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ASSESSMENT OF HEAVY METAL CONCENTRATIONS IN IARA RIVER BASIN, CLUJ COUNTY, ROMANIA

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ABSTRACT. – Assessment of Heavy Metal Concentrations in Iara River Basin, Cluj County. This study focuses on the results of analyses carried out on water samples collected in December 2024 and analyzed at the Research Institute for Analytical Instrumentation in Cluj-Napoca. The samples in question were taken within the perimeter of the Iara River basin, which was an important hub for the extractive industry during the communist regime in Romania. With the halting of many industrial and mining activities, mining infrastructure elements were abandoned, posing a significant pollution risk. In the case of the study area, these infrastructure elements are represented by residual waste dumps. However, the results of the water samples reflect not only a very low concentration of heavy metals, but also a very good example of water quality administration and management.

Keywords: *heavy metals, water quality, mining area, Iara River basin, Cluj County.*

1. INTRODUCTION

Water, through its multitude of uses, is a vital component in the proper functioning of the entire environment; water supports the development of both aquatic and terrestrial biodiversity. Water resources also prevent soil degradation and ensure the sustainability of ecosystems. This means that contamination of this fundamental element generally results in negative effects on the environment.

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Water and river systems play a critical role in the redistribution and transformation of mineral deposits through natural geochemical and hydrological processes. Precipitation acts as a primary driving force by mobilizing water that infiltrates the soil and rock layers, initiating the weathering of old mineral deposits. As river water flows across and through mineralized terrains, it enhances the washing and transport of weathered materials, progressively removing fine particles and dissolved ions. This process leads to the dilution and dispersion of heavy metals, such as iron, manganese, copper, lead, and zinc, from their original deposits into surrounding surface and groundwater systems. While dilution can reduce metal concentrations locally, continuous leaching may also expand the spatial extent of contamination downstream.

The ways in which water is used in raw industrial processes have evolved from one historical period to another, as during the industrial boom, water resources were used to cool machinery or in settling ponds to separate useful ores from the sterile material. Thus, in mining and mineral processing operations, water is essential for gravity separation, flotation, and leaching processes commonly applied to metal related ores. Water suspends finely ground ore particles, allowing minerals to be recovered through gravity or magnetic separation, while copper sulfide minerals are concentrated using flotation methods that rely on water–air–reagent interactions. Additionally, water facilitates the removal of impurities through washing and dilution, improving metal recovery efficiency. However, the extensive use of water in ore separation also has environmental implications. The interaction between water and sulfide-bearing iron and copper ores can promote oxidation reactions that generate acidic conditions and mobilize heavy metals.

The main characteristic of these harmful substances is their ability to bioaccumulate. Through this process, heavy metals can persist to the last link in the food chain by polluting the soil, water, and consequently plants and terrestrial and aquatic life. The use of polluted river water for domestic, agricultural, and industrial purposes further amplifies the environmental health implications of heavy metal contamination (Morais *et al*, 2012). Additionally, elevated metal concentrations can disrupt aquatic ecosystems by impairing reproduction, growth, and metabolic functions of aquatic organisms, ultimately reducing biodiversity and ecosystem resilience.

The Apuseni Mountains represent the highest and most expansive sector of the Western Carpathians, defined by the Mureș Valley corridor to the south and the Barcău and Someș valleys to the north, with a significant "mining foot-print" developed across millennia, starting from the Roman Empire till present time (Șerban *et al,* 2004). Besides the well-known mining deposits from the so-called "Golden Rectangle", the area is known also for the significant iron deposits in Iara Depression (Bătinaș, 2012).

The temporal analysis of scientific research over the past 30 years on mining pollution in the Arieș River catchment area (collector of Iara River) has revealed a certain heterogeneity of the studied topics. Thus, in the late 1990s till 2001, the first studies were focused on tracing different pollutants and their impact regarding environmental contamination. These efforts helped establish analytical methods later applied to river pollution research. One of the earliest quantitative analyses of heavy metals in the Arieș River using a pollution index based on dissolved metal concentrations along a major river transect was published in Studia UBB Geologia (Forray, 2001). In the next decade, until 2010, a series of papers have been related to geochemistry focusing on heavy metal concentrations in surface waters and sediments in relation to local mining (Șenilă *et al,* 2007), (Ozunu *et al*, 2009) and on the mineralogy of the ore deposits and their alteration process that can trigger environmental pollution (Ghergari *et al*, 2004) or on the chemistry analysis of surface waters and hyporheic zone (Marin, 2010). Besides the scientific papers published in various journals, some PhD thesis related to the subject have been defended in that time (Bătinaș, 2010), (Costan, 2010), (Ștefănescu, 2010).

