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Human Health Risk Assessment for Consumption of Vegetable Cultivated by Fertigation of Municipal Solid Waste Compost with Natural Soil in Jimma Town, Ethiopia

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A Thesis Submitted to Jimma University, Institute of Health, Faculty of Public Health, Department of Environmental Health Science and Technology; in Partial Fulfillment for Requirements of Masters of Science in Environmental Science and Technology

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Jimma, Ethiopia

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Approval sheet

As thesis research advisors, we here by certify that we have read and evaluated this thesis prepared under our guidance by Nega Kenea entitled as "Human Health Risk Assessment for Consumption of Vegetable Cultivated by Fertigation of Municipal Solid Waste Compost with Natural Soil in Jimma Town, Ethiopia

. We recommended that it could be submitted as fulfilling the thesis requirement.

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As member of the board of examiners of the Msc. thesis open defense examination, we certify that we have read and evaluated the thesis prepared by Nega Kenea and examined the candidate. We recommend that the thesis be accepted as fulfilling the thesis requirement for the degree of Master of Science in Environmental Science and Technology.

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Declaration

I declare that this research paper is my own original work and has not been presented for a degree or other award in any other university and that all sources of materials used for the research paper have been correctly acknowledged.

Declared by:

Name: Nega Kenea

Signature:________________________Date:___

ABSTRACT

Background: *Heavy metal pollution is a menace to our environment as they are foremost contaminating agents of our food supply, especially vegetables. This is great concern to the public health, agricultural production, and environmental health.*

Objective: *to assess human health risk for consumption of vegetable cultivated by fertigation of municipal solid waste compost with natural soil in Jimma town, Ethiopia.*

Methods: *The study was conducted in Jimma town 2019 by using cross sectional study design. The samples were collected during dry season for heavy metal analysis from two sites (Abdi Jimma and Aba Milki sites). Heavy metal concentration was analyzed by atomic absorption spectrophotometer. Health risks associated with these heavy metals (As, Cd, Cr, Pb, Cu and Zn) from consumption of vegetable (tomato, beetroot, lettuce, onion and spinach) were assessed based on total hazard quotients:*

Findings: *The concentration of heavy metals in edible parts of vegetables increase in vegetables grown in Abdi Jimma when compared with Aba Milki farm site metal concentration for Zn, Pb, Cu, and As. The mean metal concentrations in vegetable for As(0.72) and Zn(65.48) was above the safe limits of World Health Organization's standards, while the mean Cd(0.0745), Cr(0.36), Pb(0.176) and Cu(3.33) concentration were below safe limit. Health risk for As, Cd, Cr, Pb, Cu and Zn, possess nearly free of risk to the local in habitants through consumption of contaminated vegetable grown in the area as the value for total hazard quotient was less than 1, but the long term accumulation of these metal gradually increase the concentration in the environment and accumulates in the body and can cause serious health problems.*

Conclusions: *Natural compost preparation from waste materials requires detail characterization and selecting waste items with low concentration of heavy metals. Regular monitoring of heavy metals is essential to prevent excessive build up in the food chain and prevent serious health risk of population.*

Recommendation*: the composition of organic fertilizer and the soils from which vegetable crops can grow should be monitored and regulated.*

Key words: Vegetables, Metal accumulation, Daily intake of metals, Health risk index.

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LIST OF ABBREVIATIONS

AAS	Atomic Absorption Spectroscopy
ANOVA	Analysis of Variance
EPA	Environmental Protection Agency
FAAS	Flame Atomic Absorption Spectroscopy
FAO	Food and Agricultural Organization
LOQ	Limit of quantization
MDL	Method detection limit
MSWC	Municipal solid waste compost
PPM	Parts Per Million
SD	Standard deviation
SRM	Standard Reference Material
USEPA	United States Environmental Protection Agency
WHO	World Health Organization

CHAPTER ONE: INTRODUCTION

1.1. Background of the study

Heavy metals pollution is a hazard to our environment as they are for most contaminating agents of our food supply, especially vegetables (Chauhan,2014). Vegetables get contaminated by absorbing heavy metals from polluted air, soil, and water (Sharma *et al.*, 2008). Heavy metals pollution in soil and water has a lot of adverse effects and great concern to the public health, agricultural production, and environmental health (Singh *et al.*, 2010). The soil pollution is mainly due to disposal of industrial and usage of Municipal solid waste compost (MSWC).

Municipal solid waste compost (MSW) and its subsequent application to agricultural land is gaining popularity because of environmental concerns associated with the disposal of this material in landfills. It is affordable and cheaper compared to chemical fertilizers. However, there is a rising concern over MSWC often contains potentially toxic elements, that can cause soil contamination, phytotoxicity and undesirable residues in plant and animal products (Alloway *et al.*,1991).

As a matter of fact, pollution problems may arise if toxic metals are mobilized into the soil solution and are taken up by plants or transported in drainage waters. Risk for human health may then occur through consumption of such crops and intake of contaminated waters. This is particularly the case for heavy metals in MSWC due to their ubiquity and toxicity. Nevertheless, the main risks associated with the use of organic wastes in agriculture cannot be evaluated directly through determination of the total contents of metals in those materials, since the chemical or physicochemical forms of metals strongly affect their mobility, reactivity and availability to plants (Singh *et al.*, 2010).

In the long term, the use of MSWC can also cause a significant accumulation of Zn, Cu, Cr, Pb, As and Cd in the soil and plants (Goyer, 1997).Many growing areas in the developing countries are vulnerable to air pollution due to the fact that heavy metals containing aerosols are normally deposited on soil surface and get absorbed by vegetables or sometimes get deposited on plant leaves (Voutsa, 1996).The uptake of heavy metals by the plants from the soil depends on different factors, including application of agrochemicals, solubility of heavy metals, soil pH, soil type, and plant species (Lubben and Sauerbeck, 1991).

Leafy vegetables accrue higher amounts of heavy metals in roots and leaves than stems and fruits (Azimi and Yargholi, 2008). The heavy metals at exceedingly higher concentrations than the required physiological demand of vegetables can cause lethal effect in them as well as human health through food chain (Goyer, 1997).Vegetables constitute the most important daily diets in many of the households globally (Sinha *et al* 2006). However, the consumption of leafy vegetables is reported to increase in the urban community Othman (2001) various researches revealed heavy metals like Cu, As, Zn, Fe, Pb, Cd, Mn, and Cr to be significant contaminants of vegetables in urban agriculture(Sharma, *et al.,* 2008). Heavy metals like Cu, Zn, and Fe play a significant role in plant physiology but heavy metals such as Pb, As, Cd, and Cr are exceptionally toxic and dangerous environmental pollutants (Demirezen and Aksoy, 2006).

A number of studies have shown that some common vegetables including *spinach, lettuce, beetroot, tomato and onion* species are proficient of accruing high heavy metals levels from municipal solid waste compost used as organic fertilizers or contaminated irrigating water (Sharma *et al.*, 2006). The consumption of vegetables is the main route of heavy metal toxicity to humans (Intawongse and Dean, 2006).

The ingestion of heavy metal contaminated vegetables may lead to various long-term lingering diseases; for instance, continuous exposure of Cd can cause pulmonary effects like emphysema, bronchiolitis, and alveolitis (Duruibe*et al.,* 2007) while short-term exposure of Cd can cause renal effects. The chronic buildup of heavy metals in the liver and kidney of humans results in disruption of many biochemical processes, which leads to nervous, kidney, cardiovascular, and bone diseases Arup(2003) while high Zn content may cause growth and reproduction impairment. Lead toxicity causes dysfunction of kidney, reproductive and cardiovascular systems, joints problems, lessening in hemoglobin formation, and enduring impairment to the central and peripheral nervous systems (Ogwuegbu and Muhanga, 2005).

Abdi Jimma and Aba Milki farming site were located in Jimma town, Oromia region, Ethiopia. From both farm sites farmers and customers take municipal solid waste compost to improve soil fertility and to increase crop yield. However, the application of composts has raised serious doubts as it relates to public health safety of its use to grow crops destined for human consumption. Research has shown that the heavy metals content in composts have the potential to contaminate crops especially for vegetables grown using it (Manju *et al*., 2013).Thus, a better understanding of heavy metals content in the composts and their availability for uptake by plants grown on them is primary importance in assessing the health risk such plants could cause when consumed by man (Koenig *et al.*, 1990; Mench *et al.*, 1994).

Therefore, the present study assesses heavy metals' levels (As, Cd, Cr, Pb, Cu and Zn) in growing soil, irrigating water, MSWC and five popularly consumed vegetables, tomato, beetroot, lettuce, onion, and spinach from the Abdi Jimma and Aba Milki farm site. It also calculates the soil-plant transfer coefficients of heavy metals for each vegetable, heavy metal average daily intake rate, hazard quotient (HQ), and hazard index (HI). The last two indices help in assessing potential human health risk that can occur due to consumption of the vegetables. The study hypothesizes that consumption of vegetable cultivated by municipal solid waste compost with natural soil has risk effect for human health.

1.2. Statement of problem

Jimma town which have large number of population and catchment area and also different institutions with different social and economic activities which can contribute for waste production with high rate.Even though the town has such huge organization, the waste handling was poor. Study conducted in different parts of the world and also in different towns of Ethiopia shows that the urban municipal solid waste compost may contain different heavy metals and this heavy metal can accumulate in soil and it will transfer to the vegetables and finally human beings can accumulate this heavy metals during consumption and finally it will pose health effects to humans.

Different research indicated that vegetable grown on contaminated soil with MSWC have risky effects on human health by their consumption due to high concentration of heavy metal (Khan *et al*., 2008; Gosh *et al*., 2012).

Study conducted on the concentration of Cadmium, Chromium, Zinc, Arsenic and Lead in compost were recorded above the permissible limits set by WHO in Soil sample and the concentration of heavy metal in vegetable were also above the permissible limits by WHO(Alexander *et al.*,2014).

Heavy metals such as cadmium, lead, chromium, and arsenic are highly toxic due to their insistent and bioaccumulation nature. The continuing exposure to such toxic metals in the food crops has harmful effects on human health and causes bone, brain damage, mental retardation, cerebral palsy, lung cancer, gastrointestinal abnormalities, and dermatitis, death of the unborn fetus , heart, brain and kidney diseases from their consumption. Furthermore, cadmium and mercury have cancer-causing effects (Hussain *et al*., 2001; Jarup 2003) but there is no medical method through which these metals can be removed from their body (Bhuiyan *et al*., 2011). Therefore, it is necessary to assess and quantify the health consequences of the exposure to such a contaminated environment (Ma *et al*., 2006; Khan *et al*., 2015).Thus, this paper assesses human health risk assessment for consumption of vegetable cultivated by fertigation of municipal solid waste compost with natural soil in Jimma town, Ethiopia.

1.3. The significance of the study

To provide information on the fate of heavy metals in municipal solid waste compost in Jimma town; this information was guide in formulating an appropriate land use and management policy for this type of ecosystem.

This study was help: To reduce the health risk associated with consuming heavy metal contaminated vegetable and to communicate with local expertise on the result through dissemination of the finding and discussion. To provide scientific information to government organization like agricultural bureaus about the health hazards of municipal solid wastes compost. To deliver a base line data on the levels of heavy metals in soil, vegetable and municipal solid waste compost in Jimma town.

CHAPTER TWO: LITERATURE REVIEW

2.1. Heavy metals

Heavy metals are elements having a density greater than 5 g/cm3 in their elemental form (Bose and Hemantaranjan, 2005; Misra and Mani, 2009).Heavy metals are often referred to as trace metals, occurring naturally in low concentration in organisms, although the term transmittal might imply by organism for the particular metal. They are not biodegradable and undergo ecological cycle. Some metals are very essential to life but they are toxic at high level of dose (Ukpebor *et al.,* 2003). Emission of heavy metals to the environmental occurs via a wide range of process and path ways, including to the air, to surface water and to the soil. Tends be greatest effect on human health.

The accumulations of heavy metals in soil reach concentration since become a threat to vegetation and animals. Ultimately affect the quality of human life through food chain. Heavy metals are found in electrical wastes, municipal solid waste and from degradation of organic wastes (Esarru *et al.*, 2003). They can also be found from disposal of house hold wastes. Hazardous wastes, nonhazardous industrial wastes and other chemical by product (Marine *et al.*, 2005). Long-term application of municipal solid waste compost resulted in significant buildup of heavy metals in soil and vegetables and cereals and their subsequent transfer to food chain causing potential health risk to consumers(Perveen *et al.,* 2012).

2.2. Selected heavy metals

2.2.1. Lead

Lead is a common metal that has been in many consumer products but is now known to be harmful to human health if ingested or inhaled. It can be found in lead-based paint, air, soil, household dust, food, some types of pottery, and drinking water. Children could show slight deficits in attention span and learning abilities (WHO, 1985).

Lead is a well-known non-biodegradable toxic metal in the environment and now it has become a global health issue. Lead poisoning occurs when people are exposed to lead and chemicals that contain lead, breathing air, taking drinks such as water and milk, eating foods such as fruits, vegetables, meats, grains and seafood, swallowing or touching dust or dirt that contains lead(Tiwari *et al.*, 2013). Excessive intake of the Pb to human body can damage the nervous, skeletal, endocrine, enzymatic, circulatory, and immune system(Mahmoud & Ghoneim, 2016).

2.2.2. Copper (cu)

Large quantities of Cu are used in the society for example alloys, electrical cables, pluming and coins. Waste from electric and electronic equipment is the Cu containing smelting. In urban areas, corrosion of copper roofs is an important source (Berggren *et al.*, 2006; Chang, 2010). Oxidation state: commonly (II) and sometimes (I) in strongly reducing environments with suitable ligands (Berggren *et al.*, 2006). Dominating form in water; Cu^{2+} and its complex with OC, with the latter usually strongly dominating (Berggren *et al.*, 2006). Occurrence form in soil: Above all, strongly bound to organic material, but also strongly bound to Fe, Al and Mn oxides. In reducing environments, Cu forms poorly soluble sulphides. In oxidizing environments, at high pH and high Cu-concentrations, malachite, may precipitate (Berggren *et al*., 2006).

