

Accumulation of heavy metals in the soil and agricultural crops

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Abstract. This article presents the results of studies of the accumulation of heavy metals in irrigated soils and crops grown in fields contaminated with heavy metals in a territory that has not previously been studied and its ecological state has not been assessed. The accumulation of heavy metals in irrigated soils and crops *Panicum L-millet*, *Solanum lycopersicum* - tomato, *Citrullus lanatus* - watermelon, *Cucumis melo* - melon, *Capsicum annuum* - bell pepper was determined. Based on the amount of accumulated elements of heavy metals Cr, Ni, Cd, Pb, Mn, Cu, As in soil and crops, an assessment of their ecological state was carried out. The following accumulation of heavy metals in soil incisions is established: the cadmium (Cd) element accumulates in a small amount, lead (Pb) - 15.2 mg/kg, nickel (Ni) - 34.2 mg/kg, chromium (Cr) - 43.3 mg/kg. From agricultural crops in the ears of millet manganese (Mn) accumulates in the amount of 12.63 mg/kg, copper (Cu) - 9.79 mg/kg, cadmium (Cd) - 0.068 mg/kg, lead (Pb) - 0.48 mg/kg, chromium (Cr) - 0.99 mg/kg, nickel (Ni) - 2.92 mg/kg, arsenic (As) - 0.98 mg/kg; from vegetable and melon crops in the fruit of bell pepper cadmium (Cd) is contained in an amount of 0.077 mg/kg, lead (Pb) - 0.35 mg/kg, nickel (Ni) - 3.26 mg/kg, arsenic (As) - 5.33 mg/kg. Since the content of heavy metal elements Ni, Cr, Cd and As in the studied crops exceed the maximum allowable concentrations, it is not recommended to grow vegetables and melons in such fields.

1 Introduction

Being the most important life-supporting sphere, the soil is constantly experiencing various impacts in terms of time, intensity, scale and consequences due to the diverse human production activities. Anthropogenic impact, which manifests itself, for example, in the withdrawal of land for building and transport purposes, the development of erosion and digression processes, pollution and littering, etc., is a global phenomenon that causes serious concern to the world community. According to B. G. Rozanov, the total area of soils undergo to destruction and degradation during the history of humanity has reached 20 million km², which exceeds the total arable area of the modern world - 15 million km². A significant problem of in the present time of agrarian and industrial impact is the pollution

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of the environment at all possible levels – air, water, soil, plants, animals and human. The components of the environment and the factors that influence them affect the existence and reproduction of organisms (including hydrobionts and humans).

According to the authors, most toxic metal releases in Africa and other developing countries are the result of industrialization coupled with poor utilization and wastewater management. Due to the large-scale mining in South Africa, pollution is common occurrence, with devastating effects on animal and human health. Toxic metals such as zinc (Zn), lead (Pb), aluminum (Al), cadmium (Cd), nickel (Ni), iron (Fe), manganese (Mn), and arsenic (As) are the main effluents from mining operations from tailings that pollute both surface and ground water, soil and food, thereby affecting biological function, endocrine system and growth (Okereafor et al., 2020). Heavy metals are a group of metallic chemical elements that have relatively high densities, atomic weights, and atomic numbers. The common heavy metals/metalloids include cadmium (Cd), mercury (Hg), lead (Pb), arsenic (As), zinc (Zn), copper (Cu), nickel (Ni), and chromium (Cr). These heavy metals/metalloids originate from either natural or anthropogenic sources such as produced water generated in oil and gas industries, use of phosphate fertilizers in agriculture, sewage sludge, metal mining and smelting, pesticide application, electroplating, and fossil fuel burning. However, agricultural practices such application of phosphatic fertilizers; pesticides and refuse derived composts contribute to heavy metals in the soil. Heavy metals are those elements with higher density than five milligrams per liter. These metals include: arsenic (As), cadmium (Cd), copper (Cu), lead (Pb), cobalt (Co) and zinc (Zn) etc. Toxic metals such as Cu, Zn, Co, Ni, Fe, Cr, Mn, I and Se widely known as micronutrients play a crucial role in the metabolic and physiological activities of humans, plants as well as microorganisms depending on their concentrations. On the other hand, specific toxic metals such as As, Ag, Hg, Cd and Pb are of no biological relevance to plants and animals, rather, they are harmful. At higher concentration levels, these elements pollute the environment, resulting in deleterious health implications for humans, plants and animals. With the development of industrialization and urbanization, the abundance of heavy metals in the environment has increased enormously during the past decades, which raised significant concerns throughout the world. Heavy metals are non-degradable by any biological or physical process and are persistent in the soil for a long period, which pose a long-term threat for the environment. Non-essential heavy metals like Pb, Cd, As, and Hg are highly toxic with no known function in plants and may cause environmental pollution and severely affect a variety of physiological and biochemical processes in crop plants and reduce agricultural productivity. They can enter into the food chain through crops and accumulate in the human body through biomagnification, thus posing a great threat to human health. The production of crops is often restricted by the low phytoavailability of essential elements and/or the presence in the soil solution of too many potentially toxic mineral elements. Micronutrients are essential nutrient elements that are found in trace amounts in plant tissue, but play a critical function in plant growth and development. Manganese (Mn) is a distinctly favourable micronutrient that plants essential for optimum growth. Manganese plays an important role in many physiological processes such as photosynthesis and acts as an activator or cofactor in at least 35 enzymes and is involved in metabolic processes. Cadmium is a highly toxic element that affects plant growth, metabolism, and condition. Lead is not an essential element for plants; it tends to accumulate in plant roots and cause toxicity. Zinc is an essential component for plants, but, in excessive amounts, it can cause toxicity. Chromium is a toxic element for plants at concentrations higher than 0.50 mg/kg. Lead (Pb), which is spread through the air transfer, is deposited in soil and water. Due to this fact, lead exposure occurs mainly through the food chain and drinking water, which is the main route of exposure for the adult population. Intake of food, including fish meat, increases the possibility of lead entering in the human body, as these

