Heavy Metal Content in Plants of Georgia

David Kuparadze; Dimitri Pataridze; Violeta Kirakosyan

Department of the Geoecology and Applied Geochemistry
Tbilisi State University, A.Tvalchrelidze Caucasian
Institute of Mineral Resources, Georgia
CorrespondingAuthor—David Kuparadze

Publication Date: 2025/01/29

Abstract: The article presents the results of studies conducted in recent years. These studies aimed to determine the concentrations of heavy metals in biological samples (mainly corn) growing in Georgia. This plant species was chosen because both domestic animals and humans consume it. Samples were collected from corn fields near roads and highways to determine the maximum concentrations of heavy metals in biological samples. For ease of comparison, the results are presented in graphical form separately for Western and Eastern Georgia. High concentrations of heavy metals and toxic elements are observed in corn fields in different regions.

Keywords: *Pollution; Heavy Metals; Toxic Elements, Corn.*

How to Cite: David Kuparadze; Dimitri Pataridze; Violeta Kirakosyan (2025). Heavy Metal Content in Plants of Georgia. *International Journal of Innovative Science and Research Technology*, 10(1), 1142-1149. https://doi.org/10.5281/zenodo.14759702

I. INTRODUCTION

Soil pollution with heavy metals has historically been one of the most serious environmental problems, especially because their persistent toxicity causes serious damage to ecosystems, leads to economic losses and negatively affects the human food chain and health. These are abiotic environmental factors, defined as metals with a density greater than 5 g/cm3, such as cadmium (Cd), chromium (Cr), copper (Cu), lead (Pb), nickel (Ni), cobalt (Co), arsenic (As), silver (Ag), and so on. These heavy metals vary in physical and chemical properties and are considered significant environmental pollutants due to their toxic interactions[1].

In recent years, environmental pollution, in particular heavy metals (HM), has increased sharply, which particularly exacerbates the need to solve many environmental problems. The release of heavy metals into the environment has a negative impact not only on soils, but also on plants, and, due to bioaccumulation in food chains, poses a threat to human health (Golovko T. et. Al, 2008). This phenomenon is most succinctly reflected in the concept of "ecological boomerang". TM are potentially dangerous metals (toxic) for organisms; They can accumulate in the environment, causing its pollution. At the same time, it should be noted that in small doses, some of them are bioelements, i.e. vital for the body (zinc, manganese, copper, etc.) [2].

Various agricultural practices, such as the use of industrial and sewage wastewater for irrigation of crops, continuously introduce heavy metals into the agricultural soil system. Irrigation of vegetables and forage crops often uses this type of wastewater, which is discharged into freshwater bodies, especially as a result of industrial mining. Among the many approaches used for the remediation of contaminated lands, phytoremediation is currently considered a promising and cost-effective alternative. Under this strategy, plants are sometimes used to improve soil and/or water quality by removing or transporting pollutants from various areas of the soil. This does not affect the biological activity, structure or fertility of the soil, but in this case the heavy metals will harm the plants that carry out the cleaning [3].

Large amounts of these metals can be found in corn, sunflower, rice, wheat, and other plants. The type of metal contamination, the plant species, and additional chemical and climatic factors determine how much metal accumulates in plants. Corn (Zea mays L.), grown in many different agro ecological situations around the world, is a versatile grain crop. There are about fifty species with different varieties,

ISSN No:-2456-2165 https://doi.org/10.5281/zenodo.14759702

textures, sizes and shapes of kernels. Red, yellow and white are the most common shades [4].

When investigating the toxicity of heavy metals to plants, it is important to consider the nature of the contamination. The stress caused by soil contamination is long-term, which requires considering long-term molecular reactions rather than short-term ones [5]. The toxicity level of a heavy metal also depends on its oxidation state. For plant roots, the retention of heavy metals in the soil in a bioavailable state depends on their adsorption, desorption, and formation of complexes with other soil molecules. These processes are greatly influenced by soil pH, content and structure. Heavy metals exhibit increased mobility in acidic soils and their toxicity varies depending on the species. Metal-tolerant plants have defense mechanisms that protect them from damage caused by heavy metal stress. Sensitivity to heavy metals is influenced by factors such as duration and intensity of exposure, as well as other environmental conditions [7].

