0.01 a	0.89±0.04 a	0.10
Pb	0.30±0.05 a	0.18±0.01 ^b	0.35±0.03 ^a	0.30
Hg	0.25±0.10 a	0.02±0.01 ^c	0.14±0.01 ^b	0.34
Zn	8.00±0.58 a	8.83±0.33 a	8.82±0.08 a	12.31

Note: Values with the same letter superscript in a row represents no significant difference, whereas those with different letter superscripts are significantly different

In each farming site concentrations of the heavy metals varied between vegetable types. In Kuriftu samples, value of Chromium (Cr) in descending order was that concentration in cabbage >

onion > tomato, Cadmium concentration in cabbage > tomato > onion, Lead (Pb) concentration in onion > tomato > cabbage, Mercury in tomato > onion > cabbage and Zinc concentration in onion > tomato > cabbage, mercury in tomato > onion > cabbage and Zn concentration in tomato > cabbage > onion. In Melkahida samples, concentration of Chromium (Cr) in onion > cabbage > tomato. Cadmium (Cd) concentration in Cabbage > onion > tomato, Lead concentration in onion > tomato > cabbage, mercury (Hg) in tomato > onion > cabbage and Zinc (Zn) concentration in cabbage > onion > tomato in Awash melkasa samples concentration of Chromium (Cr) in onion > cabbage > tomato Cadmium (Cd) concentration onion > cabbage > tomato Lead (Pb) cabbage > onion > tomato

Mercury (Cr) concentration in tomato > onion > cabbage and Zinc (Zn) in cabbage > tomato > onion.

The concentration of Cadmium, Lead and mercury each showed significant ($p < 0.05$) difference between vegetable sampled from Awashmelkassa irrigation site (table 3). value showed that cadmium was significantly higher in cabbage and onion than in tomato which appeared to be opposite to value measured in Kuriftu where its concentration was higher in tomato than in onion. The concentration of lead was lower in cabbage than in tomato and onion as it was observed in samples from Kuriftu. On the other hand, the concentration of chromium showed no significant difference between vegetables as it was observed in samples from Kuriftus site, suggesting that chromium can equally be sequestered by the fruit of tomato, leaves of cabbage and bulbs of onion. Moreover, concentration of zinc showed no significant difference between vegetables from Melkahida site (Table 2) the concentration of mercury was higher in tomato than in cabbage and onion and showed similar pattern to samples from Kuriftu. Comparison between the permissible heavy metal concentrations in vegetables with the observed concentrations showed that concentration of cadmium were beyond the permissible level for consumption.

Table 3. Heavy metal concentration (mg/kg) determined from different vegetables sampled from Awash Melkassa site (values are mean \pm SE, n=3)

Heavy metal Type	Heavy metal concentration			Permissible concentration(FAO/WHO, 2010)
	Tomato	Cabbage	Onion	
<hr/>				

Cr	0.27±0.09 ^a	0.80±0.41 ^a	0.86±0.02 ^a	0.57
Cd	0.26±0.09 ^b	0.78±0.07 ^a	0.86±0.02 ^a	0.10
Pb	0.14±0.04 ^b	0.24±0.01 ^a	0.16±0.01 ^b	0.30
Hg	0.25±0.22 ^a	0.02±0.00 ^a	0.03±0.00 ^a	0.34
Zn	7.94±0.55 ^b	9.34±0.01 ^a	6.10±0.01 ^c	12.31

Note: Values with the same letter superscript in a row represents no significant difference, whereas those with different letter superscripts are significantly different

4.2. Heavy metal concentrations (mg/kg) of the vegetables sampled from the three irrigation sites

4.2.1. Heavy metal concentration (mg/kg) in tomato

Except that of mercury, there were significant differences ($P < 0.05$) between Kuriftu, Melkahidha and Awash Melkassa tomato samples in the concentrations of chromium, cadmium, lead and zinc (Table 4). Chromium and Lead concentrations were significantly lower in AwshMelkassa tomato samples than in Kuriftu and Melkahidha. Cadmium and zinc concentrations were higher in Kuriftu tomato samples than in Melkahidha and Awash Melkassa. Lead concentration of tomato samples were significantly higher in Kuriftu and Melkahidha tomato samples, respectively. The variations observed between the three sampling sites in terms of the concentration of each heavy metal in tomato vegetable samples may be attributed to the quality of irrigation water imparted by the geology of the soil along which the discharged waste water is flowing. According to FAO/WHO (2010) cadmium was above the safe limit to occur in the edible portion of tomato sampled from all farming sites. Tomato sampled from Awashmelkasa at an acceptable level, lead was above the limit in tomato sampled in Kuriftu while at a threshold level in Melkahida.