Cu^{2+} is characterized by very strong complex formation to humus, which is also strong even at low pH. Comparing to lead (II), Cu^{2+} forms strong complexes to humus and weaker ones to oxide surfaces, which results in that the content of organic material in the soil in general decides how much Cu^{2+} which is bound. The transport of Cu in soil and water occurs mainly as dissolved humus complexes (Berggren *et al.*, 2006).Cu is essential for both plants and animals but high levels of Cu^{2+} is very toxic. Chronic exposure can lead to an accumulation in, and damage to, liver, brain, kidney and cornea.

2.2.3. Arsenic

Arsenic has also been used for decades as an ingredient in pesticides and fungicides. Arsenic acid ($As_2O_3.H_2O$) is used as a weed killer and in leaf desiccation of cotton plants. Arsenic is also used in the smelting of ores and in electroplating (Cobb *et al*., 2000). Atmospheric fallout from smelting and other manufacturing processes can be a significant source of As in the environment.

Arsenic is typically immobile in agricultural soil and, therefore, accumulates in the upper soil horizons (ATSDR, 2000; Janssen *et al.*, 1997,) used a regression analysis of pH, organic matter content, clay content, iron oxide content, aluminum oxide content, and cation exchange capacity versus As mobility to determine how each parameter affected As mobility in soil. They found that iron oxide content was the only soil characteristic significantly positively correlated with Arsenic mobility. Arsenic mobility is more dependent on ligand exchange mechanisms, particularly with iron oxides, than the pH-dependant dissolution precipitation reactions that regulate the movement of most other metals in the soil. (Darland and Inskeep, 1997) found that arsenate (AsO_4) transport through sand containing free iron oxides was very slow at pH 4.5 and 6.5, and significantly more rapid at pH 8.5. They suggested that liming soil to increase the pH and promote metal precipitation to decrease metal mobility, may actually facilitate the movement of As.

Arsenates As (V) are more toxic and more mobile in the soil than arsenites As (III) (Geehan, 1996). Some aquatic organisms and soil bacteria can reduce As (V) to As (III), increasing its toxicity and its mobility in the soil (ATSDR, 2000; Turpeinen *et al.*, 1999). Under reducing conditions, such as temporarily flooded or saturated soil, inorganic arsenicals may be methylated to produce the less toxic organic forms, monomethylarsonic acid (MMA) or dimethyl arsinic acid (DMA) (Honschopp *et al*., 1996).

Warts and corns on the palms and the soles of the feet are caused by chronic arsenic ingestion. Discoloration of the skin of the face, neck, and back also can occur. Squamous cell carcinomas can form from hyperkeratosis warts and corns. Basal cell carcinomas are also caused by arsenic exposure but they do not form from the warts or corns. Chronic low-level exposure also increases the incidence of internal cancers. Cancers of the bladder, kidney, liver, lung, and prostate have been documented in animal studies. The Department of Health and Human Services (DHHS), the International Agency for Research on Cancer (IARC), the United States Environmental Protection Agency (EPA), and the National Toxicology Program (NTP) has all classified inorganic arsenic as a known human carcinogen (ATSDR, 2000). Organic arsenicals are less toxic than the inorganic forms.

The two primary forms of organic arsenic are monomethylarsonic acid (MMA) and dimethyl arsinic acid (DMA). MMA and DMA are primarily used as agricultural pesticides. Data about the toxicity of organic forms of arsenic are limited; however, based on available data, organic arsenic is not toxic (ATSDR, 2000). Organic arsenicals are less toxic than the inorganic forms.

2.2.4. Chromium (Cr)

Cr is extensively used for electroplating, corrosion protection and leather tanning, and is also a common additive in steel, which is why corrosion of Cr^-containing materials is a source. Other sources are the use of ferrandromium scrap from steel plants and mine waste with chromites ore. Cr is a common water pollutant as a consequence of industrial emissions and also the second most abundant inorganic contaminant of groundwater under hazardous waste sites (Berggren *et al*., 2006; Baird and Cann, 2008).

Cr normally exists in the form of inorganic ions where the common oxidation states are +3 and +6. Chromium +3 occurs under reducing conditions and low pH in cationic form, and occurs practically exclusively in the soil. Under very aerobic conditions and high pH, Cr occurs in the +4 state which is always an anion and commonly the chromate ion, CrO_4^{2-} (Berggren *et al.*, 2006; Baird and Cann, 2008; Sajidu 2008. In soil, Cr^{3+} is bound to organic material and toxic mineral surfaces and precipitated with iron oxides, and chromate is weakly adsorbed to iron and aluminum oxides (Berggren *et al., 2006*). In water, chromium (III) occurs as the Cr^{3+}ion which have a low solubility in neutral water and it is often precipitated as its hydroxide. It can also occur as different chromium (III) complexes with OC. Chromium (VI) usually occur as the chromate ion which is highly soluble in water (Berggren *et al.*, 2006; Baird and Cann, 2008). Cr (III) is strongly bound in the soil, even at low pH, through complex formation to organic material and on mineral surfaces and can also precipitate with iron oxides.

Cr (VI) can form week complexes with iron and aluminum oxides at pH below 6 but is in general rather mobile in the soil since it is not strongly absorbed by many types of soil. It can be reduced to the less mobile trivalent form by the humic substances in soils that are rich in organic matter but this is an extremely slow process and if chromium (VI) is discharged into the environment, it will persist for a very long time (Berggren *et al*., 2006; Baird and Cann, 2008; United States Environmental Protection Agency 2000).

Cr is essential but at high concentrations, it can cause problems with trachea, cause lung cancer after long exposure, and also complex binding to DNA. The hexavalent Chromium is more toxic, more soluble and more mobile than trivalent Chromium and carcinogenic making it a more severe pollution. The chromate ion enters biological cells, seemingly because of its structural resemblance to the sulphate ion. Inside the cell, chromate can oxidize DNA and RNA bases (Berggren *et al.*, 2006; Baird and Cann, 2008).

2.2.5. Zinc (Zn)

Zinc is an airborne pollutant and majorly accumulates to open and above earth crops; however, root crop plants also assimilate great proportion from Zinc contaminated soils. (Lokeshappa *et al.,* 2012). There are three major routes of entry for zinc into the human body; inhalation, through the skin, or by ingestion and each exposure type affects specific parts of the body and allows the uptake of different amounts of zinc(Plum *et al.*, 2010).

Large amounts of dietary zinc are ingested leads to increase of metallothionein expression, more zinc is bound to metallothionein, and more zinc-metallothionein complexes are excreted. Because of the difference in binding affinities between zinc and copper (copper binds metallothionein with greater affinity), a potential for pronounced copper excretion exists. Therefore, a substantial increase in zinc ingestion potentially would cause a dramatic decrease in copper absorption(Chicago and New York, 2002).

2.2.6. Cadmium

Cadmium is a naturally occurring metal and it can enter the environment from natural and anthropogenic activities and stays intact for long periods of time. Food is the major source of cadmium exposure in the general population. Chronic exposure to cadmium may cause several adverse health effects, including renal and bone damage(Nazir *et al*., 2015).

Study conducted by (Bernard, 2008) in Hungary shows cadmium as one of the most toxic elements to which man can be exposed at work or in the environment. Once absorbed, Cd is efficiently retained in the human body, in which it accumulates throughout life and it is primarily toxic to the kidney, especially to the proximal tubular cells, the main site of accumulation. The chronic effects of Cd consist of lung cancer, pulmonary adenocarcinomas, prostatic proliferative lesions, kidney dysfunction, bone fractures, and hypertension(Mahmoud & Ghoneim, 2016).In plants, Cd induces oxidative stress in plant cells and inactivates some enzymes (Wieczorek *et al*., 2004). Cd taken up by plants from the soil accumulates first of all in the roots, and then transported in smaller quantities to stems and seeds (Wieczorek *et al*., 2004).

2.3. Heavy metal in soil

When plants decay, heavy metals that had been taken into the plants are redistributed to the soil is then again enriched with the pollutants (Sawidis *et al*., 2001). It has been established that heavy metals in soil are associated with various chemical forms that relate to their solubility which directly bear on their mobility and biological availability. Heavy metals in soluble form have high relation to their uptake by plants (Arora *et al*., 2008). Apart from the source of heavy metal, the physical and chemical properties of the soil also affect the concentration of heavy metals in soils (Qishlaqi and Moore, 2007).

The uptake and bioaccumulation of heavy metals in vegetables is influenced by many factors such as climate, atmospheric depositions, the concentrations of heavy metals in soils, the nature of soil and the degree of maturity of the plants at the time of the harvest (Scott *et al*., 1996). Results obtained from a study carried out by Ebong *et al*.(2008) on heavy metal contents of municipal and rural dumpsite soils and rate of accumulation by C*arica papaya* and *Talinum triangular* revealed that plants grown on dumpsite soils bio-accumulated higher metal concentrations than their counterparts obtained from normal agricultural soils (Ebong *et al*., 2008).

2.4. Heavy metal in vegetables

Vegetables are an important part of a human beings diet because they are a source of nutrients. Vegetables constitute important functional food components by contributing protein, vitamins, iron, calcium and other nutrients which have marked health effects (Thompson and Kelly, 1990; Arai, 2002). There is an inherent tendency of plants to take up toxic substances including heavy metals that are subsequently transferred along the food chain Singh *et al*., (2010) and as such, heavy metal contamination in vegetables cannot be underestimated as food stuffs are important components of human diet.

Heavy metal contamination of the food items is one of the most important aspects of food quality assurance (Marshall, 2004; Wang *et al*., 2005; Radwan and Salama, 2006; Khan *et al*., 2008).

Contamination of foods by heavy metals has become a challenge for producers and consumers. The main sources of heavy metals to vegetable crops are their growth media (soil, air, nutrient solutions) from which these heavy metals are taken up by the roots or foliage (Lokeshwari and Chandrappa, 2006). The toxic and detrimental impacts of heavy metals become apparent only when long-term consumption of contaminated vegetables occurs. Regular monitoring of heavy metals in vegetables and other food items should be performed in order to prevent excessive build up of these heavy metals in the human food chain (Khanna and Khanna, 2011) take up and accumulate heavy metals in quantities high enough to cause clinical problems to humans (Alam *et al*., 2003).

Daily metal intake estimate does not take into account the possible metabolic ejection of the metals but can easily tell the possible ingestion rate of a particular metal. Dietary intake of food results in long-term low level body accumulation of heavy metals and the detrimental impact becomes apparent only after several years of exposure. Leafy vegetables grown on heavy metal contaminated soils accumulate higher amounts of metals than those grown in uncontaminated soils because of the fact that they absorb these metals through their roots (Bahemuka and Mubofu, 1999; Al-Jassir *et al*., 2005). Heavy metals are persistent in the environment and are subject to bioaccumulation in food-chains. They are easily accumulated in the edible parts of leafy vegetables, as compared to grain or fruit crops (Mapanda *et al*., 2005).

2.5. Health risks due to heavy metal

Heavy metals can enter the body via consumption of contaminated food stuff, water or inhalation of dust (Mahmood& Malik, 2014).Prolonged consumption of heavy metals increase the risk of damaging the organs such as the kidneys, heart and liver as well as the nervous system when accumulating in the body (Schmidt, 2012). Due to high levels, depletion of essential nutrients occur which cause malnutrition. This in turn weakens the immune system, cause growth retardation and psycho-social behavioral disabilities. A diet of heavy metal contaminated food has also been seen to increase the risk of gastrointestinal cancer (Akbar Jan *et al.*, 2010).Heavy metals can directly influence behavior by impairing mental and neurological function, influencing neurotransmitter production and utilization, and altering numerous metabolic body processes. Many cases of heavy metal burden are associated with industrial exposure and waste water, but our food; drinking water and environment do not appear to be getting any purer.

Certain trace elements are essential in plant nutrition, but plants growing in a polluted environment can accumulate trace elements at high contaminations causing a serious risk to human health when they are consumed(Pradesh *et al.*, 2013).Consumption of high quantities metals in vegetables pose clinical problems both to animals and human beings consuming these metal rich plants because there is no good mechanism for their elimination from the human body(Roy & Gupta, 2016).

CHAPTER THREE: OBJECTIVE OF THE STUDY

3.1. General objective

- To assess human health risks associated with consumption of vegetable cultivated by municipal solid waste compost with natural soil in Jimma town, known for its cultivation of vegetable (tomato, beetroot, lettuce, onion, spinach).

3.2. Specific objectives

- To determine the concentration levels of heavy metals (As, Cd, Pb, Cr, Cu, and Zn) in compost, soil, vegetable samples and to estimate the potential hazard by comparing with guideline value and standards.
- To estimate the potential health risk by calculating the transfer coefficient of heavy metals from soil, compost and water to vegetables and daily consumption
- To identify major factors strongly associated with health risks.

CHAPTER FOUR: MATERIAL AND METHOD

4.1. Study Area

The study was conducted in Jimma town found at south western parts of Ethiopia located at 356 Km away from Addis Ababa the capital city of Ethiopia at 7°40” N latitude and 36^{0}60’E longitude. Elevation within the town boundary ranges from the lowest 1720m from sea level of the airfield (kitto) to the highest 2010m from sea level at Jiren. It is bordered by Kersa Woreda in the east; with Manna Woreda in north, and Manna &Seka Chekorsa in west, Dedo woreda in south direction. According to Jimma town Finance and economic department 2014 annual report, the total population of the town was 192,256 from this male 94,205and female 98,051. The towns have no modern sewerage system and municipal solid waste management is very poor.

The major socio economic activity of the town is trade, social service and urban agriculture. Concerning agricultural activities there is urban farming such as dairy, animal husbandry and poultry activities including town surrounding small scale irrigation which used waste water and surface water as a source and MSWC as natural fertilizer. Almost all of the cultivated vegetables around the town were used for human consumption.

