

Risk assessment of manganese and some heavy metal contamination of natural waters of Chiatura Municipality

Lali Shavliashvili

Institute of Hydrometeorology, Georgian Technical University, Tbilisi, Georgia

E-mail: Shavliashvililali09@gmail.com

ORCID: <https://orcid.org/0009-0009-1168-9492>

Eka Shubladze, Dr.

Institute of Hydrometeorology, Georgian Technical University, Tbilisi, Georgia

E-mail: ekashubladze051@gmail.com

ORCID: <https://orcid.org/0000-0002-8740-1637>

Giorgi Kuchava

Institute of Hydrometeorology, Georgian Technical University, Tbilisi, Georgia

E-mail: gkuchava08@gmail.com

ORCID: <https://orcid.org/0000-0001-5146-1593>

Givi Gavardashvili.

Professor Tsoetne Mirtskhulava Institute of Water Management, Georgian Technical University, Tbilisi, Georgia

E-mail: givi_gava@yahoo.com; <https://orcid.org/0000-0001-5289-3830>

Zura Rikadze

National Environmental Agency, Ministry of Environmental Protection and Agriculture of Georgia, Tbilisi, Georgia

E-mail: zurarikadze@gmail.com; <https://orcid.org/0000-0001-5621-1649>

Abstract. The Chiatura municipality of the Imereti region of Georgia is one of the most vulnerable points in terms of environmental pollution, where ore mining and processing began in 1879. The main problem of the municipality is the intensification of mining activities (manganese production). Manganese mining in Chiatura causes great damage to the Kvirila River. It is necessary to determine the cleanliness of the river, because the Kvirila River is used to wash the mined ore, as a result of which wastewater, which contains a large amount of suspended particles, heavy metals, and manganese compounds, flows into the Kvirila River without purification and pollutes it.

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The paper discusses the assessment of the risks of pollution of the Kvirila River and spring waters in the areas adjacent to the manganese processing enterprises of Chiatura Municipality with manganese and some heavy metals (Cu, Zn, Pb, Cd, Ni, Co) for 2024-2026. The content of manganese and some heavy metals in the total form was determined in natural water samples, river suspended solids and bottom sediment samples. The Kvirila River and spring waters polluted with various ingredients were identified. The results obtained are presented in the form of conclusions. The analyzes were conducted using modern methods and equipment that comply with European standards. In the river waters, both in the background and in the samples taken from polluted areas, no heavy metal (except manganese) exceeds the maximum permissible concentration (MPC) and is within the norm. The Kvirila River and the spring waters belong to the category of slightly and moderately mineralized waters; The manganese hazard index in the waters of the Kvirila River is greater than 1 ($HQ_{sw} > 1$) and these waters are at risk. As for the content of other heavy metals, their concentration is higher than the background value, but in no case does it exceed the corresponding MPC; The manganese hazard index in the spring waters is less than 1 ($HQ_{dw} < 1$), these waters are not at risk; High concentrations of manganese are observed in the suspended solids and bottom sediments of the Kvirila River.

Keywords: Kvirila River, spring waters, manganese, heavy metals, pollution risks.

Introduction

The unlimited growth of the Earth's population, the technological revolution in industry, and the increasing degree of environmental impact have led to anthropogenic climate change. The negative impact of climate change on Georgia's ecosystems and economy poses a great threat to the country's development. The unique geographical location, complex and rugged terrain, diverse land cover and specific climate, which covers almost all climatic zones, create conditions for the manifestation of a wide range of negative consequences of climate change in Georgia. At the same time, these factors determine the country's vulnerability to climate change.

The prevention and/or minimization of climate disasters is of particular importance, as it affects all areas and sectors of life (health, ecosystems, infrastructure, tourism, agriculture, resources).

In Georgia, one of the most vulnerable places in terms of ecology is the Chiatura municipality, the main problem of which, against the backdrop of climate change, is the intensification of natural disasters (landslides, mudslides, floods, winds, erosion, etc.), which is facilitated by the intensification of mining activities (manganese production) in the municipality. Ore mining is associated with many controversial issues. On the one hand, it is a source of income and new job creation. However, it causes significant damage to the environment and the local population [1,2]. Deforestation and destruction of vegetation cover over large areas are possible; the landscape is significantly degraded, which has a significant negative impact on biodiversity; pollution of ecosystems and food products is likely; soil degradation, large material losses, etc. [3].

