Solomon Wanogho,[1] *M.Sc.; George Gettinby,*[2] *Ph.D.; Brian Caddy,*[1] *Ph.D.; and James Robertson,*[1] *Ph.D.*

A Statistical Method for Assessing Soil Comparisons

REFERENCE: Wanogho, S., Gettinby, G., Caddy, B., and Robertson, J., **"A Statistical Method for Assessing Soil Comparisons,"** *Journal of Forensic Sciences*, JFSCA, Vol. 30, No. 3, July 1985, pp. 864-872.

ABSTRACT: The soil variables: median particle size, modal class interval of particle size, and percentage of organic matter have been examined in an attempt to discriminate one soil sample from another. Using analysis of variance and the two-sample z test, statistic similarity probabilities for control soil samples as they relate to soil samples of unknown origin have been calculated. This approach has been successful in allocating the correct source of 19 out of 20 soil samples selected at random from a data bank of 100 collected from a single field. Soil from unrelated sources was correctly excluded.

KEYWORDS: forensic science, soils, comparative analysis

Soil is a multi-component system of solid, liquid, and gaseous phases together with living organisms [*1*]. Because of its more permanent nature [*2*], the solid phase, which is a mixture of mineral and organic materials, offers a better basis for classification than do the others. Mineral grains form the largest component of the solid phase in most soils. They are quite stable and undergo no significant change over the periods of time normally required by the forensic scientist to carry out investigations [*3*]. Particle size distribution analysis has therefore formed the main basis for the classification of soil by soil scientists [*2*]. Analytical methods and instruments for performing particle size analyses are numerous. Direct-indirect and automatic counting and sizing methods have been discussed by Silverman and colleagues [*4*] and Dudley [*5*] has claimed particle sizing by sieve analysis to be a useful comparative method in forensic soil analysis. However, despite extensive studies of soil systems, especially particle size distribution [*6-8*], very little work has been carried out on the variability of soil within a specified locality. This paper reports a study on soil samples collected from the same vicinity and offers a method which has proved to be successful in assessing soil samples.

Materials and Methods

Soil samples were collected from agricultural land lying between Stepps and Lenzie, north of Glasgow. A field was selected that had been cultivated but at that time of year (June 1982)

Received for publication 16 Oct. 1984; revised manuscript received 1 Dec. 1984; accepted for publication 3 Dec. 1984.

[1] Research assistant in forensic science, senior lecturer in forensic science, and lecturer in forensic science, respectively, Forensic Science Unit, University of Strathclyde, Glasgow, United Kingdom.

[2] Senior lecturer in statistics, Department of Mathematics, University of Strathclyde, Glasgow, United Kingdom.

did not have plant cover. The field lay in an area in which the geological soil type was clay. Previous use of the field was not known precisely, but it had been used as pasture and for growing barley and potatoes in a mixed farming system.

A section of the field was marked out in a grid consisting of 100 cells, rows labelled 1 to 10 and columns A to J, with each cell of an area 9 m^2. From each cell approximately 400 g of surface soil, not deeper than 5 cm, were scooped by hand into a bag.

Soil collected from each cell was sieved through a 1.4-mm square hole test sieve and the residues discarded. The fines were air-dried at room temperatures for 48 h.

Six aliquots of about 1.5 g, accurately weighed, were taken from dried soil samples from each cell, and transferred to separate thickwalled boiling tubes. To each tube were added 15 mL of 10% (v/v) hydrogen peroxide (100 volume), in 5.0-mL aliquots at 20-min intervals. The samples were allowed to stand overnight at room temperature and then placed in a boiling waterbath for 1 h to terminate oxidation of organic matter. Each tube was then removed, allowed to cool to room temperature, and centrifuged at 2500 rpm for 10 min. The resultant clear supernatants were discarded and 25 mL of 0.02*M* hydrochloric acid added to the compacted soil at the bottom of each tube. The soil pellets were dispersed using a vortex mixer and each sample then placed in an ultrasonic bath (Model K200, Kerry Ultrasonics Ltd., Hitchen, U.K.) for 1 h. The dispersed samples were again centrifuged, the acid removed by decantation, and the resultant soil pellets further dispersed in approximately 20 mL of distilled water by vortex mixing. The dispersed samples were transferred into evaporating dishes, ensuring that all particles were transferred by repeated rinsing of the boiling tubes. The evaporating dishes were placed on a boiling waterbath until the water had evaporated. The dried soil samples were left in a closed cupboard at room temperature overnight.

