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Review Article

Impacts of Heavy Metal Pollution on Ethiopian Agriculture: A Review on the Safety and Quality of Vegetable Crops

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Lack of nutritive and consumption of polluted food sources are the main health implications in African countries. Vegetable production is an optional balanced food source easily grown in the urban and rural areas. However, the levels of contaminant heavy metals in cultivated vegetables have not yet been identified. This review scrutinizes the contamination route, sources, health effects, environmental problems, food safety complications, and remedial activities of vegetable production in Ethiopian agriculture. Informal settlement, the rapid rate of urbanization, and the lack of community-based industrial expansion lead to massive increases in toxic heavy metals in ecosystems. They are supplied with food source diets unrestrictedly, mainly for vegetable consumption. Among the assessed metals, Zn (112.7 mg/kg), Cr (47.7 mg/kg), Pb (17.76 mg/kg), and Cd (0.25 mg/kg) existed in vegetables, with the highest concentrations in Ethiopia. They have negative effects on public safety, environmental security, and nutrient levels in horticultural crops. Hence, Ethiopia has no permissible standards for vegetable consumption and hazard analysis, critical control point, or food safety system. Additionally, physical, biological, and natural remedial strategies such as phytoremediation, phytoextraction, phytostabilization, rhizofiltration, bioremediation, and phytovolatilization are not applied to curtail deadly substance contents in Ethiopia. Despite this, some mitigation strategies, such as industrial waste treatment activities, are underway in Ethiopia's universities and beer and sugar factories. This review found that the use of integrated remedial strategies could help to improve the efficiency of strategies in a sustainable manner, solid safety control for heavy metal management in Ethiopia, and management should begin with local solutions.

1. Introduction

Heavy metal pollution and contamination have been increasing since the late 1960s to early 1970s, and to date, they affect hundreds of thousands of people's wellbeing across the world with severe daily health risks [1]. Lack of wastewater treatment from industries, the use of agrochemicals, uncontrolled industrial discharges, sewerage wastes, and numerous other disposals result in heavy metal contamination and pollution of the surrounding environment [2]. The spread of toxic substances to environments contaminates the soil where vegetables are grown, and environmental pollution due to heavy metal contamination has high health risks to people everywhere, as well as a high fatality ratio [3]. According to the European Environment Agency report, Poland is a highly polluted country, and the lead emissions from Poland account about 20%. In addition, heavy metal contamination has created significant challenges for China.

According to a study on the African continent [4], toxic metal exposure has become a major public concern and has attracted attention from domestic as well as international ecologists and the effluence of dangerous compounds has escalated to remarkable levels in recent decades. Recently, a study on sediments from streams in the Awatu watershed found toxic element adulteration, such as arsenic, with varying amounts with nutrient contents decreasing in the sequence of Pb > As > Hg [5]. Due to an increase in residue liquidation on industrial successes such as pulp industries, textile factories, and hide and skin working zones as well as the use of unprocessed wastewater intended for farm decisions, Ethiopian food and water may continue to include the highest level of harmful elements [6]. The most prevalent and dangerous heavy metals identified in Ethiopia are As, Cd, Pb, and Hg, and no one intentionally consumes them from leafy green vegetables [7]. These vegetable crops absorb elements from the soil and water as they grow. The study reported on the Pb level of tomato and cabbage crops in Mojo, central Ethiopia, found that they contain 38 and 36 milligrams per kilogram, respectively [7]. Additionally, other vegetables have been reported for heavy metals due to their detrimental affluences, such as cadmium, copper, manganese, lead, and zinc [8]. Increased agro-chemical use in Ethiopia often entails better use of agricultural inputs to boost production, which concerns environmental and natural risks such as pollution and the eutrophication of aquatic environments [9]. Accordingly, harmful elements are stored inside vegetable yields, inflowing into their sustenance series, and posing public risks.

