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The tailings ponds from the Fundu Moldovei mine field (Suceava County, Romania). A preliminary study

Dan Stumbea[1], Mariana Totolici[1]

[1] "Alexandru Ioan Cuza" University of Iaşi, Department of Geology, 20A Carol I Blv, 700505 Iaşi, Romania

Abstract

The aim of this study is the comparative characterization of the waste from the Dealul Negru and Pârâul Cailor tailings ponds, located in the perimeter of the Fundu Moldovei mine field. The study focuses on identifying the mechanisms that may remove and transport the detritus from the waste deposit towards the surrounding, inhabited area. The common mechanism of environmental pollution is the removal of tailings from the slopes of both tailings ponds, during heavy rain episodes. The tailings pond of Dealul Negru is more exposed to wind, which lead to a quicker dehydration of the waste and appearance of secondary salts. The presence of the latter is suggested by the higher contents of major elements (Fe, Al, K) and strong correlation between them. The secondary salts (hydrated sulfates) increase the risk of environmental pollution by their high capacity for being removed and transported by wind. The tailings pond from Pârâul Cailor runs a smaller risk of air-borne pollution, as the waste deposit is protected against the wind by the surrounding heights. In that case, however, the main way of removal and transport of waste outside the tailings pond is the temporary stream that occurs during heavy rains.

Keywords: mine tailings; grain-size analysis, soluble fraction, geochemistry; correlation coefficients, pollution mechanisms.

Introduction

The mining and extraction activities in a perimeter result in tailings ponds, which usually are abandoned when the activities in that area stop. Since most of these waste deposits are unconfined, they interact with the atmospheric oxygen and become a major concern for the environment (Simón et al., 2005; Gunsinger et al., 2006). In terms of environmental pollution, the concerns are related to processes such as: (i) removal and transport of waste by runoff water during rainy periods (Bauerek et al., 2013); (ii) release of acidic, rich in toxic elements leachates, to environment (Santos et al., 2014); (iii) removal and airborne transport of waste particles during heavy winds (Křibek et

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Corresponding author's e-mail: dan.stumbea@uaic.com

al., 2014); (iv) release of tailings during dam failure (Bird et al., 2008; Rico et al., 2008). The risks are increased by the unstable nature of the tailings ponds, location near inhabited areas and usually poor maintenance.

The fine-grained sulfides remained within the waste from the tailings pond undergo oxidation processes in the presence of atmospheric oxygen. This, along with the rain water, can lead to the generation of highly acidic leachates, known as acid mine drainage (AMD) (Balistrieri et al., 2007; Álvarez-Valero et al., 2009). The leachates display a high sulfate content, as well as an important abundance of toxic and potentially toxic elements (e.g., Cu, Pb, Zn, Cd, As) (Andráš et al., 2009; Redwan et al., 2012). Besides, during dry periods, the acidic, rich in toxic metals pore water, present within the waste, can evaporate. This process lead to the precipitation of secondary salts, i.e., highly soluble and brittle hydrated sulfates of Fe, Al, Mg etc. Similar mineral aggregates can also occur by the evaporation of water from the temporary shallow pools formed on the tailings ponds beach. Regardless the way they were born, the secondary salts (hydrated sulfates) concentrate toxic and potentially toxic metals (Bea et al., 2010). The risk of these minerals for the surrounding area is increased by their vulnerability to removal by leaching or wind. The small particle size of the waste is also an environmental risk, since it becomes susceptible to removal and transport by either runoff waters during rainfall or wind.

The aims of the present study were as follows: (i) to make a preliminary characterization of the waste from the tailings ponds of Dealul Negru and Pârâul Cailor, located in the mine field of Fundu Moldovei; (ii) to identify the peculiarities that differentiate the two waste deposits and their impact on the environmental risk. Therefore, the mineralogy of the waste (primary minerals only), as well as its physical and chemical properties (pH, soluble fraction, abundance of major and some toxic elements) were investigated.

