Forensic Pedology: From Soil Trace Evidence to Courtroom

16

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Abstract

Forensic pedology is the study of soil to answer legally related questions and problems. Soil evidence could play an important role to answer legal questions in court and to solve crimes. In this chapter, it is explained how soil is as a type of trace evidence in terms of its properties. There are various techniques and methods to study soil. In the National University of Singapore, the Forensic Science Research team uses the scanning electron microscopy coupled with energy-dispersive X-ray spectroscopy, which is a relatively new method to profile soil. Here, the team's methodology is explained. Finally, case studies in Singapore show the importance of soil science expertise in solving rape and murder cases.

Keywords

Forensic pedology · Forensic science · Soil forensics · Soil properties · Scanning electron microscopy/microscope · Energy dispersive X-ray

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16.1 What Is Trace Evidence in Forensic Science?

In 1910, French criminologist and pioneer in forensic science Edmond Locard founded the fundamental principle to associative evidence that states: “Every contact leaves a trace,” which is now commonly termed as Locard’s exchange principle (Fig. 16.1).

The contact between an individual with another individual or a location will result in the introduction or removal of something from the environment. An example of a one-way transfer will be a criminal leaving their fingerprints in a crime scene. However, two-way transfers are more likely to occur when trace evidence is contributable, whereby the criminal will also take away something from the scene like hair or glass particles. Such trace evidence is crucial in establishing the elements in the crime and linking the players in a rational, objective, and well-supported manner in the court.

> Wherever he steps, whatever he touches, whatever he leaves, even unconsciously, will serve as a silent witness against him. Not only his fingerprints or his footprints, but his hair, the fibers from his clothes, the glass he breaks, the tool mark he leaves, the paint he scratches, the blood or semen he deposits or collects. All of these and more bear mute witness against him. This is evidence that does not forget. It is not confused by the excitement of the moment. It is not absent because human witnesses are. It is factual evidence. Physical evidence cannot be wrong, it cannot perjure itself, it cannot be wholly absent. Only human failure to find it, study and understand it, can diminish its value.
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> Paul L. Kirk

Fig. 16.1 Edmond Locard with his microscope. Adapted from London multimedia news, 2015. Retrieved from https://londonmultimedianews.com/2015/03/01/forensics-the-anatomy-of-crime-opens-at-the-wellcome-collection/10077873-edmond-locard-at-a-microscope-with-his-so/

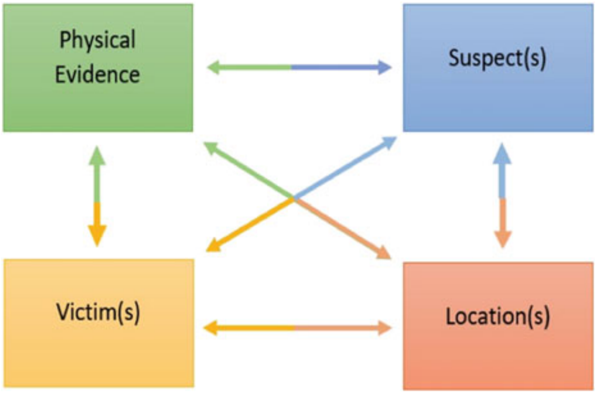

Fig. 16.2 Four-way linkage theory

Section 5 of the Evidence Act (EA) states that "Evidence may be given in any suit or proceeding of the existence or non-existence of every fact in issue and of such other facts as are hereinafter declared to be relevant, and of no others" (Singapore Legal Advice 2019) (Fig. 16.2).

Evidence admissible can be in the form of documentary evidence, oral testimonies, digital and physical evidence, which can be recorded and retrieved during the investigation process. Trace evidence, a subset of physical evidence, is essential in providing source- (association between suspect, victim, and location) and activity-level (how, what, and where) information needed for a logical crime scene reconstruction. The value of trace evidence is due to its microscopic size and individualistic nature (Blackledge and Jones 2007). Examples of trace evidence include glass fragments, hair, fibers, gunshot residues, paint particles, and the primary objective of this chapter: soil.

As you will see in this chapter, soil has helped to solve crime and has its place in a courtroom. Methods used to study soil would also be briefly described, especially in the context of National University of Singapore's Forensic Science Research lab. The comprehensive details of methodologies will not be provided, but this sneak peek might have you find soil an interesting topic in academia henceforth. This chapter will end with legal case studies in Singapore, where soil had contributed to the prosecution of a cold-blooded murderer and a rapist—truly showing you how soil evidence makes its way to the courtroom.

