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Determination of Heavy Metal Concentrations in Tomato (*Lycopersicon esculentum* Miller) Grown in Different Station Types

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Abstract

In this study, washed and unwashed tomato fruits (Lycopersicon esculentum Miller) were collected from six different station types such as; brook coast, suburban area, industrial area, inner city, roadside and village (control) in Istanbul-Turkey, in 2009. Unwashed and washed fruit samples were used to analyze cadmium, chromium, copper, iron, nickel, lead and zinc concentrations by using inductively coupled plasma optical emission spectrometry. It was observed that washing procedure reduced concentrations of all heavy metals related to station types. In accordance with the results, the lowest and highest heavy metal accumulations measured in fruits were as follows; cadmium (0.17-0.40 µg/g dw), chrome (0.94-5.67 µg/g dw), copper (7.67-14.27 µg/g dw), iron (19.16-64.53 µg/g dw), nickel (1.02-11.64 µg/g dw), lead (4.31-5.51 µg/g dw) and zinc (1.36-3.07 µg/g dw). As a result, the relative abundance of heavy metals in tomato samples were observed as iron>copper>nickel>chrome>lead>zinc>cadmium. According to the results of this study, it can be said that tomato fruits reflect heavy metal amounts well in polluted areas such as urban, industrial and roadside when compared to unpolluted (control) areas with their washed and unwashed samples.

Keywords: Heavy metal, tomato, fruit, Istanbul.

Introduction

Solanaceae family member tomato is one of the world's most cultivated vegetables with a worldwide production of 129.650.000 tons. Turkey is the third biggest producer after China and USA with 366.180 (Hg/Ha) yield and 10.985.400 tons according to the data of "Food and Agriculture Organization of The United Nations" [1]. Tomato is native to South American Andes. In the mid-1500s, Spanish conquistadors carried tomato seeds to Europe and it was later introduced from Europe to southern and eastern Asia, Africa and the Middle East [2]. It is called "tender perennials" like bell peppers and sweet potatoes, because they are truly perennials but they are generally grown as annuals the with weak, woody, densely hairy stem that often vines over other plants [3,4]. It reaches 1-3 m in height and bears clusters of edible fruits classified as vegetables [4]. Fleshy berries of the plant are globular to oblate in shape and 2-15 cm in diameter. The immature fruit is green and hairy while the ripe fruits range from yellow, orange to red. It is usually round, smooth or furrowed [2].

Tomato fruits are usually eaten whole in salads, cooked in sauces, soup and meat, fish dishes or consumed as paste and catsup [5,6]. It contains many nutrients, anti-oxidants and secondary metabolites such as vitamins C and E, b-carotene, lycopene, flavonoids, organic acids, phenolics and chlorophyll, which are important for human health [6-8].

Increasing industrialization has been accompanied by the extraction and distribution of mineral substances from their natural deposits throughout the world [9,10]. It is known that, some heavy metals (Zn, Cu, Mn or Mo) are micronutrients at low concentrations [11]. Nevertheless, metals most often found as contaminants in vegetables include As, Cd and Pb. These metals can pose as a significant health risk to humans, when they reach high concentrations in the body [12-14]. This can be expressed in the inhibition or activation of certain enzyme processes affecting their productivity from both qualitative and quantitative aspects [15]. Contamination of the soil by heavy metals is often a direct or indirect consequence of anthropogenic activities [16,17]. Sources of anthropogenic metal contamination in soils include - urban and industrial wastes; mining and smelting of non-ferrous metals and metallurgical industries [14,18]. Additionally, one of the main sources of air pollution in urban areas are traffic, industry and fossil fuel burning for heating purposes [19]. Food and vegetable crops production requires assess to fertile land, water and in some cases fertilizers, particularly in poor and developing countries of the world. Thus, it requires all the necessary inputs it deserves to realize this goal [20].

In this study, washed and unwashed tomato fruits (*Lycopersicon esculentum* Miller) were collected from six different station types such as; brook coast, suburban area, industrial area, inner city, roadside and village (control) in Istanbul-Turkey, in 2009. Samples were used to analyze cadmium, chromium, copper, iron, nickel, lead and zinc concentrations by using inductively coupled plasma optical emission spectrometry to determine heavy metal levels in different station types.

