Forensic Science International 238 (2014) 142.e1–142.e10

Contents lists available at ScienceDirect

Forensic Science International

journal homepage: www.elsevier.com/locate/forsciint

Forensic Anthropology Population Data

Short-term effects of hydrated lime and quicklime on the decay of human remains using pig cadavers as human body analogues: Laboratory experiments

Eline M.J. Schotsmans [a,*], John Denton [b], Jonathan N. Fletcher [c], Robert C. Janaway [a], Andrew S. Wilson [a]

[a] Forensic & Archaeological Sciences, School of Life Sciences, University of Bradford, West Yorkshire BD7 1DP, United Kingdom
[b] Developmental Biomedicine Research Group, School of Biomedicine, The University of Manchester, Oxford Road, Manchester M13 9PT, United Kingdom
[c] Medical Sciences, School of Life Sciences, University of Bradford, West Yorkshire BD7 1DP, United Kingdom

ARTICLE INFO

Article history:
Received 26 August 2013
Received in revised form 6 November 2013
Accepted 30 December 2013
Available online 15 January 2014

Keywords:
Taphonomy
Lime
Desiccation
Histology
Microbiology
Time since death

ABSTRACT

Contradictions and misconceptions regarding the effect of lime on the decay of human remains have demonstrated the need for more research into the effect of different types of lime on cadaver decomposition. This study follows previous research by the authors who have investigated the effect of lime on the decomposition of human remains in burial environments. A further three pig carcasses (*Sus scrofa*), used as human body analogues, were observed and monitored for 78 days without lime, with hydrated lime ($Ca(OH)_2$) and with quicklime (CaO) in the taphonomy laboratory at the University of Bradford. The results showed that in the early stages of decay, the unlimed and hydrated lime cadavers follow a similar pattern of changes. In contrast, the application of quicklime instigated an initial acceleration of decay. Microbial investigation demonstrated that the presence of lime does not eliminate all aerobic bacteria. The experiment also suggested that lime functions as a sink, buffering the carbon dioxide evolution. This study complements the field observations. It has implications for the investigation of time since death of limed remains. Knowledge of the effects of lime on decomposition processes is of interest to forensic pathologists, archaeologists, humanitarian organisations and those concerned with disposal of animal carcasses or human remains in mass disasters.

1. Introduction

A perpetrator's intent towards concealment of evidence and the identity of a victim is often reflected in introduced chemicals. Several caustic substances have been reported in forensic cases such as acid solutions [1–4], concrete [5–7] or lime [8–15].

The effects of lime on the decomposition of human remains are poorly understood with the available information rather limited and often conflicting. It is a common misconception that lime can be used to enhance the speed of decay, to reduce the likelihood of detecting a body, to destroy evidence and that ultimately lime will lead to the rapid and total destruction of human remains.

Limestone is a sedimentary rock composed predominantly of calcium carbonated ($CaCO_3$), one of the most common and widely occurring minerals [16]. Lime is a generic term for quicklime (CaO) (differently known as calcium oxide, unslaked lime or burnt lime), hydrated lime ($Ca(OH)_2$) (differently known as calcium hydroxide or slaked lime) and non pure derivatives such as hydraulic lime. When limestone is heated at a temperature in excess of 800 °C, carbon dioxide (CO_2) is driven off, resulting in calcium oxide or quicklime (CaO). Calcium oxide has hygroscopic properties and reacts exothermically with water or atmospheric moisture. When water is added to quicklime, the process of hydration takes place to form calcium hydroxide. Calcium hydroxide has the property to harden in reaction with carbon dioxide, a process called carbonation. On exposure to air, re-absorption of carbon dioxide by hydrated lime occurs and water is driven off, resulting in the formation once again of calcium carbonate.

Lime is a strong base and will form high pH solutions (pH 12–14). Contact with lime can burn eyes and respiratory tract and can cause several types of skin reactions from mild irritation to full thickness burns [17]. Lime is used in leather tanning processes where the depilatory effect of alkaline solutions is caused by the instability of keratin to alkalis [18]. Furthermore, lime is applied in

* Corresponding author at: Forensic & Archaeological Sciences, School of Life Sciences, University of Bradford, West Yorkshire BD7 1DP, United Kingdom. Tel.: +44 1274 23 5351.
E-mail address: eline.schotsmans@live.be (Eline M.J. Schotsmans).

0379-0738/$ – see front matter © 2014 Elsevier Ireland Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.forsciint.2013.12.047

agriculture to raise the pH and thereby reduce the acidity of soils. Because bacteria operate best within an optimal pH range, the addition of lime to soils will optimise the bacterial breakdown of organic matter [19]. This supports the common belief that covering a body with lime will lead to its rapid decomposition. However, the pH range tolerated by soil bacteria is generally between pH 4 and pH 10. The greater the departure from these conditions of optimal pH, the less the bacterial activity will be. If the soil is too alkaline, bacteria will not flourish. For this reason lime has traditionally been used as a disinfectant in carcass disposal and during mass disasters [20–25]. Nevertheless, the World Health Organisation (WHO) specifically advises against the use of lime as disinfectant because of its limited effect on infectious pathogens. Instead the WHO recommends the use of chlorine solutions or other medical disinfectants [26–28]. Besides disinfection, various sources suggest the use of lime to reduce putrefactive odours and discourage scavenging by predators. The only published study on odours and lime suggests that it is only effective at reducing an initial odour within the first few weeks post-mortem [29].