aquatic organisms have the ability to accumulate heavy metals such as lead. According to J. Caro, simple superphosphate contains: cadmium (50-170 mg/kg), chromium (66-243 mg/kg), cobalt (up to 90 mg/kg), copper (4-79 mg/kg), lead (7-92 mg/kg), nickel (7-32 mg/kg), vanadium (70-180 mg/kg) and zinc (50-1430 mg/kg). According to the international normative document of Russia 17.4.1.02-83 on the control of soil pollution with heavy metals, they are divided into 3 classes according to the degree of danger, i.e. high, medium and low levels. According to UNEP recommendations, the most dangerous heavy elements are cadmium, fluorine and arsenic. Other international documents usually list the elements lead, cadmium and mercury. USA environmental programs recommend monitoring the mobility and hazards of antimony, arsenic, barium, beryllium, cadmium, chromium, copper, iron, zinc, lead, mercury, nickel, and silver in the natural environment.

This work was performed via (i) analysis of the amount of toxic heavy metals in soils and agricultural crops, (ii) determination of the state of contamination with heavy metals, (iii) based on the state of accumulation of heavy metals in soils and agricultural crops, which determines their placement on agricultural land according to the degree of their ability to accumulate heavy metals, that is, on fields heavily contaminated with heavy metals, place crops that weakly accumulate heavy metals. Such placement of crops reduces the accumulation of toxic heavy metals in them.

2 Materials and methods

Study Area.

The present work has used materials of local agro-ecological monitoring, held in the Guzar district of the Kashkadarya region, Republic of Uzbekistan. The soils are light and typical gray soils. The irrigated area of the Burkhan farm, where crops were studied, is 47.4 ha, the fields are located at an altitude of 415-420 meters above sea level (Figure 1). According to the mechanical composition the soils of the fields of the selected farm Burkhan are medium and light sandy, but in the interval of layers of 0-50 cm soils are medium sandy, starting from the next layers, light sandy mechanical composition prevails.

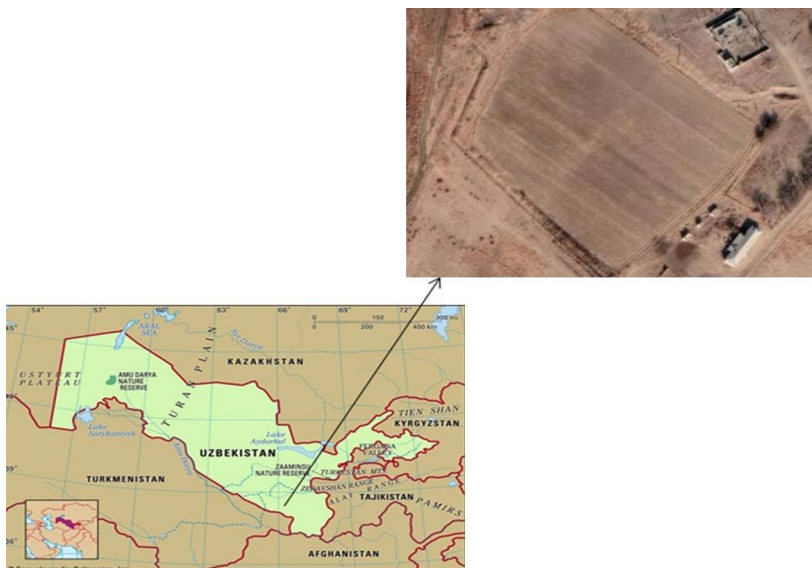


Fig. 1. Geographical overview of the study area (Image source: Google Earth scene from September 2019).