16.2 Soil as Trace Evidence

The potential of soil as highly valuable trace evidence has been gaining traction over the years. The National Academy of Sciences (NAS) report by the National Institute of Justice (NIJ) in 2009 reported on the need to recognize and respond to the immediate need for significant improvements in many aspects of forensic science, especially in the light of The Innocence Project (National Institute of Justice 2009). A section of trace evidence was included in the report but made no mention on the study of soil in trace evidence as a forensic science discipline. However, in current times, many studies have been conducted to learn the use of soil as a tool for site verification and estimating the time of death and have been applied in real life cases in some countries like the Netherlands (Netherlands Forensic Institution) and Australia (Centre for Australian Forensic Soil Sciences). As of 2016, a total of US $1,059,776 have been awarded by the NIJ to fund forensic soil research (National Institute of Justice 2016).

Since soil is abundant in many locations and is readily available, it is highly likely for soil to be present or related to a crime. Soil can be potentially collected from soles of footwear, car tires, clothing, shovels, or other equipment and related to a wide variety of crimes like sexual assault, homicide, and kidnapping (Stam 2004; Uitdehaag et al. 2016). Forensic examiners will carefully sieve out soil that has been likely disturbed from human activity for comparison against a control to calculate the degree of similarity. The weight (or evidential value) of the comparison will be assessed accordingly in a case trial (e.g., Bayesian method) (Finkelstein and Fairley 1970).

Blackledge and Jones (2007) lined out six properties of ideal trace evidence which applies to soil: nearly invisible, highly individualistic, high probability of transfer and retention, easy collection, separation and concentration, and easy characterization against a database, of which some will be further explained below. These properties, therefore, make soil a highly valuable piece of trace evidence in the criminal investigation process. Figure 16.3 below shows the various properties of soil that could influence soil forensics. Each property is further explained thereafter.

16.2.1 Class and Individual Characteristics of Soil

Soil is a cornucopia of information as it plays host to a wide diversity of organisms and chemical compounds. Microorganisms, pollen, and chemical compounds present in soil are commonly used to assess the similarity and differences between a seized and control soil sample. While water creates a homogenous environment, the coarse nature of soil particles promotes heterogeneity due to the promotion of niche differentiation and the creation of highly diverse microhabitats.

The difference in abundance of bacteria generalists (e.g., phyla *Proteobacteria, Verrucomicrobia*, *and Acidobacteria*, which are class characteristics) and presence of individualistic and novel species set the basis for comparison between different locations (β-diversity). Biogeography of microorganisms has proved useful in providing invaluable pieces of evidence in forensic science through the process of elimination and association (Schauser et al. 2016). Similarly, fungi have also been proved to be useful in identifying sites at a broader scale (Shinde et al. 2003).

Other class characteristics include color, soil class, presence of chemical elements, compounds, and molecules, which can be determined through analysis

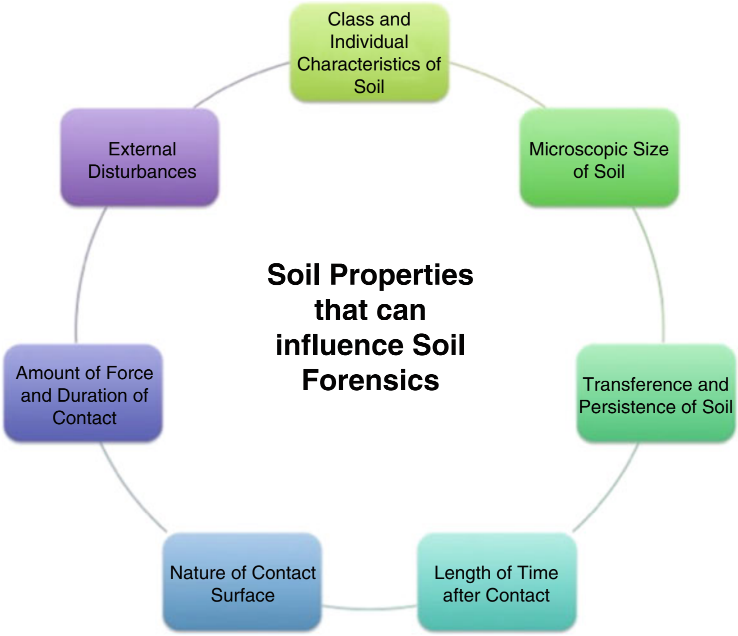

Fig. 16.3 Figure of various soil properties that can influence forensic pedology, which is the study of soil in the service of law

that is further explained later in the chapter. Figure 16.4 above shows the various types of aforementioned class and individual characteristics of soil in graphical form.

