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Noxious substance content of vegetables grown in urban and peri-urban areas

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Abstract

Ethiopians are increasingly moving from the countryside to cities, accelerating the process of urban growth. Vegetables are a vital part of overall nutrition because they comprise carbohydrates, proteins, and minerals. Such crops however encompass comparable vital and poisonous materials in different compositions. Among the most critical components of food quality management is the heavy metal pollutants of food products. Cadmium, chromium, copper, mercury, lead, and zinc are the most abundant pollutants. All of these substances are nutritionally important and required for growth. Numerous factors affect heavy metal absorption and biomagnification in vegetables, including weather, degree of contamination in soil conditions, and extent of the crops produce. Heavy metal contamination is generally triggered by pollutants from extraction and a broad range of activities. Protracted intake of dangerous heavy metal content in meals could hinder diverse bioactive substances as well as the metabolic system of the human body. These include persistent metal accumulation in the liver, altering multiple biological pathways that result in cardiac, anxiety, kidney, and skeletal problems. Pollutants pose a huge potential hazard to people of all ages who ingest fruits and vegetables cultivated in polluted soils.

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Introduction

Increase in population, agricultural activity, urbanization, and industrial expansion have all harmed the environment, and pollution has reached worrisome levels. The environmental impacts of human activity include habitat destruction, and water pollution[1].

Until recent times, environmental degradation and deterioration of water quality were not serious problems as human populations were small and lived in scattered communities[2]. The quantity and complexity of waste were much lower than the environment's assimilative capacity, and thus waste dumped into rivers were subject to diffusion and natural self-purification[3].

Ethiopia's population is increasingly moving from rural regions to large cities, resulting in rapid urbanization. The country has seen major demographic changes in the last decade, including increased rural-to-urban migration and a 'youth prominence'. Approximately 48% of the current population is under 15 years old[4].

Vegetables are an important part of the human diet as they provide essential carbohydrates, vitamins, minerals, and fibers[5]. They also serve as acid neutralizers during digestion. Vegetables have a texture and hardness due to the presence of cellulose, hemicellulose, and pectin components. These are key defense foods that are beneficial for maintaining health as well as the prevention and treatment of a variety of illnesses[6]. On the other hand, these crops contain harmful heavy metals in varying amounts[7].

Pollution and contamination of the human food chain has become unavoidable as human activity grows, especially with the use of contemporary technology[8]. In high concentrations they cause severe damage to the soil and plants. Therefore, they are assumed to be toxic.

Due to growing knowledge of the risk that toxic metals represent to food chain contamination, international and national food quality laws have decreased the maximum permitted amounts of toxic metals in food items[8].

Any element with metallic characteristics, and an atomic number of more than 20 is referred to as heavy metal[9]. Cadmium, Cr, Cu, Hg, Pb, and Zn are the most common heavy metal pollutants[10]. Metals are found naturally in soil. Some of these metals, Zn, Cu, Mn, Ni, and Co, are micronutrients required for plant growth, while others, such as Cd, Pb, and Hg, have unknown biological functions[11]. In addition, some are toxic or poisonous even at low concentrations, and the collective term now includes As, Cd, Cr, Cu, Pb, Ni, Mn[12]. Heavy metals are required in tiny amounts by living organisms, but excessive levels can be harmful.

Mercury, Pb, Cd, and As are known to be health hazards and have all been linked to severe health issues as a result of environmental contamination[13]. Iron, Cu (amine oxidases, dopamine hydrolase, and collagen synthesis), Mn (superoxide dismutase), and Zn (protein synthesis, DNA, and RNA stability) all have physiological functions, with Cr having minimal requirement (glucose homeostasis)[14]. Other heavy metal ions, even at small levels, are not thought to be necessary for human health.

Cadmium, Pb, and Hg are common air pollutants that are emitted primarily as a result of industrial processes[15]. Despite the low atmospheric levels, they contribute to soil deposition and build-up. Heavy metals are persistent in the environment and can accumulate in food chains through bioaccumulation[16]. Most heavy metals are nonbiodegradable, have lengthy biological half-lives, and have the potential to accumulate in various bodily organs, causing adverse reactions[17].

There is a significant connection between plant, animal, and human micronutrient nutrition and the absorption and effect of pollutants in these species. Leafy vegetables are widely used with other foods for culinary purposes, especially for increasing the quality of soups and for their nutritional value[18]. They are part of the daily diet in many parts of the world and are a source of vitamins and minerals. They are made chiefly of cellulose, hemi-cellulose, and pectin, which give them their texture and firmness. Consumer perception of better quality vegetables is subjective, as they consider dark green and large leaves to be characteristics of good quality. The external morphology of vegetables cannot guarantee the concentration of heavy metals because heavy metals rank high among the major contaminants of leafy vegetables[1]. The content of elements in vegetables is conditional and influenced by the properties of the soil and the capacity of crops to preferentially collect particular substances[19].

The goal of this paper is to review heavy metal concentrations in vegetables produced in urban and peri-urban areas.

Review of the evidence

Sources of Heavy Metal Pollution in Vegetables

Heavy metal levels in urban areas are increasing as a result of fast and disorganised industrialization and urbanization[20]. Heavy metals are nonbiodegradable and long-lasting contaminants deposited on surfaces and absorbed by plants[21].

Soil

Heavy metals are transported to plants primarily through growth media (soil, air, and water). Many cities in developing nations have extremely high heavy metal concentrations in their soils[22]. Heavy metal absorption in soil has been linked to a variety of soil physical and chemical properties[23]. Biotic and abiotic factors influence the uptake and bioaccumulation of heavy metals in vegetables[24]. Temperature, water and edaphic conditions are some of the abiotic factors that significantly influence heavy metal uptake by crops.

