Utilisation of environmentally degraded area by mining activity: a case study of Slovinky tailing impoundment in Slovakia

Vladimír Čech[1] *and* ***Juliana Krokusová***[1]

Revitalization of heavily modified and environmentally degraded landscape caused by industrial, respectively mining activity involves several aspects. In addition to other, interesting question is the appropriateness of using such sites as the object of tourism. In the first part, the paper deals with the general characteristics of such degraded area, namely Slovinky tailing impoundment in eastern Slovakia, characterised by the formation and development as a product of the mining and industrial activities, deals with an environmental load of this area. In the first stage, it was necessary to analyse the current state of the tailing impoundment by the heavy metal contamination analysis of samples taken from the body of the impoundment. The main aim of this study was to analyse the views of local residents to the current situation and the alternative uses of the Slovinky tailing impoundment in terms of geotourism, respectively in the educational process. Based on the questionnaire evaluation, we investigated the environmental awareness and opportunities for further development of the locality. Overall, the questionnaire filling was attended by 188 people in June 2012. Most respondents consider that tailing impoundment is an environmental problem, but they are not worried about the possible environmental disaster. The majority of respondents consider it appropriate to use tailing impoundment area as an educational locality on geography lessons on primary and secondary schools, but not as a tourist attraction. Questionnaire survey method has proved useful in identifying the local resident's awareness about this environmental burden and its further utilisation.

Key words: *environmentally degraded area, mining activities, heavy metals, Slovinky tailing impoundment, specific object of tourism*

Introduction

The tailing impoundments belong to anthropogenic forms of relief (Lóránt, 2008), and they are connected with the mining activity. According to their flat appearance, they are called “ground mirrors.” Their genesis is related to industrial sedimentation. Sludge – fluid waste from raw material extraction is being brought to the pond. Sludges are gradually gathered, and they can reach several ten meters of thickness. After mining activity, the sludges dry up. The tailing impoundment is water management construction, fundamentally in dammed valley and its dam is under precautionary water management monitoring (Zapletal, 1969; Mazúrek, 1998; Kirchner and Smolová, 2010; Szabó et al., 2010; Čech and Krokusová, 2013).

The ecological catastrophe and tragic events of 2010 at the tailing impoundment near the Hungarian village of Ajka led to increased interest from the competent state authorities in the condition of the most hazardous tailing impoundments and landfills for industrial waste in Slovakia. In autumn 2010, inspections were held at 28 such sites in Slovakia on the basis of a regulation of the Ministry of Agriculture. The current condition at 27 sites was classified as satisfactory. The exception was the Slovinky tailing impoundment near Krompachy, which was assessed as unsatisfactory with a risk of ecological disaster.

The gradual decline of mining and the closure of mining operations in 1993 brought to a definite end the historical era of mining in the Spiš region of Slovakia. The intensive mining operations over a number of decades had an extensive negative impact on all environmental media. Twenty years after the end of mining, tailing impoundments and other anthropogenic relief features remain as negative elements in the region. Their rehabilitation is not possible due to time, technical and financial restraints.

The first stage of the project “System of identification and monitoring of environmental damage caused by mining operations” was undertaken at the Slovinky tailing impoundment in 1997 as part of which a basic inventory of at-risk localities was created. The Slovinky locality (iron ore mining) was classified eighth with regard to the level of risk and requires essential remediation of the negative impacts of mining operations on the environment (Jurkovič et al., 2012). These alarming results focussed the attention of the scientific community and the general public on the need for the monitoring of certain mining relief features and on the fact that mining regions require greater attention, as the closure of mines does not automatically resolve the negative impact of mining operations on a region. As a result of these facts, a number of scientific studies were undertaken from 2011 – 2013 at the Slovinky tailing impoundment which assessed its current condition from a geochemical, mineralogical and geomorphological point of view (Čech et al,. 2011; Petrák et al., 2011; Šottník et al., 2011; Laubertová and Gerhartová, 2013; Kučerová et al., 2013; Tóth et al., 2013) and identified the environmental risks (Michaeli and Boltižiar, 2010; Čech et al., 2011; Jurkovič et al., 2012).

[1] *RNDr. Vladimír Čech, PhD., RNDr. Juliana Krokusová, PhD.* University of Prešov, Faculty of Humanities and Natural Sciences, Department of Geography and Applied Geoinformatics, Ulica 17. Novembra 1, 081 16 Prešov, Slovakia, cech@unipo.sk, juliana.krokusova@unipo.sk

Slovinky tailing impoundment is a site that is in ecological terms considered as an environmentally degraded area. Environmentally degraded areas are neglected, abandoned, contaminated, functionally unused or otherwise degraded areas that have lost their original function, poor and decline to such a degree that they become an anti-social area which, without outside intervention and contribute to its development no hope for reuse (Petríková and Finka, 2007). Environmental degradation is worsening of the natural environment (conditions of human life, flora and fauna), contamination, adverse processes (erosion, landslides), reducing biotic components of the environment, etc. (Šteffek et al., 1993).

Active mining and industrial activities in the area of the Krompachy town is the past. One has to ask how to further use of the remains of these activities. While another industrial use is also possible, the alternative is the use of the area for scientific, educational purposes, respectively exploitation in tourism. Such alternative use is only possible in cooperation with local residents, schools, private and public sector (Hronček et al., 2011; Hronček and Rybár, 2016).

