Increasing demands in rare earth and critical metals for the high-tech industry have increased interest in historical mine wastes as a source for re-mining. Nevertheless, the development of fast, cost-effective and reliable tools to quantify and model the distribution of elements in tailings, needed to assess the feasibility of secondary mining, has remained challenging.

Traditional hand-held X-ray fluorescence (XRF)-based measurements combined with chemical lab analysis of samples were successfully used to identify zones of metal enrichment on tailings and to estimate the resource potential. These applications, however, require costly drilling and sampling procedures. The lack of efficient in-situ screening tools led to the development of a new direct sensing probe based on cone penetration testing (CPT).

Fugro innovative XRF-CPT probe combines a CPT cone with an X-Ray Fluorescence Tool (XRF-CPT). The XRF-CPT is able (1) to detect metal distribution and concentration in tailing bodies for a qualified resource estimation, (2) to characterize geotechnical site conditions for the future design of re-mining activities and (3) to provide information on the lithology/soil type for the processing approach.

FUGRO XRF-CPT-CONE

The XRF-CPT-Cone is an advanced site investigation probe used to identify heavy metals and elements in soils and sediments. It delivers in situ real time data to maximise investigation efficiency.
MODE OF OPERATION
The Fugro XRF-CPT cone is based on the principles of X-ray fluorescence for identification and quantification of heavy metals in real time.

A built-in X-ray tube generates a bundled X-ray beam and directs this into the formation via a window in the cone's housing. This excites the atoms and leads to specific fluorescence being detected by a highly sensitive detection unit.

While the cone is being pushed into the subsurface, the specialist software generates a log showing soil type, soil density and metal concentrations in high resolution and real time.

FEATURES
- Provides in situ concentration of metals or other elements versus depth and in real time
- Simultaneously records in high definition geotechnical parameters, such as soil density, soil type and stratification
- Applicable to land, lagoons, rivers, lakes and near shore

FIELDS OF APPLICATION
- Fast and high resolution characterisation of tailings for feasibility studies and profitability assessments of mining tailing residues
- Identification of metal bearing zones in mine waste residues or tailings for potential remining
- Investigation and delineation of heavy metals in landfill and mine tailings for environmental impact assessments and remediation planning
- Supporting soil remediation through the rapid identification of hot spots and areas of concern
- Identification and high resolution delineation of heavy metal distribution in sediments of harbours, rivers and near shore

METHOD STATEMENT
Like standard CPT, the XRF-CPT cone is statically pushed into the ground at a rate of about 2 cm/s by deploying a 20 tons heavy CPT crawler. CPT measurements of the cone resistance, sleeve friction, and pore pressure are digitally recorded every second. Soil classification relies on the simplified chart method after Robertson et al. (1986). Simultaneously, the heavy metal concentrations are detected by the XRF system, enclosed in a sub behind the standard CPT cone, in both unsaturated and saturated zone.

The detection of metals by X-ray fluorescence relies on the emission of characteristic “secondary” (or fluorescent) X-rays from a material that has been excited by high-energy X-rays. The built-in X-ray tube generates a bundled X-ray beam, directed into the formation through a window in the cone housing. The relevant heavy metals are identified and quantified based on the comparison of the resulting energy spectra with reference spectra using specialized software. This procedure also allows for the screening of unexpected metals on-site. Quantification of the target metals is based on external calibration with standard reference materials and/or site-specific samples with known metal contents.

The current standard Fugro XRF-CPT cone detects most of the relevant metals, such as Fe, Co, Ni, Cu, Zn, As, Se, Mo, Hg and Pb with element-specific detection limits of between 100–1000 ppm. The actual detection limit and resolution depend on the measurement period, the soil matrix and occurrence of interfering elements. The most reliable results are obtained with a calibration based on representative site-specific samples. The whole data validation comprises several steps: pre-calibration, quality assurance on site, in-situ data acquisition, re-calibration and validation of the obtained XRF in-situ data based on the results of the retrieved soil samples.
PERSPECTIVES
Fugro’s XRF-CPT is a next-generation tailings exploration technology. Being 100% compatible with Fugro’s current geotechnical equipment ensures a full transfer of CPT mobile and flexible characteristics, allowing it’s worldwide application. Applicable under the strictest health and safety requirements with no hazardous waste, no soil cuttings and minimum site disturbance, the presented application of XRF-CPT is more cost-effective and less invasive compared to conventional approaches and minimizes the need for physical soil sampling.

Further developments of the XRF-CPT probe regarding broader detectable element range as well as maximum sounding depth up to 60 m below ground level are envisioned.

Several probe configurations optimized for lighter elements such as Ti, Co, V, Mn as well as heavier elements such as Pd, Cd, Sn, Sb will soon be ready for testing.