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Profiling the decomposition odour at the grave surface before and after probing

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ABSTRACT

Human remains detection (HRD) dogs are recognised as a valuable and non-invasive search method for remains concealed in many different environments, including clandestine graves. However, the search for buried remains can be a challenging task as minimal odour may be available at the grave surface for detection by the dogs. Handlers often use a soil probe during these searches in an attempt to increase the amount of odour available for detection, but soil probing is considered an invasive search technique. The aim of this study was to determine whether the soil probe assists with increasing the abundance of volatile organic compounds (VOCs) available at the grave surface. A proof-of-concept method was developed using porcine remains to collect VOCs within the grave without disturbing the burial environment, and to compare their abundance at the grave surface before and after probing. Detection and identification of the VOC profiles required the use of comprehensive two-dimensional gas chromatography–time-of-flight mass spectrometry (GC × GC–TOFMS) due to its superior sensitivity and selectivity for decomposition odour profiling. The abundance of decomposition VOCs was consistently higher within the grave environment compared to the grave surface, except when the grave surface had been disturbed, confirming the reduced availability of odour at the grave surface. Although probing appeared to increase the abundance of VOCs at the grave surface on many of the sampling days, there were no clear trends identified across the study and no direct relationships with the environmental variables measured. Typically, the decomposition VOCs that were most prevalent in the grave soil were the same VOCs detected at the grave surface, whereas the trace VOCs detected in these environments varied throughout the post-burial period. This study highlighted that probing the soil can assist with releasing decomposition VOCs but is likely correlated to environmental and burial variables which require further study. The use of a soil probe to assist HRD dogs should not be disregarded but should only follow the use of non-invasive methods if deemed appropriate.

1. Introduction

Forensic investigations involving missing persons or victims of homicide often require the detection of remains that have been either naturally concealed by environmental weathering, or intentionally concealed by burial in a shallow grave. Search and recovery efforts for human remains are most effective when using a multidisciplinary approach and a wide variety of search techniques [1]. The nature and scale of a search plan are often dependent on the terrain, accessibility of the search area and availability of resources. For buried remains, additional variables including the time since burial, burial depth and soil type may need to be considered [2]. Regardless of the environment, search techniques must be appropriately sequenced in order to preserve the integrity of an investigation and minimise potential damage to remains. Non-invasive methods commonly used for locating human remains include ground searches, photographic techniques, remote sensing, geophysical methods and the use of human remains detection (HRD) dogs [1,3,4].

HRD dogs are widely recognised as a useful search tool in forensic investigations. The training conducted for HRD dogs is highly specialised. The dogs are conditioned to alert to the odour released by decomposing human remains, thereby locating remains in large search areas. The process of human decomposition and degradation of soft tissue results in the production of a large number of volatile organic compounds (VOCs) that are believed to comprise a significant proportion of the odour profile which is released [5–9]. However, it is not yet known whether it is the presence of several specific compounds or the entire VOC

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profile that elicits a positive alert from HRD dogs. For this reason, recent studies have aimed to characterise the decomposition odour profile of human and analogue remains at various stages of decomposition, to gain a greater understanding of the specific VOCs that comprise decomposition odour and their availability for canine detection [5,6,10–16].

The ability of HRD dogs to detect buried remains is largely dependent on the extent of the decomposition odour which is released at the soil surface [4]. When a grave is too deep or the soil type lacks permeability, the VOCs may not penetrate to the surface [4]. This makes the search for remains that have been concealed via burial a challenging and time-consuming process [5]. A series of longitudinal in situ studies by Vass and co-authors from 2004 to 2008 represents the first research aimed at investigating the decomposition odour profile produced by buried remains [14,17]. A decomposition odour database was established and chemical trends were observed from above, below and at the surface of four graves containing buried human remains. Over the 4-year period, 478 VOCs were identified in eight different chemical classes. However, only 30 VOCs were detected at the soil surface, 24 of which showed concentration peaks within the first year. The fact that only a small portion of decomposition VOCs was detectable at the soil/air interface highlights the challenging conditions that exist for HRD dogs in their search for buried remains.

In order to aid the dog's search, it is common practice for the handler to vent a suspected burial site using a soil probe in an attempt to increase the decomposition VOCs reaching the surface [18]. The soil probe is a T-shaped rod which is systematically inserted into the soil surrounding a suspected gravesite to find areas of disturbance due to differences in soil compaction [18,19]. Once probing of a suspected area is completed, the soil is vented for 30 min to allow for scent to permeate to the surface; the dogs can then be guided over the probed area [18].