Industrial wastewater generated during the ore washing process contains large amounts of suspended solids, heavy metals, and manganese compounds and is discharged into the Kvirila River without treatment. In addition, thousands of tons of agglomerates are stored on the landfill located on the left bank of the Kvirila River, which contains an average of 15.4% manganese. Under the influence of precipitation, the agglomerates are washed into the Kvirila River and causes additional pollution [4].

During manganese mining, manganese oxide is released into the atmosphere in the form of dust. Wind and precipitation contribute to its spread and deposition in the municipality [5].

Manganese is an important element for humans and animals. Manganese is contained in small concentrations in almost all human organs. Manganese participates in the blood-forming functions of humans and animals, the process of bone growth, the metabolism of proteins, carbohydrates, fats, etc. In plants, manganese participates in the process of photosynthesis.

Negative effects can be caused by both deficiency and overexposure. Manganese does not cause acute poisoning. It is a poison of cumulative action and, when exposed to the body over time, is characterized by multiple manifestations and causes the following occupational diseases: manganism, bronchial asthma, allergic dermatitis, and others [6].

Research area and methods

The paper provides a physicochemical characterization of the waters of the Kvirila River in the areas surrounding the manganese processing plants of Chiatura Municipality. Determining the purity of the Kvirila River water is necessary because the Kvirila River water is used to wash mined ore, after which the wastewater flows into the river and pollutes it.

To solve the set tasks, samples of background and below pollution source water of the Kvirila River were taken; suspended solids and bottom sediments of the Kvirila River; and spring water (drinking water) were also taken.

In the collected water samples, the following were determined: pH, heavy metals: Cu, Zn, Pb, Cd, Ni, Co and the total form of manganese [7].

The risk assessment stage foresees a comparison of the level of measured Mn concentrations with environmental quality standards in specific mediums (surface waters, drinking water). This comparison envisages risk assessment according to the following formula (1):

$$HQ = MC / EQS_{SW,DW} \quad (1),$$

where, HQ – hazard index;

MC – measured concentration;

$EQS_{SW,DW}$ – environmental quality standards for surface and drinking waters [8].

In the case when $HQ > 1.0$, Mn is considered a potential risk for water medium and, as a consequence, for population health.

The following EQS limit values will be used:

- surface waters: 0.1 mg/l (maximum permissible concentrations according to Decree №425 on Approval of Technical Regulations for Georgian surface waters protection from pollution) [9];
- drinking waters: 0.4 mg/l (maximum permissible concentrations according to Resolution №58 on Approval of Technical Regulations for Georgian drinking waters protection from pollution) [10].

The analyses were conducted using modern methods and equipment that meet and comply with European standards, namely:

1. Inductively Coupled Plasma Emission Spectrometer - ICP-OES; Epa method 200.8;
2. Field portable equipment - Hanna Combo pH/EC/TDS/PPM Tester HI98129;
3. pH meter - Milwaukee-Mi 150.

Results

Table 1 shows the heavy metal concentrations in the waters of the Kvirila rivers and spring water in 2024 and 2025. The numerator shows the manganese concentration, and the denominator shows the maximum permissible concentration (MPC). As can be seen from Table 1, in May 2024, below Kvirila-LLC “Andro” and Kvirila-LLC “Jruchula”, a deviation of pH in the alkaline direction is observed and amounts to 8.1-8.2 compared to the Kvirila background (7.7). The manganese concentration is equal to 2.5649 mg/l, which is 25.6 MPC; while below Kvirila-LLC “Jruchula” - 0.1136 mg/l, which is 1.1 MPC. This is due to the fact that below Kvirila-LLC “Andro” the Kvirila River is polluted by the discharge of wastewater into the Kvirila River as a result of washing the mined ore; And below Kvirila-LLC “Jruchula” - the low concentration indicates that the enterprise may not have been operating at full capacity during that period (Fig. 1). The manganese content in the water of both springs is within the normal range. Of the heavy metals determined, except for manganese, no metal was found in quantities exceeding the MPC (Table 1, Fig. 1).