Among the heavy metals, the priority pollutants are Cd, Pb, As, Zn, since their accumulation in the environment occurs at a particularly rapid rate. Many of them have a high affinity for physiologically important organic compounds (for example, enzymes) and are capable of inactivating them. Excessive intake of TM in living organisms disrupts metabolic processes, slows down their growth and development. In agriculture, this affects the quality of products and reduces their output. In vegetable and forage crops, the accumulation of these substances often reaches levels dangerous to humans and animals without noticeable external manifestations. Heavy metals that enter the human body are excreted very slowly, and even a small amount of them in food can cause a cumulative effect.

Soil plays an important barrier role in the penetration of heavy metals into the organisms of plants, animals and humans. However, they accumulate in the soil, making it difficult to obtain environmentally safe products. The role of plants is important both in the geochemical cycle of elements and in the entry of pollutants into food chains. There is evidence that the accumulation of HM in the human body occurs mainly due to food, and to a lesser extent – due to water and air.

Some scientists of recent years [8] have voiced some basic conclusions in the study of cereal seeds, namely: 1. Low concentrations of HM cause a significant lag in the development of corn in almost all morphometric parameters. 2. Corn accumulates lead in its tissues better, and wheat - cadmium and copper. Therefore, their use should depend on the type of soil pollution.

We humans are exposed to heavy metals every hour. And this applies not only to those who live in a smoky industrial city, but also to those who live in green villages. Heavy metals constantly circulate with water and air, and the ecological cleanliness of the regions is very relative. Heavy metals enter the human body through polluted air, water, soil, consumer products and plants. Metals can accumulate in foods due to their presence in the environment, as a result of human activities such as agriculture, industry, or vehicle emissions.
In connection with the study and recording of pollution in the territory of Georgia with heavy metals, we have conducted specialized geochemical studies along highways and roads in recent years. The purpose of the study was to establish and identify pollution halos of soils and plants along highways and roads from the western regions of Georgia (Black Sea) to the eastern regions of the country. For this purpose, samples were taken at a distance from the roads no longer than 50-70 meters.

The studies we studied aimed to determine the sources of their entry into agrocenoses, as well as the features of accumulation in soil and plants. The content of heavy metals in the soil is usually determined by their amount in the parent rock and varies depending on the granulometric composition and provision of the soil with organic matter. Lead, cadmium, and mercury distributed along the soil profile, accumulate mainly in the humus horizon, which is associated with their biophilic accumulation. The content of arsenic, on the contrary, increases with depth. Plants, absorbing heavy metals from the soil, accumulate them in their tissues, mainly in the roots, stems and leaves. The purpose of this study is to determine the content of heavy metals of the 1st and 2nd hazard classes, such as lead, cadmium, zinc, copper and nickel, etc. mainly in the composition of food plant raw materials in the territory of Western and Eastern Georgia and we tried to compare these regions to determine the scale of their pollution with heavy metals. The objects of the study were plants used as food by livestock and humans. These plants were selected from natural zones.

The accumulation of Heavy Metals above the Maximum Allowable Concentrations (MAC) in the soil disrupts the physicochemical balance. It contributes to the destruction of the soil absorption complex, changes in soil structure, humus degradation and loss of fertility. To determine heavy metals in food products, we took samples of corn from arable soil layers.

Table 1 shows two main groups of chemical elements. Some are essential for the body, while others are less recommended or dangerous for biological processes.

ISSN No:-2456-2165 https://doi.org/10.5281/zenodo.14759702

Table 1. Contents of chemical elements in plant cover

Elements that are needed for body growth		**Toxic elements**		
Macronutrients	**Micronutrients**	**Highlytoxic**	**Moderately toxic**	**Slightly toxic**
H, O, N, P, S, Cl,C, K, Ca, Mn	Fe, Cu, Mn, Zn, B, Mo, etc.	Ag, Be, Cd, Cu, Hg, Sn, Co, Ni, Pb, etc.	F, S, As, B, Br, Cl, Mn, Sb, Se, Te, V, W, Mo, etc.	Br, Cl, I, Ge, N, P, S, Si, Ti, Ca, Cs, K, Li, Mg. Rb, Sr

II. RESEARCH OBJECTIVES AND METHODS

Within the framework of the existing studies, one of the differences in ecological study methods was used, which determines the quantitative determination of chemical elements, in this case heavy elements, in edible plants. We tested mainly those types of plants that are used for both human (mainly corn) and animal (corn cob, stalk, etc.) food.
The selected samples, according to the accepted methodology, were classified by species (meaning that the same sample was processed separately for its different species, for example: stem, fruit, corn cob, etc.). All samples, dried in natural conditions, were sent to the analytical center of the Caucasian Institute of Mineral Resources at Tbilisi State University for analysis. The content of heavy metals in bio-samples is selective and is mainly determined by the geochemistry of the soils.

