A Study of Bone Chemistry in Forensic Applications

by

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Certificate of authorship and originality

I certify that the work in this thesis has not previously been submitted for a degree nor has it been submitted as part of requirements for a degree except as fully acknowledged within the text.

I also certify that the thesis has been written by me. Any help that I have received in my research work and the preparation of the thesis itself has been acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

Sophil Raja

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Abbreviations

AFC = Advanced Flow Control

AFM = Atomic Force Microscopy

BMD = Bone Mineral Density

BSE = Back-Scattered Electron

C = Clay

Cont = Control (Loam Defleshed)

DSC = Differential Scanning Calorimetry

DNA = Deoxyribonucleic Acid

DTA = Differential Thermal Analysis

DTG = Derivative Thermogravimetry

DRIFT = Diffuse Reflectance Infrared Spectroscopy

DXA = Dual-energy X-ray Absorptiometry

EGA = Evolved Gas Analysis

EVA = Evaluation

ESEM = Environmental Scanning Electron Microscopy

FTIR = Fourier Transform Infrared

GC = Gas Chromatography

GE = Gel Electrophoresis

GSE = Gaseous Secondary Electron

HAP or HA = Hydroxyapatite

HTXRD = High Temperature X-ray Diffraction

ICDD-JCPD = International Centre for Diffraction Data - Joint Committee of Powder Diffraction

IR = Infrared

LA = Loam Acidic

LB = Loam Basic

LBO = Loam Boiled

LD = Loam Dry

LDG = Loam Degreased

LR = Loam Refrigerator

LW = Loam Wet

MS = Mass Spectrometry

NHMRC = National Health and Medical Research Council

NIST = National Institute of Standards and Technology

PCA = Principal Component Analysis

PCR = Principal Component Regression

PLS = Partial Least Squares

PMI = Post-Mortem Interval

Py = Pyrolysis

Py-GC-MS = Pyrolysis Gas Chromatography-Mass Spectrometry

S = Silt

SA = Sand

SD = Standard Deviation

SDT = Simultaneous Differential Techniques

SE = Secondary Electron

SEM = Scanning Electron Microscopy

SPSS = Statistical Package for the Social Sciences

TA = Thermal Analysis

TG = Thermogravimetric Analysis

UTS = University of Technology, Sydney

UV = Ultraviolet

UWA = University of Western Australia

XRAS = X-ray Absorption Spectroscopy

XRD = X-ray Diffraction

Abstract

The primary aim was to develop a method for accurately estimating the post-burial time of bones. Bones were buried in diverse soil environments for 18 months and subsequently examined using various analytical techniques. Pig rib bones were used as an analogue for human bones. The burial environments varied in factors including soil type, soil pH, moisture content and temperature. Environmental Scanning Electron Microscopy (ESEM) allowed the classification of bone samples into two categories of young and old based on differences in surface morphology. X-ray Diffraction (XRD) results showed no changes in crystallinity for a post-burial period of 18 months, making this technique unsuitable for post-burial time estimation. Thermogravimetric analysis (TG) showed an overall increasing trend in mass loss in all the bone samples up to a post-burial time of 8 months. Bones buried in an acidic soil environment showed a decreasing trend in mass loss with increasing burial time, indicating that an acidic environment is the most destructive environment. Pyrolysis Gas Chromatography-Mass Spectrometry (Py-GC-MS) was identified as being the most useful and accurate technique for estimating the post-burial time of recovered bone samples. The data showed a direct correlation between the actual and predicted post-burial time of bones for all the pre-treatment procedures studied except for boiling. The pyrograms collected for the different post-burial times demonstrated the process of diagenesis and highlighted the identifiable compounds most susceptible to degradation, as well as the identifiable compounds which persist after longer periods of burial. Comparison of the different burial environments also demonstrated that it is possible to estimate the post-burial period of bones without knowledge of the burial environment, however, information about the burial environment allows for a more accurate estimation of the post-burial time.