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## Water and Soil Pollution by Heavy Metals in the Inner and Outer Kakheti Pastures

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## Abstract

Pasture, with its purpose and area of use, is an important and irreplaceable resource for the country; therefore, it is necessary to maintain and protect its sustainable state. This article presents the content of soil cover, the determination of heavy metals in it, and the assessment of the quality of drinking water intended for livestock in the pasture area. Water and soil samples were taken with the aim of determining the participation of water in the pollution chain, as well as determining the level of pollution in it. The article presents a study that was conducted in the pasture area of Inner Kakheti. 14 soil samples were taken from 7 study sites (Akhmeta, Village Shakhvetila, Koghoto, Sagarejo-village Patardzeuli, Gurjaani-village Pkhoveli and village Arashenda), the content of heavy metals Cd-cadmium, Cu-copper, Pb-lead and Zn - zinc in these samples were determined by laboratory analysis. The studied soils are not contaminated with heavy metals, their content in the samples does not exceed the so-called maximum permissible concentration (MPC), only in the village of Pkhoveli (Gurjaani) in the upper (0-20) cm layer of soil, a "Disturbing" 155.2 mg/kg of copper (Cu) was found. The difference compared to the (MPC) (>140) is 15.2. Also, within the framework of the study, laboratory analysis of seven water samples taken

from water reservoirs in the above-mentioned study regions was carried out in order to determine the level of their contamination. Research water samples are not contaminated with heavy metals (Cd, Cu, Pb, Zn), and their content in the water samples does not exceed to the (MPC).

## Keywords

Pasture, soil, heavy metals, water, management.

## Introduction

In Georgia, natural grasslands occupy approximately 25% of the country's territory, and their wise management is important for the development of agriculture (Georgian Rural Development Strategy, 2018).

According to the latest agricultural description (2014), pastures in Georgia cover an area of approximately 1.7 million hectares, which is more than 50% of the total area of agricultural land. Pasture, as an irreplaceable source for livestock and has a great importance for the Kakheti region and its population.

Approximately 38% of Georgia's agricultural land is located in the Kakheti region. The number of hayfields and arable lands are

particularly large; Kakheti is on the first place among the regions of Georgia in terms of this category of lands, which is why it is considered a leading region in livestock and grain production.

Therefore, it is necessary to protect and properly use pasture resources through targeted management.

The unsystematic use of pastures and the disruption of the rotational grazing system have started the degradation process, as a result of which the productivity of pastures has decreased almost by half and restoration and improvement measures are required.

Rangeland degradation is accelerating under ongoing climate change; rising temperatures and more frequent droughts are having a major impact on the species composition of vegetation and the early cessation of their vegetation (GEF, FAO, 2019).

Special attention should be paid to equipping pastures with waterers for animals, arranging walking tracks, and using electric fences during grazing. etc.

In the current pasture management system, mowing of non-food, ungrazed plants, application of fertilizers, sowing of grasses and milling are of great importance (Korakhashvili, 2009).

In order to stop the degradation of rangelands and other natural ecosystems and promote their restoration and improvement worldwide, on March 1, 2019, the United Nations (UN) General Assembly, based on resolution 73/284, declared the years 2021–2030 as the Decade of Ecosystem Restoration (Government Resolution, 2019). The document aims to prevent the degradation of ecosystems, stop the ongoing negative processes and restore damaged ecosystems.

In accordance with the five voluntary Land Degradation Neutrality (LDN) targets, Georgia, taking into account the national sustainable development goals, has set the goal of maintaining healthy and productive land

resources and increasing their area (GEF, FAO, 2019).

Sustainable pasture management is an important prerequisite for the health of pastures, on which important ecosystem services depend, as follows: regulation of water and climate, reduction of soil erosion, biodiversity maintenance, plant biomass, meat, and dairy production (Bengtsson, Bullock et al., 2019).

Unsystematic grazing leads to ecosystem degradation, loss, and fragmentation of habitat for living organisms (Cravino, Perelló, 2024).

Livestock grazing affects the chemical composition and fertility of the soil. A large number of livestock, especially dairy cows, produce a significant amount of organic waste (in the form of solid and liquid excretions), which also leads to water pollution.

Each adult cow produces an average of 20 tons of manure (including both solid and liquid) per year, of which approximately 50% remains on the pasture (Bilotta, Brazier, 2007).

Pastures are natural ecosystems and sustain to the effects of variable environmental factors, including grazing.

Unsystematic grazing leads to the degradation of the ecosystem and the loss and fragmentation of living organisms' habitat (Cravino, Perelló, 2024).

