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TECHNICAL UNIVERSITY OF CLUJ-NAPOCA

FACULTY OF MATERIALS AND ENVIRONMENTAL ENGINEERING

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ABSTRACT OF Ph.D. THESIS

**STUDIES AND RESEARCH ON THE CONTENT,
DISTRIBUTION AND RECOVERY OF HEAVY METALS
FROM TAILINGS AND TECHNOLOGICAL RISK
ASSESSMENT**

**Thesis advisor
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Introduction

Multiple accidents at tailing ponds have directed public attention to the potential hazards and severe impacts on the environment, created by the discharge of hazardous substances from ponds and renewed concerns about the management and risk assessment of tailings dam.

In recent years, various European projects (Pecomines, Tailsafe, Eco-Risk) were developed in order to minimize the risks of accidents at tailing pond, by analyzing sterile materials and the security at this industrial features. Europe, with 14% of all dam failures, is the second in the world. In Romania, a methodology for identifying risks at ponds was proposed, methodology that is based on a certain criteria for assessing dams and the water risk index. This case study is based on Valea Şesei TMF, in the Apuseni Mountains, where there was an accident in 2001.

The proposed theme is based on detailed knowledge of tailing ponds and the physical and chemical characteristics of these composite materials. The storage of tailings resulting from mining, in ponds, usually separated by dams, can be a serious threat to the environment and the human population, especially where the exploitation system and management are poor.

Tailing dams failure produced, in many cases, real disasters, especially when they resulted in human fatalities. Accidents become more serious due to fine granulometry of the materials in the ponds and their content of toxic elements such as zinc, copper, cadmium, nickel and other heavy metals. Thus, when an accident occurs, there are immediate and long-term effects.

This paper is based on a case study for Valea Şesei TMF, in Alba County, Romania. The choice of study area was due to impressive size of the pond as well as previous pollution problems in the area.

Objectives of the thesis

In order to do metal recovery from tailings and to identify risks associated with tailing dams it is necessary to know the characteristics of these materials. Therefore, the thesis had the following objectives:

- Study on the composition and structure of tailings;
- Study of risk assessment methods for tailing ponds;
- Physico-chemical analysis of tailings from Valea Şesei TMF
- Spatial modeling of heavy metals dispersion in Valea Şesei TMF;
- Analysis of heavy metal recovery from tailings;
- Technological risk assessment and NATECH risk assessment at Valea Şesei TMF;
- Making a Geoinformatical risk assessment model for tailing ponds.

The thesis comprises of eight chapters to which are added a list with bibliographic references and annexes.

First chapter "*Studies regarding the composition and structure of tailings*" describes the characteristics of tailings, the chemical reactions in tailing ponds, the materials and methods for tailing dams' construction and their stability, the tailings distribution systems and the influence of their chemical composition on the environment.

The second chapter, named "*Management and risk assessment of tailings in ponds*" includes the state-of-the-art of hazard and risk assessment, the applied methods and especially their analysis at tailing ponds. It also comprises a study on the toxicity of materials from ponds.

In the third chapter, "*Physico-chemical analysis on tailings from Valea Şesei TMF*" are described the Roşia Poieni mining area, the Valea Şesei tailing pond and the solid and fluid materials in it. The tailing's mineralogy includes: quartz, periclone and traces of muscovite, orthoclase, clinocllore, kaolinite and pyrite. 75% of the tailings have sand grain size, 15% of sludge material have grain size and 12% clay. The chemical composition of the solid fraction of the tailings material contains 66.4% SiO₂, Al₂O₃ 16.25%, 5% Fe, 2.10% CaO, MgO 2.60%, S 1.35%, 0.0032% Bi, 0.0450 Mn, Cu 0.115%, 0.008% Pb and 0.016% Zn. Tailings decanting is based on grading and density of the compounds. Thus, lead oxides, bismuth, copper, iron, manganese and zinc will be the basis of the tailings, followed by aluminum oxide, silica, magnesium oxide and calcium oxide, sulfur oxides being at the surface and in contact with oxygen and water forming acid waters. Metal sulphides from tailings are oxidised under the influence of catalysts acidophilous bacteria, causing physical and chemical