16.2.2 Microscopic Size of Soil

The microscopic size of soil makes it near invisible to the naked eye. It is expected for suspects fleeing the crime scene to dispose of more obvious and noticeable evidence like physical objects (e.g., murder weapons), blood stains, or even lipstick. However, the minute size of soil makes it harder to detect and hence, disposed of.

A case study outlined in Fitzpatrick et al. (2009) observed that the yellow-brown color of the fine clay and silt (<50 μm fraction) was hard to visually detect under the larger and coarser gravel soil. Therefore, even if the suspect were to brush off the visible soil, it is difficult to remove all traces of soil particulates completely.

16.2.3 Transference and Persistence of Soil

The key characteristic that makes soil the ideal form of trace evidence is its strong capacity to transfer (primary transfer) from one object to another, forming a direct link to associate otherwise discrete elements in the crime. However, the loss of soil

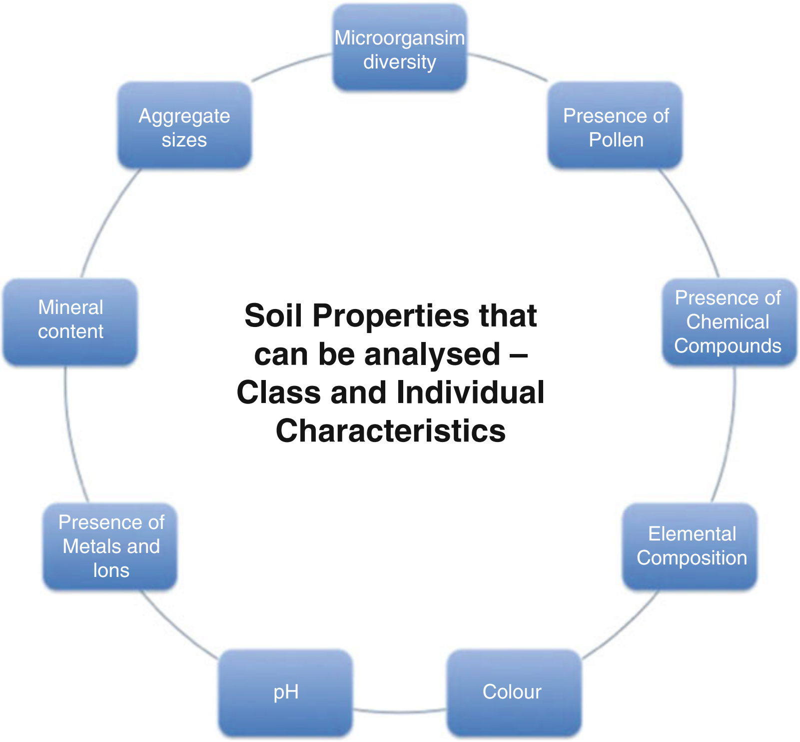

Fig. 16.4 Class and individual characteristics of soil. These properties can be analyzed in a laboratory

trace evidence through secondary transfer, which is defined to be the exchange of evidence that is not entirely associated with the crime itself, emphasizes the imminent need for investigators to retrieve the soil particles as early as possible.

The factors that determine the transfer and persistence of soil are as follows: (1) length of time after the contact, (2) nature of contact surface, (3) amount of force and duration of contact, and (4) external disturbances following contact.

16.2.4 Length of Time After Contact

The decay of soil has been determined to be similar to other forms of trace evidence (Bull et al. 2006). In general, there is an initial exponential decrease in original trace evidence with the highest proportion remaining after 4 h to be 18%. This is followed by a transient increase and then a slow decrease of trace evidence over time.

The mechanism suggested by Pounds and Smalldon (1975a, b, c) described the process to be determined by the strength of binding of the soil particulates onto the surface. A strongly bound soil particle will be less susceptible to the force of nature

Fig. 16.5 The Health Sciences Authority headquarters at Outram Road, Singapore. By Phoebedechin—Own work, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=4851411

or human activity than a weakly bound particle. In the first few hours, weakly bound particles are easily brushed off, resulting in a steep decline in the original fiber proportion. The short-term increase can be explained by the re-introduction of the trace evidence that fell from another area of the object (e.g., shirt) to another. As time since contact increases, the remaining fibers are mostly strongly bound and are increasingly harder to remove (Pounds and Smalldon 1975a, b, c). Nevertheless, particles can still be retrieved even after 7 days.