A spatula was used to free any soil particles adhering to the walls of the evaporating dishes before placing them in an oven at 100°C for 15 min. On removal, each soil sample was immediately lightly crushed with a glass pestle and then transferred to a series of watchglasses using a brush, and weighed.

The weighed soil samples were transferred in turn to a nest of five test sieves (Endecott Ltd., London, England, see Table 1), arranged so that the size of the sieve openings decreased from top to bottom with the bottom sieve in the series fitting snugly into a pan. A lid was placed in position over the top sieve and the whole arrangement was clamped in position onto the sieve shaker (Endecott Model EFL2 MKII). The pressure applied to the sieve nest was determined using an adjustable torque wrench (Model AVT 100A Neill Tools, Sheffield, England). Preliminary experiments indicated that a torque of 6 N · m was suitable since at lower values the noise level increased without a significant increase in efficiency while at higher values sieving efficiency decreased. Shaking was carried out for 10 min and the residues in each sieve, as well as fines on the pan, were carefully transferred to separate watchglasses and weighed.

The fractions were listed as percentages of the test sample weight. The difference between

TABLE 1—*Test sieve specifications (as supplied by Endecott Ltd., London, England).*

Aperture Size, μm (Square Holed)	Sieve Mesh Number[a]	Woven Wire Cloth Material
1000	18	stainless steel
500	35	stainless steel
250	60	stainless steel
90	170	phosphor bronze
63	230	phosphor bronze

[a]ASTM Specification for Wire-Cloth Sieves for Testing Purposes (E 11).

the sum of the fractions and the test sample weight was recorded as the loss that occurred during and after sieving. The difference in weight between the dried soil before sieving and the original soil weight before peroxidation enabled the organic matter content to be determined.

Statistical Methods

Analysis was undertaken on three variables. The median value of the particle size distribution of each sample from a cell was chosen as the first variable. This was considered the best measure of location as most particle size distributions were skewed. To establish if differences existed between cells, the medians were analyzed using a two-way analysis of variance with interaction. This determined whether or not significant row and column effects were present and also if there was a significant row and column interaction. It also provided an estimate of the population variance. The second variable was the percentage of particles with sizes in the interval 90 to 250 μm in each sample. This was the modal class interval, and the proportion of particles within it provided a measure of spread of the particle size distribution. Analysis of variance was similarly performed on these percentages.

The third variable was the percentage of organic matter contained in each sample from a cell. Once again this variable was analyzed using analysis of variance.

Identification of Unknown Samples

Using the three variables, soil from each of 20 cells, selected at random and presented "blindly" to one of us for analysis, was examined and the results compared with those of the 100 cells in the control set. Samples from outside the 10- by 10-m^2 grid were likewise examined.

A more general explanation of the underlying statistical principles is given in the Appendix, but an outline of the procedure adopted follows. Six 1.5-g aliquots were taken from the soil from each blind sample and analyzed as described above. The mean $\bar{y}$ of the six median particle sizes obtained was calculated and compared with $\bar{x}_i$ the mean of the six medians of particle sizes from the ith cell in the control set, using the z statistic (Eq 1):

$$z_i = \left| \frac{\bar{x}_i - \bar{y}}{\sigma/\sqrt{3}} \right| \qquad i = 1, \ldots, 100 \tag{1}$$

where σ, the population variance, was estimated from the residual variance obtained from the analysis of variance on the control cells. As a measure of similarity between the ith control cell and the blind cell, the probability $P_1(z_i)$ of a z value as extreme as z_i was calculated using an approximation to the area under the standard normal curve. The largest value of $P_1(z_i)$ predicts the cell in the control set that was most similar to the blind cell. If this value is high then a match is indicated.

