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Adriana ISVORAN[1,2*], Diana Larisa ROMAN[1,2], Daniela DASCALU[1,2]
Beatrice VLAD-OROS[1,2], Alecu CIORSAC[3], Laura PITULICE[1,2], Radojka JONOVIC[4]
Zoran STEVANOVIC[4] and Vasile OSTAFE[1,2]

HUMAN HEALTH EFFECTS OF HEAVY METAL POLLUTION IN THE CROSS-BORDER AREA OF ROMANIA AND SERBIA: A REVIEW

Abstract: This review illustrates the state of air, water and soil pollution with heavy metals resulting from mining activities in the cross-border area of Romania and the Republic of Serbia. It also emphasizes the possible human health effects that certain heavy metals can cause. The heavy metals that were identified as polluting the air, water, and/or soil in the area of interest are: As, Cd, Cr, Cu, Fe, Hg, Mn, Mo, Ni, Pb, and Zn. Acute or chronic exposure to these heavy metals may cause numerous human health effects as they affect numerous organs and tissues (gastrointestinal tract, liver, lungs, kidneys, bladder, central nervous system, reproductive system, etc.). The review shows that the pollution produced by both abandoned and active mines cannot be neglected and underlines the necessity of changes in the current mining practices so that mining operations will assure better protection for the environment and human health.

Keywords: mining activity, pollution, heavy metals, human health effects

Introduction

Mining plays an important role in the global economy and will continue to allow access to the metals and the minerals that are much needed for the development of technology and life. Over the last few decades, the gap between the economy and the mining industry has widened to the point that extracting the necessary minerals and metals has become unsustainable for the wildlife and ecosystems. The mining industry brings substantial economic growth and benefits to countries, generating revenues and creating workplaces. It is important to note, though countries with significant amounts of resources for mining activities have the potential to generate a sustainable development [1].

In recent years, mineral commodities, such as metals and fuels, have become increasingly required for agriculture, power generation, transportation, and

[1] Department of Biology-Chemistry, West University of Timisoara, Pestalozzi 14A, Timisoara, 300115, Romania, phone +40 256 592 634, fax +40 256 592 620, ORCID: AI 0000-0002-3068-2642, DLR 0000-0001-5212-4628, DD 0000-0002-0424-1245, BVO 0000-0001-7018-6750, LP 0000-0002-5991-6203, VO 0000-0003-1352-1115
[2] Advanced Environmental Research Laboratories, West University of Timisoara, Oituz 4A, Timisoara, 300086, Romania, phone +40 256 592 873
[3] Department of Physical Education and Sport, University Politehnica Timisoara, Traian Lalescu 2A, Timisoara, 300223, Romania, phone +40 256 403773
[4] Mining and Metallurgy Institute, Zeleni bulevar 35, 19210 Bor, Serbia (PAK 602002), phone +381 30 454 131, ORCID: RJ 0000-0002-8115-3134, ZS 0000-0001-5317-6884
[*] Corresponding author: adriana.isvoran@e-uvt.ro

communications. There is an increased demand for copper due to its multiple uses such as electrical equipment, refrigerators, car radiators, etc. Even though aluminium, titanium, steel and plastics are viable options for substitution, copper is the main resource used in many industries [2]. Copper mining does not produce only copper but a whole list of desired by-products (e.g. cadmium, arsenic, nickel, zinc and lead) with a wide range of applications such as farming, construction, electrical equipment and the metallurgic industry [3]. Even though these resources are being widely used in multiple industries, as every other large-scale harvest activity, mining resources comes with a great price for the human health and the environment. There are results of epidemiological studies that - revealed the fact that substances that are carcinogenic for humans and animals are affecting them at much higher rates in the areas - where mines are located [4].

It is already known that ore extraction and processing and metallurgic industries are the most environmental polluting sources. It is also commonly accepted that mining operations conduct to environmental damages and human health effects. Mineral Resources Data System [5, 6] reveals that in Romania there are 9 copper mines, three of them - are located in the cross border area: Baia de Arama (reserves of 16 million tonnes of ore grading 0.24 % copper), Sasca Montana (reserves of 12 million tonnes of ore grading 0.75 % copper) and Moldova Noua (500 million tonnes of ore grading 0.35 % copper, the second-largest copper reserve in Romania). The mining operations in all these mines are stopped, but the environmental damages are still present. One of the worst cases in this area is the Tausani-Bosneag pond, one of the three tailing ponds related to the former mining enterprise from the Moldova Noua. This tailing pond is placed between Moldova Veche town and Coronini village, Caras-Severin County. The three tailings ponds from Moldova Noua contain approximately 30 million m^3 of tailings covering an area of 130 hectares (ha) with an average height of 20-22.5 meters [7]. These tailings dumps are one of the main sources of environmental pollution of the surrounding areas due to the collected hazardous waste. To the best of our knowledge, until now, no green solutions have been in place or proposed for this area.

There are more than 15,000 inhabitants in the mining operation area near Moldova Noua [8] and their life is affected by pollution. The tailing pond is a source of pollution especially during windy periods and affects not only the Romanian city of Moldova-Noua and nearby villages, but also the touristic city of Veliko Gradiste, in Serbia, giving the pollution phenomena a cross-border character [7]. There are about 17,000 inhabitants in Veliko Gradiste and we must also take into account the tourists visiting this area [9]. Consequently, more than 32,000 persons are affected by pollution created by the tailing ponds located near Moldova Noua. The 2019 annual report concerning the state of the environment in Romania (last one that was released and is publicly available) shows that 24,432 ha of soil is polluted by mining operations (of which 10 % is situated in the Western part) and 6,639 ha of soil is polluted with heaps, tailings ponds, sterile deposits from floating and warehouses waste, of which 23.2 % represents the area of the three above mentioned mines [10]. The same report reveals that chemical pollution affects about 0.9 million ha of soil, pollution with heavy metals (Cu, Pb, Zn, Cd) and sulphur dioxide being the most aggressive. Furthermore, the particles carried by the wind affects 0.363 million ha of soil. There are about 84,000 ha of cultivated land in Caras-Severin County. About 2,500 ha situated in Moldova Noua area are polluted due to mining operations, 50 % being land cultivated with cereals, 24 % with maize, 18 % with oily plats, 9 % with potatoes, 2 % with vegetables [11]. The 2017-2022 Air Quality Management Plan of the

Caras Severin County highlights that storage of waste resulting from the ore extraction and the tailing ponds from Moldova Noua are supplemental emission sources of heavy metals pollution. This report also emphasizes that the percentage of urban population with the health affected by the exceeding of the limit values of the environmental quality index, constantly increased from 2014, passing over 25 % in 2018.