Larger particles were proposed to be more inclined to decay as compared to smaller particles (Brocard and Peyrot 2004). Grain size distributions on the sole of footwear were uni-modal for intermediate sized particles and bimodal for extreme sized particles (<0.02 mm and >4.00 mm), making the assessment of the latter useful in determining time since contact.

A potential issue highlighted in Morgan et al. (2009) is that the longer the time since the initial contact, the more problematic the interpretation of the evidence will be. In soils collected on the soles of footwear, the subsequent movement will introduce soil contaminants from irrelevant locations, producing a complex mixture of samples that rarely retain layers following a chronological order (Fig. 16.5).

Running, which is to be expected of a suspect fleeing the crime scene, further exacerbates the mixing of layers. Therefore, forensic examiners and lab technicians in the Health Sciences Authority (HSA) should exercise caution when retrieving samples for further experiments.

16.2.5 Nature of Contact Surface

Bull et al. (2006) determined that the material type majorly affects the extent of transference and persistence, even more than the particulate type. Coarser materials with a more open matrix (e.g., wool) are more likely to promote the transfer of trace evidence as compared to smoother surfaces (e.g., wood) (Lepot et al. 2015; Pounds and Smalldon 1975a, b, c). Soil particles bind strongly and weakly to rough and smooth surfaces, respectively.

A coarse donor surface is less likely to transfer soil particles, but a coarse recipient surface is more efficient in receiving the particles. The opposite is true for smoother surfaces. Therefore, in a secondary transfer, the contact between a smooth donor surface and a rough recipient surface causes a higher proportion of soil particles transferred as the soil particles are more readily dislodged.

16.2.6 Amount of Force and Duration of Contact

Transfer of soil particles may not occur through direct contact alone. Some amount of force is needed to guarantee soil transference (McDermott 2009). An increase in force results in a more significant proportion of trace particles transferred. For example, colliding into another individual will result in a higher force that shakes off the bound soil particles which increases particle transfer, as compared to merely brushing by.

Likewise, more violent crimes will likely result in a larger amount of soil deposited on the clothes. A maximum pressure of 250 kg/m^2 is the threshold whereby increasing pressure did not result in an increase in transferred fiber, though such amount of pressure is unlikely to occur in an individual's daily activities (Kidd et al. 1981). Likewise, an increase in duration of contact causes a higher proportion of trace evidence transferred.

16.2.7 External Disturbances

Secondary transfer of soil occurs naturally in their daily activities. Activities that require more rigorous contact (i.e., washing clothes and taking public transport) increase the decay of trace evidence. Across all material types, the number of soil particles found remaining decreases drastically, though a small amount of soil particles continues to persist. As only a small amount of soil sample is required for analysis, soil as a form of trace evidence is still highly valuable (Uitdehaag et al. 2016).

16.3 Soil and Its Components

To the naked eye, soil looks nothing more than a mere bunch of mess with neither structure nor organization. The image that is often ingrained in people's minds when the word "soil" is being mentioned is something that is abundant yet seemingly has nothing much to it. However, with soil, there is actually more than meets the eye.

For one, the most important pharmaceuticals like antibiotics are derived from the microbes that are found in soil (Shamarez and Manvi 2010). Without antibiotics, many of the diseases that are commonly caused by bacteria can do devastating damages to the human population, effectively sending us back to the dark ages. Apart from humans, soil benefits plants, too. Plants grow best in various types of soil. Certain species grow better in more acidic soil, and others are healthier in more neutral soil. This is crucial in parts of the world where production of food is key and yet is not as blessed with good environmental conditions. Achieving the best crop yield with the least amount of resources used is one of the sustainable goals of these countries (Oshunsanya and Nwosu 2018).

