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THE TRACE EVIDENCE CONCENTRATOR:
A SYSTEM FOR ISOLATING TRACE EVIDENCE
FROM SOIL SAMPLES

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THE TRACE EVIDENCE CONCENTRATOR: A SYSTEM FOR ISOLATING TRACE EVIDENCE FROM SOIL SAMPLES

By

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ABSTRACT

THE TRACE EVIDENCE CONCENTRATOR: A METHOD FOR ISOLATING TRACE EVIDENCE FROM SOIL SAMPLES

By

Jessica G. Johnston

This research project was conducted in order to develop and test a rapid, quantitative, and efficient method of trace evidence isolation from soil samples. The Trace Evidence Concentrator (TEC) is a hydropneumatic elutriation system that operates on a differential density principle in order to perform this separation task. That is, various low density items of trace evidence may be successfully separated from mineral soil particles by subjecting samples to this system. Standard samples of human hair, carpet fibers, and, automobile paint chips were combined with various soil standards and processed with the TEC. Trace evidence recovery ranged from 86% to 100% for each of the three items and the TEC proved to be 21% more time efficient then a conventional manual dry-sieving method for processing large volumes of soil.

To my grandmother, Agnes L. Johnston. Thank you, for all of your love and support.

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Also, my special thanks to Dr. Fred Erbicsh and the Office of Intellectual Property who provided the financial support for this research.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

The extraction of trace evidence materials from crime scene soil samples has remained a somewhat neglected area of research in forensic science. Trace evidence may be useful in event reconstruction and the association of people, places, and things. The most common techniques implemented for the processing of soil for evidentiary purposes involve manual dry sieving and/or vacuuming, accompanied by visual microscopic observation and forceps removal. Trace evidence of various forms (e.g. hairs, fibers, glass, and paint) may be associated with various soil materials. This mixture often results from crimes committed in various modes and environments. The focus here is to develop a fast, efficient, and continuous means by which trace evidence materials may be quantitatively separated from soils, without altering and/or destroying the evidence.

The necessity for a continuous separation technique arises from the inherent limitations encountered with the utilization of currently accepted methods. These methods are generally subjective, time consuming, and relatively inefficient. Furthermore, if trace evidence materials are obscured due to the adherence of soil particles they may be overlooked. A continuous trace evidence separation technique would allow analysts to process numerous soil samples from a scene and quantitatively recover uncontaminated trace evidence from large sample volumes more effectively. Such a technique could be successfully implemented and tremendously useful at crime scenes and in situations involving victim burial, explosions, cremations, and mass disasters in which trace evidence items are often combined with surface and/or deeper soil material.

The primary objective of this study was to develop and test a hydropneumatic evidence elutriation system for separating trace evidence from mineral soil materials. This method combines the elutriative separation of evidence, contained in soil samples, with a sieving process which accumulates trace evidence. Combinations of a high energy water vortex, air dispersion, water elutriation, and low energy separation and concentration by sieving separate lighter evidentiary materials from heavier mineral soil fractions. The system is based on the principle that materials having densities less than that of the surrounding soil particles will be successfully separated and elutriated to a submerged sieve. Soil samples may be continuously fed through an inlet until accumulated soil sediments interfere with maximum trace evidence separation. Another objective of the proposed research was to determine how efficiently various trace evidence materials may be separated from soil samples utilizing the hydropneumatic elutriation system. Recovery efficiencies by the TEC were compared to those of conventional manual dry sieving and visual examination methods. System efficiencies were based upon the quantities of trace evidence recoveries and sample processing times.

Literature Review

A similar hydropneumatic elutriation system has been utilized to extract root materials and other organic soil material from soil samples (Smucker, 1993; Srivastava, Smucker, McBurney, 1982). This system also separates materials based on differential density elutriation and has proven to be an efficient quantitative method of root system isolation. Used in conjunction with computer imaging, hydropnuematic elutriation allows precise quantitation of root system components (Smucker, 1993). A device consisting of a battery of eight elutriation columns is commercially available for separating root materials from mineral soils. It was, therefore, recognized that a comparable method may be utilized for the separation of trace evidence materials from soil samples.

