Journal of Scientific Agriculture 2025, 9: 250-255
doi: 10.25081/jsa.2025.v9.9697
https://updatepublishing.com/journal/index.php/jsa

Research Article

ISSN: 2184-0261

Assessment of heavy metal residual concentration and related agrochemical application practices in tomato in selected districts of Gamo Zone, Southern Ethiopia

Ermias Dureto*, Wasihun Wale, Awoke Mensa

Food science and Post Harvest Technology, Arba Minch Agricultural Research Center, South Ethiopia

Received: August 29, 2025
Revised: November 06, 2025
Accepted: November 09, 2025
Published: December 03, 2025

***Corresponding Author:**
Ermias Dureto
E-mail: ermiasdureto2009@gmail.com

ABSTRACT

Tomatoes are intensively produced in Mirab Abaya and Arba Minch Zurea districts of Gamo Zone Southern Ethiopia. To increase the production in small unit of land, farmers use numerous agrochemicals which could be possible sources of toxic heavy metals like Pb, Cr, Cu, Cd, Mn and Ni. Hence, this study aims to assess heavy metal residual concentration of tomato fruit after harvest. Tomato samples were collected from local markets and four potential producer areas of Gamo Zone, Southern Ethiopia. Before laboratory analysis, tomato samples from each location were coded and carefully prepared by following standard methods. The atomic absorption spectrometer method was used to determine heavy metals. The result showed that heavy metals were ranked in the order of Cd<Ni<Mn<Cr<Pb<Cu. respectively. When comparing the results with FAO/WHO safety limits, Lead and chromium showed higher values than recommendations that could pose adverse health effects in humans.

KEYWORDS: Tomato, Agrochemicals, Heavy metals, Pesticides, Safety limits

INTRODUCTION

Tomato is the most important fruit crop that is grown under the intensive farming system and is perishable in nature. As a result most of the time it is consumed as fresh, whole in salads, cooked in sauces, soup and meat, fish dishes or consumed as paste and catsup and incorporated in our daily dietary system (Giovanelli & Paradiso, 2002). 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 (Demirbas, 2010).

Tomato production has been considerably improved with the help of pesticides but their unrestricted and extreme use is polluting the atmosphere, foodstuffs, and aquatic and agricultural products (Aljerf, 2018). Chemical contaminants such as heavy metals are among the major contaminants of the food supply and may be the major problem for our planet and which is getting more serious all over the world. These metals are given special attention throughout the globe due to their toxic and mutagenic effects even at very low concentrations. The implications associated with heavy metal contamination are of great concern, particularly in agricultural production system. They are not biodegradable, have long biological half-lives, toxic in nature and potential for accumulation in the different body organs leading to unwanted side effects (Hall, 2002).

Heavy metal residues in fresh fruits and vegetables pose serious health risks to consumers (Jallow *et al.*, 2017). Based on their role on physiological activities, they can be divided in two groups: 1) Essential heavy metals (Fe, Mn, Cu, Zn, and Ni) which are micronutrients necessary for vital physiological and biochemical functions of plant growth (Gohre & Paszkowski, 2006). Non-essential metals (Cd, Pb, As, Hg, and Cr) have unknown biological or physiological function (Gaur & Adholeya, 2004). Both groups are toxic to plants, animals and humans above certain concentrations specific to each element (Adriano, 2001).

Sources of heavy metals in tomato could be weathering of soil minerals, land application of treated wastewater (TWW), sewage sludge and fertilizers, and industrial activities (Gupta *et al.*, 2019). Alloway (2013) discussed the different sources of heavy metals and their origin variation, which include sedimentation of aerosol particles, raindrops containing heavy metal, and agrochemicals in which our research was more interested to determine.

MATERIALS AND METHODS

Tomato Sample Collection

The sample of tomato was collected from potential agrochemical application areas of Mirab Abaya and Arba Minch Zurea Woredas of Southern Ethiopia. In addition, tomato samples were also collected from local markets in Arba Minch Town. The samples were coded and packaged with polyethylene bags and transported immediately to chemistry laboratory of Arba Minch University for heavy metals analysis.