One approach to promote this region is the development of geoturism, respectively the development of the cognitive-educational tourism. The region and the Slovinky tailing impoundment area could become an active part of the project Slovak mining road, which is a presentation of rich mining heritage in Slovakia. It is important to preserve and bring to the attention to the most tangible part of the mining heritage in the territory of Slovakia for scientists and the general public. The project also aims to raise the level of awareness to the protection of the technical and cultural-historical heritage of our ancestors. It is important to save some former mining objects in the landscape and make it available to the public.

Great importance could have the use of such objects in the learning process in schools. Here we see the use of this site not only in Slovak but also European-wide extent as a part of the presentation of the most burdened regions of Europe. This could help to the greater interest of scientists and students to this locality and in the cooperation of several European universities.

Based on these motives, we decided to realise a study about the Slovinky tailing impoundment in the cadastre unit of the Krompachy. The site selection was based on the fact that the wider territory of the former mining landscape of the Krompachy town is the research centre of the authors of this contribution. The authors, moreover, live in the immediate vicinity of this site.

The aim of this study was to analyse the views of local residents to the current situation and the alternative uses of the Slovinky tailing impoundment in terms of geotourism, respectively in the educational process. Based on the questionnaire evaluation, we investigated the environmental awareness and opportunities for further development of the locality. Our aim was to bring the views of inhabitants of the region for scientists and local government when deciding on the use of this locality. The phases of the questionnaire survey preceded the geographical analysis of the territory and determined the current environmental status on the basis of heavy metal contamination analysis.

Use of a questionnaire survey among local residents for the detection of environmental awareness and opportunities for further development of the territory has not yet been implemented in this area. It could be a valuable contribution to the potential for further development not only of this but also other former mining regions of Slovakia.

Methodological-theoretical background

The issue of the use of old mining relief forms in research or geotourism has engaged several authors. Of the more recent works of foreign authors dealing with the use of mining relief forms in geotourism, it is important to mention the works of Hose (1999), Buckley (2003), Dowling and Newsome (2006), Newsome and Dowling (eds.) (2010), Conlin and Jolliffe (eds.) (2011), Schejbal (2011), Lopez and Perez (2013).

Specific anthropogenic landforms and geolocations were analysed as geotouristical objects by works of Słomka et al., (2006), Rybár et al., (2010) and Rybár (2010). The use of information technologies in mining tourism is a part of works of Rybár and Hvizdák (2010), Rybár et al., (2010).

The specific use of abandoned quarries in tourism is mentioned in the works of Amanti et al., (1996), Weiss (2009), Hronček (2009, 2012). Underground pseudomontaneous relief shapes as geotouristic objects is the main goal of the work of Hronček (2013) and Hronček and Rybár (2016). The mine Bankov as an object of geotourism is mentioned in the work of Hvizdák et al. (2012). Reconstruction of lost mining landscapes and their use in geotourism is included in the work of Hronček and Liga (2014). Natural underground caves and mines in Italy and their use in geotourism was described by Gorofano and Govoni (2012).

Materials and methods

Before carrying out the questionnaire survey, it was necessary to analyse the current state of the tailing impoundment. Geographical conditions of the impoundment were analysed during the years 2010-2011 (Čech et al., 2011). Subsequently, the heavy metal contamination analysis of samples taken from the body of the impoundment was performed. This research was needed in terms of choice of questions in the questionnaire.

During the field phase of the study, samples were taken at three sampling sites which were chosen during the preparation phase. The analysis of the samples was undertaken in the accredited testing laboratory of the Ministry of the Environment of the Slovak Republic for geology and the environment in accordance with STN EN ISO/IEC 17025: 2005. The levels of Cu, As, Pb, Ni and Cr were determined using X-ray fluorescence spectrometry and the levels of Cd and Co were determined using atomic absorption spectrometry. The exact location of the sampling sites was determined using a mobile GPS using the coordinate system WGS 84, which was subsequently converted to the national coordinate system. In the final phase, all the data were processed, analysed and compared and the results were summarised (Tab. 1, Fig. 3, Fig. 4).

For the needs of assessment of public opinion on issues related to tailing impoundment, we constructed a questionnaire. The questionnaire contains a total of 17 questions with default responses. The questionnaire was given to fill among the local residents living near the impoundment, local government staff and at primary and secondary schools among the teaching staff. The selection of respondents was conditional on the assumption that they will have an elementary knowledge of the issues. Overall, the questionnaire filling was attended by 188 people in June 2012. Of the total number of 188 respondents - 95 respondents were male and 93 female. 17 respondents were under the age of 18 years, 45 aged 19-30 years, 42 aged 31- 45 years, 40 aged 46-65 years and 44 aged 66 years and more. 21 respondents had completed elementary education, 138 secondary education and 29 higher education.