The manganese content in the water of the Kvirila River in November below the Andros LLC is 13.9 mg/L, and below the Jruchula LLC - 13.7 mg/L. It is noteworthy that even in the background value of the Kvirila River, the manganese content is high and amounts to 0.2572 mg/L (2.6 mg/L). The content of heavy metals is less than the MPC in all cases.

Table 1. Heavy metal concentrations in the waters of the Kvirila River and spring water, 2024, 2025

N	Ingredients	Kvirila- below "Andro" LLC	Kvirila- below "Jruchula" LLC	Kvirila- Backgrou nd	Spring water 1	Spring water -2	MPC*	MPC* *
May, 2024								
1	pH	8.1	8.2	7.7	8.2	7.8	6-9	6.5-8.5
2	Manganese, mg/l	2.5649/25.6	0.1136/1.1	0.0150	0.0154	0.0030	0.4	0.1
3	Copper, mg/l	0.0134	0.0024	0.0040	0.0028	0.0008	2.0	1.0
4	Zinc, mg/l	0.0054	0.0035	0.0012	0.0031	0.0009	3.0	1.0
5	Lead, mg/l	0.0023	0.0011	0.0008	0.0021	0.0015	0.01	0.03
6	Cadmium, mg/l	0.0002	0.0001	0.0001	<0.0001	<0.0001	0.003	0.001
7	Nickel, mg/l	0.0005	0.0023	0.0007	0.0010	0.0005	0.07	0.1
8	Cobalt, mg/l	0.0004	0.0007	0.0003	0.0012	0.0009		0.1
November, 2024								
1	Manganese, mg/l	1.3958/13.9	1.3742/13.7	0.2572/2.6	0.0050		0.4	0.1
2	Copper, mg/l	0.0032	0.0038	0.0040	0.0010		2.0	1.0
3	Zinc, mg/l	0.0522	0.0456	0.0013	0.0008		3.0	1.0
4	Lead, mg/l	0.0012	0.0024	0.0009	0.0011		0.01	0.03
5	Cadmium, mg/l	0.0003	0.0004	<0.0001	<0.0001		0.003	0.001
6	Cobalt, mg/l	0.0011	0.0007	0.0005	0.0003			0.1
7	Nickel, mg/l	0.0023	0.0033	0.0015	0.0004		0.07	0.1
June, 2025								
1	pH	7.9	8.0	8.1	8.1	8.0	6-9	6.5-8.5
2	Manganese, mg/l	23.800/238.0	9.8920/98.9	0.0527	0.0025	0.0055	0.4	0.1
3	Copper, mg/l	0.0379	0.0355	0.0036	0.0009	0.0011	2.0	1.0
4	Zinc, mg/l	0.0454	0.0518	0.0050	0.0022	0.0042	3.0	1.0

5	Lead, mg/l	0.0082	0.0037	0.0015	0.0015	0.0027	0.01	0.03
6	Cadmium, mg/l	0.0007	0.0002	0.0001	<0.0001	<0.0001	0.003	0.001
7	Nickel, mg/l	0.0201	0.0467	0.0028	0.0008	0.0010	0.07	0.1
8	Cobalt, mg/l	0.0130	0.0097	<0.0001	0.0007	0.0005		0.1
November, 2025								
1	Manganese, mg/l	60.57/605.7	0.6347/6.4	0.0169	0.0376		0.4	0.1
2	Copper, mg/l	0.0078	0.0041	0.0035	0.0010		2.0	1.0
3	Zinc, mg/l	0.0336	0.0245	0.0025	0.0010		3.0	1.0
4	Lead, mg/l	0.0015	0.0039	0.0011	0.0007		0.01	0.03
5	Cadmium, mg/l	0.0002	0.0002	<0.0001	<0.0001		0.003	0.001
6	Cobalt, mg/l	0.0018	0.0020	0.0027	0.0016			0.1
7	Nickel, mg/l	0.0016	0.0031	0.0042	0.0009		0.07	0.1