Table 4. Comparison between the different heavy metal concentrations (mg/kg) of tomato sampled from different cultivation sites (values are mean±SE, n=3)

Heavy metal Type	Sampling sites			Permissible concentration (FAO/W HO, 2010)
	Kuriftu	Melkahida	Awash Melkassa	
Cr	0.65±0.11 ^a	0.51±0.01 ^a	0.27±0.09 ^b	0.57
Cd	0.97±0.01 ^a	0.51±0.01 ^b	0.26±0.09 ^c	0.10
Pb	0.34±0.01 ^a	0.30±0.05 ^a	0.14±0.04 ^b	0.30
Hg	0.22±0.10 ^a	0.25±0.10 ^a	0.25±0.22 ^a	0.34
Zn	12.41±0.04 ^a	8.00±0.58 ^b	7.94±0.55 ^b	12.31

Note: Values with the same letter superscript in a row represents no significant difference, whereas those with different letter superscripts are significantly different.

4.2.2. Heavy metal concentration (mg/kg) in cabbage

Except that of chromium and mercury, there were significant differences ($P < 0.05$) between Kuriftu, Melkahida and Awash Melkassa cabbage samples in the concentrations of cadmium, lead and zinc (Table 5). Lead and zinc concentrations were significantly higher in Kuriftu and Melkahida cabbage samples than in Awash Melkassa samples. On the other hand, cadmium concentration was lower in Awash Melkassa cabbage samples than in Kuriftu and Melkahida. The variations observed between the three sampling sites in terms of the concentration of each heavy metal in tomato fruit samples may be attributed to the quality of irrigation water imparted by the geology of the soil along which the discharged waste water is flowing. Cadmium was above the safe limit to occur in the edible portion of cabbage sampled from all farming sites (FAO/WHO, 2010). However, Pb was at an acceptable level to the contrary.

Table 5 .Comparison between the different heavy metal concentrations (mg/kg) of cabbage sampled from different cultivation sites (values are mean±SE, n=3)

Heavy metal Type	Sampling sites			Permissible concentration
	Kuriftu	Melkahida	Awashmelkasa	
Cr	0.97±0.01 ^a	0.60±0.30 ^a	0.80±0.41 ^a	0.57
Cd	1.62±0.34 ^a	0.91±0.01 ^a	0.78±0.07 ^b	0.10
Pb	0.30±0.06 ^a	0.18±0.01 ^b	0.24±0.01 ^b	0.30
Hg	0.02±0.01 ^a	0.02±0.01 ^a	0.02±0.00 ^a	0.34
Zn	12.13±0.01 ^a	8.83±0.33 ^b	9.34±0.01 ^b	12.31

Note: Values with the same letter superscript in a row represents no significant difference, whereas those with different letter superscripts are significantly different

4.2.3. Heavy metal concentration (mg/kg) in onion

Except that of mercury and chromium, there were significant differences ($P < 0.05$) between Kuriftu, Melkahida and Awash Melkassa onion samples in the concentrations of cadmium, lead and zinc (Table 6). Lead and zinc concentrations were significantly lower in Melkahida onion samples than in Kuriftu and Awashmelkasa. On the other hand, cadmium concentration was higher in Kuriftu onion samples than in Melkahida and Awash Melkassa. The variations observed between the three sampling sites in terms of the concentration of each heavy metal in tomato fruit samples may be attributed to the quality of irrigation water imparted by the geology of the soil along which the discharged waste water is flowing. According to FAO/WHO (2010) cadmium was above the safe limit to occur in the edible portion of onion sampled from all farming sites. Though at an acceptable level in onion sampled from Awash Melkassa, lead was above the limit in onion sampled from Kuriftu .

Table 6. Comparison between the different heavy metal concentrations (mg/kg) of onion sampled from different cultivation sites (values are mean±SE, n=3)

Heavy metal Type	Sampling sites			Permissible concentration (FAO/WHO,2010)
	Kuriftu	Melkahida	Awash Melkassa	
Cr	0.95±0.48 ^a	0.88±0.19 ^a	0.86±0.02 ^a	0.57
Cd	0.51±0.01 ^b	0.89±0.04 ^a	0.86±0.02 ^a	0.10
Pb	0.50±0.01 ^a	0.35±0.03 ^b	0.16±0.01 ^c	0.30
Hg	0.03±0.01 ^a	0.14±0.01 ^a	0.03±0.00 ^a	0.34
Zn	10.28±0.04 ^a	8.82±0.08 ^b	6.10±0.01 ^c	12.31

Note: Values with the same letter superscript in a row represents no significant difference, whereas those with different letter superscripts are significantly different Concentrations of heavy metal in each vegetable showed significant difference between the three farming sites.

