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Heavy Metals Concentrations in Leafy Vegetables in Jenin and Bethlehem Districts

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Heavy Metals Concentrations in Leafy Vegetables in Jenin and Bethlehem Districts

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Dedication

This work is dedicated to those who gave me life and grew me up, my parents who were always my supportive. I owe them each moment of my life.

To my beloved brothers and sisters.

To my valuable treasure my husband, for his endless love and support.

To the memory of my dear grandmother.

Declaration

I Certify that this thesis entitled "Heavy Metals Concentration in Leafy Vegetables in Jenin and Bethlehem Districts" submitted for the degree of Master is a result of my own research, except where otherwise acknowledged, and that this study (or any part of the same) has not been submitted for a higher degree to any other university or institute.

Name: Elizabeth Charly Kattan

Signed........................

Date: 17/01/2018

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List of Abbreviations	
mg/L	Milligram per Liter
cm	Centi Meter
mg/kg	Milligram per Kilogram
^{o}C	Degree Celsuis
ICP-MS	Inductively Coupled Plasma Mass Spectrometry
MARS	Microwave Digestion System
WHO	World Health Organization
g	Gram
ND	Not Detected
pH	Potential Hydrogen
ppb	Parts-per-billion, 10^{-9}
GIS	Geographical Information System
PCBS	Palestinian Central Bureau of Statistics
CA syringe	Cellulose Acetate syringe
µm	Micro meter
mm	Milli meter
FAO	Food and Agricultural Organization

Abstract

Leafy vegetables are an edible plant leaves. This kind of vegetables are rich in vitamins and nutrients. However, leafy vegetables should not contain heavy metals over a range of concentrations which could pose potential health risk to the consumers. Contamination with heavy metals is considered to be an environmental issue as these metals are toxic even at low concentrations. This study was conducted to determine heavy metals concentration in leafy vegetables in two regions in the West Bank which are Bethlehem and Jenin districts. Thus, vegetable samples, particularly spinach, arugula, and parsley, had been collected from different farms from both regions, and analysed for different heavy metals (Fe, Pb, Cr, Co, Cu, Mn, Cd, and Zn) by using ICP-MS. For some samples, the results were found to be exceeding WHO/FAO permissible limit for human consumption, while other samples were found to be within the safe allowable limit. Fe was found to be the highest in concentration while Mn and Co were the lowest. Pb and Zn concentrations varied between high and low, then comes Cr, Cu, and Cd. Soil samples in addition to irrigation water samples had been also analysed for their content of heavy metals in order to correlate the environmental factors to heavy metal contamination. However, all concentrations were below the limit set by WHO/FAO. Thus it was concluded that the contamination found in leafy vegetables samples was not related to either irrigation water or soil. Furthermore, some pesticides samples were analysed as well, where in fact the contamination with heavy metals was found. Thus, it was concluded that contamination of leafy vegetables with heavy metals was directly related to usage of pesticides. As a result, the elevated levels of metals in vegetables in the two regions was attributed to utilization of pesticides.

Chapter One

Introduction

Chapter One

1. Introduction

During the last decades, food safety has become a major concern all over the world. As well, the increasing demand of food safety has moved research towards the risks associated with food contaminated by heavy metals, toxins, or pathogens (Mello, 2003).

Palestinians in the West Bank have counted on agricultural activities for thousands of years. Farming and agriculture are actually activities that help the economic situation of the West Bank, because such activities provide Palestinians with food and jobs. Accord

ing to American Near East Refugee Aid (ANERA), agriculture makes up to 5% of the GDP and 12% of the labour force. Around 183,000 hectares of land in Palestine are cultivated (International Trade Centre, 2014). Farmers mostly plant olives, citrus fruits, grapes, vegetables, herbs, and wheat. Regarding the products, farmers sell mostly vegetables and fruits through low-cost daily markets. Other crops like tomatoes, cucumbers, eggplants, etc. supply the Israeli markets. In this manner, agriculture plays a huge role in the region’s future with its extreme effect on the economy of the West Bank (American Near East Refugee Aid, 2013).

However, Palestinian farmers face many challenging conditions due to the political situation in the West Bank and blockade restrictions to exportation of products and importation of inputs, as well as dry seasons, and water scarcity (American Near East Refugee Aid, 2013).

The main water source in the west bank region is ground water. 70% of the available water to Palestinian countries is used for agriculture. According to World Health Organization (WHO), 60 litres of water per capita each day is recommended to maintain general health and needs. But in Palestine, the average is estimated to be less than 30 litres per capita per day. Water scarcity is increasing and agriculture in West Bank is facing a challenge (American Near East Refugee Aid, 2013).

Reaching to a major point is the use of fertilizers and pesticides. Palestinian farmers are restricted to use fertilizers or pesticides by the Israeli authorities. Thus, farmers use cheap, chlorine-based fertilizers which are known to increase the soil salinity and accelerate soil degradation, not to mention its negative impacts and accumulation in vegetables that ends up affecting human health (American Near East Refugee Aid, 2013). In whatever way and according to the International Labour Organization, agriculture is considered a hazardous sector due to the risk that is posed on farmers' health, related work injuries and related diseases.

The current study conduct a comprehensive assessment for heavy metals concentration in some leafy vegetables, in particular spinach, arugula and parsley in which the study areas are different in climate, rain fall, human activities and industrial activities.

1.1 Vegetables

Vegetables are of high importance to human health. In everyday usage, human beings tend to consume vegetables as they are an essential source of antioxidants and remarkably healthy. Vegetables have many advantages to human health, starting with helping in weight loss. According to the U.S Department of Agriculture, people must consume at least three cups of green vegetables per week. In addition, vegetables are full with fibres, minerals, and vitamins which can help human body in digestion, protect the body from heart diseases, diabetes, and cancer (Science of Eating, 2014).

Leafy vegetables or so called potherbs are low in calories and fat. They are also photosynthetic tissues. This also means that the levels of vitamin K is particularly high compared to other kinds of vegetables, and that is because phylloquinone is involved in photosynthesis (Kessler, F., et al.,2014). However, they are high in vitamin C, pro- vitamin A and protein per calorie (Conde Nast, 2014).

Leafy vegetables may be consumed raw, cooked, stewed, or steamed. It is however important to vary vegetables and note the consumed quantity. As for the benefits of vegetables as well as fruits, they include reducing heart diseases and stroke, lower the blood pressure, helps in better vision, balance the blood sugar and prevent some types of cancer in addition to helping in digestive problems.

Researchers have found from the Harvard studies with several long-term studies in the U.S. and Europe that individuals who eat more than 5 servings of fruits and vegetables per day had roughly a 20 percent lower risk of coronary heart disease (He, F.J., et al., 2007) and stroke, compared with individuals who eat less than 3 servings per day (He, F.J., et al., 2006).

Regarding other benefits of consuming vegetables is the protection against some types of cancer. A report by the World Cancer Research Fund and the American Institute for Cancer Research proposes that vegetables such as lettuce and other leafy greens, broccoli, cabbage, as well as garlic, and onions protect against several types of cancers, such as mouth cancer , throat, voice box, and stomach cancer; fruits may protect against lung cancer (Wiseman, M., 2008). Moreover, leafy vegetables are believed to be a solution for diabetes and can prevent the eyes from aging-related diseases such as cataracts and macular degeneration (Cho, E., et al., 2004).

Vegetables in the West Bank vary throughout the governorates. In fact there are wholesale markets for selling agricultural products among West Bank governorates. Through these wholesale markets, the agricultural products are provided by the farmers and end up with the consumer (ARIJ, 2014). These markets also provide a variety of vegetables, fruits, and crops. Among those plants are Arugula, Spinach and Parsley.

1.1.1 Arugula

Arugula in the West Bank is grown in different areas such as Jenin, Bethlehem, and Hebron. It is mostly eaten raw as salad. The Arabic name is Jarjeer.

It is a strong-tasting edible green leafy plant with the scientific name Eruca sativa from kingdom Plantae. It has a tangy flavour. Arugula is quite popular in the Mediterranean region, Morocco, Syria, Lebanon and east Turkey (Blamey, M., et al., 1989).

In regards to Aggregate Nutrient Density Index (ANDI) which measures minerals, vitamins, and phytonutrient content and caloric content ; arugula lies among the top 20 foods since it has high content of nutrients for small amount of calories (Ware, M., 2016).

Figure (1.1): Arugula
Credit: Elizabeth Kattan

Arugula which is also known as rocket and rucola, is rich in vitamin C, potassium, and high nitrate levels (Ware, M., 2016).

According to the Medical News Today (MNT) knowledge Centre, which provides a nutritional breakdown of arugula and finds the possible health benefits, many studies have shown that arugula reduces the blood pressure since the levels of nitrate is quite high which in turn reduces the amount of oxygen needed in any activity and promote athletic performance (Ware, M., 2016). Some other studies done by the same centre have suggested that consuming more arugula can reduce the risk of diabetes, heart diseases, and obesity; in addition to helping in blocking the carcinogenic effects of heterocyclic amines generated when grilling foods at high temperature since it contains chlorophyll (Ware, M., 2016).

Regarding other health benefits of arugula is the prevention of osteoporosis; because arugula contributes to the daily body need for calcium. Arugula also contains adequate amount of potassium which improves the bone and reduces the risk of bones fractures (Ware, M., 2016).

As arugula considered a leafy green vegetable, it contains an antioxidant known as alpha-lipoic acid that helps in lowering the glucose levels, and increases the insulin sensitivity (Ware, M., 2016).

1.1.2 Spinach

Spinach in the West Bank is widely used. It is planted mostly in spring with regards to the temperature. In addition, it can be cooked or eaten raw or with salty pastry.

It is an edible plant that belongs to the kingdom Plantae. The scientific classification of Spinach is that the genus is Spinacia and the species is S.oleracea. Spinach binomial name is Spinacia oleracea. It is originally from central and western Asia. Spinach belongs to the family Amaranthaceae, and to the subfamily Chenopodioideae (Alagbe M.A., 2013).

Figure (1.2): Spinach
Credit: Elizabeth Kattan

Basically, spinach often grows up to 30 cm height; and there are three types of spinach which include the Savoy, the smooth-leaf spinach, and the semi-savoy (Alagbe M.A., 2013).

According to the USDA Nutrient Database, the nutritional value per 100 grams of raw spinach contains about 3.6 grams of carbohydrates, 2.2 grams of dietary fibres, 2.9 grams of protein, and vitamins which include vitamin A, K, B_1, B_2, B_3, B_6, B_9, C; in addition to lots of minerals that include calcium, magnesium, manganese, and iron.

Regarding minerals, Spinach contains 21% of the daily value of iron in 100 grams amount of raw spinach (USDA Nutrient Database, 2014). On another hand, spinach also contains high levels of oxalate that is considered iron absorption inhibiting substance, that can link to iron and form ferrous oxalate giving more iron that is unusable by the body (Noonan, S., et al., 1999).

As any other food, the production or marketing or storage of spinach might affect its quality and its nutritional contents (State, P., 2003). Fresh spinach loses some of its nutritional value if storage for many days.

It is important to mention the benefits of spinach on human health. Starting with anti-inflammatory, anti-cancer, antioxidant, stress-related problems, heart diseases, and bone problems (World’s Healthiest Foods, 2016).

Besides all the health benefits of spinach, still; it is one of the most contaminated leafy vegetable by pesticides (Environmental Working Group, 2015). According to the Environmental Working Group the most available pesticides found on spinach are DDT, dimethoate, and permethrin.

1.1.3 Parsley

Parsley in the West Bank is well known. It is mostly planted between August and February. Parsley is used in salads. It is a species of Petroselinum that belongs to the family Apiaceae.
It is described as a biennial herb. It is originally native to the Mediterranean region. Its name 'Petroselinum crispum' comes from the Greek word meaning rock celery (Lewis et.al., 1879).

Figure (1.3): Parsley
Credit: Elizabeth Kattan

As parsley is biennial plant, when grown the first year, it takes the form of bright green herb and its leaves 10-25 cm long with numerous 1-3 cm leaflets. However, in the second year, its leaves grow with a stem of about 75 cm tall with numerous 2mm diameter yellow to yellowish- green flowers (Blamey, M. et al., 1989).

Parsley grows in moist and well-drained soil with (22-30) °C temperature. Thus it is widely used Middle East region. However, Parsley is also used in European and American cooking (Jett J., 1980).

Related to Parsley's benefits on human health, it is an excellent source of vitamin C and A. As vitamin C is considered antioxidant and anti-inflammatory agent that can help in conditions as osteoarthritis and rheumatoid arthritis (Pattison DJ. et al., 2004).

Parsley also contains volatile oils including myristicin, limonene, eugenol, and alpha-thujene. Besides that are flavonoids that include apiin, apigenin, crisoeriol, and luteolin (Sasaki N. et al., 2003). Due to the presence of such volatile oils, Parsley is described as 'chemo-protective' food.

Additionally, parsley is a source of folic acid which has a role in cardiovascular health as well as cell division (Sasaki N. et al., 2003).

Despite all of its benefits, if parsley is consumed excessively by pregnant women, it can cause uterotonic effects (Wolters Kluwer Health Inc., 2004).

1.2 Agricultural Soil Types in Bethlehem and Jenin regions

1.2.1 Terra Rossa Soil

Terra rossa is a type of red clay soil produced by limestone weathering. The term Terra rossa is Italian and means red soil or red earth. Terra rossa soil is commonly found in regions such as the Mediterranean. This is due to its climate, heavy rainfall and warm dry seasons (Schaetzl et al., 2005). Terra rossa occurs in areas where heavy rainfall dissolves carbon from calcium carbonate parent rock and silicates are leached out of the soil to leave residual deposits.

Figure (1.4): Terra Rossa Soil
Credit: Elizabeth Kattan

Terra rossa is clay-rich soil and reddish. When limestone weathers, the clay in the rocks with insoluble rock materials are left behind, and under oxidizing conditions, iron oxide forms in the clay when the soil is above water table giving the red colour. However, compared to other clay soils, terra rossa has drainage characteristics (Harriet D., 2001).

1.2.2 Grumusol Soil

It is fine textured alluvial or aeolian sediments. It is mostly transferred from highlands. Grumusols mix between terra rossa and terra preta characteristics. The quality of soil fertility is suitable for high productivity and agriculture. It is rich in calcium and magnesium. Grumusol is usually found in grasslands or mountain valleys. This type of soil has the ability to retain moisture which is needed for summer cultivation. However, in winter this soil is described as soft, while in dry summers it forms solid agglomerates (Harriet D., 2001).
Grumusols are also found in the north and far west of the West Bank, corresponding with low-lying areas that has more temperature climate than other parts of the highlands.

Figure (1.5): Grumusol Soil
Credit: Elizabeth Kattan

1.3 Heavy Metals

In recent years, there has been an increasing ecological and global public health concern associated with environmental contamination by heavy metals especially with the rise in human exposure to these metals and their potential risks (Bradl H., 2002).
Heavy metals are defined as naturally occurring metals with quite high density, high atomic weight, and high atomic number (Tchounwou P. B., et al., 2014).

Heavy metals are often considered to be toxic; their toxicity depends on the dose of the metal, the route of exposure, the form, and the nutritional status of the exposed human being.
Heavy metals can cause organ damage, liver damage, some can cause cancer, or even DNA damage, and others can be fatal if inhaled or exposed to excessively (Tokar E. J. et al., 2013).
Among the priority metals regarding toxicity comes arsenic, cadmium, chromium, mercury, and lead (Tchounwou P. B., et al., 2014).
Heavy metals are not only toxic to human health or animals but also for the environment as a whole; raising concerns over their side effects (Luckey T. D. et al., 1977). As a result of mining, industrial waste, industrial activities, agricultural runoff, pesticides, vehicle emissions, fertilizers, etc. heavy metals became more concentrated in the environment (Luckey T. D. et al., 1977).
Although heavy metals have a negative consequences on human health but some trace amounts of some heavy metals are required by human body. These include cobalt, copper, manganese, vanadium, zinc and molybdenum. In fact, some major heavy metals have biochemical and physiological functions in plants and animals. They are also a major constituents of several enzymes in addition to their roles in oxidation reduction reactions (WHO, 1996).