Similar analysis of the variables, percentage of particles in the interval 90 to 250 μm, and percentage of organic matter gave probabilities $P_2(z_i)$ and $P_3(z_i)$, respectively. The successive inclusion of these variables to the prediction procedure was assessed by making predictions based on the largest value of the multiplied probabilities $P_1(z_i)\,P_2(z_i)$ and then based on the largest value of the products $P_1(z_i)\,P_2(z_i)\,P_3(z_i)$.

Computational Methods

The data were stored on a Honeywell 66/40 system and analysis of variance carried out using the MINITAB STATISTICAL PACKAGE [*9*]. It was also possible to condense the prediction algorithm into less than 20 lines of MINITAB instructions. The instructions in-

cluded an approximation formula [9] which was used to calculate areas under the standard normal curve.

Results

Data Bank

Typical results obtained from the laboratory analysis of one cell (F4) are presented in Table 2.

Table 3 shows the results of the analysis of variance of the three chosen variables. In all cases, the F ratios indicate significant row × column effects are present, and suggests that all three variables may be of value in characterizing a cell.

Estimation of Similarity Probability

Table 4 shows the corresponding data to that of Table 2 for one of the blind samples. Using the z statistic to compare the median particle sizes, Table 5 shows the similarity probabilities $P_1(z_i)$ of the blind cell with each of the control cells. The probabilities are given accurate to two decimal places. Using this first variable, the most probable identify of the unknown cell is predicted to be either Cell A10 or E7 with Cells A3, G10, H4, D3, D6, D9, and F7 also being possible candidates. It is extremely improbable that any of the cells in Columns I and J are the correct identity of the unknown cell. The effect of including the second variable, the percentage of particles in the interval 90 to 250 μm, is shown in Table 6 where the similarity probabilities $P_1(z_i)\,P_2(z_i)$ are listed. Only Cell A3 remains similar to the blind cell, with the probability 0.83. Cells H4, E3, and B2 exhibit some similarity but all with probability less than 0.1. Based on the two probabilities from the particle size distribution, A3 would clearly be predicted as the identity of the unknown cell.

Further refinement to include percentage organic matter reinforces the result of the previous prediction. The similarity probabilities $P_1(z_i)\,P_2(z_i)\,P_3(z_i)$ are shown in Table 7, where

TABLE 2—*Particle size distribution shown as percentage for samples from Cell F4, along with median particle size and percentage of organic matter.*[a]

Samples	<63 μm	63 to <90 μm	90 to 250 μm	250 to <500 μm	500 to <1 mm	>1 mm	Median Particle Size, μm	Organic Matter, %
1	6.4	8.2	57.5	19.7	7.7	0.6	189	7.3
2	7.2	8.7	58.8	19.7	5.5	0.1	183	7.0
3	4.7	10.0	59.4	19.4	6.1	0.4	185	6.9
4	2.3	8.4	64.6	19.8	4.6	0.4	187	6.9
5	2.3	9.2	65.3	18.2	4.6	0.5	184	6.7
6	1.7	10.2	62.3	18.6	6.6	0.6	188	7.1

[a] Median particle size is that "theoretical"[b] value of particle size, either side of which is distributed 50% of the sample. For example, for Sample 1, the interval 90 to 250 μm must contain the median particle size and 35.4% [50 − (6.4 + 8.2)] of the soil in this range must be below this value. Hence the value of median particle size must be given by

$$90 + \frac{[35.4(250 - 90)]}{57.5}$$

$$= 189$$

[b] Theoretical because the distribution within this particle size interval is unknown.