Conventional methods for the isolation of trace evidence from various substrates do exist; however, these techniques are generally limited to the processing of low volume dust samples (garments, and the like), and thus are not implemented specifically for high volume soil samples. Several authors suggest that "hand" picking, which involves the observation and subsequent removal of trace evidence material from various substrates (garments, carpet, dust samples) with forceps, needles or magnets, is the best method of evidence collection (Gaudette, 1988; Murray and Tedrow, 1992; Palenik, 1988; Saferstein, 1995; Suzuki, 1993); Swanson, Chamelin, and Territo, 1996). Murray and Tedrow (1992) suggest that following this initial examination the material should then be observed under a stereo-binocular microscope, followed by forceps removal of evidentiary items. These methods, however, are extremely tedious, time consuming, and subject to human error, especially in instances of mass disaster and cremation for which trace evidence may be combined with large volumes of soil. Others suggest that trace evidence materials be collected via vacuuming, tape-lifting, shaking, or scraping, followed by microscopic examination and separation of evidence with forceps removal (Bisbing, 1982; Osterberg and Ward, 1992; Palenik, 1998; Suzuki, 1993). However, these methods do not apply generally and are not commonly used for evidence extraction from soil samples alone. Thus, the necessity for the development of a more quantitative and efficient technique is evident.

MATERIALS AND METHODS

Apparatus

Materials of construction for the Trace Evidence Concentrator (TEC) were similar to the hydropneumatic elutriation system for separating roots with several significant modifications (Smucker, et al., 1982). The TEC system includes various engineered components of polyvinyl chloride, brass clamps, and tygon or rubber tubing. These components were sealed together using PVC glue or silicone sealant. The base of the TEC elutriation chamber was constructed by sealing a 16.9 (i.d.) x 8.5 cm cap (Figure 1B) to the 15.3 (i.d.) x 45.7 cm elutriator tube (Figure 1C), with a wall thickness of 0.8 cm. To create a high-kinetic energy washing environment, four sprayer nozzles (type, T-jet 8003) (Figure 1H) were installed around the circumference and through the cap/chamber walls at an approximate acute angle of 84 degrees. In order to lift the cleaned particles of trace evidence to the surface of the elutriator tube five air-jet (Figure 1I) nozzles were installed through the base of the cap, with four equally spaced around its perimeter and one in the center. The elutriator tube cover (Figure 1D) is a PVC reducer with an inside diameter of 16.9 to 4.7 cm, combined with a reducing collar with an inside diameter of 6.1 to 4.7 cm. The tube cover is equipped with four clamps to eliminate leakage and also includes the transfer tube (Figure 1E) and low-kinetic energy sieve assembly (Figure 1F and G). The transfer tube and low-kinetic energy sieving assembly consists of two 4.6 cm couplers, an 3.8 x 18.0 cm PVC tube (Figure 1E), and a submerged primary sieve (Figure 1F), with a small air-escape hole drilled at the top of the transfer tube. The submerged primary sieve, containing a screen with an aperture of 0.34 mm, is submerged in water bath (Figure 1G) to a depth of 1 cm above the screen. To accommodate large soil samples and facilitate multiple introductions of samples into the TEC system, a continuous feed column (Figure 1A) was installed through the wall of the elutriator tube consisting of a 3.8 cm (i.d.) street-el 3.8 (i.d.) x 62.8 cm PVC pipe. A small hole (Figure 1J) was drilled in the side wall of the feed column and plugged with a rubber stopper, to initiate drainage of the elutriation chamber before removing the top cap (Figure 1D) between samples. A second source of air was also added to flush any remaining evidentiary particles from the base of the continuous feed column, by removing the access funnel and applying air pressure to the top of the continuous feed column (Figure 1A), during the elutriation process.

