MODELLING OF TAILING SPECTRUM OF THE TUNISIAN SEMI-ARID CONTEXT

Nouha Mezned(1), Sâadi Abdeljaouad(1) and Mohamed Rached Boussema(2)

(1)Laboratoire de Ressources Minérales et Environnement,

Faculté des Sciences, Campus Universitaire du Belvédère, 1092 Tunis, Tunisie,

Téléphone : +216 70 860 325, Télécopieur : +216 70 860 325,

(2)Laboratoire de Télédétection et Systèmes d'Information à Référence Spatiale,

École Nationale d'Ingénieurs de Tunis, B.P. 37, 1002 Tunis Belvédère, Tunisie,

mezned_nouha@yahoo.fr

1. INTRODUCTION

The mine tailing present, particularly, a spatial distribution always not uniform and wide on Jebel Hallouf-Bouaouane mine site in Tunisia. In this site, the abandoned tailings threat the soils, the vegetation as well as water quality. Tailings composition, their oxidizing potential and their spatial distribution varies according to the nature of the ore being mined at the time it was produced and dumped, and to the topographic and climatic conditions.
The traditional techniques (visits on the ground, the takings of a high number of samples, analyses in laboratory) give punctual information. A spatial tailing cartography will be effective with less important costs. Field spectral data, measured on the ground by a spectroradiometer are very important and needed for tailing classification. These informations, more faithful to the natural conditions, are boring and unavailable in some dates.
In this study, we explore for the first time the mine tailing cartography with remote sensing techniques for specific mine in a semi-arid context in Tunisia. Our methodology is based on a spectral modeling using the library reflectance fusion. The main contribution is to estimate the tailing components' spectral reflectance by direct means. This allows us to replace the lack of the field data needed for mine tailing cartography. We operate the procedure using field knowledge of the mine tailings mineralogy and laboratory spectra from a publicly available spectral library. The results indicate that this methodology can be applied successfully to multispectral data. The tailing measured spectral data are used for modeled reflectance inter-comparison and validation.

2. LIBRARY AND LABORATORY DATA BASED SPECTRAL MODELING APPROACH

The spectra modeling approach (SMA), which is proposed to replace the lack of field data in the case of multispectral data cartography, makes use of the spectral linear mixing model. In the unconstrained method, abundances may assume negative values (represents the relative abundance of endemembers) and are not constrained to sum to unity (one) contrary, constraint in the Linear Mixing algorithm the abundance fractions are weighting of a sum-to-unity:

$$\sum_{i=1}^{p} a_i = 1, a_i > 1$$

Where,
a= (a_1, a_2, ..., a_p) is the ground abundance fraction in ground samples,
p is the number of endmembers.
The both number of endmembers p and their abundance fractions a_i are estimated by means of laboratory analysis results. The aim is to solve this linear equation for the unknown tailing Components' spectral reflectance. The mineralogy of the test site was identified from calcimetry, X Ray Diffraction XRD and polished section analysis of tailing samples. The corresponding abundances were also determined. For our purpose, we are interested only on the three tailing deposit considered as a pollution source. Indeed, minerals where inferred from the samples which were collected at 18 locations for

Table 1. Mean abundances and the corresponding relative abundances per grain size of the mineral species identified within the three tailing deposits of Jebel Hallouf-Bouaouane mine (DJH1, DJH2 and DBA). I, II and III refer to the three category of grain size.

Mineral	Formula	Abundance (%)	Abundance per grain size (%)
Barite	$BaSO_4$	1.32	1.027 I and 2.292 II
Calcite	$CaCO_3$	76.00	53.28 I and 22.72 II
Cerussite	$PbCO_3$	0.791	0.755 I and 0.0353 II
Fluorite	CaF_2	0.239	0.239 I
Galena	PbS	0.033	0.033 II
Goethite	α-FeO(OH)	1.105	0.549 I and 0.552 II
Gypsum	$CaSO_4\ 2H_2O$	2.386	1.549 I and 0.835 II
Hematite	Fe_2O_3	2.710	1.243 I, 1.357 II and 0.106 III
Illite	$((K,H3O)(Al,Mg,Fe))_2(Si,Al)_4[(OH)_2,H_2O]$	1.230	1.230 III
Kaolinite	$Al2Si2O5(OH)_4$	3.250	3.250 III
Pyrite	FeS_2	2.790	0.169 I, 1.567 II and 1.052 III
Quartz	SiO_2	7.860	2.206 I and 5.646 II
Smithsonite	$ZnCO_3$	0.286	0.286 III
Sphalerite	ZnS	0.0066	0.0066 III

each dike, to include tailings of various mineral compositions and oxidation stages. Each sample was gathered from the top of the tailings surface. The mean relative abundances are also estimated into three category of grain sizes (I: <45µm, II: 45-125µm and III: 125-500µm), considered in the tailing spectra modeling. The spectra of identified and quantified mineral species within tailings, were obtained from the JPL [1] spectral library and used to model (via linear combination) the spectral signature of the mine tailings. The tailing modeled spectrum (based on JPL library) are compared and validated to the once measured, directly in the laboratory, by the spectroradiometer. The comparison of both tailing spectra to the one extracted from the ETM+ data; show the contribution of the SMA approach.