Copper for example works as a co-factor for many oxidative stress-related enzymes (Stern BR, 2010). Thus, it is an important nutrient that serves in haemoglobin formation, carbohydrate metabolism, catecholamine biosynthesis, and cross-linking of collagen, elastin, and hair keratin. However, excessive exposure to copper can cause cellular damage leading to Wilson disease (ATSDR, 2002).

In the same way is manganese which helps human body to form connective tissue, bones, blood clotting factors, and sex hormones. It is also important for carbohydrate metabolism, calcium absorption, and blood sugar balance. Manganese also plays a role in brain and nerve function (UMMC, 2013). Another important element is iron, which is important for blood production. Whereas 70 percent of iron in human body is found in red blood cells (USCF, 2016). Reaching to Cobalt, it is an essential element for the formation of vitamin B12. It also helps in activating enzymes (Campbell, 2012). As for Zinc, it is found in cells all over the body and plays a role in cell division growth and wound healing. It is important for immune system to work properly and for the senses of taste and smell (Escott Stump S., 2008).

Heavy metals can be also considered as trace elements due to their presence in trace concentrations in different environmental matrices (Kabata P., 2001). Their bioavailability is affected by physical factors such as temperature, phase association, adsorption and sequestration. It is also affected by chemical factors, complexation kinetics and lipid solubility (Hamelink JL., 1994). Biological factors can also influence their bioavailability, such as species characteristics, trophic interactions, and biochemical or physiological adaptation (Verkleji J., 1993).

Far apart from organic pollutants, heavy metals cannot be biodegraded when it enters the environment. Therefore, the aim of pollution control strategies is to reduce the bioavailability and toxicity of these metals (Kapri et al., 2011). Some methods for remediation of heavy metal contamination include physical removal, detoxification, bioleaching, ion exchange, bioremediation, complexation and phytoremediation (Kapri et al., 2011).

Some toxic metals have been studied extensively; within these metals are arsenic, cadmium, mercury and lead. Regarding the entry routes of heavy metals, it include inhalation, manual handling, water resources, ingestion of food and acid rain (Balasubramanian et al., 2009). Skin absorption is rare. In fact, plants are mainly exposed to heavy metals through the uptake of water or by the applied fertilizers or pesticides (Radojevic et al., 1999).

1.3.1 Heavy Metals in Vegetables

Vegetables are important for humans since they are rich sources of vitamins, minerals and fibres along with their beneficial anitoxidative properties. But these foodstuffs may pose a risk to human health if contaminated by heavy metals. Heavy metal contamination of food is one of the most significant features of food quality assurance. As heavy metals are not biodegradable and persist in the environment, it can be deposited on the surfaces and then absorbed into the tissues of vegetables (Sharma et al., 2009).

However, there are few plants known as hyperacuumulators that can easily absorb high levels of metals from the surrounding soil. If these plants are to be used by human beings it can harm the body due to the amount levels of metals. Still, this is a concern if these plants are found in areas with high concentrations of metals in the soil. But it should be also considered that metals uptake by plants depends on soil acidity meaning its pH value. The higher the acidity, the more soluble and mobile the metals become (CHSR, 2009). In this case, the plants are more likely to take up the metals and the metals will accumulate. On the other hand, the higher pH values, the lower the bioavailability and toxicity of metals become, in particular cadmium and lead (McBride et al., 1997; Gray et al., 1999). The mechanism for this process can contribute to the increase of solubility and ion competition.

Plants uptake is primarily related to the concentration of metals in the soil solution more than metal concentrations of the soil (Kim et al., 2010). Furthermore, heavy metals may enter vegetable tissues through roots and foliage. Also it can be transferred from soil pore water into the plants though the roots in the form of dissolved ions (McLaughlin et al., 2011). Many complex processes occur in the soil pore water and crop rhizosphere.

Generally, leafy vegetables grow faster with higher transpiration rates than non-leafy vegetables (Luo et al., 2011). Therefore, heavy metals uptake by roots can be greater in leafy vegetables; this results in the translocation of metals from roots to other tissues (Zheng et al. 2007). Attributable to the leaf area, leafy vegetables are more sensitive to metals accumulation by dust from soil or rainwater.

In general, human beings are very likely to be exposed to heavy metals contamination from the soil that sticks to the plants (Adamsa et al., 2004). Still, there are other pathways to be exposed to heavy metals contamination through plant use. These include inhaling contaminants from burning plants materials, as well as inhaling contaminants from smoking plant materials, volatilization of contaminants in plant materials in enclosed areas, ingestion, or skin contact and daily use of plant materials. In particular, plants as root crops, leafy vegetables, and plants that are grown near the soil are more risky for exposure to metal contamination (CHSR, 2009). Therefore, monitoring and assessment of heavy metals concentrations in vegetables have been carried out in developed countries and some developing countries.

Moreover, contamination of heavy metals may appear on plants and changes its colour or its pattern of growth. Stressed plants may be as well a sign of metal contamination. These conditions usually mean that bioaccumulation of metals is taking place in the plants. In other cases, deficiencies in plant could happen which may influence the plant’s likelihood to accumulate metals (CHSR, 2009).

1.4 Pesticides

Pesticides are chemical or biological substances used for preventing, or controlling pests including vectors of human or animal disease, undesired types of plants or animals that could cause harm during the production, processing, storage, transport, or marketing of food agricultural goods (FAO, 2002). Pesticides include herbicides, fungicides, insecticides, termiticides, nematicide, molluscicide, bactericide, antimicrobial, animal repellent, disinfectant and sanitizer (Randall, 2013).

In 2010, the Palestinian Authority Central Bureau of Statistics described the use of the pesticides in the West Bank as excessive. Because of the large increase in population and the narrow of agricultural area, people turned to use fertilizers and pesticides to increase the productivity of the agricultural land. In the West Bank the annual rate of use of agricultural fertilizers reached 30,000 tons of chemical fertilizers and manures, and the annual rate of use of pesticides reached to 502.7 tons, consisting of about 123 types, fourteen of them are internationally banned for health reasons. Seven types of these pesticides are considered as dirty dozen. These are Aldicarb, Chlordan, DDT, Lindane, Paraquate, Parathion and Pentachlorophenol (PCBS, 2010).

According to Agricultural Statistics for the year 2009, the costs of plant intermediate consumption used for pesticides reached 19.7%, while 26.0% of these costs used for fertilizers (PCBS, 2010).

However, the Palestinian Authority has set regulations on the management of pesticides in 2012. These regulations involved registering the pesticide type, the quantity and the traders. Moreover, the regulation forbids the use of banned pesticides as classified by WHO. On the other hand, illegal trade of pesticides in the West Bank is still a challenge to control due to the political situation in Palestine, thus there is a very noticeable trade in illegal pesticides into the West Bank. It is speculated that as much as 50 percent of pesticides used in the country are illegal.

In fact, it is estimated that 96.6% of irrigated land and 87.0% of rainfed land in the West Bank region is treated with pesticides. According to a survey made by Applied Research Institute Jerusalem (ARIJ) in 1994, there is an overuse of pesticides in the West Bank, particularly in irrigated areas in Jenin, Tulkarem and Jericho. The average seasonal consumption of pesticides was found to be around 4kg/dunum in open irrigated fields and 6.5 kg/dunum under plastic.

The total quantity of pesticides used in the West Bank is estimated to be around 493.82 tons per year. In particular, of the total pesticides used, insecticides contribute 49.4%, fungicides 33.7% and herbicides 12.78%.

Another related study had been conducted on the use of agricultural pesticides in Palestine, where pesticides are mostly used on irrigated land cultivated with vegetables. Data analysis revealed a total number of 217 pesticides including 13 soil sterilizers, while 134 kinds with different active ingredients (insecticides 62; fungicides 45; herbicides 20) were applied in all districts in the West Bank. Based on the total irrigated land cultivated, the rate of pesticides per dunum reached 0.18 L in the West Bank districts. Contrary to earlier published data, the results support a trend of general decrease in the use of agricultural pesticides in the districts under study further to recent efforts encouraging pest management practice (Rashed Al-Saed , Asad Ramlawi & Amjad Salah, 2011).

Objectives of the Study

1.5 Project Background

This study generally aims at determining the amounts of heavy metals concentration in some leafy vegetables, in particular spinach, arugula and parsley; grown in Bethlehem and Jenin districts in the West Bank region. This study tackles the possibility of contamination in some leafy vegetables in the West Bank region with heavy metals due to human activities and misuse of pesticides or chemical fertilizers.

1.6 Main Objectives

The objectives of the current study is to conduct a comprehensive assessment for heavy metals concentration in some leafy vegetables, in particular spinach, arugula and parsley in Bethlehem and Jenin areas. The main objectives of the present work include:

1- To correlate the environmental factors and water chemistry to heavy metals concentrations in Bethlehem and Jenin areas.

2- To correlate between the anthropogenic factors such as pollution and chemical pesticides to heavy metals concentrations in the chosen regions.

3- To point out whether contamination exists in those vegetables and to which concentrations it has arrived compared to WHO standards in order to be able to avoid any health impacts due to the consumption of these species.

Finally, this study discusses solutions to minimize the impacts of heavy metals presence in leafy vegetables and avoid any future risks on human health.

1.7 Significance of the Study

This study has a significant importance to Palestinians who consume these foodstuffs, farmers who plant these vegetables and for relevant fields of study. It is expected that the outcome of this research could be the essence of a project which can guide farmers and consumers to plant, grow and eat vegetables free from contamination and as healthy as much, although changing their approach will not be easy. This research would also present concentrations of Iron (Fe), Lead (Pb), Chromium (Cr), Manganese (Mn), Cobalt (Co), Copper (Cu), Zinc (Zn), and Cadmium (Cd) metals in the chosen leafy vegetables which could be a parameter to be compared to WHO standards. This research could give a general idea about the situation of agricultural activities in the two chosen sites in the West Bank for further studies.

Chapter Two

Literature Review

Chapter Two

2. Literature Review

Many relevant studies have been conducted to tackle similar issue in different places around the world. Below are some scientific papers that could be highly recommended to be reviewed in order to get abroad understanding of my research.

Bagdatlioglu et al., 2010 had determined the levels of Cu, Zn, Fe, Pb and Cd in various fruits (tomato, cherry, grape, strawberry) and vegetables (parsley, onion, lettuce, garlic, nettle, peppermint, rocket, spinach, dill, broad bean, chard, purslane, grapevine leaves) grown in Manisa region. Flame and Graphite Furnace Atomic absorption spectrometry was used to determine the levels of these metals. The levels concentration ranged from 0.56 to 329.7, 0.01 to 5.67, 0.26 to 30.68, 0.001 to 0.97 and 0 to 0.06 mg/g for Fe, Cu, Zn, Pb and Cd, respectively. While the highest mean levels of Cu and Zn were found in grapevine leaves, the lowest mean levels of Fe and Pb were found in nettle. Cd was not detected in most of the studied fruits and vegetables. Levels of Cu that were found were caused by copper-based fungicides. As for zinc, it was related to soil that contained amounts of zinc. The determined daily intakes of Cu, Zn, Fe, Pb and Cd through fruits and vegetables were discovered to be below the maximum acceptable levels recommended by FAO/WHO. The metal concentrations of fruits and vegetables analyzed in this study were within the safety levels for human consumption.

Mohamed et al., 2012 did an assessment for some heavy metals in vegetables, cereals, and fruits in Saudi Arabian Markets. The concentration of Fe, Mn, Cu, Zn, Pb, Cd and Hg in various vegetables (roots, stems, leafy, fruits, cereals and legumes) grown in four major industrial and urban cities was assessed using atomic absorption spectrophotometer. The results showed that concentrations of major studied metals were above the recommended maximum levels set by the Joint FAO/WHO Expert Committee on Food Additives. Leafy vegetables were found to contain the highest metals values especially parsley (543.2 and 0.048 μg/g for Fe and Hg respectively), Jews mallow (94.12 and 33.22 μg/g for Mn and Zn respectively), and spinach (4.13 μg/g for Cd).

However, peas in legumes group got the highest Zn content 71.77 μg/g. High concentrations of heavy metals in different parts of the vegetables might be related to their concentration in the polluted air with industrial activities especially in middle and eastern areas. The study revealed that atmospheric depositions and marketing systems of vegetables play an important role in elevating the levels of heavy metals in vegetables having potential health hazards to consumers of locally produced foodstuffs.

Another related study was conducted in Bangladesh in 2011 by Naser et al., to compare and determine the concentration levels of heavy metals in leafy vegetables with growth stage and plant species variations on an experimental field near the net house of Soil Science Division, Bangladesh Agricultural Research Institute, Joydebpur, Gazipur, during November 2008 to January 2009. Seeds of spinach, red amaranth and amaranth were seeded on 14 November 2008. Plant and soil samples were collected at different growth stages, such as at 20, 30, 40, and 50 days after sowing (DAS). The concentrations of lead, cadmium, nickel, cobalt, and chromium in plant increased with the age of the plant. The rate of increase of concentration of these metals at 20 to 30 DAS was found lower than that at 30 to 40 DAS, except Cr. Heavy metal content increased at the early growing stage and fall during later stages of growth. The study showed that Pb and Co concentrations in amaranth were higher compared to those found in spinach and red amaranth. Spinach contained higher levels of Cd and Cr than those of other vegetables. The reason was using phosphate fertilizers. However, the three vegetables did not differ in Ni concentration. The order of heavy metal level in different vegetables was Cd<Co<Pb<Ni<Cr. In vegetable species in respect of heavy metal concentration Cd, Ni, and Cr was highest in spinach and amaranth showed highest concentration in Pb and Co. The highest correlation between soil-plant was found for Cd, while the lowest for Ni due to heavy metals content in soil. Metal concentrations in the studied vegetables were below the maximum allowable level in India but the concentrations of Cd and Cr were higher than the allowable levels set by the World Health Organization.

Anil Gunaratne et al., 2014 determine the content of nickel, cadmium, chromium, lead and copper in five different types of green leafy vegetables, "Kangkung (Ipomoea aquatica), Mukunuwenna (Alternanthera sessilis), Thampala (Amaranthus viridis), Nivithi (Basella alba) and "Kohila" (Lasia spinosa) that were collected from four randomly selected urban and sub urban market sites in and around Piliyandala area of Colombo District, Sri Lanka. These samples were tested using atomic absorption spectrometry. The results showed variations in elemental concentrations among the green leafy vegetables examined. The average concentrations of heavy metals found in green leafy vegetables ranged from 0.71-15.89, 0.07-0.97, 0.18-5.05, 0.18-1.59, 7.05-18.44 mg/kg for Ni, Cd, Cr, Pb and Cu respectively. Additionally, the mean concentrations of metals in the green leafy vegetables were in the order of their abundance as Cu>Ni>Cr>Pb>Cd. However, there were no significant differences ($p < 0.05$) between the heavy metal contents in combined green leafy vegetables collected from the four market sites. It was also found that the Ni, Cd, Cr and Pb levels exceeded the maximum acceptable limits set by FAO/WHO. The reason for these results was the appliance of artificial or organic pesticides.

