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An American National Standard

Standard Practice for Use of Color in the Visual Examination and Forensic Comparison of Soil Samples[1]

This standard is issued under the fixed designation E3254; 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 practice covers visual color determination of soil/geologic material within the context of a forensic examination and is intended for use by laboratory personnel.

1.1.1 This practice recommends use of soil color for: the initial screening of soil samples in forensic casework, prioritization of known soil exemplars for detailed analysis, and includes a test method for color determination in the Munsell color system and comparison among samples.

1.2 *Units*—Units in the Munsell color system are used throughout this document.

1.3 This practice is intended for use by competent forensic science practitioners with the requisite formal education, discipline-specific training (see Practice E2917), and demonstrated proficiency to perform forensic casework.

1.4 *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.*

1.5 *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.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D1535 Practice for Specifying Color by the Munsell System

E620 Practice for Reporting Opinions of Scientific or Technical Experts

E1492 Practice for Receiving, Documenting, Storing, and Retrieving Evidence in a Forensic Science Laboratory

E2917 Practice for Forensic Science Practitioner Training, Continuing Education, and Professional Development Programs

E3272 Guide for Collection of Soils and Other Geological Evidence for Criminal Forensic Applications

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *aggregate(s) [clump(s)], n*—a group of soil particles that cohere to each other more strongly than to other surrounding particles. **(1)**[3]

3.1.1.1 *Discussion*—Soil aggregates can be natural (a *ped*) or formed by human activities (a *clod*). Often the genesis of evidentiary soil aggregates is unknown, so aggregate is often a preferred term in descriptions of soil evidence.

3.1.1.2 *Discussion*—This use of the term aggregate is distinct from this term's use in construction as the sand or crushed rock mixed with cement to form mortar, grout, or concrete.

3.1.2 *color contrast, n*—the degree of visual difference that is evident between one soil color compared with another in close proximity. (adapted from Ref **(2)**

3.1.2.1 *Discussion*—Within this practice, color contrast refers to color difference between evidentiary soil samples.

3.1.3 *color contrast classes, n*—degree of color distinction (*color contrast*) between colors within a soil are categorized as *faint*, *distinct* and *prominent*. **(2)**

3.1.3.1 *Discussion*—Within this practice, these contrast classes are used to describe the degree of color distinction between two evidentiary soil samples, whereas the United States Department of Agriculture – National Resource Conservation Service – National Cooperative Soil Survey (NCSS) uses these contrast classes to describe color distinction within soil horizons. *Faint* color contrast is evident only on close examination. *Distinct* color contrast is readily seen but contrasts only moderately with the color to which it is compared.

[1] This practice is under the jurisdiction of ASTM Committee E30 on Forensic Sciences and is the direct responsibility of Subcommittee E30.01 on Criminalistics.

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[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 the list of references at the end of this standard.

Prominent indicates colors which contrast strongly with the color to which it is compared; prominent colors are commonly the most obvious color feature of the section described. The NCSS thresholds between faint and distinct color contrast (**2**) are adapted as exclusion criteria in forensic comparisons of soil (see 6.6).

3.1.4 *known soil sample, n—known soil samples* are intentionally collected, typically from crime scene or alternate locations, for comparison to a *questioned soil sample*.

3.1.4.1 *Discussion*—Soils are heterogeneous mixtures of organic matter and minerals that vary vertically with depth and horizontally across the landscape. Typically, a greater number of known soil samples are needed than manufactured materials to represent the range of variation (see Guide E3272). Reference sample and control sample are synonyms or sub-types of known soil samples (**3**, **4**).

3.1.5 *matrix color, n*—dominant or background color component of a soil sample, soil aggregate, ped, clod, or horizon. (adapted from Ref (**5**), see Fig. 1)

3.1.6 *metamerism, n*—when colors are perceived to be matching despite having different spectral profiles.

3.1.6.1 *Discussion*—These spectral differences often become apparent under different illumination conditions.

3.1.7 *mottles, mottling, n (mottled, adj.) or non-matrix color, n*—segregations within the soil matrix with different color or shades of color interspersed with the dominant (*matrix*) color (see Fig. 1).

3.1.7.1 *Discussion*—The NCSS reserves the term *mottles* for color variations that cannot be associated with compositional properties of the soil, whereas color variations attributable to compositional variations are designated with distinct terms (redoximorphic features, concentrations, ped coatings, etc; Ref (**5**). However, in a forensic examination mottling is often used to describe any *color contrast* within a soil aggregate, regardless of its origin.