TABLE 3—*Analysis of variance of median particle sizes, percentages of particles in interval 90 to 250 μm, and percentage of organic matter.*[a]

Source	DF	SS	MS	*F* Ratio	
Rows	9	5359.7	595.5	46.2	$Sp < 0.01$
Columns	9	9073.2	1008.1	78.2	$Sp < 0.01$
Rows × columns	81	6079.8	75.1	5.8	$Sp < 0.01$
Error	500	6472.7	12.9	...	
Total	599	26985.3	...	...	
Rows	9	2315.8	257.3	38.7	$Sp < 0.01$
Columns	9	6133.8	681.5	102.5	$Sp < 0.01$
Rows × columns	81	2122.8	26.2	26.2	$Sp < 0.01$
Error	500	33324.5	6.6	3.9	
Total	599	13896.9	...	...	
Rows	9	387.7	43.1	274.4	$Sp < 0.01$
Columns	9	165.6	18.4	117.2	$Sp < 0.01$
Rows × columns	81	248.3	3.1	19.5	$Sp < 0.01$
Error	500	78.7	0.16	...	
Total	599	880.3	...	...	

[a] DF = degrees of freedom, SS = sum of squares, MS = mean squared, *F* = MS value/error, and *S* = significance at the probability *p* level.

TABLE 4—*Particle size distribution shown as percentages for samples from a cell chosen blindly, along with median particle size and percentage of organic matter.*

Samples	<63 μm	63 to <90 μm	90 to <250 μm	250 to <500 μm	500 to <1 mm	>1 mm	Median Particle Size, μm	Organic Matter, %
1	4.2	14.8	56.4	17.5	6.3	0.8	178	9.6
2	1.0	16.4	56.7	18.4	7.2	0.3	182	9.8
3	1.6	17.6	54.8	17.8	7.0	1.2	180	9.7
4	1.9	16.6	56.6	16.9	7.1	0.9	179	9.6
5	1.3	16.4	56.8	18.8	6.2	0.5	181	9.8
6	3.2	16.2	57.0	15.9	6.9	0.8	176	9.7

TABLE 5—*Similarity probabilities of a blind cell to control cells using the median values of the particle size distribution.*

	Cells									
Blind Cell	A	B	C	D	E	F	G	H	I	J
1	0.00	0.00	0.15	0.02	0.00	0.00	0.00	0.00	0.00	0.00
2	0.00	0.09	0.02	0.03	0.02	0.00	0.01	0.58	0.00	0.00
3	0.87	0.04	0.20	0.75	0.20	0.00	0.01	0.20	0.00	0.00
4	0.00	0.01	0.33	0.69	0.02	0.00	0.11	0.87	0.00	0.00
5	0.04	0.02	0.33	0.52	0.47	0.02	0.47	0.04	0.00	0.00
6	0.02	0.00	0.01	0.75	0.15	0.04	0.20	0.01	0.00	0.00
7	0.00	0.02	0.02	0.13	0.93	0.75	0.23	0.81	0.00	0.00
8	0.04	0.09	0.02	0.33	0.42	0.02	0.46	0.02	0.00	0.00
9	0.26	0.08	0.04	0.75	0.00	0.87	0.26	0.020	0.00	0.00
10	0.93	0.33	0.52	0.02	0.11	0.26	0.87	0.02	0.00	0.00

TABLE 6—*Similarity probabilities of the blind cell to control cells using the two variables: median and modal class intervals.*

	Cell									
Blind Cell	A	B	C	D	E	F	G	H	I	J
1	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00
2	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	0.83	0.00	0.00	0.01	0.07	0.00	0.00	0.01	0.00	0.00
4	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.08	0.00	0.00
5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00
8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

TABLE 7—*Similarity probabilities of the blind cell to control cells using the three variables: median, modal class interval, and percentage of organic matter.*

	Cell									
Blind Cell	A	B	C	D	E	F	G	H	I	J
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	0.63	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7	0.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Cell A3 is confidently predicted to be the origin of the soil chosen blindly from the control set. Using the three variables all other cells are eliminated.

Results of Blind Trial and Use of Similarity Probabilities

The correct identity of the blind cell was indeed A3, and the above procedure illustrates how such predictions are obtained. Using all three variables the results of predicting the identity of the 20 random samples presented blindly are summarized in Table 8. Only the fifth blind sample was incorrectly identified. The identity was predicted as D10 with probability of 0.2041, whereas the correct identity was H6. However H6 was second in the prediction list, and had a similarity probability of 0.1892.