Furthermore, in August 2011, a master thesis titled as heavy metal and microbial contamination of some vegetables irrigated using waste water on selected urban farms around addis, ababa, Ethiopia; was conducted to estimate the extent of heavy metal and microbial contamination of vegetables due to irrigation with polluted Akaki and Bulbula river water of Addis Ababa on agricultural land. Three samples of vegetables such as cabbage, spinach, and lettuce have been tested for three heavy metals Cd, Cr, and Pb using atomic absorption spectrophotometry. The results showed that the heavy metals in vegetables of Akaki were higher than the vegetables in Peacock. The reason for this might be due to the Presence of many industries around Akaki farm. Lettuce revealed higher Cr, Pb and Cd concentrations than other vegetables, while elevated Cd levels were revealed by spinach. However, cabbage was found to be the least collector of heavy metals. In all the samples analysed the concentration of Cd was above the maximum limit and its level was observed to be varying; lowest in cabbage (0.234 mg/l) and highest in lettuce plant (0.503mg/l) in Peacock and Akaki farms, respectively. The Pb accumulation in spinach (0.623 & 0.892 mg/l) and lettuce (0.747 & 0.944 mg/l) was found to be above the safe limits of vegetables under study. However, Cr levels were generally within the normal range in cabbage and spinach from Peacock and Akaki farms, respectively, except in lettuce from Peacock farm (2.626 mg/l). Spinach was the most contaminated vegetable by total aerobic count in terms of CFU/g was 1.5×108, 9.7×107, in Akaki and Peacock vegetable farms respectively. High total coliform count was observed from lettuce in Akaki vegetable farm (7.7×106). In the present study, high faecal coliform count was obtained, especially in cabbage sampled from Akaki (6.0×105). Eggs of

Ascaris, being the predominant intestinal parasite were detected in 37.5% (27/72) of the vegetables examined in the present work whereas Giardia cysts were detected in 25% (18/72) of fresh vegetables examined.

Amour (2014), did an assessment of heavy metal concentrations in soil and green vegetables around the volcanic mountain of oldoinyo in ngorongoro district, Tanzania. This study aimed to assess the levels of heavy metal concentration in sample of soil and bean leaves associated with volcanic eruption of mountain Oldoinyo Lengai in Arusha Tanzania. The analysis was done using energy dispersive X- ray fluorescence system (EDXRF) of Tanzania Atomic Energy Commission, Arusha. Fifty five soil samples were collected from areas influenced by the volcanic eruptions of mountain Oldoinyo Lengai; these areas include the field near the mountain and Engare sero vegetable farm, which is located at about 14 km from the mountain. Ten bean leaves samples were also collected from Engare sero vegetable farm. Mg, Al, K, Ca, V, Cr, Mn, Fe, Cu, Zn, As, Cd, Pb and Th were detected in both soil and bean leaves samples. The results showed that the majority of elements in the volcanic soils had significantly ($p \leq 0.05$) higher concentration than their concentration in control soil samples. The results obtained from bean leaves samples showed that except for As and Cd which were in concentration below detection limits (0.6 and 2.4 mg/kg respectively), the other elements were in concentrations above FAO/WHO permissible limits. The results from this study showed that high concentrations of elements in samples from both soils and bean leaves from Oldoinyo Lengai areas might be associated with frequently eruptions of the volcanic mountain of Oldoinyo Lengai.

As a matter of fact, no similar studies have been conducted in the West Bank region concerning heavy metals concentration in leafy vegetables. However, there had been few studies concerning heavy metals in Palestine related to canned food, water, and soil.

Chapter Three

Materials and Methods

Chapter Three

Materials and Methods

3. 1 Study Area and Sampling Locations

The present study was carried out during 2016 in Bethlehem and Jenin districts in the West Bank region. Bethlehem represents the southern area, while Jenin represents the northern area (see Figure 3.1).

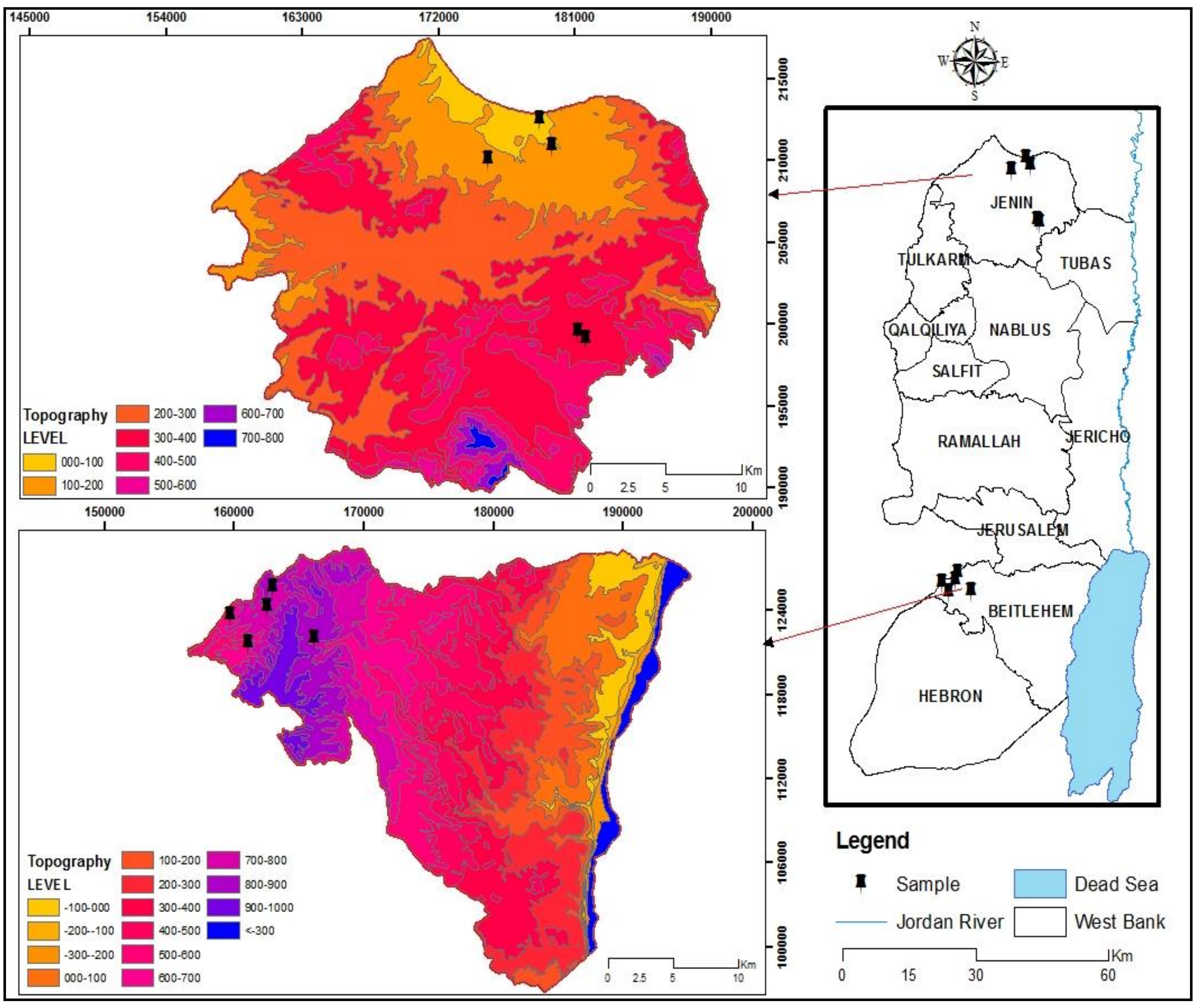

Figure (3.1): Topographic map of the Study Area
Source: GIS Laboratory at Al-Quds University

Figure (3.1) shows the topography levels of Jenin and Bethlehem along with the elevations. This figure was prepared using GIS software at Al-Quds University.

Site 1: Bethlehem District

Bethlehem is one of the governorates in Palestine. It is situated at an elevation of about 775 meters that is about 2,543 feet above sea level. It lies to the south of Jerusalem (Amara, 1999). It has a population of approximately 221,802 inhabitants (Palestinian Central Bureau of Statistics, 2016). Bethlehem Governorate has a total area of about 660 km^2.The governorate consists of many municipalities; some of these municipalities are Batir, Husan, Nahaleen, Beit Jala Beit Sahour, and Al Khader. In addition it has three refugee camps and many rural districts. (Kaufman et.al, 2006). Regarding the weather in Bethlehem district, it has a Mediterranean climate, in other words, it has dry summers and mild winters. The temperature at summer stays around 30 °C, while in winter the temperature ranges from 1 to 13 °C. Implicating to its rainfall, Bethlehem receives an average of 500 millimetres of rainfall annually (ARIJ, 2010). The average relative humidity is around 60% and it gets to the highest rates during January and February, while in May it reaches the lowest levels (Bethlehem Municipality, 2007). The main economic sector in Bethlehem governorate is tourism, in addition to other sectors that include industries, agricultural activities and trading (Amara, 1999).

Site 2: Jenin District

Jenin is one of the governorates of Palestine. It is located in the northern West Bank. It has a population of about 318,958 (Palestinian Central Bureau of Statistics, 2016). Jenin has a highest elevation of about 250 meters above sea level, and its lowest is 90 meters above sea level. Jenin lies along the southern of Marj Ibn Amer, and to the northern along Jabal Nablus (Zeitoun, 2008). In fact Jenin is 42 kilometers north of Nablus and 51 kilometers southeast of Haifa (Lewensohn, 1979). The main economic sector in Jenin governorate is agriculture. Indeed the amount of employment by economic branch of total employed in rural Jenin is 45% in 2003 (UNSCO, 2005).

Implicating to its rainfall, Jenin receives an average of 530 millimetres of rainfall annually. The average relative humidity is around 69% and it gets to the highest rates during summer (PCBS, 2015). Jenin is quite varied in the types of crops produced. This is mainly due to the type of soil, climate, and fair amounts of irrigation water and relatively high annual rainfall.

3. 2 Collection of Samples

More than 50 samples of leafy vegetables were collected during late spring 2016 grown in different farms within the study area. Thirty samples were chosen for analysis. Fifteen from Jenin's farms and fifteen from Bethlehem's. Three types of leafy vegetables were taken from different farms. These vegetables were Parsley, Spinach, and Arugula.

All collected samples were stored in clean plastic bags and brought to the laboratory for analysis.

Water samples were collected from each site for further analysis; the same water used for irrigating these vegetables. Water was stored in clean plastic bottles washed with Distilled water. In site, the water bottle was washed with the same irrigating water then was filled with water.

In addition, soil samples were taken where the type of soils were terra rossa in Bethlehem region and grumusols at Jenin zone (See figure 3.2). However, the soil that was collected was near the roots of the leafy vegetables within 5 to 10 cm depth (Chang C.Y. et al., 2013).

Additionally, pesticides samples used on leafy vegetables were also collected for analysis. The samples were stored in clean plastic white bottles that are firmly closed and sent to the laboratory for analysis. Some of the pesticides samples were collected from the farms in both regions, while others were collected from the Ministry of Agriculture in Palestine.

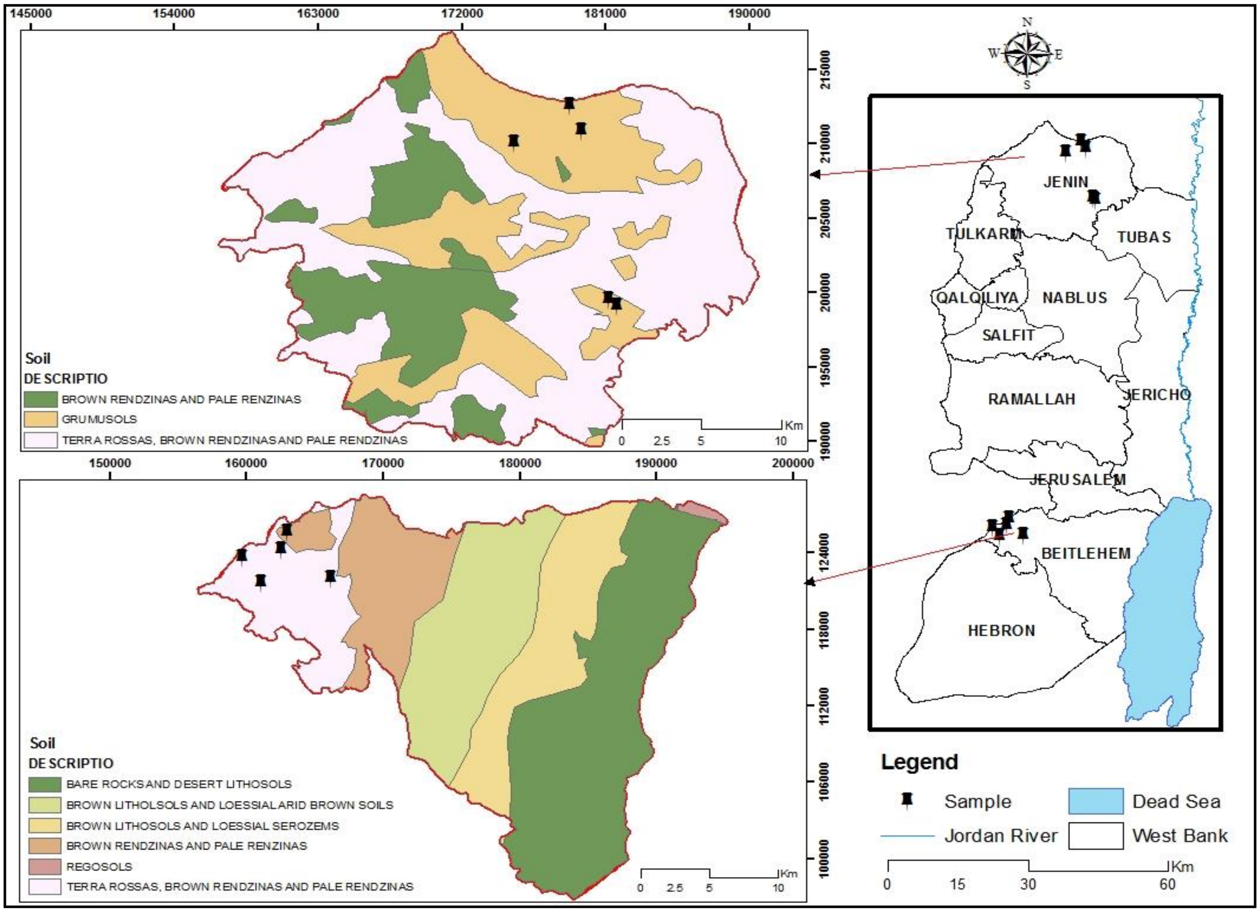

Figure (3.2): Soil Type
Source: GIS Laboratory at Al-Quds University

Figure (3.2) shows the type of soils in both Jenin and Bethlehem. It can be also seen the locations and the distribution of the samples where they were collected from.

3.3 Preparation and Treatment of Samples

The collected vegetable samples were washed with distilled water to remove dust particles. Then, samples were cut to small pieces. The leafy part was taken, and dried in an oven at 50 °C. After drying, the samples were ready for acid digestion (Chang C.Y. et al., 2013).

Figure (3.3): Preparation of Samples at the Laboratory
Credit: Elizabeth Kattan

Figure (3.4): Drying Samples in the Oven at the Laboratory
Credit: Elizabeth Kattan

Figure (3.5): Pesticides Samples at the Laboratory
Credit: Elizabeth Kattan

For acid digestion, Microwave Digestion System (MARS) was used which has a great speed, precision and high sensitivity. The method of digestion was given by the machine itself. The weight of each leaf was 0.5 grams. Then 50 ml of 65% pure nitric acid were added to each sample. The mixture was then digested till the transparent solution was achieved. After cooling, the digested samples were filtered using CA sterile syringe filters which diameter was 30mm and the pore size 0.22 µm (Aweng E.R, et al., 2011).