For our study, we selected a large part of the regions of Western Georgia, which included the entire Black Sea coast, as well as the valleys of the main rivers: Rioni, Tskhenistskali, Kvirila, Adjaristskali, Chorokhi, Natanebi, Gubazeuli and others.

For Eastern Georgia, samples (food plants) were obtained from the area from Akhaltsikhe-Borjomi to Gardabani, where the Mtkvari (Kura) River crosses the Georgia-Azerbaijan border. Researches were also conducted in the northern part of Eastern Georgia: from Natakhtari to Fasanauri and in the southern part of Marneuli region.

According to our estimates, biological pollution is often related to the rivers on which cities and other settlements are located. Therefore, sea water pollution is caused by the absence of treatment facilities on these rivers or their poor operation. It should also be noted that because samples were taken along roads and highways, the pollution was most likely related to exhaust emissions from cars and trucks.

III. RESULTS OBTAINED AND THEIR DISCUSSION

The results for ease of comparison are presented in the graphic materials below (Fig. 1, Fig. 2), separately for Western and Eastern Georgia. These graphs are presented in such a way that it is easier to compare the eastern and western regions with each other.

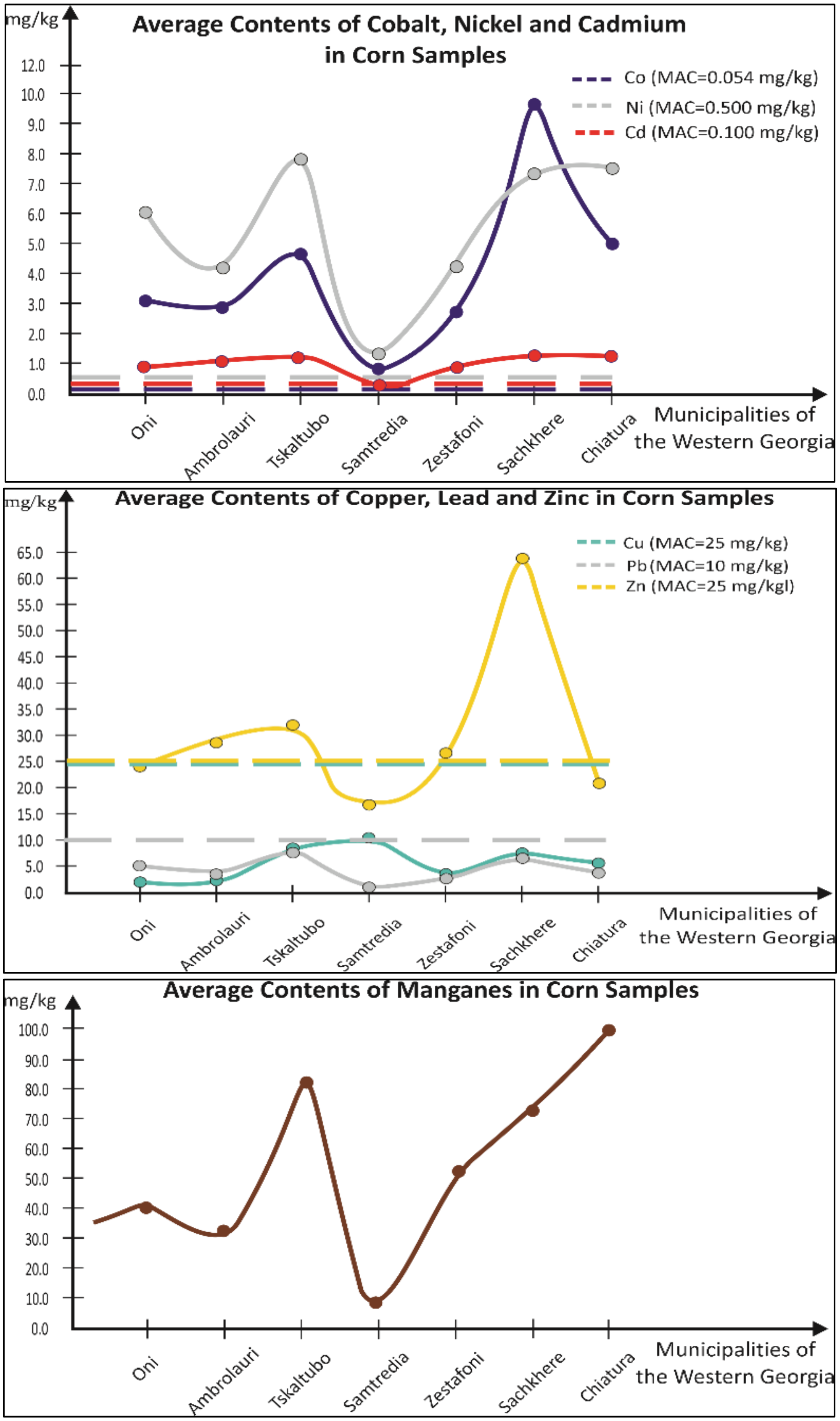

Fig. 1 Distribution of Heavy Metals and Toxic Elements (Western Georgia)