Tomato Sample Preparation

In order to remove soil particles and dust, tomato samples were washed with tap water. The tomato sample was chopped using a stainless steel knife and then blended to obtain a homogenous composite. After each sample was chopped, the chopping board and blender were washed to avoid cross-contamination. The chopped samples were packed with aluminum foil and dried at a temperature of 70°C for 72 hours in an oven drier. The dried sample of tomato was ground and homogenized into fine powder with laboratory grinder and stored in plastic bags for further chemical analysis.

Chemical Reagents and Instruments for Heavy Metal Detection

For the chopped tomato digestion procedure, nitric acid, (69%, Merck, France), 37% HCl (Fine Chem. Industries Mumbai, France) and extra pure hydrogen peroxide 30% H_2O_2, (Scharlau, European Union) were used. Other reagents and chemicals used were of analytical grade. For heavy metals in all tomato samples were carried out by atomic absorption spectrometer (Analytik Jena ZEE nit 700p) equipped with deuterium lamps as background corrector and hollow cathode lamps with air-acetylene flame was used.

Study Design and Treatments

A completely randomized study design was used to determine the heavy metals of tomato randomly collected from three locations. Each tomato sample was analyzed on a triplicate basis in order to obtain average values of selected heavy metals (Cupper, Lead, Chromium, Cadmium, Manganese and Nickel).

Data Collection and Analysis

Prior to heavy metal analysis, an assessment was conducted for the identification of major pollution sources (pesticides, insecticides, herbicides) and other cultural practices used to produce tomatoes in the study area. The survey data was collected with interviewer administrated questionnaire through face to face interview. The collected survey data was analyzed by SPSS software version 25 with confidence interval of 95% and $P<0.05$. Standard Laboratory methods were employed for selected heavy metals like Cu, Pb, Mn, Cr, Cd and Ni. The collected data were subjected to Analysis of Variance (ANOVA) and analyzed by using SAS software version 9.1. When ANOVA outputs showed significant difference at $P<0.05$, means were separated using Least Significant Difference (LSD).

RESULTS AND DISCUSSION

In this study we have observed the tomato chemical residue through its heavy metal concentration as shown in Table 1. In the present study from Tables 2-6 were survey results on tomato production practices and their agrochemical application trends in the study areas. Accordingly, agronomic practices of tomato production was indicated in (Table 2), chemical pesticide application practices against tomato disease and pest (Table 3), chemical pesticides and containers handling practice in study areas (Table 4), tomato consumption Pattern and Preparation methods in study areas (Table 5) and knowledge and attitude of farmers on tomato chemical applications in relation to health risks and tomato yield and quality reduction (Table 6). The identified heavy metals were chromium (Cr), cadmium (Cd), nickel (Ni), manganese (Mn), Copper (Cu) and Lead (Pb). The laboratory result showed a significant difference ($P<0.05$) for chromium (Cr) concentration of tomato sample collected from the Yayike location. There is a significant difference between the Manganese and Copper concentration of tomato from four collection sites (Yayike, Fura, Shelle and market) at ($P<0.05$).

Similarly, Cadmium showed significant difference at Yayike, Fura and Shelle while Nickel concentration was non-significant difference ($P<0.05$) at Fura and Shelle districts. When going across the locations in this study, heavy metals were ranged in the order of Cupper > Lead > chromium > Manganese > Nickel > Cadmium. Relatively higher concentration of Manganese (3.66 mg/kg), Cupper (18.09 mg/kg), Nikel (1.89 mg/kg) and lead

Table 1: Selected heavy metals residue in tomato fruit (mg/kg)