Geology and study area

1. Geological setting

The slurry coming from the Fundu Moldovei ore preparation plant has been discharged in the tailings ponds of Dealul Negru and Pârâul Cailor. The preparation plant was processing the Cu-rich polymetallic ore extracted from the Fundu Moldovei metallogenic field, which is a part of the Cu-rich Polymetallic Belt of the Eastern Carpathian. The latter has a length of around 200 km, a NNW-SSE orientation and consists of the following metallogenic districts (from NNW to SSE): (1) Borșa-Vișeu; (2) Fundu Moldovei-Leșu Ursului (Fig. 1); and (3) Bălan-Fagu Cetății (Berbeleac, 1988). All along the polymetallic belt, the ore is associated with the low-grade metamorphic rocks of the Group of Tulgheș. It consists mostly of quartz-schist, sericite-schist and chlorite-schist (Berbeleac, 1988; Balintoni et al., 2009). Vodă (1993) described four sub-units of the Tulgheș Group, as follows: Căboaia, Holdița, Leșu Ursului and Arșița Rea. The Cu-rich ores from the Polymetallic Belt of the Eastern Carpathian are hosted by the Leșu Ursului subunit (Balintoni, 2010).

The ore appears as massive strata or tabular bodies and strata of disseminated sulfides. The most common of the latter is pyrite, rich in Cu, and usually associated with chalcopyrite, sphalerite and galena. Pyrite appears as grains of two sizes: a few millimeters, within the disseminated ores, and under one millimeter within the massive ore bodies. Chalcopyrite is more abundant than sphalerite and galena within the ores from the metallogenic field of Fundu Moldovei (Fundu Moldovei – Leșu Ursului district). However, chalcopyrite is much less abundant than Cu-rich pyrite, making it to be considered a secondary raw mineral. It usually appears either in mineral association with pyrite or as a few millimeters thick veinlets.

2. Description of the tailings ponds

The tailings ponds identified within the mine field of Fundu Moldovei are Dealul

Negru (located westward from the center of the Fundu Moldovei village) and Pârâul Cailor (located at the northeastern edge of the village).

Dealul Negru tailings pond

The waste deposit is a side-hill tailings pond, built-up at 750 m altitude, on the right bank of the Moldova River, at the western edge of the Fundu Moldovei village. It is about 45 m high, it spreads on over 5 hectares and contains a volume of 0.7 mil. m^3 of waste. The slopes steepness is more than 45 degrees, the waste being deposited on 9–10 levels with a height of 3 m each. The upper surface of the tailings pond is 200 m long and 120 m wide; it is flat and horizontal (Fig. 2a).

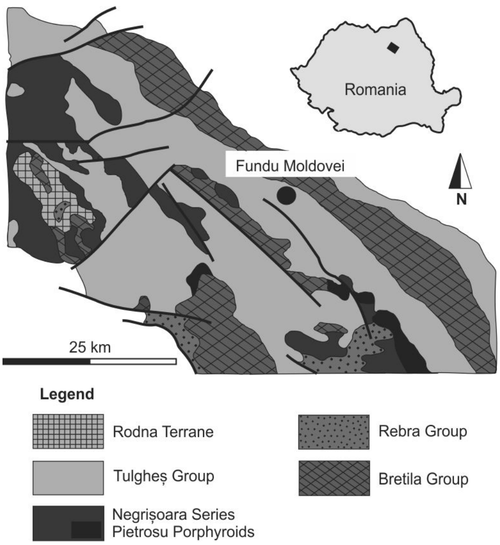

Fig. 1 Geological map of the Fundu Moldovei Metallogenic Field (Balintoni, 2010, modified).

The construction of the tailings pond started in the late 60s of the last century and ceased in the early 2000s. The waste deposit accumulated the more or less barren detritus resulting from the Cu-rich ore processing within the preparation plant of Fundu Moldovei. Despite the measures to reduce the tailings release into the surrounding areas, their efficiency was limited as shown by the erosion gullies carved on the slopes surface and the reddish color of the Moldova river bed in the area of the waste deposit (Stumbea, 2013a,b).

The climate of the Fundu Moldovei area is specific to low-altitude mountains, from the temperate regions. The average of annual precipitation is 83 mm, while the humidity of air is 78% in summer. During the warm season, the average air temperature is about 15.5 °C. The average speed of wind is 4.3 m/s and it blows mostly from W-NW.