ISSN No:-2456-2165 https://doi.org/10.5281/zenodo.14759702

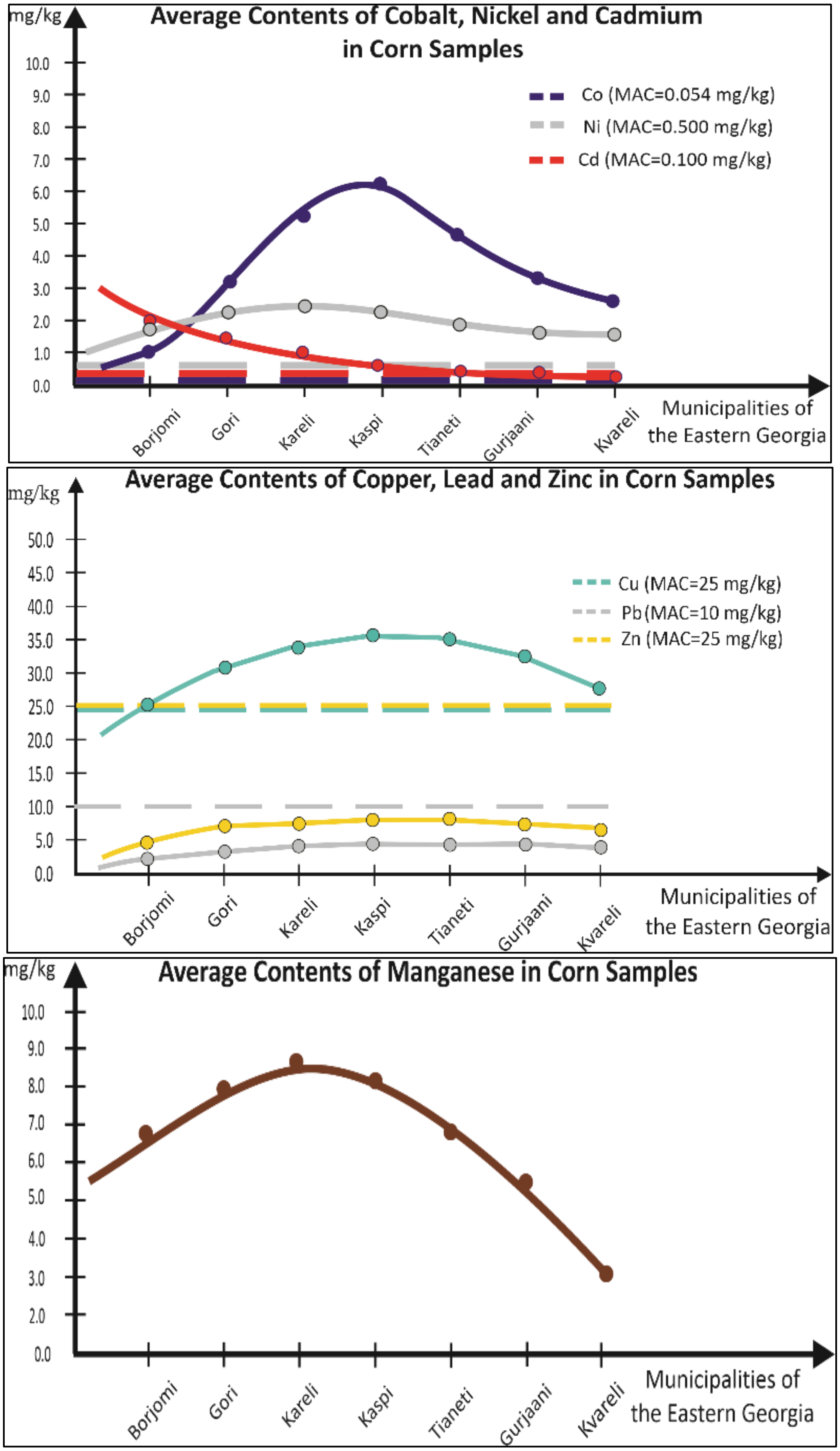

Fig. 2 Distribution of Heavy Metals and Toxic Elements (Eastern Georgia)

ISSN No:-2456-2165 https://doi.org/10.5281/zenodo.14759702

By analyzing these graphs, we will try to discuss individual elements for both regions.

- *Copper.*

Stimulates photosynthesis and the formation of iron-based enzymes, including peroxides. Excess copper leads to disproportionate development, suppression of shoot growth, and rapid wilting of plants. With an excess of copper, iron deficiency is usually observed, since these elements are antagonist. An excess of the element inhibits the absorption of phosphorus by plants and the biosynthesis of its organic compounds. Copper enters the human body with food (including corn) and is an important component of metabolism. It is involved in the synthesis of hemoglobin. Excess copper, not bound into protein compounds, becomes toxic and can settle in various organs of the human body. In particular, copper can gradually accumulate in the brain and become a catalyst for several pathologies. Typically, in unpolluted areas, copper content in plants ranges from 1 to 30 mg/kg dry weight. Concentrations exceeding 20 mg/kg dry weight are conventionally considered threshold, defining areas of normal and excessive content.

According to our analysis, copper in plants (corn) is at a completely acceptable level for both regions of Georgia [9]. It maintains stable, acceptable MAC values, although samples taken in some regions of eastern Georgia (Khashuri, Gori, Kaspi and Tianeti) show an increase in the concentration of this element.

- *Lead.*