Figure (3.6): Microwave Digestion System (MARS)

Determination of heavy metals in the filtrate of vegetables was achieved using Inductively Couples Plasma Mass Spectrometry (ICP-MS). ICP- MS is an analytical technique used for elemental determinations.

As for the soil samples, 50 grams of the soil were weighed and 250 ml of milli-Q water were added. Milli-Q water is ultrapure water as defined by ISO 3696 (Merck Millipore Organization, 2015). The processes of purification include many steps of filtration and deionization to reach a purity characterised in term of resistivity 18.2 MΩ·cm at 25°C. Milli-Q purifiers produce water pure enough to get accuracy within parts per million (Yokoyama, et. al, 1999). Soil samples were kept for fourteen days, so that what surround the soil particles can be tested. This process was performed because it is not the soil particles that need to be analysed but the surroundings of the particles; in other words the leachate. 2 ml of the sample were taken for analysis (Aweng E.R, et al., 2011).

In addition, water samples were tested for its content by the addition of 65% pure nitric acid. 2 ml of the sample were taken for analysis. Concerning pesticides samples, they were analysed by the use of ICP-MS as well (Aweng E.R, et al., 2011).

Figure (3.7): Inductively Coupled Plasma Mass Spectrometry (ICP-MS)

Regarding ICP-MS methodology, ICP- MS combines a high temperature inductively coupled plasma source with a mass spectrometer. The ICP source converts the atoms of the elements in the samples to ions which are then separated and detected by the mass spectrometer. It can measure trace elements as low as one part per trillion.

3.4 Statistical Analysis

The data of heavy metals concentrations were assessed using Microsoft Excel. Data was also interpreted using the appropriate mathematical equations with regards to the initial environmental issue which is the presence of heavy metals in leafy vegetables. Besides that, various graphs and figures were plotted to demonstrate the concentrations of heavy metals in the chosen samples and to compare samples for both areas. Some heavy metals were chosen according to its availability and values in the results.

The path of the calculation process that was relied on is the conversion of units regarding the concentration of chosen heavy metals. As ICP-MS provides the concentration in parts per billion (ppb), it was then converted to explain this ratio mg/kg in order to allow the comparison to WHO standards which are mostly expressed as mg/kg for leafy vegetables.

Chapter Four

Results and Discussion

Chapter Four

Results and Discussion

Through the sampling and by following the methodology that had been described before; the following results were obtained. All results are expressed as (Concentration± Standard Deviation) for all samples. Note the appendixes as well.

4.1 Levels of Heavy Metals in Leafy Vegetables in Bethlehem Region

Heavy metals concentrations in green leafy vegetables in Bethlehem region are presented in Table (4.1). Results revealed variable concentrations of heavy metals in the leafy part of the vegetable samples.

Table (4.1): Heavy Metals Concentration (mg/kg) in Leafy Vegetables in Bethlehem Region

Farm Name	**Sample Name**	**Sample Weight (g)**	**Fe**	**Pb**	**Cr**	**Mn**	**Co**	**Cu**	**Zn**	**Cd**
Batir	Spinach	0.501	393.34±11.37	**0.36**±0.007	0.88±0.26	58.5±10.8	0.19±0.019	14.3±1.26	35.68±2.82	0.17±0.07
	Arugula	0.503	**1045.94**±65.27	**1.77**±0.16	**2.11**±0.46	31.78±0.41	0.36±0.011	10.75±1.49	57.67±5.95	0.14±0.03
	Parsley	0.505	**451.73**±6.68	**0.38**±0.011	0.6±0.12	57.82±6.45	0.11±0.017	7.17±0.96	47.7±1.98	0.05±0.008
Nahaleen	Arugula	0.503	**1569.53**±75.3	**0.69**±0.09	**2.51**±0.86	52.8±5.22	0.48±0.02	5.68±0.38	**106.5**±3.07	**1.4**±0.28
	Spinach	0.505	**546.02**±3.25	**0.53**±0.04	0.63±0.22	43.06±1.91	0.14±0.03	13.49±1.13	85.91±2.14	**0.26**±0.04
	Parsley	0.506	**567.61**±22.4	0.3±0.04	0.66±0.30	39.36±2.56	0.14±0.03	9.16±0.25	53.37±2.06	0.07±0.03
Husan	Parsley	0.503	126.81±14.67	0.14±0.02	0.49±0.16	5.4±0.49	0.02±0.008	5.36±0.41	7.64±1.08	0.01±0.005
	Spinach	0.503	43.41±3.43	0.12±0.03	0.18±0.26	10.98±0.52	0.06±0.03	1.43±2.24	30.43±1.51	0.06±0.03
	Arugula	0.508	45.73±5.49	0.17±0.02	0.04±0.06	6.63±0.49	0.05±0.01	1.35±0.12	29.35±2.63	0.02±0.06
Wad Foqin	Arugula	0.5023	75.04±3.59	0.13±0.03	0.02±0.02	10.68±0.81	ND	0.85±0.14	5.5±0.79	0.08±0.02
	Parsley	0.504	89.86±8.69	0.28±0.012	0.02±0.06	29.91±2.51	0.01±0.015	1.93±0.15	9.1±0.65	0.02±0.006
	Spinach	0.503	25.35±4.42	0.03±0.011	0.02±0.02	2.22±0.08	0.10 ±0.02	0.81±0.08	3.61±0.46	0.01±0.007
Al Khader	Arugula	0.508	165.48±32.0	0.08±0.04	0.28±0.48	6.59±1.20	0.07±0.006	0.56±0.14	4.24±0.89	0.03±0.009
	Parsley	0.504	208.99±15.27	**0.32**±0.05	0.44±0.15	19.62±0.35	0.12±0.03	1.05±0.11	6.4±0.43	ND
	Spinach	0.5003	88.7±9.33	0.04±0.004	0.15±0.17	3.43±0.08	0.05±0.02	0.87±0.18	4.15±0.77	0.01±0.032
WHO/ FAO Safe limits			425	0.3	1.3	500	50	73	99.4	0.2

In Table (4.1), the numbers in red color have shown surpass in their levels compared to WHO/FAO permissible limits.

The levels of iron in all vegetables ranged between 25.35 mg/kg and 1569.53 mg/kg. Although leafy vegetables are rich with iron, however, in some samples it exceeded the limit given by WHO/FAO which is 425mg/kg. In fact, the concentrations of Fe in Batir in arugula and parsley samples are very high, 1045.94 mg/kg and 451.73 mg/kg respectively. The same as in spinach, arugula and parsley samples in Nahaleen, the Fe levels are 1569.53 mg/kg, 546.02 mg/kg, and 567.61 mg/kg respectively (See figure 4.1).

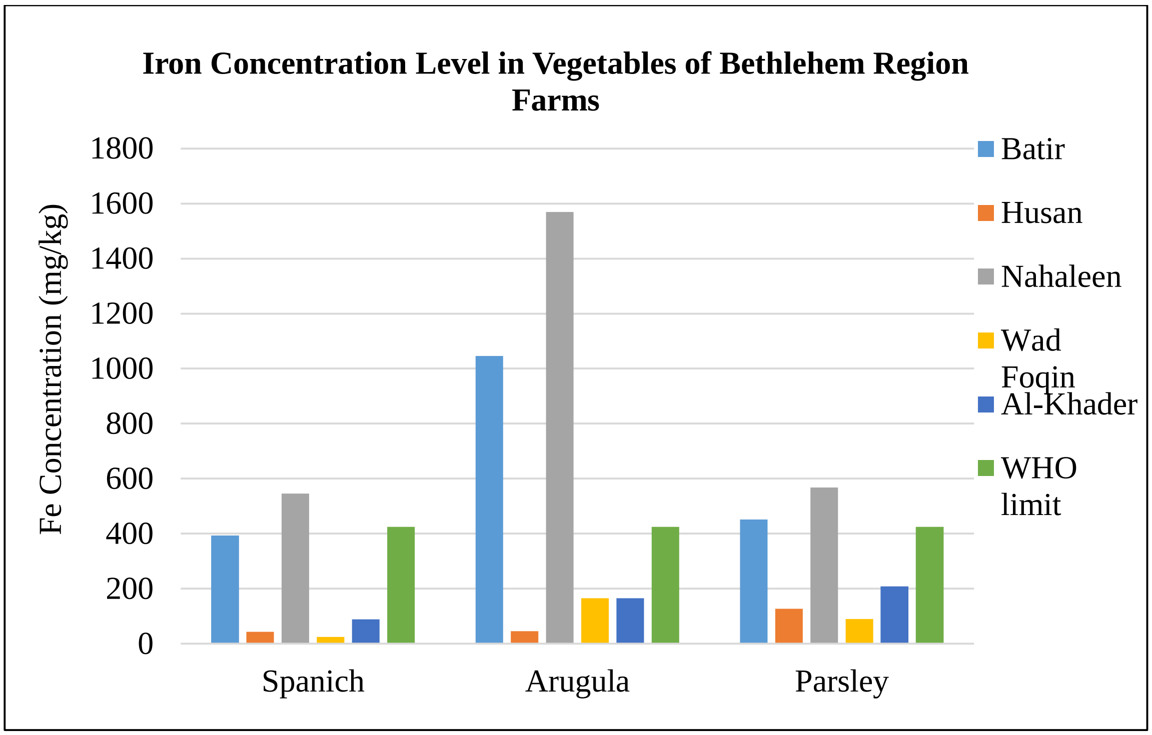

Figure (4.1): Iron Concentration Level in Vegetables of Bethlehem Farms

Regarding Lead contents, it varied from 0.03 mg/kg and 1.77 mg/kg. Its concentration levels are relatively high in Batir samples and in Nahaleen (See figure 4.2).

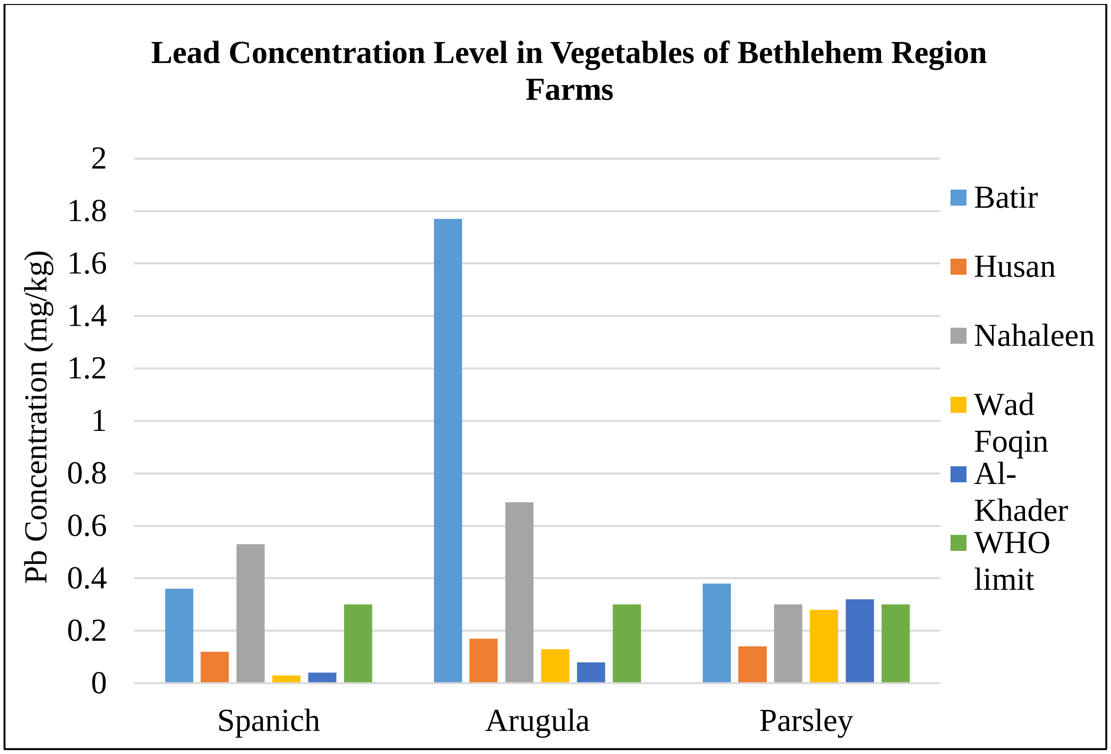

Figure (4.2): Lead Concentration Level in Vegetables of Bethlehem Farms

In regards to Chromium levels, it exceeded the allowable safety limits in Arugula samples in two farms, Nahaleen and Batir (See figure 4.3).