Pârâul Cailor tailings pond

The tailings pond is located at 825 m altitude, on the Pârâul Cailor valley, about 2.5 km upstream of the confluence with the Moldova river whose left tributary is. The waste deposit was built-up as a valley-type pond and accumulates a volume of 0.9 mil. m^3 of tailings. The southern dam, which is the largest, is 30 m high. The upper, horizontal surface (beach) of the waste deposit is 350 m long and 280 m wide (Fig. 2b), being delimited from the southern and northern dams by an 80–100 cm high tailings ridge. The construction of the tailings pond has began in 1967 and it used to accumulate the slurry resulted from the Cu-rich ore preparation plant of Fundu Moldovei. The activity ceased in early 2000s.

The northern slope of the waste deposit is much smaller (about 8–10 m high), than the southern one. Especially the latter is heavily damaged by the water runoff during intense rainfall, as it can be presumed by examining the erosion gullies developed on its surface. The northern half of the waste deposit beach is crossed by a temporary stream of water and is around 40 cm lower than the southern sector. During heavy rains, the temporary stream flows from west to east, removing and transporting the waste from the tailings pond, towards the Pârâul Cailor valley. The climate conditions are the same as for the perimeter of the Dealul Negru tailings pond.

Materials and methods

1. Sampling

Waste samples were collected in June 2013 from the beaches of both tailings ponds, as follows: 51 samples from the Dealul Negru tailings pond and 49 samples from the waste deposit of Pârâul Cailor. The samples were collected on a rectangular grids of 25 × 25 m (Dealul Negru) and 50 × 30 m (Pârâul Cailor). The waste was sampled with a plastic paddle, and then stored in plastic bags, until analysis. Only some of these samples were processed and analyzed, as it will be seen in section Results.

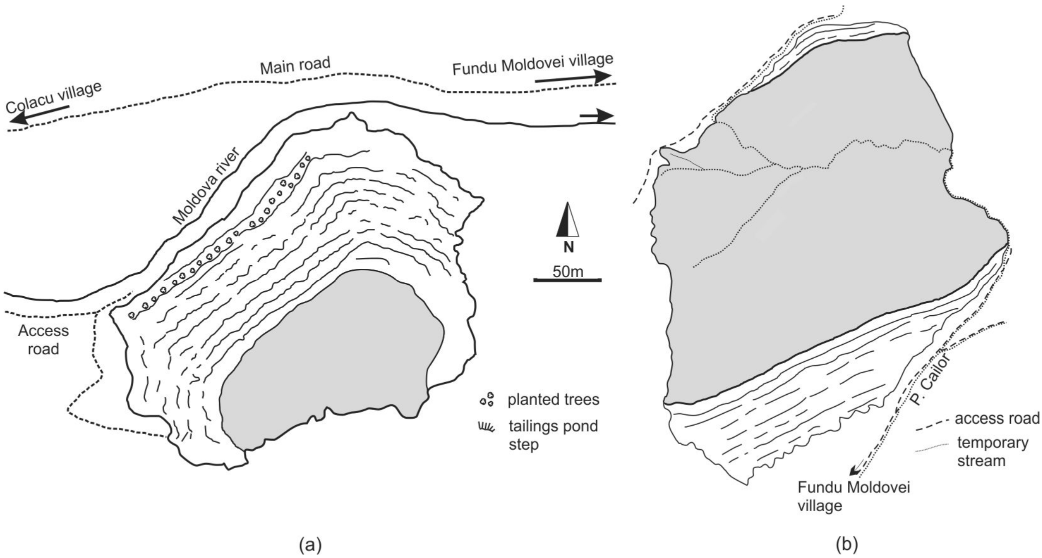

Fig. 2 Sketches of Fundu Moldovei tailings ponds; (a) Dealul Negru tailings pond; (b) Pârâul Cailor tailings pond.

2. Microscopic examination

To determine the mineralogical composition of waste, a Meiji 9400 ML stereomicroscope was used. In order to estimate the presence of secondary salts, a preliminary analysis was performed on unrinsed samples. The primary minerals (silicates and metallic minerals) were identified using rinsed samples with distilled water, so that the soluble fraction (secondary hydrated sulfates) was removed.

3. Particle size analysis

The particle size analysis of the detritus was performed using the sieving method. Prior to this, the samples were dried for 24 h, at a temperature of 50ºC, then weighed and passed through the following set of sieves: 1 mm, 0.25 mm, and 0.063 mm. Finally, the weight percent of each size range was determined.