4.3. Heavy metal concentrations in irrigation water

Except that of cadmium, there were significant differences ($P < 0.05$) between factory discharge point, Kuriftu, Melkahida and Awash Melkassa irrigation water samples in the concentrations of chromium, lead, mercury and zinc (Table 7). Chromium was higher in water sample from factory discharging point compared to all other sampling points, whereas the concentrations of other heavy metals showed increment or decrement at a given sampling point. This irregularity may be due to trapping of a given heavy metal more than the others by soils. Comparison between the permissible heavy metal concentrations in irrigation water with the observed concentrations showed that concentrations of Cr., Cd, Pb. were beyond the safe limits for use in irrigation (FAO, 2007). Therefore, pretreatment should be done before use for irrigation.

Table 7. Concentration (mg/L) of the different heavy metals in wastewater sampled from different points (values are mean±SEM, n=3)

Heavy metal Type	Sampling sites				Permissible concentration (FAO, 2007)
	Factory discharge point	Kuriftu irrigation site	MelkaHidha irrigation site	Awash Melkassa irrigation site	
Cr	1.97±0.04 ^b	5.00±0.58 ^a	4.02±0.57 ^a	4.01±0.58 ^a	0.10
Cd	0.14±0.00 ^a	0.11±0.00 ^a	0.12±0.01 ^a	0.10±0.00 ^a	0.01
Pb	2.04±0.01 ^b	1.00±0.15 ^c	4.0±2.48 ^a	1.04±0.01 ^c	0.34
Hg	0.51±0.06 ^a	0.22±0.05 ^b	0.24±0.11 ^b	0.52±0.02 ^a	0.94
Zn	5.02±0.01 ^a	0.10±0.00 ^b	5.13±0.41 ^a	4.01±0.58 ^a	5.00

Note: Values with the same letter superscript in a row represents no significant difference, whereas those with different letter superscripts are significantly different

5. SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1. Summary and Conclusions

5.1.1. Summary

In parts of Ethiopia, vegetables are being cultivated using waste water rich in toxic heavy metals discharged from industries for irrigation. The Study was conducted with the objective of assessing selected heavy metals (Cr., Cd, Zn, Hg and Pb) accumulation in the edible portions of cabbage, tomato and onion cultivated around Wonji in eastern part of Ethiopia. The concentration of the same heavy metals were also determined in water samples collected directly from industry discharge and also three irrigation sites. Samples were first optimized through wet digestion procedure and contents of heavy metals were analyzed using atomic absorption spectrometry (AAS). Results showed that each heavy metal concentration varied between vegetable types

sampled from each irrigation site. In Kuriftu site, cadmium and zinc concentrations were higher in tomato fruit and cabbage than in onion, whereas the concentration of mercury was higher in tomato than in cabbage and onion. In Melkahida irrigation site, cadmium was significantly higher in cabbage and onion than in tomato, whereas the concentration of lead was lower in cabbage than in tomato and onion.

Comparison of heavy metals between Kuriftu, Melkahida and Awash Melkassa irrigation sites on tomato showed that chromium and lead concentrations were significantly higher lower in Awash Melkassa tomato samples than in Kuriftu and Melkahida. Cadmium and zinc concentrations were higher in Kuriftu tomato samples than in Melkahida and Awash Melkassa. Lead concentrations of tomato samples were significantly higher in Kuriftu and Melkahida tomato samples, respectively. Comparison of heavy metals between irrigation sites on cabbage showed that Lead and zinc concentrations were significantly higher in Kuriftu and Melkahidacabbage samples than in Awash Melkassa samples. On the other hand, cadmium concentration was lower in Awash Melkassa cabbage samples than in Kuriftu and Melkahidha. In onion samples, Lead and zinc concentrations were significantly lower in Awash Melkassa onion samples than in Kuriftu and Melkahida. On the other hand, cadmium concentration was lower in Kuriftu onion samples than in Melkahidha and Awash Melkassa.