With such areas of research that yielded results as mentioned, how did researchers actually know what to look for in the seemingly pile of chaos? Well, soil actually has structure to it and can be broken down into the various components to be analyzed. Components include pH, microbial communities, metals and ions, elemental composition, and texturing, just to name a few. There are papers published that indicate these parameters do have a link with each other, meaning that getting a certain set of data could possibly predict what lies inside that area of soil. Take the example of the studies done in an urban park in Manhattan and an urban ring road in Beijing (Reese et al. 2015; Yan et al. 2016). The urban park soil samples were found to be more acidic in nature, which could mean a greater microbial growth. The urban ring road soil samples were found to be more neutral in nature, which could mean a greater diversity of microbial species. Both were later confirmed to be in line with the hypotheses made.

16.4 Forensic Soil Science in National University of Singapore

The examples mentioned above are global in scale. Now, let us take a look at Singapore, which has a much smaller area. Singapore's land area hovers around 721.5 km^2, about 23 times smaller than that of Beijing's land area of 16,808 km^2. Yet, differences in the soil community were noted. Whether it is within a park or along a road, the composition shifts. To guide you along the whole process of obtaining the soil samples, till ending up with the data charts, real life works on soil analysis will be shared. These works were carried out by the Forensic Science Research Lab at the National University of Singapore, in collaboration with other labs that have expertise in the area of soil.

Fig. 16.6 Photo of site after digging was done to get soil samples. The five holes can be seen in this picture

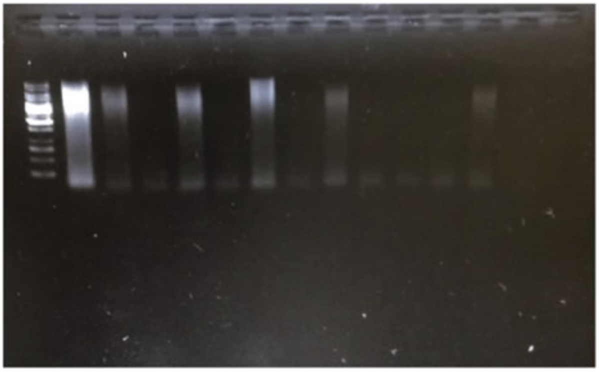

Fig. 16.7 Gel electrophoresis of some soil samples that were dug

First, a grid (1 m × 1 m) was used to locate and identify the area to be dug. Soil samples were dug from the 4 corners of the grid, as well as 1 more from the center of the grid (Fig. 16.6). During excavation, cores of different colors were already noted within the grid, highlighting the possible presence of various types of metals or elements.

The samples were then brought back to the lab and processed accordingly, either by air-drying or freeze-drying. One method of classifying soil by its color can be done through the use of the Munsell color system.

Back at the lab, soil is tested for its microbial and non-microbial aspects. To get a preliminary understanding of the soil microbial community, DNA had to be extracted from the soil samples. Here, we could tell the amount of DNA in the soil, which could translate to the amount of microbes in the soil. Below is a gel electrophoresis picture of some of the samples that were dug (Fig. 16.7).

Table 16.1 quantifies the actual amount of DNA within the sample. As shown, a brighter band corresponds to a higher amount of DNA that can be found in the soil, indicating a more abundant microbial community. Subsequently, the soil samples

Table 16.1 Quantification of the actual DNA amount in each sample

Lane	Quantity
A	35.8 ng/μL
B	10.7 ng/μL
C	Low
D	19.3 ng/μL
E	3.48 ng/μL
F	31.8 ng/μL
G	Low
H	12.3 ng/μL
I	Low
J	2.50 ng/μL
K	5.36 ng/μL
L	10.7 ng/μL

The letters correspond to the lanes shown in Fig. 16.4

Fig. 16.8 SEX-EDX machine in National University of Singapore

were sent for sequencing, to finally determine the microbial species that the soil samples contains.

In terms of non-microbial aspect, elemental composition analysis could be performed. One such method that has been used by the NUS Forensic Science lab to study the elemental composition of soil is through the use of SEM-EDX (Scanning Electron Microscopy with Energy Dispersive X-ray) (Fig. 16.8).