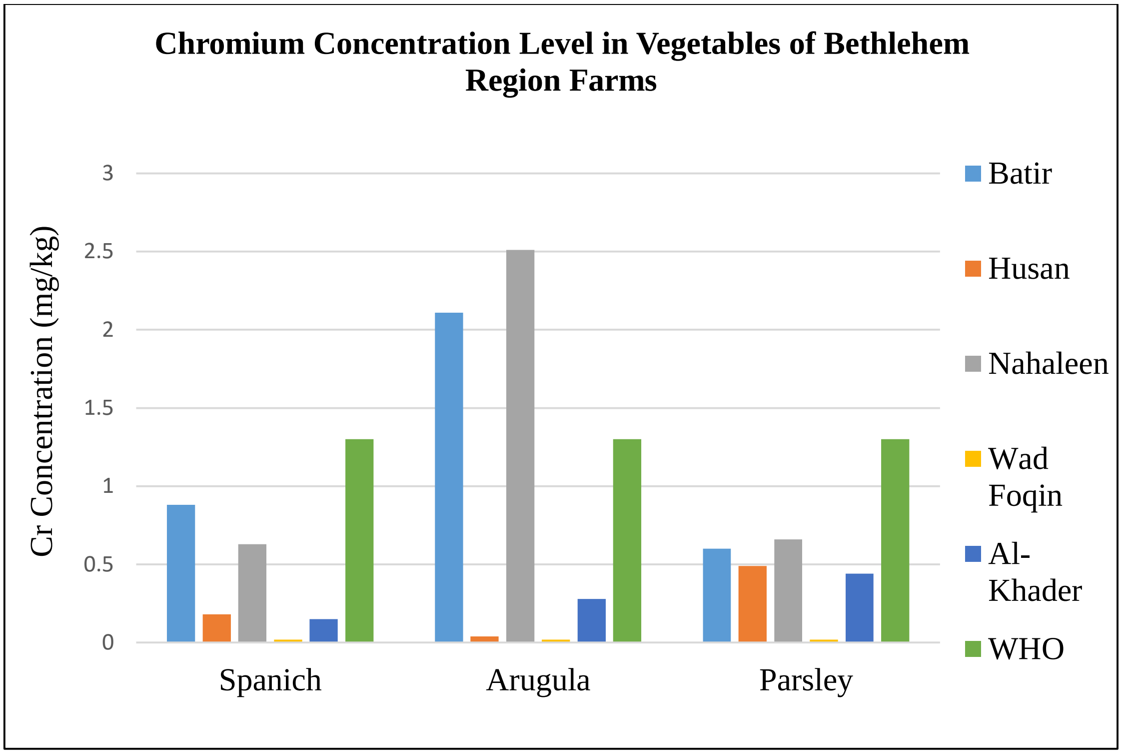

Figure (4.3): Chromium Concentration Level in Vegetables of Bethlehem Farms

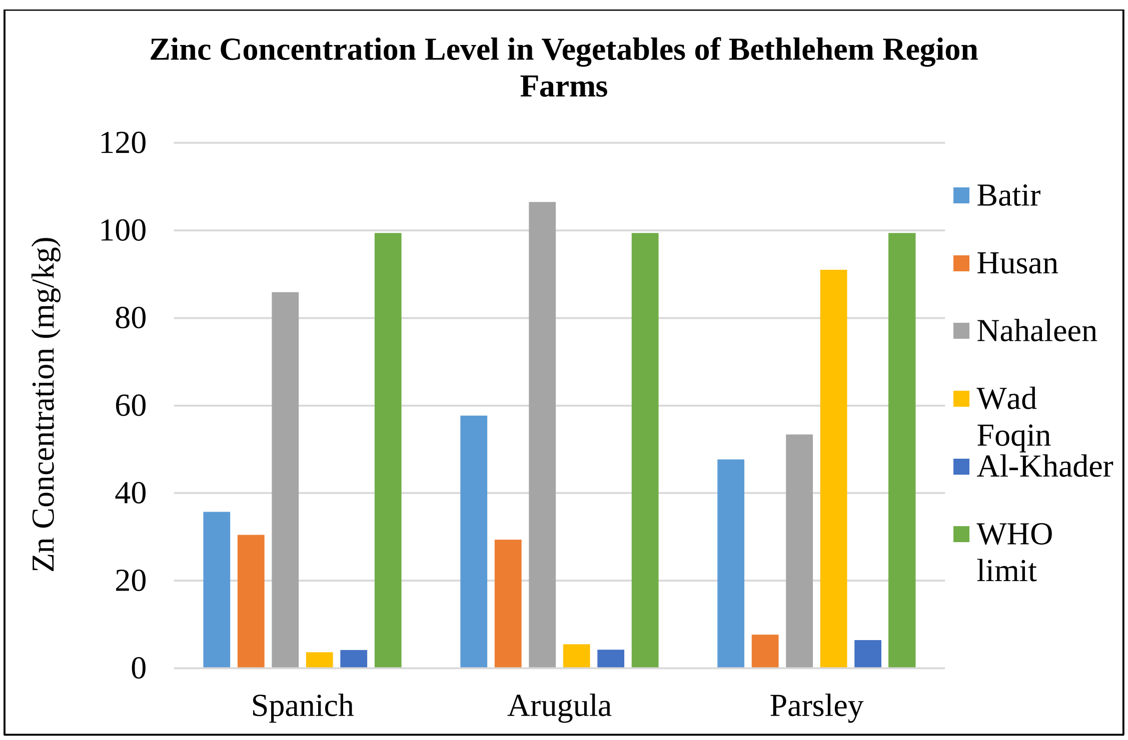

Figure (4.4): Zinc Concentration Level in Vegetables of Bethlehem Farms

Similarly, Zinc levels ranged from 3.61 mg/kg and 106.5 mg/kg. 106.5 mg/kg which is found in arugula sample in Nahaleen, is a relatively high value to exist in vegetables; since the permissible limit given by FAO/WHO is 99.4 mg/kg.

As for Cadmium, it was found that its concentration in Nahaleen in arugula sample is very high and relatively high in spinach sample (See figure 4.5).

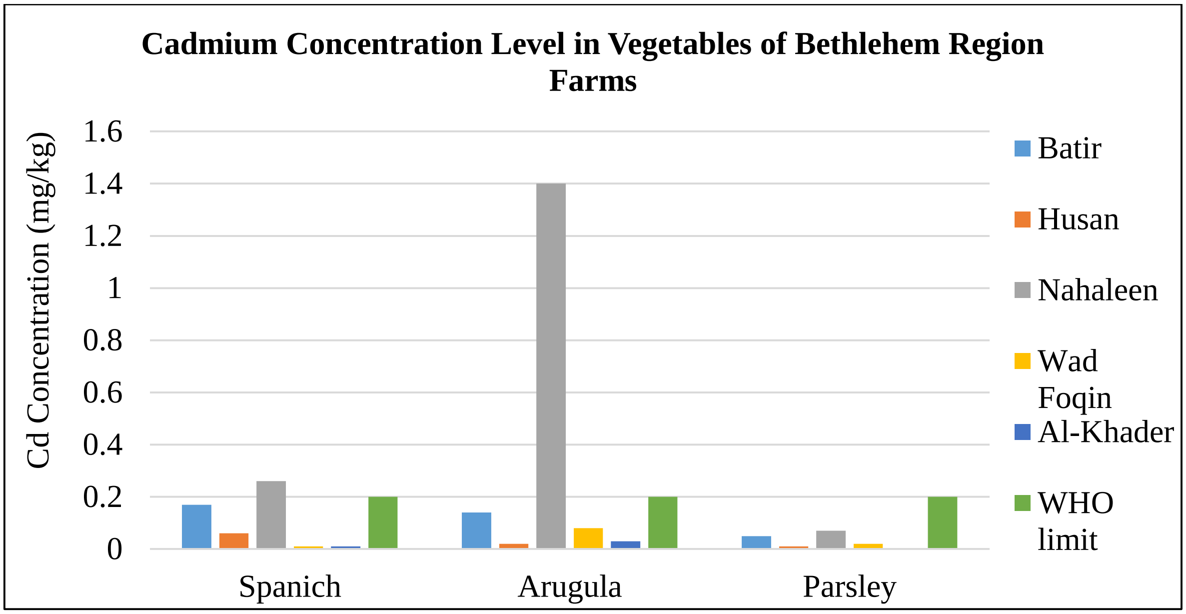

Figure (4.5): Cadmium Concentration Level in Vegetables of Bethlehem Farms

The observed concentrations of Cr, Mn, Co, and Cu were compared to the recommended limits established by FAO/ WHO to ensure the safety and well-being of consumers. All concentrations of these metals lies within the permissible limits set by FAO/ WHO.

Among all heavy metals, Fe showed maximum levels and Co showed minimum levels in all vegetable samples in Bethlehem region. Results also revealed that the mean concentrations of heavy metals in the green leafy vegetables found in the order of their abundance as Fe>Pb>Zn>Cd>Mn>Cu>Cr>Co.

Although Cu, Mn, Co and Cr are considered as essential elements for various biological activities within human body, but elevated levels of these metals can negatively affect human health.

4.2 Levels of Heavy Metals in Leafy Vegetables in Jenin Region

As for Jenin region, results were quite different from Bethlehem region. Iron, Lead, Copper and Cadmium revealed relatively high levels in some samples of leafy vegetables. Regarding Iron, its concentration is high in arugula sample located at Zababdeh farm, and relatively high in parsley and spinach sample at the same farm (See table 4.2).

Table (4.2): Heavy Metals Concentration (mg/kg) in Leafy Vegetables in Jenin Region

Farm Name	**Sample Name**	**Sample Weight (g)**	**Fe**	**Pb**	**Cr**	**Mn**	**Co**	**Cu**	**Zn**	**Cd**
Raba	Arugula	0.501	164.80 ±5.67	0.08±0.03	0.17±0.05	11.33±0.48	0.01±0.005	0.62±0.08	9.15±0.65	0.17±0.05
	Spinach	0.505	90.04±9.15	0.05±0.02	0.03±0.18	14.50±5.98	0.01±0.02	1.02±33.4	4.22±2.93	0.02±0.04
	Parsley	0.506	291.98±2.33	0.24±0.01	0.29±0.33	64.36±2.06	0.12±0.31	**278.50**±0.13	22.31±0.70	0.06±0.03
Zababdeh	Arugula	0.505	**543.10**±46.40	0.23±0.04	0.77±0.05	15.56±2.25	0.20±0.01	2.05±0.27	15.62±1.65	0.07±0.04
	Parsley	0.503	**443.04**±8.69	**0.32**±0.01	0.53±0.16	117.37±18.10	0.31±0.08	4.58±0.30	44.54±1.86	0.06±0.02
	Spinach	0.551	**475.84**±8.82	**0.67**±0.09	0.42±0.08	47.61±3.55	0.17±0.05	5.29±0.75	42.61±4.59	**1.62**±0.13
Jalameh	Arugula	0.506	50.30±6.69	0.13±0.20	ND	5.32±0.72	0.03±0.01	1.03±0.42	24.94±3.27	0.06±0.07
	Parsley	0.521	60.92±0.30	0.09±0.013	ND	16.12±2.73	0.04±0.008	1.49±0.09	18.44±2.53	0.01±0.013
	Spinach	0.500	75.09±8.01	0.11±0.05	0.15±0.37	10.21±1.63	0.06±0.03	2.59±0.62	25.83±4.82	0.03±0.07
Kofr Than	Arugula	0.505	91.58±10.7	0.03±0.029	ND	2.38±0.24	0.02±0.007	1.60±0.14	2.79±0.27	0.01±0.025
	Parsley	0.501	37.85±4.16	**0.47**±0.13	ND	8.85±0.15	0.06±0.03	1.89±0.24	16.44±0.99	0.04±0.05
	Spinach	0.500	84.90±14.4	0.07±0.09	ND	10.91±0.54	0.07±0.02	0.88±0.22	43.78±2.46	0.02±0.03
Araneh	Arugula	0.500	42.35±0.67	0.11±0.10	0.08±0.31	0.27±0.09	0.04±0.01	0.55±0.02	23.66±3.08	ND
	Parsley	0.502	83.43±12.6	0.24±0.09	0.27±0.24	14.29±3.10	0.06±0.01	1.71±0.11	30.43±2.57	0.02±0.01
	Spinach	0.504	86.21±14.2	0.19±0.03	0.11±0.16	7.01±0.30	0.08±0.02	1.50±0.08	30.45±1.35	0.02±0.06
WHO/FAO Safety limits			425	0.3	1.3	500	50	73	99.4	0.2

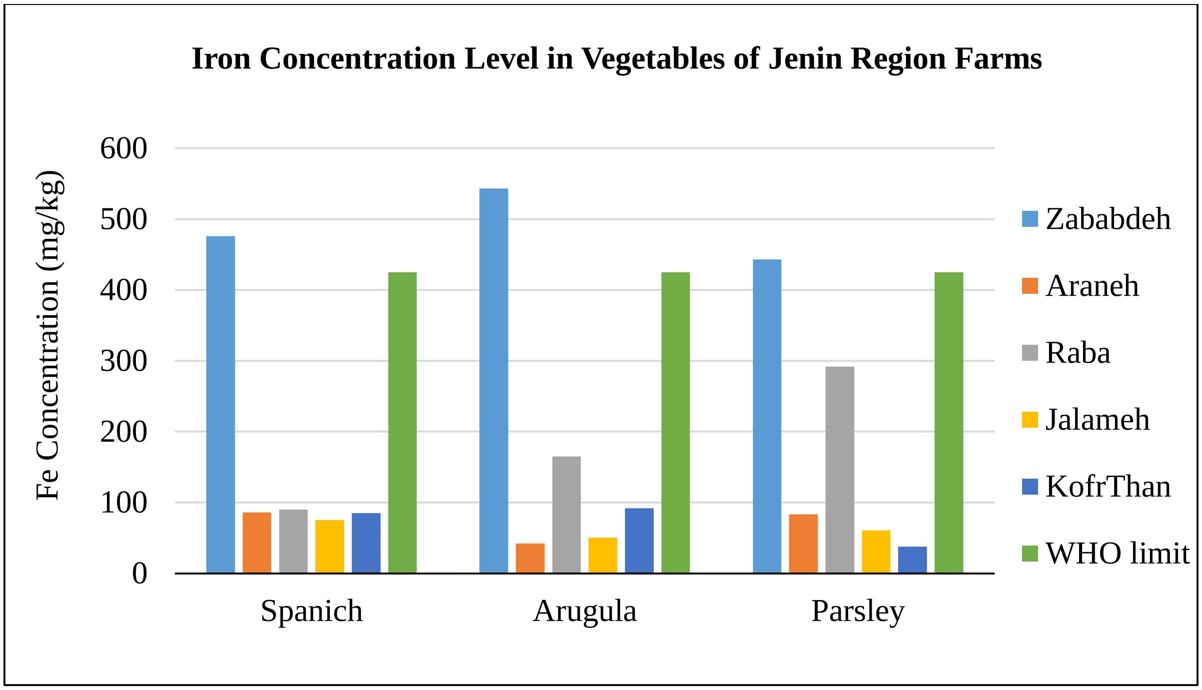

Figure (4.6): Iron Concentration Level in Vegetables in Jenin Farms

From figure (4.6), it can be noticed that the three samples in Zababdeh farm exceeded the permissible limit set by WHO for Fe which is 425 mg/kg.

Additionally, it was found that Lead levels of some vegetables sample obtained from Jenin farms exceeded the safe limits established by FAO/WHO for human consumption (See table 4.2).

The highest concentrations of Pb are 0.32 mg/kg and 0.67 mg/kg; are found in parsley and spinach samples located at Zababdeh farm; and 0.47 mg/kg in parsley sample located at kofr Than farm (See figure 4.6).

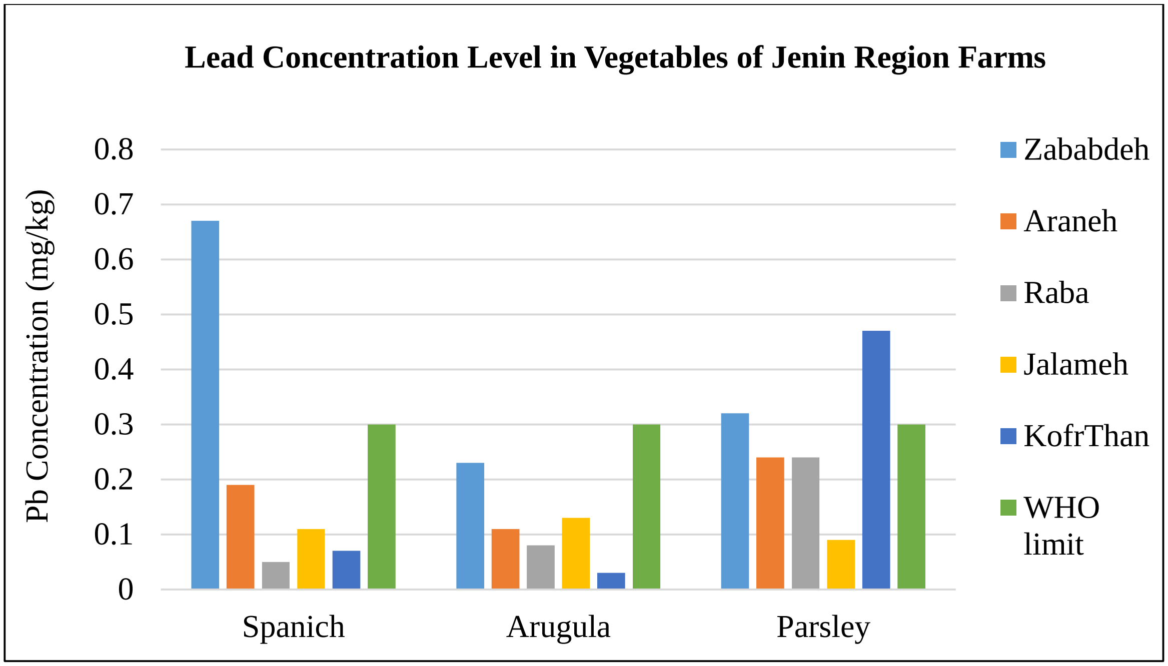

Figure (4.7): Lead Concentration Level in Vegetables in Jenin Farms

In regards to copper, it is generally found in low portions in vegetables, and usually it is added to plants by artificial or organic fertilizers to promote plant growth. However, it is found in very high concentration in one vegetable sample which is parsley at Raba farm (See figure 4.8). Without adequate copper, plants will fail to grow properly. Therefore, maintaining fair amounts of copper is important. On the other hand, increasing amounts of copper in plants will cause the plant to produce insufficient chlorophyll, and this was the case in the collected parsley sample that tend to be yellow.