* - MPC - Maximum permissible concentration according to the Technical Regulations for Drinking Water (Resolution of the Government of Georgia No. 58 of January 15, 2014, Tbilisi) [10]

** - MPC - Maximum permissible concentration in accordance with the Technical Regulations for Surface Water (Resolution of the Government of Georgia No. 425, December 31, 2013, Tbilisi) [9]

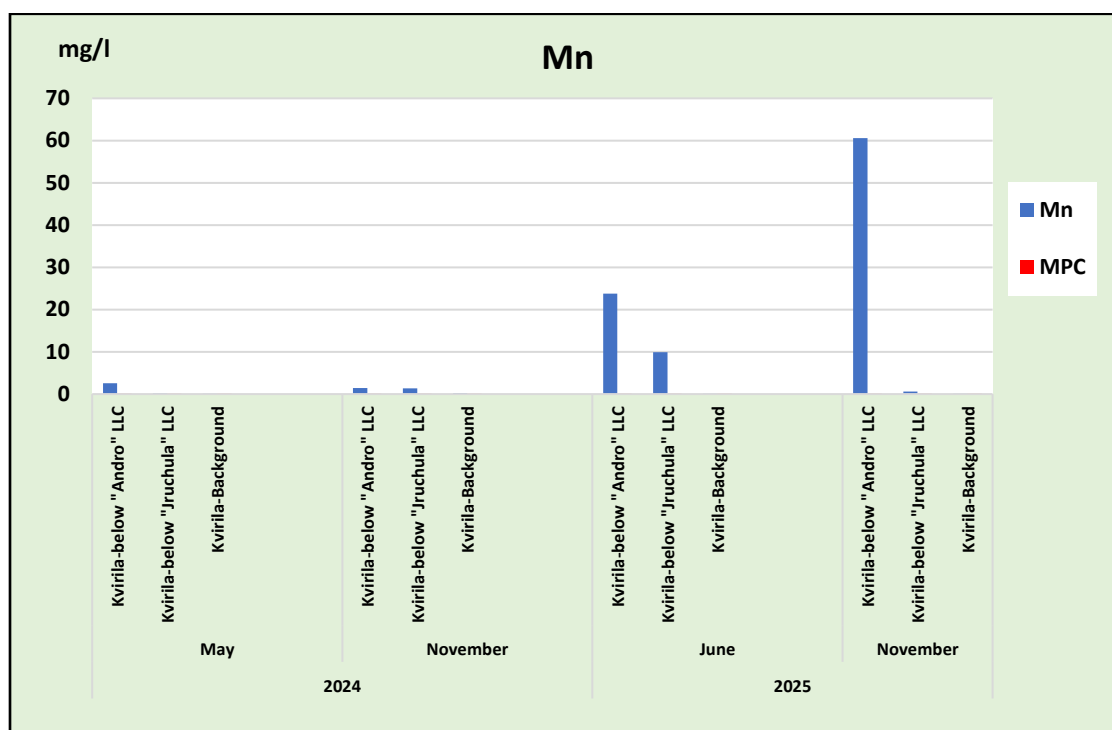


Figure 1. Manganese content in the waters of the Kvirila River - 2024, 2025

As can be seen from Table 1, in May 2025, similarly to 2024, below LLC "Andro" and Kvirila-LLC "Jruchula", a deviation of pH in the alkaline direction is observed and amounts to 7.9 - 8.1.

An alarming situation is observed in June 2025 in terms of manganese content in the river Kvirila below LLC "Andro", where the manganese concentration is equal to 23.800, which is equal to 238.0 MPC, and in Kvirila-„Jruchula” it is -9.8920 mg/l, which is 98.9 MPC (Fig. 1).

The manganese content in the water of both springs is within the normal range.

Of the heavy metals determined, none of the metals were found to be in excess of the MPC.

The manganese content in the water of the Kvirila River in November 2025 below the LLC "Andros" is particularly high and amounts to 60.57 mg/l (605.7 MPC), and below the LLC "Jruchula" -0.6347 mg/l (6.3 MPC); the manganese content at the background point of the Kvirila River is 0.0169 mg/l and does not exceed the MLD; the content of heavy metals here is also less than the MPC in all cases.