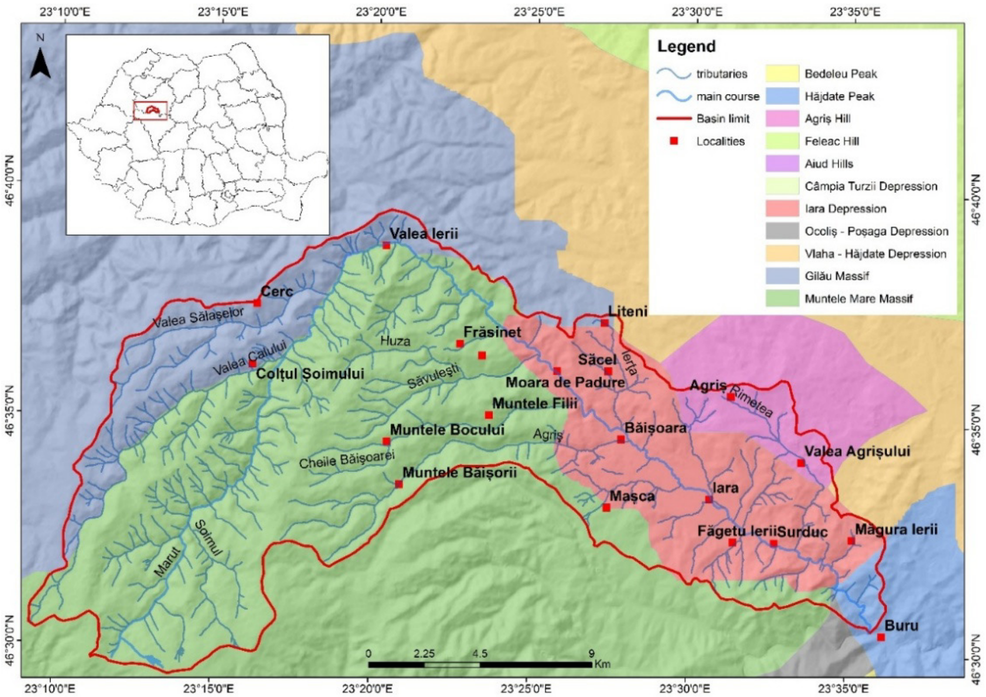

Fig. 1. Location of the Iara River basin
Source: the authors

The decade 2011-2020 was also focused on emphasizing anthropic pollution due to mining operation with focus mainly on heavy metals (Corcheș, 2011), (Levei *et al*, 2014) and radionuclides (Ioniță *et al,* 2017).

The last period (2021-present) has seen studies on water chemistry spatial variation (Moldovan *et al*, 2021) remediation of acid mine drainage methods (Glevitzky *et al*, 2025), evaluation of pollution levels using bio-indicators (Glevitzky *et al*, 2025), sustainable development issues in post-industrial present time (Botezan *et al*, 2020) and proposed remediation methods and techniques in order to mitigate historical pollution impact (Bănăduc *et al*, 2021).

The Iara River Basin, located in the south-west part of the Cluj County (western Romania), overlaps with the Băișoara – Iara mining area, which represents one of the eleven major mining zones identified within the Apuseni Mountains (Constantin, 2011). The largest left-side tributary of Arieș River, Iara basin is defined mostly by mountainous terrain, accounting for 60% (Muntele Mare and Gilău Massif), while 40% overlaps with depression terrain (Iara Depression). Location of Iara catchment and its relation with geographical units are presented in figure 1.

Historically, this region played a significant role in the local mining industry due to its rich underground resources. The industrial scale activity has begun in 1955-1957 with first complex geological explorations. The main activity has begun within Iara and later in Cacova Ierii localities in 1981 within the administration of so-called "*Mining Sector Băișoara – Mining Exploitation Iara*". The primary exploitable resource for much of the 20th century was iron ore, which supported both regional and national metallurgical activities until mining operations halted in 2006. In more recent years, attention has shifted towards the extraction of industrial dacite, a valuable volcanic rock used in construction and various industrial applications (ANRMPSG, 2021). These dacite deposits are primarily located to the northern part of Băișoara settlement, where they continue to sustain limited but ongoing quarrying activity in the Iara basin.

The Iara Basin represents a sensitive hydrographic system influenced by both natural and anthropogenic pollution sources. Scientific investigations identified a slight but persistent tendency toward water pollution, primarily associated with human activities superimposed on natural background processes. Natural pollution sources include the dissolution of water-soluble rocks (large area with limestone), soil erosion processes, and organic inputs from riparian and aquatic vegetation, which contribute suspended solids and nutrients to surface waters (Luca *et al*, 2007).