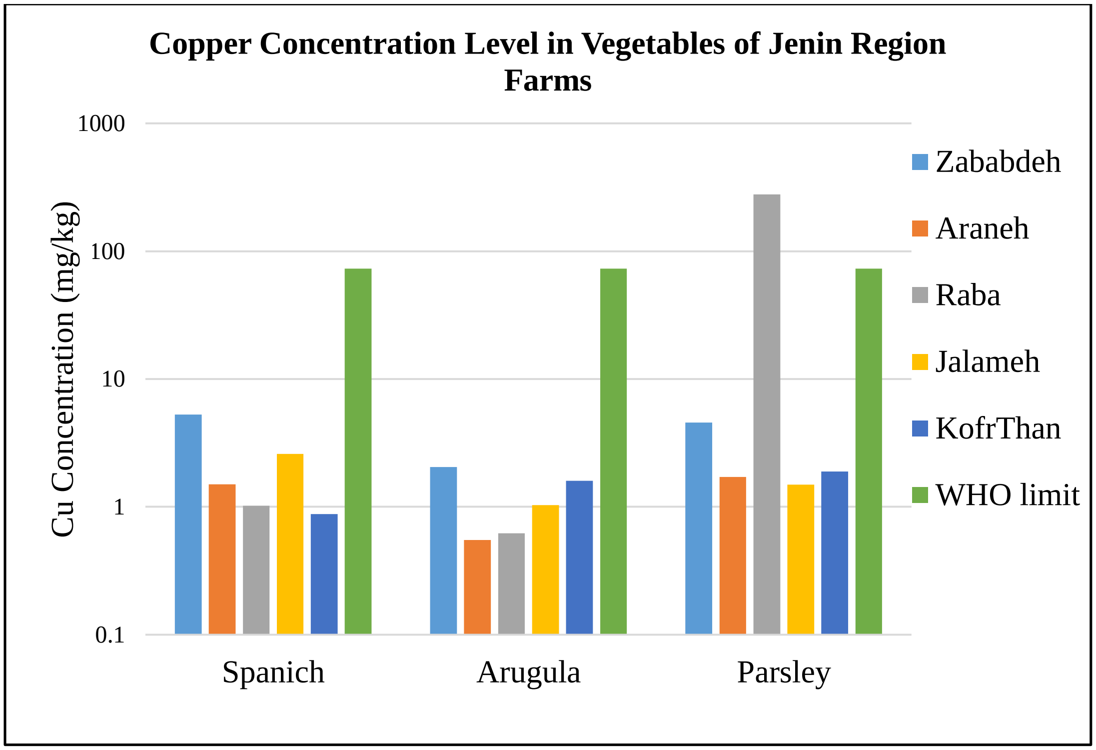

Figure (4.8): Copper Concentration Level in Vegetables of Jenin Farms

From the present analysis, it can be noticed that Cadmium is relatively high in one of the samples which is spinach at Zababdeh farm. The allowable limit for Cd in leafy vegetables is 0.2 mg/kg (See figure 4.9). Similarly to the case with lead in Zababdeh farm.

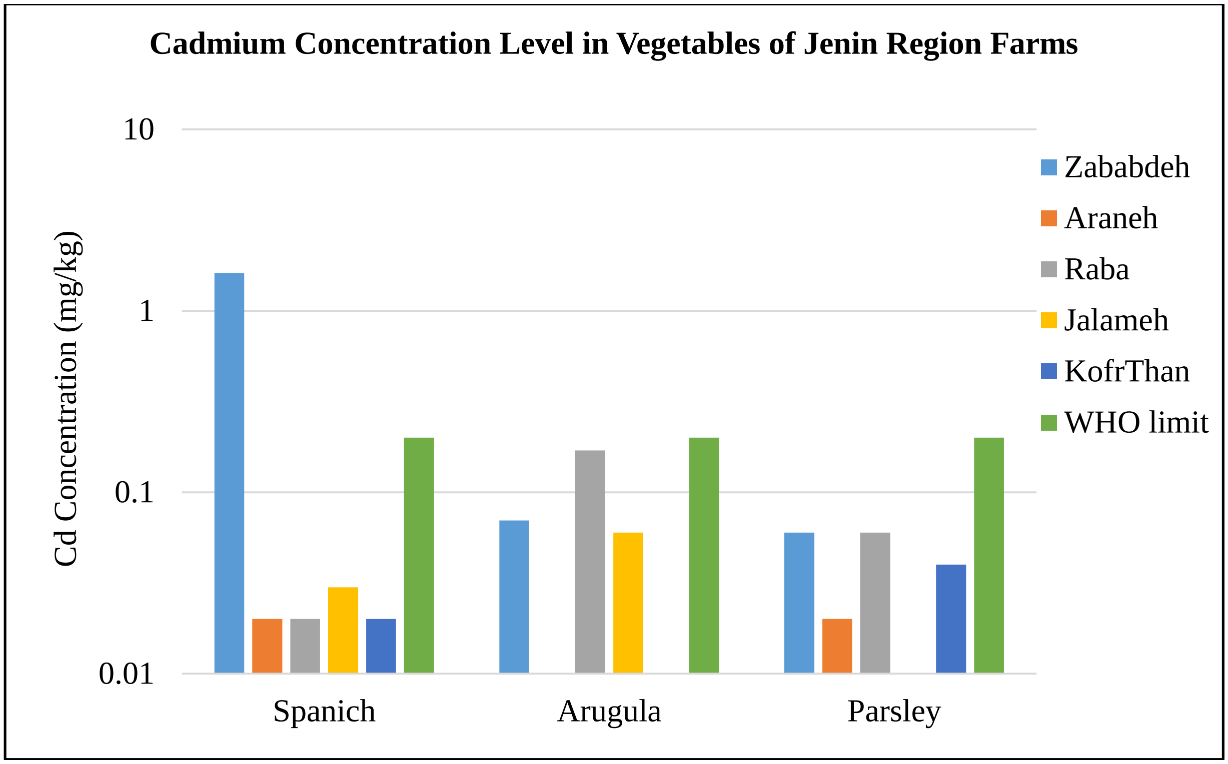

Figure (4.9): Cadmium Concentration Level in Vegetables of Jenin Farms

However, other heavy metals such as Cr, Co, Mn, and Zn contain levels below the WHO/FAO safety limits.

4.3 Concentration of Heavy Metals in the Water Used for Irrigation

Groundwater in the West Bank from wells and springs is the major source of water being used for irrigation (ARIJ, 2010).

4.3.1 Bethlehem Region

Agricultural wells and springs are the main water resources for irrigated lands in Bethlehem farms. Table (4.3) shows the concentration of heavy metals in µg/l in the water used for irrigation in Bethlehem region. The results show that there is no heavy metal contamination in water samples since all concentrations lie within the permissible safety limits set by FAO/WHO for irrigation water.

Table (4.3): Heavy Metals Concentration Levels (µg/l) in Irrigation Water in Bethlehem Region

Sample Name	Fe	Pb	Cr	Mn	Co	Cu	Zn	Cd
Batir	1454.60±11.3	0.70±0.002	0.204±0.00	0.113±0.00	0.052±0.00	0.105±0.0	0.703±0.0	0.03±0.012
Nahaleen	1463.50±27.8	1.28±0.002	0.203±0.076	0.112±0.00	0.33±0.033	0.107±0.0	0.705±0.0	0.04±0.024
Husan	1010.14±3.67	0.47±0.01	0.205±0.00	190.62±1.68	2.27±0.004	23.41±0.03	0.704±0.0	0.03±0.004
Wad Foqin	1213.62±23.8	0.12±0.006	0.204±0.00	0.15±0.01	0.09±0.006	4.31±0.08	0.702±0.0	0.02±0.008
Al Khader	290.65±3.60	0.23±0.03	0.329±0.00	0.21±0.02	0.12±0.008	13.24±0.11	57.19±0.5	0.025±0.0
FAO/WHO Safety limits	5000	5000	100	200	50	200	2000	10

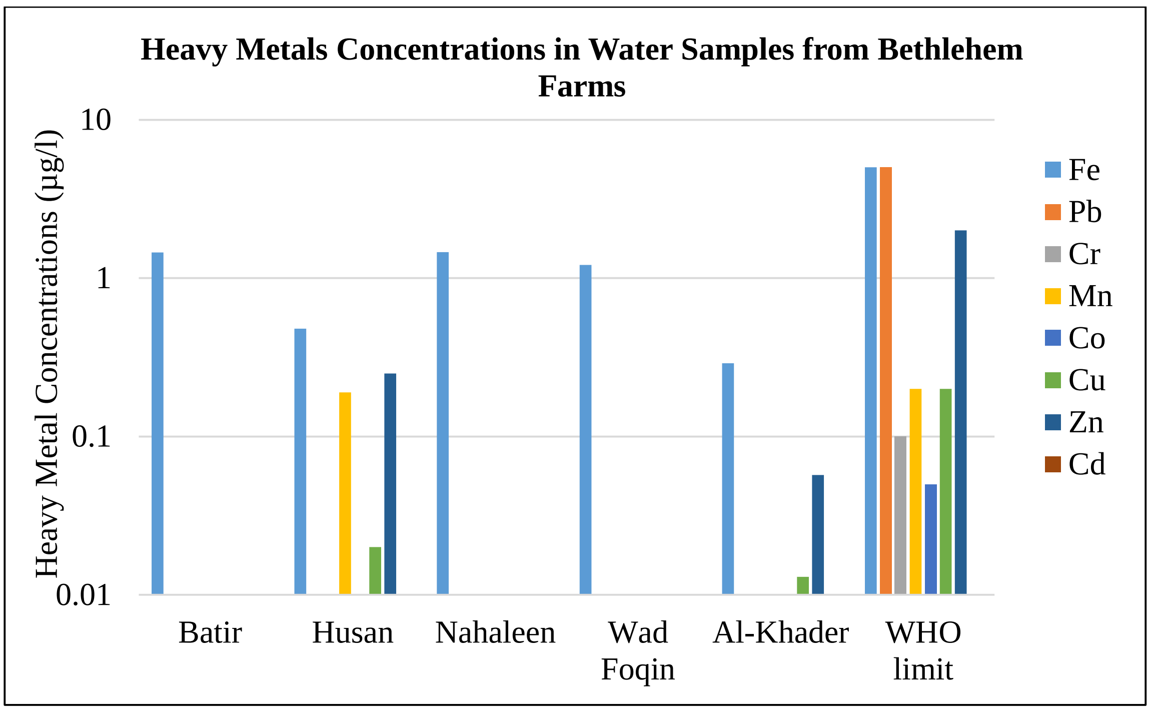

Figure (4.10): Heavy Metals Concentrations in Water Samples Collected from Bethlehem Farms

In figure (4.10), it can be noticed that all levels of heavy metals in irrigation water at Bethlehem region are below the FAO/WHO limit. Thus, no heavy metal contamination in vegetables could have resulted from irrigation water in this area for all farms.

4.3.2 Jenin Region

Regarding Jenin farms shown in table (4.4), it was also found that the used irrigation water does not contain any exceeded levels of heavy metals according to FAO/WHO standards. It is however important to say that in Jenin Districts, groundwater consists of aquifer systems that are located and recharged from rainfall in the West Bank. In addition, some farms depend on agricultural wells for irrigation.

Table (4.4): Heavy Metals Concentration Levels (μg/l) in Irrigation Water in Jenin Region

Sample Name	Fe	Pb	Cr	Mn	Co	Cu	Zn	Cd
Raba	1255.5±12.1	1.58±0.024	0.204±0.19	2.55±0.04	0.051±0.0	3.16±0.09	401.72±1.3	0.08±0.01
Zababdeh	117.1±5.86	0.62±0.012	0.203±0.0	0.19±0.07	0.052±0.0	0.31±0.45	6.65±0.47	0.05±0.01
Jalameh	566.8±3.56	0.72±0.08	2.37±0.17	12.49±0.07	0.36±0.01	124.75±0.78	280.91±1.1	0.05±0.01
Kofr Than	903.2±28.4	0.49±0.27	0.329±0.0	24.12±0.28	0.20±0.02	16.13±0.33	28.49±0.54	0.16±0.01
Araneh	32.86±0.91	1.40±0.07	0.79±0.19	3.13±0.05	0.46±0.02	8.65±0.10	252.01±2.5	0.09±0.03
FAO/WHO Safety limits	5000	5000	100	200	50	200	2000	10

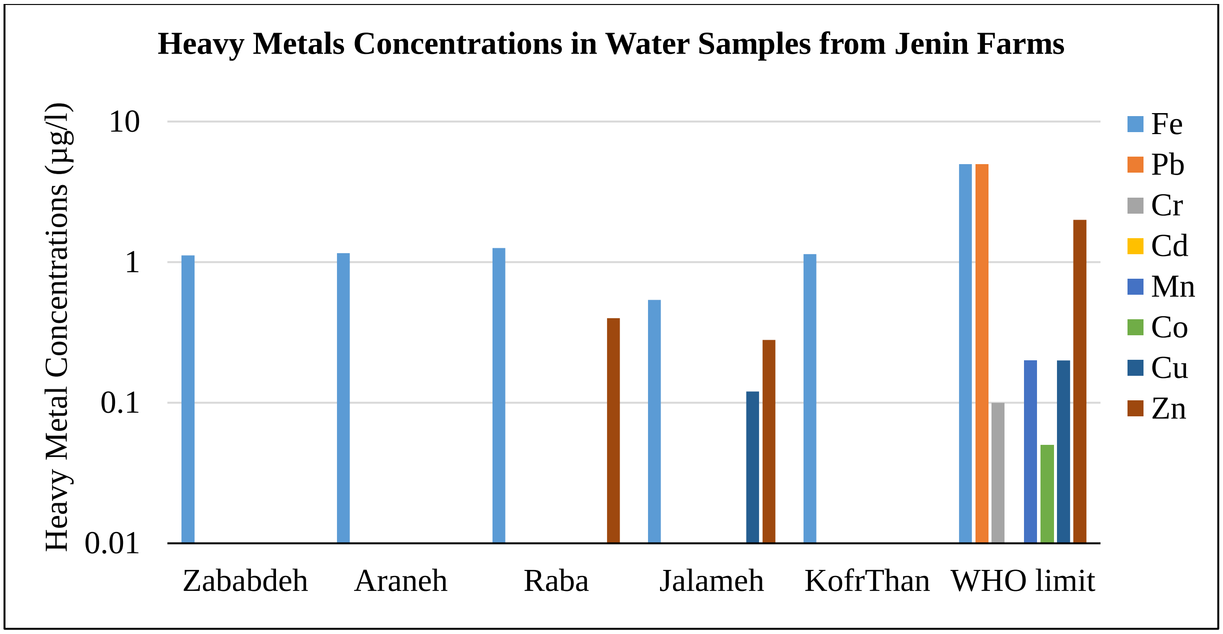

Figure (4.11): Heavy Metals Concentrations in Water Samples Collected from Jenin Farms

Figure (4.11) represents heavy metals levels in irrigation water (µg/l) in which all concentrations lie below the permissible safety limits that is set by FAO/WHO. According to these results, it is believed that contamination found in leafy vegetables is not related to irrigation water.