Locations	Chromium (mg/kg)	Cadmium (mg/kg)	Nickel (mg/kg)	Manganese (mg/kg)	Cupper (mg/kg)	Lead (mg/kg)
Yayike	5.26^{a}	0.64^{a}	1.18^{c}	2.55^{d}	18.09^{a}	7.61^{ab}
Fura	4.14^{b}	0.46^{b}	1.54^{b}	3.42^{b}	11.41^{d}	4.41^{c}
Shelle	3.72^{b}	0.24^{c}	1.66^{b}	3.00^{c}	13.74^{c}	9.22^{a}
Market	3.58^{b}	0.38^{b}	1.89^{a}	3.66^{a}	14.20^{b}	5.21^{bc}
LSD (0.05)	0.65	0.13	0.22	0.18	0.39	2.61
CV (%)	8.24	16.39	7.61	3.08	1.46	20.99

Table 2: Agronomic practices of tomato production

Agronomic practice	Trends	Frequency	Percent
Land preparation methods	oxen	30	24
	hand	42	33.6
	Tractor	53	42.4
Land preparation frequency	2-3 times	8	6.4
	3-4 times	77	61.6
	4-5 times	40	32
Types of fertilizer	Organic	-	-
	In organic	110	88
	Mixture of both	15	12
Standard rate of fertilizer for tomato	Below	32	25.6
	Optimum	80	64
	Above	13	10.4

Table 3: Chemical pesticide application practices against tomato disease and pest

Chemical pesticide application practice against tomato disease and pest	Trends	Frequency	Percent
Tomato production without chemical application	yes	16	12.8
	No	109	87.2
Tomato disease and insect pests control system	Cultural practice	-	-
	Chemical pesticides	110	88
	Integrated pest management	15	12
Purchase of chemical pesticides for tomato	Private company	123	98.4
	Government office	2	1.6
Full personal protective equipment	Yes	45	36
	No	80	64
At what tomato growth stages do you spray the chemical pesticides	Seed bed to final harvesting	118	94.4
	Transplanting to first harvesting	7	5.6
Do you consider the growth and development stage of tomato during spraying chemical pesticides	Yes	46	36.8
	No	79	63.2
Do you apple chem. pesticides on tomato which are ready to harvesting	Yes	75	60
	No	50	40
Do you follow instruction found on the chemical pesticide container during spray	Yes	55	44
	No	70	56
Do you mix different chem. Pesticides to control disease and pests of tomato	Yes	119	95.2
	No	6	4.8

(9.22 mg/kg) were respectively collected from market, Yayike, market and Shelle areas. The minimum values for Manganese (2.55 mg/kg), Cupper (11.41 mg/kg), Lead (4.41 mg/kg), Nikel (1.18 mg/kg), chromium (3.58 mg/kg) were recorded from Yayike, Fura, Fura, Yayike and market respectively.

The maximum concentration (0.64 mg/kg) of cadmium was recorded from Yayike and the minimum (0.24 mg/kg) was determined from the Shelle site. This is slightly higher than 0.4 mg/kg from the Brook coast of Istanbul- Turkey (Osma *et al.*, 2012). The Cadmium concentration from the current study is lower than the researchers report from irrigated farmlands on the bank of river Challawa, Kano, Nigeria with higher value of 0.74 mg/kg for Cadmium (Abdullahi *et al.*, 2007). The variation of Cd concentration could be due to differences in study areas and the source of heavy metals. Another study on tomato fruits obtained from different markets of Alexandria City Egypt, showed that a relatively lower (0.15 mg/kg) concentration of Cadmium than present study (Radwan & Salama, 2006).

Moreover, our finding for Cadmium (Cd) content is below as compared with records from Zhuang *et al.* (2009), in which Cd was ranged from 0.45-4.1 mg/kg and exceeded the recommended dietary allowance levels. Heavy metals may have significant toxic and hazardous effects on human health, especially cadmium as non-essential elements also causes chronic cadmium exposures result in kidney damage, bone deformities and cardiovascular problems (Fritioff & Greger, 2007).

