TECHNICAL NOTE

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A Density Gradient Technique for Use in Forensic Soil Analysis

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ABSTRACT: A high-density aqueous salt solution for the preparation of density gradients is presented. It has been used successfully by the authors in forensic soil analysis. It has a density range that allows for the separation of a soil specimen's heavy mineral components. It has no odor or toxic fumes, which eliminates the need to use a hood during preparation, and is far superior to the organic liquids normally used to prepare density gradients. This liquid should cause many forensic scientists to reexamine their attitudes towards using density gradients in forensic soil casework.

KEYWORDS: forensic science, criminalistics, density gradients, soil, analysis, comparisons, heavy mineral separation

Density gradients as a means to effectively compare forensic soil specimens have been frequently recommended in the forensic literature (1–6). Density gradients are prepared by mixing a less dense liquid with a denser liquid. Goin and Kirk suggested that bromoform (BF) and bromobenzene (BB) be used in the preparation of soil gradients (1). Absolute alcohol(s) (AA) has been given as an alternative to the use of BB as the less dense liquid (7).

This paper offers an alternative liquid for the preparation of density gradients for use in forensic soil analysis. In spite of what is published, density gradients prepared with the prescribed organic liquids are of limited use in forensic soil studies. A study from the mid-1980s points up many of the problems associated with the use of BF, BB, and AA for preparing density gradients (8).

Materials and Methods

Density gradients are prepared with mixtures of Clerici's solution (CS) and distilled water (DS). Clerici's solution is an aqueous, saturated solution of a thallium malonate-formate (Cargille®) in distilled water. Like most high density liquids made from heavy metals, CS is highly toxic. However, it is safe to use when handled with the advised precautions. Geologists have used mixtures of CS with DS to separate heavy minerals from soil specimens for many years (9).

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Generally, density gradients for soil examinations have 11 layers starting with the undiluted saturated CS (heaviest layer). Subsequent mixtures of CS/DS are added to the gradient apparatus as follows: 9:1, 8:2, 7:3, 6:4, 5:5, 4:6, 3:7, 2:8, 1:9. Distilled water is placed on top of the gradient as the final layer. Each layer is prepared in a separate glass vial prior to assembling the gradient(s). Pipette 1 mL of each prepared layer mixture into a 30 cm long glass tube having a 5.0 mm I.D. One gradient is rendered for each questioned and known specimen. Prepare a standards gradient in the same manner as the test gradients. The standards gradient is used to calibrate the density of each gradient. Allow the gradients to stand overnight to equilibrate.

After stability is attained, a 5 to 10 mg aliquot of a dry soil sample (fraction collected between the 120 and 140 mesh sieve) is placed into each test gradient. Take care that both the questioned and known soil specimens are prepared and treated in the same manner. Add small colored chips of glass and or colored minerals (i.e., amethyst, fluorite, garnet, and tourmaline) with known densities to the standards gradient and to two of the test gradients.

Allow the gradients to stand for 24 h. During this time period, it is important that the gradients are kept at constant temperature, in an isolated area of the laboratory. Final comparisons and evaluations are made at the end of this period. Gradients prepared in this manner are continuous (layers diffuse into each other), very stable, and will last for a long period of time. The results are documented by notes, sketches, photographically, and/or by video.

Monitor the reproducibility of the gradients by comparing the two test gradients with the standard density gradient. If desired, known density standards can be added to the remaining gradients in order to checked the accuracy of their density ranges. When the density gradients are no longer needed, the specimens contained within each should be recovered and safeguarded. The aqueous salt solution is then disposed of as a heavy metal waste.

An alternative method to determine the approximate density of each of the layers composing the gradient is to use the following formula adapted from Kirk's work with density gradient calibration (10) (ambient temperature must be taken into account):

$$\text{Density of mixture (DM)*} = \frac{D_{CS}\,V_{CS} + D_{DS}\,V_{DS}}{V_{CS} + V_{DS}}$$

where

D_{CS} = Density of Clerici's solution at 22°C (ambient Temp.).
V_{CS} = Volume of Clerici's solution at 22°C.

D_{DS} = Density of distilled water at 22°C.
V_{DS} = Volume of distilled water at 22°C.