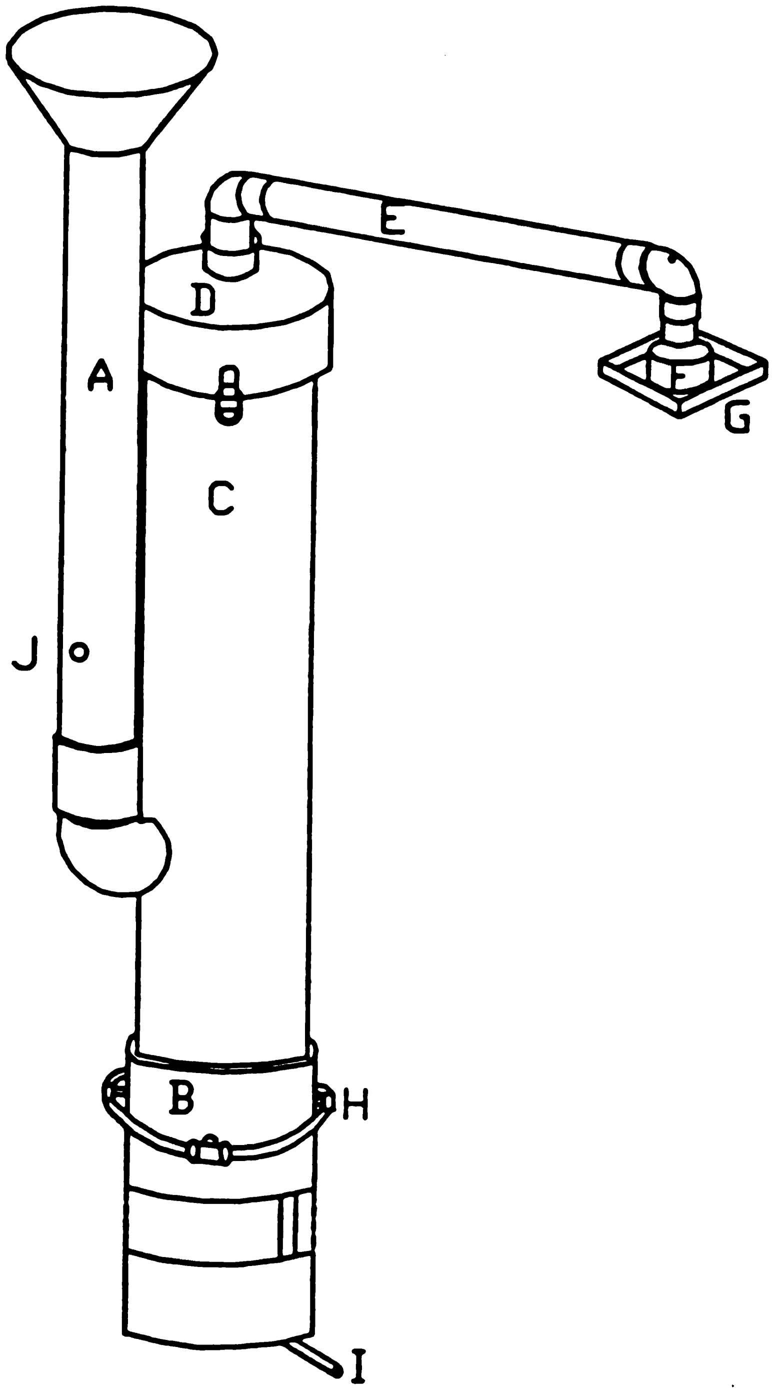

Figure 1. A diagrammatic illustration of the Trace Evidence Concentrator

<u>Procedure</u>

In order to test and evaluate trace evidence recovery by the TEC system it was necessary to determine maximum and minimum air and water pressures required to elutriate trace evidence materials without eluting coarse sand and silt particles onto the primary sieve. Soil samples without trace evidence were elutriated to determine the maximum pressures. Trace evidence materials, including human hairs, automobile paint chips, and carpet fibers, were then run through the TEC without soil materials, to determine the minimum pressures necessary to elutriate evidentiary items alone. Preliminary testing revealed that optimum air and water pressures were measured at 10 and 40 psi, respectively, for the most effective separation and deposition of trace evidence on the primary sieve (See Appendix A for detailed TEC protocol).

Preliminary experimentation was also performed to determine the basic effectiveness, known as percent recovery, for composite soil samples and standards of trace evidence from different soil types. Composite samples consisted of 150g of soil combined with 10 items each of human hair, automobile paint chips, and carpet fibers. Four 150g soil subsamples were obtained from three different soil types including Tappan clay loam, Kalamazoo loam, and Parkhill loam. Four replications of mixed samples were performed for each soil type, for a total of twelve replications. Initially, each 150g sample was exposed to the elutriation system for 15 minutes; however, during the course of sample processing it was discovered that elutriation time could be decreased to 10 minutes with the addition of a second air source employed to flush out the continuous feed column.

