



## Soil examination for a forensic trace evidence laboratory—Part 1: Spectroscopic techniques



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### ABSTRACT

In the past, forensic soil examination was a routine aspect of trace evidence examination in forensic science. However, in Australia, the apparent need for soil examinations has diminished and with it the capability of forensic science laboratories to carry out soil examination has been eroded. In recent years, due to soil examinations contributing to some high profile investigations, interest in soil examinations has been renewed. Routine soil examinations conducted in a forensic science laboratory by trace evidence scientists can be facilitated if the examinations are conducted using the instrumentation routinely used by these examiners. Spectroscopic techniques such as visible microspectrophotometry (MSP) and Attenuated Total Reflectance (ATR) Fourier Transform Infrared spectroscopy (FTIR) are routinely used by trace evidence analysts for the colour and compositional analysis, respectively, of forensic items, including paints, fibres, inks and toners, tapes, adhesives and other miscellaneous examinations. This article presents an examination of the feasibility of using MSP and ATR-FTIR as a first step in the forensic comparison of soils with particular reference to Australian soil samples. This initial study demonstrates MSP and ATR-FTIR can effectively be used as a screening test for the discrimination of “forensic-sized” soil samples prior to submission for more detailed analyses by a soil expert.

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### 1. Introduction

Soil may be encountered in many different situations in forensic science, for example: clothing and shoes from a suspect alleged to have stepped in a garden bed prior to entering the victim's house; a dirty shovel recovered from a suspect's house alleged to have been used to bury materials; and soil from a suspect's vehicle that may have been at a burial site [1–3]. Ultimately, soil can be used as evidence to exclude a suspect, a victim or an object with a particular scene, assist with identifying the scene of a crime, or contribute to forensic intelligence.

The forensic analysis of soils developed into a trace evidence sub-discipline that was commonly carried out in forensic science laboratories; however, in Australia and elsewhere, interest in the examination of traditional trace evidence waned from the late 1980s and especially through 1990s. It can be

argued that this reduction in capability has paralleled the introduction of DNA analysis and has been a general trend across trace evidence [3,4]. Whatever the relationship, there can be no argument that the last three decades have seen specialist soil examinations and soil examiners disappear from the vast majority of mainstream operational forensic science laboratories in Australia.

More recently, however, there has been renewed interest in the use of soil examinations, with soil examinations contributing to the investigation of serious crime around the world [5–11]. Unfortunately, in general, the trace evidence laboratories in Australia no longer have the skill set and knowledge for the analysis of soils. Hence, in the main at the moment, soil examinations in Australia are performed by experienced soil scientists from outside the government forensic science sector. These scientists may be excellent geoscientists, but are not primarily concerned with specific requirements of inter-disciplinary analyses for court purposes, including an awareness of biological material, fingerprints and other relevant forms of trace evidence. Further, the laboratories are not usually accredited for forensic science testing [12].

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One of the major challenges facing the scientists working in a non-forensic science facility is translating methods and approaches developed for examining and analysing samples they typically encounter to dealing with the types of specimens typically encountered in forensic science work. One aspect of the latter is the often very limited specimen size encountered in forensic work; however, it is more complex than simply limitations imposed by specimen size. Soil scientists will typically be able to select their own samples and work under relatively controlled circumstances and environments. Typically the latter is far from the situation facing the forensic science examiner who will usually be faced with a soil specimen that may not accurately represent material at the crime scene due to issues of transfer and persistence [13].

The purpose of this paper is to examine whether it is feasible to apply typical forensic techniques used in the analysis of other forms of trace evidence for the differentiation or screening of soil prior to its further examination, if warranted, by specialists. While this particular partnership approach is being developed in response to the situation in Australia, it might be applicable to other places in the world where forensic soil examination has suffered a decline. In this paper, we report on an investigation into the application of visible microspectrophotometry (MSP) and Attenuated Total Reflectance (ATR) Fourier Transform Infrared spectroscopy (FTIR) for differentiation of soil samples.