In addition, the environment has been severely harmed by population growth, agricultural change, fast urbanization, mechanization, and sewage pollution, which have increased to alarming levels [10]. Currently, migration from rural to large cities causing rapid expansion of urban towns, informal settlements, and imbalance of infrastructure cause contamination of surroundings and key health problems in Ethiopia [11]. Accordingly, unplanned urbanization and industrialization in Ethiopia have had a negative impact on aquatic and deposit classes, diversity of flora, and wildlife [10]. Vegetables are important defensive food items that remain valuables intended for general wellbeing as well as deterrence and management for a wide range of diseases in Ethiopia [12]. However, they are reported to comprehend harmful substances called toxic elements in different quantities and contamination as well as adulterations [13]. Heavy elements are indeed initiated on earth and contribute to topsoil formation and growth of vegetables, particularly Zn, Cu, Mn, Ni, and Co, which are microsustenances essential for vegetal progression, whereas Cd, Pb, and Ag need unidentified biotic roles [14]. However, heavy metals/elements such as Ag and Cd are lethal and threats to public health and welfare with little absorption and air contaminants, but common dating embraces As, Cr, Cu, and others [15]. They are less decomposable and persistent in nature, build up in the environment, creating effluence, and buildup close to the top users of vegetables [16]. The topsoil's properties, along with the measurements of vegetable yields, predispose the amount of constituents on plants to favorably accumulate certain affluences [17]. Since there are now no other options available and awareness-raising is the only solution that can be implemented to address this issue, the situation may also take longer than anticipated [18]. The recommendations for handling the situation are insufficient, the negative economic and environmental effects of heavy metals are immediate, and they are likely to worsen as a result of issues that continue to disrupt vegetable production, occupation, source stock, and speculation all over the world [19]. The key question on everyone's mind right now is "What is the solution? Therefore, this review aimed to analyze past studies on the heavy metal contamination route, health effects, environmental problems, vegetable source, food safety complications, and remedial activities.

2. Vegetable Production in Ethiopia

2.1. Contaminants in Soil and Vegetables. Vegetable crops are highly contaminated with heavy metallic elements due to the practice of growing vegetables on contaminated land (moistening with wastewater) [12]. Toxic substances have emerged principally by metal excavation, melting, and discharge of substances from various roots, resembling discarded junkyards, defecation, and chemical fertilizers [20]. Other sources comprise quarrying, manufacturing trashes, farming overflow, main acid sets, old sources of water schemes, work-related contact, dyes, and preserved wood [21]. However, burning procedures are the greatest imperative causes of metallic elements, specifically the production of energy, melting, ignition, and the inner firing engine in various countries around the world [22]. General farming, as well as fast development, is possible foundations of dense metal contamination [23]. Unprocessed wastes after agrochemicals, insecticides, vehicle reparation, washes, steel coating, workrooms, waste discharges, and other sources are liquidated into the surrounding streams, which are primarily used for vegetable production via irrigation [24]. Metallic chemical roots in Ethiopia's farmlands are moistened by means of watercourses loaded through manufacturing discharges and fertilizer and pesticide usage. Pesticides and chemical fertilizers contain varying amounts of Zn, as well as other heavy metals, depending on their source, and the repeated use of phosphate fertilizers continuously enriches agricultural soils with heavy metals [7]. The streams described by researchers focus on comprehending high absorption of micronutrients [25], and identifying pollution sources of minute constituents as well as their quantities is still very challenging [26]. Most studies on stream contamination concentrate on common heavy metals, omitting data on the longitudinal distribution of minor nutrients and the order of the urban environment [27]. Despite extensive ecological degradation in many African countries, identifying pollution sources remains a major challenge [28].

Metal contaminants in farmed soils can impair plant growth, cause functional issues, and even endanger human health, and heavy metal-induced soil toxicity may endanger urban horticulture systems and pose serious health risks [2]. Heavy metals, including Pb, Cd, and Hg, which are all present in water, are substances of significant public health concern and increased unused cleared-on-once business ventures such as pulp mills, cloth mills, and hide-skin productions could result from higher levels of toxic constituents in Ethiopia's rivers [29]. The long-term use of untreated sewage liquid is linked to an increase in toxic metal accumulation in vegetables, which has serious health consequences [30]. Studies on African leafy and root vegetables have revealed that cadmium and lead levels considerably increase when more contaminated liquid is used to water the plants [31].

Heavy metal contamination in vegetables is classified differently depending on meteorological situations and the kind of metallic components [20]. According to a study of metallic levels in plants in Addis Ababa [32], lettuce had the maximum Cd level, while head cabbage had the lowest Cd. Man-made activities such as mining, manufacturing, fabricating, and internal and agricultural use of steel produce the most ecological adulteration and anthropological disclosure [21]. On the other hand, this could remain on the loam and be engrossed via vegetation and the toxic elements released via production can settle on plant exteriors through dispensation, dissemination, and marketing. Metal-loaded aerosols pollute the air in farming areas near highways, as well as near agricultural areas, and most sources of heavy metals have been synthesized from various publications (Figure 1).

2.2. Heavy Metal Impacts on the Environment. Toxic nutrients entering in to the recycling system can harm the ecosystem, and similar components disturb the convertibility of common contaminants and produce less changeable toxins and therefore contaminating the environment twice. Water contamination by composites has emerged as one of the most serious ecological issues, and toxic elements continue to be the primary contaminants of external plus subversive rainwaters [22]. Because the maximum harmful substances stay combined with residues when they enter in to the aquatic setting, the deposits are measured as a basis of constituents as well as a record of anthropogenic impacts [33] and the diagram produced (Figure 2) shows that the effects of metals are not limited to vegetable crops.