Weather

The climate of the studied area, Guzar district, located in the southeast of the Kashkadarya region, is continental. The average annual temperature is 16°C. The average temperature in January is 1.9°C, the lowest temperature is -23°C. The average temperature in July is 26.6°C, the highest temperature is 46°C. The average annual rainfall is 285 mm. Most of the precipitation falls in spring and winter. The growing season is 272 days.

Experimental Procedures

Soil material.

The studies were carried out on fields with meadow-serozem soil with a total area of 47.4 hectares of the selected farm. Soil samples were taken from five key fields for chemical analysis. The 1st incision, located at an altitude of 420 meters above sea level, was chosen as the experimental zone. In the first decade of April, 26 soil samples were taken from layers 0-30, 31-50, 51-80, 81-100, 101-120, 121-150 centimeters using 3 incisions and 2 points of the drill (hand drill). The content of heavy metals in soils was determined according to the generally accepted method. Physicochemical analyzes were carried out on the consumable parts of all soils selected for testing the content of heavy metals according to the method of Kuznetsov et al., 1992.

Plant material.

To analyze the accumulation of heavy metals in agricultural crops grown on the fields of a farm, *Panicum L*-millet, *Solanum lycopersicum* - tomato, *Citrullus lanatus* - watermelon, *Cucumis melo* - melon, *Capsicum annuum* - bell pepper were selected in these fields. The content of heavy metals in crop products was determined according to the generally accepted method. Physicochemical analyzes were carried out on the consumable parts of all plants selected for the content of heavy metals according to the method of Kuznetsov et al., 1992.

Sample Analysis.

Soil samples were dried to an air-dry state. The extraction of mobile forms of heavy metals from the soil was carried out with 5% HNO₃ for 24 hours. The aboveground and underground parts of each plant after preliminary preparation (washing with distilled water and drying to an air-dry state) were subjected to ashing in a muffle furnace for 10-15 hours at t = 500°C. Extraction of metals from plant samples was carried out with 70% HNO₃. The concentration of toxic elements in crop products was measured in accordance with SanPiN No. 0366-19 and SanPiN No. 0191-05 maximum allowable concentrations (MAC) and approximate allowable concentrations (AAC) of exogenous harmful substances in soil (SanPiN No. 0366-19; SanPiN No. 0191-05). Analyzed Cr, Ni, Cd, Pb, Mn, Cu, As are the maximum allowable concentration of accumulated elements in soils and plants (SanPiN No. 0366-19; SanPiN No. 0191-05).

Apparatus.

Determination of the content of heavy metals (Cr, Ni, Cd, Pb, Mn, Cu, As) in acidic extracts of soil and plants was performed by flame atomic absorption spectrometry on a Perkin Elmer Atomic Absorption Spectrometer (AAS) "AAAnalyst 800" on a cuvette and flame system using acetylene-oxygen combustion.

Statistical Analysis.

Statistical analysis of the results was carried out using standard methods of descriptive statistics with the calculation of the arithmetic mean (M), its error (m) and standard deviation (S). Data analysis was performed in the Statistica PSP, version 6.0 for Windows.

3 Results and Discussion

Accumulation of heavy metals in the soil.

Laboratory analyzes revealed the accumulation of heavy metals chromium, nickel, cadmium and lead elements in the soil. According to sanitary rules and regulations, the established norm for the mobile form of lead elements is 6 mg/kg. In the 1st incision, i.e. in the arable layer 0-30 cm, the lead content is 14.0 mg/kg, 12.0 mg/kg - in the layer 31-50 cm, 13.0 mg/kg - in the layer 51-80 cm, and these indicators increase from the allowable value of 2.3 and 2.0, in the layer 51-80 cm 2.2 times, decrease to 6.2 mg/kg in layers 81-100, 101-120, 121-150 cm. The maximum allowable concentration (MAC) for the mobile form of the chromium element in the soil is 6 mg/kg, its largest amount of 43.3 mg/kg is observed in the 51-80 cm layer of the 1st incision, towards the 121-150 cm layer it decreases to 29.4 mg/kg. It has been established that the content of the chromium element in almost all incisions exceeds the MAC level by 7.22 times, and from the layer of 31-50 cm to the layer of 81-100 cm of the 1st incision it increases by 6.5→6.85→7.22 times. In other incisions, it ranges from 42.4 g/kg to 26.7 mg/kg by soil layers. The MAC of the mobile form of the nickel element in soil is 4 mg/kg, the content of this element in the 0-30 cm layer of the 1st incision is 7.25 times higher than the MAC, in the layer of 51-80 cm - 8.5 times, towards the lower 150 cm layer it changes to 25 mg/kg, that is 6.25 times more than the MAC. The MAC for the cadmium element is 0.5 mg/kg. Only in the 51-80 cm layer of the 1st incision there is an accumulation of 0.75 mg/kg, which is 1.5 times higher than the MAC. On the remaining incisions, the concentration of cadmium is below the MAC level and in the plow layer of the 3rd incision, as well as in the 51-80 cm layer of the 2nd incision, approaches the MAC level (Table 1).