4. X-ray fluorescence

The amount of major and toxic elements in waste was measured with an X-ray Fluorescence Spectrometer – EDXRF Epsylon 5. For this, the samples have been previously ground, mixed with Hoechst wax and pressed into pellets. River sediments and soil samples have been used as reference materials, to calibrate the spectrometer.

5. Leaching tests

This analytical procedure was used to determine the pH and abundance of the soluble fraction of the tailings. For this purpose, 10 g of waste sample was mixed with

10 mL of deionized water. The beaker was stirred for 1 hour at 200 rpm, and then the pH was measured with help of a Corning M555 pH/ion meter. Afterwards, the leachate from the beaker was filtered through a 0.2 µm cellulose filter, on which the insoluble fraction has remained. After drying, the insoluble fraction was weighed to the aim of calculate, eventually, the percentage of the soluble fraction.

6. Statistical analysis

The standard deviation and the correlation matrix of the amounts of major and toxic elements have been determined with help of Stat Pro 7.5 software.

Results and discussion

1. Tailings pond of Dealul Negru

The waste of the beach of the tailings pond has a sandy appearance and generally displays a grayish color; rare areas of dark-yellow to ochre tint also occur. At the bottom of the ridges that separate the horizontal surface of the tailings pond from its flanks, 2–3 mm thick accumulations of less than 1 mm quartz grains can be observed. These accumulations occur especially at the bottom of the ridges from the eastern sector of the waste deposit. This shows that they have resulted from the air-borne transport of the mineral grains by wind, which mainly blows from W-NW.

The results of the grain-size analysis explain the sandy appearance of the tailings, as about 68 wt% of the waste consists of sand-size grains (Tab. 1). The mineralogical composition was determined with help of a stereomicroscope, which only allowed the identification of the primary minerals of the tailings. This is because the hydrated sulfates, usually more or less present within the waste mass, cannot be identified by the microscope studies, because of their small size. Considering the circumstances, the mineralogical composition of the waste from the Dealul Negru tailings pond is quite constant; it consists of quartz > sericite > pyrite > chlorite > biotite > secondary minerals (probably hydrated sulfates) > sphalerite.

Tab. 1 Grain size analyses (wt%) of the waste from the tailings pond

	Medium sand-size grains	Fine and very fine sand-size grains	Silt- and clay-size grains
Dealul Negru tailings pond (*n* = 15)			
Min.	0.32	33.49	10.89
Max.	22.40	80.69	66.19
Mean	8.10	60.64	31.26
Pârâul Cailor tailings pond (*n* = 15)			
Min.	0.06	36.79	10.87
Max.	15.26	78.63	63.11
Mean	5.14	63.56	31.25

Though largely variable, the amount of soluble fraction is rather high, showing a maximum of over 28 wt% and a mean of 13.46 wt% (Tab. 2). The pH data show a high acidity (Tab. 2), specific to the waste from the tailings ponds.

The analysis of the amount of major elements (Fe, Al, Mn, Ca, and K) and toxic metals is summarized in Table 2. In order to evaluate the relationship between the chemical properties and mineralogy of the waste, the Pearson correlation has been applied (Tab. 3). Thus, the correlation matrix in Table 3 shows mutual positive correlations between Fe and Al, Mn and K, which is explained by their association within the structure of the primary minerals, i.e., sericite, chlorite and biotite. These correlations may also be assigned to the occurrence of secondary Fe, Al, Mn, and K hydrated sulfates, formed by weathering of the primary minerals. The frequent occurrence of Co as minor element in pyrite, explains its strong correlation with Fe.

Significant correlations were also recorded between the major elements and some of the toxic and potentially toxic elements; i.e.: Al-Pb, As, Co; Mn-Co; K-Pb, As, Co. The meaning of this relation seems to be the accumulation of the toxic metals, as minor elements, by the secondary salts (hydrated sulfates) of Al, Mn and K. Apart from this, some of the toxic elements (e.g., Pb, Zn, As) display high mutual correlation coefficients, which suggest their geochemical affinity and capacity for concentration, especially within the structure of secondary salts.