Table 4: Chemical pesticides and containers handling practice in study areas

Chemical pesticides and containers handling practice	Trend	Frequency	Percent
Place of chemical pesticides store after and before you sprayed them	House	50	40
	Toilet	15	12
	Tomato farm	60	48
Wash your hand with soap after spraying chemicals on tomato before eating food	Yes	115	92
	No	10	8
The way of handling, store and use of chemical pesticides is safe/not	Safe	45	36
	Not safe	80	64
Consider expire data of the chemical pesticides on the original containers during purchase	Yes	60	48
	No	65	52
The place of expired tomato chemical pesticides were disposed	Continued using the expired chemical pesticides	64	51.2
	Disposed in the soil through burned	56	44.8
	Disposed on soil without burned	5	4
The place of empty pesticide containers after you used were disposed	Damping in farm	80	64
	Burning	30	24
	Dig and disposed in soil	15	12
Do you use the empty chemical pesticide containers in your home for different purposes	Yes	80	64
	No	45	36

Table 5: Tomato consumption pattern and preparation methods in study areas

Tomato consumption pattern and preparation methods in study areas	Trend	Frequency	Percent
Consume raw tomato	Yes	95	76
	No	30	24
Who usually consume raw tomato	Children	7	5.6
	Youth	60	48
	All are consume	58	46.4
Wash of raw tomato before you eat	Yes	60	48
	No	65	52
Preparation and use tomato fruits for home consumption	Using as salad neither boiled nor cooked	23	18.4
	Eating boiled and cooked tomato fruits through chopping	68	54.4
	All of above	34	27.2
Treatment mechanism of tomato before preparation	Hot water treatment	39	31.2
	Simple chopping	2	1.6
	Washing with clean water	84	67.2

Table 6: Knowledge and attitude of farmers on tomato chemical applications in relation to health risks and tomato yield and quality reduction

Knowledge and attitude	Trend	Frequency	Percent
Do you listen eating raw tomato fruits and unsafe chemical application caused human health and environmental risk	Yes	47	37.6
	No	78	62.4
Chemical pesticide sprayed or not sprayed tomato is healthier	Chemical sprayed	74	59.2
	Not chemical sprayed	51	40.8
Major problems caused by repeated use of chemical pesticides in tomato	Tomato yield and quality reduction	63	50.4
	Injury to human and animals	40	32
	Environmental pollution such as water and air pollutions	12	9.6
	No problem observed till now	10	8
Do you know about human and environmental health risks associated with unsafe handling and repeated use of chemical pesticides	Yes	98	78.4
	No	27	21.6

On the other hand, Manganese concentration was ranged from 2.55-3.66 mg/kg in our study. In opposite to present findings, authors from Jordan carried out analysis on toxic heavy metals in tomato fruit and reported manganese residue below detection limit (Salem *et al.*, 2016). Contrary to current result, study findings from heavy metal contamination of vegetables in India reported very high amount (71 mg/kg) of manganese residue concentration (Shobhana *et al.*, 2016). Manganese, the most plentiful of the toxic heavy metals, is found in various oxidation states in nature. During combustion of methylcyclopentadienyl manganese tricarbonyl (MMT), an additive in gasoline, manganese oxides are emitted into the air. Although manganese is required for a variety of physiological activities, excessive consumption results in substantial toxicity (O'Neal & Zheng, 2015).

Nickel concentration ranged from 1.8-1.89 mg/kg with the highest concentration from market tomato and the least from the Yayike districts of the study area. This value is higher than the observation from heavy metals via dietary intake of foodstuffs from the wastewater irrigated site of a dry tropical area of India in which Nickel concentration was ranged from 0.02-0.08 mg/kg according to Singh *et al.* (2010). However, Nickel has extensive industrial uses. as it exceeds the safety limits and causes many adverse effects on humans like allergies, nasal and lung cancer, and kidney and cardiovascular diseases owing to the inhalation of contaminated air (Genchi *et al.*, 2020).