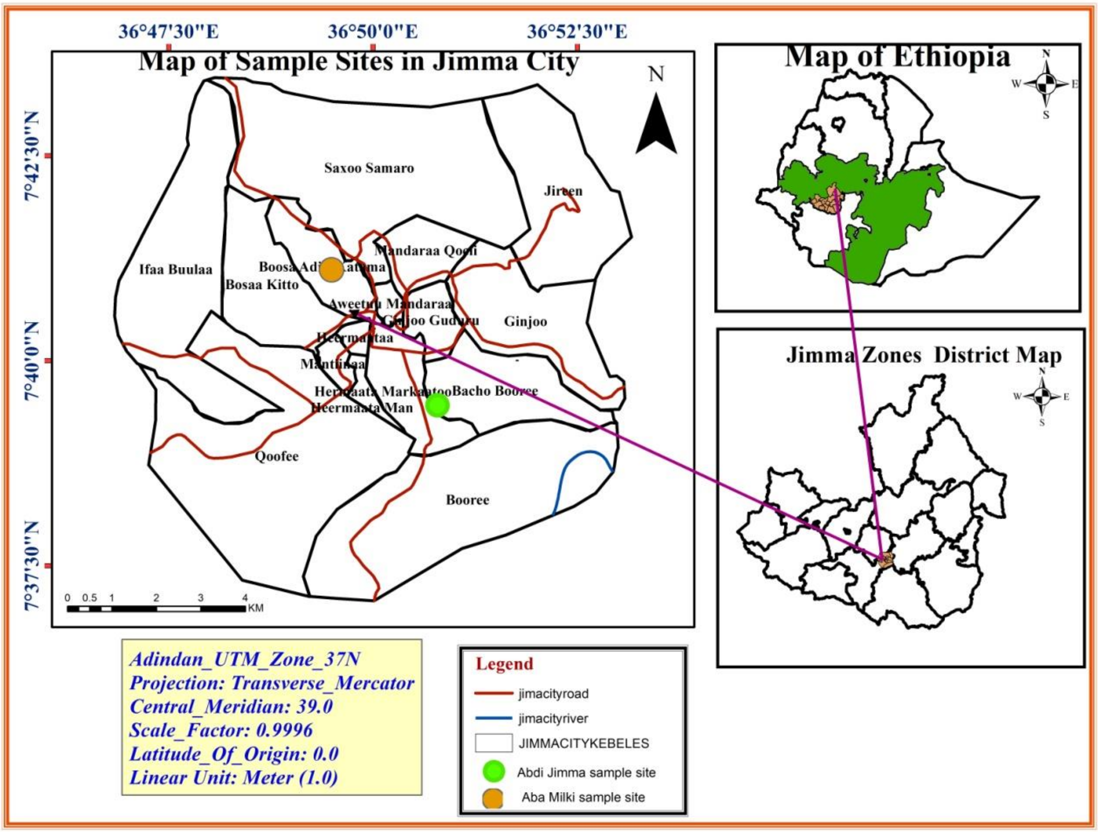

Fig 1 Map of study area

4.2. Study Design and period

Cross sectional study was conducted on April 2019.

4.3. Field Experimental Design

4.3.1. Sample collection, transportation and storage

4.3.1.1. Compost sample collection, transportation and storage

Compost samples were taken when the compost is ready for application by the plant in both farm sites. The sample was taken randomly from different point for preparation of composite sample for one sample in Abdi Jimma and for one sample in Aba Milki farm site. These samples were collected by stainless steel auger in air- tight polythene bags after proper mixing the representative sample stored in polyethylene bags and labeled carefully then transported to the laboratory for preparation. Larger particles and other debris were removed from the compost and then compost samples were air dried in a dry and dust free place at room temperature (25^0c) for five days, followed by oven drying until getting constant weights. The samples were then grounded with a mortar and pestle to pass through a 2mm sieve and homogenized. The dried, sieved, and homogenized soil samples were placed in polyethylene bags until the time of digestion.

4.3.1.2 Soil Sample collection, transportation and storage

Composite soil sampling method was applied. The soil sampling was done according to the method of (James and Wells, 1990).About (1kg) composite soil sample were collected from 10cm, 15cm and 20cm depth (10-20) cm depth from the site where the vegetables grown (for each site) with an auger from each point (Roger, 1994) and the control soil sample was collected from area outside the compost application farm. Then the sample were placed in clean polyethylene bags and transported to the laboratory for preparation.

Larger particles and other debris were removed from the soil and then soil samples were air dried in a dry and dust free place at room temperature (25^0c) for five days, followed by oven drying until getting constant weights. The samples were then grounded with a mortar and pestle to pass through a 2mm sieve and homogenized. The dried, sieved, and homogenized soil samples were placed in polyethylene bags until the time of digestion.

4.3.1.3 Vegetable Sample collection, transportation and storage

About (1000g) of Beetroot, onion, Lettuce, spinach, tomato were collected representative edible part of the vegetable. Vegetable were collected according to the sampling procedures described by (Jones *et al*., 1990). The representative reputable samples were thoroughly mixed to give composite sample as representative fraction of the vegetables (Deribachew *et al.*, 2015). The bruised or rotten portions were removed and the remaining samples were packed in polyethylene bags for transporting to the Jimma Environmental health laboratory. In the laboratory, the collected vegetable samples were washed with tap water and then with distilled water to eliminate adsorbed dust and particulate matters. The vegetable samples were cut and chopped into small pieces using plastic knife in order to facilitate drying. Accordingly, the sample were air-dried for six days and farther dried in hot air oven at 105^0c for 24hr to remove moisture and maintain constant mass. The dried sample were ground into powder using acid washed commercial mortar and pestle and then sieved to 2mm mesh size.

The sieved samples were finally stored in polyethylene bags and kept in desiccators until the time of digestion.

4.4. Chemicals, Reagents and Instruments

4.4.1. Chemicals and Reagents

All chemicals and reagents used for the study was that of analytical grade. The chemical used for heavy metal analysis was HNO_3, 70% $HClO_4$, H_2SO_4, HCl, stock standard solution 1000mg/L and 2%HNO_3, selected heavy metals were used for preparation of the working solution (which were immediately prepared before analysis) for calibration and in spiking experiment. The glassware and polyethylene containers which used during analysis was washed with tap water, then soaked in 4MHNO_3 solution and rinsed several times with deionized water.

4.4.2. Apparatus and Equipment

The instruments used for this study was FAAS, with model no.400 NOV for heavy metal determination from compost, water ,vegetable and soil, samples and a multi parameter probe (Hach-Model –HQ30d multi parameter digital meter) was used for the determination of pH and electrical conductivity. The common laboratory apparatus which were used during the study include; different sized beakers, Erlenmeyer flask, funnels, volumetric flasks, block digester, Ceramic mortar and pestle, centrifuge, hydrometer, droppers, glass pipettes, measuring cylinders, plastic knife, vinyl gloves, stirrer, polyethylene bags, digital analytical balance, conical flasks and drying oven, vaccine carrier and ice box for sample transportation from field to laboratory and freezer for water sample.

4.3. Sampling and sample size

Compost, soil, water and vegetable sample were taken from Jimma municipal solid waste composting enterprise center. The total sample size will be eight from soil, two from compost, one from control soil, two from water and eight from different vegetables edible parts which summed up to twenty one samples for the study.

Table. 1. Sample size and sampling source for heavy metal

Site	Media		N0 of sample	replicate	Total
Abdi Jimma	Soil sample		5	3	15
	Compost sample		1	3	3
	Water sample		1	3	3
	Vegetable sample	Sample from fruit edible	1	3	3
		Sample from root edible	2	3	6
		Sample leaf edible	2	3	6
Aba Milki	Soil sample		3	3	9
	Compost		1	3	3
	Water sample		1	3	3
	Vegetable	Sample from fruit	1	3	3
		Sample from root	1	3	3
		Sample from leaf	1	3	3
Total			21		

4.4. Cleaning of glassware and sampling materials

All sample containers and glassware used in the present study were washed in detergent and soaked in 30% Nitric acid for 2h to leach out adsorbed metal ion and rinsed in tap water followed by deionized water before drying in dust free area (APH, 2012).

4.5. Digestion of Compost, soil, water and vegetable sample for heavy metal analysis

4.5.1 Digestion of the compost sample

Compost sample was air-dried, mechanically ground using a stainless steel roller and sieved to obtain 2 mm fraction. A 20–30 g subsample was drawn from the bulk soil (2 mm fraction) and reground to obtain 200μm fraction using a mortar and pestle. compost samples was digested in mixture of concentrated nitric acid (HNO_3), concentrated hydrochloric acid (HCl) and according to (Al-jaboobi *et al.*, 2014).

4.5.2. Digestion of soil samples for heavy metal analysis

The digestion of soil sample was performed by taking 0.5g dried and homogenized soil samples transferred in to 100mL digest flask in triplicate .In each of these flask ,5mL of deionized water and 30mL of mixture HNO_3(69%)and 37%HCl with volume ratio of 5:1 were added. The sample dissolved in the acid mixture was digested in digestion hood (at 200^0c) for 1hr and kept to cool. After adding 2mL of H_2O_2 to the cold digestion mixture, the final mixture was filtered out through what Man No.42 filter paper to 100mL volumetric flask and finally diluted to the mark with distilled water (Loon, 1985, APHA, 2012, Hizkeal, 2012, kedir 2015).The varying filtrates obtained above were analyzed for the total content of each heavy metal by FAAS in Laboratory Horticoop Ethiopia PLC (Horticulture). The blank reagent was also digested following the same procedure as the taste soil sample.

4.5.3. Digestion of water sample for heavy metal analysis

The water sample from each sampling bottle were mixed thoroughly by shaking.A50mL filtered aliquot of water sample was transferred by pipette into a digestion flask. The metal percentage found in the water was determined by digesting in 3mL concentrated HNO_3 and 3mL H_2O_2 below 80^0c for 1hr until clear solution was observed. The clear solution was diluted to 100mL volumetric flask with distilled water and blank digestion was also carried out in the same way (Aga & Brhane, 2014).The blank solution contained all reagents except sample water. All samples were digested in triplicates and the digests were analyzed for the toxic heavy metals by using FAAS in Laboratory Horticoop Ethiopia (Horticulture) PLC.

4.5.4. Digestion of vegetable samples for heavy metal analysis

A 0.5g of homogenized powdered vegetables sample was placed in borosilicate digestion flask to which 10mL of Acid mixture containing HNO_3-HCl-H_2O_2 (8:1:1, V/V/V) ratio were added .The mixture was heated at 120^0c over 3hr on block digester. After digestion was completed, the clear and colorless solution was filtered out into 100mL volumetric flask. Each digestion tube was rinsed with distilled water to collect any possible residue, and added to the volumetric flask and finally made up to volume with distilled water.

All the dilute samples were stored in 100mL plastic bottle (high density polyethylene) until analysis. Each vegetable sample was digested and analyzed in triplicate to confirm precision of the result. The blank solution was prepared by taking a mixture of 8mL HNO_3, 1mL HCl and 1mL H_2O_2 and treating similarly as that of the sample (Street, 2008).Digestion of a reagent blank was performed along with the vegetable samples keeping all digestion parameters the same as that of taste sample. All the digested and diluted samples were stored in a refrigerator at 4^oc until analysis (Deribachew *et al.*, 2015).

The heavy metal concentrations were analyzed by FAAS in Laboratory Horticoop Ethiopia PLC (Horticulture).

4.6. Calibration procedure

Calibration curves were prepared to determine the concentration of the heavy metals in the sample solution. Intermediate standard solutions (10mL) of each heavy metal were prepared from stock standard solution containing 1,000mgL^{-1} of selected heavy metals. Appropriate working standards were prepared for each of the metal solution by serial dilution of the intermediate solution using deionized water. Each and every activity was adjusted according to the instrument operating manual to attain its better sensitivity and working standard was then aspirated one after the other into the flame atomic absorption spectrometer and the absorbance were recorded calibration curves was plotted for each of the trace heavy metals standard using absorbance against concentrations mg/L.

4.7. Physicochemical and trace metal analysis

4.7.1 Physicochemical analysis of water and soil sample

Electric conductivity is a measure of the ability of aqueous solution to carry an electric current that depends on the presence and total concentrations of ions, their mobility, valance and on the temperature (Badawy *et al*., 2013) .Electric conductivity and pH were determined in soil with ratio of 1:1 and 1:10 soil to water ratio respectively, which was stirred for 30minutes, allowed to stand for another 30minutes and stirred again for 30second, the solution EC and pH were then measured.

4.7.2. Heavy metal analysis

The prepared transparent solution of compost, soil, water and vegetable sample was filtered through what man number 42filter paper and diluted to 100mL with distilled water. The concentrations of As, Cd, Cr, Pb, Cu and Zn in the filtrate were determined by using atomic absorption spectrophotometer in Laboratory Horticoop Ethiopia PLC (Horticulture).

4.8. Data Analysis

Statistical analysis Data of heavy metal concentrations in vegetables were checked for homogeneity of variance and normality. The data of heavy metal concentrations in all analyzed vegetables across the various sample sites was subjected to two-way analysis of variance (ANOVA) to assess the significance differences in heavy metal concentrations in soil and heavy metal concentration in vegetable. All statistical analyses was computed with SPSS software version 20(Woldetsadik *et al.*, 2017).

4.9. Quality assurance

Appropriate quality assurance procedures and precaution was carried out to ensure reliability of the results. All chemicals used during analysis were that of analytical grade (AG) reagen.All solutions were prepared with double distilled water. Calibration standards for each metal were prepared by making appropriate dilution of stock solution of 1,000 ppm of E. Merck standards (Roy &Gupta, 2016).

4.10. Quality control

Quality control measures were taken to assess contamination and reliability of data. For this Blank samples (zero metal concentration) was analyzed after fourth samples. Concentration was calculated on a dry weight basis. All analysis was replicated three times. The accuracy and precision of metal analysis was checked against standards (Standard Reference Material) for every heavy metal(Chauhan, 2014).