In Serbia, the most important copper mines are located in Bor District. There are two mines with open-pit exploitation (reserves Veliki Krivelj and Cerovo), one underground mine (Jama mine), two facilities for the preparation of minerals (Mineral processing plants in Krivelj and Bor), one non-metals mine (Open Pit and Lime Production Plant in Zagradje) and Exploration Facility. Certified geological reserves amount to approximately 3 billion tonnes of ore and they contain approximately 12 million tonnes of copper. Confirmed reserves, with the average annual exploitation of 26 million tonnes of ore, guarantee the copper production for the next 100 years. In the immediate vicinity of Bor, there are huge quantities of open-pit overburden and flotation tailings, which contain hazardous and dangerous materials such as copper, nickel, arsenic, zinc, antimony, mercury, chromium, and bismuth [12]. The 2010-2019 Waste Management Strategy of the Republic of Serbia illustrates that 40,000 ha of soil is polluted by mining operation, of which 7 % are situated in Bor Region. Having on mind that total available arable soil in Serbia is 3.7 million ha [13], mining activities impacted slightly more than 1 %. Most of the copper production of Serbia is located in Bor District in two municipalities, Bor and Majdanpek, and the total polluted surface is 2,784 ha. This means that 0.79 % of the surface of Bor District is polluted by mining works. During the period 1933-1970, the flotation tailing completely degraded the valley of Bor River that flows through the village near Bor. Along the entire length of the Bor River, up to its discharge into the Krivelj River, about 70 ha of coastal land is polluted by the flotation tailings. More than 2,000 ha of the most fertile coastal land of the above rivers are threatened by pollution from the flotation tailings. In addition, the Bor River is constantly polluted by wastewater resulted from draining through the flotation tailings and open-pit overburden [14]. The project covered area's most impacted by mining activities. This area includes Bor and Majdanpek cities where are located mines and villages in downstream of Borska, Kriveljska and Pek Rivers up to Danube. Based on 2011 population Census [15], in Bor and Majdanpek live almost 68,000 inhabitants, including urban and rural areas while in villages, in downstream of polluted rivers by mining, live around 20,000 peoples. All of those people experiencing some kind of pollution by mining activities.

The two areas of the Romania-Serbia cross-border region, that are affected by pollution due to mining operations, make the subject of this study and are illustrated in Figure 1.

Mining operations can have a huge local impact on the environment and population. They produce many types of air, water and soil pollutants that may ultimately affect human health. In Serbia and Romania, copper mineralization is mostly porphyry type of deposits containing chiefly sulphur minerals associated with pyrites that are one of the main sulphuric acid generators in contact with the atmosphere. Main mining wastes generated during the treatment of those kinds of copper deposits and which cause the major environmental pollution are: tailings generated during flotation processes containing a variety of metallic and non-metallic minerals, spent ores consisting of the material remaining in either dump or heap leach piles when leaching ceases, acid rain resulting from the combination of rain and SO_2 causing damage to crops, trees and buildings for many

miles downwind [16]. Furthermore, the disposal of an enormous volume of tailings dumps poses a serious risk to the surrounding environment. It produces air pollution due to air-dried out tailings, erosion of the tailings with the potential of valuable land degradation, and leaching of soluble inorganic potentially toxic chemical species (Cu, Ni, Pb, Zn, Cd, and Cr) occurring in a variety of minerals present in the tailings dump [17]. In the area of disposal of the mining waste containing sulphide-rich minerals, the acid mine water is generated. Acid rock drainage also occurs naturally within some environments as part of the rock weathering process, but is exacerbated by large-scale earth disturbances characteristic of mining and other large construction activities, usually within rocks containing an abundance of sulphide minerals [18].



Fig. 1. Map illustrating the cross border area of interest in this study being affected by pollution with heavy metals due to mining operations

Taking into account the complexity of the pollution produced by mining operations, adverse health effects of those leaving near, downstream or downwind of mines can be substantial. Most of the time, similar pollutants are also produced by some industries (e.g. metal processing, wire production, etc.), heating plants, or even traffic and households. Their accumulation in the environment may also represent a serious hazard to human health [19].

This review aims to illustrate the possible human health effects caused by air, water and soil pollutants that were registered in the cross-border area of Romania and Serbia and mostly resulting from the mining operations.

Heavy metals as air pollutants emitted from mining operations in the cross-border area of Romania and Serbia

Air can be polluted by particles of various composition also known as particulate matters (PM). Airborne particles with a diameter of less than 10 micrometres (μm, PM10) can pass through the nose and throat and penetrate the alveoli conducting to inflammations and intoxications [20]. Those most susceptible to severe health problems from air pollution are people with cardiovascular and respiratory diseases, children, elderly and asthmatics.

Wind of various intensities disperses the dust. As the dust of the mining tailing dumps regions may contain SiO_2 and heavy metals, it may cause serious effects on human health. In the region of Moldova Noua, there is a strong wind, called Cosava, blowing from the N-E and S-W, sometimes reaching 25-30 m/s [21]. Another wind, called Gorneacul, is specific to Moldova Noua depression and blows in the NE-SW direction, with a regular intensity of 27 m/s [22]. This wind spreads and transports the dust of tailings from Moldova Noua over the Danube River to Serbian neighbourhoods, producing trans-boundary pollution. These data illustrate the risk of air pollution especially in the area adjacent to the tailing ponds in Moldova Noua, but air pollution is also observed in the cross border area of the S-W of Romania. Recent measurements made in the region of Moldova Noua (Romania) under windy conditions revealed that the daily limit values for PM10 concentrations (according to Law 104/2011 [23], Directive 2008/50/EC Ambient Air Quality and Cleaner Air for Europe [24]), were exceeded in the areas adjacent to the surface source [25]. The first step in managing air quality issues is to assess air quality. The most commonly used way to do this is to implement a fixed measuring point network that ensures an appropriate spatial-temporal resolution. In the Moldova Noua area, there are two stations: CS3 station (located in Moldova Veche, on the side of the road to Moldova Noua, which came into operation in 2009) and CS5 station (located in Moldova Noua, which came into operation in 2018). These stations assess the level of air pollution without distinguishing between the contributions given by tailing dumps, traffic, residential heating systems, activity of small enterprises, or construction works. The annual average values measured at CS3 station for air pollution in 2017-2019 period are given in Table 1 [26]. The recorded values do not exceed the maximum acceptable concentrations. In the 2017-2019 period, CS3 Moldova Noua station occasionally recorded values of over 100 $\mu g/m^3$ for the hourly average for SO_2, without exceeding the alert threshold (500 $\mu g/m^3$). The laboratory of the Caras-Severin Environmental Protection Agency has the certainty that practically the only source of sulphur dioxide nearby is the Bor Mining and Metallurgy complex in Serbia, located about 80 km south of Moldova Veche that generates SO_2 during the smelting of copper concentrates. It also underlines the presence of the trans-boundary pollution. With regard to PM10 concentrations, the daily limit value (50 $\mu g/m^3$) was exceeded 6 times at CS3 and 20 times at CS5, in most cases due to domestic heating and the spread of anti-skid materials in winter, but also to the resuspension of dust by the wind (CS5) [26].