The invasive nature of the soil probe is, however, a disadvantage of its use. Post-mortem damage to bone or soft tissue may occur when inserting the probe into the ground above a suspected burial site of an unknown depth, leading to challenges in post-mortem examination and interpretation [4]. The efficiency of the probing method is also significantly reduced when used to search large areas. Despite these limitations, the soil probe also displays many advantages as a complementary technique, being adaptable to most terrains and particularly useful when used in conjunction with other search techniques. Soil probes require little to no maintenance, are easily transported and offer an effective and rapid search technique when conducted by an experienced operator. The soil probe has been reported as a practical detection tool in both contemporary and historical burial sites [19].

While it is common practice for handlers to probe the ground of a suspected burial with the intent of releasing odour towards the soil surface, an evaluation of the usefulness of the soil probe for this purpose has not yet been conducted. The aim of this study was to develop a proof-of-concept method for detecting VOCs within a grave site and at the grave surface before and after probing. In order to determine whether the use of a soil probe enhances the type and abundance of VOCs detected at the grave surface, comprehensive two-dimensional gas chromatography–time-of-flight mass spectrometry (GC × GC–TOFMS) was used as it provides many advantages over traditional GC-MS, including enhanced sensitivity, selectivity, and peak capacity [20,21].

2. Materials and method

2.1. Field experiments

The study used domestic pig (*Sus scrofa domesticus* L.) carcasses weighing between 60–70 kg as analogues for human decomposition. The study was conducted in an open eucalypt woodland in Western Sydney, Australia. The soils in the area consist of sandy clay loam topsoil underlain by a highly weathered bedrock (saprolite) layer forming on shale/siltstone/sandstone bedrock. The topsoil at the study location is mostly acidic and ranges between pH 5.5 and 6.5 throughout the year.

The study was carried out longitudinally over a period of 8 months (January–September 2014). Four graves were prepared on the same day and to the same approximate depth (60–70 cm): two experimental graves containing pig carcasses (experimental graves 1 and 2) and two control graves with no carcasses (control graves 1 and 2). Carcasses were buried approximately 3 h after death. Control graves were established approximately 30 m from the experimental graves to monitor the natural VOC profiles of the surrounding soil and vegetation while avoiding cross contamination.

Temperature data loggers (HOBO U23 Pro v2, OneTemp, Adelaide, SA, Australia) were used to determine grave temperatures at the middle and base of the graves. Weather conditions at the field site were monitored using a Hobo Weather Station equipped with a HOBO U30 No Remote Communication data logger (OneTemp) and included hourly measurements of ambient temperature (°C), rainfall (mm), relative humidity (%), solar radiation (W/m^2), wind speed (m/s), gust speed (m/s), and wind direction (ø).

2.2. VOC sample collection

VOC sampling was conducted every 2 weeks for the first 4 months following burial and then monthly during the final 4 months of the study. Three VOC samples were collected from each grave on each sampling day: (1) the decomposition VOCs within the grave known as the 'soil gas'; (2) the decomposition VOCs at the surface of the grave before probing; and (3) the decomposition VOCs at the surface of the grave after probing. The VOCs collected at the surface of the grave were referred to as the 'grave headspace' before and after probing.

The soil gas within the grave was monitored by placing a 30 cm VOC-Mole^{TM} soil probe (Markes International Ltd., Llantrisant, Wales, UK) permanently off-centre in each grave. While we have previously proven the capability of the VOC-Mole^{TM} soil probe for the collection of VOCs in the soil beneath bodies deposited on the soil surface [6,20], this represents a new method for sampling soil gas in situ in a burial environment. This method allowed comparison of the natural VOCs within the control graves with the additional VOCs produced by the decomposition process in the experimental graves. It also provided a reference VOC profile throughout the decomposition period that could be compared to the VOCs detected at the grave surface. Pumped sampling was performed (100 mL/min for 15 min) from each probe onto a Tenax TA/Carbograph 5TD dual sorbent tube (Markes International Ltd.) connected to the exterior side of the probe cap using an ACTI-VOC low flow sampling pump (Markes International Ltd.).

A stainless steel hood was then placed over each grave prior to probing to allow the headspace to accumulate for a period of 15 min, thus preventing wind or rain dispersal of the VOCs during this time. Sorbent tubes were connected to the hood via a Swagelok bulkhead connector and the grave headspace was drawn onto the tube at a rate of 100 mL/min for 15 min using the sampling pump. Once the grave headspace samples were collected, the gravesites were probed using a 1.22 m T-bar soil probe (AMS Sampling Equipment, Australia). Five probe holes were made in each of the graves as illustrated in Fig. 1. The probe was pushed into the soil by applying bodyweight pressure and inserted into the soil approximately 40 cm to ensure no contact with the remains. The soil probe was thoroughly cleaned with acetone prior to probing each of the graves in order to prevent the transfer of odour.