The most lethal elements can affect the environment, including soil and plants, water bodies, and people, and heavy metals, are persistent pollutants that build up in the environment and damage biodiversity structures.

Cd is highly noxious at low levels, and long-standing exposure can affect renal dysfunction, lung disease, osteomalacia, osteoporosis, myocardial dysfunction, pulmonary edema, and death [34]. Elevated Pb levels in the environment can reduce plant and animal growth and reproduction and have neurological effects in vertebrates [35]. Mercury is a highly hazardous element that occurs in the environment both naturally and as an added contaminant, and the main human-related sources of mercury include coal combustion, waste incineration, industrial usage, and mining [36]. The highest levels of Ag in the air cause breathing problems, stomach and esophageal irritation, and pain in the lungs, and Ag chloride molecules might harm the organs, kidneys, eyesight, epidermis, and respiratory system [37]. Arsenic is a natural mineral found inside the subsurface, and it is also spread widely in the surroundings and is exceedingly hazardous in its elemental state [38]. Highly lethal heavy metals have a variety of acute and chronic toxic effects on the environment, as shown in Figure 3.

2.3. Health Concerns of Polluted Vegetables. Cd and Pb are the two most common heavy metals in the ecosystem, and consuming crops deemed dangerous has been related to adverse effects such abdominal pain, dizziness, abortion, and even mortality [39]. Heavy metals alter our decisions in life and confound us, and they produce a deep sadness that makes society forlorn [40].

The presumed tolerable weekly intake (PWTI) could be used to suggest consumer usage and associated potential dangers, and humans may improve food security by minimizing contaminants and teaching others about vegetable farming [41]. Excessive levels of Pb and Cd metals in vegetables have been associated with a number of health issues, including cardiac and musculoskeletal diseases [42]. Also, Pb affects fetal and neurocognitive functioning as well as distresses the function of heart.

2.4. Potential Pollution of Vegetables with Toxic Metals. Pollutants in combined sewage from factories and perhaps other sources include metal alloys, dissolved solids, viruses, and identifiable chemical compounds [43]. Extraction and a number of other sectors are the main contention sources of pollution that lead to heavy element contamination in water [44], and Zn, Cr, Pb, and Cd were all found at the highest concentrations in study samples taken in vegetable fields (Figure 4). According to the synthesized data presented below, Zn (112.7 mg/kg), Cr (47.7 mg/kg), Pb (17.76 mg/kg), and Cd (0.25 mg/kg) were all found at the highest concentrations in croplands (vegetable gardens) of Ziway, Burayu, and Addis Ababa, whereas plants are frequently grown employing effluents.

Heavy metal accumulations in vegetables are caused by sewage watering, which generates levels of heavy metals and thrash metal accumulation in soils [45]. According to the study report [46], practically all locations having quantities of Cd, Pb, and Ni that are excessive and should not be used for vegetable production and the heavy metal contents which are found in rivers used for irrigation are presented in Figure 5.

There is no danger to users from determining the accumulation of heavy metals in onion specimens, and a lack of knowledge on onion heavy metal content inquiry may effect on the entire system, ultimately harming the production process [47].

The minimum net weight value for tomato is 0.100 mg/kg for cadmium and lead, and several studies in various tomato-producing areas of Ethiopia must be conducted. Additionally, the most lethal metal, Pb, was found in the roots and stalks of tomatoes [48].

Spinach, parsley, and Jews mallow have the highest metallic concentrations [49], and various parts of Ethiopia have revealed the levels of lead and cadmium chemicals in lettuce, cabbage, and Ethiopian kale (Figure 6). Africa could establish its own guidelines for acceptable and allowed levels for all agricultural goods, not just vegetables [50].

Ethiopian potato grown with wastewater had the highest Co level (Figure 7), followed by green vegetables, such as lettuce and Swiss chard, and Ethiopian kale from Akaki and Kera locations had the highest Cu, Ni, and Zn concentrations [46].

