# Geophysical study of a potential source of secondary raw materials – the Aijala mine tailings area Southern Finland

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## Introduction

The recycling and recovery becomes more relevant for EU economy as the resources of raw material are decreasing and their prices are raising. The SMART GROUND project funded by the EU's Horizon 2020 program intends to improve availability and accessibility of information of the secondary raw material in the EU. The consortium will create an EU database (Smart Ground database) that integrates all the data from existing sources as landfills and waste facilities of extractive industries. Such database will enable the exchange of contacts and information among the relevant stakeholders (e.g. companies), which are interested in providing secondary raw materials. The project produces detailed information of secondary raw materials from three pilot landfills of each partner countries. The tailings pond of the closed Aijala mine is one of the Finnish pilots. The results of geochemical and geophysical studies were combined to get data for estimation of mineral resources of the tailings.

## Aijala tailings pond

The Aijala copper mine was active in the community of Kisko in southern Finland in years 1945 – 1958. The enrichment plant worked in Aijala till 1974, as the ore was brought from the nearby Metsämonttu Zn-Pb mine between years 1952 – 1958 and 1964 – 1974. Also ore from Telkkälä Ni-Cu mine was enriched in Aijala in 1970 (Sipilä, 1994).

The composition of Aijala tailings pond has been studied already in 1982 by Kokkola. The Aijala tailings pond contains around 2 million tons of waste which average metal content is as follows: 0.12 % copper, 0.5 % lead, 0.11 % silver and 0.69 ppm gold. Thickness of the tailings layer is on average 8.7 m and the deepest part is 12 m thick. (Sipilä, 1994, Kokkola, 1982)

## Soil drilling and geochemistry

In summer 2016 Geological Survey of Finland took additional samples of the Aijala tailings pond. Five additional drill holes were made and the tailings samples were analysed in 1 m intervals, 48 samples in total and a vast geochemical analysis was carried out.

Even if the tailings material looked the same from top to bottom, the geochemical assays of the samples taken from the drill holes revealed the interface of the tailings material from Metsämonttu and Aijala mines. The top part which contained tailings from Metsämonttu mine was rich in lead and the bottom part containing tailings from Aijala, was rich in copper (Figure 1).

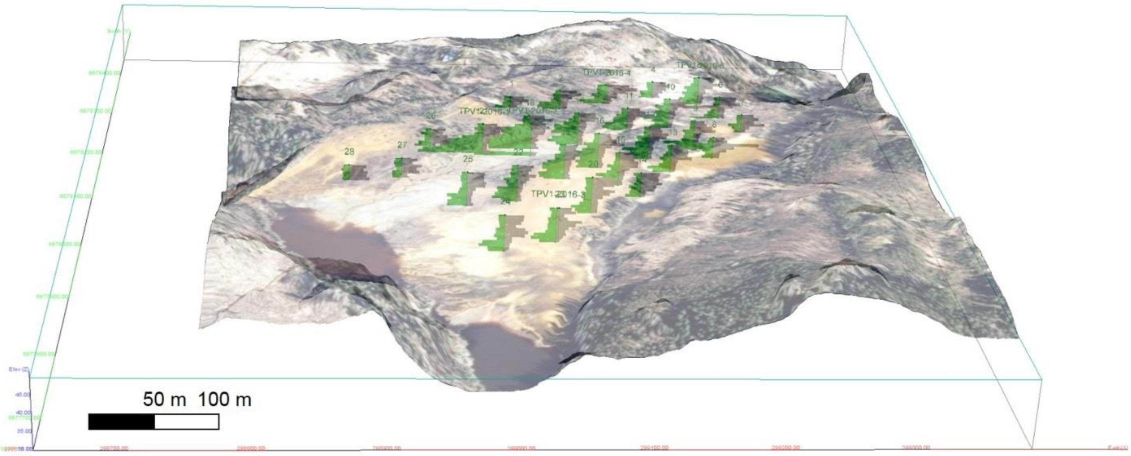


***Figure 1.*** *Topography of the Aijala tailings pond with an aerial photo draped onto the surface. The copper and lead content in the tailings are marked with green and grey bars next to the old and new drill holes.*

**Geophysical studies**

Geophysics was used to study the inner structure and dimensions of the tailings pond. Magnetic and electromagnetic GEM-2 surveys were carried out over the whole tailings area. Gravity, Electrical Resistivity Tomography (ERT) and Induced Polarization Tomography (IPT) profiles were measured in selected places nearby the new drilling points.

Results of the gravity survey were used to interpret the thickness of the tailings pond and depth of bedrock surface (Figure 2). The old and new drill holes penetrated the tailings pile and were used as reference data in interpreting the depth of the tailings. When knowing the in situ density of the tailings, the thickness of it could be defined fairly reliably by gravity interpretation. The bedrock outcrops at the ends of the measured profiles were used as reference in interpreting the bedrock topography. This method is widely used in modelling groundwater areas in Finland (Valli & Mattsson, 1998).