Lead (Pb) is one of the most common metals in the surface soil layer. Pb has a clear tendency to accumulate in the soil. In small quantities, it promotes faster plant growth and increases starch content. Pollution of soil and water with lead inhibits photosynthetic processes, which ultimately hurts crop yields. An interesting feature of plants has been noted: different parts of them accumulate different amounts of lead. Along with car exhaust gases, a huge number of heavy metals enters the environment. Among them, one of the first places is occupied by lead (Pb^{2+}). Dust containing lead settles on plants and other objects and then is washed away by precipitation into the soil. The amount of lead in roadside plants is usually quite high. For humans, Lead can have a toxic effect on many body systems and is especially dangerous for small children and women of reproductive age. It can penetrate the brain, liver, kidneys and musculoskeletal system. It can be deposited and accumulate over time in teeth and bone tissue.

Fortunately, based on our research in roadside plants in both regions of Georgia, lead appears in acceptable quantities (below MAC = 10Mg/Kg) and does not pose a danger to either plants or humans.

- *Zinc.*

The presence of the microelement in the soil is necessary for the healthy development of the plant: with a lack of zinc, the production of the growth hormone auxin is suspended, and vitality is reduced. An excess of the metal, on the contrary, leads to a slowdown in growth and the death of new shoots. Crops such as corn are particularly sensitive to zinc deficiency. Excess zinc in plant nutrition often occurs. Plant growth is weakened, young shoots die off, and leaves become covered with rusty-brown spots. The clinical picture of excess zinc in the human body is expressed in pain behind the breastbone or in the abdomen, dizziness, nausea or vomiting, weakness, fever, muscle pain, cough.