Questionnaire:

1. *Do you know that the Slovinky tailing impoundment is situated in the administrative area of our town*?
   1a) Yes, I know
   1b) No, I do not know
2. *Do you have enough information about this object?*
   2a) Yes, I have
   2b) No, I do not have
3. *Evaluate the security status of the tailing impoundment.*
   3a) Tailing impoundment is in a satisfactory condition
   3b) Tailing impoundment is in an unsatisfactory condition
   3c) Tailing impoundment is in a disastrous state
4. *Evaluate the local government attitude to the object.*
   4a) attitude is sufficient
   4b) attitude is insufficient
5. *Evaluate the owner attitude to the object.*
   5a) attitude is sufficient
   5b) attitude is insufficient
6. *Are you afraid of possible environmental accidents in this area?*
   6a) Yes, I am
   6b) No, I am not
7. *What impact does this object have on the environment?*
   7a) has a negative impact
   7b) has a positive impact
   7c) has no impact
8. *What impact does this object have to human and animal health?*
   8a) has a negative impact
   8b) has a positive impact
   8c) has no impact
9. *Is it an appropriate object for tourism?*
   9a) Yes, It is
   9b) No, It is not
10. *Is it an appropriate object for educational purposes at schools?*
    10a) Yes, It is
    10b) No, It is not
11. *What is the primary role of competent people in connection with this construction?*
    11a) ensuring a regular monitoring of this area
    11b) transfer ownership from private to state hands
    11c) using in tourism, together with other objects of the former mining activity
    11d) using in the educational process in schools
    11e) rehabilitation of damaged parts, and gradual reclamation
    11f) further processing of the tailings material, extraction of precious metals (Au, Ag)
    11g) prevent uncontrolled visits in the area
12. *Would it be appropriate to construct the orientation marks to the tailing impoundment as an object of tourism?*

12a) yes
12b) no

13. *Would it be appropriate to mark the tourist trail to the tailing impoundment as an object of tourism?*
    13a) yes
    13b) no
14. *Would it be appropriate to construct the information boards on the tailing impoundment as an object of tourism?*
    14a) yes
    14b) no
15. *Would it be suitable to guide tourists by a qualified person in the tailing impoundment area?*
    15a) yes
    15b) no
16. *When using the tailing impoundment as an object of tourism, do you propose to include it as a part of the so-called "Mining road"?*
    16a) yes
    16b) no
17. *When using the tailing impoundment in the educational process, do you propose to inform about the tailing impoundment:*
    17a) by the presentation on the geography lessons at school
    17b) by the presentation on the ecology lessons at school
    17c) by the presentation on-site within geography
    17d) by the presentation on-site within ecology

The results of the questionnaire were analysed in the graphical (Fig. 5) and text form.

General characteristics of the Slovinky tailing impoundment

The tailing impoundment is located in the cadastre unit of Krompachy in the old mining region of Spiš in eastern Slovakia. It is located in the central and lower part of a lateral valley bounded to the south-east by the hill Krompašský vrch (1025 m a.s.l.), this valley ends in the valley of the brook Slovinský potok.

Fig. 1. The location of the studied area.

The tailing impoundment has an area of approximately 15 ha. The lower edge is located at 435 m above sea level and the upper edge is at 515 m above sea level. The maximum length is 390 m and the maximum width is 330 m. The height of the dyke of the tailing impoundment is 113 m. It is the highest tailing impoundment in Slovakia. The length of the slope of the dyke is 345 m and its width is 245 m (Fig. 2).

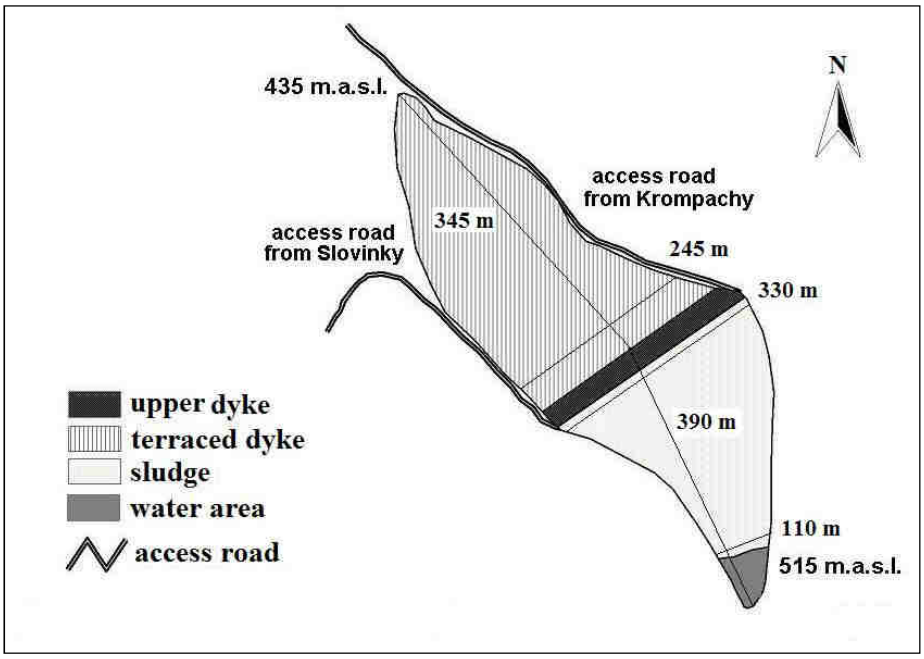


Fig. 2. The scheme of the tailing impoundment.