Heavy metal contamination can have a direct impact on crop physiology and development, and many examples of heavy metal toxicity have been identified[16]. Low biomass accumulation, chlorosis, inhibition of growth and photosynthesis, altered water balance and nutrient assimilation, and senescence, which ultimately cause crop death, are some of the impacts of heavy metals. Therefore, soil toxicity caused by heavy metals may pose a hazard to horticulture systems in urban areas[25].

Waste Water

The contamination of agricultural products with heavy metals has become a major concern around the world because of its potential negative health effects. In numerous studies, wastewater irrigation has been shown to increase heavy metal levels in receiving soils[26]. Several heavy metals are carcinogenic, including Cd, Cr, Ni, and Pb. Water pollution is fundamentally unavoidable in some locations owing to natural processes and anthropogenic activities[27]. Heavy metals such as Cd, Cu, and Pb are frequently found in wastewater from mining, electroplating, paint, and chemical labs[28]. These elements, when present in greater quantities, may damage public health conditions[29].

Research results on cabbage, carrots and lettuce in Ghana stated that Cd and Pb concentrations rose considerably with the increasing rates of wastewater for irrigation to which Cd and Pb had been added to the water[30].

Vegetables are commonly grown along rivers in metropolitan areas of developing countries[31]. Heavy metals have been found in the waters of such rivers on several occasions. The amount of elements absorbed by the plant is determined by several factors, including the plant's nature, the chemical composition of the pollutant, and the element's concentration in the soil[32].

Post-harvest vegetables may be at risk from air pollution through shipment and commercialization, resulting in higher concentrations of heavy metals in the vegetables [33]. Long-term usage of treated and untreated sewage water has been associated with an elevated accumulation of heavy metals in vegetables [34].

Vegetables

Vegetables possess essential nutrients such as carbohydrates, proteins, vitamins, and metals. They absorb metals from the soil they grow in and the water used to irrigate crops[35]. Only a small portion of the ions linked with plant roots are absorbed by cells[36]. Various types of vegetables have varying abilities to acquire metals. Plants are known to respond to the quantities of easily transportable metals in soil, regardless of the mechanism involved in element absorption by roots[37].

The classification of heavy metal contamination in vegetables varies[38]. This depends on climatic conditions and the type of heavy metals. In several species and ecotypes of natural plants, genetic variations and tolerances are well documented[39]. According to the research report of metal concentrations in vegetables from the Addis Ababa market, lettuce had the greatest Cd content, while cabbage had the lowest[40].

In vegetables from Akaki farm (Addis Ababa), which was irrigated with industrial effluent, similar tendencies of increased metal accumulation in Swiss chard and low accumulation in cabbage were detected[41].

Anthropogenetic Factors

Further manmade trace metals include manures, sludge, fertilizers, and chemicals, which can impact heavy metal absorption by changing the soil's physicochemical characteristics[42]. Increasing concentrations of metals in soil enhance crop intake[43]. Farming areas near highways are also subjected to metal-containing aerosols, which pollute the air[44]. Particulates can be sprayed on the soil and absorbed by plants[45].

Heavy metals emitted by industry and automobiles may be deposited on vegetable surfaces during processing, distribution, and commercialization[46]. For example, in Riyadh, increased amounts of heavy metals in vegetables are sold in the market owing to air deposition[47]. Air deposition can dramatically increase the levels of heavy metal contamination in vegetables regularly sold in Varanasi, India's marketplace[48].

Heavy Metals Impact on the Environment

The accumulation of heavy metals is harmful to biological systems and does not degrade through microbial degradation[49]. Harmful substances such as Pb, Co, and Cd can be distinguished from other contaminants because they cannot be biodegraded but may accumulate in living beings[50]. Heavy metals cause significant health risks to several species, with soil residence for a longer period of time[11]. Antioxidants are also recognized to influence plant development, ground cover, and soil microbiota[51]. Contaminants cannot be decomposed but are forcibly converted into harmless molecules[52]. In recent research works, it was determined that the effect of antioxidant supplementation followed heavy metal exposure[31]. They suggest that antioxidants may play an important role in abating some health hazards of heavy metals in connection with an interaction of physiological free radicals (health effects). The contamination of the physical and biological components of the environment adversely affects the whole systems of fauna and flora[43].

Arsenic (As)

Arsenic has the chemical symbol 'As' and is a semimetallic element[52]. It is a pollutant present in the environment that is highly harmful to humans and other living species[53]. It is also a very hazardous element found in a variety of forms, and the toxicity varies depending on the conditions. The pH, redox conditions, mineral composition, and microbial activity all have their own impacts. The contaminated water used for drinking, food preparation and irrigation of food crops poses the greatest threat to public health from arsenic. Long-term exposure to As from drinking water and food can cause cancer and skin lesions[54].

Lead (Pb)

The heavy metal most commonly associated with poisoning of humans is Pb[55]. Lead poisoning may occur as a result of industrial exposure, air or water pollution, foods, medicines, improperly coated food containers, or the ingestion of lead-based paints. Additionally, heavy metals, such as Pb, are a group name for metals that have been associated with contamination and potential toxicity[56]. Lead may be found in a variety of forms in natural sources worldwide and is currently one of the most extensively and equally distributed trace metals[57]. Lead from automobiles, dust, and fumes can pollute soil and the environment[58]. When present in high concentrations, it can be hazardous to humans[59]. Its contamination is highly damaging to biological systems and does not degrade through biodegradation[60].

Lead toxicity in the ecosystem occurs irreversibly, and it potentially causes risks to human health, such as brain developmental delay[61].

Mercury (Hg)

Mercury is found naturally in a variety of forms[11]. In the soil ecosystem, there are three soluble forms of Hg. It is an environmental contaminant that may enter via the food chain in fish, animals, and humans[62]. Mercury salts and organomercury compounds are among the most toxic elements in our environment[63]. The level of toxicity is highly dependent on the kind of chemical and the redox state of Hg[64]. Mercury pollution in the environment occurs in a variety of ways, including petrochemicals, mining, and painting[65].