5.1.2. Conclusion

Industrial effluents and urban pollution associated with sewage sludge and municipal waste water might have increased the levels of Cadmium (Cd), Chromium (Cr) and Lead (Pb) intake of the vegetables and soils

Generally, the results of the present study showed that the degree of accumulation of heavy metals varies with vegetable type. Moreover, concentration of each tested heavy metal showed difference between farming sites. Analysis of waters used for irrigation also varied between sampling points. Overall, comparison of the concentrations of the tested heavy metals in vegetables and irrigation waters are beyond the safe limit suggested by international standards.

5.2. Recommendations

Based on the findings, the following suggestions are forwarded

- Irrigation waters of this study area should first be checked for the concentration limit of heavy metals before use for irrigation and pretreated accordingly.
- Factories should practice safe discharge of effluents to environment
- Surrounding industries should establish wastewater treatment plant to prevent any kind of waste disposal in to rivers, canals on any reservoirs.
- Analysis on other heavy metals should also be checked in these irrigation so as to know that their concentrations are in.

The study indicates that to create awareness among consumers to reduce such Contamination by not using wastewater and cultivating in a field far away from Highway and industrial area.

6. REFERENCES

Agrawal, M., 2003. Enhancing Food Chain Integrity: Quality Assurance Mechanism for Air Pollution Impacts on Food and Vegetable System. Final Technical Report (R7530) Submitted to Department for International Development, United Kingdom.

- Akbar, F., Hadi, Z.Ullah, and Z., Zia M., 2007. Effect of marble industry effluent on seed germination, post terminative growth and productivity of Zea Mays L. *Pak. Journal Biological Science*, 2007: 10(4): 4148-4151.
- Allen SE, Grimshaw HM and AP Rowland chemical analysis In methods plant Ecology edited by P . D.Moore and S. B CHAPsMAN (Black well scientific publication, Oxford, London 91986) 285_344.
- APHA (American Public Health Association). 2005. *Standard methods for the examination of water and wastewater* (21st Ed). American Public Health Association, American Water Works Association and Water Environment Federation) Washington DC, USA
- ATSDR (US Agency for Toxic Substances and Disease Registry). 2013. *Minimal risk* Accessed from: <http://www.atsdr.cdc.gov/mrls/mrllist.asp> on 15 Oct 2015.
- Awashthi, .K. Awashthi Prevention of Food Adulteration Act No. 37 of 1954. Central and State Rules as Amended for 1999 (third ed.) Ashoka Law House, New Delhi (2000)
- Ayers, R. and Westcott, D. 1985. Water Quality for Agriculture. *FAO. Irrigation and Drainage Paper*, 29 (1):1-120
- Berra, R., Portals, P, and Watkinson, R. 2012. Chemicals and Waste, Part 1: State and Trends. *GEO-5 Report C6*: 167-192.
- Basher, I. and Ali, S. 2013. Effects of irrigation with wastewater from different industries on vegetables grown in vicinity of Faisalabad, Pakistan. *International Research Journal*, 4(6): 144-148.
- Codex Alimentations Commission, 1984 Codex Alimentations Commission Contaminants, Joint FAO/WHO Food Standards Program vol. XVII (first Ed.) Codex Alimentations (1984)
- Cui et al., 2004 Transfer of metals from soil to vegetables in an area near a smelter in Nanning, China *Environment International*, 30 (2004), pp. 785–79
- Demirezen and Aksoy, 2006 Heavy metal levels in vegetables in Turkey are within safe limits for Cu, Zn, Ni and exceeded for Cd and Pb *Journal of Food Quality*, 29 (2006), pp. 252–265
- Deribachew B., Amde M., Dechassa N. and Taddesse AM. (2015). Selected Heavy Metals in Some Vegetables Produced through Wastewater Irrigation and Their Toxicological implications In Eastern Ethiopia. *AJIFAND* 15:10013-10032