Currently, soil pollution is one of the major ecological problems (Mikanova, 2006). One of the components of degradation is soil and water contamination by heavy metals; therefore, this issue is also very important for the health of grazing areas.

In the environment, heavy metals come from various natural and anthropogenic sources (Gambashidze, 2006; Bradl, 2005).

The study of heavy metals is one of the most active, current environmental issues; therefore, many scientists have worked in this field. (Merabishvili, 2019; Bilotta et al., 2007; Kurz et al., 2007; Cravino et al., 2024; Puschenreiter et al., 2005; Etzold, Neudert, 2013; Didebulidze,

2001; Bradl, 2005; Vodyanitskii, 2017; Alexanyan, 2014; Galstyan et al., 2015; Chelidze et al., 2013; Ilyin, 2000; Bakradze et al., 2018; Urushadze et al., 2007; Ghambashidze, 2012).

To determine heavy metals in the soil, it is necessary to know the so-called (MPC) to enable comparison of the data with permissible concentration limits and to assess the level of contamination.

For this purpose, there is an act called „Assessment of Soil Chemical Pollution Quality“, which states in Article No. 6 that anthropogenic emissions of heavy metal ions in the environment contribute to the accumulation of metallic ions in natural waters and soils, both in urban and rural areas and in their nearby grazing lands.

Due to the limited resilience of soil against contamination, these substances can accumulate, move through the soil, and easily enter plants, animals, and humans (Adriano, 2001).

The contamination of grazing lands with heavy metals is a complex problem related to the toxic effects of these elements on soil, plants, and animals.

The main sources of pollution are anthropogenic (industry, agriculture, transportation) and, to a lesser extent, natural (volcanic activity).

Heavy metals such as lead, mercury, cadmium, tin, copper, and arsenic enter the soil in various ways, including industrial emissions, the use of fertilizers and pesticides, and sewage sludge.

Animals grazing on pastures can have both positive and negative effects on the quality of water.

Water pollution is one of the biggest problems in the world. As a result of water pollution, the soil becomes contaminated, plants are harmed, animals are threatened, and the risk of various diseases that are dangerous to human health increases (Besser et al., 1993; Isaacson et al., 1993; Millard et al., 1994; Guan and Holley, 2003).

In uncontrolled conditions, natural water sources are almost never tested. The elevated levels of dispersed elements or nitrates in the water can lead to poisoning of animals or negatively affect fertility.

In addition, bacteriological contamination frequently occurs in drinking water reservoirs (USAID, Caucasus Swiss Agricultural School, 2020). To conclude, water contamination is one of the biggest challenges in the world.

## Materials and Methods

The research was conducted in the following municipalities and villages of Inner and Outer Kakheti:

- Akhmeta Municipality – the villages of Shakhvetila and Kogotho (Mlasheebi);
- Sagaredjo Municipality – the village Patardzleuli;
- Gurjaani Municipality – the villages Pkhoveli and Arashenda and Gombori – the village Paldo.

In the Kakheti region, the study sites are mainly demonstrated by Cinnamonic carbonate soils and Raw carbonate soils.

Raw carbonate soil types are widely distributed in the Eastern part of the Kakheti region.

This type of zonal distribution covers a fairly large area and occupies 4.8% of the territory of Georgia, which is 331,600 ha (Urushadze, 1997). The largest part of this area is currently cultivated, while a relatively small part is covered with shrubs and forests. The area of Cinnamonic carbonate soils are under the sea level in between 500-1200 mm.

The total area of Raw carbonate soils is 4,5% (317 200 ha). These types of soils are mainly distributed in Kakheti and Kartli regions.

By the selected methodology (Soil Science, 2016) Soil samples were taken from depths of (0-20) and (20-40) cm layers, considering the chosen methodology and research components. A total of 14 soil samples were collected from seven (7)

research sites and conducted lab analysis to determine the content of common forms in the following heavy metals: Cd-cadmium, Cu-copper, Pb-lead, and Zn-zinc.

A study of heavy metals in the soil of pastures was conducted using spectrometric methods.

Water sampling was conducted in order to determine the involvement of water in the pollution chain and to ascertain the level of pollution present in it.

Water samples were taken from reservoirs in the study areas, from the main sources of drinking water used by livestock, and from wells. In total seven (7) samples, were collected and examined with the following names and numbers:

- Village Gombori – forest water (natural spring);
- Village Gombori – “Tatrisubani” (drinking water, runoff from the ravines);
- Village Gombori – drinking water source for the population and livestock;
- Village Arashenda – (drinking water-well water);
- Village Arashenda – the “Lakbe” river (main drinking water for livestock);
- Village Shakhvetila – “Vedzebi” (the only drinking spring for the population and livestock of Shakhvetila village);
- Village Shakhvetila – valley of the Ilto river (for the community of village Shakhvetila) drinking water for livestock.