3. EXPERIMENTAL RESULTS

3.1. Laboratory and spectrometry analysis

Eighteen samples of surface were gathered from the first 5 centimeters, according to radial roads. Samples were taken from the three dikes, considered as a pollution sources. It represents 54 samples on an average surface of $75m^2$. All the samples were analyzed through a complete mineralogical study, including the observation of polished sections, diffraction in the X-rays and a calcimetry chemical analysis. A spectral study was also conducted by the laboratory spectroradiometer.

The laboratory results show the mineral composition of the three tailing deposits. The identified minerals and their correspondent mean relative abundance, needed for the components' spectral reflectance estimation by the SMA, are listed in table 1. The mean relative abundances estimated into the three categories of grain sizes are also listed. All samples were also taken and analyzed under laboratory conditions with an ASD field spectrometer for tailing surface reflectance measurements.

3.2. Modeled and measured tailing spectra comparison

The spectral reflectance's of the tailing components by the SMA approach using the JPL spectral library is shown in figure1. A qualitatively and quantitatively (mineralogical diagnostic statistics) comparison of the modeled and measured spectra with corresponding landsat ETM+ spectra, reveals differences and remarkable resemblances. We indicate that the resampled tailing modeled reflectance (to the ETM+ bandpasses) shows the same curve variation as the corresponding average reflectance extracted from the ETM+ data. However, they show different intensities. The opposite case appears for the resampled reflectance (to the ETM+ bandpasses) measured by the spectroradiometer in the laboratory.
This is due to the multiple conditions of measure of the three reflectances. Indeed, the difference of reflectance intensity between the modeled signature and the one extracted from the ETM+ image is due to the luminance conditions and the purity of tailing minerals (the Landsat data were collected under natural light conditions and affected by the atmospheric conditions, while the library spectra were measured using a controlled light source and correspond to a pure mineral [2]). These conditions are not considered in the case of the tailing measured spectra (by the spectroradiometer). We measure samples which were collected from the ground (mixed sample of minerals). In that case, it is the change of the measured surface of the dyke's mineralogical composition and the surface exposure of minerals, because of the transport of the samples which influence the reflectance of dikes. Indeed, we study a complex environment, where the analysis of complicated spectra (mixed pixels) always identifies the dominant spectral phase, although the other nanophases can be present. So, the dimension of the moderate surface is considered.
A normalization of the tailing modeled spectra could be applied in an attempt to compensate differences like lighting [4]; [3]. So, the spectra were reproached. We show, at this level, that the modeled spectra are more reliable, in the case of a good identification of the mineralogical composition, than the measured spectra of the displaced tailing samples (by the spectroradiometer) in the laboratory.

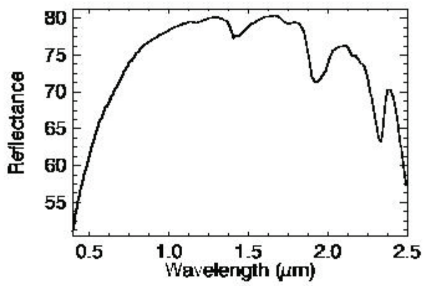

Figure 1: Tailing modeled spectra based on the JPL spectral library.

4. REFERENCES

[1] C. I. Grove, S. J. Hook, and E. D. Paylor II, "Laboratory Reflectance Spectra of 160 Minerals, 0.4 to 2.5 Micrometers", *Jet Propulsion Laboratory Publication 92-2*, 1992.

[2] G. R. Hunt, "Spectral signatures of particulate minerals in visible and near IR", *Geophysics*, V. 42, pp. 501-503, 1977.

[3] J. Shang, B. Morris, and P. Howarth, "Surface mapping of mine waste using hyperspectral imagery of the Kidd Copper mine site near Sudbury, Ontario: preliminary results", 2003.

[4] H. Stokman, and T. Gevers, "Detection and classification of hyperspectral edges. In: Caractérisation des scènes urbaines par analyse des images hyperspectrales", *Thèse de doctorat (Ph.D), ENST-Paris*, Decembre 2005, 174 p, 1999.

.