Tab. 2 Chemical properties of the ore-processing waste from the tailings ponds

Dealul Negru tailings pond (*n* = 25)							
	Fe (wt%)	Al (wt%)	Mn (wt%)	Ca (wt%)	K (wt%)	Cu (ppm)	Pb (ppm)
Min.	6.32	5.07	0.02	0.15	1.46	193	659
Max.	14.05	18.92	0.04	0.24	3.97	1089	2674
Mean	9.85	12.55	0.03	0.18	2.79	458	1508
SD	2.30	5.95	0.01	0.03	1.02	283	700
	Zn (ppm)	As (ppm)	Cd (ppm)	Co (ppm)	Ni (ppm)	pH	SF (wt%)
Min.	95	104	0.02	28	1.95	2.64	1.74
Max.	265	296	0.12	72	4.01	3.56	28.18
Mean	162	188	0.06	48	2.97	3.13	13.46
SD	48	64	0.03	14	0.66	0.30	9.34
Pârâul Cailor tailings pond (*n* = 30)							
	Fe (wt%)	Al (wt%)	Mn (wt%)	Ca (wt%)	K (wt%)	Cu (ppm)	Pb (ppm)
Min.	4.22	2.58	0.02	0.11	0.76	151	471
Max.	11.80	19.33	0.04	0.36	4.68	1982	2504
Mean	7.89	9.85	0.03	0.18	2.49	614	1204
SD	2.03	4.99	0.01	0.05	1.09	522	517
	Zn (ppm)	As (ppm)	Cd (ppm)	Co (ppm)	Ni (ppm)	pH	SF (wt%)
Min.	80	74	0.02	17	1.53	2.63	0.45
Max.	1112	304	0.52	60	6.20	3.90	10.35
Mean	222	155	0.10	38	3.41	3.10	3.47
SD	206	54	0.10	12	1.03	0.43	2.41

SD – standard deviation; SF – soluble fraction

2. Tailings pond of Pârâul Cailor

The horizontal surface of the tailings pond has a light gray color; a closer look of the waste shows its sandy to clayey appearance. The northern and southern flanks of the waste deposit, as well as the 80–100 cm high ridges that separate the waste pond beach from its flanks, display an ochre to brown-reddish color.

The average size of waste grains (Tab. 1) indicates a significant amount of sand-size detritus (over 68 wt%). Despite this, the northern sector of the beach of the tailings pond rather has a clayey appearance, due to the W-E oriented temporary water-course, which removes, transport and accumulates the detritus during heavy rains. The mineralogy of waste, determined with a stereomicroscope, is closely related to the mineralogy of the schist and associated mineralization in the area: quartz (often limonitized) > sericite > pyrite > > chlorite >> biotite >> sphalerite.

The abundance of the soluble fraction varies in a rather narrow range (Tab. 2), i.e., less than 11 wt% and has a very small mean of about 3.50 wt%. Data of Table 2 also show a low pH (mean of 3.10), ranging between 2.63 and 3.90, which is a specific property of the detritus of the tailings pond from the Eastern Carpathian (Stumbea and Chicoș, 2012; Stumbea, 2013a,b).

Tab. 3 Correlation matrix for major and toxic elements in the waste of Dealul Negru tailings pond (n = 25)

	Fe	Al	Mn	K	Cu	Pb	Zn	As	Cd	Co
Fe	1	**0.737**	**0.775**	**0.658**	-0.269	0.341	0.254	0.547	-0.324	**0.998**
Al	**0.737**	1	**0.841**	**0.989**	-0.341	**0.666**	0.567	**0.718**	0.022	**0.725**
Mn	**0.775**	**0.841**	1	**0.779**	-0.599	0.250	0.233	0.369	-0.147	**0.782**
K	**0.658**	**0.989**	**0.779**	1	-0.346	**0.699**	0.595	**0.713**	0.054	**0.641**
Cu	-0.269	-0.341	-0.599	-0.346	1	0.108	0.065	0.097	0.137	-0.279
Pb	0.341	**0.666**	0.250	**0.699**	0.108	1	**0.857**	**0.952**	0.409	0.323
Zn	0.254	0.567	0.233	0.595	0.065	**0.857**	1	**0.744**	0.512	0.223
As	0.547	**0.718**	0.369	**0.713**	0.097	**0.952**	**0.744**	1	0.241	0.534
Cd	-0.324	0.022	-0.147	0.054	0.137	0.409	0.512	0.241	1	-0.307
Co	**0.998**	**0.725**	**0.782**	**0.641**	-0.279	0.323	0.223	0.534	-0.307	1