Material and methods

Study Area

This study was realized in Istanbul, which is located in the north-west part of Turkey (41° 01.2' N, 28° 58.2' E) and is known as one of the biggest metropolitan areas of the world [21]. Istanbul has approximately 5100 km^2 land area and has the highest population (12.573.836), and continuing to increase the fastest in Turkey [22,23]. It also has an important role as being the touristic, cultural and industrial city [23-25].

Stations

Tomato fruits produced by Turkish farmers in different parts of Istanbul were collected from six different station types such as brook coast, suburban area, industrial area, inner city, roadside and village (control) in 2009 (Figure 1).

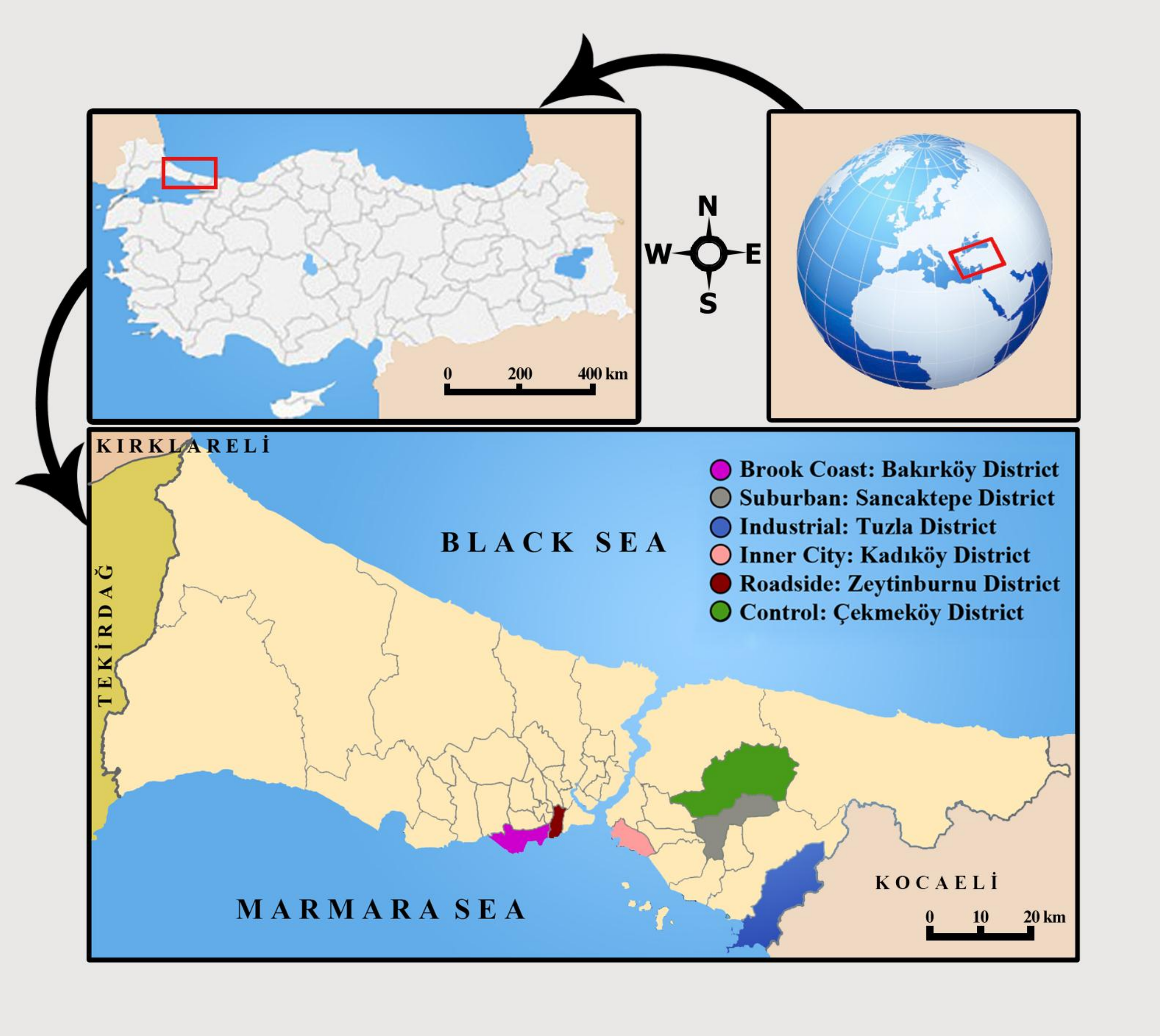

Figure 1: Istanbul City/Turkey and studied administrative districts Bakırköy, Sancaktepe, Tuzla, Kadıköy, Zeytinburnu and Çekmeköy.

Samples collected from brook coast were near Ayamama brook, which extends in the Bakırköy district. Bakırköy is a large, densely populated middle class residential district of Istanbul, Turkey on its European side, between the E5 motorway and the coast of the Marmara Sea (40° 59′ 15″ N, 28° 51′ 42″ E) [26]. The Bakırköy district has a land area of 32.42 km^2 and a population of 218.352 [22]. The suburban station’s tomato samples were collected from the Sancaktepe district, which became a district in 2008. It is on the Asian side of Istanbul and has approximately 61.90 km^2 land area and a population of 241.000 [22]. It is a typical suburb and there are many illegally built buildings, without infrastructure and without any aesthetical concern, which are called “gecekondu” in Turkish [27]. The industrial area where fruits were collected from is the Tuzla district. Tuzla is a small town of Istanbul on the Asian side of the city (40° 49′ 00″ N, 29° 18′ 03″ E) beyond the Kartal and Pendik districts. It has a land area of 123 km^2 and a population of 123.255 [22]. There are 39 shipyards operated by private sector, making it the center of Turkish shipbuilding sector in the Tuzla district. Additionally, there are many industrial processes and firms such as Organized Marble Industrial Zone (83 companies in 72 ha of land), Organized Industrial Zone for Dyes and Lacquer (102 factories in 511.000 m^2 land), Istanbul Tuzla Chemical Industrialists Organized Industrial Zone (Over 100 companies in 742 ha land), Istanbul