3.1.8 *Munsell color code, n*—Munsell color is recorded as alpha-numeric *Hue Value/Chroma*, H V/C (for example, 7.5YR 5/4 or 5R 6/4); neutral colors, lacking a hue tone, (chroma = 0) are designated with a "hue" of N and omit chroma or list it as zero (N 3/ or N 3/0).

3.1.9 *Munsell color system, n*—an ordered system to quantify and describe color based on the three qualities or attributes: *hue* (H), *value* (V), and *chroma* (C) (see Practice D1535 and Fig. 2).

3.1.9.1 *chroma (C), n*—the saturation or brilliance of a color, from 0 (no color) to ~8 (for vividly colored soils) or higher (for non-soil materials) in the *Munsell color system*. (adapted from Ref (**5**))

3.1.9.2 *hue (H), n—hue* is that attribute of a color in the Munsell color system by which we distinguish red from green, blue from yellow, etc.

3.1.9.3 *Discussion*—The *Munsell color system* has principal *hues* of red (R), yellow (Y), green (G), blue (B), and purple (P), placed at equal intervals around a neutral point. Between the principal hues are five intermediate hues: yellow-red (YR), green-yellow (GY), blue-green (BG), purple-blue (PB) and red-purple (RP) (see Fig. 2). Munsell hue is designated with an alpha-numeric code (for example, 7.5YR). (adapted from Ref (**5**))

3.1.9.4 *value (V), n*—the lightness of a color, from 0 (pure black) to 10 (pure white) in the *Munsell color system*. (adapted from Ref (**5**))

NOTE 1—Photo is courtesy of USDA Natural Resources Conservation Service.

FIG. 1 Example Orange-Brown Soil Matrix Interspersed With Grey Mottles

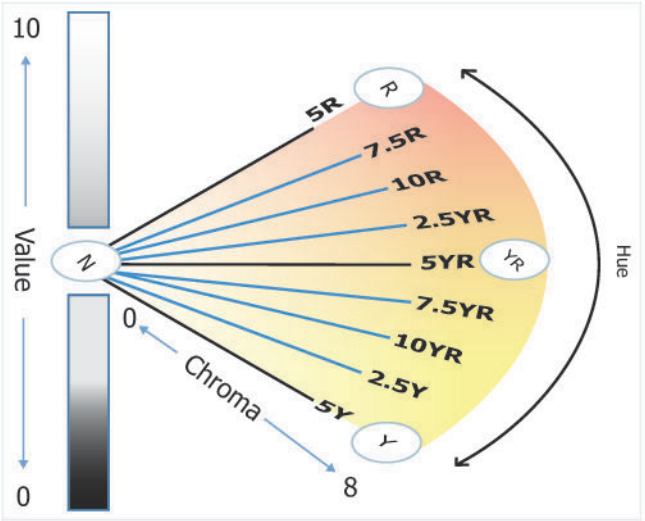


FIG. 2 Schematic Representation of the Munsell Soil Dimensions in the Hue Ranges Common in Soils

3.1.10 *questioned soil sample, n*—soil evidence of unknown origin, or *questioned soil sample*, typically consists of: debris adhering to an evidentiary object or exhibit (for example, tire, wheel well, garment, shoe, digging tool); exogenous soil left at a crime scene (for example, transferred from a shoe/tire, or adhering to a re-buried body/object); or debris recovered from within a body (for example, nasal, stomach, or lung contents).

4. Significance and Use

4.1 Color is an easily observable characteristic of soils and is integral to the taxonomic classifications of soils (**6-8**); factors including parent material, hydrology, vegetation, and extent of soil weathering, can affect soil color, making color a valuable diagnostic tool for forensic examination purposes.

4.2 Soil color is sufficiently variable among soils to be used for differentiation of many soils in forensic examinations (**9, 10**) (see Section 6 for the test method for color determination and comparison criteria) as determined by visual characterization in the Munsell color system.

4.3 Instrumental techniques are suitable for color determination of soil evidence but are not covered within this practice.

4.4 Color determinations of soil samples are also used within soil provenance assessments to provide investigative leads or aid in searches. Interpretation of soil color for soil provenance is case-specific and beyond the scope of this practice, but the methods of color determination (6.5.1 to 6.5.2) and documentation (6.7) described here should be applied to soil color within soil provenance cases.

