ASSESSMENT METHODS THAT CAN BE APPLIED FOR THE DETERMINATION OF THE TERRESTRIAL POLLUTION STATE OF AREAS AFFECTED BY MINING ACTIVITIES

Contents

Introduction

The **pollution of soil and sediment by mining activities**, especially the heavy metals pollution has become a widespread **problem** all over the world. Moreover, changes in landscape, destruction of habitats, contamination of soil and degradation of land resources are all results of mine activity, one of the most influential anthropogenic activities that lead to such results (Zhou 2015).

Methods to assess the pollution state of soils are necessary in order to evaluate the damages against the environment that mining activities produce. These methods must be based on preliminary studies about waste properties, heavy metals content and their relation to the environment (Zhou 2015).

Cooperation beyond borders.
Interreg-IPA Cross-border Cooperation Romania-Serbia Programme is financed by the European Union under the Instrument for Pre-accession Assistance (IPA II) and co-financed by the partner states in the Programme.
Project RoRS 337- ROmania Serbia NETwork for assessing and disseminating the impact of copper mining activities on water quality in the cross-border area (RoS-NET2)

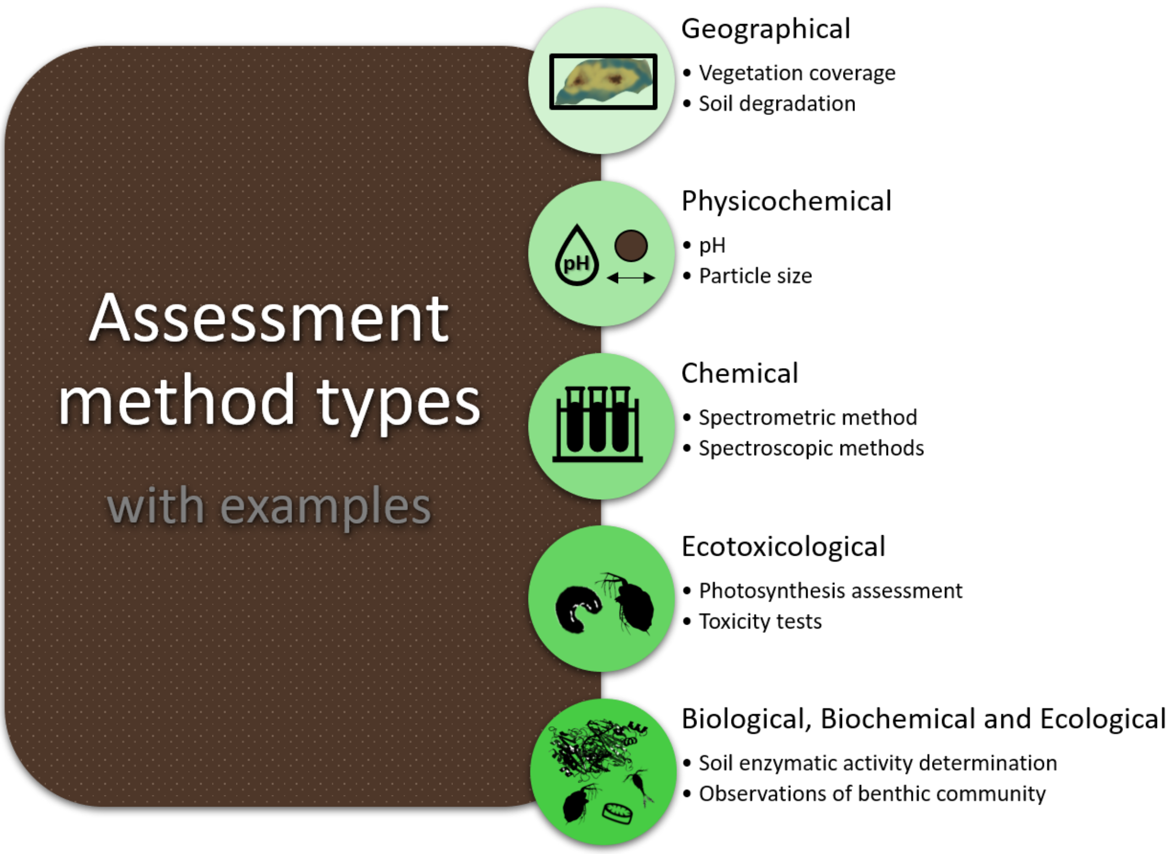
Assessment methods

The terrestrial pollution state of areas affected by mining activities, including both **soil** and **sediment** pollution, can be assessed by different **method types**, such as:

- geographical
- physicochemical
- chemical
- ecotoxicological
- biological, biochemical and ecological

These methods represent a static assessment as they describe the pollution state of the mining polluted soils and sediments at the moment of testing. If the mining activities continue, the pollution state will evolve further, thus further testing being necessary (Zhou 2015).