Table 1

Annual average values measured in 2017-2019 for air pollution at Moldova Noua, Romania [26]

Pollutant	MAC*	2017 registered value	2018 registered value	2019 registered value	
		CS3	CS3	CS3	CS5
SO_2 [μg/m^3]	NA	9.50	13.72	9.60	NA
PM10 [μg/m^3]	40.00	24.92	19.20	19.83	NA
Pb [μg/m^3]	0.50	0.02	0.02	0.06	0.01
Cd [ng/m^3]	5.00	0.77	1.35	0.44	0.47
As [ng/m^3]	6.00	0.94	1.35	0.87	1.33
Ni [ng/m^3]	20.00	1.46	5.62	2.15	2.20

*MAC - Maximum Acceptable Concentration according to Romanian Law 104/2011 [23]; NA - not available

The main sources of air pollution in Bor are metallurgy (smelter), mining (open pits, flotation tailings, and other mining wastes), industrial facilities and heating plant. The continuous air monitoring conducted to identify the values of suspended particles gave the results presented in Table 2 [27].

Table 2

Air pollutants identified in the region of Bor, Serbia [27]

Type of identified particle	MAC*	Measured value
SO_2	350 μg/(m^3 · h)	up to 3000 μg/(m^3 · h)
PM10	50 μg/(m^3 · day)	up to 150 μg/(m^3 · day)
Pb	1 μg/(m^3 · day)	up to 3 μg/(m^3 · day)
Cd	5 ng/(m^3 · year)	up to 50 ng/(m^3 · month), in average 7 ng/(m^3 · year)
Ni	20 ng/(m^3 · year)	up to 100 ng/(m^3 · month), in average 15 ng/(m^3 · year)
As	6 ng/(m^3 · year)	up to 350 ng/(m^3 · month), in average 150 ng/(m^3 · year)

*MAC - Maximum Acceptable Concentration according to Regulation on conditions for monitoring and air quality requirements [28]

In Serbia, the level of air pollutants in the mining operation area is usually much higher than the maximum admissible concentrations. The effects of these air pollutants on human health are further presented.

Heavy metals as water pollutants emitted from mining operations in the cross-border area of Romania and Serbia

One of the most impacted resources by mining industry is water system. According to the scientific literature, information regarding the water quality monitoring and water pollution with heavy metals in the area of the former mining operation near Moldova Noua is very limited. Similarly, this type of data is also missing from the reports of Romanian Environmental Agency, branch Caras-Severin for 2018 and 2019.

One study regarding the assessment of water quality was performed by Anghel et al. [29] using water samples collected in 2017 from the Bosneag river, a direct affluent of Danube, with the confluence point being situated near the tailing ponds in Moldova Veche.

The presence of six heavy metals (Pb, Cd, Ni, Cr, Cu, Zn) was assessed and data are presented in Table 3. Furthermore, within their study, Anghel et al. have evaluated the state of pollution of the sediment with heavy metals and this information is also presented in Table 3.

It is also worth mentioning that surface mining activities pollute atmospheric precipitations. A study performed between 2014 and 2017 on rainwater samples collected in Moldova Noua illustrated the presence of heavy metals: Pb, Ni, As, Cd [30]. Statistical results of all analysed concentrations in rainwater samples collected at this point are also illustrated in Table 3.

Table 3

Mean concentrations of heavy metals in water and sediment samples from the Bosneag River [29, 30]

Heavy metal	Mean value of the metal in water	MAC*	Mean value of metal in sediment	MAC*	Mean value of the metal in rainwater
	[µg/L]	[µg/L]	[mg/kg]	[mg/kg]	[µg/L]
Cd	2.10	1.00	1.60	0.80	8.84
Cr	0.50	2.50	49.80	100.00	-
Cu	16.30	1.30	191.70	40.00	-
Ni	5.20	2.10	23.90	35.00	1.87
Pb	2.40	1.70	116.10	85.00	2.77
Zn	1249.00	NA	365.70	150.00	-
As	-	NA	-		0.25

*MAC - Maximum Acceptable Concentration according to Order of the Ministry of Environment and Water Management 161/2006, for the approval of the Normative on the Classification of Surface Water Quality to establish the ecological status of the water bodies [31]; NA - not available

The authors concluded that the copper levels determined in the collected water samples surpassed the maximum admissible concentration as set by Order no. 161/2006 [31] regarding the legislative framework concerning the chemical status of monitored surface water. In the sediment samples, cadmium and zinc were found to have concentrations above the maximum standard of quality. By comparing the values presented in Table 3, it was observed that the concentration of heavy metals in the tested surface waters decreased in the following order: Zn > Cu > Ni > Pb > Cd > Cr, while for the sediment samples, the concentration distribution was as follows: Zn > Cu > Pb > Cr > Ni > Cd [29].

Concerning the rainwater, among heavy metal content, Cd was the most abundant element, followed by Pb, Ni and As. From this point of view, quantitative measurement of wet deposition allows the identification of the relative contributions of the different natural and anthropogenic sources [32]. In the case of heavy metals at Moldova Noua, Cd registered the highest wet deposition rate, 0.04 kg/(ha·year), Pb registered 0.02 kg/(ha·year), whereas Ni and As had insignificant wet deposition fluxes [30]. The toxicity potential (TP) of rainwater and consequently of heavy metals in wet deposition can be computed by dividing the registered concentrations to the recommended upper limits for metal concentrations and a value higher than 1 reveals potential toxic deposition [33]. In the case of wet deposition registered at Moldova Noua, the computed TP values are 7.49 for Cd, 1.3 for Pb, 0.66 for Ni and 0.18 for As [30]. These values suggest the potential risk of Cd and Pb for human health if the rainwater is used in households.

We have considered well water samples collected from wells located in villages situated around the mine area in Moldova Noua. The content of heavy metals in these

samples was analysed using atomic emission spectrometry with inductively plasma (ICP-OES, Spectro Arcos) and the results are presented in Table 4.