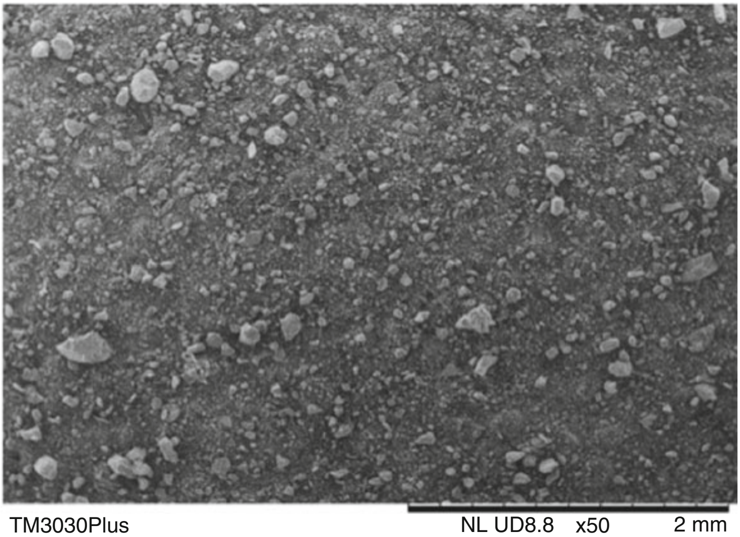

Fig. 16.9 SEX-EDX machine SE mode

The SEM-EDX machine enables you to take pictures of the soil sample using 2 modes, SE (secondary electrons) mode, which gives you a 3D-image of the soil samples, and BSE (back scatter electrons) mode, which shows the distribution of heavier and lighter elements.

Quantification and distribution of the elements within the soil samples are of interest to those in the field of pedology. Such information is useful to assist in the soil–microbial relationship research, as microbes do rely on elements in the soil to support their basic metabolic functions. The information also serves to give an indicator about the potential richness of the soil (Figs. 16.9 and 16.10).

The images above were taken from one of the soil samples that were obtained by the lab. From the pictures, there is a distinguishable difference between the 3D-image from the SE mode, and the distribution of heavier and lighter elements from the BSE mode (Figs. 16.11 and 16.12).

After seeing the data in Fig. 16.9, the surprising element that might have caught your eye might be that of titanium. In fact, there exists a variety of rare elements and metals that can be found in soil which you might not expect, but definitely not as abundant as the more common types like iron (Taylor 2006).

With characteristics that differ from each other, soil is able to present a rather unique profile, depending on which part of the country it is found in. In Singapore, soil is being utilized as part of forensic investigations. The uniqueness of the profile of soil has enabled investigators to narrow down their search to an area where the crime might have occurred. Drawing some similarities from the CSI crime shows, it is indeed as exciting and adrenaline pumping when the work to link soil to its location is a race against time as well.

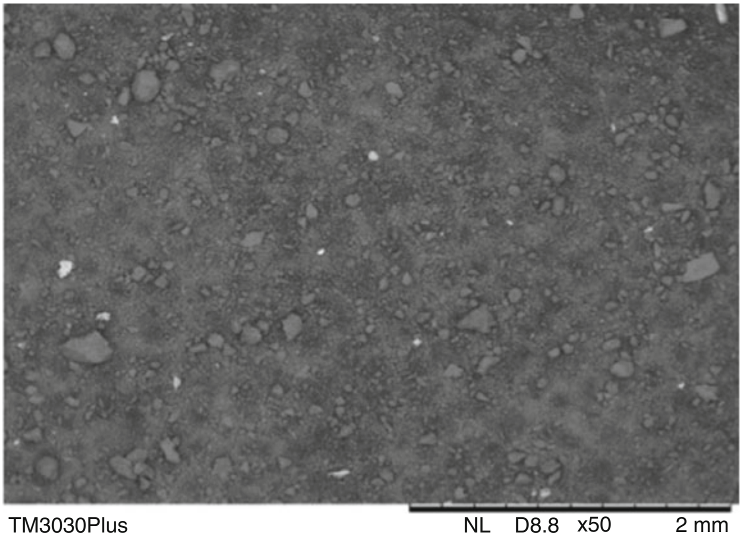

Fig. 16.10 SEM-EDX machine BSE mode

Fig. 16.11 Elemental composition from the soil sample displayed in Figs. 16.7 and 16.8

Spectrum: Point

Element	AN	Series	Net	norm. C [wt.%]	Atom. C [at.%]	Error [%]
Oxygen	8	K-series	64613	55.76	70.17	4.9
Silicon	14	K-series	63682	21.30	15.27	0.7
Aluminium	13	K-series	52049	16.23	12.11	0.6
Iron	26	K-series	5961	6.24	2.25	0.2
Titanium	22	K-series	814	0.47	0.20	0.0
			Total:	100.00	100.00	

16.5 Case Studies in Singapore

Now that we have covered what soil is about and how it is studied, we will elaborate on two cases in Singapore where soil was used as trace evidence to help solve the crime.