The construction of the tailing impoundment begun after an accident and the closure of the old tailing impoundment in Slovinky. Its operation started in 1968 with an expected operating life up to 2000, the depositing of the slurry was stopped a year earlier. The transport of slurry in the form of industrial wastewater from the water treatment facility of the plant of Železorudné bane (Iron Ore Mines) to the tailing impoundment was undertaken by three pumping stations situated one after the other along the slurry pipeline. Approximately 275 kilotons of flotation waste were stored at the tailing impoundment annually. Slovinky is the tailing impoundment with the thickest layer of tailings in Slovakia. The volume of tailings is estimated to be 4.8 mil. cubic metres.

The current state of the tailing impoundment, specifically the dam and drainage system, is unsatisfactory, there is a risk of an accident in the event of torrential rain. There has been a natural and anthropogenic devastation of the structure of the dam and of the measuring and operating equipment (erosion of the slope by precipitation; blockage of stone drainage channels by concrete rubble; dismantling and removal of the metal pipes of the drainage system and the metal covers of the observation shafts for sale as scrap; destruction of the concrete reinforcement; clearing of trees, which provide stability to the slope of the dam, etc.). On the basis of a visual inspection, the vital drainage system of the tailing impoundment can be considered to be functional for the time being, despite the local blockage with rubble. Whether this will remain so in the future, however, is very uncertain due to the extreme weather variations in recent years. As a matter of priority, it is essential to prevent further devastation to the equipment of the tailing impoundment and to organise regular monitoring by the owner, or if this is not possible, the state must take the initiative.

Experimental results of heavy metal contamination analysis

Heavy metal contamination at the Slovinky tailing impoundment and its immediate surroundings is extremely high. Contamination was measured at the dam of the tailing impoundment (SL 1), at the surface of the tailing impoundment (SL 2) and in the nearby woods (SL 3). The recorded values for heavy metals were compared with the limit values for hazardous substances specified by Act No. 220/2004 Coll. on the protection and use of agricultural land, amending Act No. 245/2003 Coll. on the integrated prevention and monitoring of environmental pollution.

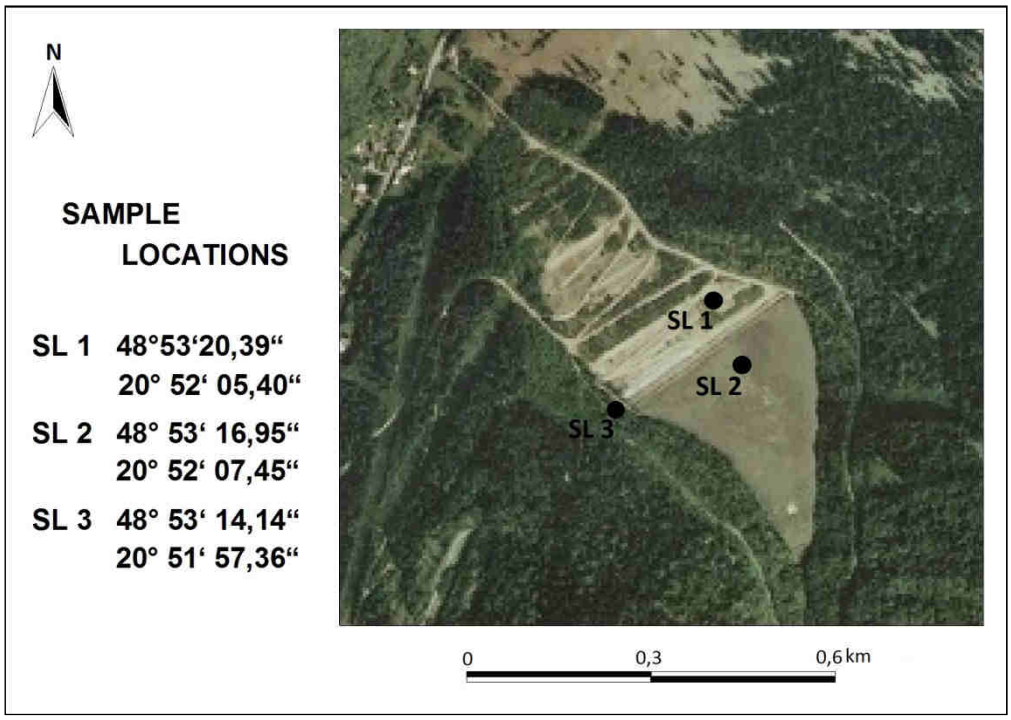
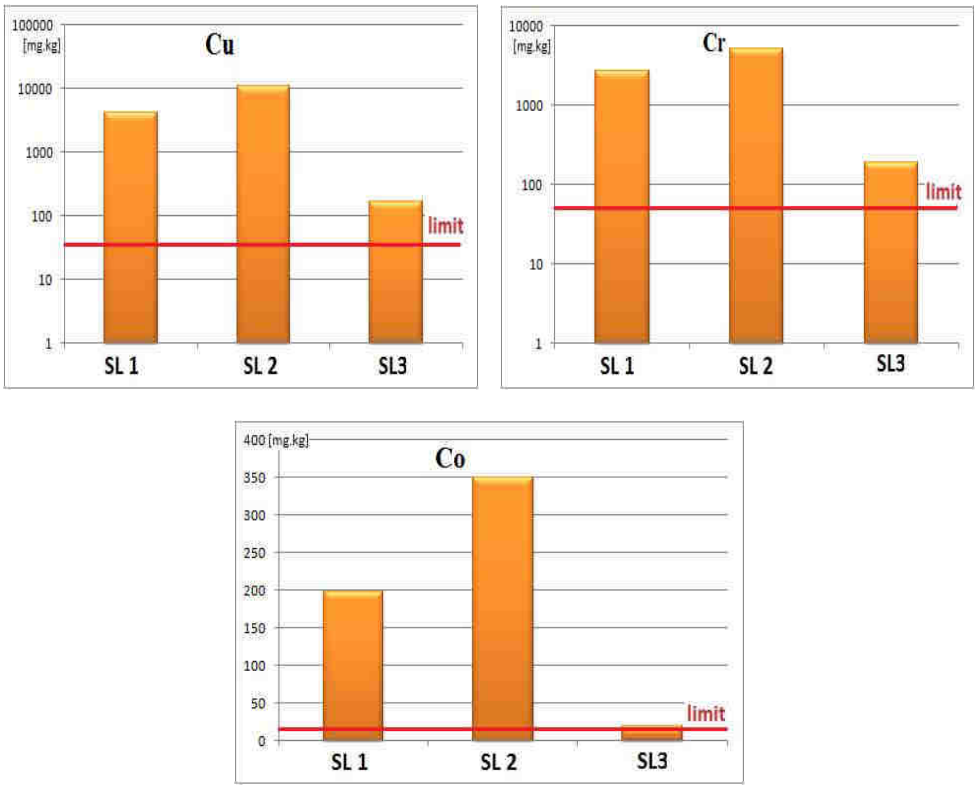