Table 4

Concentrations of heavy metals in the well waters in villages situated arround the mine of Moldova Noua

Location of well / Heavy metal content [µg/L]	Well from village of Coronini	Well from village of Moldova Veche	Well from village of Macesti	Well from city of Moldova	MAC* [34] [µg/L]
Cu	39.70	43.50	29.80	25.80	100
Fe	22.60	99.70	43.20	54.90	200
Zn	< 6.20	16.10	< 6.20	< 6.20	5000
Cd	< 0.14	< 0.14	< 0.14	< 0.14	5
Cr]	< 1.70	7.40	< 1.70	< 1.70	50
Pb	< 2.10	< 2.10	< 2.10	< 2.10	10
As	< 2.10	< 2.10	6.40	< 2.10	10
Ni	< 3.60	< 3.60	< 3.60	< 3.60	20
Mn	< 1.60	2.50	< 1.60	< 1.60	50
Mo	< 2.30	< 2.30	< 2.30	< 2.30	50

*MAC - Maximum Acceptable Concentration according to Order of the Ministry of Environment and Water Management 161/2006, for the approval of the Normative on the Classification of Surface Water Quality to establish the ecological status of the water bodies [31]

All the registered heavy metals have a content lower than the maximum admissible concentration [34].

Table 5

Concentrations of heavy metals in the water of the most polluted rivers in the region of Bor, Serbia [35]

Pollutant	Registered concentration	MAC*
	[mg/L]	[mg/L]
Cu	5.00-50.00	0.100
Pb	~0.50	0.050
Zn	~ 2.00	0.200
Cd	0.05-0.50	0.005
Ni	0.50-2.50	0.050
Se	0.10-0.20	0.010
As	0.50-2.50	0.050
Fe	0.30-1.50	0.300

*MAC - Maximum Acceptable Concentration according to Regulation on hazardous substances in waters [36]

The main rivers in Bor mine area are Bor, Krivelj, Ravna, Bela and Timok. There alsoare small river creeks and many acid mine drainages (AMD) resulting from mining operations flow into the mentioned rivers. According to Serbian legislation, most of the mentioned rivers belong to class I/II of pollution. However, after passing the mines facilities they become very polluted mostly by heavy metals that are mobilized (leached) from the surrounding mining wastes. Table 5 illustrates how many times the concentration of pollutants in the most polluted creeks and rivers is higher compared to maximum allowed concentration (MAC) for the I/II class [35]. One of the most polluted water is the waste metallurgical water originating from the Bor smelter and containing a variety of heavy metals.

Data presented in Table 5 illustrate that the concentration of heavy metals in the most polluted rivers in the region of Bor (Serbia) are between 10 and 100 times higher than MAC. We must underline that, besides these pollutants, water in most rivers smells, has a pH value in the acid range and contains suspended matters. These factors affecting water quality will be considered in another study.

In Republic of Serbia during 2020 [37] 677 million m^3 of waters were intake for the needs of drinking water supply from which 63.5 % are groundwater and spring water, 26.6 % are from watercourses and 9.9 % are water from lakes and reservoirs. From the other side, in same year 3976 million m^3 of waters were intake for the needs in industrial sectors from which 99.6 % were waters from own water intake (98.7 % of surface water and 0.9 % of groundwater) and 0.4 % from public water supply. From total quantities, the largest industry consumer is electricity production and supply plant (3877 million m^3) while manufacturing industry spent 83 million m^3 and mining industry 17 million m^3. However, it is important to mention that mining industry recorded growth of 21.6 % comparing to previous year. Out of a total of 104 million m^3 of wastewater in industry, 47.2 % were waters discharged from the electricity production and supply plant, 39.5 % from the manufacturing sector and 13.3 % from the mining. Out of total waste waters, 28 million m^3 had some kind of treatment from which 1 million m^3 from mining industry, 25 million m^3 from manufacturing industry and 2 million m^3 from electricity production and supply plants [38]. Based on above values it is clear that industry have a greatest impact on waters quality. In Table 6 are presented results from the analytical analyses of well waters in Vilage Slatina that is located on downstream of Bor river next to Bor mine. The content of heavy metals have been determined using atomic emission spectrometry with inductively plasma (ICP-OES, Spectro Arcos).

Table 6

Results from the analytical analyses of well waters in Vilage Slatina

Element/ Unit	**Range (min-max)**	**Median**	**MAC for drinking water**	**Content > MAC* [%]**
Mn [mg/L]	< 0.006-1.6000	0.052	0.050	**30.00**
Cu [mg/L]	< 0.005-0.2000	0.039	2.000	0.00
Zn [mg/L]	< 0.005-0.4600	0.125	3.000	0.00
As [µg/L]	< 2.1-15.0000	6.800	10.000	**10.00**
Ni [µg/L]	< 0.0070	-	0.020	-
Pb [mg/L]	< 2.1000	-	10.000	-
Cr [mg/L]	< 0.0050	-	0.050	-
Mo [mg/L]	< 0.0070	-	0.070	-
Hg [mg/L]	< 0.0005	-	0.001	-
SO_4^{2-} [mg/L]	108.7000-1020.6000	385.95	250.000	**80.00**

*Content > MAC (%) represent the percentage value of the number of the samples from the total number of taken samples that had measured values over MAC

As presented on Table 6 values over MAC for drinking waters were recorded for Mn in 30.00 % of samples, for As in 10.00 % of samples and for SO_4^{2-} in 80.00 % of samples. These values indicate pollution by mining with increased acidity of well waters. Maximum recorded value for As was 1.5 higher than MAC. However, median value is even lower than MAC which indicate fluctuation of content during the year. Mn is also recorded in extreme case with value which is 32 times higher than MAC but with median value close to

MAC. Maximum increased acidity of well waters was 4 times higher than MAC while median value were less than 2 times higher than MAC.

Heavy metals as soil pollutants emitted by mining operations in the cross-border area of Romania and Serbia

There are only a few published studies in specific literature related to soil pollution in the region of Moldova Noua, Romania. Earlier studies concerning the soil pollution with heavy metals were done around the tailing ponds Tausani-Bosneag, near Moldova Noua. These studies emphasized the presence of various heavy metals in the sterile and soil samples near the tailing ponds, as presented in Table 7 [25, 39, 40].

Table 7

Concentrations of heavy metals that were identified in the sterile from the tailing ponds Tausani-Bosneag (Moldova Noua area, Romania) and soil samples collected in the areas near the tailing ponds

Identified heavy metals	Concentration [mg/kg]	MAC* [mg/kg]	Reference
As	79.00	5	[39]
Cd	0.407 0.28-1.10	1	[25] [42]
Cr	87.88 22.23-27.03	30	[39] [42]
Cu	1772 173.4 362.87-1048.17	20	[39] [25] [42]
Mo	107	2	[39]
Ni	51 40.85 17.62-22.00	20	[39] [25] [42]
Pb	88 24.74 18.46-44.85	20	[39] [25] [42]
Zn	543 95.90-141.23	100	[39] [42]
Mn	401 621.85-660.75	900	[39] [42]
Hg	0.155	0.1	[25]

*MAC according to Romanian Law 104/2011 [23]

The differences between the concentrations presented in Table 5 are due to the fact that samples were collected from distinct points and in different meteorological conditions (temperature, atmospheric pressure, wind velocity, precipitations). Even if there are differences in the values of the measured concentrations of heavy metals, they reveal that most of these metals are found in soil samples in concentrations exceeding the maximum level admitted by the law. When their concentrations in the soil are above admitted limits, heavy metals are toxic for most plant species and it explains the poor presence of vegetation on the investigated tailings ponds [41]. These metals have been observed to be present (accumulated) in different parts of some aromatic plants found along the bank of the Danube River in the western Banat. It underlines that the wind spreads and transports the tailing dust from Moldova Noua over the region and it contributes to the extension of soil pollution to a wider area [40].

