RECOGNITION AND CHARACTERISATION OF MATERIALS CONTAINING ASBESTOS THROUGH HYPERSPECTRAL IMAGE ANALYSIS

INAIL

2021

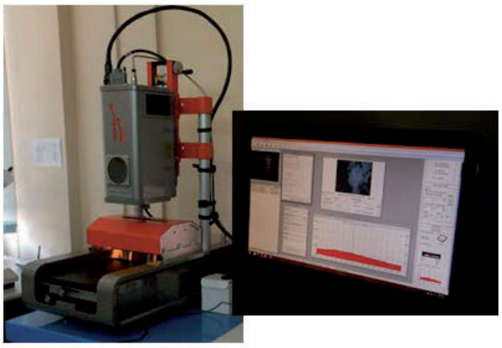
FOREWORD

As part of the Inail Collaborative Research Call (BRIC ID 58 - Special Asbestos Program) *"Recognition and characterisation of materials containing asbestos on a laboratory scale by means of hyperspectral image analysis and correlation with information extracted from proximity and remote sensing (overflight and satellite),"* new methods for the recognition and characterisation of Asbestos Containing Materials (ACMs) have been developed and perfected through the use of innovative non-invasive and non-destructive technologies. In particular, 2D mapping of ACM surfaces was performed by X-ray micro-fluorescence analysis (micro-XRF) and hyperspectral imaging (HSI). Different types of ACM were analysed, characterised by matrices of different nature (cement, resinoid, cellulosic, etc.) and origin (from reclamation sites in different Regions) and by the presence of different types of asbestos minerals (chrysotile, crocidolite, amosite, tremolite, anthophyllite and actinolite). The samples investigated were collected by Inail mainly from Superfund sites to be cleaned up. The samples were prepared in its Laboratories for the Analysis of Environmental Matrices (LAMA). The samples were subsequently acquired and analysed by the *RawMaLab* Laboratory of the Department of Chemical Engineering, Materials, Environment (DICMA) of the University of Rome "La Sapienza".

HSI: PHYSICAL PRINCIPLES AND OPERATING SETTINGS FOR THE ACQUISITION OF ACM MAPS

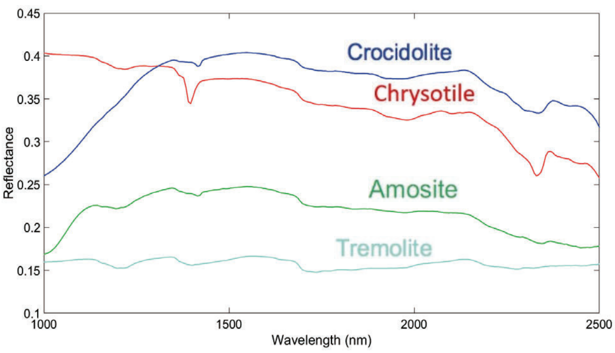
The ACMs, locked up and sealed in Duroplan® glass Petri dishes, have been analysed with an HSI system composed of an integrated hardware/software architecture capable of acquiring and managing data structures (hypercubes) characterised by two spatial dimensions and a spectral one. In particular, the analysis has used the hyperspectral system SISUCHEMA XL Chemical Imaging Workstation (Specim®) (Fig. 1) operating in the SWIR spectral range (*Short Wave Infrared Range*: 1000-2500 nm) whose sensor enables the acquisition, in "*pushbroom*" mode, of an area of 320 pixels by 240 wavelengths with a spectral resolution of 6 nm. The images are acquired with a hyperspectral imaging system (HSI) installed on a conveyor belt where the ACMs are placed. The system is connected to a PC, which runs the software for the management and processing of the acquired data hypercubes. This technology allows the spectral information of ACMs to be collected in a non-destructive way through the interaction between light and matter. This approach makes it possible to detect the spectral signature of the material, i.e. the absorptions at different wavelengths related to the molecular structure of the sample and, specifically, linked to the vibrational motions of the molecules constituting the analysed material. Thus, from the spectrum analysis it is possible to obtain surface distribution maps of the chemical elements, with information for each pixel of the acquired image. In particular, the presence of characteristic absorptions in the SWIR region by asbestos minerals can be used for the characterisation of the different ACMs (Fig. 2).

Figure 1 **Hyperspectral image analysis system SISUCHEMA XL Chemical Imaging Work-station (Specim®), acquisition unit and user interface (RawMaLab, DICMA, Sapienza University of Rome)**



The operating conditions for the recognition of asbestos fibres in ACMs require the acquisition of images using two different spatial resolutions: 1) 150 μm /pixel, field diameter of 5 cm, acquisition speed 7.35 mm/s; 2) 30 μm/pixel, field diameter of 1 cm, acquisition speed 2.55 mm/s. The resolution choice depends on the size of the bundles of asbestos fibres to be identified, from the largest to micrometric ones.