16.5.1 Kallang Body Parts Case: PP v. Leong Siew Chor

16.5.1.1 Background

Liu Hong Mei, a 22-year-old Chinese national working in Singapore, had an affair with Leong Siew Chor in mid-2004 (Lum 2006; Tay 2011). On 13 June 2005, the

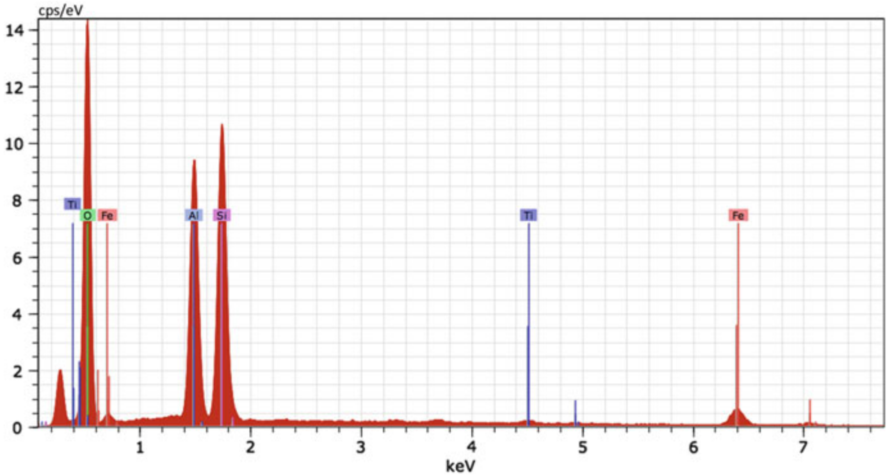

Fig. 16.12 Graph showing counts per second of each element

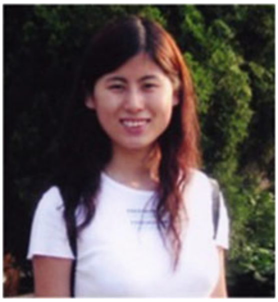

Fig. 16.13 Ms Liu Hong Mei from China was 22 years of age, who worked under Leong as a production operator. Adapted from Singapore Police Force, 2016. Retrieved from https://www.straitstimes.com/singapore/courts-crime/guilty-as-charged-leong-siew-chor-killed

couple checked into Hotel 81 Gold in Geylang, and while Liu Hong Mei was pre-occupied in the shower, Leong Siew Chor stole her automatic teller machine (ATM) card. On the very same day, Leong attempted to withdraw money from Liu's bank account at various ATMs (Tanjong Katong Complex, Joo Chiat Complex, Haig Road, and Beach Road). He went to Haig Road's ATM again on 14 June 2005, and out of these attempts, three were successful, leading to over $2000 being withdrawn (Tay 2011; Leong Siew Chor v. PP [2006] SGCA 38) (Fig. 16.13).

On 14 June 2005, Liu realized her ATM card was missing and discovered unauthorized withdrawals made from her account. She contacted Leong and lodged a police report about it. The next morning, Leong requested Liu to visit him and strangled Liu to death with a towel for fear that she will find out that he was the

Fig. 16.14 Leong Siew Chor, who killed his lover and chopped her body into seven parts. Adapted from Singapore Police Force, 2016. Retrieved from https://www.straitstimes.com/singapore/courts-crime/guilty-as-charged-leong-siew-chor-killed-lover-and-cut-up-her-body

perpetrator. He subsequently took her body to kitchen and dismembered her. He then wrapped the various body parts with newspaper and placed them in either plastic bags or cardboard boxes, which were disposed of at various locations via various modes of transportation (Tay 2011; Leong Siew Chor v. PP [2006] SGCA 38) (Fig. 16.14).

Leong cycled to Ubi Road, where he disposed her clothes, shoes, and feet into separate rubbish bins. He disposed her lower legs and head, and lower and upper torso into Singapore River and Kallang River, respectively. Liu's handbag and its contents were dumped into the rubbish bin outside Ang Mo Kio MRT station (Fong 2006; Tay 2011).

On 17 June 2005, the body parts which were dumped into Kallang River surfaced and drifted to the bank, where the lower torso were then discovered by a cleaner. The police then discovered the upper torso later that day. The head and legs in bags from Singapore River were recovered en route to Tuas incineration plant. Liu's feet, clothes, and belongings were never found (Tay 2011).