Home bleach, acid, and caustic chemicals (e.g., battery acid, household lye, muriatic acid (hydrochloric acid)), and Hg-containing instruments are among the most prevalent contributors of Hg[66]. In general, Hg naturally occurs in nature and is essential to life but can become toxic through accumulation in organisms. Mercury is the most common heavy metal that can pollute the environment[59].

Health Impacts of Contaminated Vegetables

Due to their toxic effects, heavy metals are extremely dangerous to vegetables, and they are among the pollutants encountered on the outside and inside structures of fresh fruits and vegetables[67]. Because of their aqueous solubility, several heavy metals are especially dangerous, and currently, they are widely used in industry[68].

Over several years, factors linked to the potential health impacts of Cd, Pb, and Hg exposure have been studied in occupational settings, utilizing both animals and humans exposed to natural pollution. The types of harmful health effects are well recognized, but there are limits for specific outcomes[69].

Chronic low-level thrash metal consumption has negative effects on humans and other animals since there is no efficient mechanism for removing them from the body. Metals such as Pb, Hg, Cd, and Cu accumulate as poisons[55]. Vegetables absorb heavy metals by absorbing them from contaminated soils as well as deposits on sections of vegetables vulnerable to toxic air[55]. High intake of unsafe levels of heavy metals in food may upset many biological and biochemical processes in the human body[70]. The elements Hg and Pb have been linked to the development of malformations in children. Long-term Cd exposure causes kidney failure and ovarian distortions[8].

Diet is the most common source of Cd in the general community, encompassing more than 90% of the total consumption[71]. Under some environmental conditions, Cd accumulates in soils and catchments and increases the risk of future exposure through food chains. The Collaborative Food and Agriculture Organization of the United Nations (FAO)/World Health Organization (WHO) Food Standards Programme's Codex Committee on Food Additives and Contaminants has established tentative thresholds for typical everyday consumption[72]. As a result, the consumption of heavy metals accounts for much less than 10% of the theoretical maximum daily intake (TMDI)[73]. Arsenic, Cr, Fe, and Pb are now more dangerous to one's health than the other heavy metals[74]. However, the levels of heavy metals in the vegetables analyzed would not be sufficient to determine health consequences. All this is determined by the consumers' eating habits.

Compared to the global daily consumption of 50 g of green vegetables, in Addis Ababa, Ethiopia, the mean consumption of vegetables per day is 5 g[75]. As a result, the intake of metals from the examined vegetables is substantially lower than the TMDI or presumptive tolerated weekly intake (PWTI), which can be used to indicate user consumption and accompanying health risks[76].

To determine the total exposure level in the population, the rate of contamination and consumption must be monitored regularly. Reduced crop pollution and improved food security can be achieved by lowering pollutants, enlightening vegetable cultivation and commenting on the processing[77]. The disastrous feature of heavy metal contamination of the environment is that they can only be changed from one oxidation state to another[78]. The transport of Cd via soil to the food chain is affected by a variety of factors, including the type of crops, soil characteristics, pH, and organic matter content. Cadmium sorption to soil particles is stronger in neutral or alkaline soils than in acidic soils, resulting in higher Cd concentrations in the solution[79]. Excessive levels of Pb and Cd metals in the diet have been linked to a variety of disorders, including the cardiovascular, renal, neurological, and skeletal systems[55]. Certain toxic substances have also been connected to cancer, mutagenesis, and teratogenesis[80]. Cadmium has also been recognized as a possible human carcinogen with the potential to cause lung cancer. Lead has developmental and neurobehavioral impacts on fetuses, babies, and children and raises cardiac output in individuals[81].

Contaminants, including Cd, Pb, and Hg, are frequent air pollutants that are discharged (mostly into the atmosphere) as a result of numerous industrial operations. Excessive exposure to air pollution from industrial operations, transportation, and energy generation is one of the repercussions of the current stage of economic development and the need for enhanced quality of life[82].

Reported Heavy Metal Contamination in Vegetables

Heavy Metal Content in Irrigated Water

Nitrogen, P, K, total dissolved solids, viruses, trace organic compounds and metals, particularly heavy metals, are all present in the combination of industrial and home wastewater[83]. Many heavy metal ions, such as Co, Cu, Fe, Mn, Mo, V, Sr, and Zn, are required in small amounts by living things[84]. Cadmium, Cr, Hg, Pb, As, and Sb are nonessential heavy metals of special importance to surface water systems[85].

Contaminants are emitted locally from a variety of sources, including industry (primarily nonferrous industries, power plants, iron, steel, and chemical industries). Heavy metal contamination in water is mostly produced by point source pollution from mining and a wide range of businesses[86].

The greatest quantities of metals, including Zn (113 mg/kg), Cr (47.8 mg/kg), Pb (17.7 mg/kg), and Cd (0.250 mg/kg), have been reported from samples collected from farms in Ziway, Burayu, and Addis Ababa[24].

Wastewater irrigation causes heavy metal buildup in soil and results in heavy metal accumulation in vegetables[87]. Heavy metal concentrations varied across vegetables, reflecting differences in their ability to absorb. As a result, the Cd, Pb, and Ni contents in all vegetables are above the permissible limits for human consumption (Table 2). Consumption of vegetables containing high quantities of heavy metals can lead to higher levels of bioaccumulation, resulting in health problems.

Heavy Metal Content in Fruits and Vegetables

Fruits

The quality of fresh fruits produced in very polluted areas of Romania was evaluated, and the level of heavy metals was reported to be modest[88]. Most samples showed medium values of total and mobile heavy metal concentrations (Cd, Cu, Pb, and Zn) that exceeded the maximum permissible limits. Individuals are encouraged to take more fresh fruits, which are high in vitamins, minerals, and fiber and are excellent for their wellbeing[89]. However, these fruits possess both necessary and harmful metals in different amounts. It is known that plants acquire metals from polluted soil along with accumulation on plants[90].