5. Procedure

5.1 *Preliminary Visual Examination*—Conduct a visual assessment of questioned soil samples for aggregates of varying color and texture.

5.1.1 Segregate and analyze soil aggregates of different colors, particle sizes, or morphologies separately for color determination and other subsequent analytical methods (**4, 11, 12**).

NOTE 1—Aggregates with distinctly different colors can indicate the presence of more than one soil source within the sample or mottling of the source material.

5.1.2 If segregation of the visually distinct soils is not possible, then the varied colors should be determined within the intact soil aggregates.

5.2 *Color Determination*—Soil colors are determined using a soil color chart as described in the test method, Section 6.

5.3 *Comparison of Soils Based on Color*—When forensic examinations of soil are conducted to determine if two or more soil samples could be derived from the same source, or alternatively exhibit exclusionary differences (6.6.2.4), compare the determined colors using the procedures and criteria in sections 6.5.3 and 6.6.2 within the included test method.

NOTE 2—When numerous known soil exemplars are collected, a visual color assessment can be used to quickly omit those known soil exemplars that differ most from the questioned soil evidence from more detailed examination. The omitted samples do not require full color documentation.

5.4 *Comparisons of Soil Color to Reference Data* (Optional)—Soil color determined in the context of a forensic examination may be compared to published reports of soil color, typically within soil surveys (**13-15**). Reference data may be used to describe the prevalence or rarity of a soil color within an area of interest or to aid as an investigative lead to define more likely source locations for a questioned soil.

6. Test Method — Soil Color Determination and Interpretation

6.1 *Scope:*

6.1.1 This test method covers color determination of evidentiary soils in a laboratory setting by visual comparison of soil samples to pigmented chips in a Munsell Soil Color Chart (**16**).

6.1.1.1 Munsell colors are quantitative, but discrete, when determined with a Munsell Soil Color Chart.

6.1.2 The test method provides criteria for soil color comparisons within a soil examination scheme (see 6.6).

6.2 *Significance and Use:*

6.2.1 Munsell color determinations of soils (see 6.5.1) are used as a basis for soil comparisons (see 6.5.3) and as part of soil examinations for provenance assessments.

6.2.2 This test method adapts practices used by soil scientists in field settings to soil color determination within a forensic laboratory setting (**5**, **17**).

6.2.3 Soil color differences can provide exclusionary differences in soil comparisons (**9**, **10**, **12**, and 6.6).

6.3 *Interferences and Limitations:*

6.3.1 *Moisture*—Differences in soil moisture content can change Munsell value by as much as 2.0 units and hue by as much as 0.75 hue units (0.3 pages in the Munsell Soil Color Chart) (**17**).

6.3.1.1 When determining soil colors for comparison (see 6.5.3), the soils should have similar moisture contents, typically achieved by air drying the samples at room temperature.

6.3.1.2 When comparing a soil's color to reference data (5.4), soil evidence should have similar moisture content as the reference data (moist or dry).

NOTE 3—The NCSS (**5**) recommends determining dry soil color at the point where color does not change with additional air-drying. To achieve a moist soil from an air-dried sample for color determination, add water drop-wise or with a spray bottle until the color no longer changes, but do not add enough water to make the soil surface glisten.

6.3.2 *Contamination*—Contamination of soil evidence with exogenous material (for example, human decomposition products, mold, soot/char, rust from sample storage containers) can alter the color of the soil.

6.3.3 *Alteration*—Soil evidence can be altered from its source by a number of factors, including: size fractionation, fire, change in the reduction-oxidation state (**18**, **19**), or exposure to stomach acid, etc. These alterations can impact soil color.

NOTE 4—Certain soil types are more susceptible to color alteration when removed from the ground. Anaerobic/gley soils and acid sulfate soils commonly undergo oxidation and acidification upon exposure to the air. Other soils may have precipitation or alteration of secondary minerals that might cause color changes (**20**).

6.3.4 *Soils Problematic for Color Determination:*

6.3.4.1 If the quantity of a questioned soil is so small that the observer cannot determine its color without magnification, visual color determination is unlikely; however, large color contrast can be observed in side-by-side soil color comparisons of small evidentiary soils.