- Dhanam, S. 2009. Effect of dairy effluent on seed germination, seedling growth and biochemical parameters in Paddy. *Bot. Res. Int.*, 2(1): 61-63.
- Drechsel, P. and Keraita, B. 2014. Irrigated urban vegetable production in Ghana: characteristics, benefits and risk mitigation, (2nd Ed) International Water Management Institute (IWMI) Colombo, SriLanka
- Edessa Elisa. 2014. Irrigation and Nutrient Management Practices in Vegetable Crops Production and Response of Tomato to Integrated Nutrients Supply and Irrigation Regimes under Different Growing Conditions in the Central Rift Valley of Ethiopia.
- EPA (Environmental Protection Authority) 2005. Assessment Report on the Status of Little Akaki Rivers Waters Pollution. EPA, Addis Ababa, Ethiopia.
- FAO. 2012. On-farm practices for the safe use of wastewater in urban and peri-urban horticulture: A training handbook for farmer field schools. International Water Management Institute, Rome, Italy.
- FAO. Eskinder Zinabu, Eyassu Yazew and Mitiku Haile. 2010. Assessment of the Impact of Industrial Effluents on the Quality of Irrigation Water and Changes on Soil Characteristics: A Case of Kombolcha Town. *Fourteenth International Water Technology Conference, IWTC 14, Cairo, Egypt, 1985.*
- FAO/WHO. 2001. Food additives and contaminants, Joint FAO/WHO. Food Standards Program; Codex Alimentations Commission, ALINORM 01/12A:1-289, Geneva, Switzerland,
- Freezer Eshetu. 2012. *Physico-Chemical Pollution Pattern in Akaki River Basin, Addis Ababa, Ethiopia.* Master's thesis, Department of Physical and Quaternary Geology, Stockholm University, Stockholm, Sweden.
- Fisseha Itanna. 2009. Metal in Leafy Vegetables grown in Addis Ababa and Toxicological Implications. *Ethiopian I. Health Dev.*, 3(2): 295-302
- Gebre, G. and Van Rooijen, D. 2009. Urban water pollution and irrigated vegetable farming in Addis Ababa. *WEDC. International Conference Refereed Paper 166.* Addis Ababa, Ethiopia.
- Gosh, A., Bhatt, M. and Agrawal, H. 2012. Effect of long-term application of treated sewage water on heavy metal accumulation in vegetables grown in northern India. *Environ. Monist. Assess* 184(2): 1025-1036.

- Huber's, et al, 2004. *The use of waste water in Cochabamba, Bolivia: a degrading Environment*. IDRC Books Free online. <http://www.idrc.ca>.
- Huibers, F. P., Moscoso, O., Durân, A. & Van Lier, J. B. 2004 the use of wastewater in Cochabamba, Bolivia: a degrading environment. In: *Wastewater Use in Irrigated Agriculture* (ed. by C. Scott, N. I. Faruqui & I. Rashid). CAB International, Wallingford, UK.
- Hussain I., Raschid L., Hanjra A., Marikar F. and Hoek W., 2002. *Wastewater Use in Agriculture: Review of Impacts and Methodological Issues in Valuing Impacts*. Working Paper 37 International Water Management Institute, Colombo, Sri Lanka.
- Khan, M. J.; Drochner, W.; Steingass, H.; Islam, K. M. S., 2008. Nutritive evaluation of some tree leaves from Bangladesh for feeding ruminant animals. *Indian J. Anim. Sci.*, 78 (11): 1273-1277
- Jassir Al, Shaker A, Khaliq MA, 2005 Deposition of heavy metals on green leafy vegetables sold on roadsides of Riyadh city, Saudi Arabia *Bulletin of Environmental Contamination and Toxicology*, 75 (2005), pp. 1020–1027
- Jinadasa K.B., Milham P.J., Hawkins C.A., Cornish P.S., Williams P.A., Kaldor C.J. and Conroy J.P., 1997 Survey of Cd levels in vegetables and soils of greater Sydney, Australia *Journal of Environmental Quality*, 26 (1997), pp. 924–933
- Lake D L, Kirk P W W & Lester J N 1984. Fractionation, characterization, and speciation of Heavy metals in sewage and sludge amended soil: A review. *Journal of Environmental Quality* 13: 175-183
- Larsen E.H., Moseholm L. & Nielsen M.M., 1992. Atmospheric deposition of trace elements around point sources and human health risk assessment. II: uptake of arsenic and chromium by vegetables grown near a wood preservation factory *Science of the Total Environment*, 126 (1992), pp. 263–275
- Lehoczky E, Szabo L, Horvath S, Marth P, Szabados I, 1998. Cadmium uptake by lettuce in different soils. *Communications in Soil Science and Plant Analysis*, 29: 1903–1912.
- Lemma Desalegn. 2002. *Major Vegetable Crop Varieties and their Production Practices*. Vegetable IPM Project (EARO/ICIPE) EARO, Addis Ababa, Ethiopia.

