8-2001

Evaluation of decay odor as a time since death indicator

Jennifer Cheryl Love

To the Graduate Council:

I am submitting herewith a dissertation written by Jennifer Cheryl Love entitled "Evaluation of decay odor as a time since death indicator." I have examined the final electronic copy of this dissertation for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, with a major in Anthropology.

Murray K. Marks, Major Professor

We have read this dissertation and recommend its acceptance:

Lyle W. Konigsberg, Arpad Vass, John Neff, Richard L. Jantz

Accepted for the Council:

Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

To the Graduate Council:

I and submitting herewith a dissertation written by Jennifer Cheryl Love entitled "Evaluation of Decay Odor as a Time Since Death Indicator." I have examined the final copy of this dissertation for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, with a major in Anthropology.

Murray K. Marks, Major Professor

We have read this dissertation
and recommend its acceptance:

Accepted for the Council:

Interim Vice Provost and
Dean of The Graduate School

Evaluation of Decay Odor as a Time Since Death Indicator

A Dissertation
Presented for the
Doctor of Philosophy
Degree
The University of Tennessee, Knoxville

Jennifer Cheryl Love
August 2001

Acknowledgment

There are several people who made this project possible and I would like to thank them. First and foremost, I must mention my committee members. Dr. Murray K. Marks guided me through my graduate career and provided numerous opportunities for practical training and financial support. He introduced me to the importance and difficulty of estimating time since death, and built a solid relationship with Oak Ridge National Laboratory that in turn enabled me to be involved in this research. Most importantly he managed to keep graduate school fun and exciting through many years. Dr. Arpad Vass worked with me through the daily difficulties of this study and fought to keep it funded. He showed endless enthusiasm for the potential value of odor as a time since death indicator. Drs. Richard L. Jantz and Lyle W. Konigsberg provide statistical support for this project based on years of expertise. Through their classes, they have taught me the value of human variation and developmental anatomy. Dr. Konigsberg gave me the opportunity to further my understanding of anatomy through a teaching assistantship. Dr. John Neff brought a non anthropological view to study, posing difficult questions which ultimately strengthened the study. He never hesitated to take time to teach, whether in the autopsy suite or working with this study, when an opportunity presented itself. In sum, each committee member showed great support for this study, without which this project could not have accomplished

Dr. Stacy-Ann Barshick headed the Oak Ridge National Laboratory team for the first few years of the Time Since Death research project. She first presented the aroma study to me and then helped me develop the sampling method. She once stated, "Now its

time to think outside the box," then showed me how to do it. Without her input, I would still be wiping sterile gauze over the cadavers' abdomens.

Furthermore, several fellow students, Michelle D. Hamilton, Jennifer A. Synstelien, Derek C. Benedix, Dalford D. Owens and Joanne B. Devlin, made this study possible by constructing the building, accompanying me while I sampled, and sampling for me when I was out of town. Jennifer Synstelien's good humor about the process of decay made the daily sampling bearable. Beyond contributing to the setting up my research at the Anthropology Research Facility and helping with sample collection, Michelle Hamilton provided a place for me to stay when I returned from Memphis and spent endless hours providing encouragement when this project seemed overwhelming.

Dr. Steve A. Symes provided me with an opportunity to continue to work as an anthropologist in Memphis. He gave valuable editorial comments and kept me focused after leaving the academic setting.

As we all know, nothing would be accomplished without the assistance of a strong secretary staff. Donna Patton, Charlene Weaver, and Pam Poe contributed in endless ways to the success of this study.

Finally, I would like to thank my family whose continual support made graduate school an obtainable goal. Every individual mentioned played a crucial role in this project and for that I am grateful.

Abstract

Until recently, decay odor has not been used as a forensic investigative tool beyond body reconnaissance by cadaver dogs. The research presented in this study is attempting to broaden the value of decay odor through evaluating it as a time since death indicator. Decomposition is the result of two internal processes, autolysis and putrefaction, and many external factors, i.e., bacteria, carnivores, insects. Autolysis is the breakdown to cells following circulatory stasis. Putrefaction is the destruction of the organism through bacterial activity. Some of the byproducts of putrefaction are odiferous compound such as cadaverine, putrescine, volatile fatty acids (VFA's), methane and hydrogen sulfide, which produce the decay odor. As decomposition progresses the concentration of various by-products that contribute to the decay odor are expected to vary in a predictable pattern that correlates to temperature. To test this hypothesis the odors of several decaying corpses were collected and analyzed using electronic nose technology.

The greatest obstacle to successfully studying decay odor was the collection of a representative and replicable sample. A portable sampling device was designed to collect an appropriate sample. The device consisted of connecting three glass pipettes filled with molecular sieve to the inflow nozzle of an air pump. Molecular sieve, a universal dryant, was capable of capturing the odor causing agents under field conditions and releasing the same agents under the analytical conditions of the electronic nose in the laboratory. Collecting three samples simultaneously, per the three pipettes, minimized the intersample error and reduced the sampling time.

Aroma samples were collected from eleven decaying individuals at regular intervals. The human subjects were donated for scientific study and met several criteria: 1) known time of death, 2) known cause of death, 3) received during the fresh stage of decomposition, and 4) unautopsied. Included in the study were eight males and three females. All individuals were white, non-Hispanic. Age range was from 25 to 98 years. Cause of death was natural in all case but three, two suspected drug overdose and one suicide by hanging. Ten corpses were enclosed in a body bag during the decomposition process to concentrate and isolate the odor. One corpse was not placed in a body bag. A small hole was cut in each body bag through which the sample was taken. At each sampling event the temperature and humidity, as well as the intersample high and low temperature and humidity and rainfall, were recorded. The fluctuation and accumulated effects of temperature was summarized as accumulated degree days (ADD). Control samples were collected by sampling air contained within empty body bags. Four of the ten body bags were disturbed by carnivore activity during the decay process.

The results of the study show that the aroma pattern as detected by the electronic nose did not change over time. However, the concentration of the odor did change. The intensity of the odor positively correlated to ADD when the body was isolated in an undisturbed body bag. Intensity of the odor did not correlate to ADD when the body bag was disturbed or the body was not placed in a body bag. At this time, odor as a time since death indicator is only applicable to a sample collected from bodies isolated in body bags. In order to expand the applicability of this method the sensitivity of the sampling method must be improved. Furthermore, important odor pattern variation may become detectable with increased sensor sensitivity of the electronic nose. In sum, the

concentration of odor positively correlated to ADD when specific conditions are met. However, aroma pattern change is undetectable.

Table of Contents

List of Figures

List of Tables

Tables **Page**

Chapter 1

Introduction

An accurate estimation of time since death (TSD) is often a crucial component of a death investigation. The success or failure of many investigations hinges directly upon precise assessment of the time between death and discovery. TSD is one of the hardest determinations to make because of the lack of reliable scientific means. In light of this, a large amount of forensic anthropological and pathological research has focused on developing and improving methods for estimating postmortem interval (PMI). Forensic pathologists have primarily focused their research on the initial interval following death, concentrating on rates of autolysis. Forensic anthropologists have focused their research on the later postmortem interval, concentrating on rates of putrefaction. Both fields depend greatly on the advancements of the hard sciences, i.e., analytical chemistry, biochemistry, and physics, for the development of technologies that can be applied to measuring rates of autolysis and putrefaction. The study of time since death, while remaining a challenge, is an evolving area of research.

Progression of Decomposition

The first step in measuring rates of autolysis and putrefaction is developing an understanding of the mechanisms that drive both processes. At death, organisms systematically begin the decay process by passing through a physiochemical and gross continuum of tissue breakdown from fresh to skeletal. Even though systematic, the

transition through several well-documented stages (created for scientific convenience) of decomposition is guided by the effects of several factors that include body physique, cause, mechanism, and manner of death, depositional context and the environmental conditions that may serve to temporarily arrest, retard or accelerate this process. Initially, autolysis, the irreversible cascading events of cell death, destroys cellular integrity and the cell-to-cell junctions that progressively result in widespread tissue necrosis. The by-products of autolysis subsequently fuel putrefaction; the consumption of the body tissues through the progressive proliferation of bacteria. Given appropriate time and environmental conditions, these two internal processes are sufficient, even in the absence of insects and carnivores, to reduce a body to the skeleton.

Autolysis

An understanding of decomposition is born from a fundamental knowledge of the normal biochemical function of living cells. Adenosine triphosphate (ATP) provides the energy for the biochemical and physiological pathways of the cell. In aerobic organisms, ATP is produced by respiration, the oxygen-dependent extraction of energy from food (Berne and Levy 1993). In anaerobic conditions, some aerobic organisms produce ATP through fermentation, converting pyruvate to lactate. A by-product of fermentation is the reduction of intracellular pH. The anaerobic pathway of ATP production is inefficient and the net gain of energy is insufficient to maintain cellular physiology (Gill-King 1997, Tobin and Morel 1997).

At death, circulatory stasis and the consequent loss of aerobic ATP synthesis insults cellular integrity leading to microscopic (cellular) and eventual macroscopic

(tissue) morphologic changes. The membrane transport system is destroyed by denaturing proteins in the cell membrane. With loss of the cross membrane transport system, molecules and ions essential for cell survival are unable to pass across the concentration gradient (Tobin and Morel 1997). Meanwhile, damaged membrane selectivity allows extra-cellular matrix to leak into the cell causing it to swell. Lysosomes, cellular organelles housing hydrolytic enzymes that function in intracellular digestion, rupture and releasing their contents. During aerobic cellular conditions, lysosomes fuse with the membrane of the phagosome and release the hydrolytic enzyme into the phagocytic vacuole, digesting the entity and releasing nutrients into the cytoplasm. The destructive enzymes remain locked within a membrane throughout the digestive process. With membrane structural integrity compromised, liberated hydrolytic enzymes leak in the cytoplasm; activated by the lowered pH of the cytoplasm, they begin to consume the cell (Junqueira et al. 1991).

Finally, with continued disintegration of the cell membrane, cell to cell junctions dissolve, causing localized or focal death and eventual organ tissue necrosis. During this stage, decomposition becomes observable at the gross level as tissues become subjectively paler. In addition, breakdown of the cellular junction occurring between the layers of epidermis and dermis results in gross slippage of the epidermis (Figure 1.1) (Spitz 1993).

In addition to skin slippage and generalized tissue necrosis, circulatory stasis and autolysis trigger several gross morphologic changes traditionally targeted by forensic pathology as time since death indicators: algor mortis, livor mortis, and rigor mortis. During life, normal metabolic pathways maintain the body at a core temperature of

Figure 1.1. Skin Slippage. As the junction between the dermis and epidermis deteriorates, the epidermis sheds from the body.

98.7°F. When these pathways diminish, the body begins gradually, then more rapidly, to cool to ambient temperatures. This is referred to as algor mortis.

Livor mortis, or hypostasis, is the pooling of blood in the body. Blood pools in the capillary beds of regions of the body experiencing the greatest gravitational pull, e.g., the feet of a hanging victim. Initially, livor is unfixed, meaning pressure will force the collected blood out of the capillaries, allowing the skin under pressure to blanch white. With time, the capillary blood and surrounding fat coagulates, trapping the blood. At this point blood does not recede from the capillary under pressure causing livor fixation (Figure 1.2) (Coe 1993, DiMiao and DiMiao 1996, Clark et al. 1997).

Rigor mortis is the stiffening of muscles from the binding together of fibers within the cells. Muscle cells consist of two fibers, myosin and actin, which bind and pull across each other during contraction. At rest, the binding site on the actin fiber for

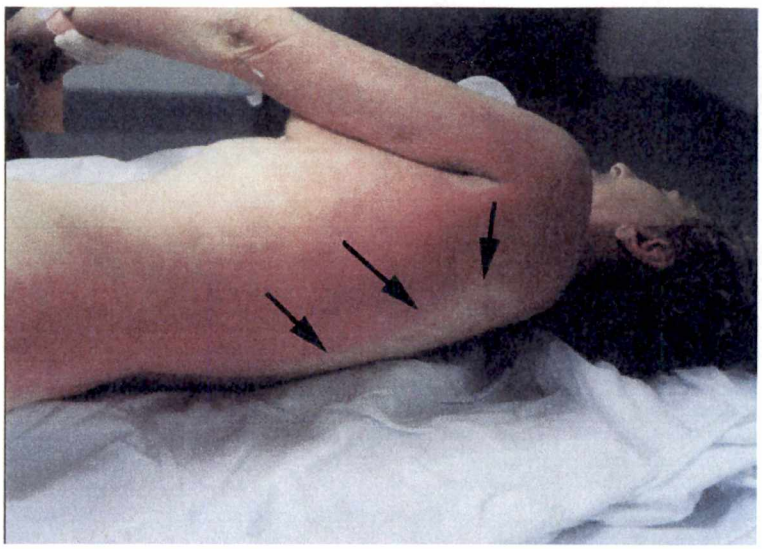


Figure 1.2. Fixed Livor Mortis. The arrows are pointing to areas of blanching. The blanched areas remain white despite the release of pressure.

the myosin fiber head is bound by a troponin-tropomyosin complex (Berne and Levy 1993, Junqueira et al. 1991). Calcium ions released from the membrane interact with the complex moving it from the binding site. These ions enable the myosin fiber head to bind to the actin fiber. At this point energy is released from ATP associated with the structures causing the myosin head to bend and the two fibers to pull across each other. The muscle cell relaxes after the calcium ion is pumped from the sacroplasm back into the cell membrane releasing the troponin-tropomyosin complex to obscure the myosin-binding site. At death, calcium ions are released from the disintegrating membrane allowing the two fibers to bind. However, in the absence of ATP, the fibers do not slide across each other and calcium ions are not pumped out of the sarcoplasm. Hence, during rigor mortis the muscles do not contract, but stiffen via fiber binding. The decreased intracellular pH also causes the cytoplasm to congeal which contributes to rigor mortis.

With time, the fibers break away from their anchoring site at the end of the cell gradually causing rigor mortis to dissipate.

Putrefaction

Putrefaction is the alteration of an organism through bacteria activity. The release of nutrients from autolyzed cells coupled with the decreased intercellular pH from loss of the buffer system creates a rich environment for endogenous bacterial proliferation (Spitz 1993, Knight 1996). The largest bacterial population during life and the earliest postmortem proliferation of putrefactive bacteria is in the bacteria-rich cecum, located in the lower right quadrant of the abdominal. Because of the size of the cecum and superficial proximity to the skin surface of the abdominal wall, putrefactive bacterial activity is often first visible in this area (Spitz 1993, Knight 1996). A by-product of this bacterial proliferation is the production of a large quantity of hydrogen sulfide gas that readily diffuses through the soft tissue. The gas reacts with the iron of hemoglobin to form a black precipitate, ferrous sulfide and sulfhaemoglobin (Gill-King 1997). The precipitate causes observable discoloration of the dermis over the cecum (Figure 1.3). Discoloration progresses through the remaining regions of the abdominal wall through the same process as well as through the release of pigments from the breakdown of biliary structures (Gill-King 1997). Hydrolytic enzymes released from pancreatic cells attack biliary structures releasing various colored pigments into the circulatory system and wall of the abdomen (Gill-King 1997, Marks et al. 2000). With time, the color of the entire body will progressively advance from the normal to slightly pasty variation of

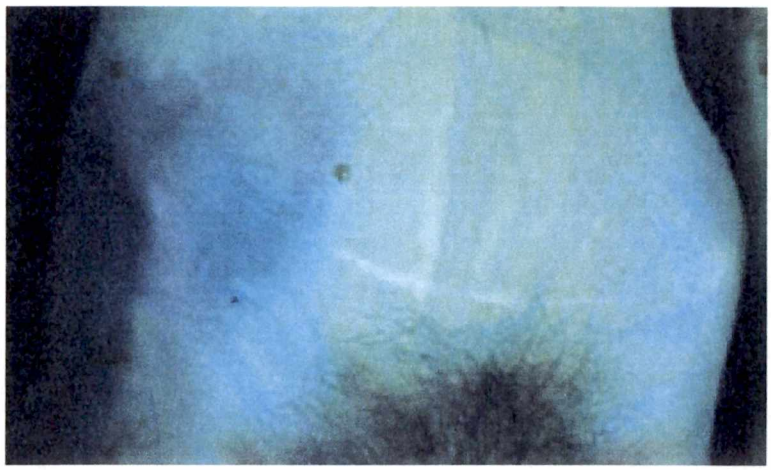


Figure 1.3. Early discoloration. The dark purple / red discoloration in the lower right abdominal quadrant is the by-product of initial bacterial proliferation in the cecum of the large intestine.

healthy pigment of the dermal and epidermal tissue, to green, purple and through various shades of brown (Knight 1996, Gill-King 1997) (Figure 1.4 and 1.5).