changes, known as bacterial leaching. This is the oxidation of iron and sulphur, resulting in sulphuric acid and in leaching and dispersion of metals. The test results show that the pond contains acidic water as well as the Valea Şesei creek downstream the TMF, which flows into Arieş River. Water pH increases with proximity to the Aries River, emphasizing the self-purification property of water. Analyzed water contains high concentrations of heavy metals, especially Cu, Fe, Mn and Zn with devastating effects on fauna and flora in the area. Also domestic animals and humans living near the pond are affected.

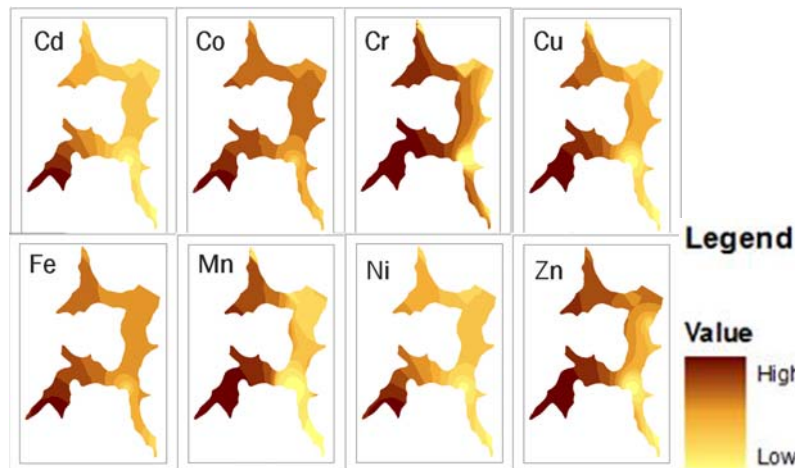


Fig. 1. Spatial distribution of 8 metals in Valea Şesei TMF

The fourth chapter “*Modeling spatial distribution of heavy metals in Valea Şesei TMF*” gives an introduction in geostatistics and kriging estimator and a case study on Valea Şesei tailing pond. Interpolated maps of heavy metals (figure 1), show an increased concentration on NE-SW, with the so-called "hot spots" in the SW. High concentrations are due to water leakage from the waste dumps, which are ending in Valea Şesei TMF. Highest values are reported for the metals: Cu, Mn, Fe and Zn.

These results were afterwards validated with the analysis of the Landsat satellite images. Supervised classification was used for determining seven classes: water, bare soil, forest, grass, houses and highly contaminated water.

The area highly contaminated area by heavy metals can be observed by comparing results from the geostatistical analysis with data collected on Landsat satellite images, showing that they are the same polluted area (figure 2). It is clear that digital image processing and interpretation of satellite images can successfully detect and identify heavy metals contamination of water.

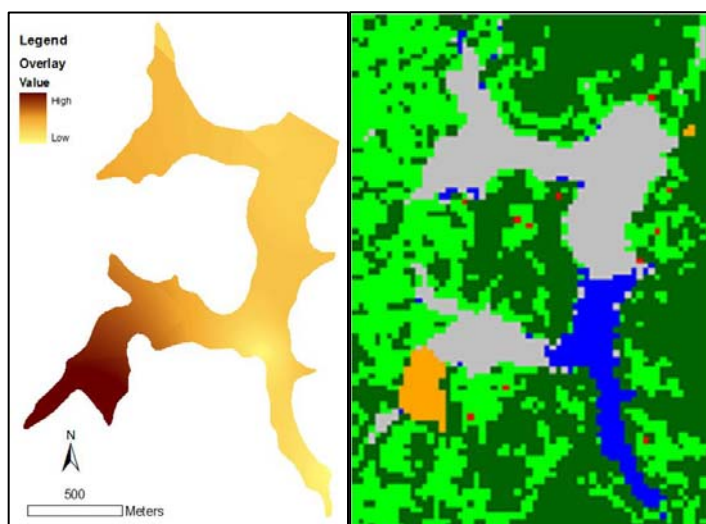


Fig. 2. Comparison between the results of geostatistical analysis and satellite imagery analysis

In chapter 5, “*Studies and research on recovery of heavy metals from tailings deposits*” are presented the heavy metal recovery methods, with special attention to copper recovery at Valea Şesei tailing pond. Sulphuric acid leaching method was chosen, obtaining a maximum output of 60%.