- Manivasakam, N. 1996. *Physical Chemical examination of water, sewage and industrial effluents* (3rd Ed). Pragmatic Prakashan, Meeret, India.
- Mapanda F., Mangwayana, E. N., Nyamangara J. & Giller K. E. (2005). The effect of long-term irrigation using wastewater on heavy metal contents of soils under vegetables in Harare, Zimbabwe. *Agric. Ecosyst. Environ.* 107(2005):151-165
- McBride, 2003 Toxic metals in sewage sludge-amended soils: has proportion of beneficial use discounted the risks? *Advances in Environment Research*, 8 (2003): 5–19
- MOWR (Ministry of Water Resources). 2004. *Ethiopian Water Resources Management Policy*. MOWR, Addis Ababa, Ethiopia
- Nagada GK, Diwan AM, and Ghole V.S. 2006. Seed germination bioassays to assess toxicity of molasses fermentation based bulk drug industry effluent. *Eur. J. Environ. Agri. Food Chemistry*, 5(4): 1598-1603.
- Pendias, A. and Pendias, H. 1992. *Elements of Group VIII. In: Trace Elements in Soils and Plants*. CRC Press, Boca Raton
- Perveen, S., Samad, A., Nazify, W. and Shah, S. 2012. Impact of Sewage Water on Vegetables Quality With Respect to Heavy Metals in Peshawar Pakistan. *Journal Botany*, 44(6): 1923-1931
- Qadir, M., et al., 2008. *The challenges of wastewater irrigation in developing countries*. *Agric. Water Manag.* <http://www.sciencedirect.com>.
- Ramana S., Biswas A.K., Kundu S., Saha J.K., Yadava R.B.R. (2002): Effect of distillery effluent on seed germination in some vegetable crops. In: *Bioresource Technology*. 82: 273-275.
- Redman, A., Bhatti, H., and Athar H. 2009. Textile Effluents Affected Seed Germination and Early Growth of Some Winter Vegetable Crops: A Case Study. *Water, Air and Soil Pollution*, 19(8): 155-163
- Sachan, S., S.K. Singh and P.C. Srivastava. 2007. Buildup of heavy metals in soil-water-plant continuum as influenced by irrigation with contaminated effluent. *J. Environ. Sci. Eng.*, 49(4): 293-296.

- Sanchez-Camazano M. Sanchez-Martin M.J. & Lorenzo L.F., 1994. M. Sanchez Camazano, M.J. Sanchez Martin, L.F. Lorenz Lead and cadmium in soils and vegetables from urban gardens of Salamanca (Spain) *Science of the Total Environment*, 163–168
- Scott D, Keoghan J M & Allen B E 1996. Native and low input grasses-a New Zealand high country perspective. *New Zealand Journal of Agricultural Research* 39: 499-512
- Sharma and Agrawal, 2006 Effects of single and combined treatment of Cd and Zn on carrots: uptake and bioaccumulation *Journal of Plant Nutrition*, 29 (10): 1791–1804
- Sharma, R.K., Agrawal, M., Marshall, F.M., 2006. Heavy metals contamination in vegetables grown in wastewater irrigated areas of Varanasi, India. *Bull. Environ. Contamination and Toxicology* 77, 311–318
- Sharma, R.K., Agrawal, M., Marshall, F.M., 2007. Heavy metals contamination of soil and vegetables in suburban areas of Varanasi, India. *Ecotoxicology. Environmental Safety* 66, 258–266
- Sharma, S. and Prasad, F. 2009. Accumulation of lead and cadmium in soil and vegetable crops along major highways in Agra (India). *E-Journal Chem.*, 7(4): 1174-1183.
- Singh, S., Nag, S. K., Kundu, S. S., Maity, S. B., 2010. Relative intake, eating pattern, nutrient digestibility, nitrogen metabolism, and fermentation pattern and growth performance of lambs fed organically and inorganically produced cowpea hay-barley grain diets. *Trop. Grassl.*, 44: 55-61
- Singh and Agrawal. 2005. Atmospheric depositions around a heavily industrialized area in a seasonally dry tropical environment of India *Environmental Pollution*, 138: 142–152
- Singh and Kumar, 2006. Heavy metal load of soil, water and vegetables in peri-urban Delhi *Environmental Monitoring and Assessment*, 120:79–91
- Singh, K.P., Mohon, D., Sinha, S., Dalwani, R., 2004. Impact assessment of treated/ untreated wastewater toxicants discharged by sewage treatment plants on health, agricultural, and environmental quality in wastewater disposal area. *Chemosphere* 55, 227–255