Endogenous bacteria are not confined to the large intestine, but are also present in the lungs and to a much lesser degree, throughout the entire organism. Bacterial contamination in the circulatory system produces hydrogen sulfide gas that easily travels through the blood vessels. The high concentration of iron in the vascular system forms ferrous sulfide when it reacts with the gas and systematically blackens vessels. This event, termed marbling, is easily seen in the superficial vessels on the body surface (Figure 1.6).

While some bacterial-produced gases diffuse through the lining of the organs and the dermal wall easily, other gases, i.e., hydrogen, methane, ammonia, hydrogen sulfide,

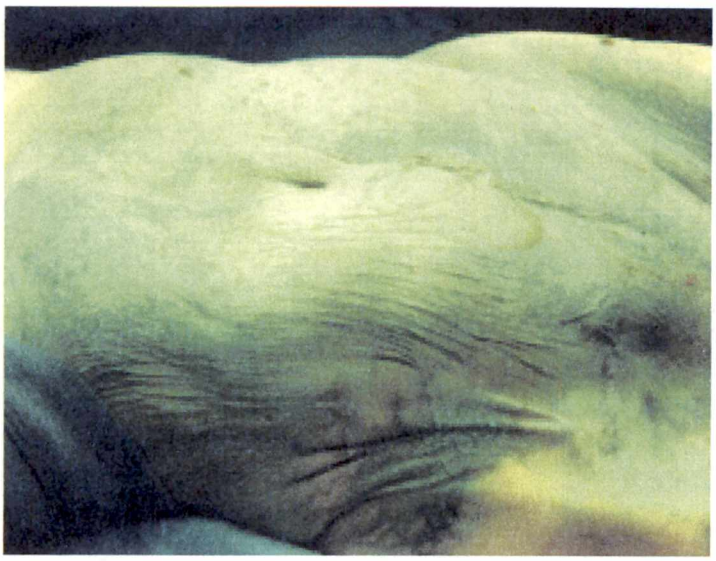


Figure 1.4. Advanced abdominal discoloration. With the continued proliferation of colonic bacteria and break down of biliary structures the entire abdominal wall discolors.

Figure 1.5. Late discoloration. As bacterial growth continues to produce color changing reactant gases and the dermis becomes exposed as a result of skin slippage, the whole body becomes reddish brown.

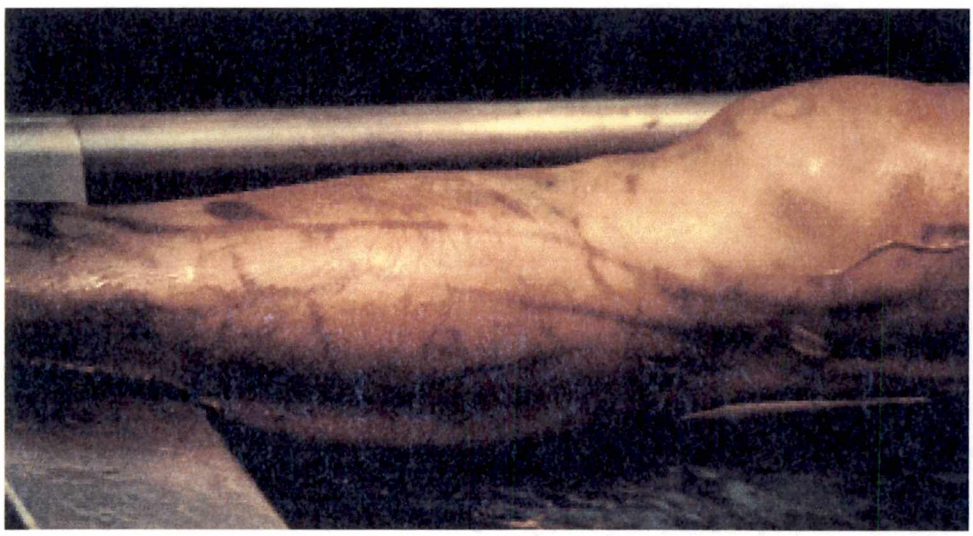
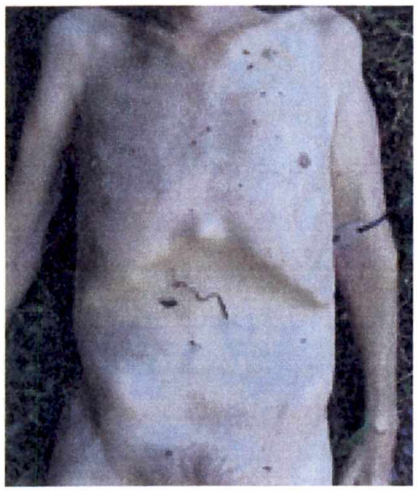


Figure 1.6. Marbling. Bacteria located in the circulatory system proliferates after death and produces hydrogen sulfide gas. The gas passes through the vascular system and reacts with the iron present in the hemoglobin to form ferrous sulfide, the same black precipitant producing abdominal discoloration.



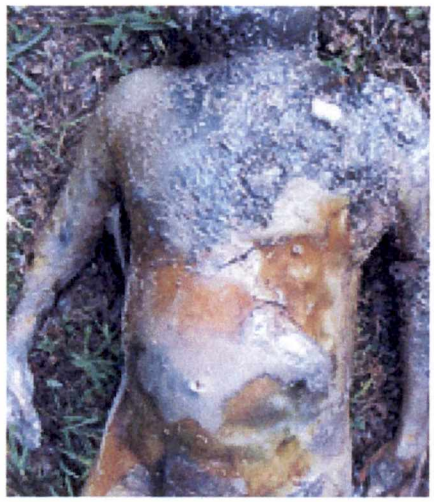


Figure 1.7 and 1.8. Before and After Bloating. The gas by-products of bacterial growth throughout the body collect and cause the body to increase in size. These figures are the same individual photographed at two days and six days postmortem, respectively. Notice the xyphoid, ribs, clavicle, and anterior iliac crest are visible in figure 1.7 but not in figure 1.8.

and carbon dioxide, remain trapped within the tissues. The collection of the gas causes the abdomen and other regions to bloat, increasing several times in size (Figure 1.7 and 1.8). In males, abdominal gas buildup often pushes into the scrotum causing it to balloon. With time, the abdominal gas build-up causes the tissues to rupture, leaking from the body and reducing it to the perimortem size or smaller (Galloway 1997).

In addition to the visible gross morphological changes associated with bacterial activity, there is also the generation of odor, a by-product of putrefaction. Presently, the molecular composition of decay odor is unknown. Suspect odor causing compounds associated with decay include cadaverine, putrescine, volatile fatty acids (VFA's), methane and hydrogen sulfide (Gill-King 1997). Putrescine and cadaverine, ptomaine compounds, are the products of decarboxylation of the amino acids ornithine and lysine,

respectfully (Gill-King 1997). VFA's are breakdown products of lipids. Of the many varieties of VFA's, only six are water-soluble: formic, acetic, propionic, butyric, caproic, and heptanoic acids (Vass et al. 1992). These VFA's are volatile at a basic pH (less then 7.0) and contribute to the decay odor in the basic environment of decomposition.

In attempts to standardize the progression of putrefaction, researchers (Reed 1958, Rodriguez and Bass 1983, Galloway et al. 1989, Clark et al. 1997, Galloway 1997, Rhine and Dawson 1997) have broken-down the progression of decay into stages. Although each researcher has developed his or her own stages for the advancement of decay, they can be melded into the following scheme: fresh, discoloration, bloating, skeletalization, and skeletal decomposition (see Marks et al. 2000). During the fresh stage, no gross morphological changes are observable beyond algor, livor, and rigor mortis. The discoloration stage begins with the first detection of abdominal color change and ends at the first detection of abdominal bloating. Gross morphological changes occurring during this stage are progressive discoloration of abdomen, thorax, and neck and early to moderate signs of skin slippage. The bloating stage begins with the initial signs of abdominal distention and ends when bloating is no longer detectable. Loss of bloating is a result of either rupture of the intestinal and organ lining or carnivore disturbance. This stage of decomposition is often skipped in frozen environments (Micozzi 1997). During this stage marbling becomes detectable and progresses through the body and skeletal exposure occurs in areas of less subcutaneous layering, e.g., cranium and bony eminences. The stage of skeletonization begins when no evidence of soft tissue bloating is apparent and ends when VFA's no longer can be detected from soft tissue decomposition. In arid areas where desiccation and mummification are common a body

may remain in the skeletalization stage indefinitely. Finally, once fully skeletonized , the bone decomposition stage includes all subperiosteal cortical weathering, i.e., exfoliation and demineralization, resulting from environmental conditions.

Estimating Time Since Death

Initial Stage of Decomposition

Autolysis progression is rapid and fairly consistent, and the compounding effects of external conditions are less influential. Because of the consistency of this stage, time since death estimation based on biochemical changes, i.e., nitrobensodiazepines levels, vitreous potassium concentration, tranylcypromine levels, and gross morphological changes, i.e., rigor mortis, livor mortis, algor mortis, are relatively accurate, with a margin of error of a few hours (Madea 1992, Coe 1993, Yonemitsu and Pounder 1993, Lange et al. 1994, Henssge et al. 1995, DiMiao and DiMiao 1996, Robertson and Drummer 1998). A large amount of forensic pathological research has focused on fine tuning time estimates based on classic signs of autolysis (algor, livor, and rigor mortis), while developing biochemical techniques to read less obvious signs of tissue breakdown.

Algor mortis, temperature loss, is typically measured through the deep core rectal temperature using a standard thermometer. Historically, a questionable rule of thumb used by pathologists was a loss of 1.5°F per hour (Madea and Henssge 1988, Henssge et al. 1995). However, bodies do not cool at a consistent rate. Initially, the core temperature drops slowly creating an early temperature plateau. With time, the rate increases. Recent research has aimed at developing mathematical models to predict the cooling curve with the goal of extrapolating the time since death from rectal and ambient

temperatures (Henssge and Madea 1988, Henssge et al. 1995). Madea and Henssge (1988) developed a nanogram that incorporated the victim's weight and ambient and rectal temperature into a time since death interval estimate. Furthermore, the nanogram includes a correction factor for the variables of clothing, wrapping materials and air currents. Despite these advances, algor mortis as a time since death indicator remains complicated by variable rates of temperature loss in individuals perishing under a wide variety of contexts.

Livor mortis, blood pooling, is qualitatively graded as not present, unfixed, and fixed. The traditional, but rough, rule of thumb for estimating TSD is that lividity is observable between one and two hours postmortem and is fixed between eight and twelve hours postmortem (Coe 1993, DiMiao and DiMiao 1989, Clark et al. 1997). Once lividity becomes fixed it can no longer be used as a specific time since death indicator. Researchers attempting to quantify livor mortis as a time since death indicator have concentrated on measuring blood pooling rates via the light absorbing properties of blood and increased brightness of effected skin. Three approaches have been taken: measuring blanching intensity with consecutive force increments (Kaatsch et al. 1994); comparing light absorption on affected and non-affected areas (Inoue et al., 1994); and measuring the color change rate over time (Vanezis and Trujilla 1996).

Kaatsch and colleagues (1994) attempted to expand and quantify the present unfixed category of livor mortis by the photometric measurement of pressure-induced blanching. They found the force required to blanch an effected area exponentially increased with time. The study consisted of 50 cadavers with known time of death; the postmortem interval studied ranged from 0-50 hours. Contrary to traditional thought, the

rate of livor mortis fixation is complicated by a wide range of effectors: skin color, antemortem physical condition, cause of death, ante and postmortem environmental factors, and storage conditions prior to measurement.

Because hemoglobin absorbs light, Inoue and colleagues (1994) measured the progression of livor mortis by projecting a 630 nanometer wavelength light through effected tissue and measuring the amount of light absorbed. To control for the amount of light being reflected by the pigment of the skin, the researchers developed a ratio of light absorbed and reflected by effected skin to light reflected by unaffected skin. The result of a pilot study using 41 cadavers between one and thirty hours postmortem was a correlation of $r = -0.75$ between the light absorbent ratio and time since death.

Vanezis and Trujilla (1996) measured the change in color brightness resulting from hypostasis with a tristimulus color measuring system. They found that the change in hypostasis brightness was correlated with postmortem interval, ($r = 0.538$). The results were based on a study using 93 cadavers with known times of death. Each cadaver was studied over a four-hour period and the postmortem intervals investigated ranged from 0-80 hours. They state that the color change of hypostasis is particularly marked in the first 12 hours postmortem. However, color change of livor mortis is applicable as a time since death indicator up to 48 hours postmortem. After this time application of this technique becomes limited.

As research has demonstrated, the value of livor mortis as a time since death indicator is limited by the short length of applicability and complicated by various skin pigment. Furthermore, despite traditional thinking that the only cause of livor mortis is gravitational pull, the rate of onset and fixation is confounded by many variables, such as

temperature, cause of death, and antemortem physique (Inoue et al. 1994, Vanezis and Trujilla 1996). Despite these shortcomings as a time since death indicator, one of the great strengths of livor mortis is as an indicator of scene tampering. As lividity becomes fixed, areas under pressure, such as skin beneath the elastic band of underwear or on the buttocks of a seated individual, will remain blanched or white (Figure 1.2). Hence, the early postmortem posture of a victim can be discerned within several hours after death given lividity patterning. Undressing or moving of an individual after lividity is fixed is easily detected from the exposure of telltale white surfaces indicating a tampered crime scene.

Rigor mortis, muscle stiffening, is clinically detected by an attempt to move various joints of the deceased. Similar to livor mortis, traditional use of rigor mortis as a time since death indicator was through correlating classification categories, absent or present, to postmortem intervals (Spitz 1993, DiMiao and DiMiao1996, Knight 1996, Clark et al. 1997). However, unlike livor mortis, rigor mortis has a systematic onset. First, rigor is noticeable in the facial muscle as the jaw tightens two to three hours postmortem (Spitz 1993, DiMiao and DiMiao1996, Knight 1996, Clark et al. 1997). It then spreads to the neck and through the rest of the body over 24 hours. A rough timeline for rigor mortis is initial development at one to two hours after death, complete stiffness at twelve hours postmortem, and waning over a final twelve-hour period (Spitz 1993, DiMiao and DiMiao1996, Knight 1996, Clark et al. 1997). However, the rate and extent of rigor is dependent on the perimortem physical activity level of the decedent and postmortem environmental conditions.

Researchers have tried to quantify the onset of rigor mortis by measuring the area and force of muscle contraction initiated by electric current (Madea and Henssge 1988, Madea et al. 1995). Madea and colleagues applied an electrical current to muscles through inserted electrodes. The resulting contraction was measured by a sensitive force transducer. These results reveal that a large amount of inter- and intra-individual variation occurs and the window of muscle excitation applicability is very short, +/- 12 hour period (Madea and Henssge 1988).

Beyond the classic signs of autolysis, algor mortis, livor mortis, and rigor mortis, histochemists and biochemists have investigated numerous chemical changes caused by disruption of cellular function within different components of the body. A detailed summary of this postmortem research is beyond the scope of this study. However, the following presents an example of the vast body of research concentrated on chemical changes occurring during the initial postmortem interval: DNA degradation (Di Nunno et al. 1998), distribution and redistribution of nitrobenzodiazepines (Robertson and Drummer 1998), changes in serum noradrenaline and adrenaline concentrations (Hirvonen and Huttunen 1996), enzyme histochemistry of the liver (Mello de Oliveira and Santos-Martin 1995), quantification of melatonin (Mikami et al. 1994), vitreous potassium concentration (Madea 1992, Lange et al. 1994), cell content of cerebrospinal fluid (Wyler et al. 1994), activity of lactate and malate dehydrogenase in liver (Babapulle and Jayasundera 1993), and tranylcypromine concentrations in blood (Yonemitsu and Pounder 1993).

Mid and Late Stages of Decomposition

As the postmortem interval increases, are ability to estimate that interval decreases. While the rate of initial internal changes resulting from autolysis is rapid and fairly consistent, the rate of putrefaction is highly dependent on environmental conditions and is much more variable. During the early stage of decomposition, while body cooling, livor mortis is unfixed and rigor mortis is setting. Here the, estimation of time since death can be accurate to within a few hours of error. Conversely, once the systematic changes driven by autolysis are complicated by the initiation of putrefaction, estimating time since death becomes increasingly more difficult and more inaccurate with more variability to consider.

