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Standard Test Methods for Use of Hyperspectral Sensors for Soil Nutrient Analysis of Ground Based Samples[1]

This standard is issued under the fixed designation D8438/D8438M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method describes procedures for sampling and testing of soils obtained from ground-based samples using diffuse reflectance spectrometry using handheld portable spectrometers measuring spectra in visible and near infrared (vis-NR) and mid-infrared (MIR) range. The sensor can measure moisture content, PH, organic matter, Cation Exchange Capacity (CEC) as well as macro and micro elemental nutrients in parts per million (PPM) or percentage, including but not limited to nitrogen, phosphorous, potassium, zinc, iron, boron, sulfur, calcium, magnesium, and manganese.

1.2 There are two methods that can be used to perform the test.

1.2.1 *Method A*—The analysis is performed in the laboratory on the sample after the sample has been oven dried and sieved.

1.2.2 *Method B*—The analysis is performed in the field on a moist sample after homogenization. After post-processing of multiple reflectance site data using methods A and B, the moisture content can be measured, and the spectral signature is normalized for moisture content.

1.3 The limitation of this method is that the results of an individual test for elemental analysis would not be the same as exacting reference values from traditional wet chemical lab analysis used by soil scientists. Results of wet chemistry tests or tests from soil science libraries may be used to calibrate a specific site model comprised of many individual tests. Spectral data for organics has shown to be as accurate as conventional methods such as Test Methods D2974.

1.4 For soil nutrient analysis the sample is not finely ground as in typical qualitative spectral analysis as outlined in standard Practice E1252. The spectrometer is checked periodically during testing using procedures in accordance with Guide E1866 performance testing.

1.5 Moisture content is a preferred term in agricultural applications. For this standard, gravimetric water content may be measured in accordance with Test Methods D2216 when drying samples and used to calibrate the site model, but the overall results of spectral analysis are more qualitative, and the term Moisture Content is used in this standard.

1.6 *Units*—The values stated in either SI units or inch-pound units [given in brackets] are to be regarded separately as standard. Wavelengths are stated only in nanometers, nm. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in nonconformance with the standard.

1.7 All observed and calculated values shall conform to the guidelines for significant digits and rounding established in Practice D6026. The procedures used to specify how data is collected, recorded or calculated in this standard are regarded as the industry standard. In addition, they are representative of the significant digits that generally should be retained. The procedures used do not consider material variation, purpose for obtaining the data, special purpose studies, or any considerations for the user's objectives; and it is common practice to increase or reduce significant digits of reported data to be commensurate with these considerations. It is beyond the scope of this standard to consider significant digits used in analysis methods for engineering design.

1.7.1 Spectral data is acquired by electrical data acquisition systems and therefore numeric data is carried through recording and into databases without rounding of numeric data.

1.8 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.9 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

[1] This test method is under the jurisdiction of ASTM Committee D18 on Soil and Rock and is the direct responsibility of Subcommittee D18.01 on Surface and Subsurface Investigation.

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2. Referenced Documents

2.1 *ASTM Standards:*[2]

D653 Terminology Relating to Soil, Rock, and Contained Fluids

D2216 Test Methods for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass

D2974 Test Methods for Determining the Water (Moisture) Content, Ash Content, and Organic Material of Peat and Other Organic Soils

D3740 Practice for Minimum Requirements for Agencies Engaged in Testing and/or Inspection of Soil and Rock as Used in Engineering Design and Construction

D4643 Test Method for Determination of Water Content of Soil and Rock by Microwave Oven Heating

D4700 Guide for Soil Sampling from the Vadose Zone

D6026 Practice for Using Significant Digits and Data Records in Geotechnical Data

D6907 Practice for Sampling Soils and Contaminated Media with Hand-Operated Bucket Augers

E11 Specification for Woven Wire Test Sieve Cloth and Test Sieves

E1252 Practice for General Techniques for Obtaining Infrared Spectra for Qualitative Analysis

E1866 Guide for Establishing Spectrophotometer Performance Tests

3. Terminology

3.1 *Definitions*—Terminology in accordance with Terminology D653 and shall be used where applicable.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *macro-nutrient, n—in agronomy*, an element required in large amounts for plant growth and development (for example, nitrogen, phosphorous and potassium).