Discussion

Soil density gradients prepared with Clerici's solution and distilled water have been used by one of the authors (NP) in casework for almost twenty years. The gradients made from CS/DS have an improved range of density (approximately 4.24 to 1.00 g/mL) over the organic gradients. The authors have successfully used CS gradients to compare soil specimens from a variety of locations, for example, beaches, cultivated parks, pristine woods, forest, lowlands, bogs, marsh, construction sites, yards, basements, and tools. Figure 1 is a typical array of density gradients used by the authors in a forensic soil comparison.

Murray and Tedrow point out that most soils are composed primarily of quartz (80%) (5). Common minerals such as feldspars have a density close to that of quartz. Soil gradients prepared from BF/BB or BF/AA have a density range from 2.89 to 1.50 g/mL, far too low to attain meaningful mineral distribution patterns. For the majority of soil samples, the organic gradients will show a major band of minerals in the 2.65 g/mL (quartz/feldspar) region and little else. All of the most diagnostically important heavy minerals will undoubtedly fall past the 2.89 g/mL (heaviest) layer to the bottom of the gradient. Consequently, the organic solvent gradients are of limited value in forensic soil comparisons. In addition, these gradients, due to their lack of discriminating power, might lead to invalid interpretations, thereby resulting in false association and/or exclusions.

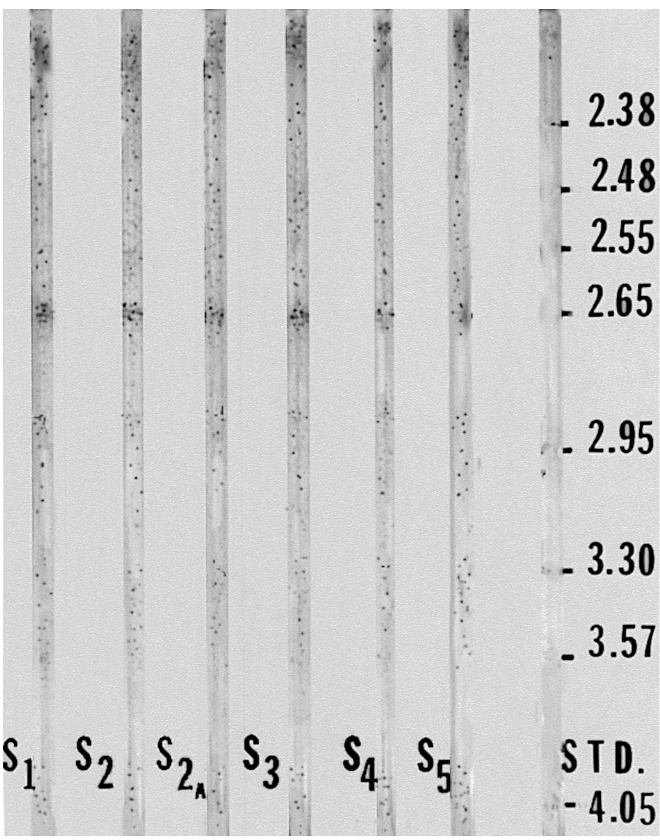

FIG. 1—*A typical soil density array used by the authors in casework. S1 is a known sample from the crime scene, S2 and S2A are samples from the victim's clothing, S3, S4, and S5 are samples from the suspects' clothing, and STD is a standards gradient.*

The density range attained in gradients prepared with CS/DS is large enough to separate soil specimens into distinct regions of light, medium, and heavy minerals components, thus making it possible to accurately compare any soil specimen likely to be encountered in a forensic soil case. Furthermore, CS/DS gradients make it feasible to differentiate soil specimens that would be undifferentiated by density gradients made from BF/BB or BF/AA.

Gradients made with CS and DS when used in conjunction with other soil examination methods, e.g., color, polarized light microscopy, and particle size distributions, add a powerful and discriminating method for forensic soil analysis (11–14). This method certainly resolves many of the short comings of the organic solvent techniques. Surely, this improved method establishes the need for a renewed look at the density gradient techniques used in forensic soil examinations as well as other forensic examinations, for example, glass.

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