Blood, guts, gore and soil: decomposition processes in graves and forensic taphonomic applications

Mark Tibbett[A]

[A]Centre for Land Rehabilitation, School of Earth and Environment, Faculty of Natural and Agricultural Sciences, University of Western Australia, Australia, Email Mark.Tibbett@uwa.edu.au

Abstract
Forensic Taphonomy aims to provide information relevant to the courts in cases where cadavers have been allowed to decompose. Here I consider the cadaver's effects on the burial environment when decomposition occurs on the soil surface or belowground. Significant advances have been made in recent years that have allowed a better understanding of cadaver decomposition, its effect on the burial environment and estimate of post-mortem interval; and these are reviewed in the context of soil-based information. I will propose how established techniques in soil science can be revised for direct applications in forensic taphonomic research that will allow rapid advances in an otherwise understudied field of applied soil science.

Key Words
Cadaver, decomposition, forensic, taphonomy, gravesoil.

Introduction

While the terrestrial environment has been much studied as a decomposition environment for materials of little forensic value such as leaf litter or dead roots (Cadisch and Giller 1997) there is clearly a need for experimental forensic taphonomy to provide rigorously tested information to practitioners and the courts to better understand gravesoils. However, forensic taphonomy must deal with the problem that it is difficult to acquire human cadavers for experimental use. Also, it is impossible to replicate human cadavers. Therefore, it is necessary to conduct field and laboratory based research using human cadaver analogues while continuing to use information from human cadaver decomposition studies and case studies.

Experimental studies of the decomposition of human cadavers under controlled conditions have rarely been carried out. Field studies, occasionally using human bodies (Rodriguez and Bass 1983; Rodriguez and Bass 1985), but more commonly animal surrogates, have been undertaken (Carter *et al.* 2008; Forbes *et al.* 2005; Micozzi 1986; Payne 1965; Payne *et al.* 1968; Turner and Wiltshire 1999). However, knowledge of the decomposition processes and the influence of the environment and edaphic parameters are limited because the primary sources of information are case studies and empirical evidence (Mant 1950; Morovic-Budak 1965; Motter 1898; Spennemann and Franke 1995). As a consequence, edaphic parameters were recognized as having little influence (Mant 1950; Mant 1987; Morovic-Budak 1965) on cadaver decomposition until the early 21st century (Carter *and* Tibbett 2008; Fiedler and Graw 2003; Forbes *et al.* 2005; Tibbett and Carter 2008). Until recently there has been almost no fundamental understanding of the processes of cadaver decomposition in soils based on contrived, replicated and properly controlled laboratory and field experiments (Tibbett *and* Carter 2009); which has made the application of an experimental soils-based approach all the more important.

A soils-based approach and it benefits to forensic taphonomy

Gravesoil is a complex and dynamic system of interdependent chemical, physical and biological processes that influence, and are influenced by, the inclusion of a body and its subsequent decomposition. These can vary by the type of soil (Fitzpatrick 2008) and have a range of eclectic physical, chemical and biological characteristics (Dawson *et al.* 2008). Examples of some basic characteristics of the burial environment that might affect the rate of cadaver decomposition include

- physical texture – whether the soil is sandy, silty or clayey can profoundly affect the rate of decomposition by limiting the movement of gasses and water to and from the site of biodegradation and O_2 demand and waste gas generation (i.e. the cadaver);
- chemistry – the acidity, alkalinity, nutrients and level of contamination of a soil may affect decomposition rates profoundly;