Table 1. Mean metal content in vegetable field soils.

Metals (mg/kg)	Ziway Kentola	Ziway Ethioflora	Burayu	Kuskuam Upper	Kuskuam Lower	Recommended maximum level in soil (mg/kg)
Cd	0.180 ± 0.070	0.220 ± 0.040	0.140 ± 0.080	0.250 ± 0.080	0.190 ± 0.050	3
Cr	3.0 ± 0.06	8.44 ± 1.29	47.78 ± 8.91	31.24 ± 1.49	32.6 ± 5.09	100
Pb	6.02 ± 0.34	7.12 ± 2.75	17.66 ± 1.66	16.38 ± 3.01	11.17 ± 1.46	100
Zn	49.98 ± 0.27	68.42 ± 4.78	88.47 ± 13.04	112.7 ± 8.34	78.02 ± 8.27	300

Source: reference [87]

Table 2. Concentrations of certain trace elements reported in the Bulbula and Kera streams and other surrounding agricultural soils in Ethiopia.

Component	Bulbula		Kera		Recommended maximum contents		
	River (μg/Liter)	Soil (total)	River (μg/Liter)	Soil (total)	Irrigation water	Soil (total)	Vegetables (mg/kg)
As	1.7	5.19	<1.00	6.8	100	20	0.2
Cd	0.07	0.71	<1.00	0.44	10	3	0.2
Co	2.69	27.95	<5.00	43	50	50	0.3
Cr	–	81	7.4	115	550	100	2.3
Cu	12.4	38.96	39	55	17	100	73.3
Fe	–	163.86	4,290	79.7	500	50,000	425.5
Ni	2.26	74.13	8.9	115	1400	50	67.9
Pb	14.1	46.74	33	110	65	100	2.65
Se	–	0.09	0.08	0.02	20	10	–
Zn	50.37	2,985.5	193	263	2,000	300	99.4

Source: reference [40]

Onion and Leek

Relatively higher levels in the onion's bulb/leaves were found for Fe, Mn and Zn. Significant anthropogenic contamination was noted for the metals in the present study. Metal levels in all onion varieties showed no significant cancer or no-cancer risk[83]. The concentration of heavy metals in the aqueous phase showed a reduction in heavy metals in humans. The toxic substances Cd, Cr, and Pb in onion leaves were reported to be in the range of 0.667−0.933, 3.870−7.870, and 5.870−7.537 mg/kg, respectively.

Tomato and Capsicum

In semiurban and rural regions of visakhapatnam, southern India, Pb, Zn, Ni, and Cu content in vegetables were measured, and Ni and Zn were found to be greater in industrial areas, but Cu concentrations in semiurban areas were found to be 2−3 times higher in tomatoes than in rural vegetables[91]. The additional elements of Pb and Zn in industrial and semiurban regions were found to obtain inputs from both ambient and soil sources in all crops.

Leafy vegetables

The levels of Pb, Cu, Cr, Zn, and Cd in spinach, coriander, lettuce, radish, cabbage, and cauliflower growing in pollutant areas near an industrial zone of Pakistan were reported[92]. The results showed that the Cu, Zn, Cr, Pb, and Cd concentrations were below the permissible limits suggested by the United FAO/WHO Advisory Group on Food Additives.

However, when compared with other portions of vegetables, the leaves of spinach, cabbage, cauliflower, radish, and coriander revealed greater quantities of Cu (0.923 mg/kg), Cd (0.073 mg/kg), Cr (0.546 mg/kg), Zn (1.893 mg/kg) and Pb (2.652 mg/kg), as previously reported[93]. This finding revealed that considerable differences in elemental concentrations occurred among the vegetables considered. Similarly, research was conducted in two popular Pumpkin leaves and Chinese cabbage cultivated in Tanzania's Morogoro municipality, and two heavy metals, Pb and Cu, were measured[94]. The results showed that there was a significant difference in the two metals across the site. The Pb and Cu levels in the two vegetables were found to be lower than the optimum acceptable limits specified by the FAO/WHO.

In Akaki, the highest Co content was detected in potato planted with wastewater, followed by lettuce and Swiss chard[97]. Lettuce from Kera had the largest quantities of Cr and Fe, whereas kale from the same location had the highest concentrations of Cu, Ni, and Zn[40]. Swiss chard and carrot from Akaki had the greatest levels of Mn and Pb, respectively (Table 4). As a result, lettuce, Swiss chard, and kale appear to be the most metal-accumulating vegetables in Addis Ababa, Ethiopia[98]. The concerns of heavy metal pollution in Addis Ababa's vegetable fields, as well as its accumulation on produce, have been recognized[99]. However, the research was limited to the issues of heavy metal deposition on vegetables as a result of industrial pollution. The levels of heavy metals in Addis Ababa's urban area are the result of geogenic conditions from the soil crust[100].

Cabbage crops accumulated the lowest content of heavy metals compared to other vegetables. However, the Cr concentration in all vegetables surpassed the permissible level[101]. The Cu, Mn, and Ni concentrations in all vegetables were determined to be less than the maximum limit. The Cd level was higher in leafy vegetables such as lettuce, Swiss chard, spinach, and radish.

Generally, a recent investigation on the heavy metal concentrations of vegetables from the Addis Ababa market found that lettuce had the highest Cd content and cabbage had the lowest[102]. Except for potato, lettuce, and spinach, all other vegetables had lower Zn concentrations than the maximum limits for vegetables. The Fe concentration was found to be lower in radish, tomato, cabbage, and beans, but all other vegetables contained more Fe than the upper limit[103]. High Fe concentrations in vegetables might be instigated by the metal industry and the wastewater that reaches the river. Certain withered leaves and necrotic patches were noted on some plants due to heavy metal toxicity[104].