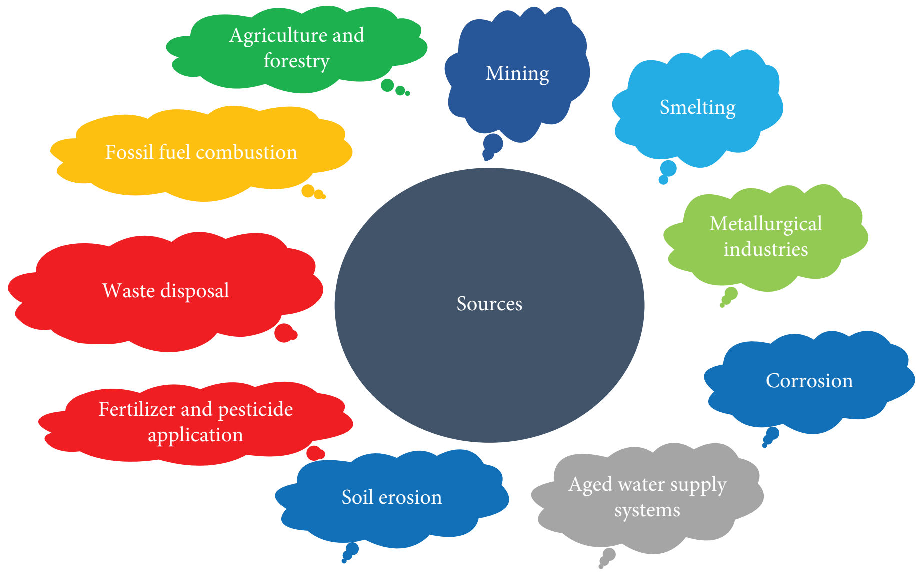

Figure 1: Summary of heavy metal sources.

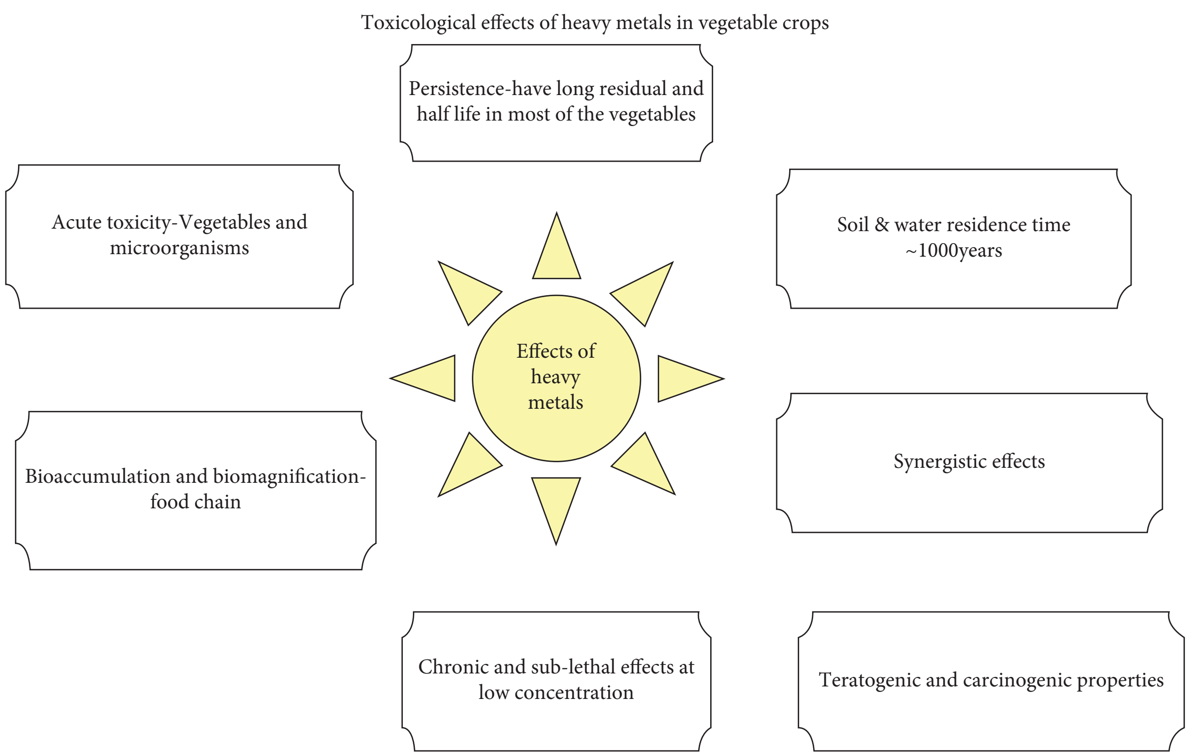

Figure 2: Toxicological impacts of metallic elements in vegetable plants.

Stem vegetables (170.91 mg/kg), leafy vegetables (134.94 mg/kg), and root and tuber crops (115.17 mg/kg) had the highest heavy metal loads in comparison to the World Health Organization's permitted standards (Figure 7) and the average values of all vegetable crops reported by different researchers [51]. However, flower vegetable crops have the lowest load of toxic substances and the level of heavy metal entry (influxes) from soil into various vegetables has a significant impact on the substance load in crops [52]. Research conducted by [53, 54] in three locations of Ethiopia (Kuskuam, Burayu, and Ziway (Ethioflora)) reported that lettuce had 41, 42, and 30% of Cd, respectively, and takes the maximum percentage of influxes of toxic substances, followed by 47, 42, and 11% of Ethiopian Kale while Swiss chard has the lowest with 2 and 36% influx (Table 1).