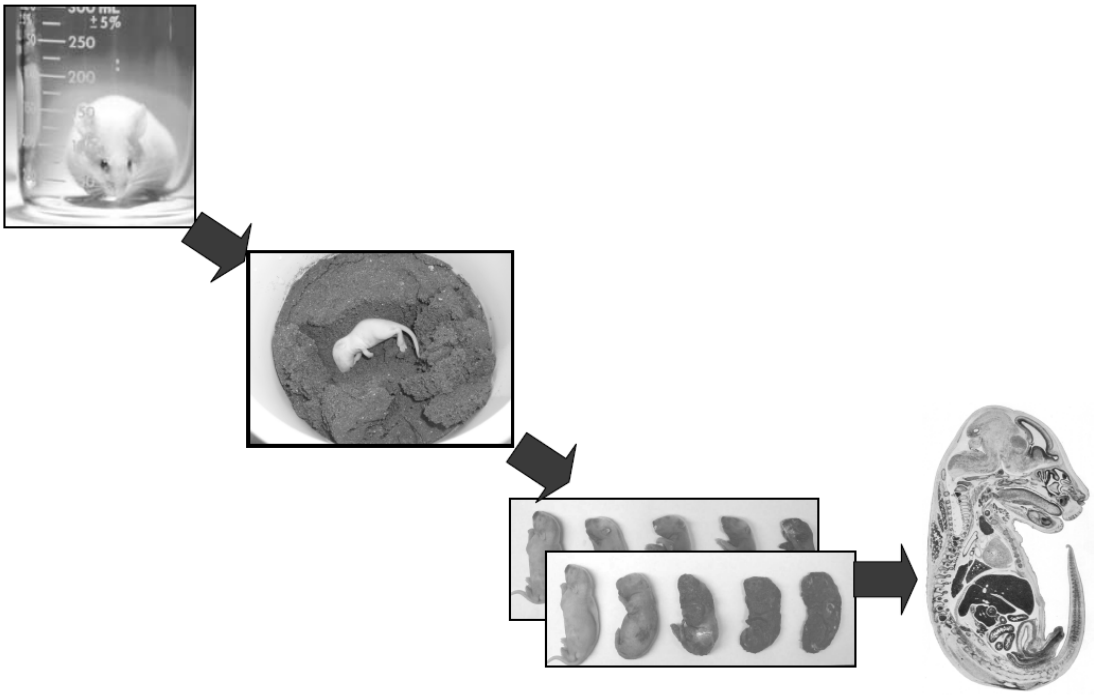

Figure 1. Idealised model for contrived soils-based studies in forensic taphonomy developed from Tibbett *et al.* (2004).

- biological activity – a soil with an active faunal population may have the capacity to decompose cadaveric tissue more quickly (Fiedler and Graw 2003) and soils exposed to cadavers (or potentially simply fertilisation with NH_4^+) previously, may have a community of bacteria and fungi adapted to cadaver decomposition (Carter and Tibbett 2008).

A more detailed understanding of gravesoil processes will likely contribute to forensic science in three primary areas: improved estimates of postmortem interval, postburial interval, and enhanced methods to locate clandestine graves and gravesoils.

Estimation of postmortem interval

An accurate estimation of postmortem interval (PMI) is one cardinal objective central to any medicolegal investigation of death, equal to victim identification and cause of death. Determination of the PMI can direct or re-orientate an investigation by serving to validate or reject an alibi or elucidate the perimortem activities of a victim. Pathology, anthropology and entomology, from oldest to recent, have developed criteria to enhance the estimation of PMI. Traditionally, in early postmortem time the pathologist best ascertained the PMI using the soft tissue indicator of rigor mortis (chemical change to muscle tissue that causes stiffening) , livor mortis (postmortem lividity or hypostasis) and algor mortis (the reduction in body temperature following death) (DiMaio and Dana 2006). As the interval lengthens to include the visual cues of numerous gross morphological attributes of decomposition (i.e., bloating, discoloration, etc.) anthropology has become increasingly astute at PMI estimation by temperature correlation (Megyesi *et al.* 2005). Most successful in estimation of the PMI, overlapping pathology and anthropology, is entomology using the developmental biology of blowflies (Higley and Haskell 2001). Blowfly larvae are at their greatest forensic value up until Advanced Decay (see Payne 1965), which can occur as soon as 10-14 days after death in warmer months. Forensic taphonomy lacks a precise method to estimate PMI once the fly larvae have begun to pupate. This time period that follows Advanced Decay, the extended PMI, is where gravesoil processes will likely have their greatest forensic impact.