Anthropogenic pollution sources are more significant and continuous, dominated by domestic wastewater discharges from rural settlements, untreated sewage, and effluents from small agro-zootechnical farms rich in organic matter.

Additional pressures arise from tourism-related activities, including camping and leisure facilities that generate wastewater similar to urban effluents. A critical pollution source is represented by uncontrolled solid waste dumps, particularly sawdust and industrial residues deposited near riverbeds, which facilitate direct runoff and soil infiltration. Historical and ongoing mining and quarrying activities, especially iron exploitation in Mașca and Cacova Ierii and associated mineral processing, further increase the risk of metal mobilization.

2. METHODOLOGY

The scientific approach of this paper is based on several stages, each of which played an important role in the completion of the study. The first stage consists of a thorough review of the literature on the chosen topic, as well as similar studies. Through the method of synthesis, a bibliography was created which, together with the existing level of knowledge on the subject, will serve as the scientific foundation for consolidating the paper output. This stage allowed both a deep understanding of the theoretical context and existing approaches, as well as the identification of gaps in knowledge and research that justify the need for the research in question. Thus, the theoretical foundation represented a solid starting point, capable of properly guiding the methodological course of the study.

The second stage constitutes the cartographic part of the study, as the working area was studied in detail by analyzing a large variety of maps from different sources in order to generate the included maps. Thus, we have combined raw data from different national available servers or databases (catchment area, river network, settlement's location, geographical units, hill shade and terrain slope) to elaborate a general map of the studied area.

The third stage constitutes the first direct contact with the study area, namely going out into the field and collecting samples for analysis; this stage took place on December 14th, 2024. For this stage, four points for sampling were selected, namely: near Dobrin Peak – at an altitude of approximately 1500 m and at a significant distance from any village in that area; in the center of the village of Băișoara – a polarizing center during the heyday of the extractive industry in Romania; in the village of Surduc – on the outskirts of the former mining area, before reaching the Surduc gorge; and at the confluence of Iara and Arieș rivers. The coordinates of the points were recorded using Google Maps, then transferred to ArcMap 10.8 to create a map of their locations (fig. 2).

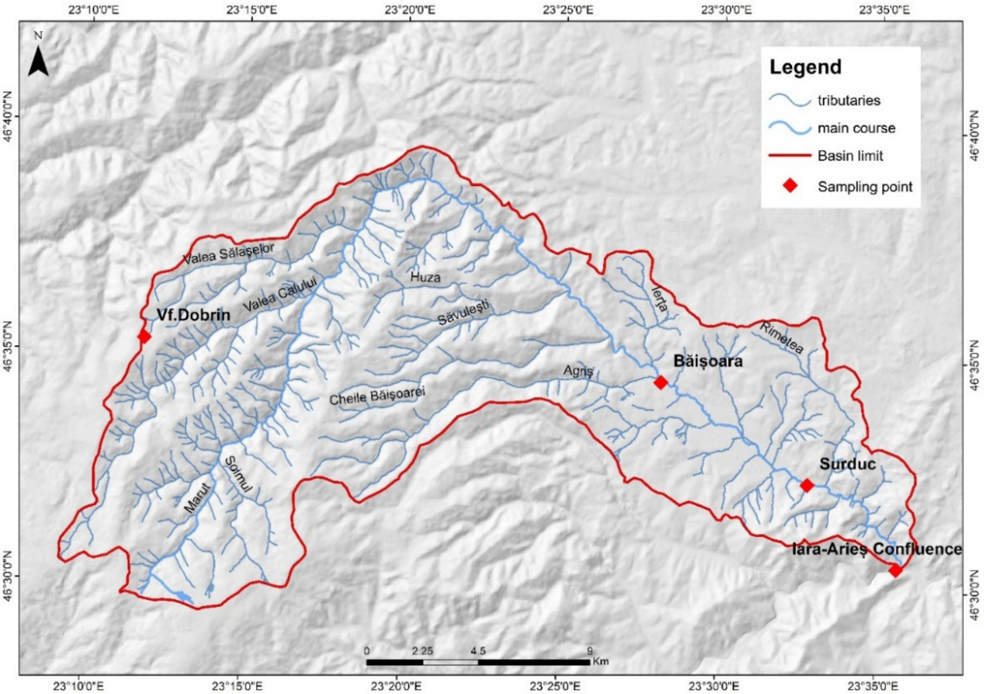

Fig. 2. Location of sampling points in Iara River basin
Source: the authors

Water samples were collected in 50 ml glass containers, stored at temperatures between 0-4°C, and then further analyzed in the laboratory of the Research Institute for Analytical Instrumentation from Cluj-Napoca (ICIA) to determine the concentration of heavy metals in the water. The following parameters were taken into account: Al, Cr, Mn, Fe, Co, Ni, Cu, Zn, As, Cd, and Pb.