Trace Evidence from Soil at a Simulated Crime Scene

The protocol for determining the efficiency of quantitative separation of trace evidence from soil by the TEC compared to that of a conventional manual dry sieving and visual examination method required a completely randomized block experimental design, with three double-blind treatments having four replications. A simulated crime scene was established first by filling twelve 38.1 x 50.8 x 12.7 cm plastic containers, referred to as experimental units, with approximately 6.5 cm soil. The coarse textured soil, contained some aggregated clay and a considerable amount of plant residue. Variable numbers of trace evidence, including human hairs, automobile paint chips, and carpet fibers were uniformly distributed within eight of the experimental units, by an individual who was not the TEC operator. Controls, or soils without trace evidence were randomly selected from four of the twelve experimental units. Soils from eight experimental units (four with trace evidence and four without) were subjected to the TEC system. Four experimental units (containing trace evidence) were processed by the conventional manual dry sieving and visual examination method.

Operation of the TEC system involves, securing the air and water tubes to the appropriate fixtures. Air flow is initiated and adjusted to approximately 10 psi before the water is turned on. The cover, transfer tube, and sieve assembly are then secured and the water set to 40-45 psi. The elutriation chamber is filled and the primary sieve submerged in at least 1 cm of water. A sample of approximately 450g of soil is pored into the continuous feed port through a funnel attached to the continuous feed column, in three subsamples of 150g at 30 second intervals. The continuous feed column is flushed with water for 10 seconds and the TEC is run for 10 minutes. Following the 10 minute elutriation period, the TEC is flushed, drained, disassembled, and emptied. This process involves removing the primary sieve and flushing the continuous feed column twice with air, forcing excess water into a container below the transfer pipe. The extruded water is subsequently emptied into the submerged primary sieve. The water flow must then be reduced to 10 psi and the stopper removed from the lower end of the continuous feed column for drainage. Following drainage, the cap at the top of the elutriation chamber is removed and the sediment emptied into a large metal sieve. The contents of the primary sieve must then be washed into a white tray and floated in water for visual examination. Repeat these procedures for the remainder of the soil samples, and ensure adequate rinsing of all TEC components between sample containers to collect any trapped trace evidence. Total time for sample processing and total trace evidence recovery was recorded.

Visual examination of the sieve contents involves the use of a high-powered illuminated magnifier. Visual examination occurred during the ten minute elutriation period. The white tray was placed under the magnifier and scanned for trace evidence. The organic sediment should be dispersed, floated, and permitted to settle at least five times in order to facilitate the observance of trace evidence. Any trace evidence observed was subsequently removed with forceps and stored.

Four experimental units were processed using a combination of manual dry sieving, utilizing a nest of wire sieves and visual examination, with the assistance of an illuminated magnifier and binocular microscope. This method involves first arranging a column of sieves with apertures measuring from top to bottom 6.30 mm, 4.76 mm, 2.00 mm, 1.00 mm, and 0.42 mm. Then approximately 650g of soil sample is measured and added to the top of the sieve column. The top sieve is covered and the column manually sieved for 30 seconds to facilitate the separation of trace evidence from soils. The cover is removed and the top sieve emptied onto a white sheet of paper. The paper and sample are then placed under the magnifier and scanned for trace evidence. Examination under a binocular microscope at 50x may be necessary for further trace evidence separation. Any trace evidence observed is removed with forceps and stored. It may be necessary to further agitate the column of sieves between sieve-content examination to ensure maximal separation of soil and trace evidence through the sieve series. Repeat these procedures with the remaining soils from the experimental unit. Total time for sample processing and total trace evidence recovery was recorded.

RESULTS AND DISCUSSION

Preliminary experimentation revealed that the TEC was highly effective in elutriating trace evidence particles from soil three different soil types. The total evidence recovery values from Tappan Clay Loam, Kalamazoo Loam, and Parkhill Loam for human hair, automobile paint chips, and carpet fibers ranged from 93-100%. Individual means and standard deviations are presented in Table 1.

Table 1. Trace evidence recovery from three soil types by the TEC (12 replications in total).