4.10.1 Accuracy

The accuracy of the method was determined by calculating percentage of recovery. It was carried out by adding known quantity of analyte solution in to the sample by the proposed method. Spike recovery analysis of each metal was made to determine the recovery due to matrix effects.

$$R = (Cs - c)/s * 100 \quad \text{……equation 1}$$

Where S=concentration equivalent of analyze added to the sample, Cs=metal content of the spiked sample, C=metal content of non-spiked sample, R=percent recovery

4.11. Method Detection Limit

Blank samples were digested following the same procedures utilized for digesting the vegetable, soil, and compost. Each blank was assayed for its metal contents (Cr, Cd, As, Zn, Cu and Pb) by FAAS. The standard deviations (SD) of the replicate blanks was calculated to determine the method detection limit (MDL) and limit of quantification (LOQ). Method detection limit (MDL) was calculated as three times the standard deviations (MDL = 3SD) and LOQ was calculated as ten times the standard deviation (LOQ = 10SD)(Deribachew, 2015).

4.12. Analytical method validation

Analytical method validation Efficiency of the optimized procedure used for digesting the vegetable samples, soil, and compost samples was checked by spiking the pre-treated vegetable, soil and compost samples with standard solutions of each metal having a known concentration. The spiked vegetables, soil, and compost samples was digested following the same procedure employed in the digestion of the respective samples(Deribachew, 2015).

4.13. Data Analysis

The geochemical results were interpreted using the pollution indices such as Transfer factor (TF) Health Risk index (HRI) and total hazard index (THI).

4.13.1. Soil-Plant transfer Coefficient (%).

Soil-plant transfer coefficient, also known as enrichment factor, enumerates comparative variations in heavy metals' plants. The coefficient depends on both soil and plant properties. The accrual of metals from soil to plant depends on factors like plant species, absorption capacity, soil type, and a metal chemical form. The soil-transfer coefficient was calculated as ratio of a heavy metal in a plant (dry weight) to a total heavy metal concentration in the soil as shown in the following equation:

$$Tc = C_{plant}/C_{soil} * 100 \quad \text{.......Equation 2}$$

Where TC is transfer coefficient (%), Cplant is heavy metal concentration in vegetable tissue (mg/100 g), and Csoil is metal concentration in soil (mg/100 g dry soil).

4.13.2. Estimation of Daily intake of heavy metal

Daily intake of heavy metals was calculated using the following equation (khan *et al*.., 2013)

$$EDI = \frac{Cm^{*}Cf^{*}Dfoodintake}{BW} \text{...Equation 3}$$

Where Cm= Heavy metals concentration in plants (mg/kg),

Cf= Conversion factor

D food intake= Daily intake of vegetables and

BW=Average body weight represent.

The conversion factor 0.085 was used to convert fresh green vegetable weight to dry weight as described by (Rattan *et al.*, 2005; Wang *et al.*, 2013).The average daily vegetable intakes for adults and children were considered to be 0.069 and 0.046 kg/person/day in Ethiopia (Marie *et al*., 2004; peam & Jeewon, 2015), respectively, while the average adult and children body weights were considered to be 53.057 and 31.04kg (WHO, 2015 and Ratul *et al.*, 2018).Exposure of consumers and related health risks are usually expressed as tolerable daily intake (DIM) as reference value established by FAO/WHO codex alimentarius commission(FAO/WHO,2001).Tables 10 represent the estimation of each heavy metal intake through consumption of studied food stuffs.

4.13.3. Health risk and total hazard quotient

4.13.3.1. Health risk index (HRI)

Health risk assessment of consumers from the intake of metal contaminated vegetables is characterized by using HRI (Xue *et al*., 2012). The HRI > 1 for any metal in food crops means that the consumer population faces a health risk. But Human are considered to be safe if HRI < 1. The following formula was used for the calculation of HRI (Khan *et al*., 2013):

$$HRI = DIM/RfD \text{..Equation 4}$$

Where, DIM= the average metal intake per day (mg/kg/day) and

RfD= approximation of daily tolerable exposure to which a person is expected to have without any significant risk of harmful effects during a life pan.

The RfD values for As, Zn, Cd, Pb, Cu and Cr are (0.050, 0.30, 0.001, 0.004, 0.04 and 1.5 mg/kg bw/day, respectively (Jan *et al.*, 2010).

4.13.3.2. Hazard Index (HI)

An exposure to more than one pollutant results in additive effects. Thus, hazard index (HI) is a vital index that assesses overall likely impacts that can be posed by exposure to more than one contaminant. When the HI is >1, this suggests that there are significant health effects from consuming pollutants contained in a foodstuff. The HI is calculated as an arithmetic sum of the hazard quotients for each pollutant as shown in the following equation.

$$HI = (HRIi + HRIii + HRIiii) \quad \text{......................................Equation 5}$$

4.14. Ethical Consideration

The permission letter from Jimma university post graduate school was given to the concerned bodies. The purpose of the study was explained to the town agriculture offices and kebele leaders and permission was asked from them with written letter. In addition, the farmers were asked for permission during sample taking from the farming site.

4.15. Dissemination of the results

The results of the finding will be disseminated for Jimma Town Administration, Jimma town urban agricultural office and Jimma University for further action and for the benefits of the community.

CHAPTER FIVE: RESULT

The calibration curves were prepared separately for all the metals by running different Concentration of standard solutions. The calibration curves for As, Cd, Cr, Pb, Cu and Zn were checked to ensure the accuracy and reliability of the instrument before running the FAAS, which are linear as shown in appendix.

5.1. Physicochemical and trace metal constituent of water, compost, soil, and vegetables

5.1.1. Physicochemical constituents of water sample

The results of the pH and EC of water samples were presented in table 3 below. The pH value of the water samples from two sampling points (Abdi Jimma and Aba Milki) farm site were 7.4±0.04 and7.2±0.04 respectively. The electrical conductivities (EC) of water samples for both farming site were 61±2.3µs/cm and 63.9±3.053µs/cm respectively.

5.1.2. Heavy metal concentration in water samples

The concentration of heavy metal in water sample from Abdi Jimma and Aba Milki farm sites were presented in table 3. The mean heavy metal concentration of As, Cd, Cr, Pb, Cu, and Zn in both farm site water sample were 0.1585±0.032mgL,$^{-1}$ 0.0903±0.01mgL^{-1}, 0.055±0.0041mgL^{-1}, 0.0115±0.002mgL^{-1}, 0.273±0.0019mgL^{-1} and 0.3965±0.0033mgL^{-1} respectively. The heavy metal concentrations of water used for cultivation of vegetables has minimal health impact during consumption when compared with FAO and WHO standards.

Table 2: Physicochemical and trace metal constituents of water samples

Site	pH	EC µs/cm	Heavy metal concentration in mg/L					
			As	Cd	Cr	Pb	Cu	Zn
Abdi Jimma	7.4+0.04	61±2.3	0.107+0.02	0.083+0.03	0.045+0.02	0.043+0.02	0.287+0.03	0.413+0.04
Aba Milki	7.2+0.04	63.9+3.0	0.21+0.022	0.098+0.03	0.065+0.02	0.18+0.03	0.26+0.02	0.38+0.03
Mean	7.3	62.45	0.158	0.0903	0.055	0.0115	0.2735	0.3965
SD	0.14	2.05	0.032	0.0106	0.0041	0.002	0.0019	0.0033
FAO (1989)	6.5-8.4		0.1	0.01	0.1	5	0.2	2
WHO(2001)					3	0.01	2	5

5.2. Physicochemical and trace metal constituent of municipal solid waste compost

The physicochemical and concentrations of heavy metal in municipal solid waste compost were given in table 4 below. The pH value of the MSWC samples from two sampling points (Abdi Jimma and Aba Milki) were 7.9±0.05, and 7.6±0.04, respectively. The electrical conductivities (EC) of MSWC for both farming site were 2.36±0.06sm/cm for Abdi Jimma and 2.01±0.06sm/cm for Aba Milki farming site.

Table 3: Physicochemical and trace metal constituents of MSW compost sample

Sample Site	pH	EC sm/cm	Heavy metal concentration mg/kg					
			As	Cd	Cr	Pb	Cu	Zn
Abdi Jimma	7.9±0.05	2.36±0.06	1.60±0.22	0.51±0.14	0.56±0.02	5.68±0.32	4.61±0.25	75.25±3.2
Aba Milki	7.6±0.04	2.01±0.06	1.23±0.13	0.80±0.09	0.483±0.03	4.62±0.4	5.043±0.38	62.97±2.9
Mean	7.75	2.1850	1.415	0.655	0.5215	5.15	4.83	69.11
SD	.21213	0.2474	0.2616	0.205	0.054	0.749	0.306	8.68
EU (2002) standard			10	0.7		45	70	200
Indian standard	5.5-8.5			5	50	100	300	

5.3. Heavy metal concentration in MSW Compost samples

The concentration of heavy metal in MSWC sample from Abdi Jimma and Aba Milki farm site were presented in table 4. The mean heavy metal concentration of As, Cd, Cr, Pb, Cu, and Zn in both farm site were 1.415±0.26mg/kg, 0.655±0.2mg/kg 0.52±0.05mg/kg, 5.15±0.7mg/kg, 4.83±0.3mg/kg, 69.11±8.68mg/kg respectively.

5.4. Physicochemical composition of soil in farming site

The electrical conductivity and pH of the soil on which vegetable grown were measured and the results were shown in table 5 below**.** In this study**,** the observed ranges in the electrical conductivity of the soil samples in both farming site were 0.16ms/mc-0.83ms/mc. The pH value of the soils sample for Abdi Jimma and Aba Milki farming site were in the range 7.1-7.67.

5.5. Heavy metal concentration of soil in farming site

The concentration of heavy metals investigated in soil sample from the farming site was shown in table 4. As can be seen, clear differences were found in the concentrations of the heavy metals between the farming sites. The heavy metals' levels in soil were highest for Zn followed by Pb, Cu, As, Cr, and Cd. The levels of heavy metals in soil samples ranged from 1.08±0.13 to 1.65±0.08mg/kg, from 0.41±0.07 to 0.54±0.22mg/kg, from 0.46±0.12 to 0.57±0.07mg/kg, from 3.02±0.32 to 5.60±0.21mg/kg, from 3.47±0.19 to 6.07±0.25mg/kg, and from 36.94±0.34 to 116.37±3.71mg/kg for As, Cd, Cr, Pb, Cu, and Zn respectively, with mean concentration of 1.43mg/kg, 0.485mg/kg, 0.528mg/kg, 4.406mg/kg, 4.355mg/kg, 68.65mg/kg and respectively.

Table 4: Physicochemical and trace metal constituents of soil samples

Sample site	Sample code	pH	EC ms/cm	Concentration of heavy metal in mg/kg					
				As	Cd	Cr	Pb	Cu	Zn
Abdi Jimma	P1	7.61±0.43	0.61±0.21	1.65±0.08	0.54±0.21	0.57±0.07	5.60±0.21	6.07±0.25	116.37±3.71
	P2	7.50±0.39	0.24±0.04	1.49±0.24	0.54±0.22	0.54±0.09	4.47±0.08	4.20±0.07	109.09±1.86
	P3	7.21±0.52	0.28±0.01	1.61±0.052	0.50±0.09	0.56±0.06	4.96±0.067	5.08±0.06	66.91±2.12
	P4	7.67±0.46	0.46±0.032	1.46±0.033	0.47±0.06	0.53±0.05	4.64±0.25	3.86+0.09	45.52±2.71
	P5	7.58±0.65	0.16±0.07	1.45±0.07	0.48±0.06	0.52±0.03	4.40±0.4	4.22±0.054	36.94±0.34
Aba Milki	P6	7.1±0.64	0.47±0.05	1.08±0.13	0.49±0.023	0.53±0.071	3.02±0.32	3.71±0.13	61.58±0.69
	P7	7.43±0.49	0.83±0.24	1.51±0.07	0.45±0.083	0.46±0.12	3.81±0.076	4.13±0.068	59.32±2.3
	P8	7.37±0.38	0.54±0.15	1.19±0.21	0.41±0.071	0.51±0.20	4.35±0.12	3.47±0.19	53.49±4.51
	Mean	7.43	0.449	1.43000	0.48500	0.52750	4.406	4.355	68.652
	SD	0.199	0.218	0.197195	0.043753	0.0337	0.519949	0.651261	24.1203
Control soil		7.16±2.4	0.26±0.001	1.1±0.032	0.39±0.04	0.41±0.028	3.06±0.082	2.31±0.06	7.68±0.28
FAO,2001					0.02-0.5	0.002-0.2	0.3-10	1-12	12-60
EC, 2002				20	0.003	0.15	0.3		

Table 5: Comparison of Metals in Soil Samples with Different Standards (mg/kg)

Element	Mean value	Dutch	FAO	EU	Austria
Pb	4.406	85	0.3-10	300	100
Cd	0.485	0.8	0.02-0.5	3	5
Cr	0.528	100	0.002-0.2	150	100
Cu	4.355	36	1-12	140	100
Zn	68.67	140	12-60	300	300

Source, Chiroma *et al., 2014,*Maleki *et al., 2014)*

5.6. Heavy metal concentration in vegetable

The concentrations of the heavy metals in the edible parts of the 5 species vegetables are summarized in Table 6. In both farming site heavy metals levels revealed significant variations in the five studied vegetables. The levels ranged from 0.421±0.03 to 1.314±0.07mg/kg for As, from 0.0001±0.0001 to 0.115±0.004mg/kg for Cd, from 0.0385±0.005 to 0.692±0.024mg/kg for Cr, from 0.0003±0.0002 to 0.5734±0.04mg/kg for Pb, from 0.003±0.002 to 12.032±0.46mg/kg for Cu, from 31.18±3.43 to 188.987±6.13mg/kg for Zn.