Beside waters, Bor mine has also a strong impact on air and soil especially because of copper smelter located near city centre. The main sources of soil pollution in Bor are the huge areas with mining operations with many open-pits and flotation tailings as well as the metallurgic industry activities. As a result of these activities, the most fertile lands in the valleys of the Borska and Timok rivers were destroyed. Due to the smelting of copper concentrate, a high concentration of the sulphur dioxide caused acidification of the soil, destruction of vegetation and erosion. Increased soil acidity is observed in almost all villages around Bor. It is estimated that in the surrounding of the 7 villages that are situated in this area, there are around 25,500 ha of land that is destroyed. It covers 60.6 % of the agricultural land of the municipality of Bor. Moreover, it is estimated that in the area around Bor mine, about 2 billion tonnes of mining waste are dumped conducting to a continuous soil pollution. Heavy metals are present in almost all parts of Bor municipality but the most polluted area is in S-E and eastern area of Bor. Table 8 illustrates the contents of heavy metals in some soil samples collected in the surrounding area of Bor [43].

Table 8

Content of heavy metals in some soil samples collected in the surrounding area of Bor, Serbia [43]

Heavy metal	Content	MAC*
	[mg/kg of soil]	[mg/kg of soil]
Cu	> 12000	110
Ni	> 50	44
Pb	> 1300	310
Zn	> 7000	430
As	> 1000	42

*MAC according to Regulation on allowable quantities of hazardous and harmful substances in the soil and methods for their investigation [44]

The heavy metals found in soil reach the human organism along with consumed vegetables that absorb them from the soil or / and along with the dust, being deposited on the leaves of some plants that are consumed [45].

Effects of heavy metals pollution on human health

Data presented in above sections illustrate that pollution of air, water and soil with heavy metals due to the mining operations in the cross-border area of Romania and Serbia mainly refers to As, Cd, Cr, Cu, Fe, Hg, Mn, Mo, Ni, Pb, and Zn. Quite similar results have been registered for soil pollution produced by iron ore mines in Nizna Slana (Slovakia) [46].

The effect of heavy metals on human health is determined by numerous characteristics, including absorption, distribution, metabolism, and interactions with physiological processes. In low concentrations, some of these metals are beneficial for human organism. Copper, for example, is essential in cellular respiration, neurotransmitter function, free radical defence [47], antioxidant defence and immune function [48]. Zinc has an important role for the activity of more than 70 enzymes, acts as an antioxidant and is required for insulin secretion [49]. Iron participates in various metabolic processes, including oxygen transport, deoxyribonucleic acid synthesis, and electron transport [50]. The health effects of heavy metals also depend on the form of metal (metallic, inorganic or organic compounds containing the metal), the amount of metal, the characteristics of the exposed person (age,

health), how long the exposure lasts, and the way of exposure. The main routes of human exposure to heavy metal are ingestion, inhalation and dermal exposure. Furthermore, taking into account the duration, exposure is classified as acute (less than 14 days), intermediate (between 15 and 364 days), and chronic (at least 365 days) [51]. Taking into account the factors above, the effects of heavy metal exposure can be very severe, subtle, or may not occur at all. In the following, we illustrate both the human requirements of some of these metals with their biological roles and the human health effects produced by heavy metals polluting the air, water and soil in areas of mining operations from the cross-border region of Romania and Serbia. We must underline that we do not present the mechanisms of toxicity of these metals, we only focus on their toxicological endpoints.

Unfortunately, in Romania, the National Institute of Public Health or the Caras-Severin Health Directorate have never conducted a study in the last 25 years on the impact of pollution on the health of inhabitants in the Moldova Noua area. Health report in Romania in 2019 illustrated that environmental pollution with PM is a risk factor for 16 % of Romania's population, especially for those living in areas with high level of pollution [52]. In an interview on the national television station in April 10, 2020, doctor Ioan Lor, from the City Hospital of Moldova Noua, admitted that the cases of cancer have doubled, especially the lung cancer, but also the cases of respiratory diseases.

The results of a pilot study conducted by the Serbian Environmental Protection Agency on the impact of industrial pollution on the health of the population in Bor, show that the inhabitants of this city are significantly at greater risk of getting and dying from cancers and skin tumours more than from other diseases. Among the results of the pilot study conducted during 2018 and 2019, it is stated that a significantly higher risk of lung cancer was registered in both men and women in Bor. It has also been observed that higher risk includes colon and rectal cancer, leukemia, kidney, bladder, thyroid, pancreas, Hodgkin's and non-Hodgkin's lymphoma. Due to diseases of the circulatory system, digestive and respiratory, as well as urogenital diseases, it has been noticed that there is a higher risk of mortality in Bor in almost all groups [53]. Dr. Svetlana Dimitriev, oncologist General Hospital in Bor, in an interview for the newspaper "Novosti" said that there is a continuous increase in the number of patients with malignant diseases in the Bor municipality.

Arsenic

Arsenic (As) is a common element in the crust of the Earth, it is toxic and has not a biological role for humans [54]. It is a metalloid revealing both metallic and non-metallic chemical characteristics, existing in nature in several states of oxidation, the arsenates As(V) prevailing in the oxidizing conditions and arsenites As(III), prevailing in the reducing conditions. The As(III) is more toxic than the As(V) as As(III) is more water-soluble (is the dominant arsenic species in groundwater), has an increased mobility and illustrates severe effects on human health [55]. The human exposure to arsenic occurs by ingestion (mainly by drinking contaminated water) but also through inhalation and skin contact, mining activity being the predominant source of arsenic pollution [56]. There also is a natural presence of high levels of arsenic in drinking water due to geological characteristics [57]. Arsenic is absorbed by ingestion, inhalation, contact with mucous membranes or skin penetration, is distributed through the bloodstream to various organs (liver, kidneys, lungs, bladder) and muscle and nerve tissues, the greatest accumulation of inorganic arsenic occurring in the liver [58]. Arsenic induces the formation of reactive oxygen species (ROS) and the exposure deregulates several cellular processes at the

molecular level: DNA repair, epigenetic regulation, normal gene expression, proliferation and apoptosis resistance [59]. It is commonly known that arsenic exposure may cause multiple human cancers (liver, lung, skin, kidney, bladder and prostate). The most common diseases caused by chronic exposure to arsenic being lung, skin and bladder cancer [56] and the references therein. Some of these health effects have been also observed in the investigated areas: lung and bladder cancers, skin tumours [53].