Chapter 6 “*Influence of tailings on risks, case study at Valea Şesei tailing pond*” comprises an ontology for risk analysis methods, followed by the technological risk assessment as well as NATECH (Natural Hazards Triggering Technological Disasters) risk assessment. Technological hazards at tailing ponds are associated with acid mine drainage, heavy metal pollution and physical stability of the dam. The spatial distribution of calculated risk regarding heavy metals is shown in figure 3. The results indicate a very high risk for Cd, Cu, Fe and Mn. Based on a mathematical model (Lăzărescu & Ghindă) a simulation of the wave propagation of tailings and water in case of an accident, was made. The animation shows how the wave arrives in the Arieş River, affecting some homes downstream. The distance traveled by wastes is 5.5 km and the distance in elevation is 190 m.

Natural Hazards Triggering Technological Disasters at tailing dams can be: earthquakes, floods, landslides etc. On the seismic hazard scale, Valea Şesei TMF lies between 6.5 and 6.5 degrees on the MSK scale, which indicates a low to medium intensity earthquakes in which only poorly

designed buildings are damaged. In the area of Rosia Poieni the likelihood of an earthquake is low. From the spatial modeling, the risk of landslides around the tailing pond is low to moderate, but with important consequences. The surface runoff in the area was also estimated, based on the SCS-CN method with the help of GIS techniques. The results show high runoff volumes around Valea Şesei TMF, with negative effects in case of heavy rainfall.

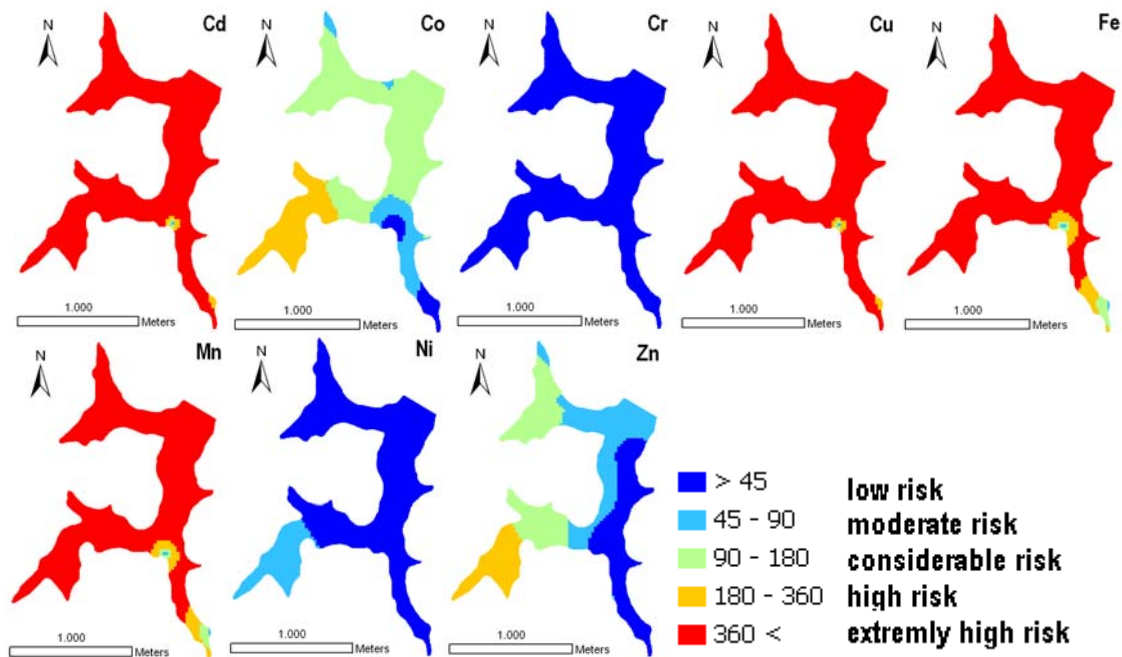


Fig. 3 Spatial distribution of potential risk of metals Co, Cd, Cr, Cu, Fe, Mn, Ni, Zn