The concentrations of Cd, Cr, and Zn in lettuce were greatest at the Kuskuam farm (which uses tap water from the public water supply) compared to other farms, followed by the Burayu field (utilizes water from the Gefersa River)[92]. Burayu farm, on the other hand, has a larger concentration of Pb than other farms, while Ethioflora from Ziway (water from Lake Ziway) has the lowest concentration of all metals[105]. The lettuce from Burayu farm had the greatest mean concentration of Pb, followed by lettuce from Kuskuam and Ethiopian Kale in Burayu farm. Vegetables can absorb heavy metals into their systems when exposed to more acidic conditions[106]. The concentration of Pb in all vegetables from different farms was not significantly different. As presented in Table 5, Pb-containing vegetables may contribute to high Pb levels in the body, increasing the risk of anemia and neurological problems[107].

Research was conducted at Peacock farm, which was irrigated by the Bulbula River, and Kera farm, which was irrigated by the Kebena River. Hence, as per the authors' observations, cabbage was the smallest metal absorbent[40]. Additionally, the metal concentrations were greater in lettuce and Swiss chard cultivated at Kera than on Peacock farms. The As, Cr, Fe, and Pb contents in these vegetables have surpassed maximum allowable levels in a few cases, whereas cabbage has a Cu shortage.

Table 3. Estimated Pb and Cd contents in vegetables worldwide.

Vegetables	Nigeria		Egypt		Pakistan		India		Tanzania		Greece		Vegetables	Addis Ababa		Gondar	
	Pb	Cd	Pb	Cd	Pb	Cd	Pb	Cd	Pb	Cd	Pb	Cd		Pb	Cd	Pb	Cd
Spinach	0.56	0.03	0.34	0.11	–	–	1.44	1.96	0.30	0.05	0.05		Lettuce	0.25	4.99	1.78	0.17
Lettuce	0.07	0.01	0.58	0.07	–	–	–	–	0.37	0.04	0.05		Cabbage	0.82	0.03	0.38	0.03
Tomato	–	–	0.26	0.01	1.56	0.33	–	–	–	–	0.01		Kale	0.7	0.66	0.77	0.11
Onion	–	–	0.14	0.02	0.06	0.07	–	–	–	–	0.03		Carrot	0.64	0.04	0.09	0.11
Cauliflower	–	–	–	–	–	–	1.56	2.57	–	–	–						
Lady's finger	–	–	–	–	–	–	1.03	1.41	–	–	–						

Source: references [92, 95, 96]

Table 4. Trace element content in the leaves of crop varieties planted using urban industrial effluent (Addis Ababa).

Crop	Farm	Metal/metalloid concentration									
		As	Cd	Co	Cr	Cu	Fe	Mn	Ni	Pb	Zn
		(µg/kg)			(mg/kg)						
Cabbage	Kera	<1000	<50	62	0.89	3.03	73	29	0.8	0.21	31.8
	Peacock	<1,000	<50	133	1.71	3.3	173	25	0.91	0.29	31.81
	Akaki	<1,000	<50	131	0.68	2.5	219	30	1.37	0.37	32.49
Swiss C.	Kera	1,210	78	681	2.05	8.06	527	37.5	2.10	1.79	56.19
	Peacock	<1,000	<50	317	1.04	7.88	4.61	67	0.89	0.61	48.91
	Akaki	1,020	193	532	0.9	14.95	555	218	1.81	1.63	81
Carrot	Mekanisa	<1,000	59	130	0.82	7.68	403	53	2.44	0.91	44.87
	Peacock	<1,000	<50	84	0.28	7.79	205	29	0.98	0.54	29.9
	Akaki	<1,000	84	256	0.82	8.99	469	57	1.66	2.15	59.03
Kale	Kera	<1,000	130	308	0.99	9.92	331	126	4.64	0.53	63.71
	Akaki	<1,000	<50	187	1.1	3.05	173	30.5	1.31	0.37	35.08
Potato	Kera	<1,000	78	256	0.7	9.66	364.5	66	1.4	1.8	28.25
	Akaki	1,205	159	882	1.35	13.15	816	69.5	2	2.02	64.7
Lettuce	Kera	1,040	126	757	9.47	6.62	1345	106	1.86	1.59	48.63
	Bulbula	<1,000	75	165	1.21	6.24	351	54	0.71	0.39	47.8
Recommendation Levels (mg/kg)		0.43	0.2	–	2.3	–	425.5	–	67.9	0.3	99.4

Source: reference [98]

Table 5. Total load of heavy metals in vegetables treated using Akaki river water.

Vegetables	Total metal load (µg g^{-1})						
	Cd	Cr	Cu	Zn	Mn	Fe	Ni
Beet	0.254 ± 0.08	10.28 ± 1.94	32.25 ± 3.0	90.3 ± 5.8	161.0 ± 6.02	566.20 ± 8.4	7.57 ± 1.06
Potato	0.281 ± 0.14	7.18 ± 1.06	35.13 ± 3.1	105.00 ± 6.2	148.05 ± 5.8	634.04 ± 9.4	5.99 ± 1.68
Carrot	0.198 ± 0.06	8.05 ± 1.08	22.18 ± 2.6	80.12 ± 5.2	95.10 ± 6.2	426.01 ± 8.8	4.51 ± 1.08
Onion	0.271 ± 0.12	8.58 ± 1.6	25.13 ± 2.4	65.9 ± 4.2	107.9 ± 8.06	578.0 ± 9.4	3.67 ± 1.02
Tomato	0.115 ± 0.06	4.91 ± 1.4	13.21 ± 1.8	45.11 ± 3.8	69.17 ± 4.08	322.3 ± 8.4	2.21 ± 0.08
Pepper	0.180 ± 0.08	5.55 ± 1.6	17.21 ± 2.6	49.15 ± 3.8	56.29 ± 2.6	429.26 ± 8.8	5.38 ± 1.02
Head cabbage	0.101 ± 0.04	4.11 ± 108	14.20 ± 1.8	48.47 ± 3.6	45.4 ± 3.8	245.2 ± 6.4	1.95 ± 0.06
Green-bean	0.199 ± 0.04	6.12 ± 1.2	12.52 ± 1.6	62.54 ± 6.6	86.25 ± 6.04	251.54 ± 6.2	2.1 ± 0.08
Lettuce	0.345 ± 0.18	24.11 ± 2.4	24.25 ± 2.4	108.94 ± 8.8	145.6 ± 6.02	511.27 ± 8.2	2.95 ± 0.08
Maximum limits for vegetables	0.2	2.3	–	99.4	–	425.5	67.9