Soil Type	Human Hair %	Paint Chips %	Carpet Fibers %
Tappan Clay Loam (n=4)	98(±8)*	100(±0)	93(±15)
Kalamazoo Loam (n=4)	100(±0)	95(±10)	100(±0)
Parkhill Loam (n=4)	100(±0)	100(±0)	100(±0)

*Values in () are standard deviations of the percent

It must be noted, however, that on occasion paint chips were retrieved from the bottom of the elutriation chamber. That is, because some paint chips were comprised of several layers, increasing their density, they tended to remain with the coarse mineral fraction. However, these items were thoroughly cleaned and easily separated from this fraction following the elutriation period. Similarly, other higher density trace evidence items such as glass fragments and rubber pieces could be recovered from the coarse mineral fraction, but none of these items were generally deposited on the primary sieve.

Simulated crime scene results indicate that both the TEC and manual dry sieving are effective quantitative isolation techniques for trace evidence combined with large quantities of soil. To aid in the efficiency comparison between these two separation systems it was necessary to determine means and standard deviations for air-dry weight values of simulated crime scene soil experimental units (Table 2).

Table 2. Air-dry weights of soil samples from experimental units of the simulated crime scene.

Soil Condition	TEC Elutriated Samples (g)	Sieved Samples (g)
Blank Control	5173.1(±315.31) (n=4)	N/A
Trace Evidence	5177.9(±283.25) (n=3)	4986.5(±374.77) (n=4)
Combined	5174.8(±268.38) (n=7)	N/A

The TEC method of evidence concentration proved to be an effective, efficient, and quantitative technique for trace evidence separation. Total recovery results for human hairs, automobile paint chips, and carpet fibers were

86%, 87%, and 100%, respectively. Means and standard deviations are presented in Table 3.

Table 3 also depicts the total trace evidence recovery results for the manual dry sieving method. Similarly, this technique proved to be very effective. Total recovery results for human hairs, paint chips, and carpet fibers were 92%, 100%, and 100%, respectively.

Table 3. Trace evidence recovery from experimental units of the simulated crime scene.

Soil Condition	TEC Elutriation		Manual Sieving	
	X/Y*	%	X/Y*	%
Blank Control (n=4)	0 (±0)	0 (±0)	N/A	N/A
Trace Evidence				
Human Hairs	7/7,4/7,1/1	86 (±3) (n=3)	19/20,9/10, 11/12	92 (±3) (n=3)
Paint Chips	17/22,10/10 9/13,5/5	87 (±15) (n=4)	11/11,0/0, 7/7,2/2	100 (±0) (n=4)
Carpet Fibers	9/9,11/11, 14/14	100 (±0) (n=3)	13/13,3/3, 26/26,3/3	100 (±0) (n=4)

*X Number of items recovered
*Y Number of items in sample acquired from experiment director, following separation work.

Trace evidence recovered by both the TEC and manual sieving methods were not significantly different, Table 3. However, the time required to process each kilogram of soil with the TEC was 34.1(±1.0) minutes and with the manual sieving method was 41.1(±1.3) minutes. Thus, the TEC was an average of 21% faster than the manual sieving method for processing experimental units.

Because the TEC had not been exposed to the magnitude of soil sample encountered in this portion of the experiment some trouble-shooting was necessary during sample processing. That is, an optimum amount of soil sample had to be determined in order to prevent system back-up, which did indeed occur during the processing of the first sample. This back-up could thus explain the diminished evidence recovery, for paint chips in particular compared to that of preliminary experimentation. TEC paint chip recovery was also slightly low for the fourth sample. The explanation here involves the nature of the soil. The high organic content of soil employed as the substrate may have impaired recovery. That is, following sample elutriation it was necessary to examine the primary sieve contents and remove the trace evidence particles from the organic material. This process was somewhat hindered by the high organic content and, thus could explain the lower paint chip recovery. These results do not, however, compromise the value of utilizing the TEC for trace evidence recovery. Instead they provide further insight for determining the samples for which it may be optimally employed. That is, implementation of the single TEC unit, may be most effective for samples consisting of either small volumes of high organic content soils, or large volumes of low organic content soils. However, the TEC is designed for the potential of operating collectively with several other units. In order to most effectively process large volumes of high organic content soil an arrangement of TEC units with a mechanized device for routinely emptying the primary sieve could be employed. Such a combination of several TEC systems would effectively prevent organic content from accumulating on the primary sieve and obscuring trace evidence. Thus, facilitating trace evidence removal from primary sieve contents.