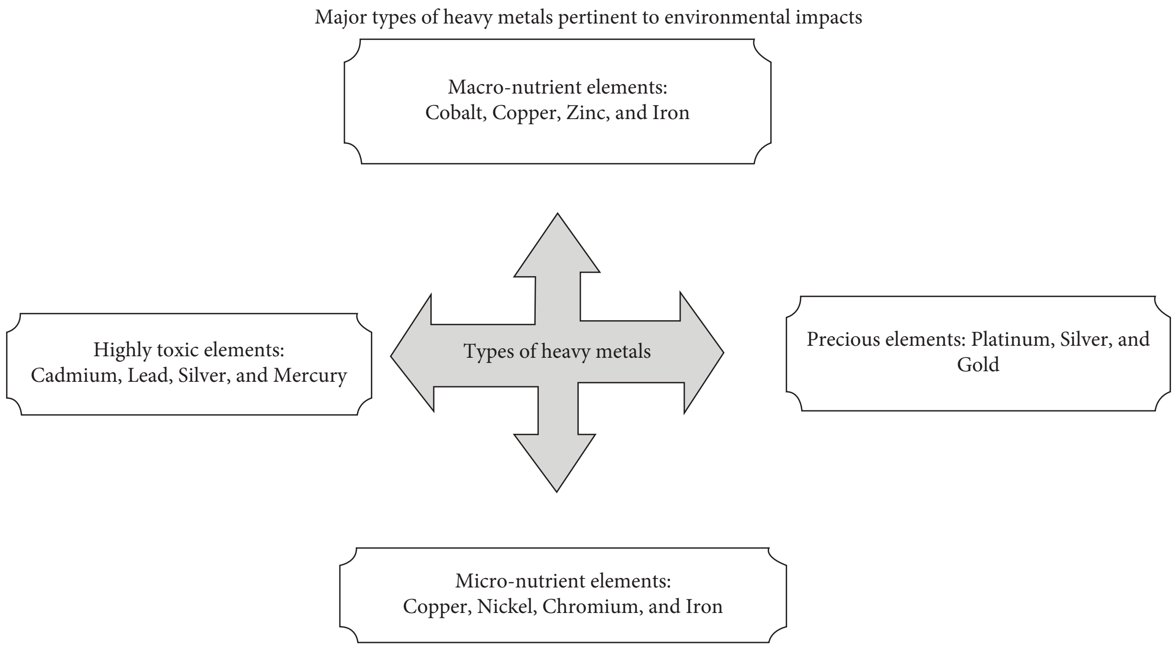

Figure 3: Summary of heavy metals based on their impact classification.

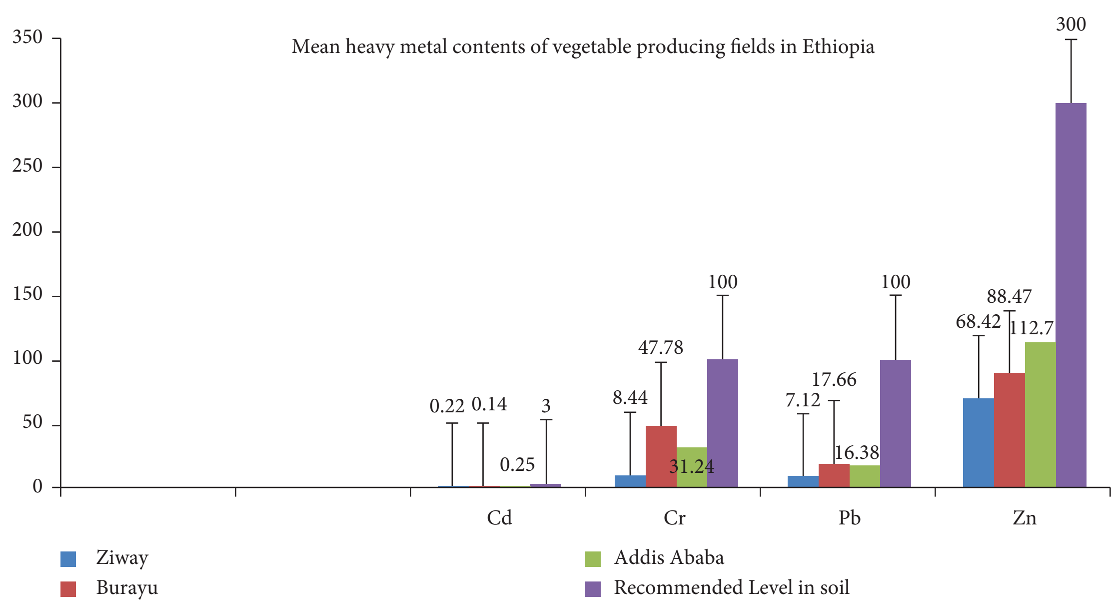

Figure 4: Synthesized amount of the mean heavy metal content in vegetable fields of Ethiopian soils.