Table 1. The amount of heavy metals in the soil of farm Burkhan, mg/kg.

Incision No.	Layer depth, cm	The mobile form, mg/kg			
		Cr	Ni	Cd	Pb
1	0-30	39±1.0	29±0.53	0.12±0.02	14±0.85
	31-50	41.1±0.97	31.5±0.20	0.35±0.04	12±0.46
	51-80	43.3±0.60	34.2±0.26	0.75±0.05	13±0.72
	81-100	38±0.56	30±0.46	0.42±0.04	6.2±0.61
	101-120	32±0.36	27±0.36	0.12±0.03	7.3±0.79
	121-150	29.4±0.20	25±0.46	0.18±0.02	6.4±0.60
2	0-30	31.3±0.36	24±0.26	0.42±0.03	14.5±0.66
	31-50	37±0.46	28.2±0.40	0.36±0.03	14.6±0.92
	51-80	38±0.26	25±0.66	0.52±0.04	14.7±0.87
	81-100	41±0.46	23±0.26	0.37±0.03	8.3±0.72
	101-120	42.4±0.20	27.3±0.36	0.25±0.05	8.8±0.85
	121-150	37±0.26	26.1±0.82	0.47±0.05	7.1±0.40
3	0-30	36±0.36	27.3±0.56	0.54±0.04	15.2±0.82
	31-50	34±0.10	29.2±0.30	0.39±0.02	14.2±0.75
	51-80	41.2±0.62	24.5±0.40	0.42±0.03	10.8±0.61
	81-100	39±0.56	26.5±0.20	0.28±0.05	8.9±0.53
	101-120	36±0.36	21.4±0.44	0.49±0.04	5.1±0.36
	121-150	35±0.26	28.3±0.53	0.38±0.05	3.7±0.56
4	0-30	39±0.53	31.2±0.36	0.42±0.075	8.2±0.66
	31-50	37.5±0.61	32.8±0.30	0.45±0.03	9.2±0.46
	51-80	36.1±0.40	41.2±0.50	0.36±0.026	7.4±0.78
	81-100	39.3±0.85	27.2±0.36	0.22±0.046	4.6±0.50
5	0-30	34.1±0.36	27.2±0.35	0.42±0.036	11.4±0.48
	31-50	33.3±0.36	25.4±0.50	0.43±0.072	10.3±0.44
	51-80	28.8±0.70	22.1±0.20	0.36±0.06	9.5±0.36
	81-100	26.7±0.40	18.4±0.62	0.23±0.062	7.7±0.62

Accumulation of heavy metals in agricultural crops.

During the research, the analysis of accumulation of heavy metals in agricultural crops such as millet, tomato, watermelon, bell pepper and melon was carried out. Before the agricultural activities the maximum accumulation of the manganese element in parts of the millet plant amounted to 3.84 mg/kg in the stems of plants, the smallest - 0.12 mg/kg in the roots. After agricultural activities, the application of organic fertilizers (20 tons of manure and 10 tons of hay per 1 ha), it was found that the manganese element accumulates in parts of plants, i.e. in roots 6.93 mg/kg, in leaves and ears - 12.43-12.63 mg/kg (Table 2 and Figure 2).

Table 2. Amount of heavy metals in various agricultural crops, mg/kg.