Zinc contents in corn samples indicate clearly increased values in both East and West Georgia[10] Moreover, for western Georgia, increased values of this element were recorded both for corn cob and for the stem. It should be noted that in the ears of corn from Western Georgia, zinc exceeds the MAC by three times. For plants from Eastern Georgia, zinc content sometimes exceeds MAC by two times. Especially the samples taken in the Sachkhere region showan increase in the concentration of this element.

- *Cobalt.*

The cobalt content in the soil determines the amount of this element in plants and the levels of its intake by animals. With a lack of cobalt in feed (corn), animals develop anemia, growth retardation, and exhaustion. Typically, the average cobalt content in plants ranges from 0.01 to 0.6 mg/kg. It should be noted that cobalt in high concentrations is a naturally toxic metal. Its widespread use in various industries has led to large-scale pollution of the environment, including plants. The negative impact of cobalt in high concentrations is mainly associated with the fact that its excessive intake into the human body can be accompanied by a state of hypoxia or a feeling of lack of oxygen.

High concentrations of cobalt have been shown in cornfields in both western and eastern Georgia. Moreover, for the plants of Western Georgia, the cobalt content in corn cobs exceeds the Permissible Values about 30 times and reaches 14 mg/kg, and in Eastern Georgia this amount is equal to 8 mg/kg, which are also very large values. We should especially mention such regions as: Kareli, Kaspi, Gori, Tianeti, Tskaltubo and Sachkhere, where a significant increase in the importance of cobalt is observed.

- *Nickel.*

Nickel is classified as a heavy metal that is unevenly distributed in different regions. This may be due, for example, to the presence of “mother” rocks. As a result, in these areas not only increased levels of heavy metals may be observed in plant and animal tissues, but also possibly in humans. Nickel is similar in its biochemical properties to iron and cobalt. In soils, nickel stimulates microbiological processes of

ISSN No:-2456-2165 https://doi.org/10.5281/zenodo.14759702

nitrification and mineralization of nitrogen compounds and helps increase the productivity of agricultural crops. Nickel is one of the priority pollutants of the natural environment. In addition to the geographical location of the "mother" rocks, the pollution of agrocenoses with nickel can occur as a result of emissions from metallurgy, instrument-making and mechanical engineering enterprises, unregulated use in agriculture as a fertilizer and sewage sludge. This element, when used in food, accumulates in the brain, stomach, liver, kidneys, lungs and heart. It is carried around the body by blood, mainly in a bound form with albumin, and almost does not accumulate in organs, tissues. Most of the component is found in the adrenal glands and thyroid gland.

For last years, we also found fairly high concentrations of nickel in corn fields in both West and East Georgia. Only in isolated samples taken from corn cobs did nickel concentrations reach acceptable levels. These values, according to the analytical material we have, are 3-4 times higher than the permissible concentrations for both Eastern and Western Georgia.

➢ *Manganese.*

When there is a lack of manganese in the soil, plants become infected with grey spot, which can cause plant death, and when the deficiency is less severe, crop yields decrease. Excess manganese is a dangerous phenomenon that can have a negative impact not only on the harvest, but also on the health of the plant itself, and subsequently on animals and humans. Excess manganese delays the flow of iron into plants, which also results in chlorosis. The accumulation of manganese in concentrations toxic to plants is usually observed on acidic sod- soils. Usually, the maximum amount of manganese accumulates in the vegetative parts of the plant, and the most demanding crops for manganese are: beets; corn; tomatoes; legumes and fruits. The negative impact of manganese on humans primarily affects the functioning of the central nervous system. Its excessive accumulation manifests itself in the form of constant drowsiness, memory impairment, and increased fatigue. Manganese is a polytropic poison that has a harmful effect on the functioning of the lungs, cardiovascular system, and can cause an allergic or mutagenic effect.

The manganese content in our biosamples is selective and mainly determined by the geochemistry of the soils. High levels of manganese (Mn) are characteristic of both soils and vegetation. This fact is especially noticeable in those areas of Western Georgia that are located near manganese deposits. And also, along the rivers that flow from Georgia's manganese deposits and reach the Black Sea. This also applies to areas of central and Eastern Georgia. These regions include the Rioni Valley, including Poti and the Upper Imereti-Zestafoni region.