Lead is a non-biodegradable metal that is available in nature and found in relatively low amounts. Atmospheric lead levels are increasing continuously because of the human activities including manufacturing, mining, and fossil fuel burning. Lead is toxic to the human body when exposed to amounts greater than the optimum level. Children are at higher risk of lead poisoning; when they come into contact with dust laden with environmental lead, the severity of poisoning increases (Loh *et al.*, 2016). In our study lead concentration is very high (9.22 mg/kg) on tomato sample collected from Shelle Districts of Southern Ethiopia. Its concentration is about Thirty times greater than the recommended safety limits (0.3 mg/kg) by Commission Regulation E.C., No 1881/2006, implying adverse health effects as mentioned above.

The lead concentration from the present findings matches greater than 0.48 mg/kg of its content as reported by Demirbas (2010). Another study found comparably lower results (5.5 mg/kg) of lead concentration on tomato samples grown near the area of Amravati City (Mohod, 2015).

Copper is recognized as a vital micronutrient for living organisms. It has a role in normal physiological functions of plants, such as the formation of chlorophyll, photosynthesis, and carbohydrate and protein metabolism. Copper deficiency alters important metabolic processes, and elevated exposure causes toxicity (Schwartz *et al.*, 2003). Copper has also a wide range of other applications in agriculture (nutrients, pesticides, and fungicides), wood preservation, and medical applications (Kanoun-Boule, 2008). In our study slightly increased Copper concentration in Yayike location could be due to improper application of Copper based agrochemicals such as pesticides, insecticides and herbicides.

Copper residue concentration ranged from 11.41-18.09 mg/kg in tomato samples collected from different locations in this study. Researchers determined a comparatively higher amount 19.3 mg/kg) of copper concentration on tomato fruit from study done on trace elements in fruit and vegetables (Papa *et al.*, 2009). This value is below the recommended permissible limits by FAO/WHO codex alimentarius Commission 2001 which is 40 mg/kg for copper safety limits (FAO, 2021). On Another hands, study from Industrial area of northwest part of Turkey reported similar results for copper concentration (18 mg/kg) to present finding (Osma *et al.*, 2012).

Chromium is used extensively in industry and can be carcinogenic (Coetzee *et al.*, 2020). However, some heavy metals are involved in the control of certain physiologic bodily functions. Naturally found vital heavy metals penetrate into the body via food, air, and water, where they regulate numerous biological activities (Roohani *et al.*, 2013).

The Chromium concentration of tomato in our study was recorded with highest value of 5.26 mg/kg at Yayike district and lowest (3.58 mg/kg) value was recorded from market. This content of chromium is more than twice higher as compared with FAO/WHO (mg/kg) safety limits for the chromium metal which is about 2.3 mg/kg accordingly. Our result is greater than the records from assessment of the level of trace metals in commonly edible vegetables locally available in the markets of Karachi city, Pakistan (Hashmi *et al.*, 2007). Another study from Istanbul-Turkey mentioned slightly similar result (3.29 mg/kg) for chromium content in tomato sample collected from roadside (Osma *et al.*, 2012). Chromium could apparently pose a health threat in view of its concentration levels from the tomato samples investigated.

Across all collection sites, heavy metal concentration was varied from one location to another in this study. Similar study conducted on heavy metal concentrations in tomato from different stations in Istanbul- Turkey out looked the concentrations of heavy metals such as Cd, Cr, Cu, Pb, Mn and Ni were quite variable (Osma *et al.*, 2012).

The survey results also indicated that almost all (87.2%) farmers use agrochemicals/chemical pesticides to produce tomato. Among other tomato diseases and insect pest control methods, majority of the respondents (88%) apply chemical pesticides. Integrated pest management practices other than only chemical application was very poor (12%) among intensive tomato producer farmers in the study area. Generally, using safety cloths, following instruction on pesticide bottles and plastics, chemical storage places, container handling practices, removal of pesticide bottles and processing of tomato fruit before consumption were very poor in study area

CONCLUSION

From this result, agrochemicals handling and application practices were very poor and heavy metals residue content of tomato was determined and compared with FAO/WHO maximum permissible values. Among toxic heavy metals identified in laboratory analysis, Lead (Pb) and chromium (Cr) concentration were far away from safety limits which could pose adverse health effects.