The water analysis was conducted on the “Pelkimelmer” firm's Analys-400, which was equipped with both an aluminum photometer and an electric HGA-900 atomizer.

1.Cadmium standard for AAS Lot: BCBK 6488 V;

2.Zinc Standard for AAS Lot: BCBL 0587V;

3.Copper standard for AAS Lot: BCBL 1118V;

4.Lead Standard for AAS Lot: BCBL 7911V.

Zn-zinc and Cu-copper were measured in ash, while Cdcadmium and Pb-lead were measured in a graphite furnace. The determination of chemical elements was carried out using accompanying methodology, the sample was

prepared according to GOST', acidification and filtration. The obtained results for Cd, Cu, Pb, and Zn are given in mg/l.

## Results

In the soil samples, minor changes in the content of heavy metals were observed, which were presented in the table No.1 below as results. Received results have been compared to (MPC) which formulated by (Bakradze, Urushadze, et al.,2018) (Tab. No 2).

Compared to the permissible concentration limits, lead and cadmium contamination was not observed in the investigated soils of the natural pasture. It is clearly shown in (Table № 1) that the result is below the critical threshold.

In the case of the village of Pkhoveli, which belongs to the Gurjaani Municipality, there was a high concentration of copper (Cu) in the 5 samples taken from the 0-20 cm depth, which is upper of (155.20 mg/kg. Tab. №1) the “disturbing” (>140mg/kg. Tab № 2) threshold.

It is very likely that this comes from past agricultural crops cultivated in the same area or from a vineyard that was grown exactly in this pasture area.

In case of other samples, there was a difference of approximately 3-5 to 8-10 mg/kg in the soil layers based on the content of heavy metals. It can be said that this difference may originate naturally from the rock, so it is possible that this is a natural process and is defined by the “acceptable” criteria.

In case of copper and zinc, the difference between the upper and lower layers, that is, the depths (0-20) and (20-40) cm, was insignificant, which means that the heavy metal content is almost equally distributed. Based on the above, it is likely that there was no source of contamination for these elements in the studied areas; it was presumed that this concentration mainly originates from the soil-forming rock, which could also be influenced by biogenic

factors, with the stock accumulated in the upper layer of the pasture, formed from the plant cover. In the researched pasture area, a variation of 9-10mg/kg of zinc and copper content was recorded between soil layers, which may be caused by the abundance of natural content originating from the rock in the lower layer of the soil.

A study was conducted to assess the natural state of pastures in order to determine their overall condition. The aim was to determine whether there has been an increase in the concentration of heavy metals in heavily used pastures.

According to the population, it was interesting for them to know the level of soil contamination in their village pastures and whether it was risky for their livestock to graze in the mentioned area. The population does not have the possibility to verify this, due to objective reasons, as it is often related to a lack of resources. The deterioration of pasture quality might have been linked to contamination, and to determine this, a small amount of mixed samples was taken.

However, it is not excluded that there are plant species known as “hyperaccumulator plants” or “rapidly accumulating plants” on the studied pastures, although different plants accumulate heavy metals in varying amounts. Therefore, they belong to the group of plants that are easily palatable for livestock, meaning „easily consumable plants.“

Consequently, it is likely that continuing this study from a botanical perspective will also be very interesting. The results are evaluated based on the significance of the recommended grading characteristics, which are intended for the determination of heavy metals present in Georgia, as shown in Table № 2.

The soil contamination with heavy metals at the above-mentioned research sites was not detected, and its content, as well as the ratio compared to the permissible concentration limits, is completely acceptable for each sample.

As mentioned at the very beginning, water was also investigated alongside the soil.

This was done by collecting appropriate water samples and conducting laboratory analysis.

As a result of the laboratory analysis of water, the presence of Cd-cadmium was recorded in the water of all seven objects at a level of 0.001-0.002 mg/l, while no such presence was noted for the remaining two objects. The obtained results do not exceed the LTL (0.003) according to the “approval of the technical regulation for drinking water” (Table №. 4).

Out of seven objects, the copper content, was not detected in five samples out of them, while in the two remaining objects, it was recorded within the range of 0.009-0.015 mg/l, which also complies with the set requirements for permissible concentration.

Pb-lead, the results obtained from the seven mentioned objects ranged from 0.001 to 0.004 mg/l, which corresponds to the permissible standard of 0.01 mg/l. Zn-zinc, in five samples of water taken from the investigated objects, values of 0.02 to 0.021 mg/l were recorded, which is compatible with the 3.0 mg/L limits of the permissible standard (refer to document № 4).