Leather Organized Industrial Zone (496 leather and subsidiary industry firms in seven million m^2 land) [28]. Inner station samples were collected from Göztepe vicinity in the Kadıköy district. The Kadıköy district is located on the Asian side of Istanbul (40° 59' 08" N, 29° 01' 45" E) on the north coast of the Marmara Sea. The district covers 34 km^2 and has the typical physical characteristics of coastal cities in the region [23,29]. It has a population of 553.670 [22]. Kadıköy is a large, populous, and cosmopolitan district of facing the historic city centre on the European side of the Bosporus. Göztepe vicinity reflects the similar properties with the Kadıköy district [29]. Roadside samples were collected from Prof. Dr. Muammer Aksoy Street in the Zeytinburnu district. Thousands of vehicles pass along the street everyday. Zeytinburnu is a working class suburb of Istanbul, Turkey on its European side, on the shore of the Marmara Sea (40° 59′ 20″ N, 28° 53′ 75″ E) just outside the walls of the ancient city, beyond the fortress of Yedikule [30]. The district has 1261.90 km^2 land area and a population of 288.743 [22]. Zeytinburnu is an important lesson for city planning in Turkey, because it was one of the first gecekondu districts. In most cases, the ground floor of buildings was used as a small textile workshop, and thus it became a bustling industrial area with a large residential population living above the workshops. There was an unplanned build leather industry, which now has largely moved out to Tuzla, but the rows of six-storey apartments with textile workshops in the first floor remained [30]. Our last station where the control samples were collected was a village (Paşaköy village) in the Çekmeköy district. The district is located on the Asian side of Istanbul and became a district in 2009. There are five villages and 17 neighborhood units in 148.08 km^2 land area and the population of the district is 135.603 [22,31].