Fig. 3. The spatial distribution of sample locations.

The most alarming results concern Cu contamination, the limit value (60 mg.kg^{-1}) was exceeded at the dam by more than 70-fold and on the surface of the tailing impoundment by almost 180-fold. The limit value was also exceeded in the nearby woods almost threefold. This is a result of the fact that copper ore was mined and processed in this region for a number of decades.

We found similar negative results for other heavy metals – Cr. The limit value (70 mg.kg^{-1}) at the dam was exceeded almost 40-fold and on the surface of the tailing impoundment, it was exceeded 70-fold. In the woods, it is exceeded almost 2-fold.



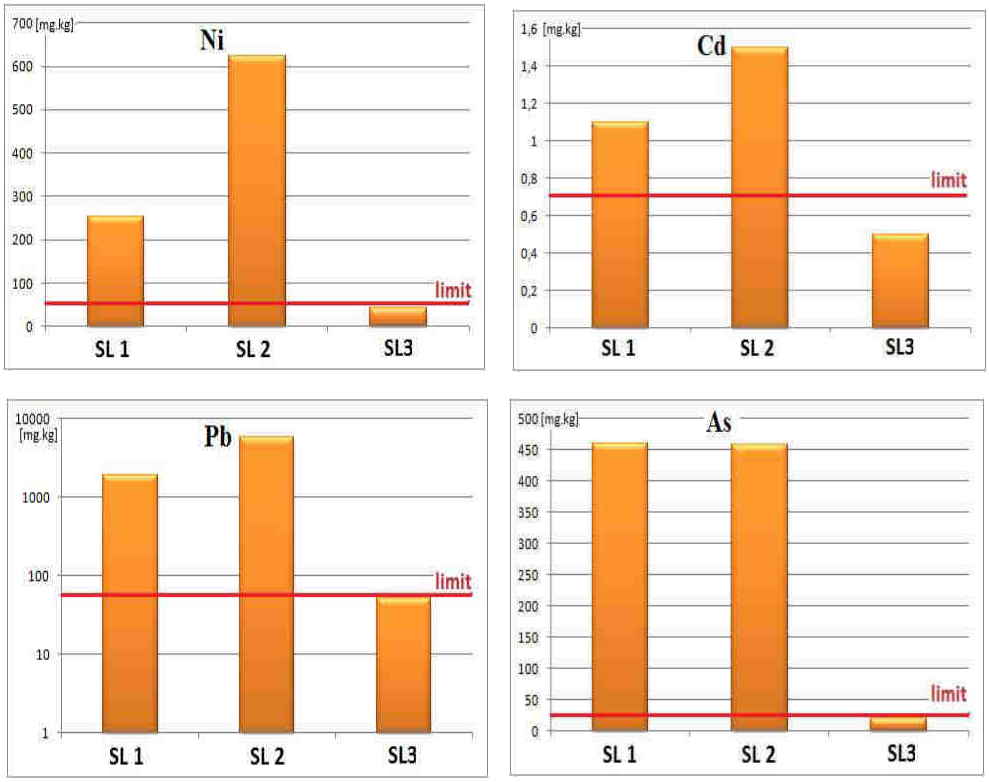


Fig. 4. Heavy metal contamination at the Slovinky tailing impoundment in mg.kg^{-1}.