Tab. 4 Correlation matrix for major and toxic elements in the waste of Pârâul Cailor tailings pond (n = 25)

	Fe	Al	Mn	K	Cu	Pb	Zn	As	Cd	Co
Fe	1	0.269	-0.008	0.171	0.339	**0.521**	**0.376**	**0.770**	0.324	**0.994**
Al	0.269	1	**0.530**	**0.976**	-0.320	**0.368**	-0.105	0.278	-0.142	0.215
Mn	-0.008	**0.530**	1	**0.489**	**-0.780**	-0.064	**-0.559**	-0.015	**-0.659**	-0.083
K	0.171	**0.976**	**0.489**	1	-0.295	**0.392**	-0.111	0.252	-0.144	0.118
Cu	0.339	-0.320	**-0.780**	-0.295	1	0.307	**0.747**	0.276	**0.797**	**0.410**
Pb	**0.521**	**0.368**	-0.064	**0.392**	0.307	1	**0.421**	**0.687**	**0.397**	**0.510**
Zn	**0.376**	-0.105	**-0.559**	-0.111	**0.747**	**0.421**	1	0.287	**0.976**	**0.434**
As	**0.770**	0.278	-0.015	0.252	0.276	**0.687**	0.287	1	0.283	**0.753**
Cd	0.324	-0.142	**-0.659**	-0.144	**0.797**	**0.397**	**0.976**	0.283	1	**0.386**
Co	**0.994**	0.215	-0.083	0.118	**0.410**	**0.510**	**0.434**	**0.753**	**0.386**	1

Table 2 presents the chemical properties of the waste from the Pârâul Cailor tailings pond, while the correlation matrix for major and toxic elements is shown in Table 4. The latter indicates that only Al and K strongly correlate each other (correlation coefficient of 0.976). In these circumstances, it can be presumed that the precipitation of secondary salts over the surface of the waste deposit is low. Again, the correlation matrix reveals the strong correlation between Fe and Co (correlation coefficient of 0.994), as a result of their geochemical relation within the structure of pyrite. Except for this, only few correlations between major elements and toxic elements were recorded: Fe-As; Mn-Cu; Mn-Cd. This small number of correlated elements may be justified by the presumed poor development of the secondary salts on the surface of the waste. The assumption seems to be supported by the reduced number of pairs of toxic and potentially toxic elements which show significant correlation coefficients: Cu-Zn; Cu-Cd; Pb-As; As-Co. The very strong correlation between Zn and Cd (correlation coefficient of 0.976) is explained by the presence of Zn within the structure of sphalerite and its strong geochemical affinity for Cd.

3. Comparative approach

This section consists in a critical comparison between the waste of the Dealul Negru and Pârâul Cailor tailings ponds. The comparison lies on the physical, mineralogical and geochemical properties presented in the previous sections.

The grain-size data in Table 1 show a similar type of waste in both tailings ponds, i.e., an especially sandy waste, as the mean of over 68 wt% of sand-size detritus suggests. The similarity can be explained as follows: (i) the detritus from both waste deposits resulted from the processing of the same type of rocks and associated ore; (ii) the waste comes from the same preparation facility, which is expected to be followed the same procedure of ore processing over time. However, the waste of Pârâul Cailor has a rather sandy to clayey appearance, especially in the northern half of the tailings pond. This is because of the temporary stream that occurs and flows during heavy rains; it determines the transport of the tailings and its sedimentation onto the northern sector of the beach, as 4–5 cm thick sorted detritus.

In terms of mineralogy as well, the tailings of the two waste deposits are similar. Thus, quartz and sericite are the most abundant minerals, followed by pyrite, chlorite and, accidentally, biotite and sphalerite. The waste of the two deposits shows a similar mineralogy because it resulted from the technological processing of the same types of metallic minerals closely associated with the same gangue (quartz-, sericite- and chlorite-rich schist). Although further investigation is needed (i.e., XRD analyses) to determine rigorously the mineralogy of the waste, the presence of secondary salts can be presumed based on microscopic observations. Thus, in some of the waste samples from the Dealul Negru tailings pond, white, needle-like salt crystals were observed. The lack of the latter mineral aggregates in the waste from Pârâul Cailor tailings pond seems to be related to the location of this waste deposit within the study perimeter. Thus, this tailings pond is a cross-valley waste deposit, with a roughly N-S orientation, being protected against de wind by the surrounding heights. Therefore, the dehydration of waste is reduced and, consequently, precipitation of secondary salts lowered. On the contrary, the waste deposit of Dealul Negru is a side-hill tailings pond (Fig. 2a), quasi-parallel with the Moldova valley. This location makes it exposed to the general blowing direction of wind in the perimeter, which is from W-NW, to E-SE.