16.5.1.2 Investigative Process

Leong Siew Chor was arrested on 17 June 2005 and charged with murder the following day. Due to forensic investigations conducted by the police, Liu's funeral was delayed. It was a complicated and difficult process due to the decomposed nature of the victim's body parts (Tay 2011). Leong had his trial in May 2006.

Trace evidence (e.g., soil), as well as DNA evidence, were admitted into court. They conclusively linked Leong Siew Chor to the murder of Liu Hong Mei. Leong was then convicted of murder and sentenced to death by Justice Tay Yong Kwang on 19 May 2006 (The Straits Times 2016).

Soil particles were recovered from Leong Siew Chor's sandal. Upon further inspection, the origin of the soil was traced back to that from Kallang River Bank. There were bougainvillea thorns, and small seashells found in the sandy soil particles, consistent with vegetation and soil at the Kallang River Bank (Singapore Academy of Law 2009) (Fig. 16.15).

Fig. 16.15 The police found the murdered woman's head. Photo adapted from the Straits Times, Singapore, 2016. Retrieved from https://www.straitstimes.com/singapore/courts-crime-guilty-as-charged-leong-siew-chor-killed-lover-and-cut-up-her-body-to-cover

16.5.1.3 Importance of Soil Evidence

Soil recovered from Leong's sandals provided undisputed evidence that Leong was indeed at the site of disposal. This shows that soil evidence indeed can play an important role in linking suspects to the location of interest, by looking at the various properties or materials trapped in the soil particles. The sandy soil, bougainvillea thorns and small seashells found could provide enough clues that it belongs to Kallang River Bank, and hence investigators can form linkage between the suspect and the location at which the body was disposed of.

16.5.2 Rape Case: PP v. Lim Choon Beng

16.5.2.1 Background

On the morning of 9 February 2013, Lim Choon Beng raped and sexually assaulted a 24-year-old woman thrice at three different locations along Martin Road, all in a span of 20 min (Lum 2016).

The victim, a Chinese national, had been working in Singapore as a performing artiste (Lum 2016). She was walking home in the early morning on 9 February 2013 from Havelock Road alone. In order to reach her house, she would have to cross a bridge at Saiboo Street, walk along Martin Road, and then turn onto River Valley Close. At this time, Lim was near Saiboo Street and had been drinking at a bar. As the victim was walking along Martin Road, she noticed the accused crossing the road and appeared to be approaching her. The accused engaged the victim when she slowed her pace so that he could walk ahead of her (PP v. Lim Choon Beng [2016]

Fig. 16.16 Lim Choon Beng raped the victim three times in 20 min. Photo from Singapore Police Force, 2016. Retrieved from https://www.straitstimes.com/singapore/courts-crime/man-who-raped-woman-3-times-gets-close-to-17-years-jail-and-22-strokes

SGHC 169). Lim then sexually assaulted and raped the victim thrice at three different locations along Martin Road (Fig. 16.16).

The victim managed to escape as Lim stood up to put on his pants. She stopped a car and requested the female driver to drive her to the police; however, the female driver could not locate the police station. Hence, the victim phoned a friend and her friend called the police on behalf of the victim. The victim was then instructed to return to the area of River Valley Close where the last sexual intercourse happened. She found police officers with the accused and identified the accused to the police as the perpetrator (PP v. Lim Choon Beng [2016] SGHC 169).

16.5.2.2 Investigative Process

Upon investigation, the woman's torn panties were found among the vegetation at the first spot and the zipper of her bloodstained dress was dislodged from the right side. Soil was found on a few areas of the victim's dress and her shawl. There were also soil-like stains that were found on the lower half of the sleeves of the accused as well as the front right region of his shirt. Similarly, soil-like stains were found on the front right and left knee regions of the jeans of the accused (PP v. Lim Choon Beng [2016] SGHC 169).

Lim Choon Beng was subsequently found guilty and was sentenced to 17 years' jail and 22 strokes of cane by Judicial Commissioner Foo Chee Kock (Chelvan 2016).

16.5.2.3 Importance of Soil Evidence

Soil found on the victim's dress and shawl can link the victim back to the crime scene, which were the various locations she was raped and sexually assaulted. In addition, the soil-like stains on the accused clothes can link the accused to the crime scene and establish his alibi. Similarly, the location of the soil-like stains on clothes of the accused can show how the accused got his clothes stained, and in what position could he have been in when sexually assaulting and raping the victim.

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