The use of Munsell colour examinations is a well-established pedological technique for assessing colour [14]. This relies on the observer's subjective visual comparison of the soil sample against the Munsell Soil Colour Chart to arrive at a colour formula. Variations in visual colour assessments between different observers can be of significant magnitude and result in different Munsell colour assignments [15]. Munsell Soil Colour Charts may have been printed at different times or may have faded [16], again potentially resulting in different Munsell colour formulae. Additionally, the moisture content of the soil and the lighting conditions under which the examination is conducted affect the accuracy and precision of Munsell colour assessment [17]. In a forensic science context, the very small questioned specimen usually present in a case can make it difficult for comparisons against large amounts of reference soil. Trace evidence examiners regularly use visible MSP for the objective measurement of colour for typical forensic science items – from single fibres, to individual paint layers, and inks and toners on documents [18].

Soils are an extremely complex matrix composed of both organic and inorganic materials. The majority of well-established pedological techniques used by geologists for the examination and discrimination of soils involve the analysis and identification of the inorganic component, i.e. the soil mineralogy [19]. IR spectra can provide information on both the inorganic and the organic content of a soil sample. Trace evidence examiners regularly use ATR-FTIR for the comparison of typical forensic science items – including paints, rubber, tapes, adhesives and other miscellaneous materials. ATR-FTIR is particularly useful to the forensic scientist as the examination requires little or no sample preparation, only a very small sample is required, and the non-destructive nature of the analysis means that the sample is still available for further testing.

This paper discusses the merits of a MSP procedure that can be used for the objective colour analysis of soil specimen as well as an ATR-FTIR procedure for the comparison of the bulk organic and inorganic components of soil specimens, with particular reference to Australian soils.

## 2. Materials and methods

The soil specimens used in this study consisted of specimens collected from six sites around the Canberra area and specimens

previously collected by the Commonwealth Scientific and Industrial Research Organisation (CSIRO) and stored as part of the CSIRO National Soil Archive. At each Canberra area site a five metre by five metre square grid was established with 9 locations at regular intervals within the grid determined as collection positions. At each collection position, the surface debris and leaf litter was removed then the surface soil (0–5 cm depth) and sub-surface soil (5–10 cm depth) collected. As the scope of this research did not include an assessment of the homogeneity of soil across a soil site, specimens were combined for each collection position within the grid, resulting in two soil specimens per Canberra area site. In addition, 17 soil specimens were selected from the CSIRO National Soil Archive, covering Queensland, New South Wales, South Australia and the Northern Territory. The collection method for the CSIRO samples varied, however all soil samples are surface soil (0–5 cm depth). A total of 29 soil specimens were examined in this study.

The soil specimens were oven dried for 24–48 h at 47 °C then lightly crushed, using a mortar and pestle to break up any agglomerates, and dry sieved [20]. The <38 µm fraction was collected for analysis. No attempt was made to remove any organic content. Refer to Fig. 1 for a representation of Australia and the soil collection sites.

### 2.1. MSP method

For analysis using the MSP, each soil sample was lightly pressed into a Diffuse Reflectance Infrared Fourier Transform Spectroscopy (DRIFTS) sample holder, ensuring a flat examination surface for presentation to the MSP. The DRIFTS sample holders used in this study and filled in this manner held approximately 6 mg of soil.

Each soil specimen was analysed in the reflectance mode using a Craic QDI 2010 microspectrophotometer fitted with a xenon arc lamp and a 10× dark-field objective. Each soil specimen was analysed in triplicate. A minimum of 5 spectra were collected for each triplicate. Spectra were collected in the 380–770 nm range. The spectra were converted to L\*a\*b\* colour co-ordinates using Craic MSP (version 5.0.1) software and the following parameters: CIE 1964 Standard Observer (10° Observer) and D65 as the illuminant, corresponding to average daylight at a temperature of 6504 K. The L\*a\*b\* colour co-ordinates of the 5 spectra for each triplicate were then averaged.

The averaged L\*a\*b\* colour co-ordinates for each soil triplicate were entered into Minitab16 (version 2.2) statistical software to construct a matrix plot of the L\*a\*b\* colour co-ordinates.



Fig. 1. Map of Australia [21] with approximate locations of soil sites used in this study.

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