➢ *Cadmium.*

Cadmium is a toxic element that poses a serious danger to humans and animals. Cadmium is very similar in its properties to zinc and is its constant companion in natural compounds. Potential anthropogenic sources of cadmium entering the elements of the natural environment, including plants, are usually cement, metallurgy, galvanic, glass production, and cadmium is also released into the atmosphere during the combustion of coal and, to a lesser extent, oil. Cadmium is contained in fuel oil and diesel fuel, in solid household waste, mineral and organic fertilizers. One of the main sources of cadmium pollution of soils is the application of fertilizers, especially superphosphate, where cadmium is included as an impurity. For humans, with excessive intake of cadmium into the gastrointestinal tract, intoxication occurs as severe gastroenteritis, nausea, vomiting, salivation, spastic abdominal pain and diarrhea develop. Chronic intoxication leads to renal dysfunction, anemia, respiratory failure, osteomalacia, hypertension, chronic rhinitis, pharyngitis, loss of smell, etc. Based on the above, the amount of cadmium found in the plants largely affects human health.

Cadmium content in corn kernels located in Georgian fields also indicates a sharp increase in their values in corn. Particularly significant Cd values are reached both in Western (Tskaltubo, Sachkhere, Chiatura) and Eastern Georgia (Borjomi, Kareli, Gori) (see the diagram provided). These data obtained by us deserve additional attention and study.

➢ *Arsenic.*

Arsenic is one of the World Health Organization's 10 major chemicals that pose a threat to public health. Arsenic is a natural component of the Earth's crust and is widely distributed in all environments, in air, water, soil and plants. Humans are exposed to high levels of inorganic arsenic during irrigation of crops. Cereal crops can be a source of arsenic, although exposure from these foods is much lower than from contaminated groundwater.

In our studies, arsenic is mainly observed in the regions of Western Georgia. It is mainly observed in increased levels in the regions of Racha, Svaneti and Upper Imereti, which are associated with arsenic deposits.

In conclusion, all of the above data and our considerations are only initial data for subsequent discussions and require further research and monitoring in order not only to more accurately determine the presence of these heavy metals in plants and soils, but also to determine the areas of their distribution

ISSN No:-2456-2165 https://doi.org/10.5281/zenodo.14759702

REFERENCES

[1]. Haider F.U. et al., Cadmium toxicity in plants: Impacts and remediation strategies. Ecotoxicology and Environmental Safety. Elsevier Inc., Vol. 211, 15 March2021, 22 p.
[2]. Ilyin V.B. Heavy metals in the soil-plant system, Novosibirsk, Nauka, 1991, 150 p.
[3]. Shafique F. et al. Heavy metal toxicity and it's physio-biochemical effects on maize (Zea mays L.). Plant Cell Biotechnology and Molecular Biology.Vol. 21, № 45–46. 2020, p.p. 94–102.
[4]. Kidane T.M., Sukhenko L. Study of the degree of metal accumulation and toxicity of corn plants grown on heavy metals contaminated (artificially) soil. II International Conference on Agriculture, Earth Remote Sensing and Environment (RSE-II-2023). Vol. 392, 2023.
[5]. Atta M.I. et al. Assessing the effect of heavy metals on maize (Zea mays L.) growth and soil characteristics: plants-implications for phytoremediation // PeerJ. 2023. Vol. 11. P. 1–25.
[6]. Fasani E. et al. The potential of genetic engineering of plants for the remediation of soils contaminated with heavy metals // Plant Cell Environ. 2018. Vol. 41, № 5, p.p. 1201–1232.
[7]. Protasova N.A. Microelements: biological role, distribution in soils, influence on the spread of human and animal diseasesSoros, educational journal. - 1998. - No. 12, p.p. 32 - 37.
[8]. Korzh A.P., Gura N.O., Savchenko I.G., Koba S.V., Karin A.M. Possibility of Using Cereals To Clean Soils From Heavy Metals. Bulletin of Zaporizhzhya National University, No. 2, 2012,p.p.116-123.
[9]. Kuparadze D., Pataridze D. –Ecological Problems of West Georgia. Monograph. "TSU Science". 2024. 150 pg.
[10]. Kvinikadze M., Kuparadze D., Kirakosyan V., Pataridze D., Khundadze N. Geo-Ecological Features of Georgia. Publisher –Tbilisi State University "TSU Science". #3. December, 2012. p.p. 30-35.