No.	Plant name	Parts of the plants	Mn	Cu	Cd	Pb	Cr	Ni	As
1	Millet, before the agricultural activities	Root	0.12±0.08	3.53±0.18	0.04±0.03	0.28±0.14	2.21±0.15	0.08±0.02	1.22±0.035
		Stem	3.84±0.65	30.64±3.29	0.031±0.04	0.46±0.063	1.45±0.46	1.46±0.07	3.86±0.11
		Leaves	2.24±0.51	5.0±0.77	0.037±0.036	0.39±0.065	2.0±0.39	1.32±0.08	2.30±0.11
2	Millet, after the agricultural activities	Root	6.93±0.86	9.76±0.93	0.074±0.016	0.24±0.051	0.86±0.13	1.63±0.11	8.72±0.23
		Stem	6.08±0.95	10.85±0.99	0.067±0.019	0.31±0.095	0.8±0.14	3.85±0.22	4.89±0.18
		Ear	12.63±0.52	9.79±0.37	0.068±0.019	0.48±0.039	0.99±0.16	2.92±0.069	0.98±0.04
		Leaves	12.43±1.27	10.54±1.04	0.066±0.23	0.47±0.042	0.98±0.16	2.09±0.12	4.38±0.17
3	Tomato	Root	1.04±0.19	4.59±0.76	0.06±0.015	0.06±0.015	2.36±0.46	0.03±0.011	6.67±0.88
		Leaves	9.28±0.84	2.24±0.41	0.065±0.021	0.13±0.038	1.99±0.26	0.72±0.07	5.1±0.55
		Stem	16.68±0.89	4.17±0.37	0.061±0.016	0.12±0.023	1.11±0.17	1.45±0.094	0.57±0.056
5	Watermelon	Root	5.02±0.34	7.59±0.57	0.07±0.026	0.49±0.043	1.02±0.16	1.05±0.06	2.2±0.12
		Stem	5.61±0.39	7.89±0.53	0.083±0.017	0.35±0.042	1.09±0.18	1.05±0.07	4.2±0.07
		Leaves	4.8±0.38	6.6±0.53	0.085±0.022	0.15±0.029	1.03±0.22	1.58±0.11	3.7±0.17
6	Bell pepper	Root	6.72±0.53	7.03±0.68	0.077±0.018	0.09±0.02	1.06±0.25	3.02±0.11	5.39±0.08
		Stem	5.02±0.34	7.22±0.79	0.083±0.017	0.40±0.04	0.65±0.18	3.48±0.05	2.8±0.07
		Leaves	9.79±0.73	3.49±0.57	0.083±0.022	0.34±0.053	0.76±0.18	3.06±0.14	4.46±0.15
		Fruit	8.21±0.54	5.22±0.76	0.077±0.019	0.35±0.056	0.03±0.02	3.26±0.08	5.33±0.18
7	Melon	Root	6.57±0.44	9.85±0.63	0.075±0.013	0.49±0.039	0.01±0.01	2.95±0.07	2.07±0.054
		Leaves	5.21±0.54	10.0±0.75	0.091±0.016	0.19±0.01	0.7±0.22	2.53±0.11	6.82±0.09
		Stem	4.83±0.41	8.96±0.47	0.079±0.012	0.39±0.022	1.3±0.33	0.61±0.02	0.63±0.04

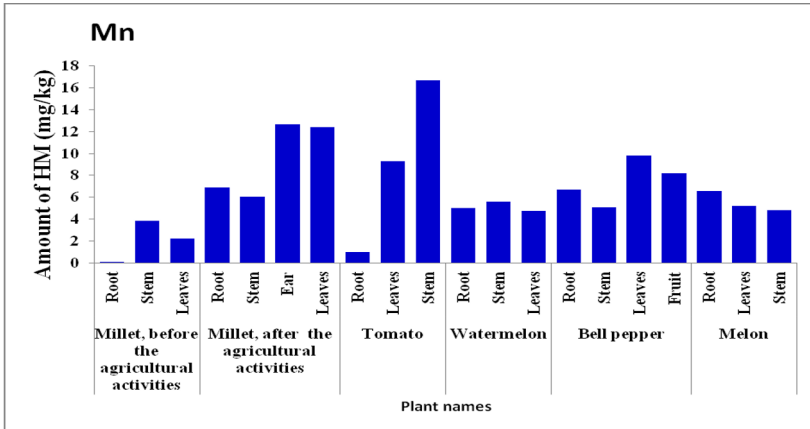


Fig. 2. Accumulation of the Mn element in agricultural crops.

The established MAC of the element of copper for grain crops is 5 mg/kg, but the accumulation in the roots of the millet plant is 3.53 mg/kg, planted in the field without agricultural activities, in the stems - 30.64 mg/kg. After agricultural activities, the concentration of copper in the leaves and stems is 9.76 mg/kg, in the root - 10.85 mg/kg, in the ear - 9.79 mg/kg, in the leaves - 10.54 mg/kg, which is 1.96 times more than the MAC of an ear. The established MAC of the copper element for vegetable and melon crops is 10

mg/kg, the accumulation of the copper element in vegetable and melon crops in the obtained analyzes is below the MAC level (Table 2 and Figure 3).