There is a paucity of scientific information about the effect of lime on the decay of human remains. Laudermilk [8] was the first researcher who proved that lime neither destroys bodies or accelerates decay based on small scale experiments with quicklime on a dead owl and pieces of beef. Other controlled laboratory microcosm experiments with sections of pig tissue and lime are carried out by Forbes [30] in a study on adipocere formation, and by Van Strydonck et al. [31] in a project on limed cremated remains. Forbes' experiments demonstrated that a burial environment containing lime significantly inhibits decomposition and that adipocere formation was not evident. The lime had formed a shell encasing the tissue sample and a large quantity of the original tissue remained [30].

Thew [32] and Schotsmans et al. [33,34] reported the effect of lime on complete pig carcasses in field experiments. Thew [32] analysed the effect of hydrated lime on 6 buried pigs on a farm in north western Indiana (USA). Two pigs were interred for 30 months and four pigs were buried for 6 months. It was concluded that hydrated lime retards the rate of decay significantly. Schotsmans et al. [33,34] studied the effects of quicklime and hydrated lime on pig cadavers buried for 6, 17 and 42 months. The results showed that the general decomposition is slowed down by both quicklime and hydrated lime, but the end result for each mode of burial will ultimately result in skeletonisation. The differences in preservation were the greatest after 6 months of burial [33]. The more advanced the decay process is, the more similar the degree of liquefaction between the unlimed and limed remains [34].

The study presented here serves as an addition to the field experiments by Schotsmans et al. [33,34]. The microcosm experiments were designed to look at the short term effects of lime and to limit unknown variables by conducting laboratory-based experiments at the University of Bradford. The macroscopic and microscopic effects were investigated in conjunction with the microbiological and taphonomic changes.

2. Materials and methods

2.1. Laboratory set-up

In the taphonomy laboratory at the University of Bradford an artificial decomposition environment was created. A pig was placed on its right side in a stainless steel chamber measuring 110 cm × 50 cm × 60 cm. The chamber was sufficiently aerated to maintain an aerobic environment. From an opening in the lid a ducting was connected to a fumehood to vent odours and make sure that the environment was kept aerobic. Inside the flexible tubing a mesh was attached to limit access by insects. A slanted stainless steel shelf was positioned in the chamber on which each pig was placed. Stainless steel drip trays were arranged under the platform to collect putrefactive liquids emanating from the carcass.

2.2. Human analogues

Due to ethical reasons within the United Kingdom, the use of human cadavers was not possible for this study. Moreover, working with donated human remains is often unrepresentative for controlled experiments because they do not die to order, they are usually elderly and frail, and they often die following a period of illness and therefore may have been on medication or have atypical pathology. Current considerations suggest that pig cadavers best mimic human decomposition because of their comparable skin structure, subcutaneous fat layer, fat muscle ration, body mass and physiology [35–37]. The greatest dissimilarity between pigs and humans are the bones which have a different microstructure [38]. Other differences are the limbs of these animals. Because the architecture of their skeleton is adapted to a quadrupedal stance, it is not possible to bury pigs supine. Pigs buried on their side causes lateral decomposition which has implications for the localised decomposition environment. Nevertheless, so long as burials are consistent this issue is seen as minor, given that human individuals in clandestine burials are not always buried supine either.

2.3. Pre-experimental records

A project design was developed based on two pilot pigs (one without lime and one with quicklime (PC1)) to analyse variables, practical issues and monitoring requirements. Once the project design was complete, refined and standardised, the aim was to observe and monitor three pigs over 77 or 78 days: an unlimed pig, a hydrated lime pig and a quicklime pig. Table 1 summarises the source data of the pigs. Three pigs (*Sus scrofa*), aged between 20 and 24 weeks, were used as substitutes for human bodies. All pigs were free from notifiable diseases and euthanised by captive-bolt shot into the brain a few hours before being put in the chamber. Because the pigs were larger and older than those used in the field experiments [33,34], a greater amount of lime was used. 25 kg of hydrated lime (*Limbux Trulime CL-90S, Buxton Lime & Cement, Tarmac)* and quicklime (*Calbux 90, Buxton Lime & Cement, Tarmac*) was applied to the carcasses of PB1 and PC2 on day 1 (20 h after death).

2.4. Environmental monitoring

Several dataloggers were placed in and around the chamber to monitor temperature, humidity and carbon dioxide (CO_2) (Table 1). Three Tinytag temperature and humidity loggers (TGP 1500) were installed to compare temperature and humidity inside and outside the chamber. One logger was installed inside the chamber, another logger served as back-up, installed in the ducting and one logger was installed in the laboratory in the direct vicinity of the chamber. The dataloggers were programmed to take hourly readings.

An additional Tinytag dual channel temperature logger (TGP1520) measured the temperature on the pig's body surface (between the pig and the lime) and the core body temperature of the pig (rectum) every hour. The laboratory experiments ran consecutively through winter and summer. Despite a degree of climate control, the ambient temperatures in the laboratory varied and it was not possible to maintain the same precise conditions for each experiment.

A Tinytag CO_2 datalogger (TGE0011) was installed in the chamber next to the temperature-humidity logger to monitor