Gravesoil research holds promise as it may provide a rapid and reliable technique to estimate PMI and help control for the increasing time error that accompanies extended decomposition stages (Tibbett and Carter 2008; Tibbett and Carter 2009). This is a particular problem in rural areas where bodies can go undetected for several months following death. At present, only the technique developed by Vass *et al.* (2002) can be used to estimate PMI directly following the migration fly larvae. Thus, a great need exists to develop rapid,

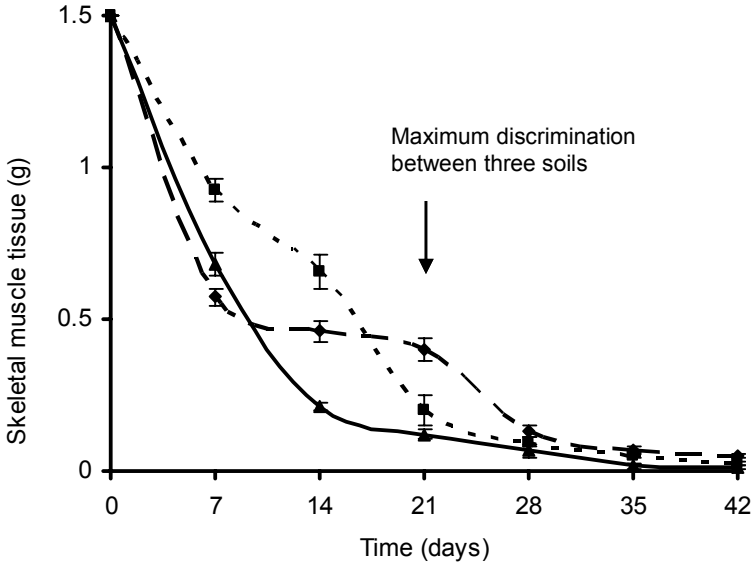

Figure 2. Decomposition of skeletal muscle tissue (1.5 g) as measured by mass loss for three soils over a six week laboratory incubation. Soils were: (i) acidic Podsol (solid line with triangles), (ii) neutral Cambisol (Brown Earth) (dotted line with squares), (iii) alkaline Rendzina (dashed line with diamonds). Note the contrasting decomposition for each soil type after two weeks incubation. Bars equal standard error of the mean, n = 6. Adapted from Haslam and Tibbett (2009).

reliable, and inexpensive techniques that use the biology and chemistry of gravesoil as a basis to estimate postmortem interval (Tibbett and Carter 2008; Tibbett and Carter 2009). For this, I propose the use of contrived soils-based studies in forensic taphonomy (Figure 1). From such studies we are now able to reliably quantify for the first time the effect of environmental and edaphic parameters on cadaver decomposition, and these include soil temperature, moisture, pH and the effect of freezing (Carter *et al.* 2006; Carter *et al.* 2008; Haslam and Tibbett 2009; Stokes *et al.* 2009)(e.g. Figure 2).

References

Cadisch G, Giller KE (1997) 'Driven by nature: Plant litter quality and decomposition'. (CAB International: Wallingford, UK).

Carter DO, Tibbett M (2008) Does repeated burial of skeletal muscle tissue (Ovis aries) in soil affect subsequent decomposition? *Applied Soil Ecology* **40,** 529-535.

Carter DO, Yellowlees D, Tibbett M (2008) Temperature affects microbial decomposition of cadavers (Rattus rattus) in contrasting soils. *Applied Soil Ecology* **40,** 129-137.

Dawson LA, Campbell CD, Hillier S, Brewer MJ (2008) Methods of characterising and fingerprinting soils for forensic application. In 'Soil Analysis in Forensic Taphonomy: Chemical and Biological Effects of Buried Human Remains', (Eds M Tibbett, DO Carter) pp. 271-315. (Taylor and Francis/CRC Press: London).

DiMaio VJM , Dana SE (2006) 'Handbook of Forensic Pathology'. (CRC Press: Boca Raton, FL, USA).

Fiedler S, Graw M (2003) Decomposition of buried corpses, with special reference to the formation of adipocere. *Naturwissenschaften* **90,** 291-300.