SUMMARY AND CONCLUSIONS

With regard to overall time efficiency the TEC is definitely superior. The manual dry sieving and visual examination required an average of 21% longer per kilogram of soil processed than did the TEC. This difference may not appear significant here, however, incidents such as explosions, arsons, and the like do occur in which hundreds of kilograms of soil may require processing in order to locate important trace items. Although the TEC is not designed to recover insoluble or soluble chemicals that are not present in an aggregated form, it may be implemented after chemical analyses in order to recover solid incendiaries associated with such incidents.

In summary, the TEC system would appear to be the obvious candidate for crime scene investigators faced with the challenge of isolating trace evidence from both small and large soil sample volumes. The effectiveness of the TEC system has been clearly demonstrated by the research conducted. The results reveal that the TEC method provides a quantitative, user-friendly approach to trace evidence isolation from soil samples. Furthermore, it is important to recognize that the TEC system technology is not limited to the present application, but is designed to accommodate any further modifications, additions, and/or adaptations that may be required for the separation of any other desired materials of interest. That is, the TEC system, is not limited to utilization for trace evidence recovery, but may be adapted and implemented to isolate materials associated with other disciplines such as anthropology, archeology, and the like.

APPENDIX

APPENDIX A

A DETAILED TEC PROTOCOL

I TEC assembly and sample addition

a) Secure water tube with metal connector

b) Secure air tube with plastic connector

c) Turn on and adjust air to approximately 10 psi

d) Place stopper in continuous feed column

e) Place transfer tube into tube cover/reducer

f) Place cover onto elutriation tube and align with clamps.

g) Place primary sieve into submersion pan

h) Turn water on and adjust water to 40 psi

i) Allow TEC to operate to equilibrium

j) Measure 450g of soil sample

k) Add three 150g portions at 30 second intervals

l) Rinse continuous feed column with water for 10 seconds

m) Allow to elutriate for 10 minutes following last 150g portion

II TEC disassembly

a) Following 10 minute elutriation period remove primary sieve

b) Flush continuous feed column for 5-10 seconds with air, catch water in a beaker, and repeat

c) Adjust water to 10 psi and remove stopper from continuous feed column

d) Pour beaker contents into submerged primary sieve and rinse beaker thoroughly

e) Rinse primary sieve into white tray

f) Remove feed column and allow to drain

g) Remove TEC top cover

h) Adjust water to 40 psi and pouring elutriation chamber sediment into metal screen

J) Return to I d) above and continue with next sample

BIBLIOGRAPHY

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Bisbing, R.E. (1982). The forensic identification and association of human hair. In R. Saferstein (Ed.), Forensic Science Handbook, Vol.1 (pp. 184-221). Englewood Cliffs, NJ: Prentice Hall.

Gaudette, Barry D. (1988). The forensic aspects of textile fiber examination. In R. Saferstein (Ed.), Forensic Science Handbook, Vol. 2 (pp. 209-272). Englewood Cliffs, NJ: Prentice Hall.

Murray, R. & Tedrow, J.C.F. (1992). Forensic Geology. Englewood Cliffs, NJ: Prentice Hall.

Osterberg, J.W. & Ward, R.H. (1992). Criminal Investigation: A Method for Reconstructing the Past (5th ed.). Cincinnati, Ohio: Anderson Publishing Co.

Palenik, Skip. (1988). Microscopy and microchemistry of physical evidence. In R. Saferstein (Ed.), Forensic Science Handbook, Vol. 2 (pp. 161-202). Englewood Cliffs, NJ: Prentice Hall

Saferstein, R. (1995). Criminalistics: An Introduction to Forensic Science (5th ed.). Englewood Cliffs, NJ:Prentice Hall.

Smucker, A.J.M., McBurney, S.L., & Srivastava, A.K. (1982). Quantitative separation of roots from compacted soil profiles by the hydropneumatic elutriation system. Agronomy Journal, 74, 500-503.

Smucker, A.J.M. (1993). Soil environmental modifications of root dynamics and measurement. Annual Review of Phytopathology, 31, 191-216.

Suzuki, Edward A. (1993). Forensic Applications of Infrared Spectroscopy. In R. Saferstein, Forensic Science Handbook, Vol. 3 (pp. 24-70). Englewood Cliffs, NJ: Prentice Hall.

Swanson, C.R., Chamelin, N.C., & Territo, L. (1996). Criminal Investigation (5th ed.). McGraw-Hill.