MONITORING OF SUPERFICIAL CONTAMINATION PRODUCED BY MASSIVE SULPHIDE MINE WASTE ALONG THE ODIEL RIVER (ANDALUSIA, SPAIN) USING HYPERSPECTRAL DATA

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1. INTRODUCTION

Rivers draining abandoned sulphide ore mines are often seriously affected by acid run-off from mine workings and tailings, and waste rock piles. Although oxidation of sulphide minerals (particularly pyrite) results in the discharge of considerable quantities of metal ions to river waters, a large proportion of the metal is stored in Fe-ochres which flocculate and adsorb metal cations. These ochres, and mobilized metal-bearing tailings and waste, can be stored in alluvial sediments for considerable period of time (tens to thousands of years) and constitute a long-term threat to river and agricultural quality.
The Odiel river drains the Iberian Pyrite Belt (Southwest Spain and Portugal) where pyrite mining extends through history for 5000 years at least [1]. Massive sulphide deposits hosted on a volcano-sedimentary complex, a thick stratigraphic series of volcanic detrital origin, are widespread throughout the region [2]. The geological frame provides high geo-availability for pyrite oxidation. The water quality of the river is subject to seasonal variations related to rainfall rate [3]. Industrial operation of most metallic mine sites in the Iberian Pyrite Belt has stopped today. Most mine facilities are abandoned and under environmental control of the authorities. The overall objective of this project, supported by Andalusia, is to define standard procedures for contamination monitoring based on hyperspectral imagery that will be implemented by regional authorities in their Environmental Information and Evaluation System, the objective of which is mainly water quality assessment. This should help control the efficiency of remediation at the abandoned mine sites. Imaging spectrometer data have already demonstrated their potential to accurately map acid mine waste [e.g. 4]. However, monitoring water quality is more difficult because water absorbs infrared light, limiting the possibility to map sediments in the river stream. Our study therefore focuses on sediments exposed on river banks or on pebble bars. Identification and mapping of specific minerals, that can adsorb or release heavy metals as a function of pH, based on their spectral signatures will help define quality indices.

2. METHODOLOGY

2.1. Data Sets

For this purpose, HyMap imaging spectrometer data were acquired over the Odiel river on August 1st, 2008, during the dry season (7 flight lines to cover most of the stream). A first set of representative sediment samples were concurrently collected on pebble bars and river banks and during a field campaign in September 2008. Reflectance spectra of various ochres and “clean” sediments were also acquired in the field with an ASD FieldSpec FR3 spectrometer and in the laboratory under artificial illumination. XRD and SEM will be used to complement and validate sample compositions.

2.2. Methodology

Laboratory and field spectra of reference samples were compared to reference spectral libraries [5, 6] in order to identify main minerals and mineral mixture present along the banks and on pebble bars. They were then used, after spectral resampling to HyMap bandpasses, as reference to help identify endmembers extracted from the HyMap images.

Images were processed as follows [7] :
(1) A spectral library with basic land use endmembers is built based on a false color composite.
(2) Spectral Angle Mapper is then used to produce a first estimation of the spectral diversity of open land which is digitally used as a mask on subsequent image processing steps.
(3) The areas mapped as open land are then explored with MNF transform, PPI and n-D visualizer.

(4) Spectra of pixels corresponding to key minerals or mineral mixtures characteristic of pyrite oxidation products are finally selected as endmembers and archived in a spectral library. They are compared to the field and laboratory spectra of field samples.
(5) This library is finally used in various mapping algorithms (SAM, SFF, Binary Encoding, etc.) to derive spatial patterns of pyrite oxidation products.

3. PRELIMINARY RESULTS AND PERSPECTIVES

At this stage, laboratory spectra of samples collected in the field were visually compared to spectra of typical minerals from a reference data bases [6, 7]. Iron oxides and hydroxides such as Goethite and Hematite and sulphates such as Jarosite, Schwertmannite, possibly Melanterite. Some samples also show strong evidence of Gypsum. This is consistent with previous work focusing on the Sotiel-Migollas Mine site [8] where similar minerals were mapped. HyMap images are being processed for mineral mapping. A spectral predictive model, developed for the Brukunga Mine in South Australia [9], will tentatively be applied to generate predictions of surface pH from HyMap imagery, extending the application of imaging spectrometry beyond mineral mapping and demonstrating quantitative multi-annual monitoring capabilities. Through our collaboration with local hydrologists, results will be cross-correlated with parameters characterizing water quality to define quality control indices. Previous analyses focusing on the Sotiel-Migollas Mine [8] show increase in pH that could possibly be attributed to remediation efforts. This requires confirmation at the scale of the Odiel river and a follow up. Therefore, yearly flights are scheduled over the river to monitor changes, sometimes twice a year to take seasonal effects into account. This study will lead to quantitative multi-temporal monitoring capabilities using airborne hyperspectral data.

4. REFERENCES

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