3.2.2 *micro-nutrient, n—in agronomy*, an element required in smaller amounts for plant growth and development (for example, sulfur, calcium, magnesium, manganese, zinc, copper, boron, iron, sodium).

3.2.3 *Power Spectral Density (PSD), n—in spectral analysis*, the energy variation that takes place within a vibrational signal, measured as frequency per unit of mass.

3.3 *Acronyms:*

3.3.1 *Vis-NIR*—near infrared light spectrum from 350 to 2500 nm.

3.3.2 *MIR*—mid infrared light spectrum from 2500 to 4000 nm.

4. Summary of Test Methods

4.1 The test methods involve obtaining a sample that is homogenized to eliminate the effect of stratification.

4.1.1 Method A the sample is air dried or dried in accordance with Test Methods D2216 or Test Method D4643 then homogenized through sieving prior to scanning.

4.1.2 Method B the samples are only homogenized via mixing and stirring.

4.2 The samples are then scanned with a hyperspectral sensor to collect the spectral signature in the soil sample.

4.3 A reflectance and adsorption record for each test is obtained for each sample and all data are combined into a site database for post processing modeling calibration.

5. Significance and Use

5.1 Spectral analysis of soils for agricultural use is being used worldwide to obtain rapid data on soil nutrients. for the purpose of agricultural management including fertilizer application and other amendments such as pH adjustment, organic supplements, etc. Satellite, aerial, and ground-based sampling methods are being used. This test method applies to ground-based, terrestrial field applications where samples are taken from the ground, generally in the root zone. Use of these rapid remote sensing techniques allow for more detailed and economic data acquisition than older cumbersome sampling and wet chemistry testing methods used in the past by soil scientists for soil nutrient evaluations.

5.2 This test method describes procedures for sampling and testing of field soils using diffuse reflectance spectrometry using handheld portable spectrometers measuring spectra in visible and near infrared (vis-NR) using dried sieved or wet samples. There is a worldwide effort to collect spectral databases of soils. The procedures specified here follow procedures as outlined in the United Nations Food and Agricultural Organization (FAO) primer on Vis-NIR and MIR spectroscopy of soils (**1**)[3]. Other organizations such as IEEE are actively working on additional guidance documents that will be incorporated in future revisions of this test method.

5.2.1 This standard describes the procedures (Section 12) for using hyperspectral sensor data to measure moisture content as a percentage, pH, Organic Matter (OM) as a percentage, Cation Exchange Capacity (CEC) measured in 10 cmol c /kg could hold 10 cmol of Na + cations (with 1 unit of charge per cation) per kilogram of soil, but only 5 cmol Ca 2+ (2 units of charge per cation), as well as micro and macro nutrients in soils measured in PPM (parts per million)or a percentage, including, but not limited to nitrogen, phosphorous, potassium, boron, zinc, iron, sulfur, calcium, magnesium, and manganese.

5.2.2 Research has shown that the Vis-NIR data for OM content is as accurate as other tests such as the burn off test in Test Methods D2974(**2**). Analysis of natural moisture samples using method B can provide faster testing and better estimates of OM are normalization for moisture (**3**). Wet sampling allows for many more samples to be rapidly scanned in the field and therefore more samples and more detailed coverage of the site.

5.3 This standard does not address sensors that measure in the mid infrared range, MIR, are more expensive and there is less spectral data available. MIR spectral analysis is performed on dried samples that are finely grinded (**4**). MIR modeling

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] The boldface numbers in parentheses refer to a list of references at the end of this standard.