The successive inclusion of variables was necessary for accurate prediction. Using only median particle size, 6 out of 20 predictions were correct and the associated probabilities were such that none of the predictions were made with confidence. In contrast, median particle size and percentage of particles in the modal class considerably increased the success of the method. A total of 16 out of 20 were predicted correctly although only 12 of these could be considered to be confident predictions. Finally, the use of median particle size, percentage of particles in the modal class, and percentage of organic matter gave 19 correct predic-

TABLE 8—*Predicted identity and similarity probabilities based on three variables for soil from cells selected blindly.*

Blind Cell	Predicted Identity Using Three Variables	Similarity Probability	Correct Identity
1	A3	0.3812	A3
2	C7	0.7191	C7
3	F4	0.6852	F4
4	G1	0.4596	G1
5	D10	0.2041	H6
6	I5	0.4063	I5
7	B8	0.5306	B8
8	I7	0.5062	I7
9	A3	0.6279	A3
10	D6	0.6148	D6
11	G1	0.6376	G1
12	G5	0.6064	G5
13	A5	0.6718	A5
14	C1	0.2024	C1
15	F2	0.5724	F2
16	F4	0.4941	F4
17	A5	0.6339	A5
18	D4	0.4677	D4
19	F6	0.7954	F6
20	H8	0.5965	H8

tions out of 20, of which 17 were made with confidence. None of the samples taken from outside the grid gave similarity probabilities that would have led to assignment of origin.

Discussion

Subjective observation of the analytical results from the soil samples taken from the grid suggested that soil variation throughout the field was minimal. However, the similarity probabilities obtained as described proved to be a powerful tool for assessing the origin of even such closely similar soil samples taken from within one field. Furthermore, comparison of soil samples taken from neighboring fields with those of the defined location, rejected them as having arisen from the latter, thereby further emphasizing the predictive power of the method.

The procedure is not only able to tell which is the most probable member of the reference set from which an "unknown" soil sample has originated but also the relative probability that it may have originated from another cell within that set. The confidence can be assessed in two ways, from the ratio of the similarity probabilities and by their absolute values. More data, including that from casework, are required before the "significance" level can be set, but at present similarity probabilities over 0.3 suggests sameness and those below 0.2 suggest difference.

Some investigations into the effect of sample size, that is, the mass of soil available for analysis, have been carried out and will be reported in a future communication. Optimization of the number of soil replicates to be taken, the grid size, and operator variability have still to be assessed. Examination of the optimal combination of variables has shown that a combination of median size and proportion of sample in the modal class interval $[P_1(z_i)$-$P_2(z_i)]$ appeared to be less effective than a combination of median and percentage of organic matter $[P_1(z_i)\ P_3(z_i)]$ or modal class interval and organic matter $[P_2(z_i)\ P_3(z_i)]$ in predicting the similarity of soil samples. The combination of all three variables used by us gave excellent prediction of origins, but it may be that some other variable, such as metal content [*10*],

may be at least as good itself or in combination with other variables. Moreover it must not be assumed from this work that dry sieving is a preferred technique. Details of wet sieving in relation to the present work will be presented in a future communication.

Caution should be exercised in the use of organic matter content, since for levels greater than 15% of the total soil mass the organic content has been found to change with time. To ensure that significant changes are not taking place throughout the period of analysis, it is recommended that repeat analyses should be performed and that samples for comparison should be stored under identical conditions.

This approach to characterizing the soil locus is very flexible. It is easy to incorporate other measured soil variables, such as saccharide level [11], into the calculation of similarity probability and the z test described could be replaced by alternative statistical tests such as the nonparametric Mann-Whitney test. The general approach could be applied to other forensic science comparisons such as hair or glass.

APPENDIX

Suppose soil is to be characterized by a single variable X, and the origin of soil from a set of c control cells is to be predicted. Measurements on m soil samples from control cell i and n soil samples from an unknown cell provide respective means $\bar{x}_i$ and $\bar{y}$. Hypothesis testing associated with control cell i and the unknown cell having the same population mean is well known but for completeness is given as follows.