Sample Collection and Preparation

Samples were taken by hands protected with vinyl gloves and carefully packed in polyethylene bags [32]. Only the edible parts of each plant were used for analytical processes. Samples were divided into two sub-samples; some of them were thoroughly washed several times with tap water followed by distilled water to remove dust particles in a standardized procedure, and rest of the fruits were untreated and then the samples are oven dried at 80 ^{o}C for 24 h. As it is known, drying of the collected plant materials is important since it protects the material from microbial decomposition and ensures a constant reference value by determining dry weight in contrast to fresh weight, which is difficult to quantify [33,34]. To ensure the uniform distribution of metals in the sample, all materials were milled in a micro-hammer cutter and sieved through a 1.5-mm sieve. Dried and milled samples were powdered and kept in clean polyethylene bottles [35].

Analytical Techniques

Approximately, one kg of tomatoes were collected and analyzed for each station type. Samples were digested with 10 mL of pure HNO_3 using a CEM Mars 5 (CEM Corporation Mathews, NC, USA) microwave digestion system. The digestion conditions were as follows; the maximum power was 1200 W, the power was at 100 %, the ramp was set for 20 min, the pressure was 180 psi, the temperature was 210 ^{o}C and the hold time was 10 min. After digestion, solutions were evaporated to near dryness in a beaker. The volume of each sample was adjusted to 10 mL using 0.1 M HNO_3. The determination of the elements in all samples was carried out by using a Varian Inductively Coupled Plasma-Optical Emission Spectrometry (ICP-OES). The stability of the device was evaluated at every ten samples by examining an internal standard. Reagent blanks were also prepared to detect any potential contamination during the digestion and analytical procedure. All chemicals used in this study were analytical reagent grade (Merck, Darmstadt, Germany).

Results and discussion

The mean values of Cd, Cr, Cu, Fe, Ni, Pb and Zn concentrations in tomato fruits studied are given in Table 1. The concentrations of heavy metals in these samples are quite variable such as Cd (0.17-0.40 µg/g dw), Cr (0.94-5.67 µg/g dw), Cu (7.67-14.27 µg/g dw), Fe (19.16-64.53 µg/g dw), Ni (1.02-11.64 µg/g dw), Pb (4.31-5.51 µg/g dw) and Zn (1.36-3.07 µg/g dw). Washing procedure reduced all heavy metal values related to airborne pollution sources and other factors between 1.48-89.90 % in different station types.

Table 1: Cd, Cr, Cu, Fe, Ni, Pb and Zn concentrations (µg/g dw) of unwashed (UW) and washed (W) tomato fruit samples and collected stations.

Location	Cd		Cr		Cu		Fe		Ni		Pb		Zn	
	UW	**W**	**UW**	**W**	**UW**	**W**	**UW**	**W**	**UW**	**W**	**UW**	**W**	**UW**	**W**
Brook Coast	0.40	0.33	5.67	4.33	14.27	12.54	64.53	57.55	5.49	2.36	4.75	4.43	2.92	2.45
Suburban	0.28	0.24	2.82	1.33	11.24	8.07	46.33	25.59	1.08	1.02	5.51	4.50	1.92	1.48
Industrial	0.29	0.17	1.88	1.63	13.71	11.25	47.75	39.00	1.69	1.60	4.76	4.68	2.53	2.20
Inner City	0.36	0.34	2.38	2.33	9.08	8.10	60.48	49.76	10.50	1.06	4.68	4.43	1.72	1.66
Roadside	0.30	0.23	3.29	3.15	13.83	13.38	53.39	37.39	11.64	1.32	4.42	4.31	3.07	3.01
Control	0.28	0.26	1.89	0.94	9.65	7.67	32.25	19.16	1.35	1.33	4.69	4.44	1.46	1.36

In our study, while the highest Cd values were found in the brook coast (0.40 µg/g dw) and inner city (0.36 µg/g dw), the % Cd removal value was the highest in industrial area with 41.38 % shows air borne sources in the area (Table 1-2). In this study, Ayamama brook was the source of irrigation water of tomato samples collected from brook coast originated in the Başakşehir district and many industrial units discharge their wastes into it until our station. The higher Cd accumulation in fruits could be the result of this situation in brook coast.