RECOMMENDATIONS

Considering the potential for the use of agrochemicals will increase with the need for tomato production in the future; hence, governments must manage the usage by farmers via alternative methods such as cultural, biological and guidelines for pesticide application and handling, providing training for producer farmers and building the capacity of agricultural experts in intensive tomato producing areas like Mirab Abaya and Arba Minch Zurea Woredas.

In addition, further study needs to focus on heavy metals not included in this study such as Arsenic and mercury which are common heavy metals in intensive tomato production.

REFERENCES

Abdullahi, M. S., Uzairu, A., Harrison, G. F. S., & Balarabe, M. L. (2007). Trace metals screening of tomatoes and onions from irrigated farmlands on the Bank of River Challawa, Kano, Nigeria. *Electronic Journal of Environmental, Agricultural and Food Chemistry, 6*(3), 1869-1878.

Adriano, D. C. (2001). *Trace Elements in Terrestrial Environments: Biochemistry, Bioavailability and risks of Metals*. (2nd ed.). New York, US: Springer. https://doi.org/10.1007/978-0-387-21510-5

Aljerf, L. (2018). Data of thematic analysis of farmer's use behavior of recycled industrial wastewater. *Data in Brief, 21*, 240-250. https://doi.org/10.1016/j.dib.2018.09.125

Alloway, B. J. (2013). Sources of Heavy Metals and Metalloids in Soils. In B. J. Alloway (Ed.), *Heavy Metals in Soils* (pp. 11-50) Dordrecht, Netherlands: Springer.

Coetzee, J. J., Bansal, N., & Chirwa, E. M. N. (2020). Chromium in environment, its toxic effect from chromite-mining and ferrochrome industries, and its possible bioremediation. *Exposure and Health, 12*, 51-62. https://doi.org/10.1007/s12403-018-0284-z

Demirbas, A. (2010). Oil, micronutrient and heavy metal contents of tomatoes. *Food Chemistry, 118*(3), 504-507. https://doi.org/10.1016/j.foodchem.2009.05.007

FAO. (2021). FAOSTAT. Food and Agriculture Organization of the United Nations. Retrieved from https://www.fao.org/faostat/en/#data/RP/visualize

Fritioff, A., & Greger, M. (2007). Fate of cadmium in *Elodea canadensis*. *Chemosphere, 67*(2), 365-375. https://doi.org/10.1016/j.chemosphere.2006.09.090

Gaur, A., & Adholeya, A. (2004). Prospects of Arbuscular Mycorrhizal Fungi in Phytoremediation of Heavy Metal Contaminated Soils. *Current Science, 86*(4), 528-534.

Genchi, G., Carocci, A., Lauria, G., Sinicropi, M. S., & Catalano, A. (2020) Nickel: Human health and environmental toxicology. *International Journal of Environmental Research and Public Health, 17*(3), 679. https://doi.org/10.3390/ijerph17030679

Giovanelli, G., & Paradiso, A. (2002). Stability of dried and intermediate moisture tomato pulp during storage. *Journal of Agricultural and Food Chemistry, 50*(25), 7277-7281. https://doi.org/10.1021/jf025595r

Gohre, V., & Paszkowski, U. (2006). Contribution of the arbuscular mycorrhizal symbiosis to heavy metal phytoremediation. *Planta, 223*, 1115-1122. https://doi.org/10.1007/s00425-006-0225-0

Gupta, N., Yadav, K. K., Kumar, V., Kumar, S., Chadd, R. P., & Kumar, A. (2019). Trace elements in soil-vegetables interface: Translocation, bioaccumulation, toxicity and amelioration - A review. *Science of The Total Environment, 651*(Part 2), 2927-2942). https://doi.org/10.1016/j.scitotenv.2018.10.047

Hall, J. L. (2002). Cellular mechanisms for heavy metal detoxification and tolerance. *Journal of Experimental Botany, 53*(366), 1-11. https://doi.org/10.1093/jexbot/53.366.1

Hashmi, D. R., Ismail, S., & Shaikh, G. H. (2007). Assessment of the level of trace metals in commonly edible vegetables locally available in the markets of Karachi City. *Pakistan Journal of Botany, 39*(3), 747-751.