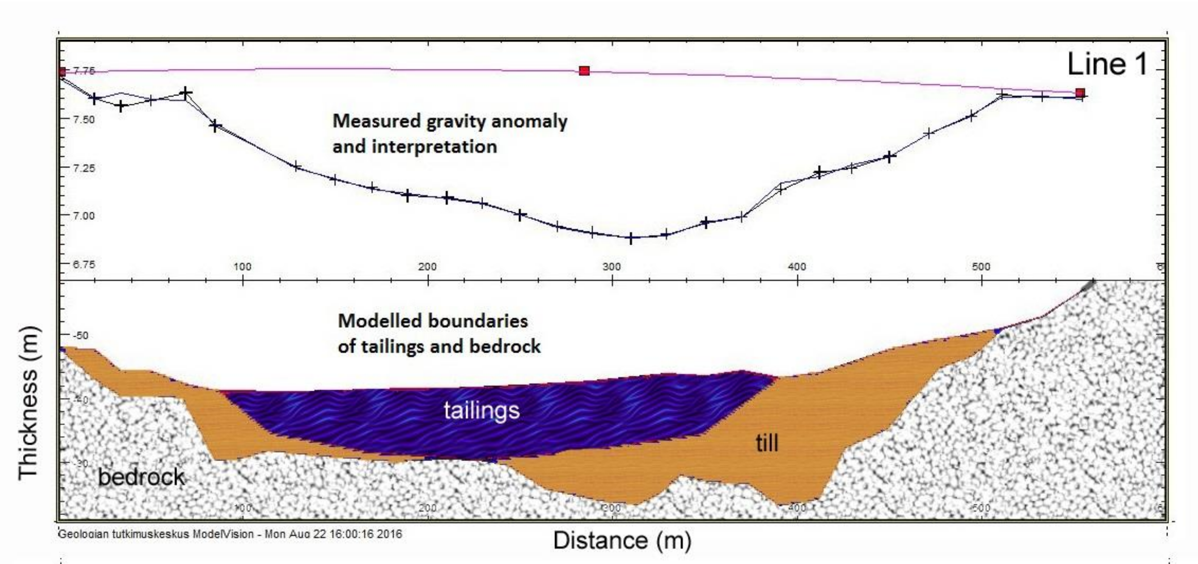


***Figure 2.*** *Cross section of gravity interpretation. The density 1.95 kg/m*$^3$ *of the tailings material has been determined in situ sample. The lower soil layer assumed to be typical Finnish saturated till having a density of 1.9 kg/m*$^3$*.*

GEM-2 method (Won et al., 1996) was utilised to map electrical conductivity of the tailings ponds surface layers up to about 10 m depth. From the responses of the four different frequencies apparent conductivity and susceptibility were calculated. The conductivity varies quite much in the tailings pond area. From GEM-2 responses 2-layer inversion was also calculated to find out the suitability of GEM-2 investigations to this kind of geological situation and possible to get the thickness variations of tailings pond. The inversion result is presented in Figure 3. Magnetic measurement was used to find out and locate the high suskeptibility contained material of tailings. These areas are situated roughly at the same areas as the most conductive areas according to GEM-2 results.

ERT and IPT were used to study changes in the electrical conductivity of the tailings material. The tailings with highest conductivity parts can be detected easily from the resistivity results. The IP anomalies were typically weak and the highest values appeared in top layer. More detailed interpretation of the results were made after integrating the interpretations with another data (Figure 4).

The results of the geophysical interpretations played an important role in defining the inner structures of the tailings pond and they also gave more information of the variation of the tailings ponds bottom and bedrock surface. The results were utilised in 3D modelling of the structure of the tailings pond.

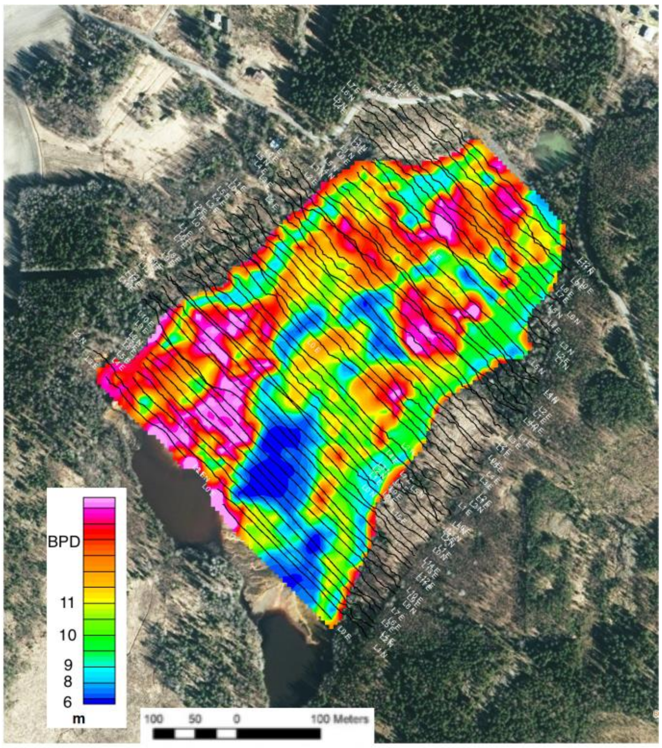


***Figure 3.*** *Thickness of conductive tailings from 2-layer inversion of GEM-2 responses. BPD= below the penetration depth.*