3. RESULTS AND DISCUSSIONS

As a result of the sampling analysis presented in the table below, we can now say that at least in the measured points location' the actual concentrations of heavy metals are complying with the maximum acceptable concentration (MAC). Current legislation act that regulates the maximum concentrations allowed in rivers is the *Regulation on the classification of surface water quality in order to establish the ecological status of water bodies – No. 161 from February 2006*.

According to this regulation, water quality is classified on five quality classes, first one been considered the best, while the fifth the worst in respect with its quality and its possible use.

Table 1. Results of water samples analysis and compliance with standards regulation

No.	Metals	Heavy metal concentrations (µg/l)						
		Dobrin peak	**Băişoara**	**Surduc**	**Confluence**	**Moldovan, 2021***	**MAC** 1st class**	**MAC** 5th class**
1.	Al	1.4	1.0	1.8	4.5	79	-	-
2.	As	<1	1.1	1.5	1.5	2	<10	>100
3.	Cu	<1	2.0	1.3	2.4	94	<20	>100
4.	Cd	<1	<1	<1	<1	28	<0.5	>5
5.	Cr	<1	<1	<1	<1	23	<25	>250
6.	Fe	1.1	1.2	<1	1.4	37	<300	>2000
7.	Mn	<1	7.8	<1	<1	34	<50	>1000
8.	Ni	<1	2.8	<1	1.6	59	<10	>100
9.	Pb	<1	<1	<1	<1	69	<5	>50
10.	Zn	31.2	37.4	4.7	19.8	23	<100	>1000

**Moldovan, 2021*

***Regulation on the classification of surface water quality in order to establish the ecological status of water bodies – No. 161 from February 2006*

Source: the authors

The results do not reflect any exceedance of the legislation standards, but fluctuations in the maximum concentrations recorded at the sampling points in the lower basin, corresponding to the former mining area, can be observed. These variations may be associated with both natural processes of dilution and transport of substances in the riverbed and the possible remobilization of residual contaminants from sediments deposited during periods of mining activity. In addition, hydrological factors, such as seasonal flows or episodes of torrential rain, can temporarily influence the measured values, causing a redistribution of chemical elements from the soil and alluvial material to the water column. Therefore, although the levels do not exceed the permissible limits, the presence of these fluctuations indicates the persistence of a historical anthropogenic influence within the analyzed ecosystem.

Latest research deployed in the same area has been validating that the concentration of heavy metals tends to decrease in Iara catchment. A recent study (Moldovan *et al*, 2021), about water chemistry variables within Arieș catchment has found significant greater values for heavy metals concentration at the confluence of Iara River with its collector Arieș river. Thus, all ten indicators have shown values with two digits, except *Arsenic* which was in the same level with the values recorded in mid-December 2024. Comparing the values from that study with the regulation act, we notice in several cases the limits of first water quality class have been exceeded.

4. CONCLUSIONS

The Iara River basin is located at the intersection of mining, agricultural, and tourism activities. With a small population but a rich history, this unique area is characterized by a series of diverse occupational and ecological transformations; these transformations reflect the stages of Romania's political and economic evolution. During the communist regime, rapid industrialization meant that the study area underwent partial reconstruction in order to generate capital, resulting in a series of constructions such as quarries, tailings ponds and waste dumps, designed to maximize the efficiency of these activities to the detriment of natural environmental factors. Once these activities ceased, a difficult process of restoring the area began, marked by sustained efforts to rehabilitate the environment and restore the natural balance. This process is highlighted, for example, by the greening of the former tailings pond in Surduc, where recultivation and slope consolidation works have helped reduce the risk of erosion and heavy metal remobilization.

Although there are still vulnerable areas, especially where waste deposits have not been completely stabilized or vegetation is still in its early stages, analyses of heavy metal concentrations in the river show a decreasing trend. This reflects the effectiveness of the measures implemented by the authorities responsible for monitoring, managing, and rehabilitating the river basin, suggesting a trend towards improving environmental quality and a gradual reduction in historical anthropogenic influences. Although measured water quality parameters remained within legal limits during the study period, the coexistence of multiple pollution sources highlights the basin's vulnerability and the necessity for continuous monitoring and preventive environmental management.

Understanding the behavior of heavy metals in river systems, particularly their accumulation in sediments and biota, is essential for effective water resource management and environmental protection. Monitoring metal concentrations, controlling mining discharges, and implementing remediation strategies are critical steps to minimize bio-accumulation risks and safeguard both ecosystem health and the sustainable use of river water resources.

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