In terms of soluble fraction amount, there is a significant difference between the wastes from the two tailings ponds. Thus, while the waste of Dealul Negru shows an average abundance of about 13.5 wt% soluble fraction, for the tailings of Pârâul Cailor only less than 3.5 wt% soluble fraction was recorded (Tab. 2). The secondary salts (hydrated sulfates) are highly soluble minerals; therefore it may be assumed that the abundance of soluble fraction is closely related to salt precipitation over the surface of the tailings pond. This assumption agrees with the hypothesis which explains the presence of hydrated sulfates almost exclusively in the tailings from Dealul Negru. However, the low abundance of soluble fraction within the waste of the Pârâul Cailor tailings pond may also be a consequence of the temporary water stream which removes it from northern sector of the waste deposit.

The pH of tailings shows no variation, ranging in both tailings ponds between 2.6 and less than 4.0 and having an average value of about 3.1 (Tab. 2). The chemical composition of the waste and the correlation matrix for major and minor elements show significant differences between the two tailings ponds, as follows:

(i) Higher amounts of major elements (Fe, Al, K) in the waste of Dealul Negru, which suggest an enrichment caused by a more intense precipitation of secondary salts. The latter process results in further combinations of major elements, i.e., within the structure of secondary hydrated sulfates, which are added to the already existing combinations within the structure of primary silicates. This can also explain the strong correlation identified for almost all pairs of major elements.

(ii) Higher amounts of most of the analyzed toxic elements (Cu, Zn, Cd, and Ni) in the waste of Pârâul Cailor. The waste of Dealul Negru tailings pond has lower amounts of toxic elements because they are concentrated within the structure of secondary hydrated sulfates; the latter, being highly soluble, are removed by the rainfall, along with the toxic elements.

Conclusions

The tailings ponds from Fundu Moldovei mine field produce risks of environmental pollution through similar mechanisms, such as: removal and air-borne transport of waste particles towards the surrounding areas; removal and transport of waste particles as suspensions, by the runoff waters, during rainfall; transport of tailings as soluble fraction. The present study indicates the most likely mechanism of pollution to occur for each of the two waste deposits in the area, as following:

(1) The tailings pond of Dealul Negru presents a higher risk of pollution through two mechanisms: (i) air-borne transport of bulk detritus and/or secondary salts; (ii) removal and transport of waste from the slopes, during heavy rains. Thus, the tailings pond of Dealul Negru is the most exposed to wind, which leads to a more rapid drying of waste and to the appearance of highly soluble and brittle secondary sulfates. The latter are easily removed either by wind or runoff waters, and transported towards the surrounding, populated area. However, the risk of waste removal from the horizontal surface is low, as it is surrounded by a 1–1.5 m high ridge which delimits it from the slope of the waste deposit. Nevertheless, the removal of detritus from the slopes is intense during heavy rains, as runoff gullies developed over the flanks show. The waste is therefore transported into the Moldova River, which becomes an important vector in spreading the effects of such a type of pollution.

(2) Through its position and type, the tailings pond of Pârâul Cailor its well protected against the wind. Under this circumstance, the risk of environment contamination through air-borne transport is unlikely. Also, the development of secondary sulfates over the surface of the waste is poor. Consequently, the most risky mechanism of environmental pollution is the removal of waste by water. This can occur in two ways: (i) by runoff waters from the especially southern slope, where deep gullies were observed; (ii) by the temporary stream of water which occurs during heavy rains, in the northern sector of the waste deposit. In both cases, the detritus is discharged in Pârâul Cailor creek, tributary of Moldova River. It only reaches the waters of the latter during the heavy rain periods of the year, thus reducing the pollution effect on a larger scale.

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