Fitzpatrick RW (2008) Nature, distribution and origin of soil materials in the forensic comparison of soils. In 'Soil Analysis in Forensic Taphonomy: Chemical and Biological Effects of Buried Human Remains'. (Eds M Tibbett, DO Carter) pp. 1-28. (CRC Press: Boca Raton, FL).

Forbes SL, Dent BB, Stuart BH (2005) The effect of soil type on adipocere formation. *Forensic Science International* **154,** 35-43.

Haslam T, Tibbett M (2009) Soils of contrasting pH affect the decomposition of buried mammalian (*Ovis aries*) skeletal muscle tissue. *Journal of Forensic Science* **54,** 900-904.

Higley LG, Haskell NH (2001) Insect development and forensic entomology. In 'Forensic Entomology: the Utility of Arthropods in Legal Investigations'. (Eds JJ Byrd, JL Castner) pp. 287-302.)CRC Press: Boca Raton, FL, USA).

Mant AK (1987) Knowledge acquired from post-war exhumations. In 'Death, Decay and Reconstruction: Approaches to Archaeology and Forensic Science'. (Eds A Boddington, AN Garland, RC Janaway) pp. 65-78. (Manchester University Press: Manchester).

Megyesi MS, Nawrocki SP, Haskell NH (2005) Using accumulated degree-days to estimate the postmortem interval from decomposed human remains. *Journal of Forensic Sciences* **50,** 618-626.

Micozzi MS (1986) Experimental study of postmortem change under field conditions: effects of freezing, thawing and mechanical injury. *Journal of Forensic Sciences* **31,** 953-961.

Morovic-Budak A (1965) Experiences in the process of putrefaction in corpses buried in earth. *Medicine Science and Law* **5,** 40-43.

Motter MG (1898) A contribution to the study of the fauna of the grave. a study of one hundred and fifty disinterments, with some additional experimental observations. *Journal of the New York Entomological Society* **6,** 201-231.

Payne JA (1965) A summer carrion study of the baby pig Sus scrofa Linnaeus. *Ecology* **46,** 592-602.

Payne JA, King EW, Beinhart G (1968) Arthropod succession and decomposition of buried pigs. *Nature* **219,** 1180-1181.

Rodriguez WC, Bass WM (1983) Insect activity and its relationship to decay rates of human cadavers in east Tennessee. *Journal of Forensic Sciences* **28,** 423-432.

Rodriguez WC, Bass WM (1985) Decomposition of buried bodies and methods that may aid in their location. *Journal of Forensic Sciences* **30,** 836-852.

Spennemann DHR, Franke B (1995) Decomposition of buried human bodies and associated death scene materials on coral atolls in the tropical Pacific. *Journal of Forensic Sciences* **40,** 356-367.

Stokes KL, Forbes SL, Tibbett M (2009) Does freezing skeletal muscle tissue affect its decomposition in soil? *Forensic Science International* **183,** 6-13.

Tibbett M, Carter DO (Eds) (2008) 'Soil Analysis in Forensic Taphonomy: Chemical and Biological Effects of Buried Human Remains'. (CRC Press: Boca Raton).

Tibbett M, Carter DO (2009) Research in forensic taphonomy: a soil-based perspective. In 'Criminal and Environmental Soil Forensics'. (Eds K Ritz, L Dawson, D Miller) pp. 317-331. (Springer: Netherlands).

Tibbett M, Carter DO, Haslam T, Major R, Haslam R (2004) A laboratory incubation method for determining the rate of soft tissue decomposition in soil. *Journal of Forensic Science* **49,** 560-565.

Turner BD, Wiltshire PEJ (1999) Experimental validation of forensic evidence: a study of the decomposition of buried pigs in a heavy clay soil. *Forensic Science International* **101,** 113-122.

Vass AA, Barshick S-A, Sega G, Caton J, Skeen JT, Love JC, Synstelien JA (2002) Decomposition chemistry of human remains: a new methodology for determining the postmortem interval. *Journal of Forensic Sciences* **47,** 542-553.