

# **& Biotechnology Metals** 2024

Institute of Geotechnics, Slovak Academy of Sciences, Košice  
Faculty of Natural Sciences, University of Ss. Cyril and Methodius in Trnava  
Slovak Mining Society  
ALGAJAS s.r.o.



Editors:

Jana Hroncová, Eva Mačingová, Alena Luptáková, Jana Sedláková-Kaduková



ISBN: 978-80-89883-15-8

October 10-11, 2024, Stará Lesná, High Tatras, Slovakia

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## **Proceedings**

**6<sup>th</sup> International Scientific Conference  
on Biotechnology and Metals**



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## Preface

### **Dear colleagues and friends,**

it is honour to welcome you at the 6<sup>th</sup> International Scientific Conference on Biotechnology and Metals.

In the present time, biotechnology contribute to various solution that address many societal and environmental challenges, such as access to and sustainable use of natural resources, restoration of vital nature systems, climate mitigation and adaptation, food supply and security, and human health. They belong to the most promising technologies of this century and have research and technological priorities also within the programs of the European Union.

The rapid development of biotechnological procedures was also noted in the field of environmental biotechnologies, especially regarding the processing of various raw material sources and waste for the purpose of obtaining critical raw materials and protecting the environment.

The goal of the Biotechnology and Metals conference is to support multidisciplinary, to combine the skills of microbiologists, biologists, chemists, physicists, geologists, engineers, economists and other experts, so that they can jointly participate in the development of innovative technologies in order to utilize a vast potential of microorganisms and plants for the restoration and conservation of the environment and for the sustainable utilization of resources.

The conference is organized by four institutions - Institute of Geotechnics, Slovak Academy of Sciences, Košice; Faculty of Natural Sciences, University of Ss. Cyril and Methodius in Trnava; Slovak Mining Society and ALGAJAS s.r.o.

We wish you to enjoy your time at the conference and in Stará Lesná, as well.

We believe that we will meet again also for next, 7<sup>th</sup> year of Biotechnology and Metals conference.

Alena Luptáková and Jana Sedláková-Kaduková

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## BIOAVAILABILITY OF POTENTIALLY TOXIC ELEMENTS IN SELECTED Cu-DEPOSITS OF EUROPE

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### Abstract

Bioavailability of potentially toxic elements from four dump-field material at several abandoned European Cu-deposits: Špania Dolina (Slovakia), Caporciano and Libiola (Italy) and São Domingos (Portugal) was studied. The three steps sequential analyse study show some relation among geological setting and mineralogical composition of ores vs. bioavailability of metals. The best bioavailable metals at first three mentioned deposits are Cu and Cd (in one case, at São Domingos As and Co). The results confirmed that the geological setting substantially influence the order of the bioavailability.

**Keywords:** Cu-deposits, abandoned dump-fields, potentially toxic elements, bioavailability

### 1 Introduction

The aim of the study is to compare the bioavailability of potentially toxic elements (PTEs) at dump-fields of several European abandoned Cu-deposits. Three copper deposits situated in different geological settings were studied. Špania Dolina belongs to the important Cu-deposits of Slovakia. The investigation was realized at Richrárová dump-field. The second studied deposit was the dump-field Caporciano in Val di Cecina and Libiola (Italy). For comparison was selected the area of extensive mining field in São Domingos (Portugal; Fig. 1).

The volcano-sedimentary Cu-mineralization at Špania Dolina is situated in crystalline complex of Permian age. The main exploited economically important minerals were chalcopyrite and tetrahedrite [1, 2]. The chalcopyrite, bornite and chalcocite ore body at great Caporciano mine is associated with ophiolites, formed by diabase, gabbros and serpentinites [3]. The Libiola mine is situated in the ophiolite complex. There are two types of mineralization: the first one is connected to and the second one is serpentinite hosted. The ore mineralization is represented mainly by pyrite and chalcopyrite (less also by sphalerite and pyrrhotite) [4]. São Domingos belongs to the very important world deposits. The mineralization is situated in the Iberian Pyrite Belt black shales and basic volcanics of the volcano sedimentary complex near Spanish border. The exploited ore predominantly consists of following sulphides: chalcopyrite, pyrite sphalerite, tetrahedrite and arsenopyrite. [5, 6]. The average pH at Špania Dolina is 5.29, at Caporciano 6.56, at Libiola 4.03 and in São Domingos is more acid pH = 4.29 [7].

### 2 Material and methods

At each studied locality 25 - 30 technosol samples were taken from the dump-field polygon in such a way to characterize the average dump-material. The samples were dried and mixed to get average sample. Subsequently these samples were homogenized and pulverized (80 mesh).