The sources of Cd in industrial activities are mining, ore dressing, and smelting of nonferrous metals, Cd compound production, battery manufacturing industry and electroplating [36,37]. In our study, the industrial area is newly established and contains firms manufacturing tolls for shipping industry, leather industry, iron, steel and textile industries and has been actively working for a couple of years and this could be the result of slightly lover Cd levels. In addition, combustion of fossil fuels, iron and steel production, nonferrous metals production and municipal solid waste combustion are the main sources of Cd emissions to air [38-40]. Phosphate fertilizers, nonferrous metals production, and the iron and steel industry are the sources of Cd in water [38]. Main inputs to agricultural soils, which are of primary relevance to human exposure to Cd, arise from atmospheric deposition, sewage sludge application, insecticides, fungicides and phosphate fertilizer application [40-42]. In our study, all of the farmers used commercial fertilizers for tomato cultivation.

In a study realized in urban and rural areas of Kayseri, Turkey, researchers found Cd values in tomato fruits 0.41 µg/g and 0.33 µg/g respectively [35]. Their results show broad agreement with our study. In another study, the average Cd value was measured as 0.7351 mg kg^{-1} in irrigated farmlands on the bank of River Challawa, Kano, Nigeria, [43]. Our measured lower Cd levels in tomato fruits are gratifying results especially in different sites of a crowded metropolitan, Istanbul. However, the Cd results of tomato fruits obtained from different markets of Alexandria City Egypt were quite lower than our results [44].

The mean Cr concentrations in tomato fruits collected from different station types are shown in Table 1. As a result of the measurements, the average highest value of Cr accumulation was obtained from unwashed tomato fruits collected from brook coast (5.67 μg/g dw) and the lowest value was detected as 0.94 μg/g dw with washed tomato fruits collected from the control area. In addition, % Cr removal values due to washing procedure varied between 2.10 % to 52.84 % related to station type (Table 2).

Table 2: Total percentage of Cd, Cr, Cu, Fe, Ni, Pb and Zn removed from the fruit samples of *Lycopersicon esculentum* Miller through washing procedure in six different stations.

Location	Cd (%) Removal	Cr (%) Removal	Cu (%) Removal	Fe (%) Removal	Ni (%) Removal	Pb (%) Removal	Zn (%) Removal
Brook Coast	17.50	23.63	12.12	10.82	57.01	6.74	16.10
Suburban	14.29	52.84	28.20	44.77	5.56	18.33	22.92
Industrial	41.38	13.30	17.94	18.32	5.33	1.68	13.04
Inner City	5.56	2.10	10.79	17.72	89.90	5.34	3.49
Roadside	23.33	4.26	3.25	29.97	88.66	2.49	1.95
Control	7.14	50.26	20.52	40.59	1.48	5.33	6.85

Cr is widely distributed in the earth's crust, though usually at very low levels of concentration. It has many industrial uses, both in its metallic form and in various compounds [45]. The main sources of exposition to toxic forms of Cr are dyes and leather tanning, when wastes are discharged directly into waste streams, either as liquids or as solids [42,46,47]. In air, the compounds of Cr exist primarily as particles of fine dust that eventually are placed on land or water. Other commercial applications include alloys of steel, catalyzers, fireproof products, drilling muds, electroplating cleaning agents, production of chromic acid and special chemicals [42, 47-49]. In our study, the higher Cr levels in the brook coast could be the results of many leather firms near the area, which discharge their wastes into the brook. Additionally, the other higher values in roadside could be the result of air pollution, which supported by many researches realized in the same area [49-52].

Previous studies claimed that, Cr amounts in tomato fruits vary related to their growing areas in different countries of the world. Abdullahi *et al.*, 2007 and Akan *et al.*, 2009 observed higher Cr values in tomatoes in River Challawa, Kano Coast, Nigeria. Like our study, obtaining higher Cr values near a river is remarkable, especially similarity of the pollutant types [43,53]. However, in Karachi, Pakistan quite lower values than ours were observed in tomato fruits obtained from different markets [54].

The mean Cu concentrations in washed and unwashed tomato fruits are shown in Table 1. The average highest Cu accumulation (14.27 μg/g dw) was in unwashed samples collected from brook coast while the lowest (7.67 μg/g dw) was collected from control area. It was observed that washing the fruits reduced Cu amounts between **3.25** to 28.20 % (Table 2).