The rate at which a body decomposes is dependent on climatic conditions. The gross morphological changes associated with putrefaction are found in both arid and humid climates, but the progression of decay is considerably different in environments of periodic freezing and thawing. Working in the Arizona-Sonoran Desert, Galloway (1997) found bodies initially decomposed rapidly due to high temperatures. However, the low humidity resulted in indefinite soft tissue preservation. Working in the hot and humid climate of East Tennessee, Bass (1997) found that a covered body could be a nearly complete skeleton after one month. Studying the effect of freezing on rates of decomposition, Micozzi (1997) found decomposition essentially ceases at freezing temperatures, and once thawed the body decomposes in a unique pattern. Rather then decomposing from the "inside out" as shown with discoloration, marbling, and bloating, bodies once frozen decompose from the "outside in", showing no intestinal distention. The probable causes for the alternative decay pattern is freezing temperatures either kill

or alter the growth pattern of the endogenous bacteria (Zugibe and Costello 1993, Micozzi 1997). Furthermore, it appears the freezing process weakens the epidermis and connective tissue making the external surface of the body more susceptible to insults of foreign bacteria and insects.

Despite the characteristic variability of decay patterns during the later stages of decomposition, there are several methods for estimating time since death. The most convenient and probably the most widely used method for estimating TSD during the putrefaction stage is summarizing the condition of the body through external exam and estimating the postmortem interval based on personal experience. Since this method is highly qualitative, subjective, and unavailable to beginners, anthropologists are attempting to standardize it. Researchers have attempted to correlate gross morphologic progressions of decay to time through two methods of study: (1) cross-sectional studies using data from medical examiner records and (2) longitudinal studies using data from observing bodies decay from fresh to skeleton. Galloway's work (1989, 1997) is an excellent example of the cross-sectional approach. She correlated the time between last seen and discovery to the stage of decomposition in 468 medical examiner cases from Arizona and plotted the stage of decomposition against the postmortem interval illustrating the variability of the decay rate in an arid environment. Rhine and Dawson (1997), using 50 medical examiner cases, developed a similar plot illustrating the variability of decay rates from New Mexico. The strength of this research is a clear correlation of the decay stages to time intervals, making the visual examination method available to inexperienced pathologists and anthropologists, as well as veterans in the fields. A weakness of this research is the reliability of postmortem interval. In order to

reconstruct time since death from medical records the researcher assumed the reported date last seen was very near the time of death. This assumption is not always accurate.

Equipped with a unique open-air research laboratory, the Anthropological Research Facility (ARF), designed exclusively for studying decomposition in East Tennessee, Bass and coworkers have observed numerous bodies progress through the stages of decomposition, documenting the postmortem interval at each stage (Rodriquez and Bass 1985, Mann et al. 1990, Bass 1997, Marks et al. 2000). The strength of the research being done at ARF is multi layered. First, the research is conducted on donated bodies of which time of death and cause of death are known. Second, viewing the bodies at regular intervals enables a more concise description of each stage of decomposition and the taphonomic processes affecting those stages.

Although invaluable to the understanding of progression and rates of putrefaction, the previously mentioned studies, (except Marks et al. (2000)), correlate rates of decay to time without consideration of temperature; a perspective that has become central to current research (see Barshick et al. 2000, Marks et al. 2000). Correlating decomposition progression to time without the consideration of temperature leads to inaccurate time since death estimations. The rate of decomposition or the amount of time necessary for a corpse to pass from fresh to skeleton is highly dependent on temperature. Endogenous bacteria proliferate and are active at a specific range of temperatures, 5 to 36°C. Below and above these thresholds, bacterial cell division rate is greatly retarded. Furthermore, within the functional range of endogenous bacteria there is a direct correlation between rate of putrefaction and temperature (Micozzi 1997). During the later stages of decay, insects play a large role in decomposition and like bacteria, their life cycle is influenced

by temperature (Haskell et al. 1997). A method to systematically define fluctuating temperature is through a process termed: accumulated daily degrees (ADD) (Edwards et al. 1997). A degree day is calculated by subtracting a base temperature from the average temperature over a 24 hour interval of time. An ideal base temperature when measuring rates of putrefaction is 5°C, the minimal temperature threshold of bacteria activity. Consecutive degree days are then added together. The resulting temperature is then correlated to the decomposition stage.

In 1992, Vass and colleagues were the first to correlate ADD to advancement of decay status. They measured the concentration of volatile fatty acids (VFA), a by-product of putrefactive breakdown of fat and muscle, in soil samples taken from beneath decomposing bodies. They discovered that the concentration of VFA in the soil was equivalent at an ADD despite the time necessary for the temperature to be reached. For example, the expected concentration of propionic acid, a VFA, is 16 millimols per gram of soil (dry weight) at 450°C ADD; whether 450°C was reached in 18 days with 25°C average daily temperatures or in 45 days with 10°C average daily temperatures was irrelevant.

Marks and colleagues (2000), working at ARF and following the models of Vass et al. (1992), Galloway (1989, 1997), and Rhine and Dawson (1997), recently photographically recorded progression of decomposition while measuring temperature and humidity. They plotted the stages of decomposition against ADD and correlated the rate of decomposition to temperature, while illustrating variability of decay rates.

Entomological research has developed outstanding methods for time since death estimation based on the maturity rates of carrion insects (Catts and Haskell 1990, Haskell

et al. 1997). To date, the succession, activity and longevity/maturity of a variety of arthropods reflect the stage of decay to a more accurate degree than assessment of gross morphological change. Larval maturity, for example, although temperature influenced, is an excellent measuring tool of the time since the body became accessible to insects. For example, in most settings, the *Calliphoridae* (blow fly) is the first carrion insect interested in a corpse. This insect is present on a corpse within the first few hours of deposition and oviposition has been observed as early as 24 hours post deposition (Rodriguez and Bass 1983). If death occurred near the time of deposition, the maturity level of the *Calliphoridae* larva are the most sensitive indicators of time since death (Catts and Haskell 1990).

"Forensic botany is the study of plants related to the law" (Hall 1997:353). Many forms of botanical remains provide significant evidence in medico legal investigations, including indications of time since death. After the soft tissue decomposes in a burial or surface context, it is not uncommon for plant roots to become associated with the skeletal remains. Plant roots and root masses (to a lesser extent), like trees, form annual growth rings and root age corresponds to a minimum estimation of time since death (Willey and Heilman 1987, Hall 1997). If a root growing through the first cervical vertebra contains two annuali, the individual has been in situ for a minimum of two years. It must be remembered that this two-year interval excludes the time necessary for the body to decompose and any time between death and deposition. Furthermore, root etching on a bone surface can also contribute an estimation of time interval (Lyman 1984). Although not a closed or very precise estimate of the postmortem internal, knowing the minimum time since death can be pertinent to a medico-legal investigation.

Alternative Rates of Decomposition

As previously stated, the rate of decay is dependent on temperature and humidity. The pattern of decay is significantly altered by periods of freezing which contribute to difficulties of estimating time since death during the putrefaction and skeletonization process. These difficulties become further entangled by decay rate variation resulting from depositional context and perimortem trauma. Depositional context can decrease or increase the decay rate. Research conducted by Rodriguez and Bass (1983) and Rodriguez (1997) showed that a body buried at depths of four feet or greater decomposes approximately eight times slower than a body placed on the surface. In East Tennessee, complete skeletonization of a surface body is expected in about a month in mid summer (Bass 1997). The same body would have significant tissue after a year of decay if buried. There are several factors contributing to the slower skeletonization: 1) the grave acts as a barrier to insect and carnivore activity; 2) ground temperatures are lower and more stable; and 3) adipocere formation. Saponification is the process of converting lipids to adipocere, a gray-white caseous material traditionally termed "grave wax" or "corpse wax" (Figure 1.9) (Gill-King 1997). The percentage of water, fat , potassium and sodium dictates the rate of adipocere formation. However, given enough time, some will form in a grave. Adipocere is detectable years after the other soft tissues have dissolved. Bodies submerged into water also experience a much slower rate of decomposition for reasons similar to buried bodies (Manhein 1997, O'Brien 1997). If placed in fresh moving water, decomposition can be slowed by two times the expected rate of a surface deposition in

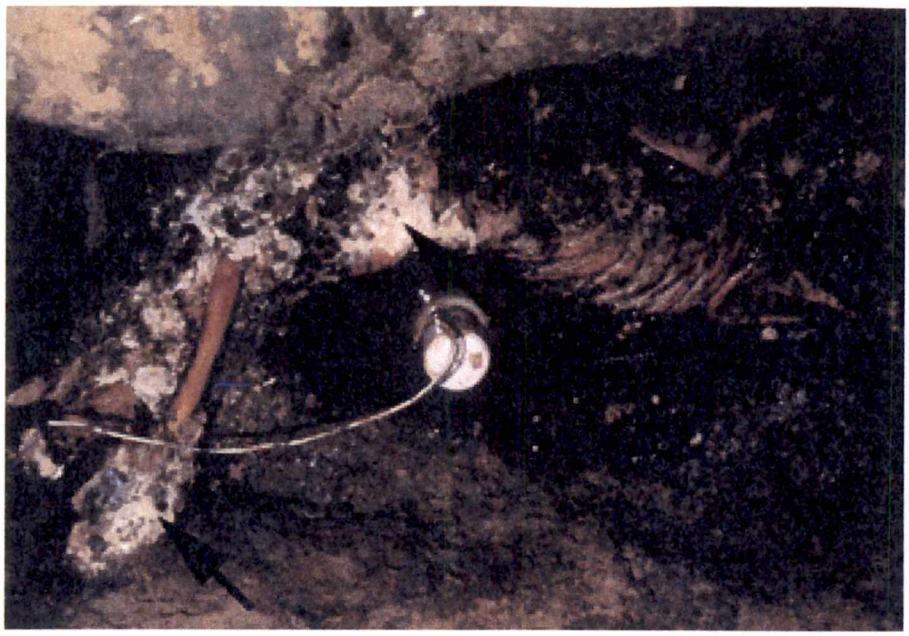


Figure 1.9. Adipocere. Saponification, or soap forming, of lipids creates a white waxy substance. The victim was buried four years in a wet grave. Notice the water pump located next to the skeleton. The arrows pinpoint adipocere formation at the right knee and pelvis.

the same climate. Water also serves as a barrier to insect and carnivore activity, but exposes the body to marine life. Cool water insulates the body from high temperatures that retards bacterial growth. Remains deposited in stagnant waters will decompose faster then remains deposited in fresh water because of the rich bacterial population (Rodriguez 1997).

Perimortem trauma, physical or chemical agents, or prior local bacterial infections (during life) can affect the decay rate. All three agents act as a portal to bacteria and insects and result in differential decomposition. The element that has received the insult will skeletonize significantly faster than non insulted areas (Haglund 1997). Knowledge of potential causes of differential decomposition can assist during reconstruction of perimortem events. Meanwhile, tannic materials and plastic wrapping create an

environment destructive to aerobic bacteria and slows decay rates (Rodreguiz and Bass 1983).

The Study

Oak Ridge National Laboratory

Once the decay process is understood and strengths and weaknesses of existing methods are defined, new research topics can be directed at these weaknesses. A team of researchers including biochemists, analytical chemists and statisticians, from Oak Ridge National Laboratory (ORNL) managed by University of Tennessee / Batelle are developing better techniques for estimating time since death in the late autolysis and early putrefaction stage of decay (Barshick et al. 2000). The research team's focus is to identify biomarkers in soft tissue that are indicative of time since death. They are studying proteins, amino acids, DNA, and other cellular components in the brain, lungs, heart, liver, kidneys, and skeletal muscle for a systematic breakdown that correlates to accumulated degree days. In order to obtain appropriate tissue samples, ORNL formed a partnership with The University of Tennessee (UT), Forensic Anthropology Center (FAC), to utilize the Anthropology Research Facility. In return, ORNL made their laboratories available to the Anthropology Department and provided the instrumentation for this study. The result of the marriage between ORNL and UT FAC is a research team that has the understanding of the forensic questions needed to be answered and the necessary technology to accomplish the task.

This relationship made the electronic nose, Aromascan®, available for evaluating the evolution of decay odor as a time since death indicator. The electronic nose had

traditionally been used in the consumer and food industry and has only recently been implemented in the field of forensics. Barshick et al. (1995) used electronic nose technology to detect the aroma pattern of fire accelerants in fire debris, to characterize the odor pattern of several drugs of abuse, and to evaluate odor pattern changes in soil consecutively collected under a decomposing body. Barshick et al. (1995) found the intensity of the soil odor consistently changed with accumulated degree days. As mentioned, Vass et al. (1992) found that the concentration of various water-soluble volatile fatty acids detected in the soil underneath a decomposing corpse correlate with accumulated degree days. Theoretically, the odor pattern and intensity detected with the electronic nose was the result of concentration variation of water-soluble VFAs present in the soil. Theoretically, air surrounding a decomposing body should contain VFAs and other odor causing agents in concentrations that reflect the internal bacterial activity.

Based on these findings, I hypothesize that decay odor mirrors the advancement of putrefaction and therefore, is a potentially valuable time since death indicator.

The most difficult obstacle of studying aroma with an Aromascan®, a non-portable electronic nose, is transporting the odor from the field to the laboratory. The sample must be both representative of the decay odor and replicable. Once collected, the pattern and intensity of the odor is easily obtained using the electronic nose detection technology. In light of this obstacle, the first step of this study is to develop a method for sampling the odor of decay then ultimately obtaining and estimating the time since death.

Chapter 2

Materials and Method

Materials

Studying the odor of decaying cadavers in a non-traditional laboratory proved to be difficult when defining and controlling variables. The strength of the study lies in the sampling method. The consistency in which the samples were taken generated representative and repeatable samples. However, using cadavers donated for scientific study introduces several uncontrollable variables such as age, race, sex, physique, and cause of death. Furthermore, working outdoors, the research is complicated by fluctuating temperatures, humidity, and rainfall. Overcoming this difficulty required a well developed experimental design that defined, recorded, and equally incorporated the multiple variables.

The Anthropology Research Facility

The Anthropology Research Facility (ARF) is a unique outdoor, decomposition laboratory. It is a two acre semi-wooded area bounded by a chain-linked fence bordered with razor wire that encircles a privacy fence. Once placed in the laboratory the taphonomic processes affecting a decaying corpse is limited to weathering, small animals, birds, insects, and researcher activity. Before the sampling method development phase of the project began, an area within the Anthropology Research Facility was chosen and prepared for the study. Originally, ARF consisted of a wooden shed built on a concrete slab encaged in a chain linked fence. Built many years ago, the wooden shed

had deteriorated. A Royal pre-fabricated vinyl building was constructed to replace the shed. The building served as a dry shelter for record keeping and storage of project supplies. An area immediately leading up to the building was chosen to place bodies while they were studied. The ground was prepared by covering it with a layer of gravel. This area was well shaded by two large trees. Temperature, humidity, barometric pressure, wind speed and direction, and rainfall were all recorded by a weather station.

Human Remains

The human remains used in the study were donated to the Forensic Anthropology Center at The University of Tennessee Anthropology Department for the purpose of scientific research. Eleven donated bodies were included in the study and each met several criteria: 1) known time of death, 2) known cause of death, 3) received during the fresh stage of decomposition, and 4) unautopsied. Included in the study were seven adult males and three adult females. All individuals were white, non-Hispanic. Ages ranged from 25 to 98 years. Manner of death was natural in all but three case, two suspected drug overdoses and one suicide (Table 2.1). Once received at ARF, the body was examined and its physique, decompositional condition, and demographics were recorded. Ten bodies were then undressed, place supine, and zipped inside a body bag. One body (11-00) was not placed in a body bag. The body bag prohibited animal and bird activity, but the body remained accessible to insects. The first body was received on September 26, 1999 and the study continued until August 29, 2000.

Table 2.1. Scientific Donations Included in the Study.

Identification Number	Age	Sex	Time of Death	Cause of Death/History	Condition of the Body
30.99	65	M	9.25.99	Natural	Black bruise on abdomen, subclavian needle, no signs of decomposition
32.99	97	M	11.9.99	Natural	No signs of decomposition
33.99	94	F	11.12.99	Natural	No signs of decomposition
3.00	43	M	3.20.00 @1503	Strangulation	Extreme congestion of head and neck, small cut on neck.
4.00	56	M	3.22.00 @2115	Natural	Individual thin, edema of right arm, no signs of decomposition
5.00	89	M	Approx. 3.28.00	Natural	Fresh rat gnawing marks on right eye and arm, no additional signs of decomposition
9.00	43	F	4.21.00	Drug Overdose	No signs of decomposition
11.00	55	M	6.13.00	Natural	Eye donor, no signs of decomposition
HC6-99	57	M	3.14.00	Natural	No signs of decomposition
HC7-99	63	M	4.25.00	Natural	Slight discoloration of abdomen lower right quadrant
HC01-99	25	F	8.6.00	Drug Overdose	No signs of decomposition

Methods

Sample Collection

During the early stages of decomposition (fresh, discoloration, and bloating), bacterial proliferation generates rapid, externally visible changes. Samples were collected at approximately 24 hour intervals throughout this period. Once the cadavers entered the skeletonizing stage, the sampling interval was extended to 48 –72 hours. At each sampling event the aroma was collected following the active sampling method (see below). The odor was sampled from the body not placed in a body bag by holding the pipette approximately two inches above the chest of the individual.