2.5. Food Safety Levels of Ethiopian Vegetable Crops. Food safety is the practice of handling, processing, and preserving food in a way that prevents foodborne illness and injury and contamination resulting from subpar food standards, which endanger the food business and hurt people all around the world [56]. Foodstuffs may come into contact with a variety of health impacts when they enter the system, and nutrition security helps protect consumers from the risks of foodborne diseases and allergies. By ensuring that procedures are successfully in place, vegetable producers can help improve food safety compliance [57]. Understanding the risks associated with each of the four types of food safety hazards can greatly lower the likelihood of contracting a foodborne illness [58], and Ethiopia's food safety system is less organized and developed than that of other developed countries. The proportion of people who know about food safety ranges from 24.5% in Godey Town, East Ethiopia [59], to 75.9% in Debarq Town, Northwest Ethiopia [60].

2.6. Mitigation Strategies of Heavy Metals from the Environment. Most developing nations' urban areas lack adequate waste management systems and urban development with sufficient infrastructure leading to daily outdoor

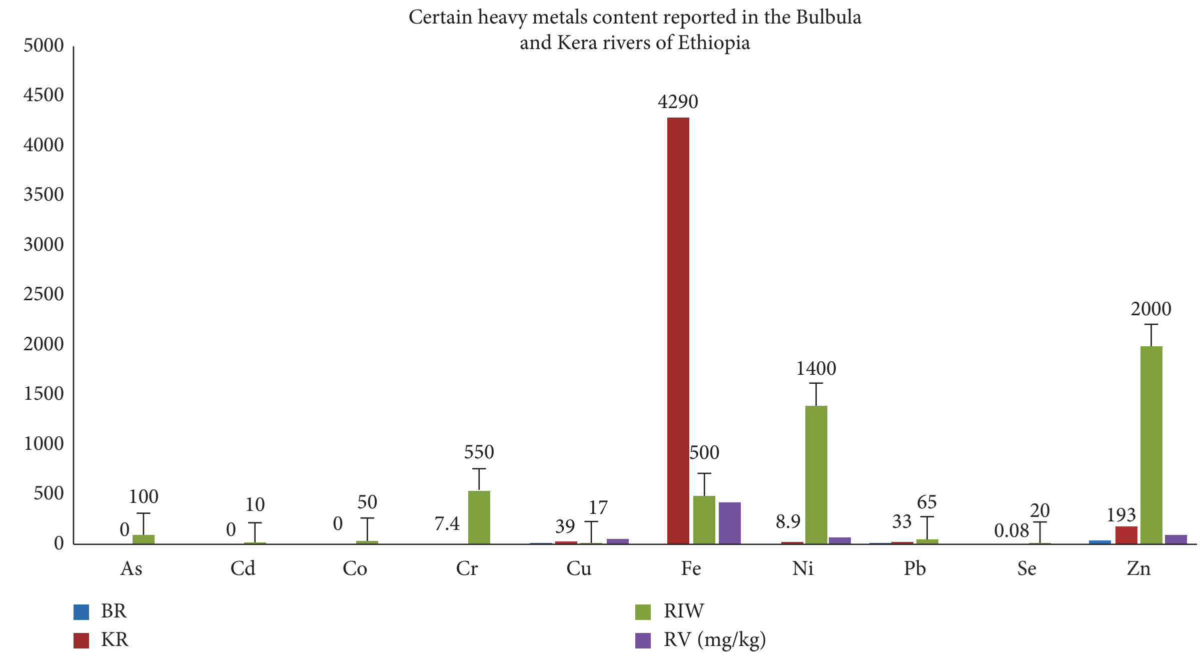

FIGURE 5: Heavy metal contents of some Ethiopian rivers used for irrigation compared to the World Health Organization standard, where BR = Bulbula river, KR = Kera river, RIW = recommended irrigation water, and RV = recommended heavy metal content in vegetables.