- Sinha S., Pandey K., Gupta AK., Bhatt K., 2005 Accumulation of metals in vegetables and crops grown in the area irrigated with river water. *Bulletin of Environmental Contamination and Toxicology*, 74 (2005):210–218.
- Sisay Teklu. 2012. *Wastewater production, treatment and agricultural use in Ethiopia: The case of Addis Ababa city*. Ministry of Water and Energy, Addis Ababa, Ethiopia
- Turkdogan MK, Kilicel F, Kara K, Tuncer I, Uygan I 2002. Heavy metals in soil, vegetables and fruits in the endemic upper gastrointestinal cancer region of Turkey. *Environ Toxicol Pharmacol* 13:175–179. Doi: 10.1016/S1382- 6689(02)00156-4.
- Ullah, H., I. Khan and I. Ullah. 2011. *Impact of sewage contaminated water on soil, vegetables and underground water of peri-urban Peshawar, Pakistan*. *Environ. Monit. Assess.* Epub.ahead of print, Pakistan
- UNEP/WHO, 1996. *Water Quality Monitoring - A Practical Guide to the Design and Implementation of Freshwater Quality Studies and Monitoring Programs*. Geneva, Switzerland
- USDA (United States Department of Agriculture). 1954. *Diagnosis and improvement of saline and alkali soils:U.S.D.A. Hand Book No. 60*. U.S. Salinity Lab. Staff, Washington D.C. USA
- USEPA (United States Environmental Protection Agency). 1999. *Conducting Sanitary Surveys of Public Water Systems: Surface Water and Ground Water*. EPA Guidance Manual, Washington DC., USA.
- Van, R., and Taddesse, G., 2009. *Urban sanitation and wastewater treatment in Addis Ababa in the Awash Basin, Ethiopia*. 34th WEDC international conference, Addis Ababa, Ethiopia
- Voutsas D A, Grimanis A & Samara C 1996. Trace elements in vegetables grown in industrial areas in relation to soil and air particulate matter environ. *Environmental Pollution* 94: 325-335
- Water quality for Agriculture: Recommendations of the FAO for the quality of water used for irrigation purposes. Available at <http://www.fao.org/DOCREP/003/T0234E/T0234E00.htm>
- WHO (World Health Organization). 2006. *Guidelines for the Safe Use of Wastewater, Excreta and Grey-water, Volume II: Wastewater Use in Agriculture*. WHO, Geneva, Switzerland

- WHO (World Health Organization). 2012. *Five keys to growing safer fruits and vegetables: promoting health by decreasing microbial contamination*. WHO, Geneva, Switzerland
- WHO / FAO. Food Standard Programmed Codex Alimentations (ALINORM 07/30/13). Report of the Thirty Eight Session of the Codex Committee on Food Hygiene, Houston, United States of America, 2007.
- Wins JA, and Morgan M. 2010. Effect of textile mill seffluent on growth and germination of black gram Vegan mango (L.) Hepper. *Int. J. Pharma. Bio. Sci.* 1(1): 1-7.
- Yusuf, I., Ali, S., and Yasmin, A. 2010. Germination and early growth response of glycine max varieties in textile and paper industry effluents. *Pak. J. Bot.*, 42(6): 3857-3863.

7. APPENDEXES

Appendix- 1

Table 1: Concentration Mg/Kg) of Cadimum (Cd) in the Sampled Vegetable

Vegetable	Sample	Sites						Average moon
		Kuriftu		Melkahida		Awash melkasa		
		M	SD	M	SD	M	SD	
Tomato	1.	0.67		0.51		0.39		
	2.	0.68		0.49		0.1		
	3.	0.66		0.52		0.3		
	Av.m	0.67	0.073	0.506	0.080	0.26	0.057	0.48
Cabbage	1.	0.959		0.936		0.67		
	2.	0.97		0.9		0.78		
	3.	0.98		0.89		0.9		
	Av.m	0.97	0.014	0.91	0.027	0.78	0.0081	0.9
Onion	1.	1.96		0.86		0.9		
	2.	1.95		0.97		0.83		
	3.	0.94		0.83		0.85		
	Av.m	0.95	0.0316	0.886	0.021	0.86	1.732	0.89

Appendix- 2

Table 2: Concentration Mg/Kg) of Lead (Pd) in the Sampled Vegetable

Vegetable	Sample	Sites						Average moon
		Kuriftu		Melkahida		Awash melkasa		
		M	SD	M	SD	M	SD	
Tomato	1.	0.33		0.39		0.1		
	2.	0.34		0.20		0.21		
	3.	0.35		0.3		0.1		
	Av.m	0.34	0.0258	0.296	0.081	0.136	0.0818	0.21
Cabbage	1.	0.2		0.19		0.251		
	2.	0.31		0.18		0.24		
	3.	0.4		0.17		0.23		
	Av.m	0.303	0.057	0.18	0.124	0.240	0.099	0.24
Onion	1.	0.501		0.4		0.165		
	2.	0.52		0.36		0.16		
	3.	0.48		0.3		0.146		
	Av.m	0.500	0.177	0.353	0.352	0.16	0.16	0.34