Fig. 1. Localization of the studied Cu-deposits (A - Špania Dolina, B - Caporciano, Libiola)

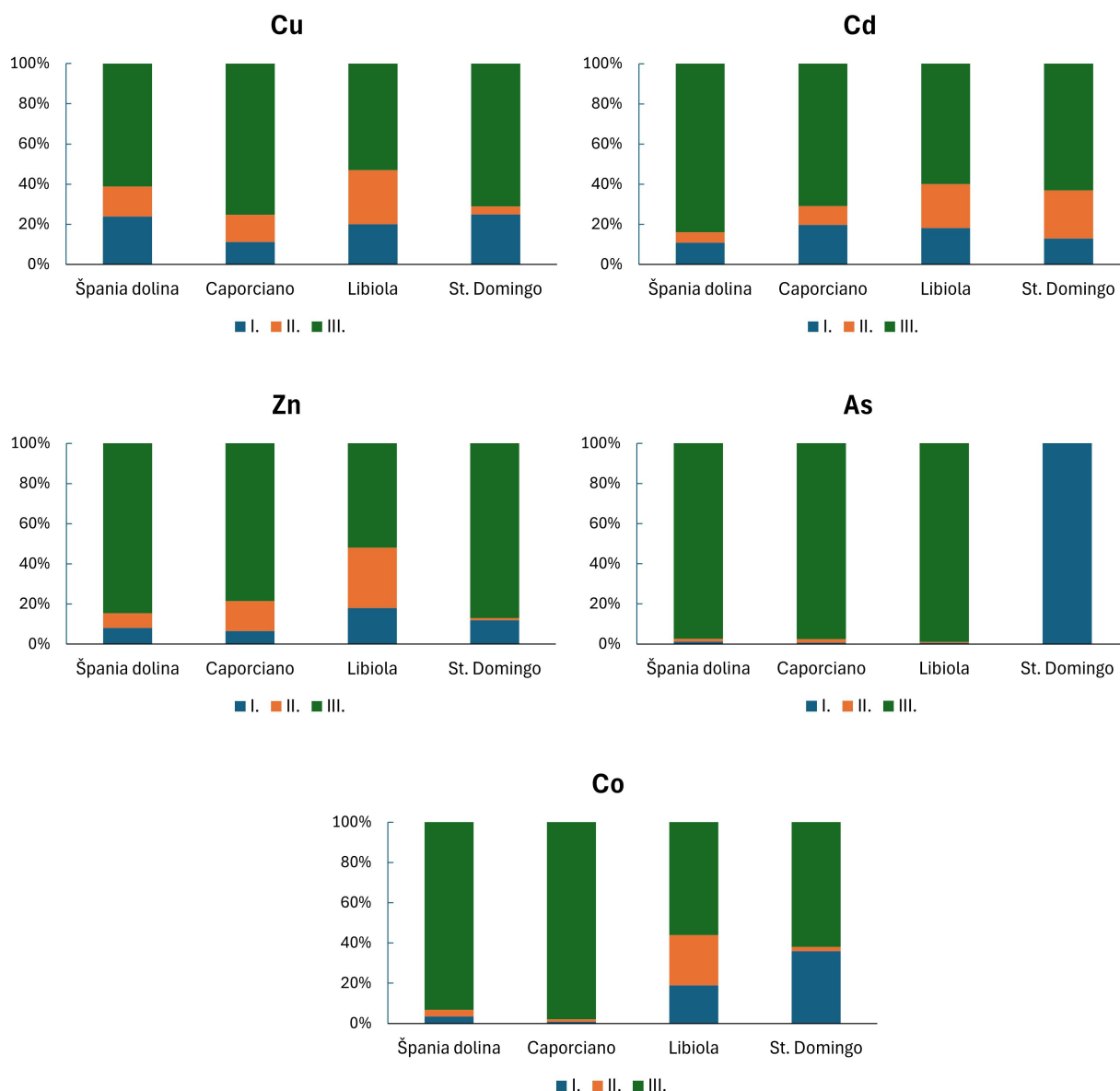
The identification of the bioavailability of selected PTEs was studied by sequential extraction procedure [8]. At first the analyzed sample was dried at 60 °C for 24 hours. 1 g of sample in 50 ml falcon tube was extracted using 5 extraction solutions: The ICP-MS analyses were realized in laboratories of TU-Bergakademie Freiberg. The analyses took the place in the laboratories of Biowissenschaften at TU-Bergakademie Freiberg (Germany). The total concentration of PTEs was measured using 100 mg of sample dissolved in aqua regia. For the sequential extraction analysis was used 1 g of technosol sample. Four steps of sequential extraction was executed: I. distilled resp. deionized water; II. 1M solution of  $\text{NH}_4\text{CH}_3\text{CO}_2$  (ammonium acetate) at pH 7; III. 0.01M  $\text{C}_6\text{H}_8\text{O}_7$  (citric acid) solution. First 2 fractions can be considered as exchangeable [9].

### 3 Results and discussion

There are interesting similarities between Špania Dolina and Caporciano. At the dump-fields of both deposits are the most bioavailable PTEs Cu and Cd, only the order of these elements at individual localities is different: at Špania Dolina is the most bioavailable metal Cu and in Caporciano and in Libiola Cd (Fig. 2). The less bioavailable PTEs in Špania Dolina are As and Co, whereas in Caporciano Co and As (Fig. 2). At Libiola decrease the bioavailability in rate:  $\text{Cu} > \text{Zn} > \text{Cd} > \text{Co} > \text{As}$ .