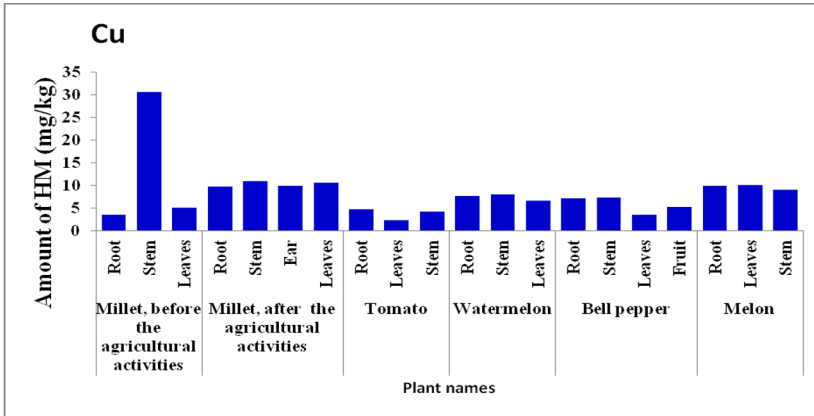


Fig. 3. Accumulation of the Cu element in agricultural crops.

The established MAC for the cadmium element for grain crops is 0.02 mg/kg. The distribution of cadmium in the millet plant was observed as follows: in the variant without agricultural activities, the accumulation of cadmium in the root is 0.04 mg/kg, in the stem - 0.031 mg/kg, in the leaf - 0.037 mg/kg, and in the variant with agricultural activities in the root - 0.074 mg/kg, in the stem - 0.067 mg/kg, in the ear - about 0.068 mg/kg, which is 3.4 times more than the MAC. In various parts of vegetable and melon crops directly consumed by humans, the accumulation of cadmium is 2-2.8 times higher than the MAC. The established MAC for cadmium for vegetable and melon crops is 0.03 mg/kg (Table 2 and Figure 4).

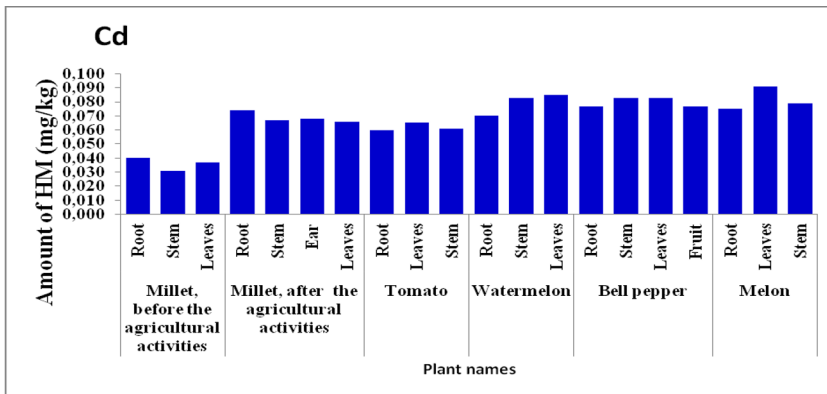


Fig. 4. Accumulation of the Cd element in agricultural crops.

A high accumulation of the lead element in all parts of the millet plant was revealed, 1.2-2.4 times more than the established MAC (0.2 mg/kg), especially the largest accumulation in the ear of millet. It has been established that in vegetable and melon crops the accumulation is at the MAC level of 0.5 mg/kg (Table 2 and Figure 5).

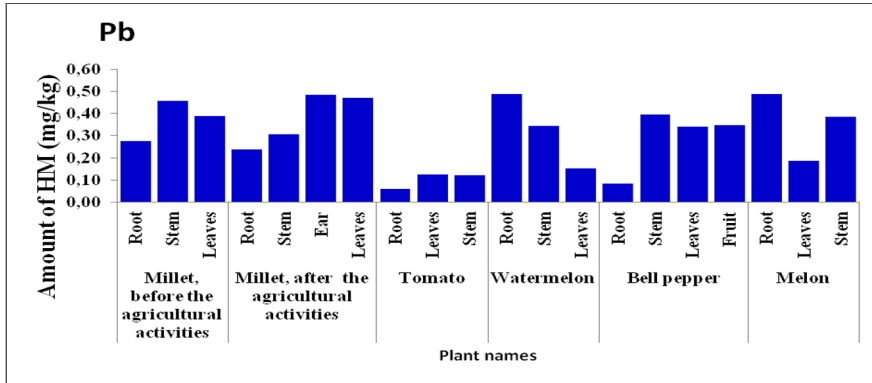


Fig. 5. Accumulation of the Pb element in agricultural crops.