Kinetic assessment methods, such as multivariate statistical analysis that use static data, are essential for the evaluation and prediction of future pollution states which are of great significance in proposing better plans for pollution abatement (Zhou 2015). As these methods include primarily statistical calculations and not laboratory determinations, these are not discussed in this document.



Geographical assessment methods

In order to determine the pollution state of soil in areas affected by mining activities, several methods can be used to determine geographical parameters such as:

- land cover (Saedpanah and Amanollahi 2019)
- land use (Saedpanah and Amanollahi 2019)
- erosion (Saedpanah and Amanollahi 2019)
- soil degradation (Saedpanah and Amanollahi 2019)
- vegetation coverage (Saedpanah and Amanollahi 2019)
- land utilization type (Saedpanah and Amanollahi 2019)
- slope degree (Saedpanah and Amanollahi 2019)
- rock and soil structure (Saedpanah and Amanollahi 2019)
- mine exploitation degree (Saedpanah and Amanollahi 2019)

Physicochemical assessment methods

Some physicochemical methods, that can be applied to analyze the pollution state of soil and sediment samples, are:

- pH determination (Seklaoui, Boutaleb et al. 2016)
- electrical conductivity assessment (Seklaoui, Boutaleb et al. 2016)
- loss-on-ignition (%LOI) (Romero-Freire, Minguez et al. 2018)
- particle size (with laser diffraction granulometer) (Romero-Freire, Minguez et al. 2018)

Chemical assessment methods

The chemical methods for soil and sediment sample analysis from areas affected by mining activities involve the determination of the concentration of different mining pollutants. These methods rely on the use of specific equipment and techniques such as:

Equipment / Technique	Pollutants analyzed	References
Graphite furnace atomic absorption (GFAA)	Hg, As, Sb	(Seklaoui, Boutaleb et al. 2016)
Flame atomic absorption spectrometer (F-AAS)	As, Hg, Zn, Cu, Co, Ni, Cr, Pb, Cd	(Seklaoui, Boutaleb et al. 2016, Demková, Jezný et al. 2017)
Inductively coupled plasma-atomic emission spectroscopy (ICP-AES)	Ag, As, Cd, Co, Cr, Cu, Mo, Ni, Pb, Sb, Zn	(Moore, Sheykhi et al. 2016)
Inductively coupled plasma-optical emission spectrometry (ICP-OES)	heavy metals	(Sima, Zobrist et al. 2008)
Inductively coupled plasma-mass spectrometry (ICP-MS)	rare earth elements (La, Ce, Pr, Nd, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu)	(Romero-Freire, Minguez et al. 2018)
X-ray fluorescence spectrometry	Hg, Cd, Pb, Ni, Cr, Zn, Cu, Fe, Mn, Mg	(Sima, Zobrist et al. 2008, Fazekašová and Fazekaš 2020)
Wavelength dispersive X-ray fluorescence (WDXRF) spectrometry	K, Ca, Na, Mg, Si, Al, Mn, Ti, Fe	(Wu, Teng et al. 2014)
Atomic fluorescence spectrometry (AFS)	Pb, Cr, Zn, Cu, Cd, Mn, As	(Li, Yin et al. 2010, Cheng, Drozdova et al. 2018)
Cold vapor atomic fluorescence spectroscopy (CV-AFS)	Hg	(Cheng, Drozdova et al. 2018)
Bernard calcimeter	$CaCO_3$	(Seklaoui, Boutaleb et al. 2016)
Walkley and Black's rapid titration method	organic matter	(Seklaoui, Boutaleb et al. 2016)

Ecotoxicological assessment methods

Some of the ecotoxicological assessment methods of soil and sediment samples from areas affected by mining activities that can be applied are described in the following table:

Test / Method	Organisms used	Recommended species	References
Microbial toxicity test	luminescent marine bacteria	*Aliivibrio fischeri*	(Chiochetta, Radetski et al. 2013, Romero-Freire, Minguez et al. 2018)
Algal growth inhibition test	microalgae	*Scenedesmus subspicatus*	(Chiochetta, Radetski et al. 2013)
Photosynthetic efficiency test based on the production of chlorophyll fluorescence	green algae	*Chlorella vulgaris*	(Romero-Freire, Minguez et al. 2018)
Daphnids mortality test	daphnids	*Daphnia magna*	(Chiochetta, Radetski et al. 2013)
Ostracod chronic toxicity test	ostracods	*Heterocypris incongruens*	(Romero-Freire, Minguez et al. 2018)
Phytotoxicity test	monocotyledonous or dicotyledonous plants	*Brassica oleracea* var. *capitate* *Lactuca sativa* *Zea mays*	(Chiochetta, Radetski et al. 2013)
Germination and root elongation toxicity test	monocotyledonous or dicotyledonous plants	*Lactuca sativa*	(Romero-Freire, Minguez et al. 2018)
Earthworm toxicity test	earthworms	*Eisenia andrei* *Eisenia foetida*	(van Coller-Myburgh, van Rensburg et al. 2015, Maboeta, Oladipo et al. 2018) (Chiochetta, Radetski et al. 2013)

Biological, biochemical and ecological assessment methods

Some biological, biochemical and ecological assessment methods that can be used to establish the pollution state of soils affected by mining activities are:

- soil enzymatic activity determination for enzymes (van Coller-Myburgh, van Rensburg et al. 2015) such as:
    - dehydrogenase (van Coller-Myburgh, van Rensburg et al. 2015)
    - β-glucosidase (van Coller-Myburgh, van Rensburg et al. 2015)
    - urease (van Coller-Myburgh, van Rensburg et al. 2015)
    - invertase (Zhou 2015)
    - acidic phosphatase (van Coller-Myburgh, van Rensburg et al. 2015)
    - alkaline phosphatase (van Coller-Myburgh, van Rensburg et al. 2015)
    - hydrolytic enzymes (Chiochetta, Radetski et al. 2013)

- soil bacterial community diversity assessment (Qu, Ren et al. 2011)

- assessment of structure and function of soil nematode communities (Zhou 2015)

- sediment quality assessment through benthonic community observations:
    - observation of natural benthic communities from mining polluted sediments (Somerfield, Michael Gee et al. 1994)
    - testing the effects of mining polluted sediments on benthic communities in laboratory (Mevenkamp, Stratmann et al. 2017, Trannum, Næss et al. 2020)

- soil quality assessment which is based on the calculation of different indices from parameters such as:
    - physical parameters such as:
        - soil moisture (Andrews and Carroll 2001)
        - available water (Andrews and Carroll 2001)
    - chemical parameters such as:
        - total carbon, nitrogen contents (Andrews and Carroll 2001)
        - micronutrients (Andrews and Carroll 2001)
        - pH (Andrews and Carroll 2001)
    - biological parameters such as:
        - microbial C and N (Andrews and Carroll 2001)
        - soil respiration (Andrews and Carroll 2001)

- determination of soil pollution / contamination index (Krishna, Mohan et al. 2013, Moore, Sheykhi et al. 2016)

Cooperation beyond borders.
Interreg-IPA Cross-border Cooperation Romania-Serbia Programme is financed by the European Union under the Instrument for Pre-accession Assistance (IPA II) and co-financed by the partner states in the Programme.
Project RoRS 337- ROmania Serbia NETwork for assessing and disseminating the impact of copper mining activities on water quality in the cross-border area (RoS-NET2)