The results from São Domingos show the best bioavailability surprisingly for As and Co. The bioavailability decreases in rate  $\text{As} > \text{Co} > \text{Cu} > \text{Cd} > \text{Zn}$  (Fig. 2). The degree of bioavailability corresponds for example with results published by Kim [10] and Lalhruaitluanga [11].

The results show that the bioavailability is substantially influenced by geological setting, geochemical conditions (different characteristics of the rocks/technosol), pH and mineralogical forms of the present PTEs.



**Fig. 2. Bioavailability of PTEs at the studied deposits**  
(First 2 fractions can be consider as bioavailable)

#### 4 Conclusions

The substantial part of the bioavailable PTEs was generally released from the technosol in the deionized water and less also in 1 M solution of ammonium acetate. At first three deposits (Špania Dolina, Caporciano in Val di Cecina and Libiola) is possible distinguish generally two bioavailable PTEs: Cu and Cd. Less bioavailable are Co and Zn. Except the dump-field São Domingos the less immobile metals are As and Co. In São Domingos are the most bioavailable metals As and Co. The relationship between the bioavailable PTEs and pH was not proved.

#### Acknowledgements

The article was supported by of grant agency VEGA 1/0220/23.

#### References

- [1] Jeleň, S., Galvánek, J., Andráš, P., Križáni, I. História baníctva Španej Doliny. *Minerál*, 20 (4), 2012, p. 291-308.
- [2] Andráš, P., Jeleň, S., Ferenc, Š. Geologicko-ložisková charakteristika Cu-ložísk Špania Dolina, Staré Hory, Ľubietová a Poniky. In Andráš, P., Dirner, V., Turisová, I., Vojtková, H. *Staré báňské zátěž*

- opuštěných Cu-ložisek*. Remnants of old activity at abandoned Cu-deposits. Mendelej, Ostrava, 2013, p.123-141. ISBN 978-80-86832-75-3.
- [3] Dolfini, A., Angelini, I., Artioli, G. Copper to Tuscany - Coals to Newcastle? The dynamics of metalwork exchange in early Italy. *PLoS ONE*, 15 (1), 2020, p. 1-35.
- [4] Buccheri, G., Andráš, P., Astolfi, M.L., Canepari, S., Ciucci, M., Marino, A. Heavy metal contamination in water at Libiola abandoned copper mine, Italy. *Romanian Journal of Mineral*, 87 (1), 2014, p. 65-70.
- [5] Matos, J.X., Oliveira, D.P.S., Batista, M.J., Pereira, Z., Albardeiro, L., Morais, I., Mendes, M., Marques, F., Solá, R., Salgueiro, R., Carvalho, J., Gonçalves, P., Oliveira, J.T. Iberian Pyrite Belt Exploration. *Comunicações Geológicas*, 107, 2020, p.150.
- [6] Vieira, A., Matos, J.X., Lopes, L., Martins, R. Evaluation of the mining potential of the São Domingos mine waste, Iberian Pyrite Belt, Portugal. *Comunicações Geológicas*, 107, 2020, p. 91-100.
- [7] Andráš, P., Midula, P., Matos, J.X., Buccheri, G., Drímal, M., Dirner, V., Melichová, Z., Turisová, I. Comparison of soil contamination at the selected European copper mines. *Carpathian Journal of Earth and Environmental Sciences*, 16 (1), 2021, p. 163-174. ISSN-1842-4090.
- [8] Midula, P., Wiche, O., Wiese, P., Andráš, P. Concentration and bioavailability of toxic trace elements, germanium, and rare earth elements in contaminated areas of the Davidschacht dump-field in Freiberg (Saxony). *Freiberg ecology online*, 2, 2017, p. 101-112.
- [9] Midula, P., Wiche, O., Wiese, P., Andráš, P. Concentration and bioavailability of toxic trace elements, germanium, and rare earth elements in contaminated areas of the Davidschacht dump-field in Freiberg (Saxony). *Freiberg ecology online*, 2, 2017, p. 101-112.
- [10] Kim, R.Y., Yoon, J.K., Kim, T.S., Yang, J.E., Owens, G., Kim, K.R. Bioavailability of heavy metals in soils: definitions and practical implementation - a critical review. *Environmental Geochemistry and Health*, 37, 2015, p. 1041-1061.
- [11] Lalhruaitluanga, H., Prasad M.N.V., Radha, K. Potential of chemically activated and raw charcoals of *Melocanna baccifera* for removal of Ni(II) and Zn(II) from aqueous solutions. *Desalination*, 271 (1-3), 2011, p. 301-308.

Proceedings: Proceedings of the 6<sup>th</sup> International Scientific Conference on Biotechnology and Metals

Editors: Jana Hroncová, Eva Mačingová, Alena Luptáková, Jana Sedláková-Kaduková

Publishers: Institute of Geotechnics, Slovak Academy of Sciences, Košice & Slovak Mining Society  
at the Institute of Geotechnics SAS

Reviewers: All conference papers went through the anonymous review process

Year: 2024

Pages: 273

ISBN: 978-80-89883-15-8

**ISBN: 978-80-89883-15-8**