The established MAC for the chromium element in grain and vegetable and melon crops is 0.2 mg/kg. High accumulation was observed in all analyzed parts of plants, with the highest accumulation in plant parts of millet and tomato, from 5.5 to 11.8 times higher than the MAC (Table 2 and Figure 6).

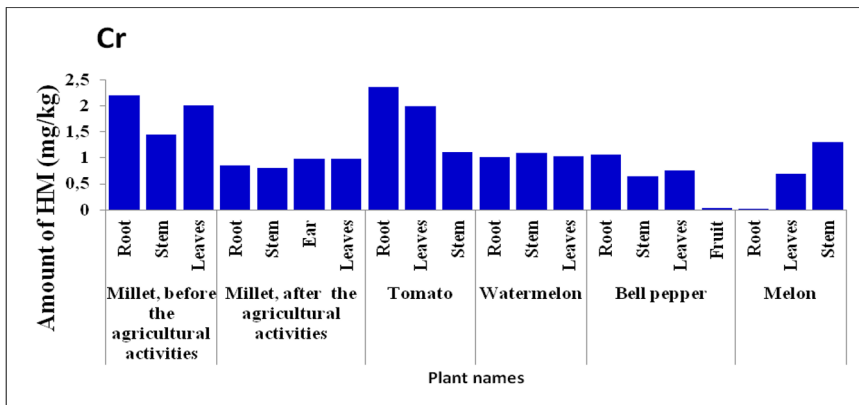


Fig. 6. Accumulation of the Cr element in agricultural crops.

For grain and vegetable-melon crops, the established MAC of the nickel element is 0.5 mg/kg, revealed high accumulation in all parts of the crops from 0.61 mg to 3.85 mg, which is 1.22-7.7 times more than the MAC (Table 2 and Figure 7).

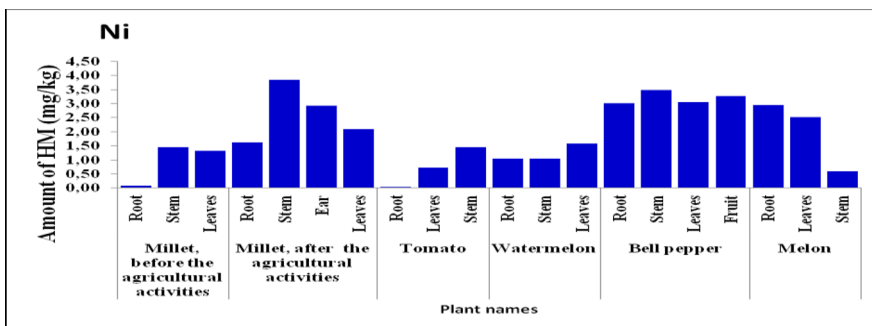


Fig. 7. Accumulation of the Ni element in agricultural crops.

The established MAC of arsenic (As) element in grain and vegetable-melon crops is 0.2 mg/kg. High accumulation is observed in all organs of plants, from 2.85 times to 43.2 times the MAC, in the fruit of bell pepper it was 5.33 mg/kg, accumulated more than 26.65 times the MAC (Table 2 and Figure 8).

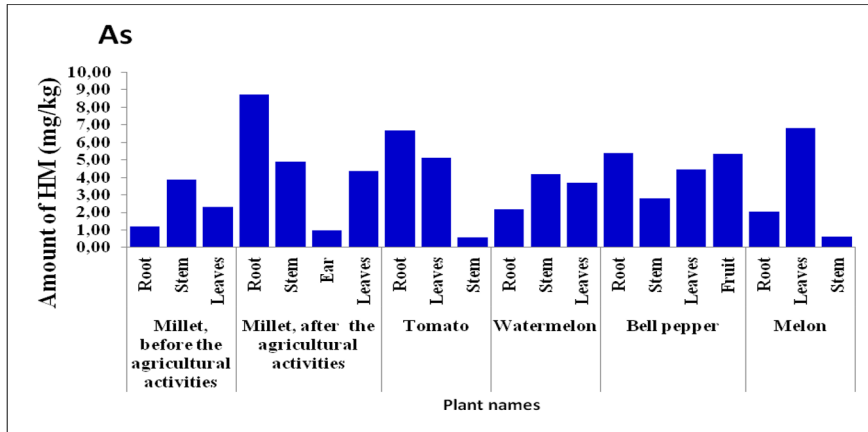


Fig. 8. Accumulation of the As element in agricultural crops.