Copper

Copper (Cu) has important roles in the metabolic processes of the human body [54] being an essential element required for haemoglobin synthesis, absorption of iron, and cardiovascular integrity. The recommended daily intake values for copper range from 900-1700 μg for men and 900-1500 μg for women [60, 61]. In excess, copper may lead to acute toxicity.

Copper is one of the heavy metal found abundantly on the Earth's crust and also a major pollutant occurring both naturally and anthropogenically, major anthropogenic sources including industries and mining drainage [62]. Human exposure to copper is similar to other metal ions, copper being ingested with vegetables that extract it from soil solution via roots or by copper-contaminated water and via the inhalation of particulate matter. Having a high density, copper is less mobile in soil and tends to accumulate and persists for many years due to its low mobility and solubility [63]. In soil, copper is found in inorganic forms (around 80 %) as oxides and sulphides that are insoluble and reveal low phytoavailability and as hydroxyl and carbonate forms (about 20 %) that are generally plant-available [64]. Copper particles in ambient air and especially copper in ultra-fine particulate induces reactive oxygen species in biological tissues causing adverse health effects [48, 65]. Copper is absorbed in the stomach and duodenum and is transported to the liver, distributed within hepatocytes and exported to the blood and is then distributed to the various organs. Concerning human health, the toxicity of copper is relatively low compared with other heavy metals, but excess copper accumulation in subjects following high-dose chronic exposure and into sensitive populations results in hepatic cirrhosis with jaundice, haemolytic anaemia, and degeneration of the basal ganglia, cardiotoxicity (hypotension, tachycardia, tachypnea) gastrointestinal disorders (ulcerations, mucosal acute haemolysis and haemoglobinuria), nephropathy (azotaemia, oliguria) and central-nervous-system manifestations (dizziness, convulsions, lethargy, headache, stupor, coma) [47, 66]. These health effects were not registered in the investigated areas.

Cadmium

Cadmium (Cd) is one of the most toxic and mobile elements widely distributed in the environment coming from both natural and anthropogenic sources. Important anthropogenic Cd sources include mining (usually wastewater), industry, and waste management activities [67]. Cadmium has no biological roles in animal organisms [54]. Cadmium pollution is observed in soil (by contamination of irrigation water by mining activities) and groundwater. The primary route of contamination with cadmium is through ingestion (through vegetables due to high mobility in the soil-plant system) but inhalation was also observed [68]. Once entered into the human body, cadmium accumulates to a high level in several organs [69]. Cadmium exposure is usually associated to renal tubular dysfunction, osteomalacia and osteoporosis as a result of competition with calcium [70], endocrine system disruption [71], glucose metabolism disorders [72], prostate, kidney,

bladder, breast and lung cancer [69, 71], cerebral infarction and cardiac failure [57]. Bladder, kidney and lung cancer are the human health effects that were registered in the investigated areas [53].

Chromium

Chromium is one of the most common elements in the Earth's crust and seawater. It is found in the environment in several oxidation states: metallic (II), trivalent, Cr(III), and hexavalent, Cr(VI). There are controversial results published in specific literature concerning the effects of chromium. Some studies have indicated that chromium supplementation had improved the glucose metabolism and the serum lipid profile, and had increased muscle gain and fat loss associated with exercise, but other studies have indicated little or no benefit of chromium on the above-mentioned effects [73]. Trivalent chromium is essential for a good health if ingested in small amounts and it is found in foods and dietary supplements [73]. Chromium uptake depends on its oxidation state and solubility, the Cr(III) is mainly absorbed by ingestion and Cr(VI) is readily absorbed by both inhalation and ingestion. An adequate intake of chromium is 35 μg/day for young men and 25 μg/day for young women [74]. Ingestion of chromium in all states is due to food and drinks consumption, accidental swallowing of contaminated water or contaminated soil, gastric juice reduces hexavalent chromium to trivalent chromium [75]. Once absorbed, chromium is distributed to various tissues of the body but appears to be most concentrated in the kidney, muscle, and liver [76].

Chromium proved to be very toxic both when ingested, inhaled and by dermal contact. When ingested or inhaled, Cr(VI) seems to be more toxic than trivalent chromium but it is unstable in the human organism being reduced to Cr(V), Cr(IV) and Cr(III) [77]. The reduction of Cr(VI) to Cr(III) conducts to the formation of reactive intermediates that produce cytotoxicity, genotoxicity and carcinogenicity [78]. Both in vitro and in vivo studies have illustrated that Cr(VI) is able to induce oxidative stress through enhanced production of reactive oxygen species resulting in several types of deoxyribonucleic acid (DNA) lesions, gene mutations and inhibition of macromolecular synthesis. Furthermore, chromium affects different components of the immune system and may conduct to immunostimulation or immunosuppression [78]. Acute inhalation of Cr(III) salts or Cr(VI) produce nasal injuries, hypersensitivity reactions and chronic exposure to these pollutants conducts to nasal ulcerations, asthma, possible renal disorders and lung cancer [75, 77, 79]. Dermal exposure may be due to swimming, bathing/showering, or contact with contaminated water and / or soil. Inhalation of hexavalent chromium (usually found as CrO_3) from dust and aerosols is also an important route of exposure. Acute dermal exposure produces contact dermatitis, but chronic exposure may conduct to deep skin ulcerations [77]. In the investigated areas, renal disorders, lung cancer, respiratory and skin diseases were registered [53].

Iron

Iron is an essential component of every living organism as it participates in oxygen transport, electron transport and DNA synthesis [80]. However, its concentration in the human organism must be regulated because iron can form free radicals and, if found in excessive amounts, it can lead to numerous disorders: anaemia to iron overload, neurodegenerative diseases [50] and genetic and metabolic diseases [81]. There are two forms of dietary iron: heme (usually found in meat and sea food) and nonheme (found both

in vegetables and meat). Recommended daily intake of iron varies between 0.27 and 18 mg, depending on age and gender, pregnant women needed more iron, up to 27 mg [74]. The main routes for exposure are ingestion and inhalation. Acute exposure by drinking water contaminated mainly with iron exceeding the permissible limits conducted to liver cirrhosis [82], liver cancer, diabetes, infertility, and diseases related to the heart (hypotension, shocks, lethargy, tachycardia), metabolic acidosis, central nervous system disorders [77, 83], and in case of chronic exposure it may lead to death [77]. Air polluted with PM containing iron may conduct to increase in acute respiratory infections [84] and lung function abnormalities (sideroses, lung cancer) as iron oxides found in dust are potential contributors to inflammation in the human lung [85, 86]. Furthermore, the oxidation of iron conducts in generating hydroxyl radicals (OH-). These free radicals can react with biological molecules (proteins, DNA) damaging them and to induce an oncogenic effect in the colon [87]. Not at last, Fisher Material Safety Data Sheet for iron [88] illustrates that: (i) exposure to particulates or solutions containing iron may cause eye injuries (conjunctivitis, ulceration, corneal abnormalities), skin irritation, gastrointestinal disorders (gastrointestinal irritation, nausea, vomiting, diarrhea; (ii) acute toxicity due to exposure to iron may include weakness, shock, cyanosis and acidosis; (iii) chronic exposure may lead to liver and lung damages; (iv) repeated exposure may cause diabetes, pancreatic damage, and cardiac abnormalities. Among these effects, lung cancer has been observed to appear frequently in the investigated areas [53].