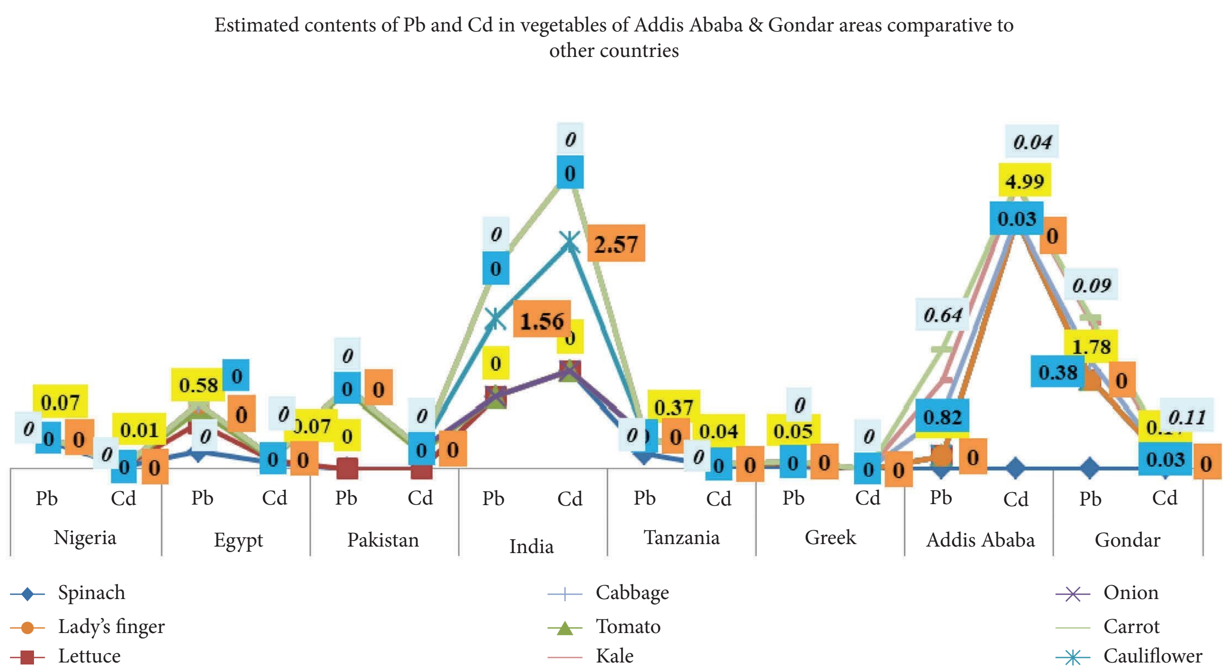

FIGURE 6: Synthesis of the Pb and Cd contents of some garden crops grown in Ethiopia's capital city and Gondar region in comparison to other countries.

garbage disposal and unregulated effluent [61]. Moreover, agricultural practices are led by political motivations rather than skilled manpower which commence the rural communities to use tremendously contaminating chemicals for agricultural activities. As a result, recently superb level environmental pollution needs intervention. Therefore, among the biologically accepted mechanisms that are recommended including bioaugmentation, biosorption, and biosparging are the aforementioned strategies as microbial management options stated by many researchers [62, 63].

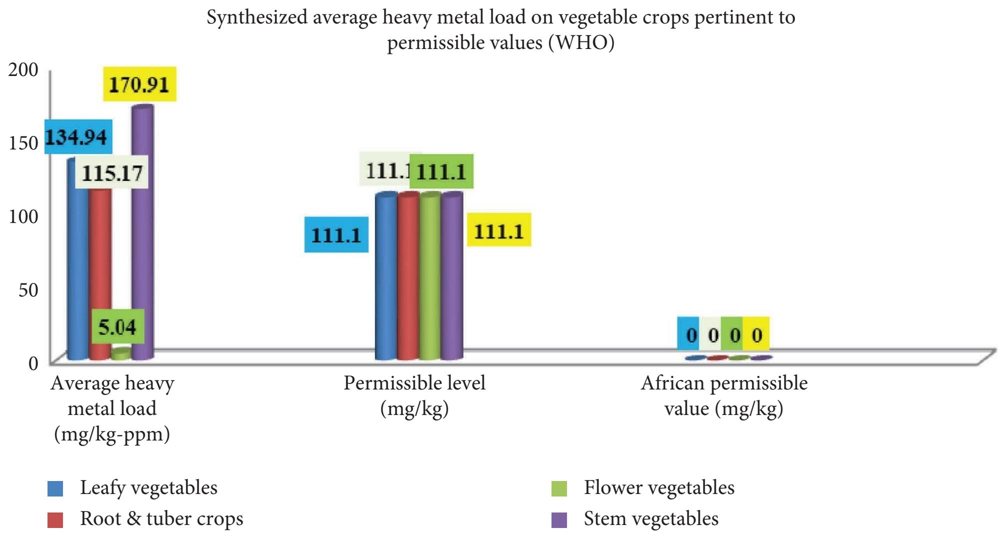

Figure 7: Synthesis of the average heavy metal load on various vegetable crops in relation to allowable values.

Table 1: Maximum amount of soil-derived metal influxes in vegetable tissues.

Leafy crops	Metallic elements	Farmlands		
		Kuskuam (Gondar) (%)	Burayu (%)	Ziway (Ethioflora) (%)
Lettuce crop	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	26.1	2	—
	Cr	1.09	39	—
	Pb	36.02	1	—
	Zn	2.08	36	—

Source: reference [55].