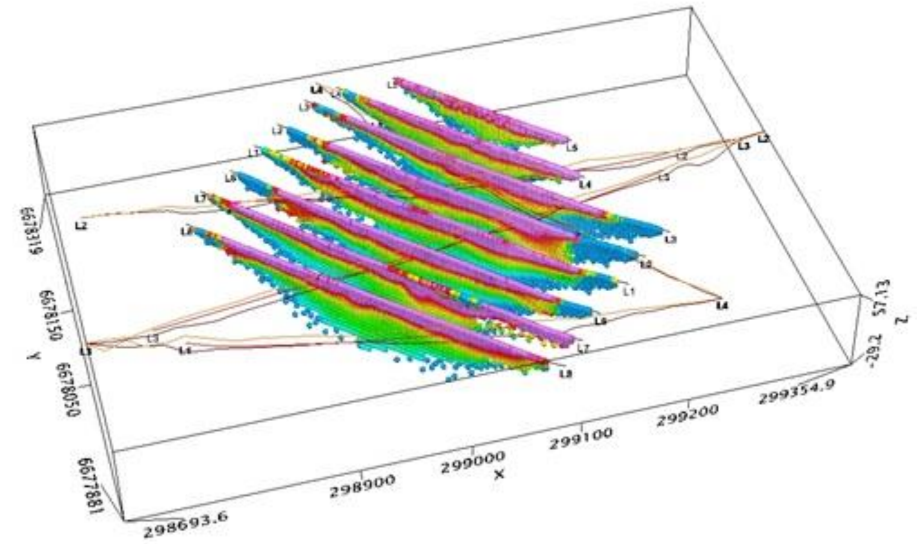


***Figure 4.*** *Interpreted gravity lines together with resistivity results. Brown line is bedrock surface, red line is bottom of tailings and orange ground surface.*

**Mineral resources estimation**

The mineral resources in the Aijala tailings pond were estimated by interpolating the metal contents in the old and new drill cores into a 1 $m^3$ resolution block model (Valjus & all, 2016). The interpolation was carried out separately to the Metsämonttu and the Aijala mine tailings layers. The blocks belonging to the different layers were determined by the layers generated according to the gravity interpretations of the tailings bottom and bedrock surface.

Inverse Distance method was used to interpolate the metals contents in the block model. The used search ellipsoid was horizontal and 200 m in length and in width and 2 m in depth. This is because the metal content of the layers is assumed to be rather continuous in horizontal direction, and the changes in metal content are more likely to be in vertical direction.

Figure 5 shows as an example the interpolated copper content in the Metsämonttu mine tailings layers. The total volume of the layer is 852 399 $m^3$, and it contains approximately 678 tons of copper.

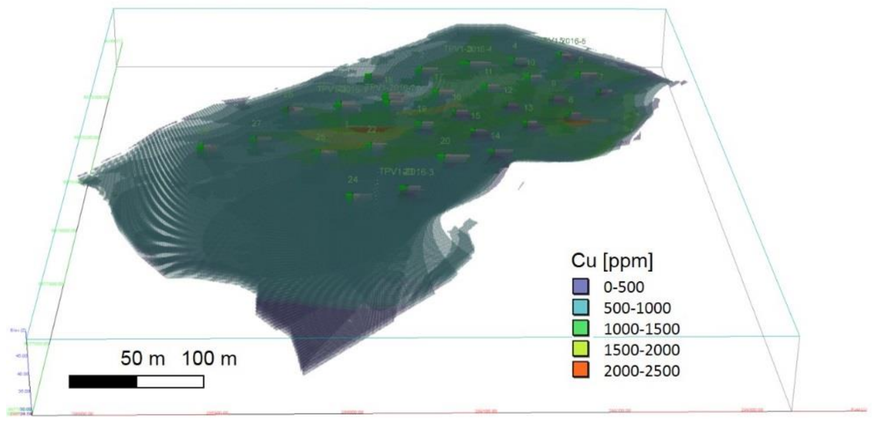


***Figure 5.*** *Block model showing the interpolated copper content in Metsämonttu mine tailings layer. The drill holes show copper (green) and lead (grey) contents in the analyzed samples.*

**Conclusions**

The tailings pond of the closed Aijala mine was studied as an example of a source of secondary raw materials in EU. The use of detailed geophysical interpretations integrated to the geochemical sampling proved to be a profitable way in defining the inner structures of the mine tailings and they also gave more information of the variation of the tailings ponds bottom and bedrock surface. The results were utilised in 3D model of the structure and volumes of mineral resources of the tailings pond. The information concerning the landfill can be found later in the standardised EU landfill database, and it can be utilised by the possible re-user of the raw material to make feasibility study and planning the operations.

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