Lead

Lead (Pb) is the most toxic element that is present in the environment as a result of both natural and anthropogenic sources [89]. It is not necessary for human health as it is not involved in biological processes and there is no level of exposure to lead that does not conduct to harmful effects. Exposure of human populations to environmental lead is due to industrial activities, lead processing, mining and smelting activities [90]. It was shown that the extensive processing of lead ores released about 300 million tonnes of lead into the environment, mostly within the past 500 years [91]. The primary routes of lead exposure are through ingestion and inhalation [92]. Environmental lead may be bioavailable for humans after consumption of plants and animals that have accumulated lead, and through occupational exposure. Once absorbed, lead binds to erythrocytes and travels in the blood to various tissues (liver, kidneys, lungs, brain, spleen, muscles, heart) and moves further into bones and teeth, and may affect every organ or system in the body by disparaging fundamental biochemical processes [92]. Exposure to lead may conduct to numerous human health effects, the brain and kidney being most affected by lead toxicity in both children and adults [93, 94]. Even at low concentration, it can induce neurotoxicity (neurobehavioral dysfunctions, deficits in cognition, aggressivity) [95], anaemia [94], cardiac dysfunction and vascular damage [96], nephrotoxicity as lead is eliminated through the kidney [97], male and female reproductive system effects [98], bone toxicity (osteopenia, osteoporosis, osteomalacia) by reduction of bone calcium content [99] and alters the major cellular functions (expression of metabolic enzymes, metallothionein expression, protein kinase activity) [100]. Kidney diseases have been also registered in the investigated areas [53].

Manganese

Manganese (Mn) is a metal naturally occurring in soil and water. In humans, it is an essential nutrient assuring bone mineralization, metabolic regulations, cellular protection from free radical species, and an enzyme activator [101]. Adequate intakes of manganese vary between 0.003 mg for new borne to 1.8 mg for adult women and 2.3 mg for adult men, respectively [74].

The main routes for exposure to manganese are from contaminated water, inhalation of dust, intake from vegetables grown in contaminated soil. There also is a dermal exposure to manganese from dust and water, but there is little evidence that dermal contact with manganese leads to significant absorption through the skin [102]. Soil concentration of manganese ranges between 40 and 900 mg/kg, but in the areas of mining activities, it may reach 7000 mg/kg [103] and therefore pose a risk of excess exposure. The population living in the areas of mining activities may be exposed by inhalation to high levels of manganese in the dust. Inhalation of particulate manganese compounds can lead to the inflammatory response in the lungs, leading to increased pneumonitis and pneumonia, especially in manganese-exposed worker populations, but also in populations living and attending school near the area with dust containing manganese [102]. Chronic exposure to excessive manganese levels may conduct to cardiovascular effects [104] and psychiatric disturbances [105]. It was shown that exposure to excess levels of contaminated drinking water with manganese ($\geq$ 0.2 mg/L) may lead to neurological deficits [105] and increased time spent in mining operations may increase the manganese poisoning [106]. These effects have not been mention to appear in the investigated areas.

Molybdenum

Molybdenum (Mo) does not exist in nature in the pure metallic state but occurs in association with other elements. It presents five oxidation states (II-VI) and the predominant ones are Mo(IV) and Mo(VI) [107]. It is an essential trace element for human health being a cofactor for enzymes (sulphite oxidase, xanthine oxidase, aldehyde oxidase, and mitochondrial amidoxime), but it can lead to toxicity when ingested in high doses [108]. Recommended dietary allowances for Mo are 2 µg for a newborn to 45 µg for adults [74].

The main routes of exposure are ingestion from contaminated water and inhalation of dust containing molybdenum or its oxides, the major sources of metallic molybdenum including mining operations and by products of copper mining operations [107]. Most natural waters include low levels of molybdenum (2-3 µg/L), but anthropogenic sources may contaminate the water. For example, near molybdenum mining areas, the surface water contains up to 0.2-0.4 mg/L of molybdenum and in groundwater, it may reach 25 mg/L [109]. The solubility of molybdenum increases when the pH of environment is high and, consequently, its transfer from soil to water is facilitated. Molybdenum concentrations in drinking water are usually less than 0.01 mg/L, while in areas near mining sites, it may extend up to 0.20 mg/L and considerable contamination of drinking water with molybdenum may occur [110]. Little information is available on the human toxicity of molybdenum. The blood level of molybdenum is increased in persons living in areas rich in molybdenum [111]. Furthermore, people living in an area containing a high concentration of molybdenum in the soil, experienced hyperuricemia, joint pain, articular deformities, hepatomegaly, renal and gastrointestinal disorders [112]. Workers in the

copper-molybdenum mines that were exposed to a high level of dust (usually containing molybdic oxide) experienced headache, weakness, fatigue, skin irritation, and impairment of the central nervous system [113]. The presence of molybdenum and its derivatives in the dust may irritate the upper respiratory tract [107]. It was also observed that molybdenum compounds easily cross the placental barrier and may affect the newborns [114]. No human effects caused by dermal exposure to molybdenum were identified. Among these effects, respiratory and skin diseases have been observed in the investigated areas [53].