The temperature and humidity at each sampling event was recorded, as well as the high and low of each reached during the intersample interval. The rainfall between sampling intervals was also recorded. After the sample was collected, the body bag was unzipped and the condition of the body was noted and photographed. Aroma controls were collected by sampling air from an empty body bag. To stop contamination of the empty body bag it was stored and sampled inside the building.

Following the collection of the sample, the molecular sieve was transferred to a 22 milliliters (mL) vial, 2mL of distilled water were added, and the vial was sealed. The samples were then transferred to Oak Ridge National Laboratory (N4500) and analyzed. The samples and controls collected over several days were analyzed randomly using the Multisampler-SP automative sampler of the Aromoscan ®.

Development of a Sampling Method

The most difficult obstacle in studying odor is transferring the odor as a representative and replicable sample from the field to the laboratory. A further restriction is that the Aromascan® requires the sample to be contained within a 22mL sealed vial. The first step in developing a sampling methodology was to define several criteria required to collect a successful reproducible sample. Three criteria were defined. First, the sampling medium had to absorb the decay aroma at ambient (field) temperature and release it into the vial headspace at analytical temperatures. Second, intra-sampling error had to be minimized. Third, the sampling interval had to be relatively short to capture subtle odor changes.

Sampling Medium Selection

The most obvious method for collecting odor is to dissect a small portion of decomposing tissue and place it in the appropriate vials. Although simplistic, this method fails to collect a representative odor. Each tissue contributes different decay by-products to the odor and not necessarily in equal proportions (Gill-King 1997). Odor resulting from only a few types of tissue may not mirror the smell of a decomposing corpse. With this in mind, the aroma sample clearly had to be taken from the odiferous air surrounding the body and not the tissue. The following sampling media were evaluated: cotton gauze, absorbent disks, and various loose absorbent laboratory materials.

Cotton Gauze

Without being able to use the soft tissue, the first step in the development of a sampling method was to identify a medium capable of trapping aroma in the field and releasing it in the laboratory. Realizing that cotton clothing often traps odors that could be sensed when removed from the odor source, an experiment to test the absorbent capability of sterile cotton gauze was designed. Three gauzes were rubbed over the abdomen of a decomposing cadaver. Each gauze was rubbed over an equal and adjacent area on the abdomen. The sample collecting strokes ranged from the xyphoid process to the umbilicus and back to the xyphiod process. The gauze were then folded and sealed in the 22mL vials. Three controls were constructed by sealing sterile cotton gauze in 22mL vials. Comparison of the experimental and control groups showed remarkable differences between the histogram patterns (Figure 2.1). Although the pieces of gauze were seemingly successful in collecting a sample, the method failed to collect a representative and replicable sample. Wiping the gauze over the abdomen ensured the collection of decay by-products present on the epidermis but not in the air surrounding the body. Furthermore, each pass of gauze over the same area conceivably collects less decay by-product, creating a large amount of intrasampling error. However, the success of this experiment lies in the fact that aroma collected on an absorbent material, cotton, under field conditions was released into the headspace under analytical conditions.

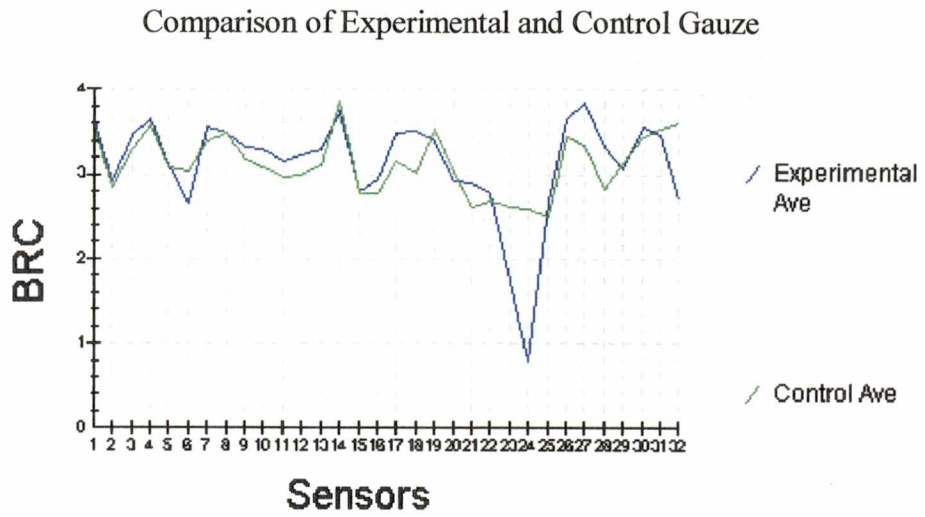


Figure 2.1 Results of the gauze experiment. The experimental and control average is the average of the three respective histograms. BRC is the percentage of base resistance change at each sensor. The aroma pattern is observable differences between the experimental and control group.

Absorbent Disks

A second experiment used absorbent Teflon and fiberglass disks coated with vapor absorbing material. The material of the disks were as follows: C18 / fiberglass, C8 / fiberglass, SDB / fiberglass, C18 / Teflon, C8 / Teflon, carbon / Teflon, and SDB/ Teflon. The disks were placed on the abdomen and loosely covered with plastic wrap to stop rainwater from contaminating the disks. The body was then zipped in a body bag and left undisturbed for 24 hours. Following completion of the sampling interval, the disks were collected and sealed in vials. Controls were constructed by sealing non-sampled disks in vials. Comparison of the sample and control groups illustrated unremarkable histogram differences indicating the disks did not collect significant decay odor (Figure 2.2 and Figure 2.3).

Various Laboratory Materials

A third experiment was designed to test the absorbent property of various common laboratory materials. The investigated materials included drierite, molecular sieve, baking soda, glass beads, cellulose, gauze, chromosorb, silica gel, activated charcoal, xad-7, xad-2, and tenax. One gram of each material was placed in a 22mL vial. The vials were positioned in a wire basket that was in turn enclosed in a nylon stocking, to stop contamination by insects. The samples were then placed next to the cranium of the cadaver and the body bag was zipped closed. After 72 hours of passive sampling the vials were collected from the body bag, 2mL of distilled water was added to each vial and they were sealed. Controls were constructed by sealing one gram of material with 2mL of distilled water in a vial. Comparison of the experimental and control groups showed

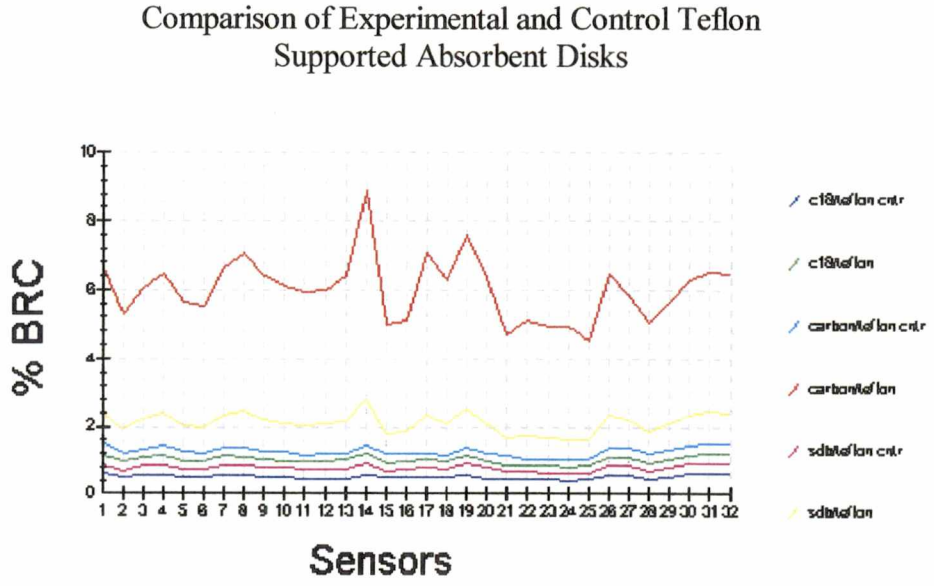


Figure 2.2. Comparison of odor collected on and released from experimental and control (cntr) teflon supported disks. Although the intensity of the carbon/Teflon aroma pattern is observably different than the control the maximum percent base resistance change (%BRC) is less than 10%.

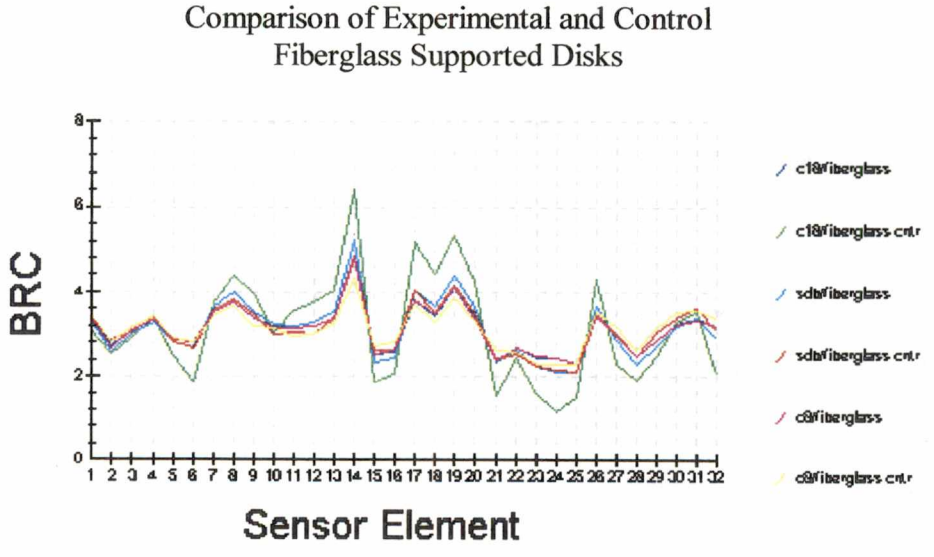


Figure 2.3. Comparison of experimental and control group of fiberglass supported absorbent disks. Very little pattern difference is observed between each experimental disk and its respective control. BRC is the percent of base resistance change.

remarkable histogram differences in six of the twelve materials: molecular sieve, glass beads, drierite, activated charcoal, chromosorb, and silica gel (Figure 2.4 and Figure 2.5). Beyond the remarkable histogram differences, the results of this experiment were significant because the samples were collected from the ambient air in the body bag.

Given the promising results of the previous experiment, a fourth experiment was designed to determine which of the six sampling media collected the most consistent and intense sample. Five one-gram aliquots of each material were placed in 22mL vials. The vials were again lined in the wire basket and enclosed in the nylon sock. The basket was placed next to the cranium of the cadaver and the body bag was closed. The samples were collected from the body bag after 45.5 hours of sampling. Comparison of intensity and variability of the five repeat samples showed that molecular sieve collected the greatest amount of sample with a relatively small intrasampling error (Table 2.2). The remarkable histogram difference between the sample and the control, the amount of sample collected, and the minimal intrasample error indicated that molecular sieve met the first criterion (collect an aroma sample at field temperature and release it at analytical temperature) and the second criterion (minimized intrasampling error) and was chosen as the sampling medium for this study.

Molecular Sieve

Molecular sieve is a crystalline metal aluminosilicate with a three-dimensional interconnecting network of silica and alumina tetrahedra. The sodium 4-8Å mesh

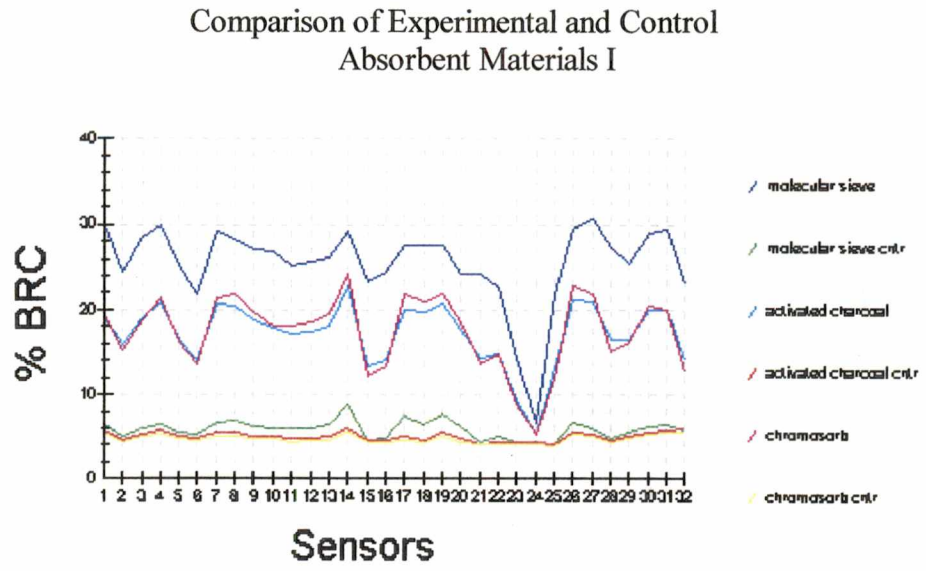


Figure 2.4. Comparison of odor collected on and released from experimental and control (cntr) sampling media. The sample collected with molecular sieve, activated charcoal, and chromosorb generated a large percent base resistance change (%BRC).

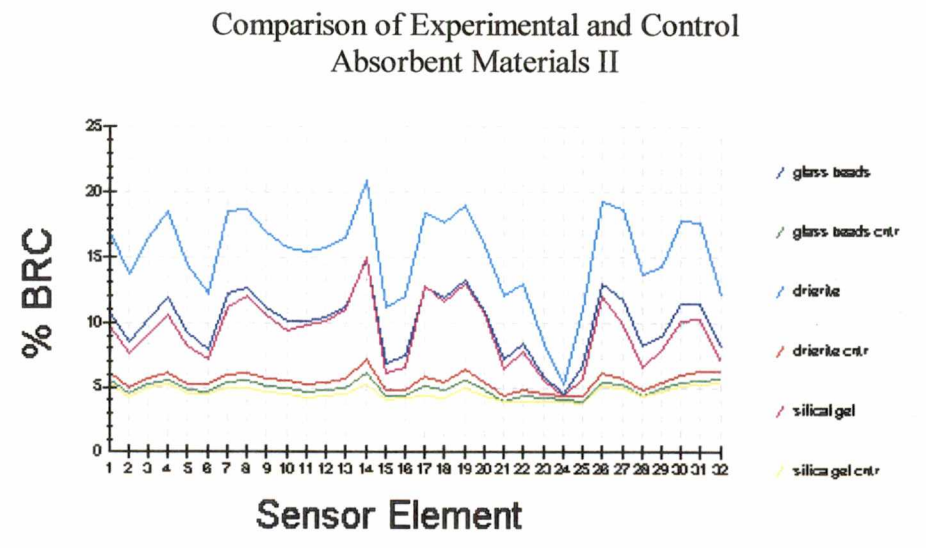


Figure 2.5. Comparison of odor collected on and released from experimental and control (cntr) sampling media. The sample collected with drierite, glass beads, and silica gel generated a large percent base resistance change (%BRC).

Table 2.2. Comparison of Five Replicate Sampling Matrix.

Sampling Material	Total %BRC	Average Total %BRC	Standard Deviation
Drierite	1290	1144	92.8977933
	1080		
	1140		
	1160		
	1050		
Chromosorb	1370	1336	74.02702209
	1390		
	1380		
	1210		
	1330		
Glass Beads	2660	1074.68	1329.896316
	43		
	241		
	39.4		
	2390		
Molecular Sieve	2590	2882	255.9687481
	2750		
	3190		
	3110		
	2770		
Silica Gel	245	1097.4	1896.690618
	213		
	255		
	4490		
	284		
Activated Charcoal	671	692	16.2080227
	699		
	679		
	706		
	706		

The total percent base resistance change (%BRC) is the sum of each sensor response to the sample.

bead sieve is used in this study. This form is generally considered a universal drying agent in polar and nonpolar media and recommended by the distributor, Aldrich, for gas phase applications. Conditioning requires slow-heating of the sieve to 200-315°C. The molecular sieve was conditioned by heating it to 250°C in a convex oven for 48-72 hours prior to use.

Sampling Apparatus

Active Sampling

During the sampling medium selection process, the samples were collected passively by placing vials containing sampling medium inside the body bag. This method required lengthy sampling intervals: 72 and 45.5 hours. To reduce the sampling time, an active sampling system was designed. The active sampling system connected a 40mL borosilicate vial to the inflow nozzle of a Du Pont air pump. The sampling medium was placed within the vial. The system pulled air held within the body bag through the vial containing the molecular sieve. Access to the interior of the body bag, without releasing the contained air, was gained by cutting a small hole near the cranium of the corpse.