The seven chapter “A geoinformatical model for risk assessment at Valea Şesei tailing pond” was achieved based on all analysis from the previous chapter. This model was done to simplify the process of risk assessment. A chart/diagram/layout can be seen in figure 4.

A new geoinformatical model for risk assessment at tailing ponds is useful to decision-making factors, easy to implement, less expensive and requires less time than traditional models.

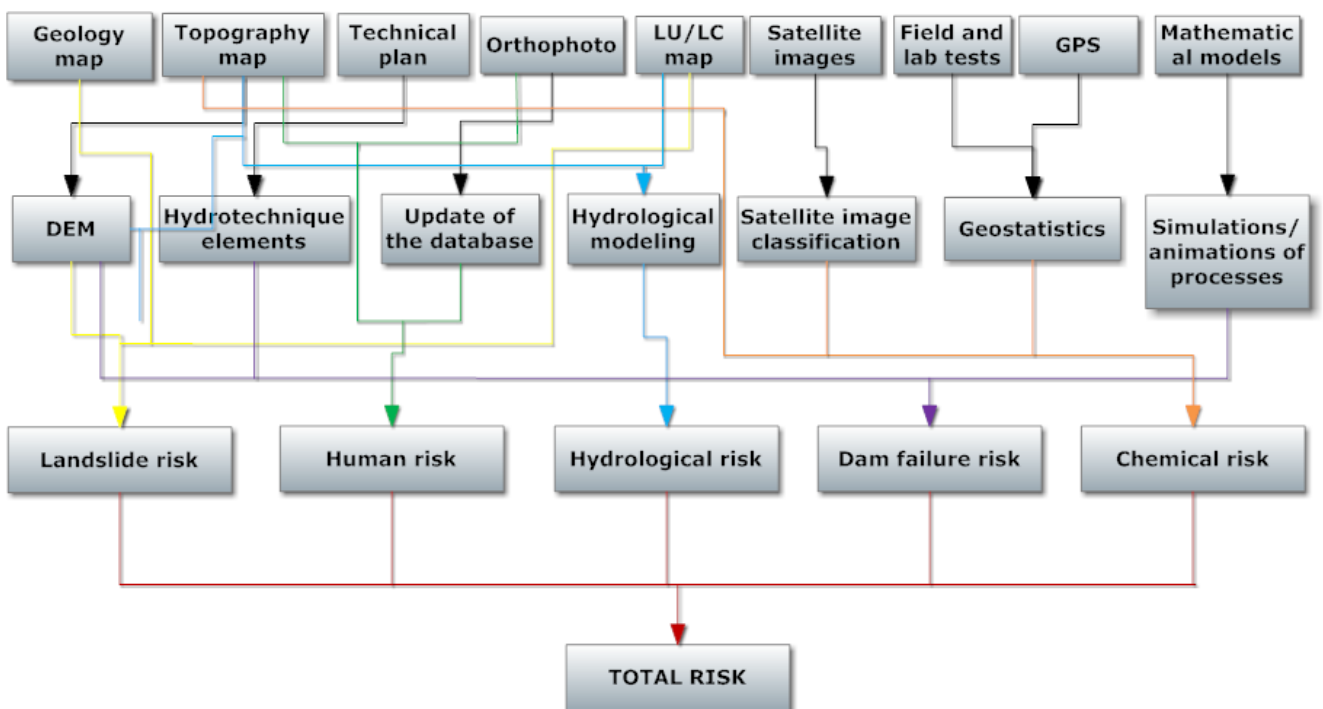


Fig. 4 Geoinformatical model for Valea Şesei tailing pond risk assessment