In May 2024, the Mn content in the suspended solids and bottom sediments of the Kvirila River is high, especially its content is especially high with "Andro" LLC compared to "Jruchula" LLC. At the same time, the Mn content in the bottom sediments is higher than in the suspended solids and is 68.5 and 58.3 g/kg, respectively. While the manganese content in the bottom sediments at "Jruchula" is 66.7 and in the suspended solids - 23.6 g/kg.

In November, Table 2 shows the Mn content in the suspended solids and sediments of the Kvirila River (November, 2024). As the analysis results show, the manganese content in the sediments below the Kvirila-LLC "Jruchula" is particularly high and amounts to 125.3 g/kg, while below the Kvirila-LLC "Andro" - it is much lower (48.87 g/kg). The manganese content in the suspended solids is similarly high and amounts to 23.37 and 23.95 mg/kg, which indicates manganese pollution of the Kvirila River.

Table 2. Mn content in suspended solids and sediments of the Kvirila River - 2024,

2025

N	Sampling location	Coordinates	Analysis result	
	Suspended solids	2024	g/kg	
			May	November
1	Kvirila-below "Andro" LLC	X-363027 Y-4686103	58.3	23.37
2	Kvirila-below "Jruchula" LLC	X-363791 Y-4686878	23.6	23.95
	Sediments			
1	Kvirila-below "Andro" LLC	X-363027 Y-4686103	68.5	48.87
2	Kvirila-below "Jruchula" LLC	X-363791 Y-4686878	66.7	125.3
	Suspended solids	2025	June	Novemb er
1	Kvirila-below "Andro" LLC	X-363027 Y-4686103	41.5	85.5
2	Kvirila-below "Jruchula" LLC	X-363791 Y-4686878	19.7	31.3
	Sediments			
1	Kvirila-below "Andro" LLC	X-363027 Y-4686103	46.1	69.40

2	Kvirila-below "Jruchula" LLC	X-363791 Y-4686878	54.3	70.14

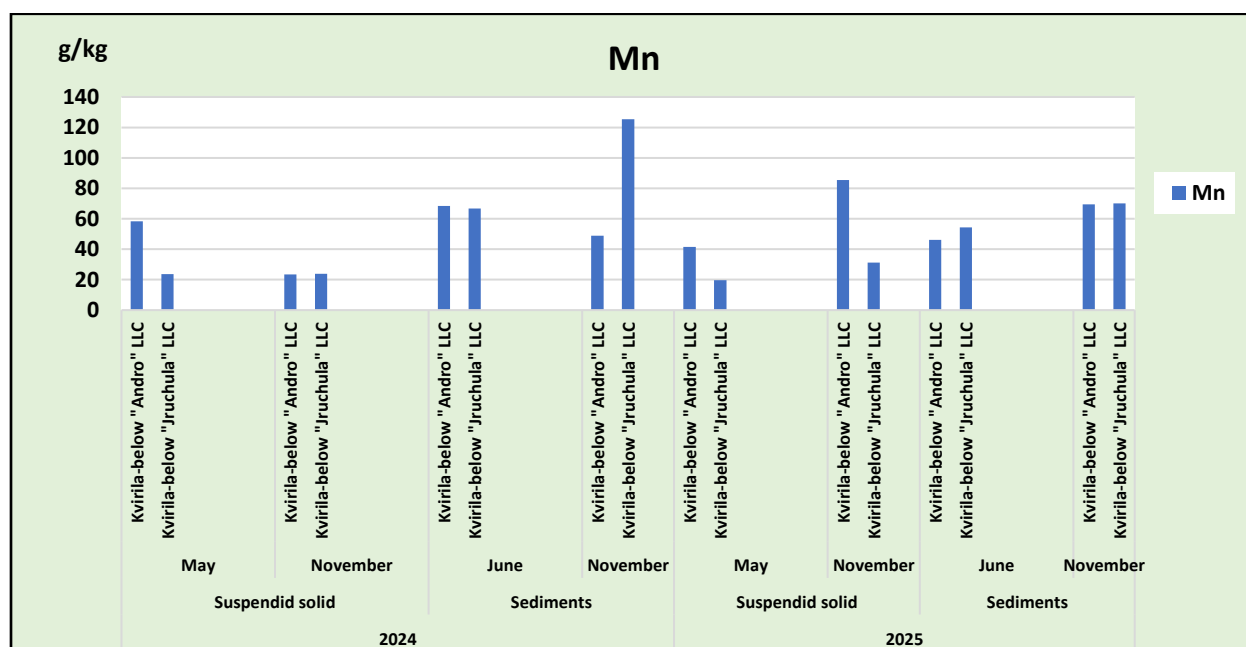


Figure 2. Manganese content in suspended solids and sediments of the Kvirila River - 2024, 2025