Before comparison of the active and passive sampling methods, the optimal sampling conditions of the active system were defined. Three flow rates, 10, 100, and 1000 mL / minute, and three sampling intervals, 5, 10, and 15 minutes were compared. Three repeat samples were sequentially collected at each flow rate and sampling interval. The 15 minute sample interval collected a more intense sample at all three flow rates, with the greatest amount of sample collected with the 15 minute sampling interval

(Figure 2.6). Given these results, a 15-minute sampling interval at a flow rate of 1000 mL/minute was determined to be the optimal sampling condition for the active sampling system.

The sampling time was decreased by connecting three glass pipettes, each containing 1.5 grams(g) of molecular sieve, to the inflow nozzle of the air pump. This alternative sampling apparatus enabled three repeat samples to be collected simultaneously, possibly further reducing intrasampling error. To accommodate the three pipettes, each containing a greater amount of molecular sieve, the inflow rate of the pump was increased until 1000 mL/minute pulled through each pipette.

An experiment was designed to determine which of the two variations of the active sampling system (vial or pipettes) collected the greater amount of sample. Three samples were collected with the pipette system using 1.5g of molecular sieve over a 15 minute interval. Six samples were consecutively collected with the vial system over a 15 minute sampling interval; three vials contained 1.0g of molecular sieve and three vials contained 1.5g of molecular sieve. Directly comparing the percent base resistance change showed the pipette system collected a more intense sample (Figure 2.7). In sum, the optimal active sampling conditions based on the results of the previous experiments required using the pipette apparatus with the air pump flow rate set at 1000mL/minute for a 15 minute sampling interval.

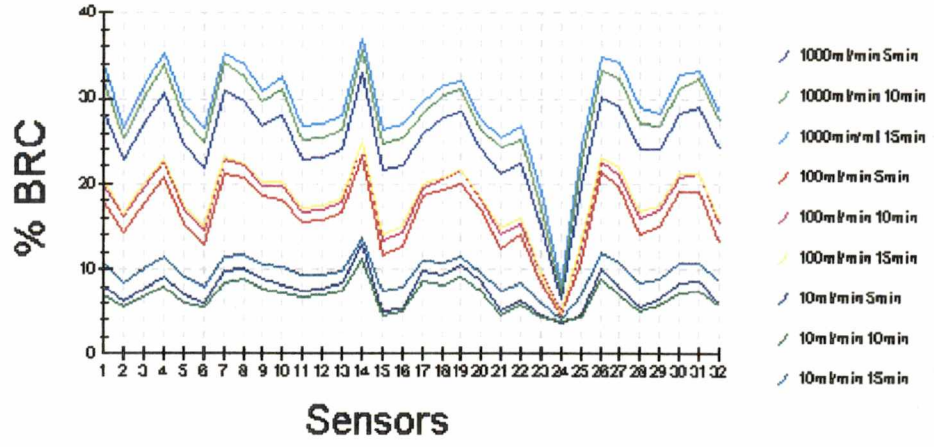


Figure 2.6. Plot illustrating the percent of base resistance change (%BRC) resulting from samples collected at several flow rates and time intervals. Each series is the average of three repeat samples. The greatest amount of sample was collected at a flow rate of 1000mL/minute with a sampling interval of 15 minutes.

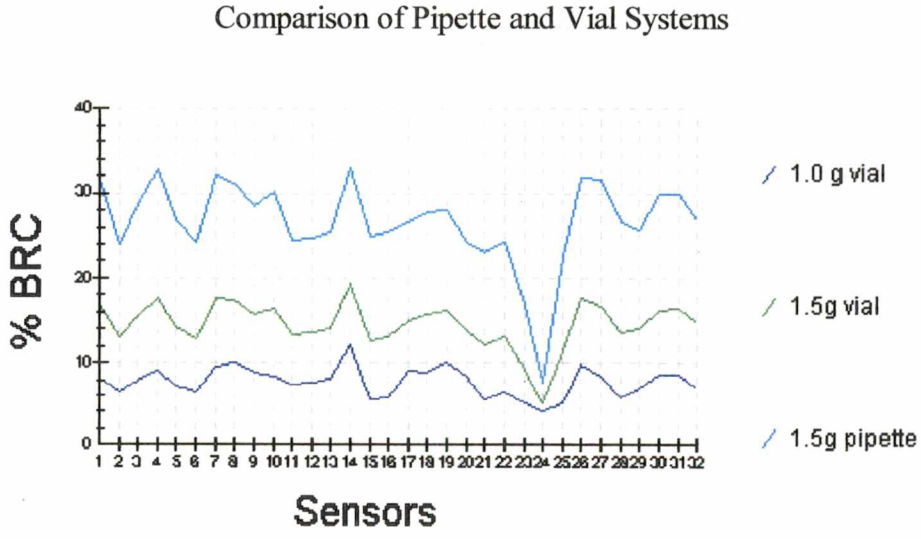


Figure 2.7. Plot comparing the intensity (through total percent base resistance change (%BRC))of the sample collected with the pipette and vial active sampling system. Each series represents the average of three repeat samples. The pipette system collected more intense samples.

Comparison of Active and Passive Sampling Methods

Finally, an experiment was designed to directly compare the active and passive sampling methods. Three active samples were collected following optimal active sampling conditions. Six vials each holding 1.5 g of molecular sieve were then secured in a wire basket, enclosed in a nylon sock and placed next to the cranium of the cadaver. The body bag was then closed. After one hour of passive sampling, three of the vials were removed from the body bag. Twenty-three hours after passive sampling began, three samples were actively collected over a one hour sampling interval. After the one hour active sample was completed the final three passive samples were collected from the body bag. Comparison of the base resistance change showed that the active sampling method collected a more intense sample in 15 minutes than the passive sampling method collected in 24 hours (Figure 2.8). The one hour active sampling interval collected only a slightly more intense sample then the 15 minute active sampling interval showing a sampling interval longer than 15 minutes was not necessary. Based on these results, the active sampling method proved to be the more efficient method and met the third criteria, a short sampling interval.

Each pipette held 1.5 grams of molecular sieve. Given this fact, designing an experiment to test odor intensity collected with various quantities of material was unnecessary.

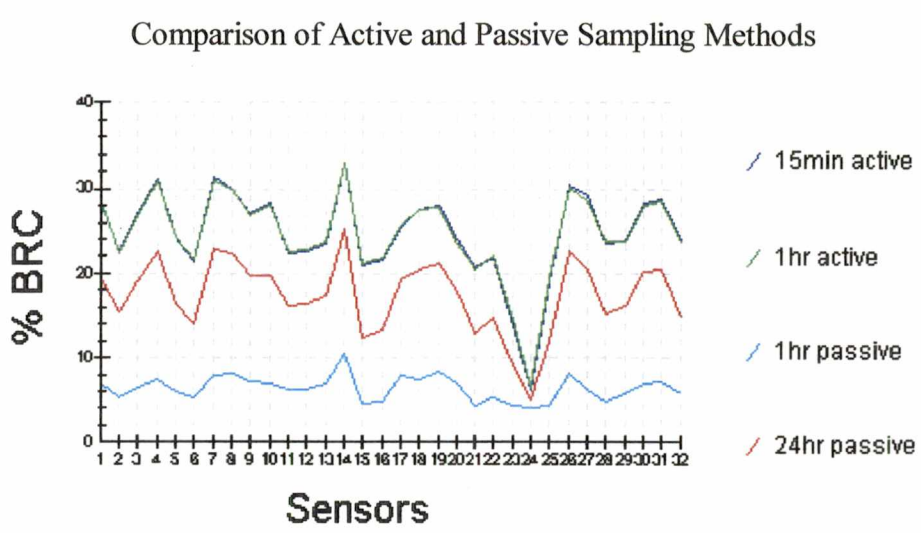


Figure 2.8. Plot illustrating the percent of base resistance change (%BRC) resulting from samples collected with the passive and active sampling methods over various sampling intervals. Each series represents the average of three repeat samples.

The Aromascan®

Sample Preparation

When analyzing a sample that contains moisture the Aromascan® manufacturers suggest setting the relative humidity at 50%. However, when a sample does not contain moisture the relative humidity should be much lower. The aroma samples contained moisture, but the controls did not, preventing analyzing the two types of sample with the same analytical conditions. In order to circumvent this problem, two milliliters of distilled water was added to all the samples. An experiment was designed to define the effects of the distilled water on the experimental samples. Four repeat samples of the aroma were passively collected with one-gram of molecular sieve. Two milliliters of

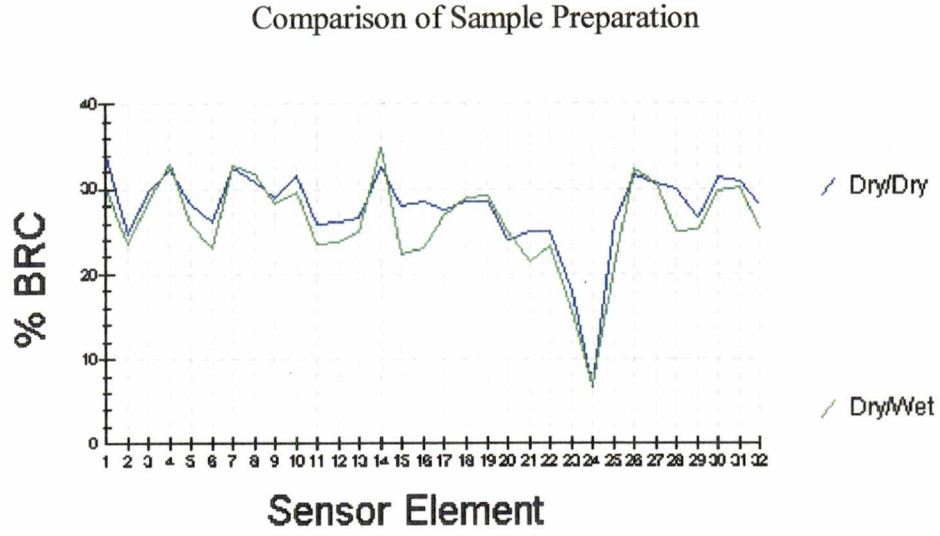


Figure 2.9. Plot illustrating the difference percent base resistance change (%BRC) when comparing sensors prepared with adding water after sampling (Dry/Wet) and the without adding water (Dry/Dry).

distilled water were added to two of the four vials. Two controls were also collected with water added to only one. Direct comparison of the dry and the wet samples showed that the resulting histograms were nearly identical (Figure 2.9). However, when the dry control was run at 50% relatively humidity several of the sensors registered negative percent base.

The final sampling method was portable, uncomplicated, and relatively inexpensive. In sum, 1.5 grams of molecular sieve were placed in nine inch disposable glass pipette. Three pipettes were simultaneously connected to the inflow nozzle of a Du Pont air pump. The air pump was set at a flow rate of 1000mL/minute. The tips of the three pipettes were placed through a small hole cut in the body bag near the cranium of the cadaver and left undisturbed for a 15 minute sampling interval. Immediately

following the collection of the sample, the molecular sieve was transferred to a 22 mL vial, 2 mL of distilled water were added, and the vial was sealed. Controls were collected using the same sampling method, sampling air contained within an empty body bag. The results of this multistep experimental process met the initially stated parameters and criteria defining a successful sampling method. The molecular sieve collected cadaver aroma at field temperatures and released the aroma during analysis. The active sampling method collected a representative and repeatable sample within a relatively short sampling interval and with minimal intrasample error. Furthermore, the sample was easily transferred to the vial required by the Aromascan® instrument.

Instrumentation

Odors are very important to mammals, not only keying food and danger, but even evoking emotions and behaviors (Ronhi 1996). Both the food industry and consumers recognize the importance of odor to product preference. "The many hundreds of volatiles which make up odor are by far the most important in defining product type and individual preferences" (Hodgins and Simmonds 1995: 179). Recently, the field of forensics has become aware of the potential importance of odor in the detection of fire accelerants, drugs of abuse, and cadavers (Barshick et al. 1995, Zanoni et al. 1998). Advancements in the food and consumer industry and more recently the field of forensics have generated a need to develop technologies capable of quantitative odor analysis.

Prior to the development of an appropriate instrument, odor analysis was carried out using a human panel (Moy et al. 1994). Each individual in the panel smelled and described various products and foods. Although efficient for product development, this

technique was inadequate for product control (Moy et al. 1994).

Gas Chromatography / Mass Spectrometry

Initial attempts to standardize odor analysis employed gas chromatography and mass spectrometry (GC/MS) techniques (Hodgins and Simmonds 1995: 179). The GC/MS traps a sample onto a GC column. The components of the sample thermally desorbs from the column at specific temperatures. As the compounds are released from the column they are identified by their molecular mass. GC/MS analysis of odor is limited in two ways. First, the analytical time is lengthy. Second, the separatory function of the chromatograph measures the molecular concentration of the sample. Humans do not register odor through breaking down its complex composition, but rather process it as a single pattern (Moy et al. 1994). Furthermore, the odor pattern is not dependent on uniform molecular concentration but rather the concentration of a few significant electrically charged elements. Volatile compounds that trigger strong sense response generally have a strong electric charge (i.e., sulfur derivatives, amines, oxygenated compounds, and unsaturated molecules); hence minor peaks as defined by GC/MS may contribute largely to the overall odor (Moy et al. 1994).

Electronic Nose

In order to accurately analyze odor, an instrument must meet two criteria: 1.) detection of volatile compounds at very low concentrations and 2.) respond strongly to odorant molecules with strong electrically charged components (Moy et al. 1994). (The detection rate of the human nose is estimated at one part per billion (Hodgins and

Simmonds 1995). The detection rate of lower mammals is thought to be even more sensitive (Ronhi 1996)). Conduction polymer gas sensors, the analytical component of an electronic nose, meet both criteria. The polymer gas sensors, comprised of a conducting polymer, counterion, and solvent, are formed by the electropolymerization of a thin film of silicon substrate between two electrodes, creating a simple resistor (Moy et al. 1994, Hodgins and Simmonds 1995). The resulting polymer, i.e. polypyrrole, is in an oxidized form containing cationic sites balanced by anions from the electrolytes creating an electrically conductive composite. The sensor reacts via electron transport at the cation sites. The conductivity is sensitive to the electron donating or withdrawing property of a compound, altering the electrical resistance of the sensor (Hodgins and Simmonds 1995). The measured change of electrical resistance of the sensor is the output of the instrument. Sensors vary by the type of polymer, counterion, or solvent. The various components dictate the response of the sensor to components of the vapors (Moy et al. 1994).

The Aromascan®

An array of polymer sensors working in concert is needed to successfully analyze a complex headspace containing thousands of odorants. Aromascan®, the electronic nose used in this study, has an array of 32 conducting polymer sensors. Each sensor has a different polymer structure, dictating its reactivity to various classes of compounds (Table 2.3). The array of polymer sensors exhibits a broad-band response to many thousands of chemical species. The Aromascan® is connected to a MultiSampler-SP, an automative sampler designed to consistently condition each sample, a crucial component

Table 2.3. Selectivity Characteristics of the Sensor Array.

Sensor	Amines	Short Chain Alcohols	Long Chain Alcohols	Carboxylic Acids	Aromatics	Chlorinated Hydrocarbon	Short Chain Esters	Long Chain Esters	Ketones	Water
1	M	M	N	M	N	N	N	N	W	M
2	M	M	M	M	M	M	M	M	M	M
3	M	M	W	M	W	W	W	N	W	M
4	W	M	W	W	W	W	M	N	W	M
5	M	M	W	M	N	N	W	N	W	M
6	W	M	W	W	N	N	N	N	W	M
7	S	M	W	S	N	N	W	N	W	M
8	M	M	W	M	N	N	W	N	W	M
9	M	M	M	M	M	M	M	M	M	M
10	M	M	M	M	M	M	M	M	M	M
11	M	M	M	M	M	W	M	W	M	M
12	M	M	M	M	M	M	M	M	M	M
13	M	M	M	M	M	M	M	M	M	M
14	M	M	W	M	N	N	W	N	W	M
15	M	M	N	M	W	W	W	N	W	M
16	M	M	N	M	N	N	W	N	W	M
17	M	M	S	M	S	S	S	V	S	M
18	M	M	V	M	V	V	S	V	S	M
19	M	M	M	M	W	W	M	W	M	M
20	M	M	M	M	M	M	M	M	M	M
21	M	M	W	M	W	W	M	W	M	M
22	W	M	V	W	V	V	S	V	S	M

Table 2.3. Selectivity Characteristics of the Sensor Array (Cont.).