6.3.4.2 Questioned soil samples consisting of mixtures of soils from more than one source are unsuitable for color determination unless these soil mixtures can be physically segregated into its components or if different soil sources can be characterized *in-situ*.

6.3.5 *Non-Representative Known Soil Samples*—Sparse sampling of known soil exemplars submitted for comparison to a questioned soil might not represent the full range of colors at the source location.

NOTE 5—Refer to Guide E3272 for recommendations for collection of known soil exemplars.

6.4 *Reagents and Materials:*

6.4.1 *Munsell Soil Color Charts*—Munsell Soil Color Charts (X-Rite, **16**) consist of pigmented chips of color standards, labeled with Munsell color notations, which span a range of colors common in soils (Note 6 and Note 7).

NOTE 6—The GLOBE Soil Color Book (**21**) is a suitable alternative to the Munsell Soil Color Chart (**22**, **23**), but the color chips are physically arranged in a different configuration.

NOTE 7—Soil color books, particularly those used in field settings, often become contaminated with soil, obscuring the true colors of the pigmented chips. Some studies have indicated that the chips in Munsell Soil Color Charts do not fade or change color over decades (**22**) while others have observed fading with use (**24**).

NOTE 8—Pages of specific hues, from 5R to 5Y in increments of 2.5 hue units, each have a grid of chips that systematically range in both value (dark to light) and chroma (weak to vivid) (see Fig. 3 and Note 9)

NOTE 9—The "hue pages" are supplemented by "10G 5GY" (for glauconitic or other green-hued soils), two "GLEY" pages (for soil colors formed under anaerobic conditions), and "WHITE" (e.g., evaporites, carbonate accumulations, albic horizon, and E-horizons).

6.4.2 *Light Source(s):*

6.4.2.1 A consistent polychromatic light source (common indoor illumination is suitable).

6.4.2.2 (Optional) sunlight simulant, D65 or similar.

6.4.2.3 (Optional) additional illuminants with different spectral ranges (for example, UV source).

6.5 *Procedure:*

6.5.1 *Soil Color Determination*—Determine soil color by visual comparison to the pigmented chips of the Munsell Soil Color Charts.

NOTE 10—Soil color is typically determined early in the examination scheme of soils because this property can be characterized quickly, non-destructively, and with minimal or no sample modification.

NOTE 11—The *in-situ* determination of the color of soil adhering to an item of evidence, like a garment, requires that the soil completely obscures the color of the underlying substrate.

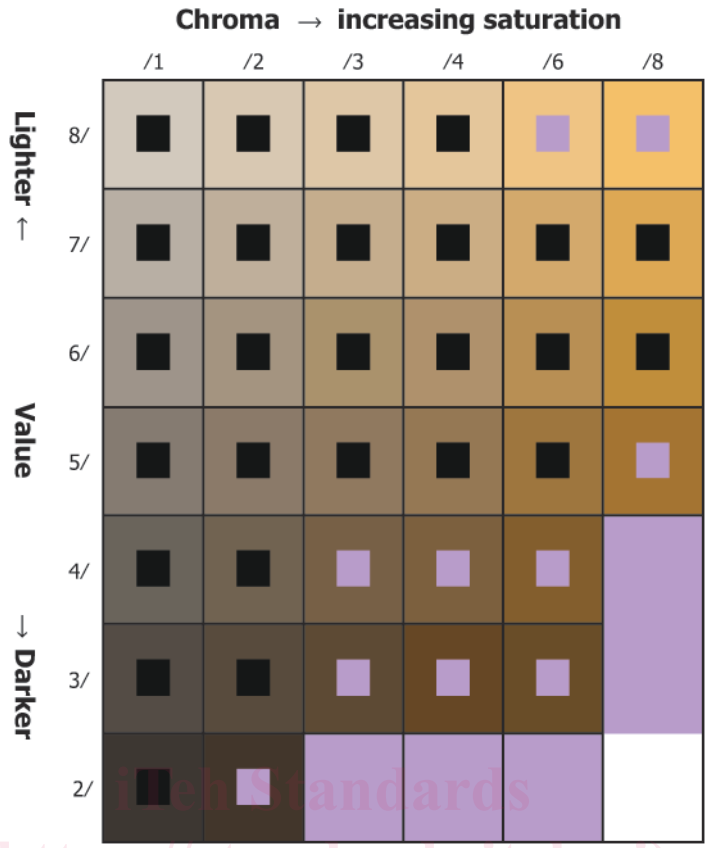
6.5.1.1 *Use of a Single Color Book*—Within a case, use a single soil color book for all color determinations and document the book used.