Table 6: Heavy metal concentration in vegetables

Site	vegetable	As	Cd	Cr	Pb	Cu	Zn
Abdi Jim	tomato	0.709+0.05	0.112±0.002	0.422±0.08	0.0003±0.0002	0.003±0.002	31.18±3.43
	beetroot	0.5955±0.08	0.037±0.002	0.402±0.06	0.0007±0.0002	7.391±0.31	55.197±2.1
	lettuce	1.083+0.05	0.115±0.003	0.692±0.24	0.5734±0.04	3.258±0.12	84.195+4.8
	Onion	0.421±0.03	0.0001±0.0001	0.0385±0.05	0.0007±0.0003	0.976±0.03	33.42±2.21
	spinach	1.314±0.07	0.049±0.002	0.511±0.091	0.474±0.02	12.032±0.46	188.987±6.13
Aba Milki	tomato	0.53±0.05	0.24±0.002	0.401±0.06	0.007±0.002	0.086±0.05	27.36±1.02
	Onion	0.342±0.04	0.0021±0.002	0.057±0.047	0.00815±0.002	1.24±0.09	41.62±0.954
	spinach	0.82±0.31	0.041±0.002	0.36±0.007	0.351±0.03	1.68±0.23	61.94±1.42
Mean		.72681	.07453	.36044	.17691	3.33313	65.48738
SD		.333432	.079635	.218921	.246812	4.250007	53.384413
WHO(2007)		0.43	0.20	5	0.3	40	60

Samuel *et al* (2018)

5.7. Soil-Plant Transfer Coefficients

The soil-plant transfer coefficient, also known as enrichment factor, enumerates comparative variations in heavy metals' bioavailability to plants. Soil-plant transfer coefficient is an imperative component of human exposure to heavy metals through food chain as it describes movement of contaminants from soil to plants. The findings in Table 7 indicate that all the five vegetables had high Zn transfer coefficients followed by Cu, Cr, As, Cd, and Pb. Among the vegetables, *spinach and lettuce* had highest transfer coefficients for Zn, Cu, Cr, and As

Table: 7. Transfer coefficient of heavy metal from soil to vegetable

Site	Vegetable	Heavy metal transfer factor					
		As	Cd	Cr	Pb	Cu	Zn
Abdi Jimma	Tomato	0.4297	0.2074	0.74	$5.357e^{-5}$	0.000495	0.268
	Beetroot	0.4	0.0685	0.7445	0.0001566	1.759	0.506
	Lettuce	0.673	0.23	1.236	0.1156	0.6413	1.257
	Onion	0.288	0.000213	0.0726	0.015	0.2528	0.734
	Spinach	0.906	0.102	0.9827	0.108	2.85	5.12
Aba milki	Tomato	0.4907	0.4898	0.58	0.00116	0.218	0.41
	Onion	0.2265	0.00467	0.196	0.00213	0.06	0.58
	Spinach	0.689	0.0512	0.78	0.081	0.61	0.511
Experimental mean results		0.82	0.0626	0.413	0.209	0.7989	1.173
Recommended Max. limit for vegetables, WHO, 2001		0.43	0.20	2.30	0.3	40	

5.8. Soil results correlation Analysis

Correlation analysis was carried out for inter-metallic and pH parameters association to understand the significance ($p < 0.05$) of association among the metals and the pH. The Pearson correlation coefficient matrix for trace heavy metals (AS, Cd, Cr, Pb, Cu and Zn) and pH of the soil samples are presented in Table 9. The analysis of interrelationship between the heavy metals and pH offers remarkable information on the free ions availability. The computed statistical results shows that Cr has moderately significant positive correlation with Cd and Pb(r =0.698,* 0.680*) while Zn, and Pb have weak negative correlation with As. Cd has weak insignificant positive correlation with Pb, Cu, Zn and pH (r =0.486, 0.103, 0.270, 0.147) respectively. Pb, Cu and Zn have weak negative correlations with pH (r = -0.386, - 0.187, -0.128) respectively

Table.8: Correlation coefficient matrix for the trace metals in soil samples

Parameter	As	Cd	Cr	Pb	Cu	Zn	PH
As	1						
Cd	.513	1					
Cr	.297	.698*	1				
Pb	-.227	.486	.680*	1			
Cu	.289	.103	.002	.213	1		
Zn	-.018	.270	.198	.219	.546	1	
PH	.524	.147	.023	-.386	-.187	-.128	1

**. Correlation is significant at the 0.01 level (2tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

5.9. Comparison of heavy metal in soil and vegetables

The concentration of heavy metals in vegetables and their respective soil was show in table 9 below and the concentration of heavy metals were higher in soils than vegetables grown on respective soil except Zn and Cu in spinach and Lettuce vegetables. This indicates that only small portion of soil metal is transferred to Vegetables and the root acts as barrier to the translocation of heavy metals within plant (Mohammed *et al*., 2011).But there is general weak correlation between concentration of metals in soils and vegetables.

Table 9: Comparison of heavy metal in vegetable and soil

Site	Vegetable	As_v	As_s	Cd_v	Cd_s	Cr_v	Cr_s	Pb_v	Pb_s	Cu_v	Cu_s	Zn_v	Zn_s
Abdi Jimma	Tomato	0.709	1.65	0.112	0.54	0.442	0.57	0.0003	5.60	0.003	6.07	31.18	116.37
	Beetroot	0.595	1.49	0.037	0.54	0.402	0.54	0.0007	4.47	7.39	4.20	55.19	109.09
	Lettuce	1.083	1.61	0.115	0.56	0.56	0.692	0.5734	4.96	3.25	5.08	84.19	66.99
	Onion	0.421	1.46	0.0001	0.47	0.038	0.53	0.0007	4.64	0.976	3.86	33.42	45.52
	Spinach	1.314	1.45	0.049	0.48	0.511	0.52	0.474	4.40	12.032	4.22	188.98	36.94
Aba Milki	tomato	0.53	1.08	0.24	0.49	0.401	0.53	0.007	6.02	0.086	4.81	27.36	81.58
	Onion	0.342	1.51	0.0021	0.45	0.057	0.46	0.0082	3.81	1.24	5.36	41.62	79.32
	spinach	0.82	1.19	0.0021	0.41	0.36	0.51	0.351	4.35	1.68	4.87	61.94	103.49

Which has also been reported (Agbenin *et al.*, 2009) indicates that other sources such as foliar absorption might have contributed to heavy metals load in vegetables. Moreover, the transfer coefficient depends on bioavailability of a metal itself, levels of metal in soil, chemical form of a metal, plant uptake capabilities, and plant species growth rate (Tinker, 1991).

5.10. Distribution of heavy metal in farming site from the four different sources

Distribution of heavy metal in farming site of water, soil, vegetable, and compost was listed in the following fig.

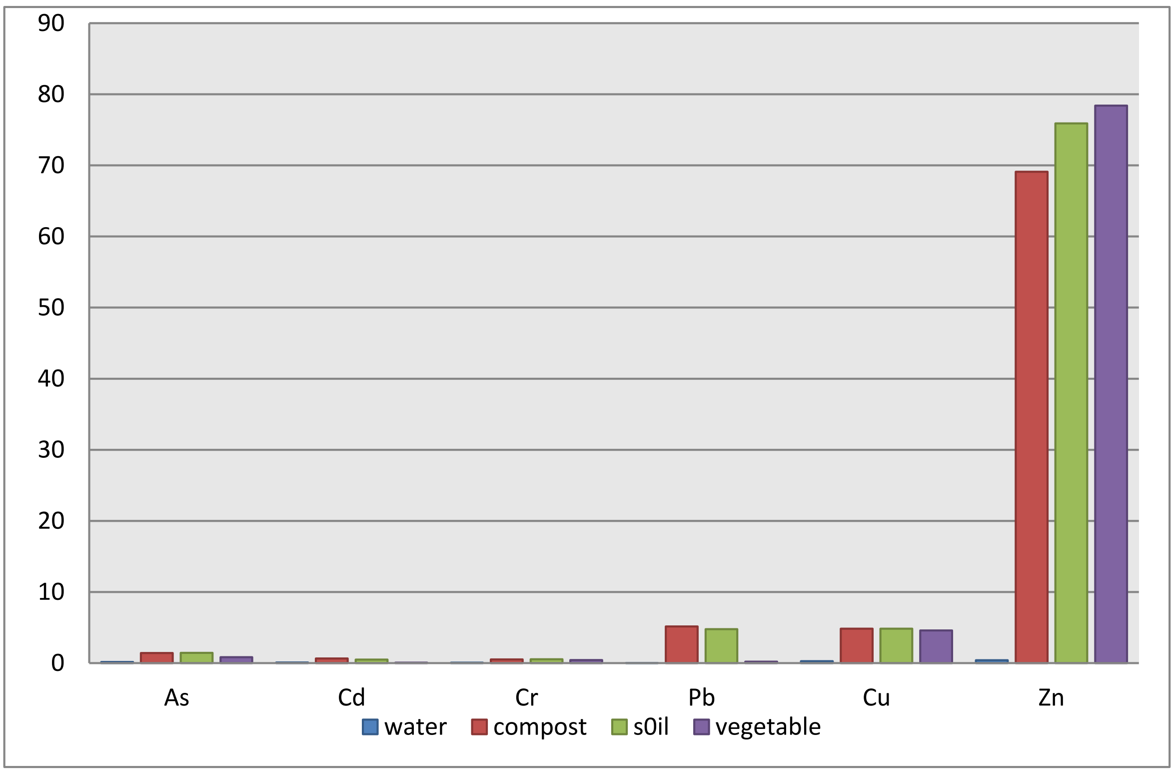

Fig 2 Heavy metal distribution in different source

5.11. Estimation of Daily intake of heavy metal

The EDI of metals was evaluated according to the average concentrations of each metal in each food crops and the respective daily consumption rate (Zhuang *et al.*, 2009).

Exposure of consumers and related health risks are usually expressed as tolerable daily intake (DIM) as reference value established by FAO/WHO codex alimentarius commission(FAO/WHO,2001).Table 10 represent the estimation of each heavy metal intake through consumption of studied food stuffs.

Table10.Daily intake of heavy metal from vegetables

Sample site	Vegetable	Category	As DMI	Cd DMI	Cr DMI	Pb DMI	Cu DMI	Zn DMI
Abdi Jimma	Tomato	Adult	$7.86E^{-5}$	$1.2E^{-5}$	$4.6E^{-5}$	$3.3E^{-8}$	$3.3E^{-7}$	0.0034
		Child	$8.9E^{-5}$	$1.4E^{-5}$	$5.3E^{-5}$	$3.7E^{-8}$	$3.7E^{-7}$	0.0039
	Beetroot	Adult	$6.5E^{-5}$	$4.0E^{-6}$	$4.4E^{-5}$	$7.7E^{-8}$	$8.1E^{-4}$	0.0061
		child	$7.5E^{-5}$	$4.6E^{-6}$	$5.0E^{-5}$	$8.8E^{-8}$	$9.3E^{-4}$	0.007
	Lettuce	Adult	$1.1E^{-4}$	$1.2E^{-5}$	$7.6E^{-5}$	$6.3E^{-5}$	$3.6E^{-4}$	0.0093
		Child	$1.4E^{-4}$	$1.4E^{-5}$	$8.7E^{-5}$	$7.2E^{-5}$	$4.1E^{-4}$	0.0106
	Onion	Adult	$4.6E^{-5}$	$1.1E^{-8}$	$4.2E^{-6}$	$7.7E^{-8}$	$1.0E^{-}$	0.0036
		Child	$5.3E^{-5}$	$1.25E-^{8}$	$4.8E^{-6}$	$8.8E^{-8}$	$1.2E^{-4}$	0.0042
	Spinach	Adult	$1.5E^{-4}$	$5.4E-^{6}$	$5.6E-^{5}$	$5.2E^{-5}$	0.0013	0.02
		Child	$1.6E^{-4}$	$6.1E^{-6}$	$6.4E^{-5}$	$5.9E^{-5}$	0.002	0.024
Aba Milki	tomato	Adult	$5.8E^{-5}$	$2.6E^{-5}$	$4.6E^{-5}$	$7.7E^{-7}$	$9.5E^{-6}$	0.003
		Child	$6.6E^{-5}$	$3.02E^{-5}$	$5.3E^{-5}$	$8.8E^{-7}$	$1.08E^{-6}$	0.0034
	onion	Adult	$3.7E^{-5}$	$2.3E^{-7}$	$6.3E^{-6}$	$9.0E^{-7}$	0.000137	0.0046
		child	$4.3E^{-5}$	$2.6E^{-7}$	$7.1E^{-6}$	$1.0E^{-6}$	0.000158	0.00524
	spinach	Adult	$9.0E^{-5}$	$4.5E^{-6}$	$3.9E^{-4}$	$3.85E^{-5}$	0.00019	0.0068
		child	$1.0E^{-4}$	$5.1E^{-6}$	$4.5E^{-4}$	$4.4E^{-5}$	0.00021	0.0078

5.12. Health risk and total hazard quotient

The exposure routes to the target organisms are used to detect the health risk of any pollutant as it is very essential to estimate exposure level. There are many pathways of heavy metals exposure to humans. Ingestion of vegetables contaminated with significant amounts of heavy metal could cause harm to the human health.

The human health risk associated with the average daily dose was determined manually using the mean concentrations of Cd, Cr, Pb, As, Zn and Cu in the various vegetables and their results are presented in Table11. It is evident that HQs were all less than 1 for all vegetables for both adults and children. Hence, there is no need for concern regarding the continuous consumption of the vegetables in terms of potential health risk.