23	W	M	V	W	V	V	S	V	S	M
24	N	M	S	N	V	V	S	V	S	M
25	M	M	M	M	M	M	M	M	S	M
26	M	M	M	M	M	M	M	M	M	M
27	M	M	M	M	M	M	M	W	M	M
28	M	M	N	M	N	N	N	N	W	M
29	M	M	M	M	M	M	M	M	M	M
30	M	M	W	M	W	W	W	N	W	M
31	W	M	W	W	W	W	M	N	W	M
32	W	W	N	W	N	N	N	N	N	M

V = Very Strong (R > 9%) W = Weak (1% <R < 2%)
S = Strong (5% < R < 9%) N = Negligible (R < 1%)
M = Medium (2% < R < 5%)
Note: Resistance (R) of sensors decrease when exposed to carboxylic acids.

of successful odor comparison (Figure 2.10 and Table 2.4).

The Aromascan® was designed to correct for temperature variation across the sensor array and dead volume. There are two weakness common to electronic nose technology. The electrical resistance of the conducting polymer sensors are temperature sensitive. The Aromascan® sensor array is supported by a ceramic substrate that is in direct contact with a heating element. The sensors are placed in an area of less then $2cm^2$. The small size of the ceramic substrate ensures temperature control of $\pm 0.1°C$ across the sensor array. Furthermore, the electrical current to the circuit board is supplied by a single edge connector that minimizes the electrical noise within the system (www.aromascan.com). Over time the electrical resistance of each sensor changes as it deteriorates. In order to control for this variability, the Aromascan® calibrates each sensor's electrical resistance prior to the introduction of the sample.

Dead volume, the area of space existing over the sensors, effects the distribution of the samples over the sensor array. The smaller the dead volume, the more reliably the volatiles are distributed across the sensor array, which enables all the sensors to react to the headspace simultaneously. The dead volume of the Aromascan® is less then 1mL which is a relatively small volume.

Sample Analysis

Analysis of each sample is accomplished through a multi-stepped process. Initially, approximately one gram of solid or powder sample is placed in a 22 mL sampling vial constructed from inert glass. The vial is sealed with a septum and a

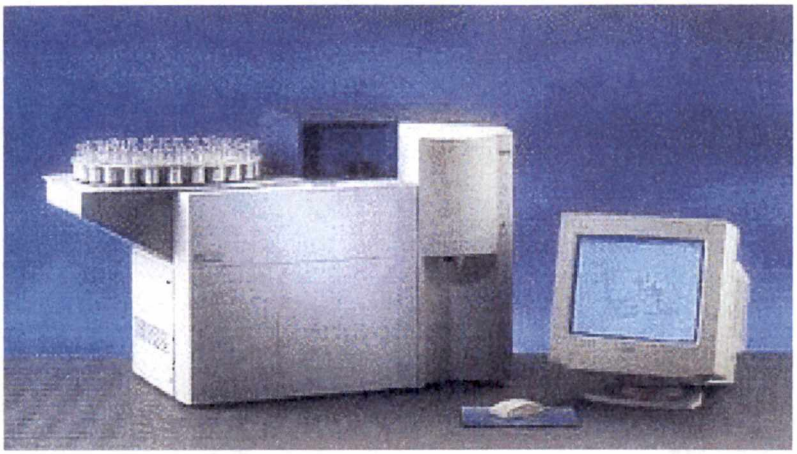


Figure 2.10. The Aromascan®, consisting of an electronic nose connected to the Multisampler-SP.

Table 2.4. Performance Specifications of Multisampler-SP

Parameter	**MultiSampler-SP**
Temperature range	Ambient +15°C to 150°C
Humidity range	20-50% relative humidity at 30° 20 psi
Humidity stability	±.02% relative humidity
Sampling methods	Dynamic Headspace (sparging, bubbling the sample with a long needle, or stripping, sampling the head space with a short needle)
Sampling containers	22 ml glass vials
Capacity	50 samples (49 samples + 1 wash vial)
Throughput	Time between samples is sample dependent
Repeatability – within a day	0.25% repeatability without calibration; 10 measurements per month for 9.5 months; normalized pattern of all 32 sensors
Long-term repeatability	1.25% repeatability without calibration; 5 measurements per month for 9.5 months; normalized pattern of all 32 sensors

www.aromascan.com

crimped cap. The vial is then heated by the platen temperature to a predetermined optimal temperature for a set equilibration time. The temperature can be set between ambient and 150°C. During the equilibration time, nitrogen gas is introduced into the vial at a constant flow rate through a dual concentric needle. The headspace is then extracted from the sample vial and transferred to the sensor array via a transfer line. The sensor array and transfer line are held at constant temperatures. Prior to the purging of the sample headspace ultra-pure nitrogen gas is pulled over the sensors for 30 seconds. The sensors zero their resistance values during this time, calibrating the sensors. The sample headspace is then pulled across the sensor long enough for a stable pattern to be established. Water vapor is then passed over the sensors to remove any residual volatiles from the sensors and transfer components. Finally, the change in sensor electrical resistance experienced during sampling is displayed as a histogram. Pooling the sensor specific histograms into a single plot generates a pattern or fingerprint of the odor.

For the cadaver odor study the analytical conditions of the Aromascan® were set as follows: 30°C platen temperature, 50% relative humidity, 15 minute equilibration time, and a 10 minute wash with isopropanol. Although the temperature could be set as high as 150°C, the manufacturers recommended not setting the temperature above 30°C when analyzing samples that contain moisture. Keeping the platen temperature well below the boiling point of water ensured minimal moisture was released from the samples slowing the deterioration of the sensors (Aromascan®, personal communication). Again because of the moisture within the samples, the manufactures of the instrument recommend setting the relative humidity to 50%. The sample equilibration time was set at 15 minutes, and the sample time was set at three minutes. Fifteen minutes is longer than

suggested by the Aromascan® manufacturer for equilibration of a sample, but given the nature of the sampling procedure (eluting odor from the molecular sieve), the researcher felt the longer equilibration time was necessary. Furthermore, the results of the analysis showed that a three minute sampling time was sufficient to establish a stable pattern. Finally, the sensors were washed for 10 minutes using 2% isopropanol solution. The relatively long wash time was necessary given the adherent property of several of the volatile compounds found in cadaver odor, ie., cadaverine and putrescine.

In sum, following the manufacturers recommendations, the conditions of the Aromascan® and MultiSampler-SP were set as follows: 30°C platen temperature, 50% relative humidity, 15 minute sample equilibration time, 3 minute sample time, and 10 minute wash time. The analytical conditions were sufficient to obtain a stable odor pattern and to remove residual sample from the sensors.

Aromascan® Statistical Analysis

As previously mentioned, the output of the Aromascan® is a histogram of the change in electrical resistance as each sensor responds to the complex headspace. The Aromascan® is equipped with several methods to statistically compare two or more aroma patterns. The difference in sensor response between two odor patterns is statistically defined through Euclidean Distance (ED), a sum of the squares function:

$$(ED)^2=\Sigma_1^{32}(x-x^1)^2$$

Where x is the response of the sensor element n to sample A;
x^1 is the response of the sensor element n to sample B.

To compare more than two odor patterns the Aromascan® is equipped with linear and nonlinear mapping techniques: principal component analysis (PCA) and Sammons mapping technique. Odor analysis with an array of sensors generates multi-dimensional patterns. Visually recognizing structural relationships in multi-dimensional space is extremely difficult. In order to examine complex data of this nature the high-dimensional pattern space of the data must be translated into low-dimension pattern space without great loss of the special relationships. There are several ways to transform high-dimensional data into low dimensional data. The Aromascan® is equipped with a principal component analysis (PCA), a powerful linear mapping algorithm to cluster and classify volatile chemicals (Persaud 1995). However, the response of the sensor array generates a nonlinear multi-dimensional pattern structure which contain concentration-independent pattern data sets making a nonlinear mapping technique more efficient in accurately classifying gases and odors (Persaud 1995). The Aromascan® is also programmed with the Sammons mapping technique, a nonlinear mapping function. The Sammons mapping technique is an effective method of multivariate data analysis which allows visual display of multi-dimensional patterns on a two-or three-dimensional pattern. The Sammon technique has been compared to linear mapping techniques, such as eigenvector projection, using twenty Gaussian-generated clusters located in a nineteen-dimensional space, and showed the Sammon technique to give superior results (Sammon 1970).

Finally, Aromascan® software is designed to easily export the electrical resistance change experienced by each sensor at second intervals to alternative statistical

programs. Using the exported data, the results of the odor analysis can be studied with many statistical tests.

In addition to the comparison of two or more aroma patterns the system can be trained to recognize aromas through a neural network. During the training of the system, the sensors analyze a variety of samples that represent the different conditions of a substance. The user identifies each aroma pattern for the system. Accuracy of pattern recognition is dependent on the extent of training (www.aromascan .com). An unknown sample is then analyzed. The system compares the unknown aroma pattern to the database and matches it to an identified pattern. The confidence of the recognition is then reported as a percentage. If the pattern is not recognized the system will report it as "Unknown". The downfall of the neural network is each sensor array perceived odor differently. The sensor array has a limited lifetime, deteriorating with use. After changing the sensor array the neural network must be retrained.

Statistical Analysis

Odor Pattern Summarization

In order to compare the aroma intensity of the eleven bodies studied, the intensity of each sample as registered by the Aromascan® was summarized as the total base resistance change (BRC). The conversion of the sample intensity was accomplished by totaling the electrical charge of the sample as recognized by each sensor during a 30 second interval. The 30 second interval was a slice of the three minute of sample

analysis. The sample pattern remained stable during the thirty second interval which indicated the interval represents the sampling run. The sensors' electrical response to the sample were measured and recorded every second during the run interval. Totaling the 32 sensors electrical response over the thirty second interval generates a single number, the total base resistance change (BRC), which summarizes the aroma intensity of the sample.

The rate of decomposition is hypothesized to be dependent on temperature. Hence the concentration of volatile compounds produced by bacterial activity is hypothesized to be dependent on the accumulated degree days (ADD). In order to test this hypothesis the total base resistance change of each sample was correlated to the ADD. The initial step plots BRC against ADD to illustrate any elementary pattern (Figures 2.11-2.21) and to correlate BRC to ADD (Table 2.5). Three repeat samples were collected at each sampling event. The base resistance change of all three samples was plotted to illustrate intrasampling error. A basic pattern is recognizable in the plots of bodies HC6-99, HC7-99, 3.00, 4.00, 5.00, and 9.00, where a spike in BRC is present around 200 ADD then a slow decrease or fluctuation in BRC. The samples collected from the other bodies fail to form a similar pattern. Given this initial starting point, the goals of the statistical analysis were to determine why the correlation between BRC and ADD was highly variable, and what additional environmental or non-environmental conditions are affecting the intensity of the aroma sample. The BRC was exported to SPSS Statistical Program for Windows 98 for statistical analysis.

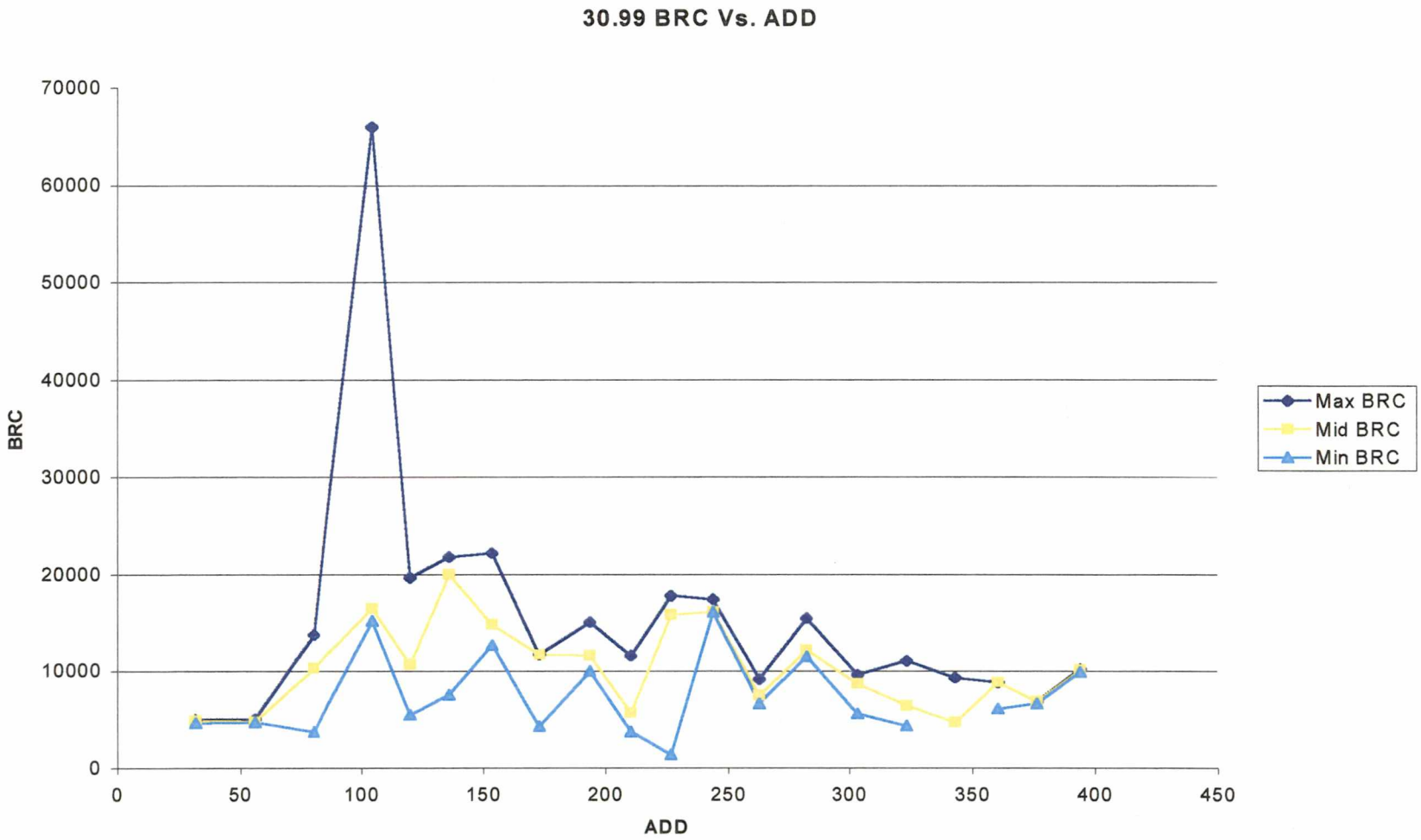


Figure 2.11. Plot of base resistance change (BRC) against accumulated degree days (ADD) for cadaver 30.99. Each data point represents one of the three sample collected during a sampling event.

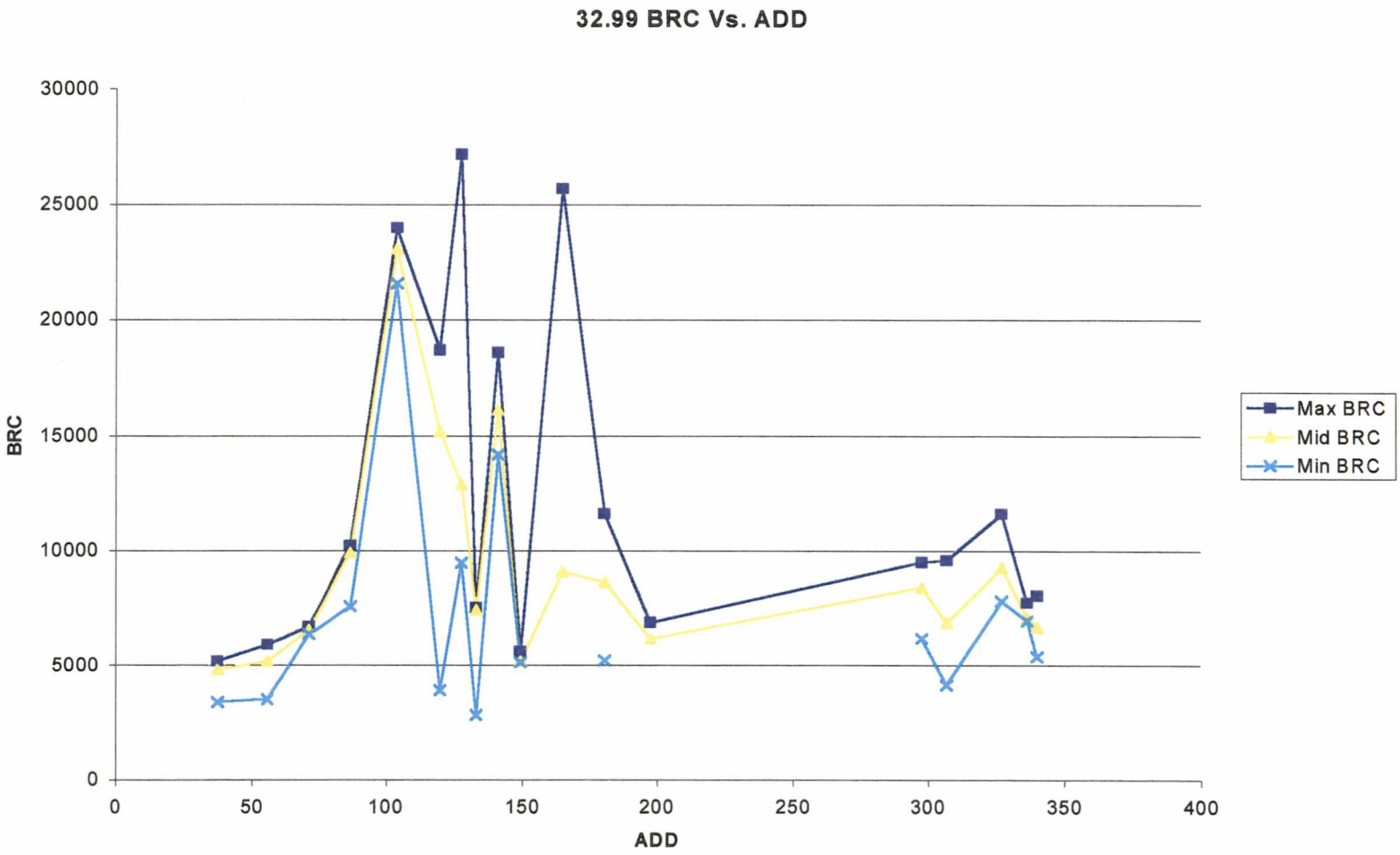


Figure 2.12. Plot of base resistance change (BRC) against accumulated degree days (ADD) for cadaver 32.99. Each data point represents one of the three sample collected during a sampling event.