Tab. 1. The presence of heavy metals on Slovinky tailing impoundment (1 – the dam of the pond, 2 – the body of the pond, 3 – forest 70 m south-west from the body of the pond).

heavy metal	measurand	1	2	3
Cu	[mg.kg^{-1}]	4226	10790	166
As	[mg.kg^{-1}]	461	458	20
Cd	[mg.kg^{-1}]	1,1	1,5	<0,5
Pb	[mg.kg^{-1}]	1928	5791	52
Ni	[mg.kg^{-1}]	254	624	42
Cr	[mg.kg^{-1}]	2687	5121	190
Fe	[%]	19,3	26,2	4,87
Co	[mg.kg^{-1}]	198	349	19

The Co limit value (15 mg.kg^{-1}) is greatly exceeded at the dam and the surface of the tailing impoundment. It was exceeded at the dam by more than 10-fold and at the surface of the tailing impoundment by more than 20-fold. The level of cobalt in the woods is slightly above the stipulated limit.

The limit values of a further set of elements – As, Pb, Ni (As – 25 mg.kg^{-1}, Pb – 70 mg.kg^{-1}, Ni – 50 mg.kg^{-1}) were greatly exceeded. At the dam of the tailing impoundment, As is exceeded almost 20-fold, Pb almost 30-fold and Ni 5-fold. At the surface of the tailing impoundment, As is also exceeded almost 20-fold, a similar value as for the dam, Pb is exceeded more than 80-fold and Ni is exceeded 10-fold. The levels of heavy metals As, Ni, and Pb are slightly below their limit value in the woods.

The monitored area is not highly contaminated by Cd. The limit value is not exceeded (0.7 mg.kg^{-1}) in the woods and the limit values at the dam and the surface of the tailing impoundment are only slightly exceeded.

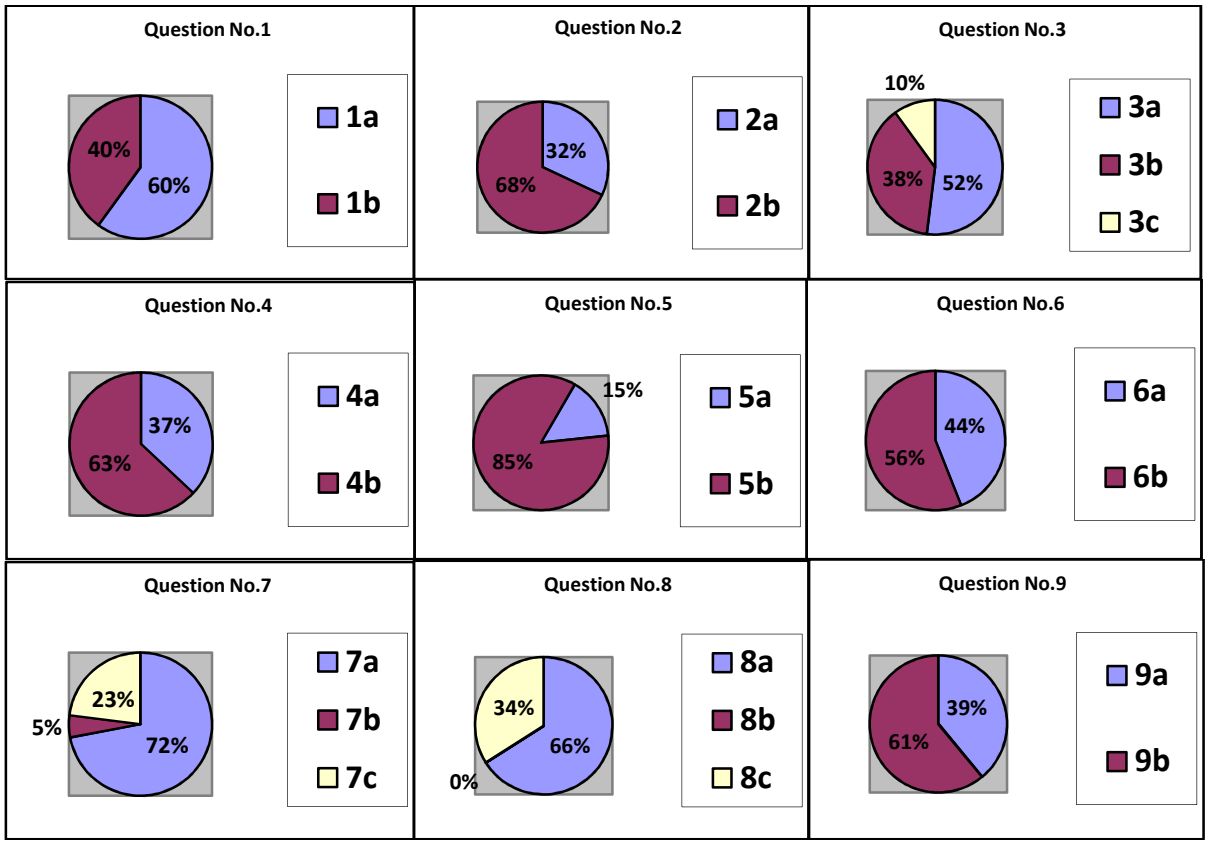
The levels of the elements – Cu, Pb and Cr were plotted using a logarithmic scale in the graphs due to the large range of values.