In figure (4.12) which represents heavy metals in water samples collected from both Bethlehem and Jenin regions, it can be noticed that Fe concentration in all water samples has a higher value compared to other elements such as Pb, Cr, Co, and Cd that were not detected in noticeable values. In addition, Zinc is relatively high compared to other heavy metals. Despite this, all heavy metals do not exceed the permissible limits.

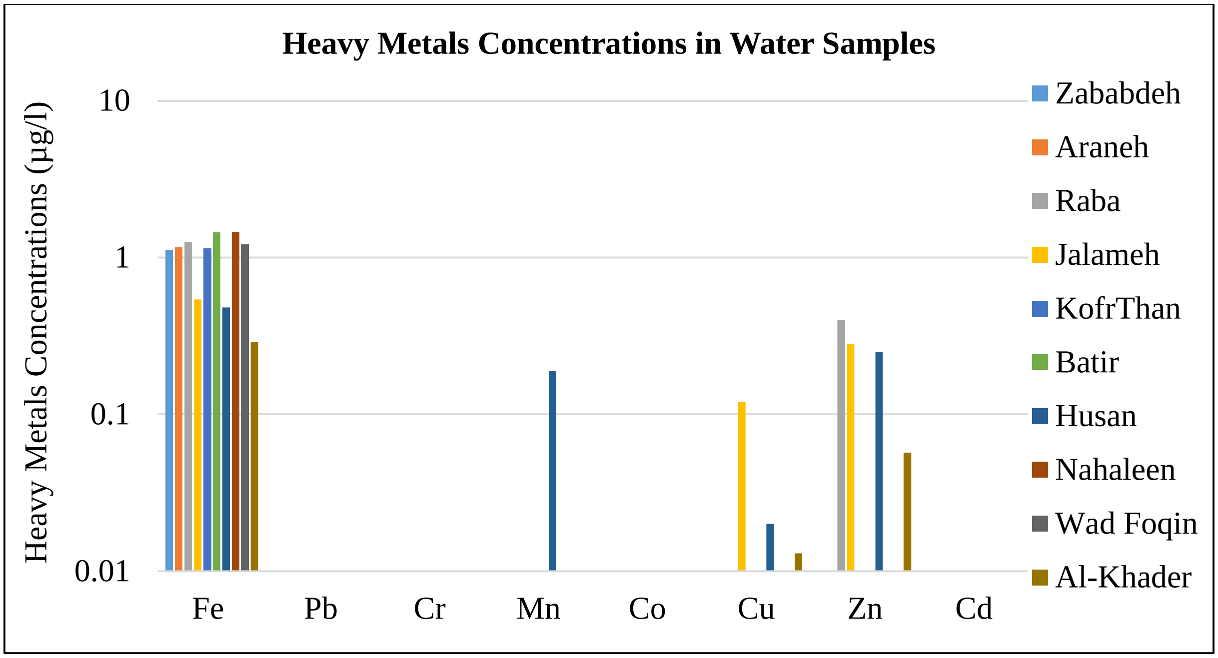

Figure (4.12): Heavy Metals Concentrations in Water Samples from Bethlehem and Jenin Farms

4.4 Heavy Metals Concentrations in Leachate Soil Samples

Heavy metals concentrations in leachate soil samples are shown in table (4.5) and table (4.6). It was found that all metals for all soil samples in Bethlehem farms and Jenin farms do not exceed the permissible limits given by FAO/WHO. Based on these results, it can be said that no heavy metals contamination in vegetables samples could have resulted from the soil.

Table (4.5): Heavy Metals Concentration Levels in Leachate Soil Samples (mg/kg) in Bethlehem Farms

Sample Name	**Sample Weight (kg)**	**Fe**	**Pb**	**Cr**	**Mn**	**Co**	**Cu**	**Zn**	**Cd**
Al Khader	0.05	1.33±5.80	ND	ND	ND	ND	0.02±0.02	0.03±0.29	ND
Batir	0.05	13.9±0.01	0.01±0.03	0.01±0.04	4.18±14.6	0.02±0.12	0.14±0.82	0.12±2.01	ND
Nahaleen	0.05	7.31±0.01	0.01±0.01	ND	3.41±14.8	0.01±0.13	0.06±0.47	0.02±1.04	ND
Husan	0.05	4.17±2.64	ND	ND	0.18±0.49	ND	ND	ND	ND
Wad Foqin	0.05	11.04±0.01	0.04±0.01	ND	0.03±0.03	0.01±0.13	0.09±0.15	ND	ND
FAO/WHO Safety limit		ND	100	0.1	ND	50.0	100	200	ND

In figure (4.13), which shows heavy metals concentration in soil samples at Bethlehem region, it can be seen that Fe levels are higher than other metals and its concentration is the highest at Batir. However, it still lies within the allowable limit for soil set by FAO/WHO.

It is also noticed that cadmium do is not exist in soil samples as well as chromium or have not been detected by the machine due to its low value. In addition, other heavy metals such as Mn, Co, Cu, Pb and Zn are found in very small amounts in the soil.

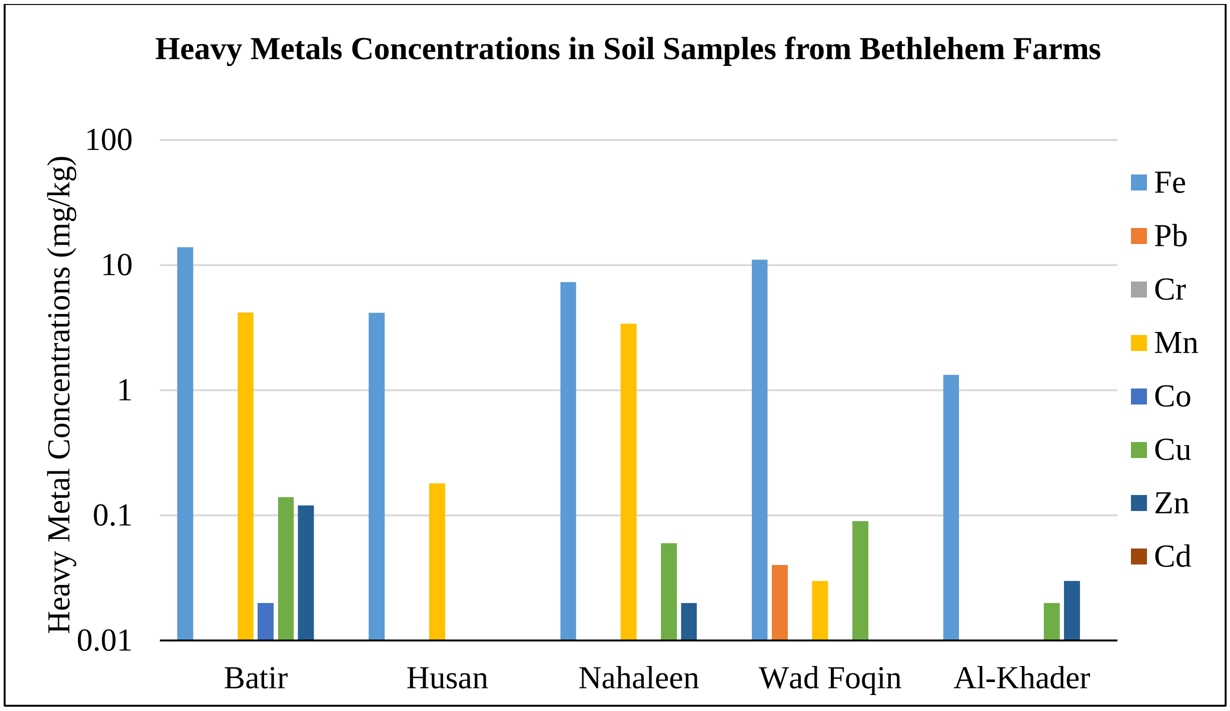

Figure (4.13): Heavy Metals Concentrations in Soil Samples Collected from Bethlehem Farms

Table (4. 6): Heavy Metals Concentration Levels in Leachate Soil Samples (mg/kg) in Jenin Farms

Sample Name	Fe	Pb	Cr	Mn	Co	Cu	Zn	Cd
Raba	4.44±0.14	ND	ND	0.15±1.34	0.01±0.06	0.15±0.93	0.04±7.88	ND
Zababdeh	13.63±0.31	ND	ND	16.21±5.37	0.04±0.25	0.05±0.36	0.04±3.17	ND
Jalameh	1.78±4.68	ND	ND	0.01±0.042	ND	0.04±0.09	1.17±2.04	ND
Kofr Than	5.93±18.31	0.01±0.04	ND	4.23±6.62	0.03±0.07	0.07±0.11	3.01±2.85	ND
Araneh	1.35±4.85	0.04±0.16	ND	0.01±0.026	0.01±0.02	0.04±0.31	0.11±0.37	ND
FAO/WHO Safety limits	ND	100	0.1	ND	50.0	100	200	ND

In figure (4.14), it can be seen that Chromium and Cadmium do not exist in these soil samples or they are below the detection limit of the machine. In addition, Fe is the most available heavy metal but does not exceed the permissible limit set by FAO/WHO. It can be also noticed that Manganese exists in Kofr Than farm quite higher compared to other farms. Still, none of these metals is harmful or has any effects within their existed concentrations.

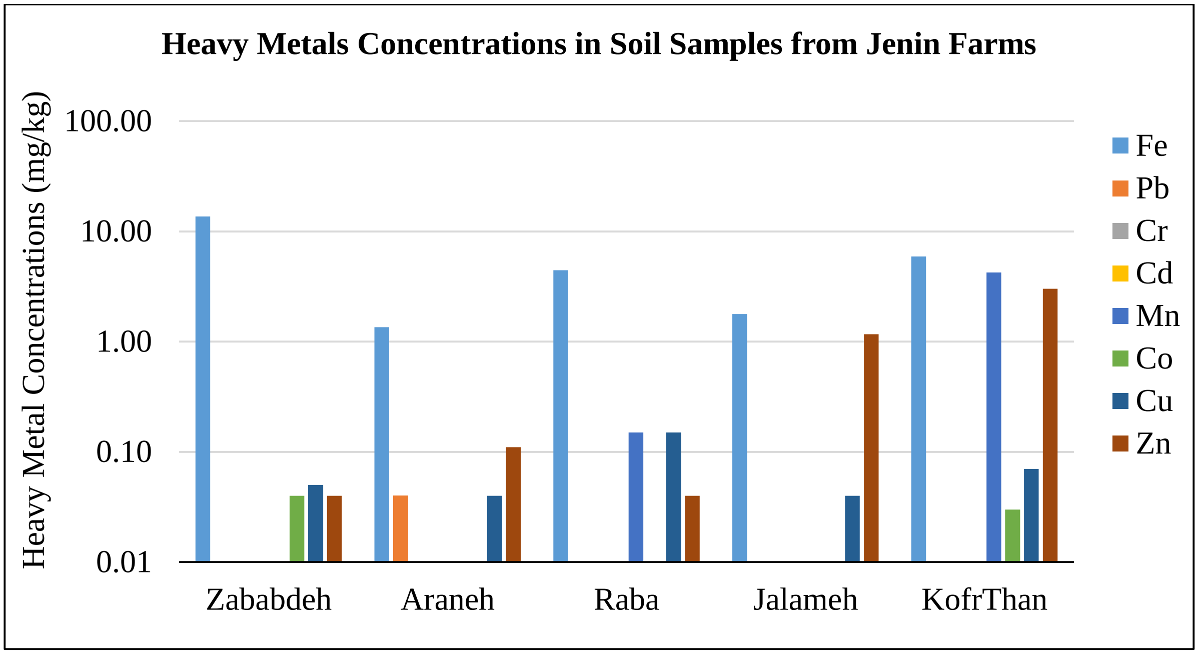

Figure (4.14): Heavy Metals Concentrations in Soil Samples Collected from Jenin Farms

However, when comparing level concentrations of heavy metals in both regions, it can be seen that Fe has the highest value among other elements in all soil samples. Manganese takes the second place then Zinc. All other heavy metals have very low concentrations in soil (See figure 4.15). The presented results of heavy metals in soil indicates that heavy metal content in soil is not relevant to heavy metal contamination found in leafy vegetables.

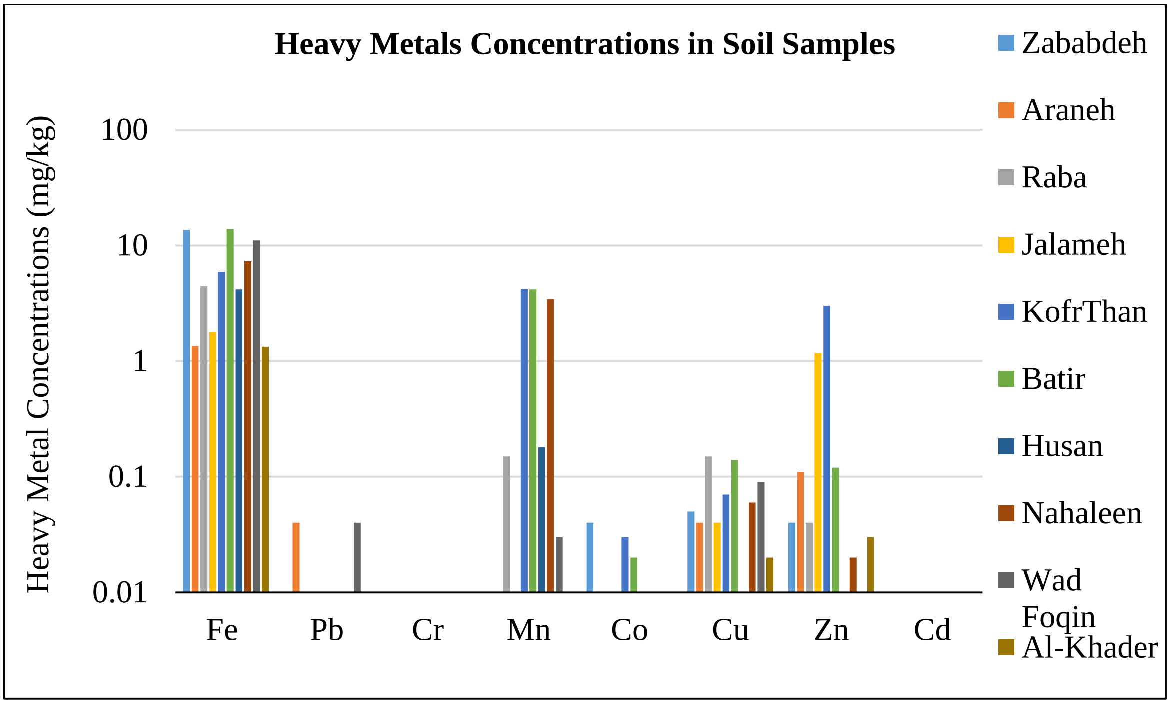

Figure (4.15): Heavy Metals Concentrations from Soil Samples from Bethlehem and Jenin Farms

4.5 Heavy Metals Concentrations in Pesticide Samples

Pesticides samples that were used on leafy vegetables were analysed for their heavy metals content levels. Table (4.7) shows some of the used pesticides with their heavy metal concentration in mg/l. Generally, these pesticide types are the ones often used by farmers when planting and growing leafy vegetables whether in Bethlehem or Jenin regions. Some of these types are used for organic agriculture, others are used as insecticides or nematicide as well as acaricides.