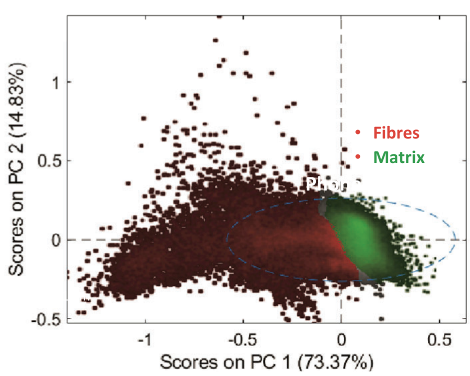
Figure 2 **Average reflectance spectra acquired by HSI in the wavelength range 1000-2500 nm, of the main types of asbestos present in ACMs (RawMaLab, DICMA, Sapienza University of Rome)**



IDENTIFICATION OF ASBESTOS IN COMPACT MATRICES USING HSI

The characterisation of ACMs by HSI takes place through the application of chemometric techniques. The identification of the presence of bundles of asbestos fibres on the investigated surface is obtained by comparing the spectral lines of the sample with those of pure asbestos minerals (chrysotile, crocidolite, amosite, tremolite, actinolite and anthophyllite) previously acquired as known reference spectra. First of all, a preprocessing of the hypercubes is carried out, which makes it possible to highlight the spectral differences between the various materials present on the sample surface (matrix and asbestos fibres). Subsequently, through an exploratory analysis in PCA *(Principal Component Analysis)* (Fig. 3) it is determined whether the ACMs are actually recognisable based on the spectral characteristics detected. Finally, the PLS-DA classification model is applied *(Partial Least Square Discriminant Analysis)* to obtain false colour prediction maps of the different materials present on the surface (matrix and asbestos fibres) (Fig. 4).

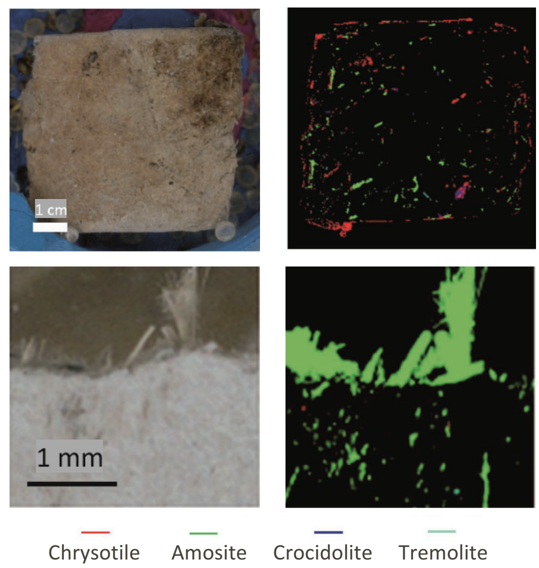
Figure 3 **Example of exploratory analysis (PCA) of an ACM sample. The PC1-PC2 score plot shows that the pixels of the fibres (in red) are arranged in a different region from that in which the pixels of the matrix are positioned (in green) (RawMaLab, DICMA, Sapienza University of Rome)**



The HSI applied to the recognition of ACMs offers numerous advantages, as it does not involve either the preparation or the destruction of the sample. In addition, the analysis can take place without direct contact, enabling a higher level of safety than that necessary with the use of the classical analysis techniques (MOCF, SEM, XRD, FTIR).

This technique does not require the presence of an expert operator once the classification model has been developed and fine-tuned and also leads to a reduction in costs and analysis times. HSI can therefore represent a potential solution for the characterisation and classification of ACMs, both of anthropogenic and natural origin. Moreover, thanks to the continuous and constant technological implementations (both in terms of analytical sensitivity and resolution capacity), it will be increasingly used for real-time analysis with miniaturised scanning systems. In this sense, further advantages can also be envisaged in the use of these methods for the characterisation of aggregates/waste, including from disasters. The results of the hyperspectral image analysis obtained at the laboratory scale can subsequently also be used as "ground check" for the calibration of the data acquired remotely (overflight, drone, satellite) for the purposes of remote sensing of asbestos cement roofs.

Figure 4 **Example of prediction maps in false colours obtained by PLS-DA classification, for 2 different ACM samples, from which it is possible to detect the presence of asbestos and the type of mineral present (Source: RawMaLab, DICMA, Sapienza University of Rome)**



REFERENCES

- Bonifazi G., Capobianco G., Serranti S. (2016), "A fast and reliable approach for asbestos recognition in complex matrices adopting a hyperspectral imaging based approach", Proceedings CRETE 2016, Fifth International Conference on Industrial & Hazardous Waste Management, Crete (Greece) 27-30 September 2016. ISBN: 978-960-8475-24-3. ISSN: 2241-3138.
- Bonifazi G., Capobianco G., & Serranti S. (2018), "Asbestos containing materials detection and classification by the use of hyperspectral imaging", Journal of hazardous materials, 344, 981-993.
- Paglietti F., Malinconico S., Di Molfetta V., Giangrasso M. (2012) "Guidelines for Asbestos Remediation at Italian Super-fund Sites", in Journal of Environmental Science and Health, Part C: Environmental Carcinogenesis and Ecotoxicology Reviews, 30:3, 253-286, Taylor and Francis Editore.
- Paglietti F., Malinconico S., Conestabile della Staffa B., Bellagamba S., De Simone P. (2016) "Classification and management of asbestos-containing waste: European legislation and the Italian experience", Waste Management, 50, 130-150.

ISBN 978-88-7484-693-1
Printed by Inail Tipolitografia in Milano • Edition 2021 **Authors: : F. Paglietti, B. Conestabile della Staffa (Inail), S. Serranti, G. Bonifazi, G. Capobianco, C. Massaro, I. Lonigro (University Sapienza) • Graphics and Editing: D.G. Cogliani, F. Ceruti**