Results of the Questionnaire

The results of the questionnaire are in percentage shown in Figure 5.

Most of the respondents (60 %) know that the tailing impoundment is located in the administrative area of our town (question 1). More men than women know about this locality, mostly in the age of 46-65 and 66 and more years. Respondents know about it from media information. Some of them visited the tailing impoundment personally. By the majority of respondents (68 %), the amount of information about the tailing impoundment is

not sufficient (question 2). More women than men lack information about the issue. Lack of information indicates mostly in the category up to 18 and 19 to 30 years. Mostly the enlightenment from the local government is missing. By the majority of respondents (52 %), the security status of the tailing impoundment is sufficient (question 3) and they are not worried (56 %) about the possible environmental accident in this area (question 6). More men than women are satisfied with the state of the impoundment. The greatest satisfaction manifested category of 46-65 and 66 and more years old. The majority of respondents are not satisfied with the local government attitude (63 %) and owner attitude (85 %) to this object (question 4 and 5). More men than women are not satisfied with this attitude, mostly in the category up to 18 and 19-30 years old. The tailing impoundment impact to the state of the environment (question 7) and human and animal health (question 8) majority of respondents assessed as negative (72 % and 66 %). Especially women declare negative impact, mostly in the category of 31-45 years old. By most of the respondents (61 %), the tailing impoundment is not a suitable object for tourists (question 9). More men than women think this way, especially in the category of 19-30 and 31-45 years old. According to their opinion, multiple objects nearby are more appropriate for tourism. By the majority of respondents (82 %), the object is suitable for use in the educational process in schools (question 10), the use within the geography based on field trips and presentations on-site (51 %, question 17). The most respondents preferred the using this issue in the educational process in schools in the category of up to 18 and 19-30 years old. By the biggest group of respondents (26 %) - the main priority is to repair damaged parts and gradual reclamation of tailing impoundment (question 11). More men than women think this way, especially in the category of 19-30 and 31-45 years old. In the case of the use of tailing impoundment as an object of tourism, the majority of respondents (63 %) would prefer to build the information boards in the tailing impoundment area instead of the marked tourist trail (39 %) and orientation tables (42 %) (questions 12-14). Respondents recommend (68 %) a qualified guide for the tailing impoundment area (question 15). More women than men recommend a qualified guide for the tailing impoundment area, mostly in the category of up to 18 and 31-45 years old. The reason is also the greater control of the movement of people in the tailing impoundment area. The inclusion of the object among other objects of the former mining activities within the “Mining road” (question 16) is preferred by the majority of respondents (52 %). More women than men recommend this, mostly in the category of 19-30 years old. By the respondents - the limits are the large financial costs and questionable profitability of the construction of such a “Mining road”.