6.5.1.2 *Illumination and Color Assessment*—Illuminate the sample and place the soil color chart atop of it, so that both the sample and standard chips can be viewed simultaneously. View the sample through the holes (when using the Munsell Soil Color Charts) and determine which color chip most closely resembles the color of each soil or component of interest (for example, matrix, mottles, etc.).

NOTE 12—When comparing soil color to published reference data (see 5.4), the illuminant used for color measurement should be similar to the light used to create the reference data (for example, for soils colors from the NCSS databases determined in field settings (**13-15**), the illuminant should be similar to sunlight, D65).

NOTE 13—The optional use of multiple illuminants, adding and removing ultraviolet (UV) light in particular, assists in soil color comparisons by permitting documentation of metamerism.

6.5.1.3 *Optional Sample Treatments*—Other sample preparations techniques may be used prior to color determination, including: disaggregation and subsequent particle size fractionation (that is, sieving or sedimentation, **25**); heating or low temperature plasma ashing for removal of organic matter; removal of iron oxides (**9**, **10**), or removal of clay coatings. Record color both prior to and after any optional treatments.



NOTE 1—Black cells indicate value/chroma chips that are present on all hue pages, and purple cells indicate value/chroma chips that are present on some of the hue pages. Colors approximate the 10YR hue page. On other hue pages, chips with values of 2.5 are included instead of a value of 2.

FIG. 3 Arrangement and Population of Hue Pages (5R to 5Y) in the Munsell Soil Color Charts (16)

NOTE 14—The potential benefits of these treatments can be outweighed by the benefits of retaining an unmodified portion of soil evidence. Color determination of multiple soil fractions can be done, but color comparisons should be conducted among fractions subjected to the same treatments.

6.5.2 *Documenting Soil Color(s)*—Record color to the nearest chip and details of sample treatments (6.5.1.3), if performed, in case notes (6.7).

6.5.2.1 (Optional)—When a soil color is intermediate between two Munsell color chips on the basis of chroma or value, the Munsell color may be interpolated to be intermediate between the adjacent chips (for example, 10YR 4.5/4 or between 10YR 4/4 and 10YR 5/4).

6.5.2.2 (Optional)—The color name may be appended to the Munsell color code as designated in the Munsell Soil Color Chart (for example, 10YR 4/4, dark yellowish brown).

6.5.3 *Comparison of Soil Color(s):*

6.5.3.1 Within the examination scheme of a soil comparison, determine (see 6.5.1), document (see 6.5.2 and 6.7) and then compare soil colors with the caveats of 6.5.3.2 through 6.5.3.4 and the criteria within 6.6.

6.5.3.2 When comparing soil samples, determine colors under the similar lighting (see 6.5.1.2), moisture (see 6.3.1), and physical conditions (see 6.5.1.3).

6.5.3.3 In addition to recording the Munsell soil color designation of different soil samples (see 6.5.2), assess the two soils being compared (questioned to known, or questioned to questioned) side-by-side to directly compare their colors.

NOTE 15—If two or more soil samples are nominally similar in color (for example, their colors are determined to be similar to the same chip on the Munsell Soil Color Chart), but there is a visually observable, but unquantifiable, color difference between the samples, a statement may be reported such as "soils A and B were each determined to have a Munsell color of 5YR 4/3, however, soil A was visibly redder/darker than B."

6.5.3.4 *Consideration of Interferences and Limitations*—When visual inspection of soil evidence or case circumstances indicate likely contamination (see 6.3.2) or alteration (see 6.3.3) of one of the soils, do not compare the soils based on color, and document the rationale for rejection of color determinations (6.7).

6.6 *Interpretation of Results:*

6.6.1 The NCSS soil color contrast classes are adapted for evaluation of the similarities between colors of soil evidence.

6.6.1.1 Color contrast comparison criteria are established to minimize false exclusions because color is used within this initial screening of soil evidence.

NOTE 16—The NCSS uses color contrast categories of: *faint* (color contrast is evident only on close examination), *distinct* (color contrast is readily seen but contrasts only moderately with the color to which it is compared), and *prominent* (color contrasts strongly with the color to which it is compared) to characterize color differences within a soil