Appendix-3

Table: - 3 Concentration Mg/Kg) Of Zink (Zn) in the Sampled Vegetable

Vegetable	Sample	Sites						Average moon
		Kuriftu		Melkahida		Awash melkasa		
		M	SD	M	SD	M	SD	
Tomato	1.	12.36		9.00		8.90		
	2.	12.48		8.00		7.92		
	3.	12.39		7.00		7.00		
	Av.m	12.41	0.718	8.00	2.499	0.94		9.146
Cabbage	1.	12.12		9.5		9.325		
	2.	12.13		8.5		9.34		
	3.	12.14		8.5		9.346		
	Av.m	12.13	1.291	8.83	0.812	9.34	0.812	10/31
Onion	1.	10.34		8.96		6.09		
	2.	10.3		8.79		6.08		
	3.	10.2		8.7		6.10		
	Av.m	10.3	1.067	8.78	0.8173	6.09	2.05	8.376

Appendix4

Table: - 4 Concentration Mg/Kg) of Mercury (Hg) in the Sampled Vegetable

Vegetable	Sample	Sites						Average moon
		Kuriftu		Melkahida		Awash melkasa		
		M	SD	M	SD	M	SD	
Tomato	1.	0.3		0.33		0.7		
	2.	0.025		0.34		0.019		
	3.	0.33		0.035		0.018		
	Av.m	0.218	0.036	0.235	0.0433	0.0356	0.06	0.025
Cabbage	1.	0.015		0.018		0.015		
	2.	0.016		0.024		0.013		
	3.	0.018		0.005		0.019		
	Av.m	0.0163	0.160	0.0156	0.615	0.016	0.067	0.016
Onion	1.	0.035		0.137		0.025		
	2.	0.034		0.135		0.041		
	3.	0.033		0.133		0.035		
	Av.m	0.034	0.036	0.135	0.0361	0.0336	0.036	0.07

Appendix5

Table: - 5 concentration mg/kg) of Chromium (Cr) in the sampled vegetable

Vegetable	Sample	Sites						Average moon
		Kuriftu		Melkahida		Awash melkasa		
		M	SD	M	SD	M	SD	
Tomato	1.	0.595		0.52		0.4		
	2.	0.86		0.49		0.1		
	3.	0.49		0.51		0.3		
	Av.m	0.65	0.073	0.51	0.080	0.266	0.057	0.49
Cabbage	1.	0.96		0.85		1.61		
	2.	0.96		0.94		0.29		
	3.	0.99		0.00		0.5		
	Av.m	0.97	0.014	0.596	0.027	0.8	0.0081	0.9
Onion	1.	1.75		0.54		0.84		
	2.	1.00		1.2		0.9		
	3.	0.10		0.9		0.84		
	Av.m	0.95	0.0316	0.88	0.021	0.86	1.732	0.89

Appendix6

Table: - 6 Concentration of Heavy Metal in Water Samples

Heavy Metal	Sample	Wastewater discharged from factory	Sites		
			Kuriftu	Melkaahida	Awash melkas
Cd	1.	0.14	0.11	0.10	0.11
	2.	0.143	0.10	0.12	0.1
	3.	0.15	0.11	0.14	0.10
	Av.m	0.14	0.106	0.12	0.103
Pb	1.	2.04	1.3	1.01	1.04
	2.	2.03	0.9	2.00	1.05
	3.	2.05	0.8	8.90	1.03
	Av.m	2.04	1.00	1.97	1.04
Cr	1	1.90	6.00	3.04	4.021
	2.	2.01	4.00	4.02	3.0
	3.	2.00	5.00	5.01	5.001
	Av.m	1.97	5.00	4.02	4.007
Hg	1.	0.52	0.21	0.031	0.50
	2.	0.411	0.13	0.4	0.56
	3.	0.61	0.31	0.30	0.49
	Av.m	0.5136	0.216	0.33	0.516
Zn	1.	5.03	0.11	4.50	4.02
	2.	5.01	0.10	5.89	3.01
	3.	5.02	0.101	5.00	5.01
	Av.m	5.02	0.1036	5.13	4.01