Jallow, M. F. A., Awadh, D. G., Albaho, M. S., Devi, V. Y., & Tomas, B. M. (2017). Pesticide knowledge and safety practices among farm workers in Kuwait: results of a survey. *International Journal of Environmental Research and Public Health, 14*(4), 340.

Kanoun-Boule, M., De Albuquerque, M. B., Nabais, C., & Fretias, H. (2008). Copper as an Environmental Contaminant: Phytotoxicity and Human Health Implications. In M. N. V. Prasad (Ed.), *Trace Elements as Contaminants and Nutrients: Consequences in Ecosystems and Human Health* (pp. 653-678) New York, US: John Wiley & Sons, Inc. https://doi.org/10.1002/9780470370124.ch25

Loh, N., Loh, H.-P., Wang, L. K., & Wang, M.-H. S. (2016). Health effects and control of toxic lead in the environment. In L. K. Wang, M.-H. S. Wang, Y.-T. Hung, N. K. Shammas (Eds.), *Natural Resources and Control Processes* (pp. 233-284) Cham, Switzerland: Springer. https://doi.org/10.1007/978-3-319-26800-2_5

Mohod, C. V. (2015). A review on the concentration of the heavy metals in vegetable samples like spinach and tomato grown near the area of AmbaNalla of Amravati City. *International Journal of Innovative Research in Science, Engineering and Technology, 4*(5), 2788-2792. https://doi.org/10.15680/IJIRSET.2015.0405019

O'Neal, S. L., & Zheng, W. (2015). Manganese toxicity upon overexposure: a decade in review. *Current Environmental Health Reports, 2*(3), 315-328. https://doi.org/10.1007/s40572-015-0056-x

Osma, E., Ozyigit, I. I., Leblebici, Z., Demir, G., & Serin, M. (2012). Determination of Heavy Metal Concentrations in Tomato (*Lycopersicon esculentum* Miller) Grown in Different Station Types. *Romanian Biotechnological Letters, 17*(1), 6962- 6974.

Papa, S., Cerullo, L., Di Monaco, A., Bartoli, G., & Fioretto, A. (2009). Trace elements in fruit and vegetable. *International Journal of Environmental Quality, 2*(2), 79-83. https://doi.org/10.6092/issn.2281-4485/3819

Radwan, M. K., & Salama, A. K. (2006). Market basket survey for some heavy metals in Egyptian fruits and vegetables. *Food and Chemical Toxicology, 44*(8), 1273-1278. https://doi.org/10.1016/j.fct.2006.02.004

Roohani, N., Hurrell, R., Kelishadi, R., & Schulin, R. (2013). Zinc and its importance for human health: An integrative review. *Journal of Research in Medical Sciences, 18*(2), 144-157.

Salem, N. M., Albanna, L. S., & Awwad, A. M. (2016). Toxic heavy metals accumulation in tomato plant (*Solanum lycopersicum*). *ARPN Journal of Agricultural and Biological Science, 11*(10), 399-404.

Schwartz, G. G., Il'yasova, D., & Ivanova, A. (2003) Urinary cadmium, impaired fasting glucose, and diabetes in the NHANES III. *Diabetes Care, 26*(2), 468-470. https://doi.org/10.2337/diacare.26.2.468

Singh, A., Sharma, R. K., Agrawal, M., & Marshall, F. (2010). Risk Assessment of Heavy Metal Toxicity through Contaminated Vegetables from Waste Water Irrigated Area of Varanasi, India. *Tropical Ecology, 51*, 375-387.

Zhuang, P., McBride, M. B., Xia, H., Li, N., & Li, Z. (2009) Health Risk from Heavy Metals via Consumption of Food Crops in the Vicinity of Dabaoshan Mine, South China. *Science of The Total Environment, 407*(5), 1551-1561. https://doi.org/10.1016/j.scitotenv.2008.10.061