In nature, Cu occurs in rocks, water, air and it is essential for the normal growth and metabolism of all living organisms [55]. It is present naturally in the environment in the elemental form, but most of the commercial production comes from sulfides and oxide minerals [56]. Cu is still widely used for electrical equipment; construction, such as roofing and plumbing; and industrial machinery, such as heat exchangers and alloys. Cu has also a wide range of other applications in agriculture (nutrients, pesticides, and fungicides), wood preservation, and medical applications [55,57]. Our slightly higher values, especially in brook coast could be the result of industrial activities and/or the usage of commercial fertilizers by the farmers in our stations.

In a study, tomatoes were cultured by using conventional, integrated pest management (IPM) and organic farming techniques and Cu amounts were measured between 0.46 to 0.65 mg kg^{-1} [58]. Abdullahi *et al*., 2008 also measured lover values (6.24±2.22 mg/kg) than ours in irrigated farmlands on the Bank of River Challawa, Kano, Nigeria [43], like another study realized in different station types of Visakhapatnam City, India [59]. In a study realized in Egypt, very low Cu values measured in market samples [44]. Although our Cu values are higher than many previous studies, concentrations of Cu in tomato fruits grown in different sites of Istanbul are within recommended permissible limits (2-20 mg Cu kg^{-1}, dw) [60]. However, Singh *et al*., 2010 observed higher Cu values in tomatoes collected from wastewater irrigated site of a dry tropical area of India [61] and Demirezen and Aksoy, 2006 in both urban and rural areas of Kayseri/Turkey [35].

In our study, the average highest Fe amounts (64.53 μg/g dw) were measured in unwashed tomato fruits which were collected from brook coast like Cd, Cr and Cu elements. The average lowest values were obtained in washed tomato samples collected from control area like Cr and Cu as well (Table 1). Washing procedure reduced Fe amounts between 10.82-44.77 % (Table 2).

Fe is an essential element for all forms of life. It takes part in photosynthesis, respiration, DNA synthesis, and hormone structure and action [62]. Uptake and transport of Fe by the plant is an integrated process of membrane transport, reduction, and trafficking between chelator species, whole-plant allocation, and genetic regulation [62-64]. In soils, Fe occurs mainly in forms of oxides and hydroxides, as amorphous compounds, small particles, fillings in cracks and veins, and coatings on other minerals or particles [65]. Fe is mostly used in steel industry as a raw material, in paint industry with its oxidized form as pigment, as a compound in carbon and some other metals, in constructions and buildings [49,66].

In a similar study, quite lower Fe values were measured in tomato fruits obtained different markets of Karachi, Pakistan [54]. Although Akan *et al*., 2009 observed higher Cd, Cr and Cu values than our tomatoes samples, in River Challawa, Kano Coast, Nigeria, their Fe values were lower than ours (2.00-10.00 μg g^{-1}) [53]. In another study, researchers planted tomato seedlings and furrow irrigated with different mixtures of potable water to treated wastewater and they observed lower Fe values (4.130-12.220 mg/kg) [67]. It can be said that our Fe values are quite higher than some similar studies realized in other countries. Higher Fe amounts in soil and Judas tree samples collected from Istanbul, especially in our study areas reported in another study, could be the result of the higher Fe in tomato fruits [49]. However, literature indicates that, the normal limits of Fe are in the range of 2-250 μg/g for plants [46]. In this situation, the Fe contents of our plant samples are within normal limits although they are higher than some similar researches.

In this study, average highest Ni values (11.64 μg/g dw) were measured in unwashed tomato samples collected near roadside, while the lowest (1.02 μg/g dw) were measured in washed samples, which collected from suburban area (Table 1). The highest reduction ratio (89.90 %) was observed in inner city (Table 2). Additionally, in all stations, the levels were closed to each other and varied between 1.02-2.36 μg/g dw, in washed tomato fruits.