(On the approval of the technical regulation of drinking water), № 349/n, Tbilisi, December 17, 2007.

Based on the conducted laboratory research, it can be stated that the risk of contamination in the collected water samples is very low. The indicators of the obtained results were compared with the maximum allowable concentration present in the “Technical Regulation for Drinking Water, Sanitary Standards and Rules”, and the results show that the measured values do not exceed the permissible limits.

## Conclusion

The studied soils are not contaminated with heavy metals (Cd, Cu, Pb and Zn), as their content in the samples does not exceed the so-

called maximum permissible concentration (MPC).

Only in the village of Pkhoveli (Gurjaani) was there a “Disturbing” copper (Cu) content of 155.2 mg/kg found in the upper (0-20 cm) layer of the soil.

The difference relative to the MPC threshold (>140 mg/kg) was 15.2 mg/kg. This may indicate a local or systemic problem, but there is no precise answer at this stage based on the research. Similar studies suggest that additional detailed research should be conducted in this area in the future to determine the real cause of this difference and to identify possible pollution sources.

Due to the low concentration of heavy metals in the soil of the studied pastures, it is impossible for their content to transfer into the food chain and contaminate products.

The studied water samples are not contaminated with heavy metals (Cd, Cu, Pb and Zn), and their content in the samples does not exceed the allowed limits.

Based on the existing research, we can conclude that there is no evident contamination of soil and water in the pasture area, while certain cases where variability was noted among the results are likely attributed to natural conditions.

Conflicts of interest should be stated as: “The authors declare that they have no conflicts of interest.”

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## Results Tables

**Table 1.** The content of heavy metals in soils (mg/kg)

No	Objects	Soil Depth, cm	Cu	Zn	Cd	Pb
1	Shakhvetila	0-20	42.88	58.95	<1	<5
2		20-40	38.29	56.24	<1	<5
3	Patardzeuli	0-20	38.55	49.52	<1	<5
4		20-40	37.50	44.67	<1	<5
5	Pkhoveli	0-20	155.20	62.87	<1	<5
6		20-40	44.24	53.49	<1	<5
7	Arashenda	0-20	39.48	58.94	<1	<5
8		20-40	33.33	48.17	<1	<5
9	Mlasheebi/Vill.Koghoto	0-20	29.52	37.86	<1	<5
10		20-40	57.09	53.07	<1	<5
11	Cheremi	0-20	56.45	53.61	<1	<5
12		20-40	58.17	55.16	<1	<5
13	Paldo (Plot)	0-20	51.30	58.73	<1	<5
14		20-40	41.59	61.97	<1	<5

**Table 2.** The significance of the recommended gradation characteristics for heavy metals in Georgian soils (E. Bakradze, T. Urushadze et al., 2018)

Element	Ecological Conditions (State) of Soil					
	Disturbing	Extraordinary	Equilibrium	Critical	Satisfactory	Acceptable
Highly dangerous heavy metal						
Cadmium (Cd)	>3	3-1	1	1-0.5	0.5-0.1	<0.1
Moderately hazardous heavy metals						

Copper (Cu)	>140	140-100	100	100-75	75-50	<50
Low hazardous heavy metals						
Zinc (Zn)	>500	500-300	300	300-200	200-150	<150
Lead (Pb)	>200	200-150	150	150-100	100-75	<75

Table 3. Heavy metal content in water (normative, not exceed, mg/l)

No	Location	Heavy Metals			
		Cd	Cu	Pb	Zn
		Maximum Permissible Concentration			
		(0,003)	(2,0)	(0,01)	(3,0)
1	Vill. Gombori – (forest waternatural spring)	0.002	0.018	0.001	0.014
2	Vill. Gombori – “Tatrisubani” (drinking water, runoff from the ravines)	0.002	0.009	0.003	0.002
3	Village Gombori – drinking water source for the population and livestock.	Not	Not	0.001	0.021
4	Village Arashenda – (drinking water, well water)	Not	Not	0.003	Not
5	Village Arashenda – river “Lakbe” (main drinking water souce for livestock)	0.001	Not	0.004	Not
6	Vill. Shakhvetila – “Vedzebi” (Vill. Shakhvetila Community) The only one running water souce to drink for population and livestock.	0.001	Not	0.004	0.015
7	Vill. Shakhvetila – River “Ilto” (Vill. Shakhvetila community) Drinking water for livestock.	0.001	Not	0.004	0.003

Table 4. Technical regulation for water samples (mg/l)

<b>Characteristics</b>	<b>Normatives</b>
Cd	0.003
Cu	2.0
Pb	0.01
Zn	3.0