The study also found that maize leaves had mean concentration of Zn 0.115, Cd 0.04, Cu 0.117, Co. 0.041 and Pb 0.323 mg/kg. The results were below WHO standards except Co and Pb which had slightly higher levels than the recommended WHO standards. The analytical results from this study provided important baseline statistics on the concentration of selected heavy metals in maize grains and leaves besides being an important assessment of environmental pollution in rural areas where maize farming is predominant. Lead accumulation induced both physiological and biochemical changes in *A. auriculiformis* with Pb tolerance proportional to the increased of Pb concentrations and significantly increased level of antioxidative enzymes (catalase). The results demonstrated that *A. auriculiformis* can tolerate Pb toxicity up to 2 g/kg Pb of soil, and hyper-accumulate a significant amount of Pb content in roots and shoots through phyto stabilisation and phyto-extraction. Metal levels in soil samples were within the permissible limits of Indian and EU standards even though, the Pollution Load Index (PLI) revealed significant metal loading. PLI values were 26.35, 4.81, 54.18, 2.01 and 1.55 for Cd, Ni, Pb, Zn and Cu, respectively. Metals in food crops were higher than in soils, with ranges of 19.63-53.93, 19.45-142.39, 99.42-357.15, 27.01-76.21, and 1.42-5.84mg/kg for Ni, Cu, Zn, Pb and Cd, respectively. Pb, Cd, Zn and Cu in plantain exceeded FAO/WHO recommended values while in cassava, Pb, Cd and Zn exceeded recommended levels (Zango et al., 2021). The results from the study show that Cr concentrations accumulated in the following order; Stem > Root > Leaves at the impacted areas. The average mean of Cr at the impacted site for cocoyam (0.11 mg/kg) and plantain (0.02 mg/kg) were less than the control value of 0.15 mg/kg and 0.48 mg/kg respectively. Metals in the soil samples were in the ranges of 25.71-41.45, 17.69-23.59, 0.79-2.56, and 26.04-47.29 for Cr, Co, and Cd, and Pb, respectively. Concentrations of all metals in the vegetables, except Co, were found to be above the safe limits set by different international organizations for consumption, posing a serious health hazard to humans. Therefore, regular monitoring of effluents, soils, and vegetables are essential to prevent excessive build-up of the toxic heavy metals in food. AS, Pb, Cd, Cr and Hg levels exceeded the recommended values in vegetable samples with concentrations ranging from 1.93-5.73, 3.63-7.56, 0.56-1.56, 1.49-4.63 and 3.43-4.23 mg/kg, respectively. It was observed that leafy vegetable (cabbage) has accumulated heavy metals to greater

extent compared with tomato. Rapid development and industrialization has brought in hazardous heavy metals through air, soil, water and eventually, through plants. Agrochemicals such as fertilizers, pesticides and herbicides, which are sources of heavy metals, are most often inappropriately used especially in our developing countries. In some instances, water of doubtful quality is used for irrigation, exposing these crops to heavy metal contamination. The concentrations of As (0.51 mg/kg and 0.38 mg/kg), Co (1.41 mg/kg and 1.39 mg/kg) and Pb (1.36 mg/kg and 1.31 mg/kg) in the cabbage and carrot, respectively, were above the WHO/FAO, permissible limits for human consumption.

In the studied soils, the highest value for the lead element was found to fluctuate from 15.2 milligrams to 7.7 milligrams, and we can say that this situation is the beginning of lead pollution. During the study, it was noted that as a result of the movement of chromium and nickel elements, towards the lower layers of the soil they accumulate in quantities greater than the MAC. When calculating the amount of all chemical elements, it was found that among agricultural crops they accumulate in large quantities in melon and bell pepper plants. As noted in the analysis, the element arsenic (As) alone accumulates in tomato roots at about 6.67 mg/kg. The accumulation of the nickel element in the amount of 3.26 mg/kg, arsenic - 5.33 mg/kg, copper - 5.22 mg/kg and lead - about 0.35 mg/kg in bell pepper fruits was considered.

4 Conclusion

Since in all products grown on soils contaminated with heavy metals, the elements Ni, Cr, Cd and As accumulate in quantities exceeding the MAC, it is not recommended to grow vegetables and melons crops in such fields. Perhaps these fields should be used for growing technical crops. A large amount of toxic elements accumulating in agricultural plants, together with food products, has a direct negative impact on human health along the trophic chain. To prevent this, it is recommended to clean up soil contaminated with heavy metals by repeatedly selecting and planting plants using existing remediation methods. According to the results of our research, the millet plant can be used for this purpose.

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