Ni is an abundant element naturally found in soil, water and food [68]. Natural sources of atmospheric nickel are dusts from volcanic emissions and the weathering of rocks and soils, while natural sources of aqueous nickel are derived from biological cycles and solubilization of nickel compounds from soils [69,70]. The sources of Ni are mainly vehicles running on petroleum and diesel fuel, which can easily contribute to Ni emissions to the atmosphere [68]. Redistribution of this metal in the environment from the burning of fossil fuel, application of sludge to agricultural lands, and by industrial emissions should be of concern [46]. Ni is an element for which several hyperaccumulator plants have been reported, with levels above 1000 mg/kg dw [71,72]. Human exposure to nickel occurs primarily via inhalation and ingestion. Wearing or handling of jewelry, coins, or utensils, which are fabricated from nickel alloys or have nickel-plated coatings may result in cutaneous nickel absorption. Occupational exposure to Ni occurs predominantly in mining, refining, alloy production, electroplating, and welding [70,73]. Additionally, some other nickel containing compounds are nickel-cadmium batteries, some computer components, various paints and ceramics, magnetic tapes and goods containing stainless steel (sinks, cooking utensils, cutlery) [49,68].

Previous studies showed that, there is not much Ni pollution for many places and in general, Ni values of selected fruit samples are within normal limits [60]. Abdullahi *et al*., 2007, Akan *et al*., 2009 (River Challawa, Kano Coast, Nigeria), measured Ni values similar with ours [43,53]. However, in another study realized in Kayseri, Turkey, similar values were measured in urban areas but lower in rural areas [35].

The mean Pb concentrations in both types of (unwashed and washed) tomato samples are shown in Figure 1. In this study, the average highest Pb values were observed from unwashed tomato samples collected from suburban area, while the lowest were observed from washed samples collected from roadside. Additionally, measured Pb values of unwashed samples were closer to each others in all types of stations, which varied between 4.31-4.68 μg/g dw. According to the literature, the normal limits of Pb in plant tissues are between 0.1-10 μg g^{-1} dw and between 30-300 μg/g dw are considered as toxic levels [46]. Like other elements, washing procedure reduced Pb values in all samples, but the reduction was fewer than other elements (Table 2).

Pb can be found in small amounts in the earth's crust, existing in different chemical forms: metallic (pure metal); inorganic compounds, such as lead oxide, lead sulfate, lead chromates, lead silicates, lead arsenates, and lead chloride; and organic compounds, such as tetraethyl lead [42]. It has been mined since ancient times and known to be toxic since then [46]. World production amounts to millions of tons and is used in the manufacture of accumulators, batteries, solders, pigments, cables, ceramics, soldering and building materials (because its excellent resistance to corrosion), and anti-rust agents (red lead/lead oxide), and leaded petrol [42,74,75]. Additionally, some fertilizers, which are used in many countries, also contain lead [42]. Among various natural and anthropogenic sources of Pb contamination, the impact of industrial emissions and previously used leaded petrol are considered to be of the greatest environmental risk [76]. Other sources of lead pollution in the environment are the laying of lead sheets by roofers as well as the use of paints and anti-rust agents [46,74-76].

As it is known, leaded petrol is forbidden in Turkey since 2004 and older and newer measurements in different sites of the city showed that, the Pb levels were reduced considerably especially in roadside and urban areas [50-52,77]. In this study, the slightly lower Pb values could be the result of this decision.

Demirezen & Aksoy, 2006 (Kayseri, Turkey) and Abdullahi *et al*., 2007 (Kano, Nigeria) measured higher Pb values in their tomato samples [35,43]. In addition, Akan *et al*., 2009 observed similar Pb values in Nigeria [53]. In another study, lower Pb values were measured in market samples in Egypt [44]. Srinivas *et al*., 2009 also measured lower Pb values in their tomato samples collected from different station types of Visakhapatnam City, India [59]. In this study, although our Pb values are higher than some previous studies, concentrations of Pb in tomato fruits grown in different sites of Istanbul is within recommended permissible limits (5.0 mg kg^{-1}, dw) [60].

Zn amounts in washed and unwashed tomato fruits in six different station types are shown in Table 1. The results were as follows; the average highest Zn (3.07 μg/g dw) was measured in roadside with unwashed samples while the lowest was measured in control area (1.36 μg/g dw). In addition, washing procedure reduced Zn values like our other elements (Table 2).