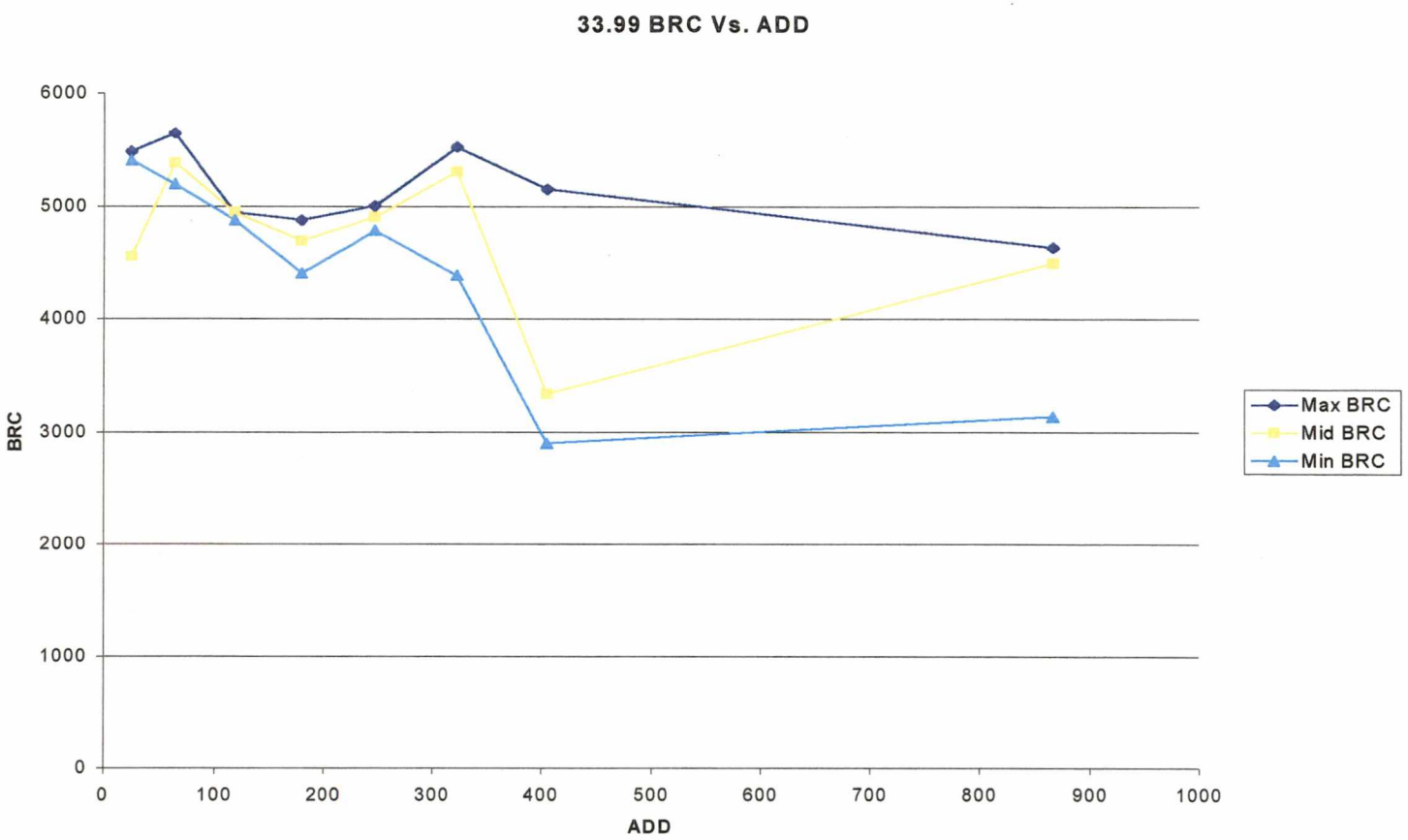


Figure 2.13. Plot of base resistance change (BRC) against accumulated degree days (ADD) for cadaver 33.99. Each data point represents one of the three sample collected during a sampling event.

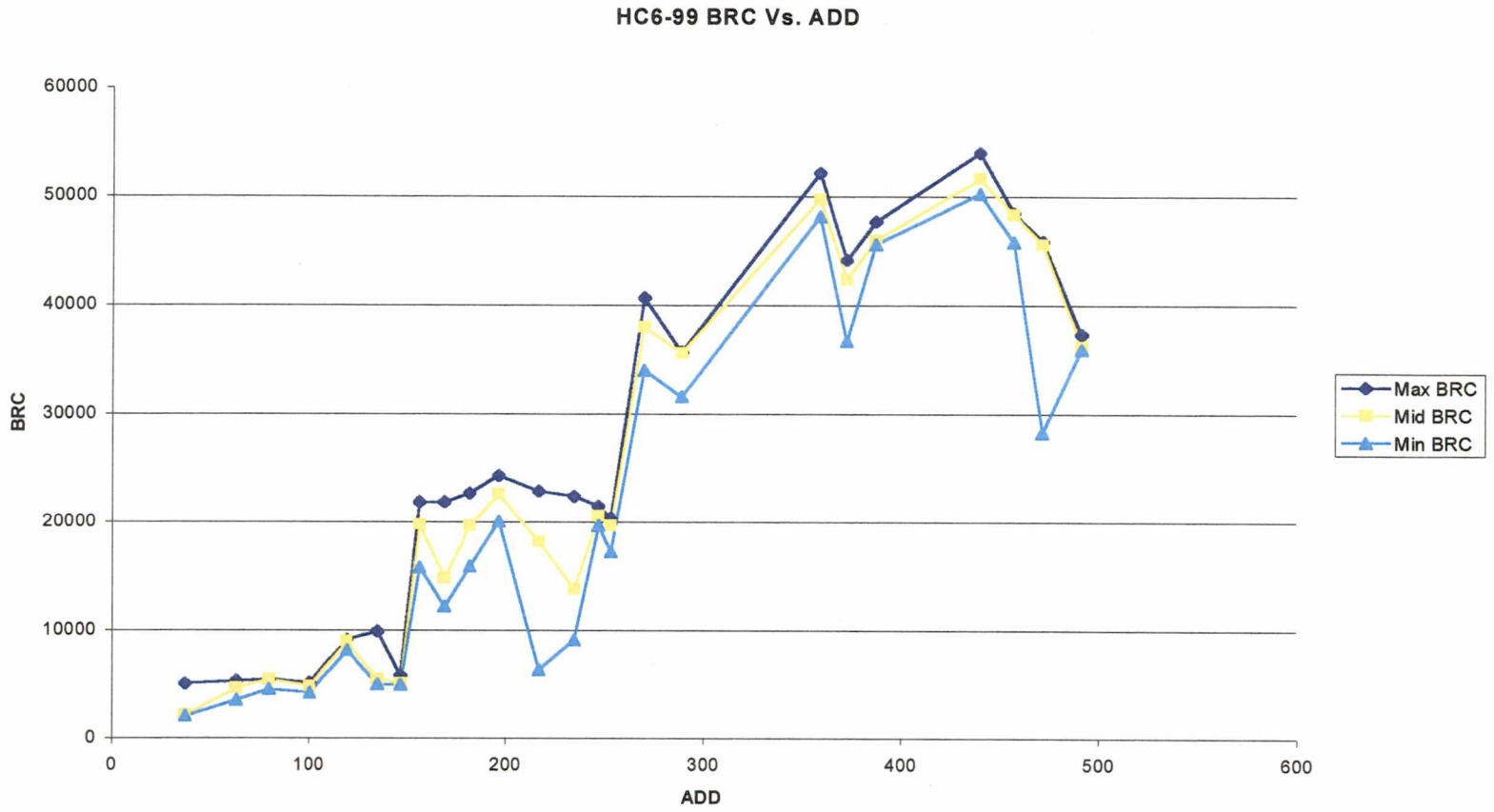


Figure 2.14. Plot of base resistance change (BRC) against accumulated degree days (ADD) for cadaver HC6.99. Each data point represents one of the three sample collected during a sampling event.

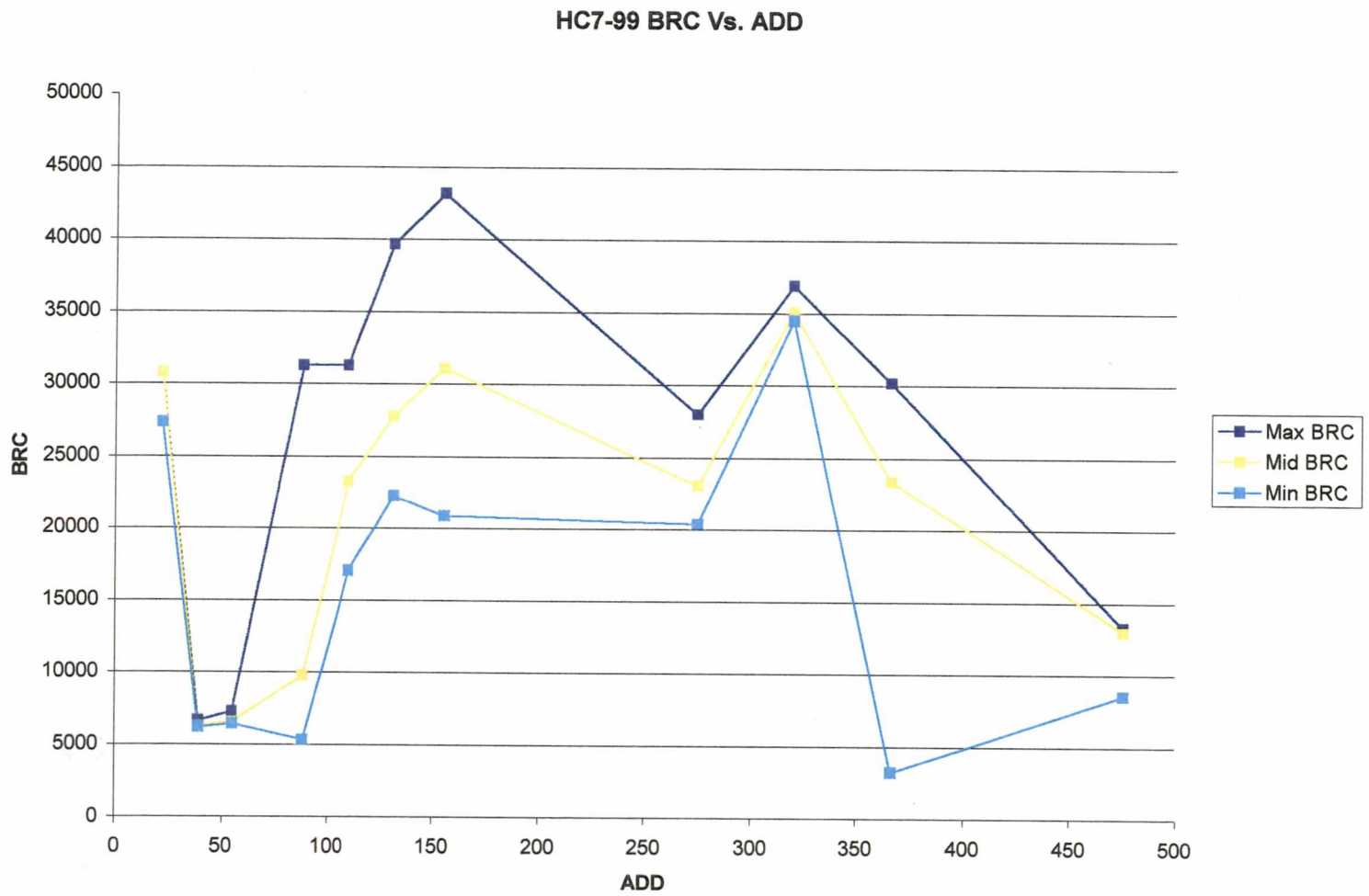


Figure 2.15. Plot of base resistance change (BRC) against accumulated degree days (ADD) for cadaver HC7.99. Each data point represents one of the three sample collected during a sampling event.

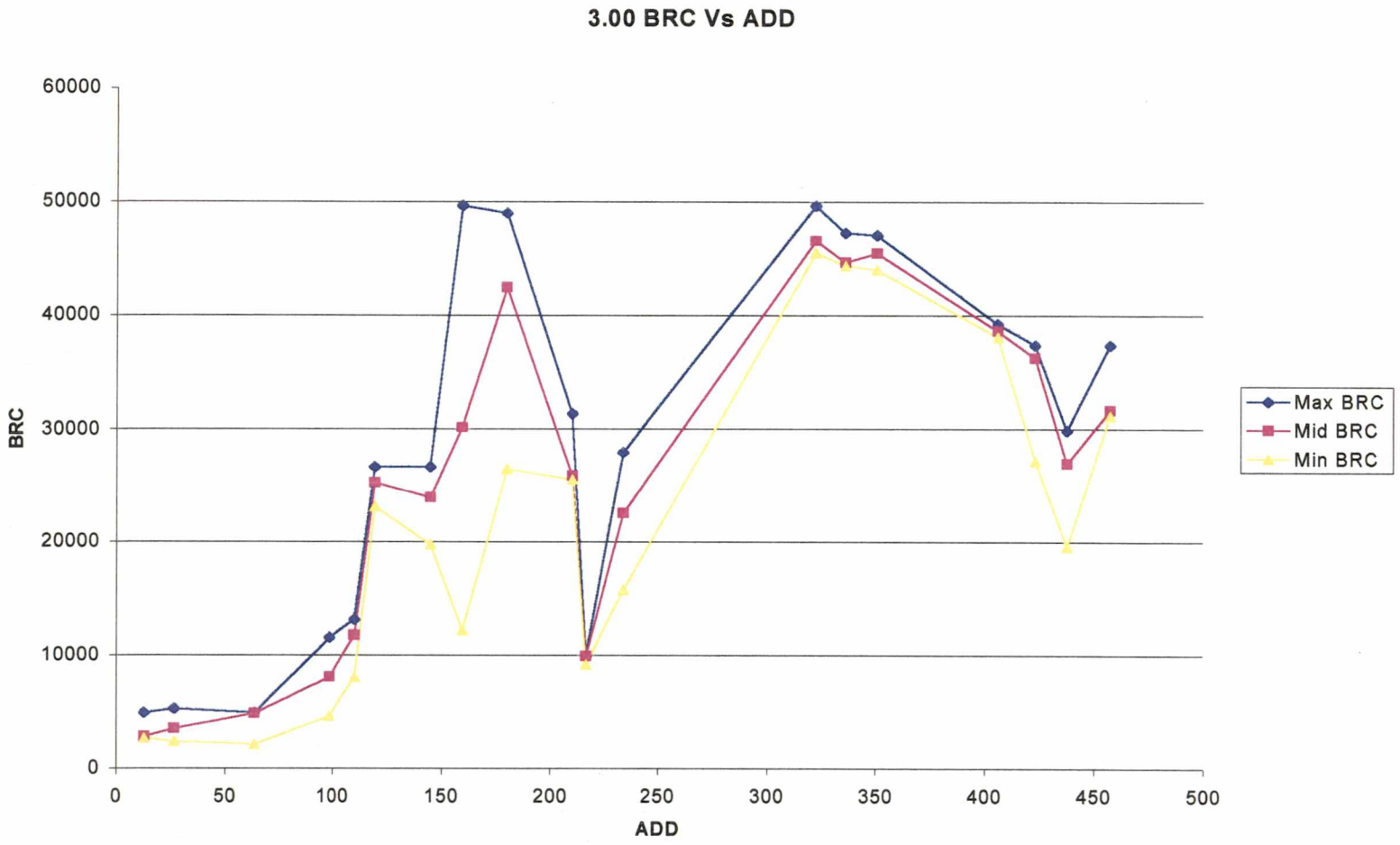


Figure 2.16. Plot of base resistance change (BRC) against accumulated degree days (ADD) for cadaver 3.00. Each data point represents one of the three sample collected during a sampling event.