In June 2025, the manganese content in the suspended solids and bottom sediments of the Kvirila River is higher below the Andro LLC in the Kvirila River compared to the Jruchula LLC and is 41.5 and 19.7 mg/kg, respectively.

Meanwhile, the manganese content in the bottom sediments is higher compared to the suspended solids and is 54.3 below the Jruchula LLC and 46.1 g/kg below the Andro LLC.

Table 2 shows the Mn content in the suspended solids and sediments of the Kvirila River in November (November, 2025). As the analysis results show, the manganese content in the sediments below the Kvirila-LLC “Jruchula” is particularly high and amounts to 70.1 g/kg, while below the Kvirila-LLC “Andro” it is slightly lower (69.4 g/kg). On the contrary, below the LLC “Andro” the manganese content is high and amounts to 85.5 g/kg, in the suspended solids, while below the LLC “Jruchula” it is much lower and amounts to 31.3 g/kg.

Discussion

Based on scientific research conducted by us in Chiatura Municipality in 2024–2025, the contents of heavy metals and manganese have been determined, both in the water of the Kvirila River, as well as in sediments and suspended solids. In particular, in the water of the Kvirila River, downstream of both enterprises, high manganese contents and a hazard index $HQ_{sw} > 1$ are noted, therefore these waters are at risk. It is worth noting the high manganese contents in the suspended solids and sediments of the Kvirila River, which are expressed in g/kg. As for the content of heavy metals (Cu, Zn, Pb, Cd, Ni, Co), although their content is less than the MPC and is within the norm, in almost all cases their concentrations in water samples taken after the enterprises exceed the background value. Similar studies were conducted by us in 2022-2025 in the rivers Tskhenistskali and Lukhun of Ambrolauri municipality using the same methodologies for determining the content of heavy metals and arsenic and assessing risks. The results obtained are consistent and fully consistent with the results of long-term monitoring studies of the National Environmental Agency. Also, the risks of various polluting ingredients were assessed according to the methodology of the Slovak Water Institute, which were successfully implemented in the studies conducted by us [11-13].

At the same time, it should be noted that intensive mining of manganese ore is underway in the territory of Chiatura Municipality, both underground and open-pit mining. The color of the Kvirila water is black in the vicinity of the enterprises, which is due to industrial wastewater generated during the ore washing process and which contains large amounts of suspended solids and sediments, heavy metals, and manganese compounds, which unfortunately flow into the Kvirila River without treatment and cause its pollution.

Conclusion

- According to 2024, the pH of the Kvirila River varies within 7.7-8.2, and in the spring waters - within 7.8-8.3; and according to 2025, the pH of the Kvirila River varies within 7.9-8.1, and in the spring waters - within 8.0-8.1; in both cases, a deviation of pH in the alkaline direction is noted;
- The concentration of manganese in 2024-2025 downstream of the enterprises almost always exceeds the MPC, which is due to the fact that downstream of the enterprises, the Kvirila River is polluted by the discharge of wastewater from the washing of mined ore into the Kvirila River;
- The manganese hazard index in the Kvirila River water $HQ_{sw} > 1$, therefore, these waters are at risk;
- The total content of Mn in the suspended solids and bottom sediments of Kvirila is quite high compared to the background;
- The manganese content in the spring waters does not exceed the MPC and is within the norm; The manganese hazard index $HQ_{Dw} < 1$, therefore, these waters are not at risk;
- Of the heavy metals determined in natural waters (Cu, Zn, Pb, Cd, Ni, Co), none of the metals was found in quantities exceeding the MPC.

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