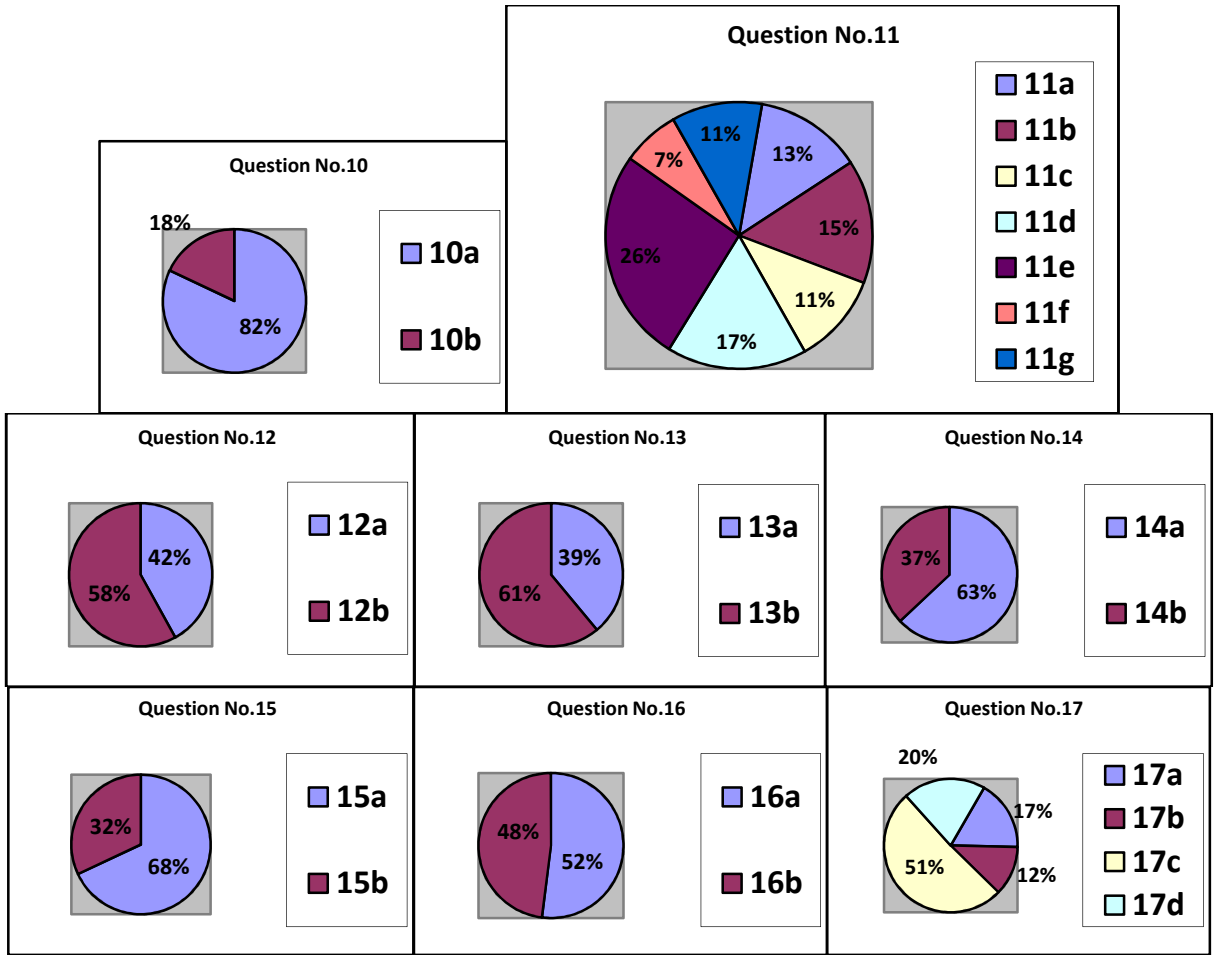


Fig. 5. Questionnaire evaluation.

Discussion and conclusion

Until 1993, when the Slovinky mine was closed, flotation slurry from mining operations was deposited here. After 1993, the local water treatment facility processed slag from the Kovohuty Krompachy plant until 1999. This slag currently comprises the uppermost strata. Two layers can be distinguished in a vertical cross-section through the tailing impoundment. The top layer of the Slovinky tailing impoundment comprises brown slag from the Kovohuty Krompachy plant with a thickness of 5 – 6 m. Under this, there are flotation tailings from the processing of sulphide-siderite ores. The tailing impoundment is dry, and the surface layer has not yet been recultivated. The mineral material of the tailing impoundment primarily comprises silica, siderite and sulphide minerals, namely, chalcopyrite, tetrahedrite, arsenopyrite, pyrite, and small amounts of galenite, sphalerite, bornite, bournonite, jamesonite, antimonite, and Cu-arsenopyrite. Based on the comprehensive geochemical assessment, it can be stated that the tailing impoundment sediments have an alkaline character and do not produce active acidity and potentially toxic elements are relatively tightly bound in these sediments. The tailing impoundment sediments can, therefore, be considered as geochemically stable (Tóth, 2013).

The stability and the degree to which heavy metals are bound in the tailing impoundment was also confirmed by our study since their levels in the surrounding woods are markedly lower. It is essential to take note of the following risk factor, which was confirmed by our field study: the tailing impoundment is dry, its surface has not yet been recultivated and the fine upper layers are blown away from the tailing impoundment during drier periods, which spreads heavy metals into the surrounding area. Most at risk are the inhabitants of the village of Slovinky, who live close to the tailing impoundment.

The levels of heavy metals at the Slovinky tailing impoundment are high and exceed their limit values. In addition, the limits for levels of Cu, Cr and Co are exceeded in the surrounding woods. This is in line with the results of the works of Šottník et al., (2011), Jurkovič et al., (2012) and Tóth et al., (2013). Due to the long-term mining of copper ore, the level of contamination of all the environmental media in the region remains very high and represents a risk to the health of the inhabitants of nearby villages. Our results are consistent with the results of the similar works from different localities around the world (Ai et al., 2015; Feketeová et al., 2015; Arranz-Gonzalez et al., 2016; Jackson and Parbhakar-Fox, 2016).

The results of our research based on the analysis of the questionnaire indicate the fact that the public sees further use of tailing impoundment mainly in the educational process in schools, to a lesser extent in tourism. Most respondents do not consider it appropriate to include Slovinky tailing impoundment as an object of geotourism. This points to a possible conflict of perception of the attractiveness of this area for geotourism among local residents and scientists or tourists (Dowling and Newsome, 2006). Local residents generally do not think that the tailing impoundment area is something they could be proud of it and to offer this locality to tourists. The public considers tailing impoundment as an environmental problem (as shown by the results of our analysis of heavy metals contamination), but the majority of people are not afraid of the potential environmental disaster. Questionnaire survey method has proved useful in identifying the local residents awareness about this environmental burden and its further utilisation.

In conclusion, it can be stated that the Slovinky tailing impoundment will require regular monitoring in the near future. It is important to monitor the impact of the tailing impoundment on the quality of surface water and groundwater and its impact on air quality, which has never been monitored. It is essential to monitor the stability of the dam to prevent an ecological disaster.

Fig. 6. The upper dyke of Slovinky tailing impoundment (photo: authors).

Fig. 7. The surface of Slovinky tailing impoundment (photo: authors).

Fig. 8. 9 Concrete channels are in the bad condition in some parts (photo: authors).

Fig. 10. Author of this article during the lecture on the Slovinky tailing impoundment. The lecture was prepared for Finnish and Spanish students during the "The Faces of Landscape" programme (photo: authors).

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