Table11: Health risks and Hazard quotient

Site	Vegetable	category	As HRI	Cd HRI	Cr HRI	Pb HRI	Cu HRI	Zn HRI	THQ
Abdi Jimma	Tomato	Adult	0.0016	0.012	$3.0E^{-5}$	$8.2E^{-6}$	$8.2E^{-6}$	0.011	0.024
		Child	0.0018	0.014	$3.5E^{-5}$	$9.2E^{-6}$	$9.2E^{-6}$	0.013	0.029
	Beetroot	Adult	0.0013	0.004	$2.9E^{-5}$	$1.9E^{-5}$	0.02	0.02	0.045
		Child	0.0015	0.0046	$3.3E^{-5}$	$2.2E^{-5}$	0.023	0.023	0.052
	Lettuce	Adult	0.002	0.012	$5.0E^{-5}$	0.016	0.009	0.031	0.07
		child	0.003	0.014	$5.8E^{-5}$	0.018	0.01	0.035	0.08
	onion	Adult	0.0009	$1.1E^{-5}$	$2.8E^{-6}$	$1.9E^{-5}$	0.003	0.012	0.0159
		Child	0.001	$1.2E^{-5}$	$3.2E^{-6}$	$2.2E^{-5}$	0.003	0.014	0.018
	spinach	Adult	0.003	0.0054	$3.7E^{-5}$	0.013	0.033	0.069	0.12
		Child	0.003	0.0061	$4.2E^{-5}$	0.015	0.05	0.08	0.15
Aba Milki	tomato	Adult	0.00116	0.026	$3.0E^{-5}$	$1.9E^{-4}$	$2.3E^{-4}$	0.01	0.03761
		child	0.00132	0.0302	$3.5E^{-5}$	$2.2E^{-4}$	$2.7E^{-5}$	0.0113	0.043
	onion	Adult	$7.4E^{-4}$	$2.3E^{-4}$	$4.2E^{-6}$	$2.2E^{-4}$	0.0032	0.015	$1.9E^{-2}$
		child	$8.6E^{-4}$	$2.6E^{-4}$	$4.7E^{-6}$	$2.5E^{-4}$	0.0037	0.02	$2..4E^{-2}$
	spinach	Adult	0.0018	0.0045	$2.6E^{-4}$	0.0096	0.0047	0.022	0.042
		Child	0.002	0.0051	$3.OE^{-4}$	0.011	0.0052	0.026	0.049

CHAPTER SIX: DISCUSSION

6.1 Physicochemical constituents of water sample

The pH and EC of water sample were measured by using digital pH meter and EC was measured by portable probe and the result was recorded and shown in table 2. The mean pH of both farming site were 7.3 which was in line with (FAO, 1985) safe limit range 6.5-8.4 for water used for irrigation .The EC of water sample was measured and result show that 61µS/cm and 63µS/cm it was in line with (FAO,1985) guidelines which was 70µS/cm. According to the present result the pH and EC of the irrigation water cannot affect the metal mobility of heavy metal in the irrigation water since the acidity and alkalinity of the water was in the neutral condition and ions in the water was very low when we see their EC.

6.1.1 Heavy metals in water sample

Mean concentrations of selected heavy metals in irrigation water samples collected from both farming sites are given in Table 2. Across the two sampling sites, except Zn and Cd the metals concentrations are in line with the recommended maximum limit for irrigation water set by FAO (Ayers and Westcot, 1985).

The mean concentrations of As, Cd, Cr, Pb, Cu and Zn were 0.158$\pm$0.072mg/L, 0.09$\pm$0.0106mg/L,0.055$\pm$0.0141mg/L,0.0115$\pm$0.097mg/L,0.2735$\pm$0.019mg/L,0.3965$\pm$0.0233 mg/Lrespectively. As compared to the concentrations reported in the present study, (Aschale *et al.*,2015) reported lower mean ranges of Cd(0.04–0.06µg L-1),Cu (3.3–6.6ugL-1), Pb(1.4–5.1 µg L-1), Cr (2.4–255 µg L-1) and Zn (10.9–22.5 µg L-1). But the mean cadmium concentration in the water sample from this study 0.09mgL^{-1} was in line with 0.06mg/L(Direbachew *et al.*, 2015) and greater than (WHO and FAO/2011) which recommended the maximum permissible level 0.01mg/L but less than 0.10mg/L which reported by (khan *et al.*, 2013).

The mean lead concentration in the water sample from the present study 0.0115mg/L was greater than study conducted by (Aschale,2015) which reported 1.6ug/l, but much less than the (WHO and FAO/2011) guidelines for safe limit which was 5mg/L in water used for irrigation. The heavy metal concentrations of water used for cultivation of vegetables has minimal health impact during consumption when compared with FAO and WHO standards.

6.2. pH, Electric Conductivity and Heavy Metals Concentrations in Municipal Solid Waste compost in both farming site.

The mean pH values of the municipal solid waste compost were 7.75 which are lower than the finding of similar study at Harar city on MSWC (8.05) by (Alemayehu, 2017). pH values of Municipal solid wastes compost (MSWC) were relatively alkaline (7.8 and 7.6) for Abdi Jimma and Aba Milki farming sites, respectively (Table 4). pH range of 6.5 to 8 is acceptable for composting, and most common feed stocks fall within this range (TDMSW, 2013). The recorded pH for both sites were close to the similar finding by (Karim *et al*., 2014) at Matuail and Khulna MSW compost 7.76 and 7.95 respectively, in Bangladesh. MSWC pH increase to some extends. This increase in pH is due to the mineralization of C and subsequent production of OH^- ions by ligand exchange as well as introduction of basic Cations, such as K^+, Ca^{++} and Mg^{++}. (Brady and Weil, 1995) had reported that micronutrients and metal Cations are most soluble and available for plant uptake under acidic conditions so MSWC would help in mitigating the heavy metals availability.

Electrical conductivity: EC of the municipal solid wastes compost were 2.36 and 2.01ms/cm at Abdi Jimma and Aba Milki farming sites, respectively as shown in (Table 3). The recorded EC for both sites were higher than (Manju *et al.*, 2013) 0.58-0.83µS/cm finding in India. (Brady and Weil 1995), were reported EC levels ranges from 0.369 - 0.749 mS/cm in MSWC which is below the present study. In the present study the pH and EC values are within the limits to be used as green compost.

6.2.1. Heavy metals concentrations in municipal solid waste compost

The concentrations of most heavy metals (As, Cr, Zn, and Pb) in municipal solid waste compost at Abdi Jimma farming site were relatively greater than at Aba Milki farming site (Table 3).More accumulation of electronic wastes was observed during compost samples collection at Abdi Jimma than Aba milki farming site. Therefore, higher concentration of these metals at Abdi Jimma might be due to more electronic waste.

The recorded Cd concentration was close to the similar finding by (Mamtaz and Chowdhury2006) and (Adjia *et al*., 2008) to be 0.8 mg/kg and 0.48 mg/kg in municipal solid waste compost respectively. Concentration of Zn (69.11 mg/kg), Cu (4.83 mg/kg), and Cr

(0.5215 mg/kg) were greater than the finding of similar study in Harari city (Alemayehu 2017), but concentration of Cd and Pb were low. The difference could be due to the composition and types of waste. (Lawan *et al*.,2012) reported that concentration of heavy metals in waste vary from time to time and site to site due to variables such as waste composition, moisture content and types of wastes. At both farming sites concentration of zinc Higher than others heavy metals. High level of Zinc could be attributed to zinc containing organic waste, zinc batteries and fluorescent lamps increase the concentration of Zink in compost. (Ayari *et al*., 2010) also reported higher zinc concentration than other heavy metal concentrations in MSWC.

Application of these municipal solid wastes as organic fertilizer to soils may be major potential source of metal pollution into farm lands. At both farming site these compost used as organic fertilizers. Therefore, these heavy metals can easily enter in to the food chain through soil to plant system. (Alexander, 2014) revealed that soil to plant transfer is a major pathway of human exposure to toxic metals via the food chain.

The transfer of metals from the compost into the soil and subsequently into the vegetables could be expected. Therefore, excessive use of these municipal solid wastes as organic fertilizer may be the pathway for transferring heavy metals to human beings and cause serious health problems. Generally, the concentrations of heavy metals recorded in municipal solid wastes compost were below the WHO and EU limits but continuous use of this compost as organic fertilizer may be hazardous for plants and human being. The use of municipal solid waste compost over long period increases the heavy metal contents of soils above the permissible limit. Ultimately, increasing the heavy metal content in soil also increases the uptake of heavy metals by plants depending upon the soil type, plant growth stages and plant species (Afzal *et al*., 2011).

6.3. PH, Electrical conductivity and Heavy metals Concentrations in Soil at Abdi Jimma and Aba Milki farming Sites.

In this study, conductivity of the soil samples collected from Abdi Jimma and Aba Milki farmlands were determined at 25^0c.Electrical conductivity and pH were determined in soil with ratio of 1:10 soil water ratio and the result revealed that electrical conductivity in the collected soil samples were in the range 0.16ms/cm-0.83ms/cm(table 4)in both farm site.

The EC of the soil in the present study was less than the FAO/1985 recommended safe limit value for soil. The pH value of the soils ranged were 7.1-7.67 (table 4). According to (Hizkeal, 2012) soil with pH range of 6.6-7.4 are neutral. Based on this classification, soil sample collected from vegetable growing areas in both farmlands with the value of the range 7.1 to 7.67 were neutral. The recorded pH of soil from municipal solid waste compost amendment site in (Aba Milki and Abdi Jimma) farm sites are relatively less than the mean values of similar studies by Hunachew and Sandip, (2011) in Addis Ababa and in Cameroon by Adjia *et al.*, 2008*)*. pH is one of the factors which influence the bioavailability and the transport of heavy metal in the soil and heavy metal mobility decreases with increasing soil pH due to precipitation of hydroxides, carbonates or formation of insoluble organic complexes (Uduma, 2013).

The amount of heavy metals mobilized in soil is function of pH, properties of metals, redox conditions, soil chemistry, organic matter content, clay content, cation exchange capacity and other soil properties (Uduma, 2013).According the current result, the pH of the soil sample has no effect in the mobilization of heavy metal from one point to another, the metal in the soil will maintained to its original place, and it can be up take by respective vegetable grown on it. The result of pH was in line the WHO guidelines which was 6.5-8.4 for soil.

6.3.1. Heavy metals concentration in soil.

The distribution of heavy metals in the cultivated soils is shown in Table 4. The sequence of heavy metal total concentrations in soils was Zn >Pb>Cu >As>Cr>Cd. The heavy metal total concentrations of the cultivated soils were significantly higher on the farming sites amended with MSWC compared to the control soil with no waste. Which show presence of metal containing wastes contributing enormously to heavy metal pollution. This is in agreement with the results obtained from similar study by (Amusan *et al.*, 2005).(Ideriah *et al.*, 2006) also reported higher levels of some heavy metals in soils around designated municipal solid waste dump site compared to the control site.

As shown in Table 4, the recorded results of accumulated heavy metals in soil showed that zinc, Copper, Lead has the higher value at Abdi Jimma farming site than Aba Milki relative to other heavy metals. The possible sources of these heavy metals could be road runoff and atmospheric deposition (Tasrina *et al.*, 2015).This is due to the fact that the Abdi Jimma farm sites are about 30m from the Jimma to Bonga main road, which is round the clock a busy road with heavy traffic.

This indicates that Heavy metal pollutants such as copper (Nyangababo and Ichikuni, 1986) lead and zinc (Alloway and Davies, 1993) from additives used in gasoline and lubricating oils are emitted from heavy traffic road and deposited on road side soil and vegetation.

Cadmium (Cd): Cd was also detected in soil at both farming sites as indicated (Table 4). The mean recorded results were 0.485mg/kg. It was more concentrated in farming sites soil than the control sites soil. Recorded results for Cd were also greater than WHO standard (0.02 – 0.5 mg/kg) for Abdi Jimma farm site (0.506) but Aba Milki farm site in line with WHO standard. (Tamiru, 2006) reported that the Cd content of Burayu MSW dumping area was (0.05mg/kg), which is lower than the Cd content in soil at present study. But lower than similar study at Addis Ababa MSW dumping area site soil was 2.41±2.4mg/kg *(*Hunachew and Sandip, 2011). This might be due to differences in generated and composition of MSW compost amended to soil.

Chromium: The mean concentration of Cr in soil at farm site was 0.528mg/kg. Its concentration was greater than the results reported by (Alemayehu, 2017) for similar study at Harar city. Mean Cr concentrations in soil were higher than critical permissible level which is0.002-0.2mg/kg for soil recommended for agriculture. Chromium concentrations in soil at both sites were also lower compared to the result (269 mg/kg) reported by (Tamiru, 2006) in Addis Ababa. This might be due to site differences and repeated application of MSW compost amended to soil.

Lead: maximum contamination levels for lead in soil are 0.3-10, 85, 100 and 300 mg/kg for WHO, Dutch, Austria and EU standards, respectively (table 5). Its concentrations were below the standard limits except the WHO limits. Lead concentrations in soil at both sites were also lower than the report of (Hunachew and Sandip, 2011) for MSW dumping area in Addis Ababa. Concentrations of lead in soil from control area were lower than in soils from MSWC amendment farming site areas. This indicates long term application of MSWC increase hazardous heavy metal concentration at farming site compared to control area. According to (Moturi *et al*., 2004), Pb ion is less mobile in soil compared with other heavy metal ions.

Copper: The mean Concentrations of Cu in soil was 4.84mg/kg. The recorded results show that concentrations of Cu in soil at farming sites were greater than the control sites (2.31mg/kg). This due to long term application of MSWC contributed to increased concentration of Cu in soils at the farming sites. The investigation found higher concentration of Cu compared to that in the soil of Harar (2.18) mg kg-1 as reported by (Alemayehu, 2017). The study obtained lower concentration of Cu compared to that in the soil of Gazipur (55-65) mg kg-1 as reported by Habib *et al*. (2009). Though higher than mean values reported in soils of Tunisia (73.56 mg/kg) as reported by (Ayari *et al*., 2010).This is due to composition and repeated application of municipal solid waste compost. In general, Cu concentrations in the investigated soil were unpolluted since it is below the maximum acceptable limit of 70-80 mg/kg set by Federal Environmental Protection Agency, (FEPA, 1997).

Zinc: The concentration of zinc in soils was in the range of 36.94-116.37mg/kg which was the highest relative to the concentration of other Five heavy metals analyzed (Table 4).Lower level of Zn were obtained in the investigated soil when compared to mean values obtained by (Chukwuocha *et al.*, 2015) reported 268.67 mg/kg of Zn in top soils of Owerri, Imo state, Nigeria. Concentrations in soil at both sites were also lower than the report of(Ayari *et al.*, 2010) (151.4mg/kg) in Tunisia. But its concentration was greater than the results reported by (Alemayehu, 2017) for similar study at Harar city. concentrations in soil at both sites were higher than the accepted standards (12-60) mg/kg suggested by (Odukoya *et al.*, 2000).The abundance of zinc in the soil is due to high concentration level of Zink in MSW compost, and atmospheric deposition from busy road with heavy traffic.

6.4 Heavy Metals concentration in Plant

Concentrations of heavy metals in edible parts of the analyzed vegetables are summarized in Table 6.Accumulation of metals in edible vegetables poses a great threat to human health especially to local communities that collect vegetables which are growing on contaminated soil by municipal solid waste compost and waste water. For this reason the International and national regulations on food quality have lowered the maximum permissible levels of toxic metals in food items due to an increased awareness of the risk, these metals pose to food chain contamination(Radwan MA, 2006).