Under H_0: $\mu_x = \mu_y$ the test statistic

$$z_i = \left| \frac{\bar{x}_i - \bar{y}}{\sigma\sqrt{\frac{1}{n} + \frac{1}{m}}} \right| \qquad i = 1, \ldots, c$$

will be approximately normally distributed with mean 0 and variance 1 for large m and n, where σ^2 is the variance of X.

The probability of obtaining such an extreme value z_i will be

$$P(z_i) = P(Z < -z_i) + P(Z > z_i)$$

$$= 2\Phi(-z_i)$$

where

$$\Phi(-z_i) = \int_{-\infty}^{-z_i} \frac{1}{\sqrt{2\pi}} e^{-z^2/2}\, dz$$

Among the control set the most probable cell for the unknown soil to originate from, will be the cell i corresponding to

$$\max[P(z_i)] \qquad i = 1, \ldots, c$$

Characterization of the soil by N variables $X_1, \ldots, X_N$ can similarly be carried out using the respective probabilities $P_1(z_i), \ldots, P_N(z_i)$ determined for each of the variables. Assum-

ing the variables are independent multiplication of the extreme probabilities and selecting the cell i associated with

$$\max\left[\prod_{j=1}^{N} P_j(z_i)\right] \qquad i = 1, \ldots, c$$

predicts the most probable cell for the unknown soil to have originated from.

References

[1] Greenland, D. J. and Hayes, M. H. B., "Soils and Soil Chemistry," in *The Chemistry of Soil Constituents*, D. J. Greenland and M. H. B. Jayes, Eds., Wiley and Sons, London, 1978, pp. 11-28.

[2] Murray, R. C. and Tedrow, J. C. F., *Forensic Geology*, Rutgers University Press, 1975, pp. 63 and 180.

[3] Graves, W. J., "A Mineralogical Soil Classification Technique for the Forensic Scientist," *Journal of Forensic Sciences*, Vol. 24, No. 2, April 1979, pp. 323-337.

[4] Silverman, L., Billings, C. E., and First, M. W., *Particle Size Analysis in Industrial Hygiene*, prepared under the direction of the American Industrial Hygiene Association (AIHA) and U.S. Atomic Energy Commission (Division of Technical Information), Academic Press, New York and London, 1971, pp. 76-234.

[5] Dudley, R. J., "The Particle Size Analysis of Soils and Its Use in Forensic Science—The Determination of Particle Size Distribution Within the Silt and Sand Fractions," *Journal of the Forensic Science Society*, Vol. 16, 1976, pp. 219-229.

[6] Lewis, A. J. M., "Standardization of Sample Preparation Techniques for the Analysis of Soil by Particle Sizing," M.Sc. thesis, University of Strathclyde, 1981.

[7] Thomas, C. J., "A Comparison of the Efficiency of the Dry and Wet Sieving Techniques in Particle Size Distribution Analyses of Soils," M.Sc. thesis, University of Strathclyde, 1982.

[8] Dudley, R. J. and Smalldon, K. W., "The Objective Comparison of the Particle Size Distribution in Soils with Particular Reference to the Sand Fraction," *Medicine, Science and the Law*, Vol. 18, 1978, pp. 278-282.

[9] Ryan, T. A., Joiner, B. L., and Ryan, B. F., *Minitab Reference Manual*, Duxbury Press, North Scituate, MA, 1982.

[10] Hoffman, C. M., Brunelle, R. L., and Snow, K. B., "Forensic Comparison of Soils by Neutron Activation and Atomic Absorption Analysis," *Journal of Criminal Law, Criminology and Police Science*, Vol. 60, 1969, pp. 395-401.

[11] Dudley, R. J., "A Colorimetric Method for the Determination of Soil Saccharide Content and Its Application in Forensic Science," *Medicine, Science and the Law*, Vol. 16, 1976, pp. 226-231.

Address request for reprints or additional information
B. Caddy, Ph.D.
University of Strathclyde
Forensic Science Unit
Royal College, 204 George St.
Glasgow G1 1XW, U.K.