Source: reference [101]

Table 6. The percentage of metal influxes in vegetable tissue sourced from soil.

Vegetables	Metals	Vegetable farms		
		Kuskuam	Burayu	Ziway Ethioflora
Lettuce	Cd	28%	36%	14%
	Cr	3%	2%	9%
	Pb	7%	7%	7%
	Zn	41%	42%	30%
Ethiopian kale	Cd	47%	42%	11%
	Cr	2%	2%	19%
	Pb	3%	4%	9%
	Zn	44%	37%	35%
Swiss chard	Cd	26%	2%	–
	Cr	1%	39%	–
	Pb	36%	1%	–
	Zn	2%	36%	–

Source: reference [108]

Research results reported that there is a significant accumulation of heavy metals in vegetables watered with effluent[111]. The concentrations of Fe, Mn, Cu, and Zn in wastewater-irrigated vegetables were 116–378, 12–69, 5.2–16.8, and 22–46 mg/kg, respectively. Mint and spinach had the greatest amounts of Fe and Mn, while carrot had the highest levels of Cu and Zn. According to the findings of this study, both adults and children who eat vegetables produced in wastewater consume large amounts of these elements. Contaminated water includes significant quantities of toxic substances, which causes problems[112]. A high buildup of toxic substances due to wastewater irrigation may contaminate not only the land but also the food safety standards[113].

Vegetables, generally, are one of the plants that absorb contaminants to meet their body's requirements based on their genetic composition, the soil in which they are cultivated, and the water with which they are irrigated[114]. The differences in heavy metal content across vegetables were also ascribed to the vegetable's self-selectivity for a certain type of heavy metal[115]. Based on availability and soil qualities, the levels of heavy metals in various crops varied from one area to the other. Although significant heavy metal concentrations in soils were identified, availability may be restricted by the presence of clay in the northern parts of Addis Ababa. A high amount of metals in the soil needs careful consideration since it might cause serious problems if soil qualities are changed to acidic conditions[116].

Table 7. Metal content in leafy vegetables in Addis Ababa's (Ethiopia) Kera and Peacock farms.

Elements (mg/kg)	Cabbage		Lettuce		Swiss chard		Recommended maximum level for vegetables
	Kera	Peacock	Kera	Peacock	Kera	Peacock	
As	0.13	0.11	1.04	0.31	1.21	0.34	0.43
Cd	0.02	0.01	0.13	0.08	0.08	0.04	0.2[b]
Co	0.06	0.13	0.76	0.17	0.68	0.32	50[c]
Cr	0.89	1.61	9.47	1.21	2.05	1.04	2.3
Cu	3.03	3.3	6.62	6.24	0.06	7.88	–
Fe	73	173	1345	351	527	461	425.5
Mn	29	25	106	54	37.5	67	500[c]
Ni	0.8	0.91	1.86	0.71	2.1	0.89	67.9
Pb	0.21	0.29	1.59	0.39	1.79	0.61	0.3[b]
Zn	31.8	31.81	48.63	47.8	56.19	48.91	99.4

Source: references [109, 110]

Amount of Heavy Metal Contamination in Washed Vegetables

According to the differences in the amount of diminution in the toxic metals, vegetable washing is an important activity to remove heavy metals. Reasearch indicates that vegetables can be cleaned adequately before eating to lessen the health risk[47]. The amounts of Pb, Cd, Cu, and Zn in washed and unwashed vegetables were measured. However, the results showed that consuming heavy metals, especially leafy vegetables, does not pose a health risk to consumers (Table 3).

However, in Agra India, research was performed to evaluate the accumulation of airborne heavy metals in edible parts of crops, and the results demonstrated that unwashed vegetables had a higher extent of hazardous substances than washed vegetables[117].

Heavy Metal Content in Vegetable Distribution and Sales

Transportation and marketing of vegetables in polluted environments may increase the amounts of heavy metals. Eating vegetables directly from producing areas may be less harmful to human health than the intake of vegetables from contaminated public market places. Contaminants are harmful, but the negative effects appear obvious only after long-term consumption of polluted vegetables. It was proposed that toxic substances in vegetables and other food products be monitored regularly to avoid the excessive development of these pollutants in the human food chain. Appropriate safeguards should also be followed during vegetable shipment and distribution.

Heavy metal levels of Zn, Mn, Cu, and Pb in vegetables taken from Nigerian trash sites were shown to be high. Accordingly, cars are a key source of heavy metals along roadside areas. The extent of heavy metal deposition on vegetable surfaces differed according to the morpho-physiological character of the plants[8].