The concentrations of heavy metals in vegetables differ from one sampling location to the other and vary from one species of vegetable to the other. This may be attributed to differential uptake capacity of vegetables for different heavy metals through roots and their further translocation within the plant parts (Zurera *et al*., 1989; Vousta *et al.,* 1996). It can also be due to soil characteristics such as acidity and organic matter contents and ability of the root type of the plants to penetrate where the heavy metals are found (Okoronkwo*et al*., 2006). Among all heavy metals analyzed, the concentration of Zn (188.987 mg/kg dw) detected in *spinach* was the highest and that of Cd (0.0001mg/kg dw) detected in *onion* was the lowest in all vegetables analyzed. Similar results were reported by (Radwan and Salama, 2006and Charles Kihampa *et al.*, 2011) in Tanzania in which highest concentration of Zn and lowest concentration of Cd were detected in vegetables.

Arsenic. The concentration of As obtained was from 0.342- 1.314mg/kg. All of the vegetables, concentration of As was higher than the permissible level (0.1mg/kg). Its highest and lowest concentrations were recorded in spinach (1.314mg/kg) and onion (0.342mg/kg) respectively from the farming sites. Similar result was recorded by (Okorosaye-Orubite *et al*., 2017) in Nigeria. (Bhupendra *et al.*, 2014), reported concentration of As in some common vegetables in Yamuna flood plains, New Delhi. The range of As concentration according to their work varied from 0.6 to 2.52mg/kg which were well above present study.

Concentration of Arsenic is high in leaf vegetable than root and fruit in this study. Similar study in leafy vegetables grown in Addis Ababa and their toxicological implications ‘reported (ATSDR, 2004) that the content of Arsenic was found to be (1.04) Lettuce and Swiss chard (1.21) those collected from Kera. This reported result by those authors is in line with present study. This is due to foliar absorption of As from atmosphere. As is also largely present in the atmosphere and finds its way into the soil during the rainy season principally in form of As^2S^{-2} as mineral salts. Arsenic is a general protoplasmic poison and it affects small systems in the body. It is a cumulative poison. The concentration of arsenic exceeding the maximum permissible limit (0.03mg/Kg) in food stuff cause short term (nausea, vomiting, diarrhea, weakness, loss of appetite, cough and headache) and long term (cardiovascular disease, diabetes and vascular diseases) health effects. Arsenic poisoning also affects bone marrow and cellular elements of blood. Arsenicals are known to be carcinogenic to lungs. They may also lead to skin cancer through the initial skin lesions.

Cadmium. Mean Cd concentrations were the list in vegetables harvested from Abdi Jimma and Aba Milki farming sites, than the other heavy metal with levels ranging from 0.0001mg/kg (onion) to 0.24mg/kg (tomato) dry weight. The recorded result was below the RML standard. Higher Cd levels which surpassed the recommended maximum limit were reported by Okorosaye-Orubite *et al*., (2017) in Nigeria. Conversely, lower levels of Cd in vegetables at various vegetable farming sites of Addis Ababa were reported by (Aschale *et al.*, 2015) and (Mekonnen *et al*., 2015). Cadmium levels exceeding the RMLs were reported by (Gupta *et al*., 2010).Cd uptake by plants is partly limited by presence of calcium, phosphorus and chelating compounds in the soil (Wieczorek *et al*., 2004).

Chromium. Mean Cr concentrations among vegetable were in the order of Lettuce (0.692mg/kg)>spinach (0.551mg/kg)>tomato (0.422mg/kg)>beetroot (0.402mg/kg)>Onion (0.0385mg/kg. The mean levels of Cr in vegetables in the present study were significantly lower than FAO/WHO limit values. It was observed that lower concentrations of Cr were recorded in the present study, when compared with other studies.(Gupta *et al.*, 2008) recorded mean concentration of (34.83-96.30 mg kg-1) in West Bengal, India. (Sharma *et al*., 2007) observed mean Cr level of (5.37-27.83 mg kg-1) in Varanasi, India, while (Charlse *et al.*,2011) recorded values ranging from 1.15-29.29 mg/kg in vegetables grown in the application MSWC as organic fertilizer. Which were all higher than the result of the present study but chromium content in vegetables was below values reported in (Francis Chizoruo, 2017) in Nijeria (0.08mg/kg). The low concentration of Cr in the farm site could be due to low concentration Cr in soil and leaching capabilities of the metal to deeper part of the soil (Banks *et al*., 2006).

Lead. The highest Pb concentration in vegetables obtained from farm site was recorded in leaf vegetables (lettuce 0.5734) and the least in root vegetables (beetroot <0.0007). In this study, the concentrations of Pb are quite generally higher than the permissible levels by WHO 0.3 mg/kg in leaf vegetable but low in root and fruit vegetable. Lead content in vegetables was below values reported in Titagarh, West Bengal, (21.59-57.63 mg/kg) and also lower than the mean concentration of Pb (409 mg/kg) reported in vegetables from

Turkey by (Turkdogan *et al.*,2002) but comparable with Pb level reported (0.18-7.75 mg/kg) in China (Liu *et al.*, 2005). In leafy vegetables the accumulation of airborne lead largely exceeds the soil borne part taken up via roots.

This confirms the Pb levels of vegetables analyzed previously in Addis Ababa's urban vegetable farming sites (Weldegebriel *et al.*, 2012) and with results reported from other African cities (Muchuweti *et al.*,2006; Odai *et al*., 2008; Lente *et al.*, 2012). The high levels of lead in some plants may probably be attributed to pollutants due to pollution from the main road traffic (Akinola and Njoku *et al*., 2007). Leafy vegetables from open field have been documented to possess higher concentrations of Lead (Pb) than vegetables grown in green houses due to anthropogenic sources of contamination (Song *et al*., 2009). According to (Hamilton *et al.*, 2005), plant roots can absorb Pb but may not translocate it to shoots. In fact, high soil pH, clay and organic matter content are not supporting Pb uptake via roots. Pb is highly toxic heavy element and its intake via vegetable consumption can cause both acute and chronic poisoning. It has adverse effect on liver, kidney, vascular and immune system (Satter *et al*., 2016).

Copper. Concentrations of Cu in vegetables across the 5 vegetable farming sites were varied and all are very low when compared to WHO (40mg/kg) permissible level for food. At Abdi Jimma, ranged from 0.003 (Tomato) to 12.032mg/kg (Spinach), in Aba Milki farming site they ranged from 0.086mg/kg (tomato) to 1.68mg/kg (spinach). However, the concentration of Cu recorded in the present study is higher than the mean concentration of Cu (2.00 ±1.174) mg /kg observed by (Aktaruzzaman *et al.*, 2013).

Lower concentrations of Cu in various vegetables were also reported in selected vegetable farming sites in Addis Ababa and its outskirts (Aschale *et al.*, 2015; Mekonnen *et al.*, 2015; Alam *et al.*,2003) reported mean Cu concentrations of 15.5mg kg-1 and 8.51 mg kg-1in leafy and non-leafy vegetables respectively from Samata village, Jessor, which is higher than the present findings.

In this study higher Cu concentration recorded in leaf vegetable (12.032mg/kg).Similarly higher mean concentration of Cu (22.19-76.50) mg kg-1 was reported in leafy vegetable species from Turkey (Demirezen and Aksoy, 2006). According to this study the concentration of Zn, Cu, As, and Pb where highest in the leafy vegetables than root this could be attributed to the fact that the sampling site is very near to the main asphalt road from Jimma to Bonga towns. In Abdi Jimma, farm site, this entertains many vehicle, traffics throughout 24 hours all the seasons and assists the more deposition of those elements from car exhausts in to the nearby farmlands.

Zinc. The level of Zn in the vegetables from sampled farms ranged from 27.36 mg/kg to 188.987mg/kg with the highest recorded in *spinach* and the least in *tomato* from Abdi Jimma and Aba Milki farm site respectively. The mean concentrations of zinc in the analyzed vegetable were higher than the WHO guideline values. Higher Zn levels which surpassed the recommended maximum limit were reported by (Alexander Uriah *et al.*, 2014) (424.77mg/kg) in Nigeria. Conversely, lower levels of Zn in vegetables at various vegetable farming sites of Nigeria were reported by (Okorosaye-Orubite *et al.*, 2017).

The abundance of zinc in the vegetable is due to high concentration level of Zink in compost, soil and water increasing the concentration level of Zink in vegetable and the other is location of the farm, which is situated along the hectic road traffic. Generally, Cu and Zn, which are important nutrients for humans, are considered a much lower health risk to humans than Pb, Cd, and As (Tariq *et al.*, 2006). Poor health can be caused by a lack of these required elements (Voutsa *et al.*, 1996) but excessive ingestion can also have adverse effects on human health (Rahman *et al.*, 2014)

6.5 Transfer of heavy metals from soils to vegetables

In order to assess the transfer of heavy metals from soil to vegetable, the transfer factor (TF) values of six heavy metals were calculated (Table 7). It defined as ratio of heavy metal concentration in vegetable (dry weight) to that in soil (dry weight) (Cui *et al.*, 2004; Liu *et al.*, 2005).The mean values of TF for As, Cd, Cr, Pb, Cu and Zn were 0.539, 0.121, 0.669, 0.0478, 0.755 and 1.167 respectively. The TF values were greatly lower than the results reported by (Liu *et al.*, 2005; Alexander *et al.*, 2014) and which may be related to the low plant concentrations in this study. The mean TF values of six heavy metals showed the trend as Zn>Cu>Cr>As>Cd>Pb. Zn had the highest TF and Pb had the lowest in this study.(Naser *et al.*, 2011) reported similar result where they observed that Zn had the highest transfer factor among other metals. From the findings, the soil-plant transfer coefficients are directly related to the observed levels of heavy metals.

The highest coefficient value for Cu and Zn might be due to increased contamination through municipal solid waste compost application, foliar transfer after deposition of atmospheric particles on the leaf surfaces, higher mobility of these heavy metals with a natural occurrence in soil (Alam *et al.*, 2003) and the lower retention of them in the soil than other cations (Zurera *et al.,* 1987).The highest and lowest TF for were found in leaf spinach and tomato, respectively. The highest and lowest TF for Cu was observed in spinach and tomato, respectively. Lettuce had highest TF for Cr and spinach for Zn.

These findings indicate that Zn has higher transferability, while *spinach* is having high absorbing capability followed by *Lettuce.* Moreover, the transfer coefficient depends on bioavailability of a metal itself, levels of metal in soil, chemical form of a metal, plant uptake capabilities, and plant species growth rate (Tinker, 1981). As a whole, tomato as a kind of fruit vegetable had relatively lower TF for Cd, Pb, Zn and Cu, compared to the leafy vegetables. Therefore, tomato was recommended to cultivate considering the food safety in this area. In the general weak correlation between concentration of metals in soils and vegetables which has also been reported. (Agbenin *et al*., 2009) indicates that other sources such as foliar absorption might have contributed to heavy metals load in vegetables.

6.6. Daily intake of metals (DIM)

The values estimated daily intake of metals by human being from the consumption of the vegetables grown using MSWC are presented in Table 10.The daily intake of metals (DIM) were calculated to averagely estimate the daily metal loading in to the body system of specified body weight of consumer (Ratul *et al.,* 2018).DIM may be the realistic estimate for the average intake of metals from vegetable. For each individual metal measured in the present study were substantially lower than the values reported for other countries (Alexander Uriah *et al*., 2014) in Nigeria. Trend of the metal in take from all vegetables were Zn>Cu>As>Cr>Hg>Pb>Cd. The provisional tolerable daily intakes (PTDIs) for Cd, Cr, Cu, Pb and Zn are 0.06mg, 0.2mg, 3mg, 0.214mg and 60mg, respectively (National Research Council, 1989). For each individual metal measured in the present study, none of the EDIs exceeded its corresponding PTDIs, nor did approach the doses. The DIM values suggested that the consumption of vegetables grown in agricultural soil with municipal solid waste compost were nearly free of risks. This low DIM may be due to low concentration of heavy metals and low consumption pattern of vegetable in the area.

6.7. Health risk index (HRI)

To assess the human health risk of heavy metals, it necessary to calculate the level of human exposure to that metal by tracing the route of exposure of pollutant to human body. There are many exposure routes for heavy metals that depend up on a contaminated media of soil and vegetables on the recipients. Receptor population use the vegetable enriched with higher concentration of heavy metals which enters the human body leading to health risks (khan *et al.*, 2013).The estimated HRI for both adults and children for consumption of vegetables for all measured heavy metal were given in table 11. Trend of health risk of heavy metals for the consumption of vegetables are Zn>As>Cu>Cd>Pb>Cr. The present study was much lower than the study conducted by Alexander Uriah *et al.*, (2014) in Nigeria.

The result revealed that HRI for all measured heavy metals for all studied vegetables are lower than 1 indicating nearly free of risks for the consumer. This may be due to low vegetable consumption pattern in the area and low concentration of heavy metal in vegetable, but the health risk may raise in long term consumption of the heavy metals contaminated vegetables by local community through accumulation in the body and it needs great attention for the future.

6.8. Total hazard quotient (THQ)

The total metal THQ (sum of individual metal THQ for the analyzed vegetables) is shown in table 11.The results in table 11 show that the highest THQ was found in spinach (0.12 *)* followed by Lettuce (0.08)>Beetroot (0.05)>Tomato (0.029)>Onion(0.018). When the THQ surpasses unity, this tells us that eating of the vegetable can cause health effects. In the studied sites, the consumption of all analyzed vegetables resulted in THQ values of less than 1,it is clear that heavy metals pose nearly free of risk to local inhabitants through the consumption of vegetables grown on MSWC amendment soil vegetable farming sites.