References

- Andrews, S. S. and C. R. Carroll (2001). "DESIGNING A SOIL QUALITY ASSESSMENT TOOL FOR SUSTAINABLE AGROECOSYSTEM MANAGEMENT." Ecological Applications **11**(6): 1573-1585.
- Cheng, X., J. Drozdova, T. Danek, Q. Huang, W. Qi, S. Yang, L. Zou, Y. Xiang and X. Zhao (2018). "Pollution assessment of trace elements in agricultural soils around copper mining area." Sustainability **10**(12): 4533.
- Chiochetta, C. G., M. R. Radetski, A. X. R. Corrêa, V. Tischer, E. N. Tiepo and C. M. Radetski (2013). "Abandoned coal mining sites: using ecotoxicological tests to support an industrial organic sludge amendment." Environmental Science and Pollution Research **20**(11): 7656-7665.
- Demková, L., T. Jezný and L. Bobuľská (2017). "Assessment of soil heavy metal pollution in a former mining area–before and after the end of mining activities." Soil and Water Research **12**(4): 229-236.
- Fazekašová, D. and J. Fazekaš (2020). "Soil Quality and Heavy Metal Pollution Assessment of Iron Ore Mines in Nizna Slana (Slovakia)." Sustainability **12**(6): 2549.
- Krishna, A. K., K. R. Mohan, N. N. Murthy, V. Periasamy, G. Bipinkumar, K. Manohar and S. S. Rao (2013). "Assessment of heavy metal contamination in soils around chromite mining areas, Nuggihalli, Karnataka, India." Environmental Earth Sciences **70**(2): 699-708.
- Li, J., R. Yin, Y. Luo, Y. Lu and L. Zhang (2010). "Assessment of heavy metal contamination of soils in Daxin Manganese mine Guangxi." Environmental Science & Technology (China) **33**(7): 183-190.
- Maboeta, M. S., O. G. Oladipo and S. M. Botha (2018). "Ecotoxicity of Mine Tailings: Unrehabilitated Versus Rehabilitated." Bulletin of Environmental Contamination and Toxicology **100**(5): 702-707.
- Mevenkamp, L., T. Stratmann, K. Guilini, L. Moodley, D. van Oevelen, A. Vanreusel, S. Westerlund and A. K. Sweetman (2017). "Impaired Short-Term Functioning of a Benthic Community from a Deep Norwegian Fjord Following Deposition of Mine Tailings and Sediments." Frontiers in Marine Science **4**(169).
- Moore, F., V. Sheykhi, M. Salari and A. Bagheri (2016). "Soil quality assessment using GIS-based chemometric approach and pollution indices: Nakhlak mining district, Central Iran." Environmental Monitoring and Assessment **188**(4): 214.
- Qu, J., G. Ren, B. Chen, J. Fan and Y. E (2011). "Effects of lead and zinc mining contamination on bacterial community diversity and enzyme activities of vicinal cropland." Environmental Monitoring and Assessment **182**(1): 597-606.
- Romero-Freire, A., L. Minguez, M. Pelletier, A. Cayer, C. Caillet, S. Devin, E. M. Gross, F. Guérold, S. Pain-Devin, D. A. L. Vignati and L. Giamberini (2018). "Assessment of baseline ecotoxicity of sediments from a prospective mining area enriched in light rare earth elements." Science of The Total Environment **612**: 831-839.

- Saedpanah, S. and J. Amanollahi (2019). "Environmental pollution and geo-ecological risk assessment of the Qhorveh mining area in western Iran." Environmental Pollution **253**: 811-820.
- Seklaoui, M. h., A. Boutaleb, H. Benali, F. Alligui and W. Prochaska (2016). "Environmental assessment of mining industry solid pollution in the mercurial district of Azzaba, northeast Algeria." Environmental Monitoring and Assessment **188**(11): 621.
- Sima, M., J. Zobrist, M. Senila, E.-A. Levei, B. Abraham, B. Dold and D. Balteanu (2008). "ENVIRONMENTAL POLLUTION BY MINING ACTIVITIES--A CASE STUDY IN THE CRIŞ ALB VALLEY, WESTERN CARPATHIANS, ROMANIA." GeoEcoMarina **14**(1).
- Somerfield, P. J., J. Michael Gee and R. M. Warwick (1994). "Benthic community structure in relation to an instantaneous discharge of waste water from a tin mine." Marine Pollution Bulletin **28**(6): 363-369.
- Trannum, H. C., R. Næss and H. Gundersen (2020). "Macrofaunal colonization of mine tailings impacted sediments." Science of The Total Environment **708**: 134866.
- van Coller-Myburgh, C., L. van Rensburg and M. Maboeta (2015). "Assessing the Ecotoxicity of Gold Mine Tailings Utilizing Earthworm and Microbial Assays." Water, Air, & Soil Pollution **226**(7): 218.
- Wu, J., Y. Teng, S. Lu, Y. Wang and X. Jiao (2014). "Evaluation of soil contamination indices in a mining area of Jiangxi, China." PloS one **9**(11): e112917.
- Zhou, H. (2015). "Soil heavy metal pollution evaluation around mine area with traditional and ecological assessment methods." Journal of Geoscience and Environment Protection **3**(10): 28.