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Quantitative detection of settled coal dust over green canopy

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The main task of environmental and geoscience applications are efficient and accurate quantitative classification of earth surfaces and spatial phenomena. In the past decade, there has been a significant interest in employing spectral unmixing in order to retrieve accurate quantitative information latent in in situ data. Recently, the ground-truth and laboratory measured spectral signatures promoted by advanced algorithms are proposed as a new path toward solving the unmixing problem in semi-supervised fashion. This study presents a practical implementation of field spectroscopy as a quantitative tool to detect settled coal dust over green canopy in free/open environment. Coal dust is a fine powdered form of coal, which is created by the crushing, grinding, and pulverizing of coal. Since the inelastic nature of coal, coal dust can be created during transportation, or by mechanically handling coal.

Coal dust, categorized at silt-clay particle size, of particular concern due to heavy metals (lead, mercury, nickel, tin, cadmium, mercury, antimony, arsenic, isotopes of thorium and strontium) which are toxic also at low concentrations. This hazard exposes risk on both environment and public health. It has been identified by medical scientist around the world as causing a range of diseases and health problems, mainly heart and respiratory diseases like asthma and lung cancer. It is due to the fact that the fine invisible coal dust particles (less than 2.5 microns) long lodge in the lungs and are not naturally expelled, so long-term exposure increases the risk of health problems. Numerus studies reported that data to conduct study of geographic distribution of the very fine coal dust (smaller than PM 2.5) and related health impacts from coal exports, is not being collected.

Sediment dust load in an indoor environment can be spectrally assessed using reflectance spectroscopy (Chudnovsky and Ben-Dor, 2009). Small amounts of particulate pollution that may carry a signature of a forthcoming environmental hazard are of key interest when considering the effects of pollution. According to the most basic distribution dynamics, dust consists of suspended particulate matter in a fine state of subdivision that are raised and carried by wind. In this context, it is increasingly important to first, understand the distribution dynamics of pollutants, and subsequently develop dedicated tools and measures to control and monitor pollutants in the free environment. The earliest effect of settled polluted dust particles is not always reflected through poor conditions of vegetation or soils, or any visible damages. In most of the cases, it has a quite long accumulation process that graduates from a polluted condition to long-term environmental and health related hazard. Although conducted experiments with pollutant analog powders under controlled conditions have tended to con- firm the findings from field studies (Brook, 2014; Brook and Ben-Dor 2016; Brook, 2016), a major criticism of all these experiments is their short duration. The resulting conclusion is that it is difficult, if not impossible, to determine the implications of long-term exposure to realistic concentrations of pollutants from such short-term studies.

In general, the task of unmixing is to decompose the reflectance spectrum into a set of endmembers or principal combined spectra and their corresponding abundances (Bioucas-Dias et al., 2012). This study suggests that the sensitivity of sparse unmixing techniques provides an ideal approach to extract and identify coal dust settled over/upon green vegetation canopy using in situ spectral data collected by portable spectrometer. The optimal NMF algorithms, such as ALS and LPG, are assumed to be the simplest methods that achieve the minimum error. The suggested practical approach includes the following stages: 1. In situ spectral measurements, 2. Near-real-time spectral data analysis, 3. Estimated concentration of coal dust reported as mg/sq m. The stage 2 is completed by calculating: 1. Unmixing between the green canopy and the settle dust extraction only coal dust fraction, 2. Converting spectral feature of coal dust to concentration via PLSR spectral model. The spectral model was trained and validated PLSR model developed at laboratory using spectra across MIR (FTIR reflectance spectra) and NIR regions and XRD analysis. The obtained RMSE was satisfying for both spectral regions. Thus, it was concluded that field spectroscopy can be used for this purpose, and it can provide fully quantitative measures of settle coal dust.

Nowadays this approach (both spectrometer and algorithm) has been accepted as a practical operational tool for environmental monitoring near power station Orot Rabin in Hadera and will be used by the Sharon-Carmel Districts Municipal Association for Environmental Protection, Israel as a regulatory tool. In summary, this work shows that coal dust can be assessed using in situ spectroscopy, making it a potentially powerful tool for environmental studies.

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