However, it is worth considering the effects that may result from the interaction of the metals. Additionally, for special populations, such as those with a weak constitution, those that were sensitive, and women that were pregnant, the potential health risks of heavy metal accumulation through vegetable consumption were likely to be higher than for the normal population. However, vegetable consumption was just one part of food consumption. In addition to vegetable consumption, rice (Zheng *et al.*, 2007), meat (Bortey-Sam *et al.*, 2015), fish (Wang *et al.*, 2005) and tobacco (Dong *et al*., 2015) consumption also led to ingestion of large amounts of heavy metals. For the residents of mining area, food consumption, inhalation of soil particles, drinking water, and dermal contact were the important pathways for human exposure to toxic metals (Zhu *et al*., 2011).

CHAPTER SEVEN: CONCLUSION AND RECOMMENDATION

7.1. Conclusion

What has emerged from this study is the revelation that the application of municipal solid wastes as organic fertilizer in vegetable gardens is a major source of metal pollution into farmlands. Consequently vegetable grown on such contaminated farmland with high heavy metals concentrations will absorb such metals depending on the metal uptake capabilities and storage. The mean concentration of As, and Zn in vegetable was found higher than the safe limits by different organizations. The transfer factor (TF) of different plant species vary from one type to another. Soil to plant transfer is a major pathway of human exposure to toxic metals via the food chain.

The transfer of metals from the compost into the soil and subsequently into the vegetables has been established.TF values for As, Cd, Pb and Cr for various vegetables were not significantly high since it was less than 1, but Zn and Cu in spinach vegetable greater than 1.DIM values suggested that the consumption of vegetable grown in agricultural soil with the amendment of municipal solid waste compost is nearly free of risks because it is below the daily tolerable intake of metal. Trends of health risk of heavy metals for the consumption of vegetables were Zn>As>Cu>Cd>Pb>Cr. The result revealed that HRI for both measured heavy metals were lower than 1 indicating safe for consumers. But in the long term application of municipal solid waste compost on agricultural farm gradually increase the concentration in the environment and along the food chain and thus can cause serious health problems. There for, significant attention should be paid to prevent excessive buildup of heavy metal in the food chain by regular monitoring in municipal solid waste compost, agricultural soil and vegetables. Natural compost preparation from waste materials requires detail characterization and selecting waste items with low concentration of heavy metals. These results may serve as a base line data for determination of heavy metal in compost, soil and vegetable in the study area.

7.2. Recommendation

The composition of MSWC and the soils from which vegetable crops are grown should be monitored and regulated to reduce its adverse effects on human health.

Based on the findings of this study; it is recommended that further research work should be carried out to study the levels of heavy metals in vegetables in and around Jimma in order to maintain and or improve measures to reduce their levels in vegetables and ultimately prevent these avoidable health problems.

For the future continuous composting of MSW can create serious environmental and health problems. So, the Jimma municipal should design other waste management methods like separates waste based on source and type then recycling, and treatment system modern sanitary landfill site should be designed.

The potential health risks of heavy metals through other exposure pathways should be the subject of future study.

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Annex 1

Determination of calibration curve for heavy metals

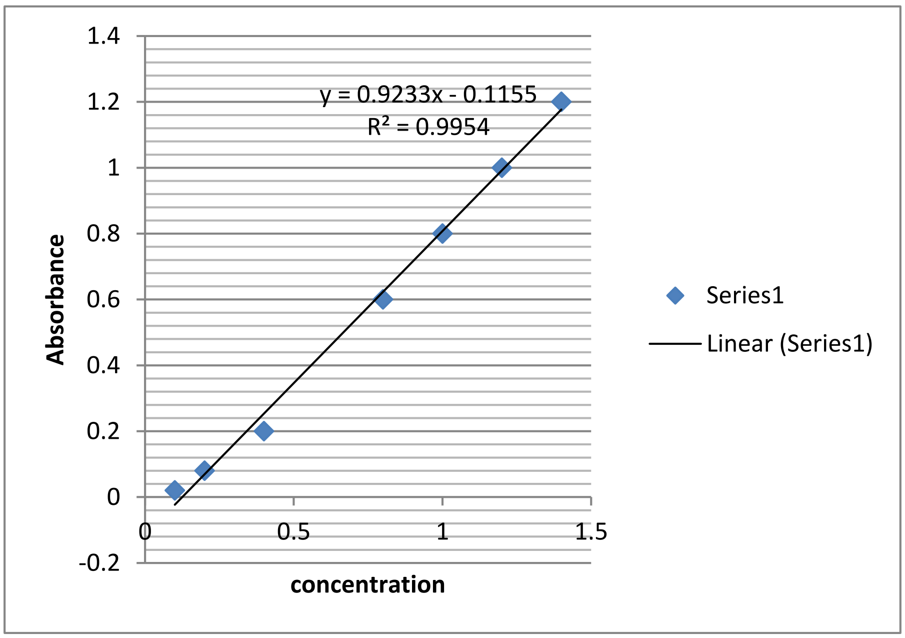

Fig 3 calibration curve for Arsenic

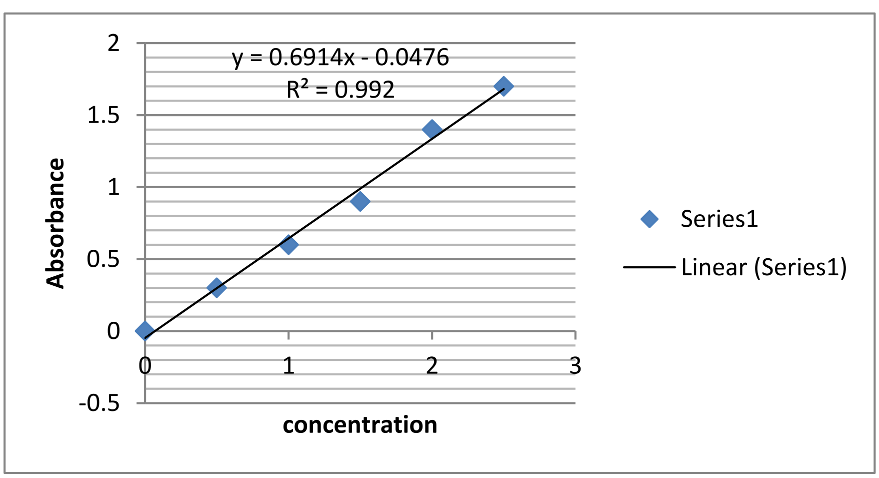

Fig 4 calibration curve for cadmium

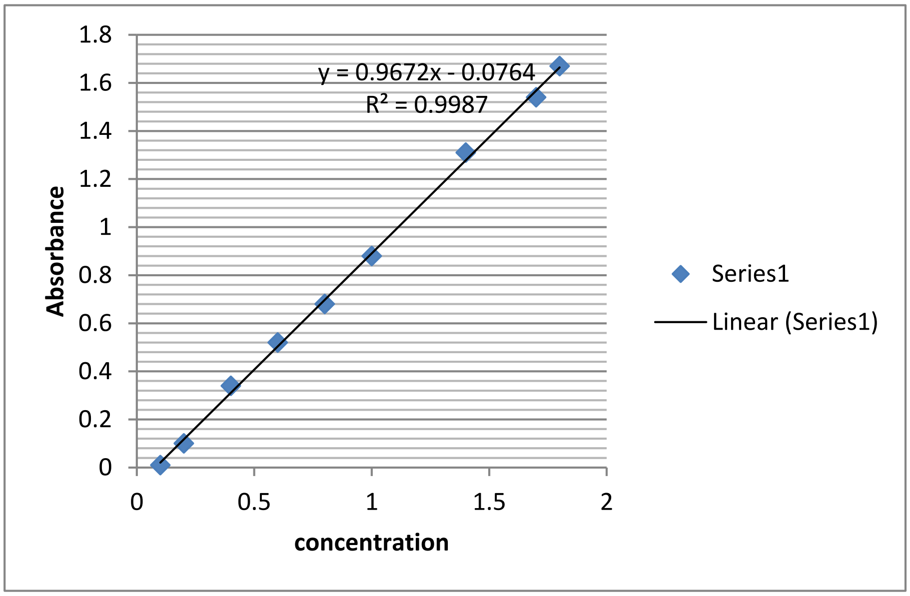

Fig 5 calibration curve for lead

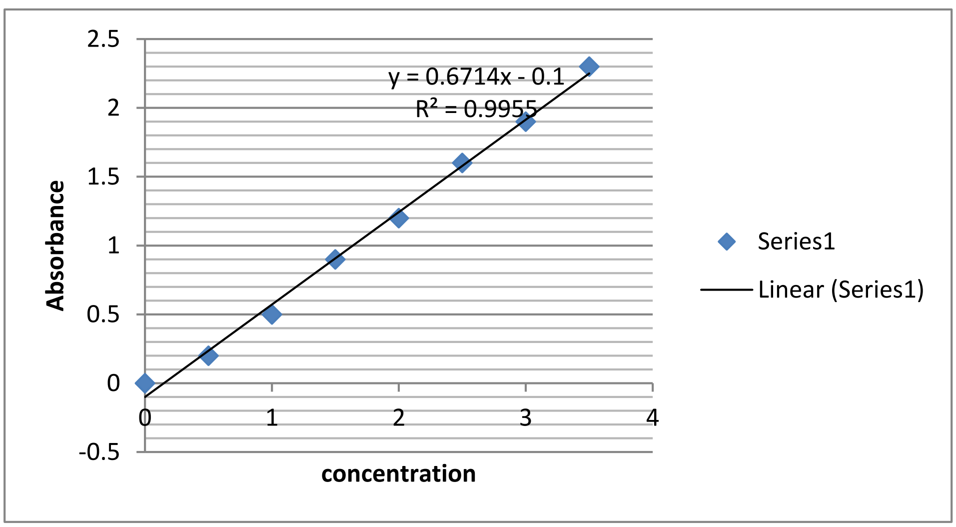

Fig 6 calibration curve for Zink

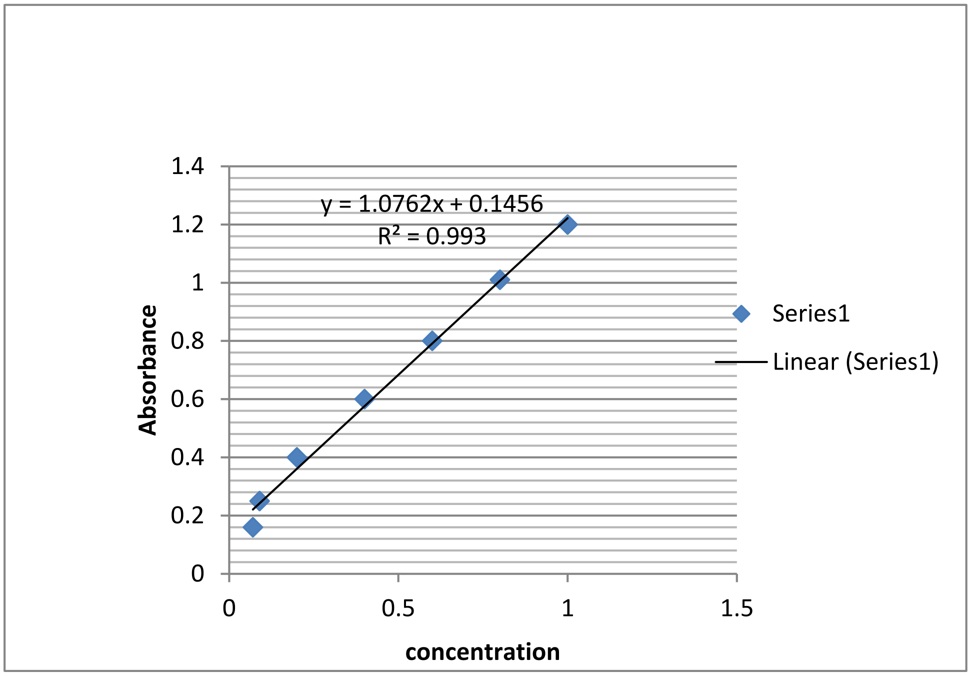

Fig 7 Calibration curve for Chromium

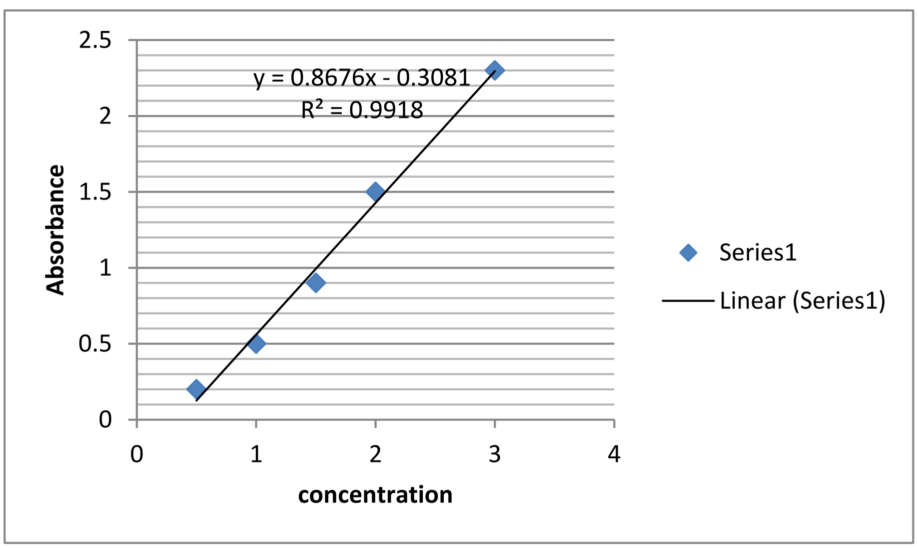

Fig 8 calibration curve for copper

Annex 2

Method detection limit, Limit of quantification and % of recovery

sample	Metal	MDL	LOQ	%Recovery
vegetable	As	0.0325	0.325	102.71
	Cd	0.000302	0.00302	103.6
	Cr	0.002788	0.02788	95.9
	Pb	0.000279	0.00279	98.21
	Cu	0.000346	0.00346	101
	Zn	0.00894	0.0894	102

Annex 3

Proposed Standards for MSW Compost in Developing Countries by mg/kg

Heavy metals proposed standards

Arsenic	10
Cadmium	3
Chromium	50
Copper	80
Lead	150
Mercury	1
Nickel	50
Zinc	300