Mercury

Mercury (Hg) is a naturally occurring element that exists in three forms: elemental (metallic) Hg (Hg°), inorganic Hg (Hg^{+1}, Hg^{+2}) and the organic mercury that results from methylation process (monomethyl RHg^{+} and dimethyl R_2Hg) [115]. Mercury is toxic in all its forms and has no biological roles in humans [116]. Mercury is bio-accumulative in its elemental and organic forms, monomethyl Hg being the most toxic as it acts as a neurotoxin. Mercury is considered among the most poisonous metals adversely affecting both environment and human health. Mining and industrial activities are producing mercury pollution in the atmosphere, sediments and soils. Contamination of soil with mercury may occur naturally from geologic sources or through natural events, but a significant proportion of it is due to anthropogenic activities including mining operations [117]. The most common route of exposure to mercury and its compounds found in the environment is the ingestion of contaminated food as it accumulates in the various aquatic animals [118]. Mercury is considered a bio-accumulative toxin as it remains in the atmosphere up to 0.5-2 years [116]. Hg changes its forms chemically in the surroundings and translocate from one place to another, being found in soils and sediments. Exposure to mercury or its compounds conducts to serious health effects: renal (acute tubular necrosis, glomerulonephritis, renal cancer and nephrotic syndrome), cardiovascular (cardiomyopathy, Young's syndrome) and pulmonary (bronchitis, pulmonary fibrosis) impacts, and developmental neurotoxicity (depression, paranoia, irritability, hallucinations, memory loss, inability to concentrate, tremors of the hands, head, lips, tongue, weight loss, fatigue) [116, 119]. Mercury also produces changes in the membrane permeability, alterations in macromolecular structures and affects the endocrine system (damage to the pituitary, thyroid, adrenal glands) and pancreas (the production and metabolism of hormones like insulin, estrogen, testosterone, and adrenaline) [120]. Furthermore, the organic form of mercury crosses through the placental wall and produces fetal injuries leading to the infantile cerebrum and Minamata disease [119]. Renal and pulmonary impacts have been observed to people living in the investigated areas [53].

Nickel

Nickel (Ni) is a metal broadly distributed in the environment. It is released from both natural sources and anthropogenic activity and is present in the air, water, soil and biological materials. The main routes of exposure to nickel are inhalation and dermal contact, but also ingestion may take place [121].

In the human body, nickel may serve as a cofactor or structural component of specific metalloenzymes of various functions, including hydrolysis and redox reactions and gene expression. Nickel may also serve as a cofactor facilitating iron absorption or metabolism [74]. A tolerable daily intake (TDI) of 2.8 μg Ni/kg body weight has been established [122].

Literature data illustrate that nickel at high doses and in certain forms is toxic to both humans and animals. The sources of air pollution with nickel include wind-blown dust resultant from the weathering of rocks and soils, fossil fuel consumption, industrial production, the incineration of waste, etc. [123]. Drinking water usually contains nickel, but high concentrations (200 μg/L) were recorded in the nickel ore mining areas [124]. In the case of professional exposure, inhalation is the most significant way of uptake for Ni compounds (mainly nickel carbonyl, nickel sulphides and oxides). It has been shown that inhalation of nickel and its compounds produces the following effects [125, 126]: irritation and / or inflammation of the respiratory tract, bronchitis, pulmonary fibrosis, asthma, and pulmonary edema, kidney and cardiovascular diseases. Dermal contact and oral intake of contaminated food may conduct to allergic contact dermatitis. The most alarming aspect of exposure to Ni compounds is their carcinogenicity [125, 126]. In case of consumption of water contaminated with nickel salts, the registered health effects were: gastrointestinal disturbances (nausea, abdominal pain, diarrhea, vomiting) and altered haematological parameters [127]. Respiratory diseases have been registered in the investigated areas [53].

Zinc

Zinc (Zn) is an essential element for humans as it is involved in numerous aspects of cellular metabolism and in the catalytic activity of various enzymes maintaining immunity, antioxidant defence and protein metabolism. Zinc recommended daily intake is elevated in men as compared to women, ranging from 4.2 to 14 mg for men and from 3 to 9.8 mg for women depending on age and physiological state [60, 61]. Excessive Zn consumption causes deficiencies in iron and copper, fever, nausea, vomiting, tiredness, and abdominal pain. Zinc is widely present in soils and plants and acts both as an essential and a toxic element depending on its concentration and speciation in solution. Many anthropogenic activities release large amounts of zinc in the environment, mining and metal processing being the major source of zinc in the air and soil [128]. The main routes of exposure to nickel are through inhalation and ingestion of polluted water, but dermal exposure is also considered. The contributions of various sources of pollution with zinc conduct to find zinc in particulate form or in larger deposits that are leached by rainfall, forming water overflow containing high zinc concentrations and polluting river water and sediments [129]. River basins supply a large part of the available fresh water on Earth and consequently, it is important to control Zn concentrations in surface water. In the EU, zinc is the specific pollutant of the river basins and is the most often monitored. Literature data reveal that inhalation, exposure of the skin, or ingestion of high concentrations of zinc and / or some zinc salts can produce injuries of epithelial tissue, affect levels of pancreatic enzymes and lipoproteins in serum, alter the immunological function [130], disturb pregnancy, produce growth retardation, anorexia and disorders in energy metabolism [131]. None of these health effects were not registered in the investigated area.

Conclusion

This review had been focused on aspects of human health effects due to pollution with heavy metals generated by copper mining operations in the cross-border area of Romania and Serbia. The copper mining operations in Romania are stopped, but due to permissive national regulation, there is a poor ecological restoration practice of abandoned extraction mines and consequently a continuous pollution that results in environmental damage and

human health effects. The heavy metals that were identified as pollutants of the air, water, rainwater, wet deposits, sediments and / or soil due to the mining operations in the cross-border area of Romania and Serbia were: As, Cd, Cr, Cu, Fe, Hg, Mn, Mo, Ni, Pb, and Zn. Heavy metals are not biodegradable and their toxic effects appear both at their generating points and distance from the source, conducting to severe health risks to exposed people. Information synthesized in this study emphasizes that exposure to the mentioned heavy metals resulting from mining activities and / or wastes can cause numerous human health effects, from as mild as headaches to serious as cancer. Considering also the variety of pollutants released by mining operations, the pollution generated by both abandoned and active mines cannot be neglected.

There are not consistent studies regarding the impact of pollution caused by mining operations on the health of inhabitants in the cross border area of Romania and Serbia. Serbia started recently to implement a program to investigate the human health effects produced by the contaminated sites, but in Romania the impact of pollution on the human health is not investigated. The few known data emphasize that pollution caused by mining operations in investigated areas produced especially pulmonary, kidney and skin diseases. It does not mean that the other human health effects that were highlighted in this review did not appear, since they have not been investigated. This review may be used as a starting point for serious studies meant to assess the human health impact of pollution created by mining operations in the cross border area of Romania and Serbia.

Mining activities are spread all over the world due to the increasing demand for raw materials. They are also important for the socio-economic growth of the regions and countries. Mining activities disturb the environment and have negative effects on human health because mining wastes and activities release hazardous and toxic materials leading to the contamination of drinking water, air and soil. The information presented in specific literature and synthesized in this review underlines the necessity of changes in the current mining practices so that mining operations contribute to community progress and assure better protection for ecosystems. Mining activities should be environmentally acceptable and yield to sustainable development by updating the technology in use, filter all the products and byproducts in a method that is environmentally friendly, thus reducing the pollution of heavy metals in air, water and soil. Abandoned mines should be ecologically restored such as to not allow the continuation of environmental damages and human health effects.

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