Zn is one of the trace elements that are present in all living structures, both in plants and animals [78]. It is a structural component of over 300 enzymes, important for metabolism of all macromolecules, metabolism of nucleic acids and metabolism of other minerals [78,79]. Zn is used in many industries, mainly as corrosion protection on steel components and other metals. It is an important component of various alloys and is widely used as catalyst in different chemical production (e.g., rubber, pigments, plastic, lubricants, and pesticides). Due to its versatile properties, its use has been documented in different sectors such as batteries, automotive equipment, pipes and household devices. Different compounds of Zn have dental and medical applications [65].

Zn is constantly being transported by nature, a process called natural cycling. Rain, snow, ice, sun, and wind erode zinc-containing rocks and soil. Wind and water carry small amounts of Zn to lakes, rivers, and the sea, where it is collected as sediment or is transported further. Natural phenomena such as volcanic eruptions, forest fires, dust storms, and sea spray all contribute to the continuous cycling of Zn through nature [80]. In Europe, Zn is the element deposited in largest amounts to the atmosphere, followed by Pb and Cu [81].

In previous studies, Radwan & Salama, 2006, Hashmi *et al*., 2007 and Abdullahi *et al*., 2007, obtained higher values in their tomato samples whilst Akan *et al*., 2009 obtained similar results [43,44,53,54]. Demirezen & Aksoy, 2006, obtained similar values in urban and very high results in suburban and they commented their results as the disparity could be explained by the influence of anthropogenic activities, especially the sewage-sludge in Turkish lands [35]. Additionally, our Zn values are quite lower than many similar studies. In another study, much lower Zn values were measured in their soil samples collected from different parts of the Pendik district, Istanbul [78]. Eyupoglu *et al*., 1994 analyzed 1511 soil samples collected from all provinces of Turkey and they showed that 50 % of the cultivated soils in Turkey are Zn-deficient [82]. These lower soil Zn values could be the result of lower Zn values in our tomato fruits.

Based on the results of this study, tomato fruit samples that are collected from six different station types showed different heavy metal levels according to the station types and pollutant sources. However, measured heavy metal levels were within acceptable limits of many comities and literatures [46,60,65] and lower than results of many previous studies. The relative abundance of the trace metals in tomato samples (exposed and control) analyzed followed the sequence Fe>Cu>Ni>Cr>Pb>Zn>Cd. This situation is gratifying, especially in a big metropolitan city, Istanbul. Nevertheless, slightly higher results were obtained in brook coast for Cd, Cr, Cu and Fe, in roadside for Ni, in suburban for Pb and in roadside for Zn. The concentration of heavy metals in tomato fruits varied with nearby factors like proximity industries, irrigation water, and use of fertilizers and fungicides. In our study, tomato plants were watered with Ayamama brook's water in brook coast and it had been polluted by wastes of many industrial units for a long time. However, it is being cleaned recently by Istanbul Metropolitan Municipality in the coverage of a big project. When compared to the results of other studies with samples collected near polluted brooks or rivers, it can be seen that heavy metal values are higher than other stations like our study [20,43]. This could be the result of different pollutants being drained by different types of production plants. In our study, the industrial area is newly established and industrial firms have been actively working for a couple of years and this could be the reason of lower heavy metal levels than expected.

In this study, washing the samples reduced heavy metal concentrations for all heavy metals. Additionally, plants grown in village, farms and fields contained lower heavy metals than any parts of the city. Bo *et al.*, 2009 also suggested this result as mentioning that vegetables grown in open lands have more heavy metals than the ones grown in nurseries [83]. It is obvious that airborne pollution is reduced to the minimal limits in closed areas and effects the plants positively. In accordance with the results we have obtained, there are some issues that should be taken into consideration when growing vegetables;

1 - Vegetables should not be grown in areas where intensive industrial plantations and high traffic density is present.

2 - The use of agricultural chemicals and pesticides should be considered for their polluting effects and attention should be paid to biological control.

3 - The quality of irrigation water should be paid attention and water should be protected against pollution.

4 - Nurseries should be encouraged and fruits and vegetables grown in nurseries have to be consumed preferably.

5 - The vegetables should be washed thoroughly before being consumed.

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