Table (4.7): Heavy Metals Concentration (mg/l) in Pesticides Samples

Sample Name	Pb	Cr	Mn	Fe	Co	Cu	Zn	Cd
Mafisto	0.121±0.003	0.142±0.091	0.049±0.010	0.809±0.68	0.009±0.004	0.044±0.019	2.680±0.093	0.006±0.002
Neemacor	0.160±0.026	0.033±0.050	0.029±0.016	0.882±2.06	0.002±0.001	0.031±0.013	2.736±0.048	0.008±0.008
Kung Fu	0.543±0.007	1.361±0.250	5.209±0.37	222.91±22.0	0.088±0.011	0.170±0.024	17.001±0.078	0.079±0.016
Vertimec	0.132±0.012	0.016±0.010	0.016±0.020	0.426±0.277	0.003±0.003	0.031±0.013	1.348±0.008	0.008±0.003
Timor C	0.247±0.005	0.112±0.062	0.562±0.046	198.94±17.26	0.027±0.003	0.133±0.002	30.551±0.251	0.007±0.009
Agriron	0.090±0.010	0.302±0.241	0.197±0.050	22.797±11.23	0.006±0.002	0.756±0.243	1.931±0.050	0.006±0.006
Defender	0.295±0.007	0.032±0.100	3.493±0.58	34.609±7.00	0.007±0.004	0.012±0.025	2.196±0.041	0.013±0.033
Siperin 10	0.056±0.002	0.306±0.291	0.299±0.051	8.705±1.45	0.012±0.003	0.041±0.023	0.761±0.015	0.007±0.003
Bio-T plus	0.152±0.016	0.038±0.117	19.64±0.99	25.458±1.91	0.008±0.004	9.186±0.486	21.838±0.076	0.016±0.012
Match	0.095±0.013	0.057±0.054	0.177±0.035	9.614±0.27	0.009±0.001	0.038±0.030	1.166±0.016	0.009±0.012
WHO/ FAO Limit	0.1	0.05	ND	ND	ND	0.1	15.0	0.06

It can be noticed that some metals are presented in relatively high concentration, particularly Iron, Lead, and Zinc. It is noticeable that these concentrations exceeded the permissible limit set by WHO/FAO regarding the presence of heavy metals in pesticides. Obviously, Iron is the most available heavy metal in the pesticides samples used on leafy vegetables. Zinc actually takes the second place regarding its availability in the selected pesticides. Other heavy metals are found in variable amounts as shown in the previous table.

These pesticide types are legal to be used according to the Ministry of Agriculture in the West Bank. Thus using them will not pose a direct problem; however, the validity of such pesticides depends on its concentration and the usage method; whether it is being used in the allowable concentration, or if being diluted correctly, etc.

Additionally, it is important to acknowledge that plenty of pesticides used by Palestinian farmers are illegal according to officials' statements and controllers at the Ministry of Agriculture. Besides, the smuggled illegal pesticides plays a direct role in contamination of vegetables as confirmed by Ministry of Agriculture. Other sources in the West Bank confirm the same statement including the Palestinian Central Bureau of Statistics that reported the excessive use of pesticides where 50% of these pesticides were insecticides. In addition to another institute which is Applied Research Institute Jerusalem (ARIJ) that collected background data about pesticides use in the West Bank, where results had shown widespread problems in both usage and disposal of pesticides. Some of the pesticides used in the West Bank are either suspended, cancelled or banned by the World Health Organization.

Table (4.8): Detailed Information about the Pesticides Samples

Sample Name	**Generic Name**	**Type**	**Active Ingredient Concentration**	**Source of Collection of Pesticide**
Mafisto	Acetamiprid	Insecticide	200 g/L	Ministry of Agriculture
Neemacor	Fenamiphos	Nematicide and Insecticide	400 g/L	Ministry of Agriculture
Kung Fu	Lambda Cyhalothrin	Pesticide	50 g/L	Bethlehem and Jenin Farms
Vertimec	Abamectin	Insecticide	18 g/L	Ministry of Agriculture
Timor C	Pyrethrin	Organic Control Material	15 g/L	Bethlehem Farms
Agriron	Abamectin	Acaricide	18 g/L	Jenin Farms
Defender	Cyflumetofen	Pesticide	215 g/L	Jenin Farms
Siperin 10	Cypermethrin	Insecticide and Acaricide	100 g/L	Ministry of Agriculture
Bio-T plus	Bacillus Thuringiensis	Organic Control Material	16 g/L	Bethlehem and Jenin Farms
Match	Lufenuron	Insecticide	50 g/L	Ministry of Agriculture

In table (4.8) which shows the generic name of each pesticide along with the concentration of the active ingredient in addition to the category that each pesticide belong to; it can be noticed that the concentration of the active ingredient varies. These pesticides are found in forms of emulsifiable concentrate, wettable powder, soluble liquid concentrate, soluble powder, suspension concentrate, capsule suspensions, and water dispersible granules.

However, it is quite obvious that the presence of heavy metals in leafy vegetable samples is directly related to the use of some of these pesticides. Probably the pesticides were being mixed wrongly, mishandled and misused. As stated by the Palestinian Central Bureau of Statistics in 2010, the use of pesticides in the West Bank is excessive. Thus, it can be concluded that pesticides have a major role in the contamination found in leafy vegetable samples. Other related Palestinian studies in the West Bank assured that most farmers need more educational programs regarding the safety and use of pesticides (Zyoud S., 2010).

To further explain the results, starting with Fe levels in leafy vegetables at Bethlehem region (see table 4.1) which is not found in contamination levels neither in irrigation water or leachate soil, then its presence in vegetables samples mainly in Nahaleen and Batir is related to pesticides appliance. In particular, due to usage of Timor C and Kung Fu Pesticides. As for Pb source, the reason could also be connected to pesticides especially kung Fu, and Defender. Concerning the source of Cr in the same region, it can be linked to the utilization of either Kung Fu, Agriron, or Siperin 10. In addition. Zn levels in Nahaleen Farm is relevant to the use of Timor C or Bio-T plus pesticides. Whereas for Cd levels in Nahaleen, the results leads back to the use of Kung Fu (note the concentrations of heavy metals in table 4.7).

Therefore, it can be concluded that the present heavy metal contamination is due to pesticides appliances in the mentioned farms in Bethlehem region. Specifically speaking, samples in Nahaleen and Batir showed high concentrations of heavy metals which were relevant to specific pesticides including Timor C, Kung Fu, Defender, Bio-T, Agriron and Siperin 10. However, the values obtained varied between one vegetable type and the other due to the quantity differences, dilution method, concentration of each pesticide, and the rate of exposure.

Still, there could be a possibility of contamination due to rapid industrialization and urbanization in the above areas in Bethlehem region. Thus, through atmospheric deposits, heavy metals can be absorbed into the plant tissues.

In addition to that, Fe concentration which was observed high in some samples, could be a result of use of iron chelate, which is a soluble complex of iron and chelating agent that is sprayed to plants to treat chlorosis; a condition in which leaves produce insufficient chlorophyll. The high results appeared in plants not in soil samples, because iron chelate is not held by the soil, and does not go under hydrolysis or biodegradation but easily absorbed by the plant. However, this remains a possibility and cannot be assured since there were no collected samples of iron chelate to analyse.

Regarding Jenin region, iron levels exceeded the permissible limits set by WHO/FAO in Zababdeh farm, and the reason for such result was confirmed to be the use of Kung Fu. However, it is noticeable that the used quantity of this pesticide was not the same as in Bethlehem farms since the concentrations were lower compared to those in Bethlehem. Similarly the concentration of lead at Zababdeh farm and Kofr Than farm were the results were also linked to the use of Kung Fu and Defender.

Additionally, copper as apparent in figure (4.8) exceeded the limit in Parsley sample at Raba farm. It can be considered that parsley in that farm was exposed to copper containing pesticide though in small portions. These pesticides could include Bio-T plus or Agriron.

In regards to cadmium (see figure 4.9), which is relatively high in spinach at Zababdeh farm, the cause for this result could be the exposure of spinach to other types of pesticides but in low portions.

However, it is believed that other farms such as Araneh, Jalameh, Husan, Wad foqin, and AlKhader use pesticides for improving their production but with regards to the allowable limits and according to regulations set by the Ministry of Agriculture. This could be the reason why leafy vegetables in these farms were not contaminated with noticeable heavy metals.

It is important to acknowledge that long term consumption of heavy metal contaminated vegetables may possibly cause numerous health hazards in human. Therefore, regular monitoring of heavy metals is crucial to avoid excessive build-up of these metals in human food chain especially that some pesticides could be illegal; even if legal, some can be misused or misapplied whether by the quantity, exposure rate and duration, or the dilution method.

Chapter Five

Conclusion and Recommendations

Chapter Five

5.1 Conclusion

From the present study, it can be concluded that some heavy metals (Fe, Pb, Cr, Cu, Zn, Cd) concentrations in some green leafy vegetables obtained from Bethlehem and Jenin regions were above the permissible limits set by FAO/WHO for human consumption. However, levels of Mn and Co in all leafy vegetables collected found below the maximum allowable limit. The results also indicated that the source of contamination was using pesticides. Some pesticides could have been misused whether by the concentration or the quantity or even the dilution process. Despite the significant relation between water, soil and vegetables, there were no clear evidence that contamination results from any of these parameters.

The results reveal that farmers apply pesticides in violation of the recommendations, they use high concentrations, and they use illegal unsafe chemicals, and ignore risks and safety instructions.

Yet, long term consumption of heavy metals may cause several health hazards in human. Thus, regular monitoring of heavy metals in leafy vegetables is crucial to avoid accumulation of such metals in the human food chain, also more attention should be paid to pesticides.

5.2 Recommendations

1. Raising awareness among farmers that pesticides should be used exactly according to the exact concentrations and instructions. Illegal pesticides should not be used.

2. Other studies should be conducted for monitoring heavy metals in leafy vegetables in other locations in the West Bank region.

3. Control the quantity of pesticides used on leafy vegetables as well as their concentration.

4. Raising awareness between all related fields whether farmers, workers, consumers, or institutions working in the fields of environmental problem.

5. Discussing heavy metal treatment regarding leafy vegetables is highly recommended for the future.

6. More detailed studies should be conducted in the contaminated farms especially Nahaleen, Batir, and Zababdeh to get clearer overview.

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Appendixes

A. Descriptive Statistics Heavy Metals Concentrations in Vegetables Samples in Bethlehem Region

Concentration (mg/kg)	**Heavy Metals**							
	Fe	**Pb**	**Cr**	**Mn**	**Co**	**Cu**	**Zn**	**Cd**
Minimum	25.35	0.03	0.02	2.22	0.00	0.56	3.61	0.00
Maximum	1569.53	1.77	2.51	58.50	0.48	14.30	106.50	1.40
Average	362.9	0.356	0.602	25.25	0.12	4.98	32.48	0.155
Median	165.48	0.28	0.44	19.62	0.07	1.93	29.35	0.05
SD	437.06	0.43	0.748	20.78	0.136	4.905	32.36	0.351
RSD (%)	1.20	1.21	1.24	0.82	1.13	0.98	0.99	2.26
% of samples that found to contain the heavy metal	100	100	100	100	86.6	100	100	93.3
Allowable limits	425	0.3	1.3	500	50	73	99.4	0.2
% of samples that exceeded the limit	33.3	40	13.3	0	0	0	6.66	13.3

B. Descriptive Statistics for Heavy Metals Concentrations in Vegetables Samples in Jenin Region

Concentration (mg/kg)	**Heavy Metals**							
	Fe	**Pb**	**Cr**	**Mn**	**Co**	**Cu**	**Zn**	**Cd**
Minimum	37.85	0.03	0.00	0.27	0.01	0.55	2.79	0.00
Maximum	543.10	0.67	0.77	117.37	0.31	278.50	44.54	1.62
Average	174.76	0.20	0.19	23.07	0.09	20.35	23.68	0.15
Median	86.21	0.13	0.11	11.33	0.06	1.60	23.66	0.03
SD	174.2	0.174	0.231	31.20	0.083	71.42	13.27	0.409
RSD (%)	0.99	0.86	1.22	1.35	0.97	3.50	0.56	2.77
% of samples that found to contain the heavy metal	100	100	66.6	100	100	100	100	93.3
Allowable limits	425	0.3	1.3	500	50	73	99.4	0.2
% of samples that exceeded the limit	20	20	0	0	0	6.66	0	6.66

تراكيز المعادن الثقيلة في الخضراوات الورقية في محافظتي بيت لحم وجنين

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الملخص

تعتبر النباتات الورقية من الخضراوات الصالحة للاكل والمطلوبة بشكل كبير في فلسطين، حيث انها تحتوي على الكثير من المعادن و الفيتامينات الضرورية لجسم الانسان. ولكن من المهم جداً الأخذ بعين الاعتبار أن تراكيز المعادن و خاصة الثقيلة منها لا يجوز أن تتخطى المعدل المسموح به و الذي تم وضعه من قبل منظمة الصحة العالمية.

تلوث النباتات الورقية بالمعادن الثقيلة هي أحد أهم القضايا البيئية لأن هذه المعادن تعتبر سامّة حتى على تراكيز منخفضة. ركزت هذه الدراسة على معرفة تراكيز المعادن الثقيلة بالنباتات الورقية و بصورة خاصة السبانخ، الجرجير، والبقدونس. عينات الدراسة أخذت من مزارع مختلفة من محافظتين في الضفة الغربية وهما بيت لحم وجنين نظراً لإختلاف طبيعة وبيئة المنطقتين عن بعضهما البعض. بالتالي تم الحصول على عينات مختلفة من النباتات الورقية من مزارع متنوعة في المنطقتين، بالاضافة الى عينات من مياه الري المستخدمة، وعينات تربة من كل مزرعة. كما وتم جمع عينات من المبيدات المستخدمة على هذه الخضراوات.

المعادن الثقيلة التي تم تحليلها عن طريق جهاز مطياف الكتلة البلازمي هي الحديد، الخارصين، الرصاص، كادميوم، كوبلت، منغنيز، النحاس، والكروم، حيث تعنى الدراسات المختلفة بتراكيز هذه المعادن نظراً لأهميتها و خطورتها إذا إرتفع تركيزها. كما و تعرف هذه المعادن بتأثيراتها السلبية الكثيرة على صحة الانسان.

كان هناك تباين في نتائج التحليل نوعا ما بين المنطقتين. وجد أن بعض عينات الخضراوات الورقية تحتوي على تراكيز أعلى من الحد المسموح به، بينما بعض العينات الاخرى لم تحتوي على عناصر ثقيلة و البعض

الآخر تحتوي على تراكيز قليلة جدا. تبين أن عنصر الحديد احتل المرتبة الاولى من حيث تواجده في النباتات، بعدها عنصر الرصاص و الخارصين. تراوحت أيضا النتائج بين عنصر النحاس و الكروم و الكادميوم حيث أنها تواجدت في النباتات لكن بتراكيز اقل مقارنة بالحديد و الخارصين والرصاص. اما نتيجة تحليل عنصري الكوبلت و المنغنيز لم تتخطى التراكيز المسموح بها من قبل منظمة الصحة العالمية.

أما بالنسبة لعينات مياه الري و التربة فتبين بأنها لا تحتوي على معادن ثقيلة، اذ كانت جميع العينات ضمن المعدل المسموح به. أما عينات المبيدات فقد كانت تحتوي على العديد من المعادن الثقيلة و بتراكيز متفاوتة، مما أدى الى ربط وجود العناصر الثقيلة الموجودة بالنباتات الورقية باستخدام المزارعين للمبيدات الكيماوية. حيث ان السبب قد يكون استخدام المبيدات بطريقة خاطئة او بتراكيز مبالغ فيها او استخدامها بشكل مستمر على فترات متقاربة وعدم التزام المزارعين بتعليمات وزارة الزراعة الخاصة بالمبيدات وتجاهل أثرها على صحة الانسان.