This method has not yet been implemented as advanced technologies are needed to incubate the microorganisms [64]. Removing metals from polluted soil and accruing them in the root system, stems, and branches of plants is also a promising technology for cleaning polluted sites [65], and some plants have the innate ability to collect, breakdown, or render air, liquid, or soil toxins harmless [66].

Plants are harvested after dangerous metals accumulate in their tissues and are grown on contaminated soil *in situ*, and phytoextraction is a long-term solution for the removal of heavy metals from polluted soils [67]. Phytostabilization involves crops temporarily posing health risks so that these toxic substances remain below ground [68]. Rhizofiltration is the desorption, precipitation, or absorption of dissolved substances from or into vegetable roots, and it involves purifying polluted groundwater, rainwater and sewage through a dense network of roots to eliminate toxins or extra resources, and microbial bioremediation of toxic substances is also developing as an advanced tool [69]. Transpiration is the process by which soil contaminants are absorbed by crops, transformed into unstable substances, and subsequently discharged into the air [70]. It also encompasses the removal and release of pollutants from soils, and through transpiration, crops draw contaminants from the soil and release them into the atmosphere, and growing plants absorb water and soilborne organic contaminants [71]. Normally speaking, the main outlines are listed in Figure 8.

3. Review Gaps

It is necessary to investigate heavy metal consumption regulations for Ethiopia and the continent of Africa. It is indeed important to examine how heavy metal accumulation is impacted by climate change. Currently, there is no sufficient research on food safety, environmental balance, ethical questions, or sociopolitical considerations. It is also necessary to research the management strategies that are flexible regarding to the environment mainly from emerging industries that use heavy metals and chemicals in processing industries. Machine technologies that should be used to identify the level of heavy

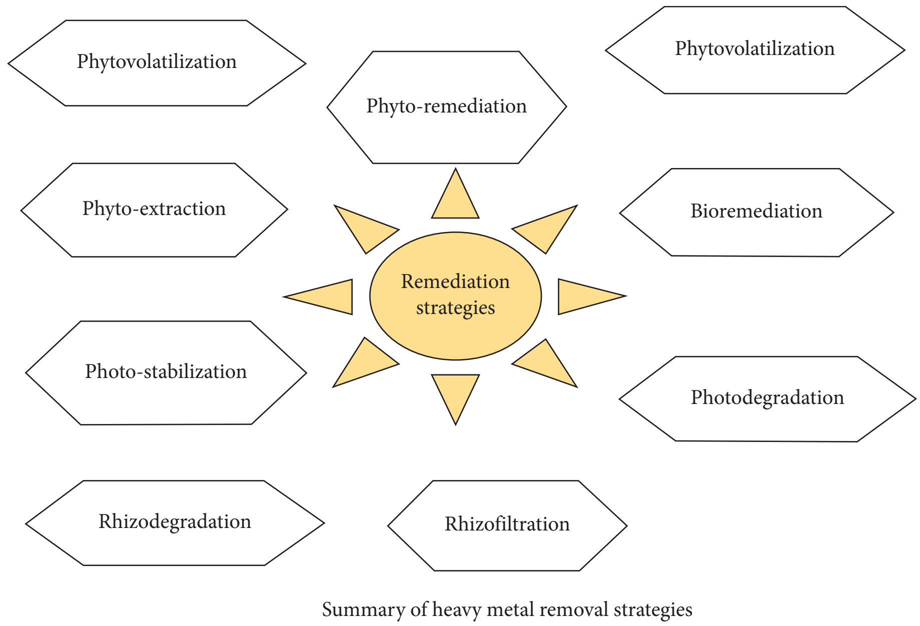

Figure 8: Heavy metal removal strategies of vegetable crops.

metals in agriculture land, vegetable crops, and other aspects should be developed. Artificial intelligence and predictive and systematic agronomy technologies should be researched.

4. Conclusions and Recommendations

Multiple problems are having an increasing impact on Ethiopian agriculture. Thrash metal precipitation or flow pollutes agricultural soils on the outskirts of cities, increasing the quantity of hazardous compounds in food products, notably vegetables. One of the primary routes for heavy metals to enter the body is through contaminated vegetables, which can result in a variety of diseases. Ethiopia can employ phytoremediation, phytoextraction, phytostabilization, rhizofiltration, bioremediation, and phytovolatilization through an integrated approach to improve the efficiency of strategies in a sustainable manner, together with local solutions.

Data Availability

The data used to write this review came from previously reported studies and datasets.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Authors' Contributions

Yohannes Gelaye developed the idea and designed the structure and both authors approved the draft of the manuscript.

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