Percentage of Heavy Metal Contamination in Boiled Vegetables

Heavy metal levels in boiled vegetables are greatly diminished. After boiling vegetables in water for 15 min, the Cd content in cauliflower purchased from Gariahat, Maniktala, VIP market, Shyambazar, and Brinjal **(**India**)** was purchased from Gariahat, Maniktala, VIP market; Shyambazar fell below the safe level. Even after boiling, cauliflower from Lake market and VIP market had a Cd level that was somewhat more than the acceptable value[118]. After washing and boiling, the Pb concentration of all vegetables remained greater than the permissible level. The Cu level in unwashed Brinjal (Lake market, Maniktala) and Indian Spinach (VIP market, Shyambazar) surpasses the safe limit. However, the Cu level of boiling vegetables did not surpass the permissible limit. Chromium levels in brinjal and Indian spinach were found to be higher than the acceptable limit in a few samples. The only sample of Red Indian spinach bought from Maniktala exhibited a greater level of Cr following washing. The Pb concentration in all vegetables (washed, unwashed, and boiled) was above the acceptable standard (0.2 mg/kg)[119].

Sensitivity Reduction Approaches for Heavy Metal Eating

Restoration strategies of certain microbes, such as biosorption, can breakdown and detox some pollutants[120]. While these life systems become less resistant to external changes than other earlier systems, they are believed to be more affluent[121]. Some of the methods are stated below.

Phytoextraction

Phytoextraction is also called phytomining. It is defined as the absorption and transfer of pollutants by the root system into subterranean sections of the plants[122]. It can be performed by the utilization of plants for heavy metal removal from the contaminated matrix (soil and water) through their uptake into the harvestable parts of the plant. For example, chromium is toxic to higher plants at concentrations above 100 μM/kg dry weight. Unlike phytostabilization, by which plants only temporarily contain heavy metals and these heavy metals still remain belowground, phytoextraction is a permanent solution for the removal of heavy metals from polluted soil. Therefore, it is more suitable for commercial application.

Phytostabilization

Phytostabilization is the use of specific plant species to immobilize pollutants in soil and groundwater through absorption and accumulation in plant tissues[122]. It involves the reduction of the mobility of heavy metals in soil. Immobilization of metals can be accomplished by decreasing wind-blown dust, minimizing soil erosion, and reducing contaminant solubility or bioavailability to the food chain. It is also a promising technology for cleaning polluted sites by using plants to extract heavy metals from contaminated soil and accumulate them in roots, stems, and branches. Various species of grass, such as red fescue (*Festuca rubra L.)* are the most useful in the process of aided phytostabilization of heavy metals in soils.

Rhizofiltration

Rhizofiltration is the adsorption or deposition of pollutants in solution around the root zone on plant roots[11]. It is also the adsorption or precipitation of dissolved compounds onto plant roots or absorption into the roots. A few examples of plants that are employed for rhizofiltration are sunflower, tobacco, spinach, rye and Indian mustard. Plant species in addition to hyperaccumulators can also be used, as heavy metals need not be translocated to the shoots. Rhizofiltration is a form of phytoremediation that involves filtering contaminated groundwater, surface water and wastewater through a mass of roots to remove toxic substances or excess nutrients.

Bioremediation

Bioremediation is any procedure that employs microorganisms, fungi, and green plants[123]. Bioremediation methods are categorized as either *in situ* or *ex situ*. It is also a technique for removing/converting harmful contaminants such as heavy metals into less harmful substances; removing toxic elements from the contaminated environment; or degrading organic substances and ultimately mineralizing organic substances into carbon dioxide, water, nitrogen gas, etc. Microbial bioremediation of heavy metals is emerging as an effective technique. Microbial bioremediation is a highly efficient and environmentally friendly procedure that also reduces the cost of the cleanup process associated with heavy metal contamination. It relies on stimulating the growth of certain microbes that utilize contaminants such as oil, solvents, and pesticides for sources of food and energy. These microbes convert contaminants into small amounts of water, as well as harmless gases such as carbon dioxide. *In situ* bioremediation treating polluted material on site and *ex situ* bioremediation require removing the contaminants to be handled elsewhere[124]. Bioventing, commonly ascribed, bioreactors, composting, bioaugmentation, rhizofiltration, and biostimulation are some of the types of biomonitoring systems[125].

However, not all pollutants are easily removed by bioremediation utilizing microorganisms. Heavy metals, such as Cd and Pb, are not quickly digested or caught by microbes[126]. The incorporation of elements such as Hg into the food chain may aggravate the situation. In these cases, phytoremediation is advantageous because natural or transgenic plants may bioaccumulate these poisons in their aboveground sections[127].

Phytoremediation

Phytoremediation is the inherent capacity of some plants known as chelators to accumulate, decompose, or make pollutants benign in soils, water, or air[128]. It is applied to underground waters, surface waters and waste waters. Rhizofiltration is used to remove radioactive substances or metals from contaminated waters. The plants used in this method are directly planted on contaminated soil, and contaminant adaptation is ensured. To eliminate heavy metals from contaminated fields, phytoremediation is considered a clean, inexpensive, and nonenvironmentally damaging method[129]. It is also a plant-based approach that involves the use of plants to extract and remove elemental pollutants or lower their bioavailability in soil. Plants have the ability to absorb ionic compounds in the soil, even at low concentrations, through their root system. Green plants have been promoted for *in situ* soil phytoremediation, which has become a prominent research and development area[130]. However, another important drawback of phytoremediation is that it takes a lot of dedication as the process is based on growing plants, toxin tolerance, and biomagnification potential[131]. Arsenic is absorbed by the sun flower *(Helianthus annuus)* or the Chinese Brake fern (*Pteris vittata*), both of which are hyperaccumulators[132]. Arsenic is stored in the leaves of the Chinese Brake fern[133]. According to Greger & Landberg[134], willow (*Salix viminalis*) has a high phytoextractor potential for Cd, Zn, and Cu. Because hawthorn has several unique attributes, such as high metal transport capacity from root to shoot and a large quantity of plant biomass.

Cadmium and Zn were explored using Alpine pennycress (*Thlaspi caulescent*), a hyperaccumulator of both metals reaching hazardous levels in many plants[135]. On the other hand, the presence of Cu appears to inhibit its development. Lead may be removed from the environment by planting Indian mustard (*Brassica juncea*), Ragweed (*Ambrosia artemisiifolia*), and Hemp Dogbane (*Apocynum cannabis*).

Additional statements were also reported regarding the elimination of several heavy metals, such as Cu, Zn, Ni, and Cr, by free and immobilized microalgae[136]. For repeated applications of algal beads (*microalgal beads*) for the removal of heavy metals and recovery, an exposure decomposition process was designed. Investigators observed that alginate-immobilized *C. vulgaris* pearls managed to remove Cu (more than 95% removal) from industrial effluents[137].

Phytovolatilization

Phytovolatilization is the process by which plants absorb pollutants from the soil, convert them to volatile forms, and then expel them into the atmosphere[138]. It is also a process in which plants take up contaminants from soil and release them in volatile form into the atmosphere through transpiration. The process occurs as growing plants absorb water and organic contaminants. It is described as the utilization of plants, both terrestrial and aquatic, in their roots to absorb, concentrate, and precipitate pollutants from contaminated water sources. In recent years, heavy metal pollution in saline soil has become increasingly severe due to the rapid development of industry and agriculture. Plants absorb and convert toxic contaminants into less toxic forms. The remediation of heavy metal-contaminated sites must be viewed seriously, as they affect animal and human health. Rhizofiltration can be utilized for heavy metals such as Pb, Cd, Cu, Ni, Zn, and Cr that are largely retained inside plants[139]. Sunflower, Indian mustard, tobacco, rye, spinach, and corn have all been examined for their potential to eliminate Pb from water. Indian mustard has a biomagnification value of 563 for Pb, which is necessary to eliminate Pb at a wide range of concentrations (4–500 mg/L)[139]. The flexibility to employ both land and marine plants for *in situ* or *ex situ* use is one of the benefits of root uptake[140]. An additional benefit is that pollutants are not transported to the plants.

As a result, species other than hyperaccumulators can be employed. Aerial plants are favored, as their root systems are flexible and considerably longer, increasing the amount of plant root zone[141].

Factors Influencing Uptake Mechanisms

Various factors can influence heavy metal availability and uptake efficiency by crops[142].

Crop types

Different plants or types are evaluated, and the ones with the best restoration characteristics are chosen[143]. Vegetation type characteristics influence chemical absorption. The selection of appropriate plant species that hyperaccumulate heavy metals and produce large amounts of product using current crop production[144].

Medium Properties

Agroecological approaches (pH correction, inclusion of chelators, fertilizers) are being proposed to improve rehabilitation[145]. The quantity of lead taken by plants, for instance, is controlled by soil pH, vegetable material, and phosphorus level[146]. The pH of the soil was corrected with calcium to a range of 6.5−7.0 to minimize lead uptake.

Root Zone

In phytoremediation, the root zone is of particular relevance. It can absorb pollutants and store or metabolize them inside plant tissue[141]. Another phytoremediation technique is the degradation of pollutants in the soil by plant enzymes secreted from the roots. A morphological adaptation to drought stress is an increase in root diameter and decreased root elongation as a reaction to the dry soil's decreased permeability[147].

Vegetative Uptake

Environmental factors influence vegetative absorption. Temperature influences growth stimulants and, as a result, root length. The root structure in the field contrasts with that in the glasshouse. The achievement of bioremediation, specifically phytoextraction, is dependent on the presence of a pollutant hyperaccumulator[148]. Knowing mass conservation assessments and the metabolic destiny of toxins in crops is critical to demonstrating phytoremediation's potential application[149].

Imminent Scenarios

Rhizobial studies under controlled and field conditions are required to investigate the antagonistic and synergistic effects of multiple heavy metal ions in soil solution and polluted water[150]. Soil microbial studies are also required to recognize microbes that are strongly linked to metal precipitation. The majority of the toxic substances discovered have toxicity profiles, but the negative effects never become evident[151]. As a result, it is proposed that constant monitoring of heavy metals in plant tissues is required to prevent excessive accumulation in the human food chain[8].

Supervision and evaluation of the levels of heavy metals in vegetable crops require extensive study to minimize the health hazards to humans. However, there is no comparison of the accumulation of heavy metals in the air and trade sites in the literature reviewed[152].

Conclusions

Vegetables are a major part of nutrition because they comprise carbohydrates, enzymes, minerals, and natural fibers that are important for health. Environmental change and pollution of the food chain are unavoidable as human activities rise. The absorption of toxic substances by plants in contaminated soils has been investigated. Among food quality management practices, heavy metal content determination is critical. Because of the high attention to the threat of the substances in food production, national and international restrictions have been decided. This is to lower the concentrations of pollutant metals in foodstuffs. Most contaminants are non biodegradable, have longer biomedical splits, can accumulate in various body parts and have adverse environmental effects. There is a strong correlation between plants, animals, and human beings on the notation of micronutrient nourishment and absorption of toxic substances. The composition of crop components also depends on the soil conditions and the type of crop cultivated. Metal pollutants in the soil, water, plants, and air are major issues due to possible inferences on human health and environmental existence. To maintain scarce natural resources and genetic pools, economical and easily accessible technologies are needed, especially for low- and middle-income countries.

Over the last decade, great efforts have been made to recognize flora and fauna and their courses of heavy metal uptake and hyperaccumulation trends. The introduction of heavy metals into the environment (soil, water, plants, and air) is profoundly laden with the concern given for the potential implications of the substance on humans and the environment. Thus, to secure biodiversity and genetic resources, operative and affordable policies and strategies should be applied.

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Conflict of interest

The author declares that there is no conflict of interest.

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