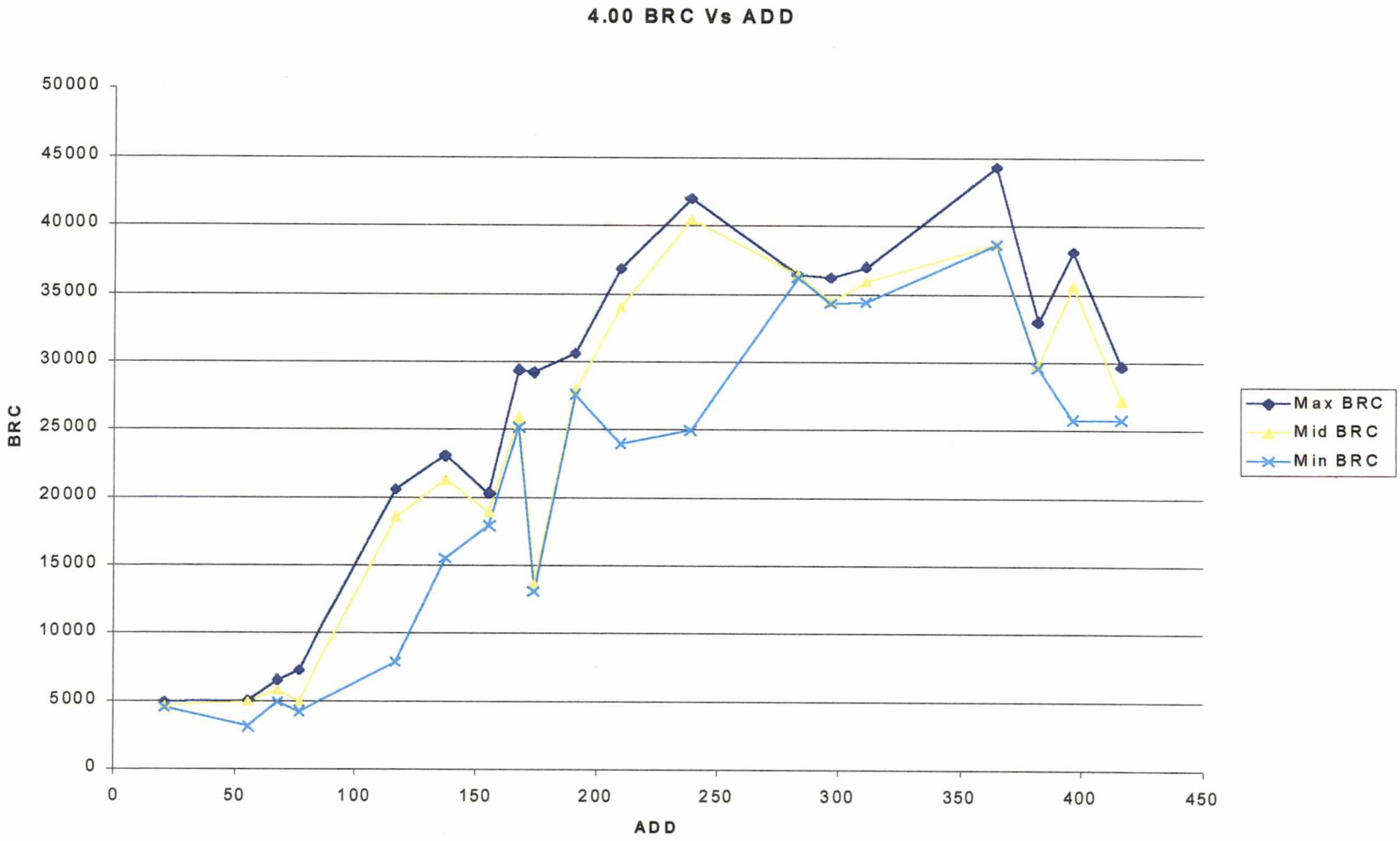


Figure 2.17. Plot of base resistance change (BRC) against accumulated degree days (ADD) for cadaver 4.00. Each data point represents one of the three sample collected during a sampling event.

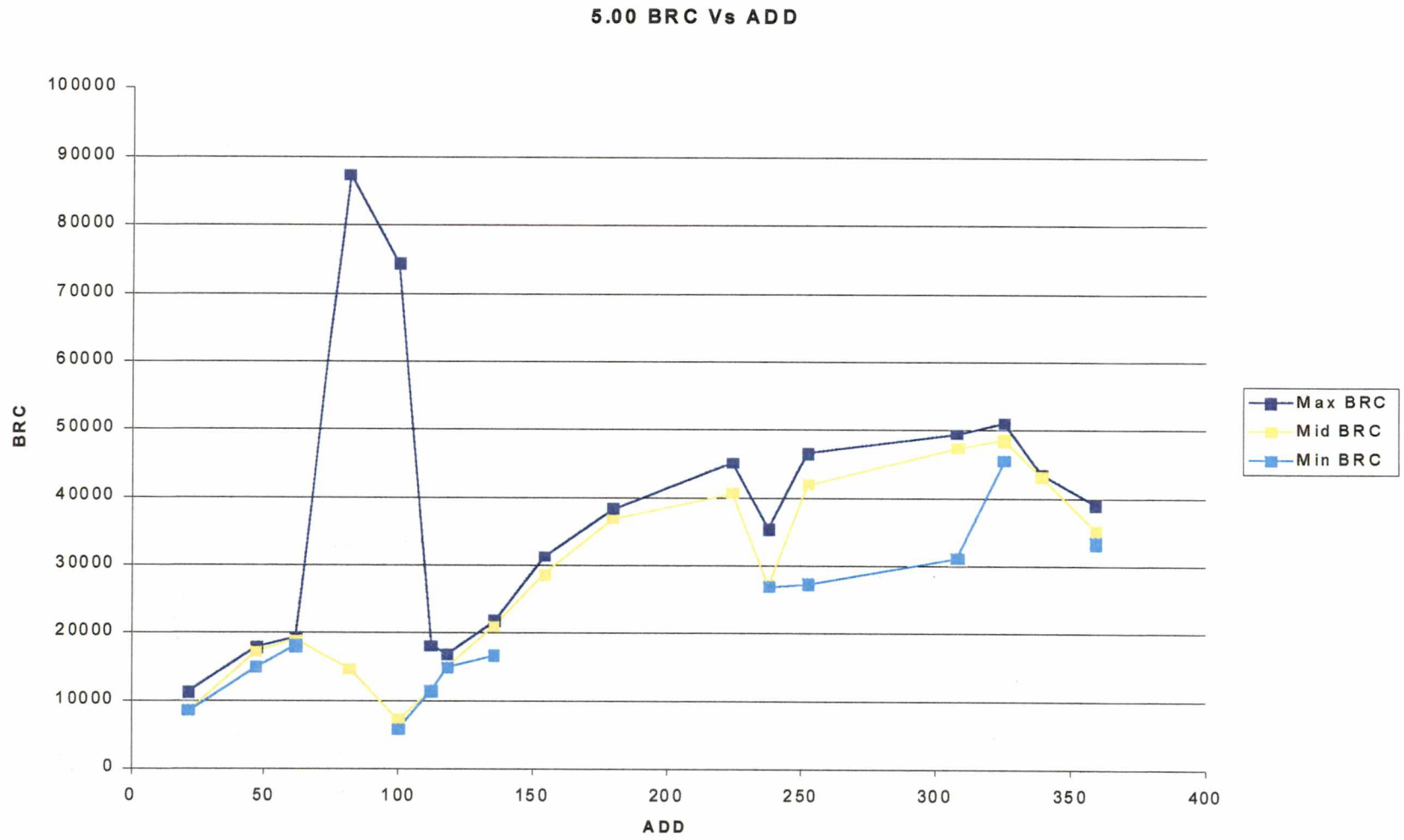


Figure 2.18. Plot of base resistance change (BRC) against accumulated degree days (ADD) for cadaver 5.00. Each data point represents one of the three sample collected during a sampling event.

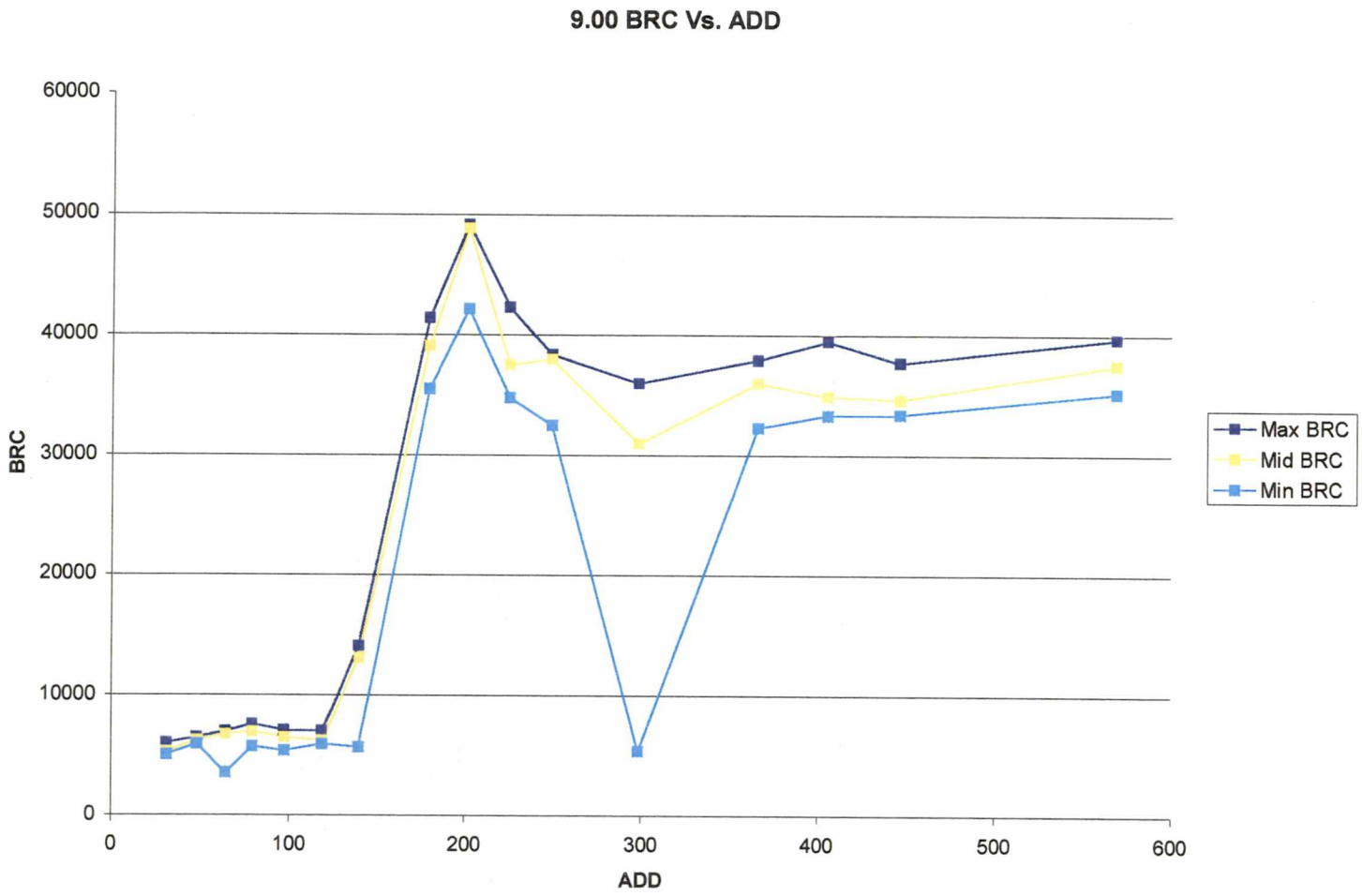


Figure 2.19. Plot of base resistance change (BRC) against accumulated degree days (ADD) for cadaver 9-00. Each data point represents one of the three sample collected during a sampling event.

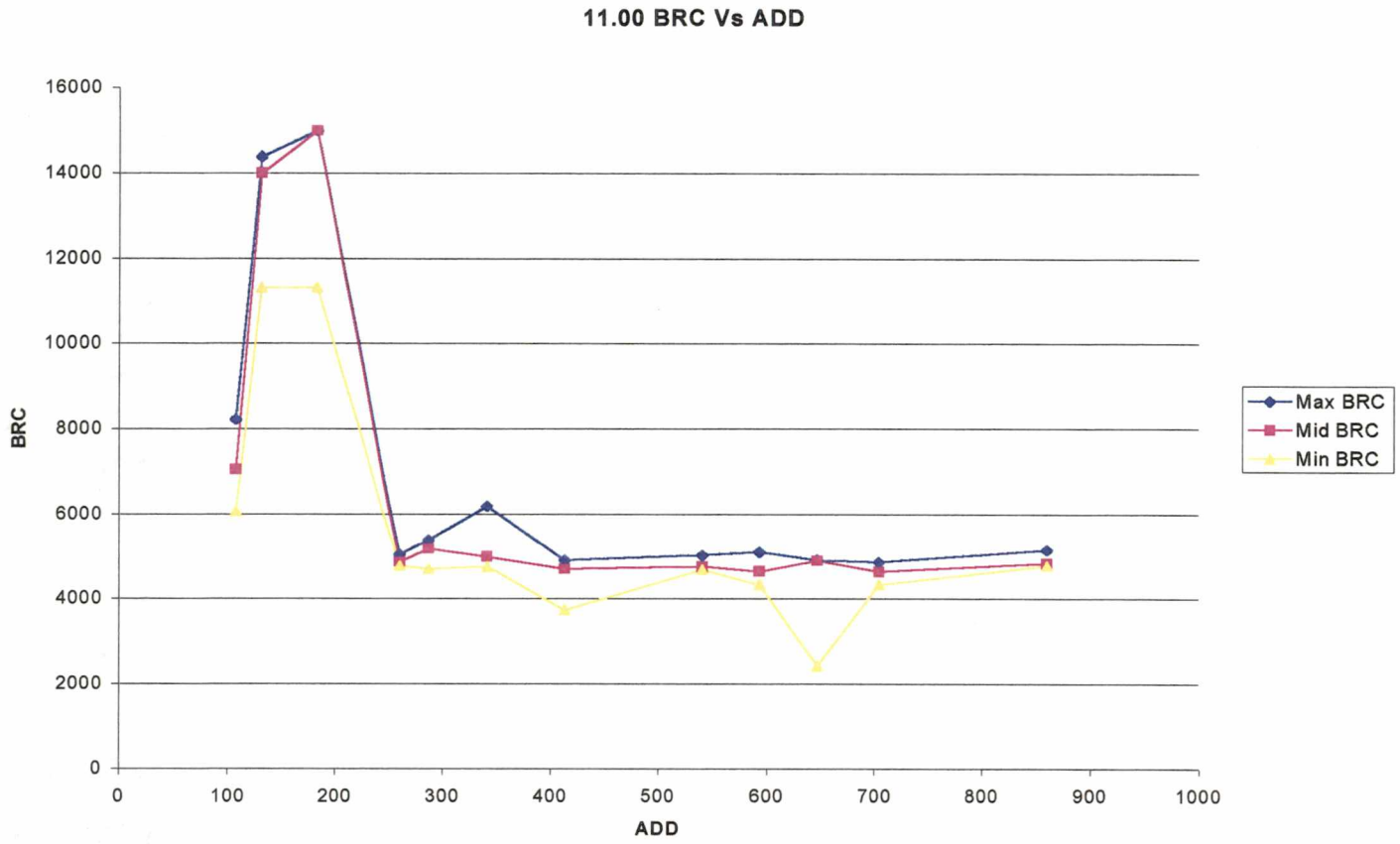


Figure 2.20. Plot of base resistance change (BRC) against accumulated degree days (ADD) for cadaver 11-00. Each data point represents one of the three sample collected during a sampling event.

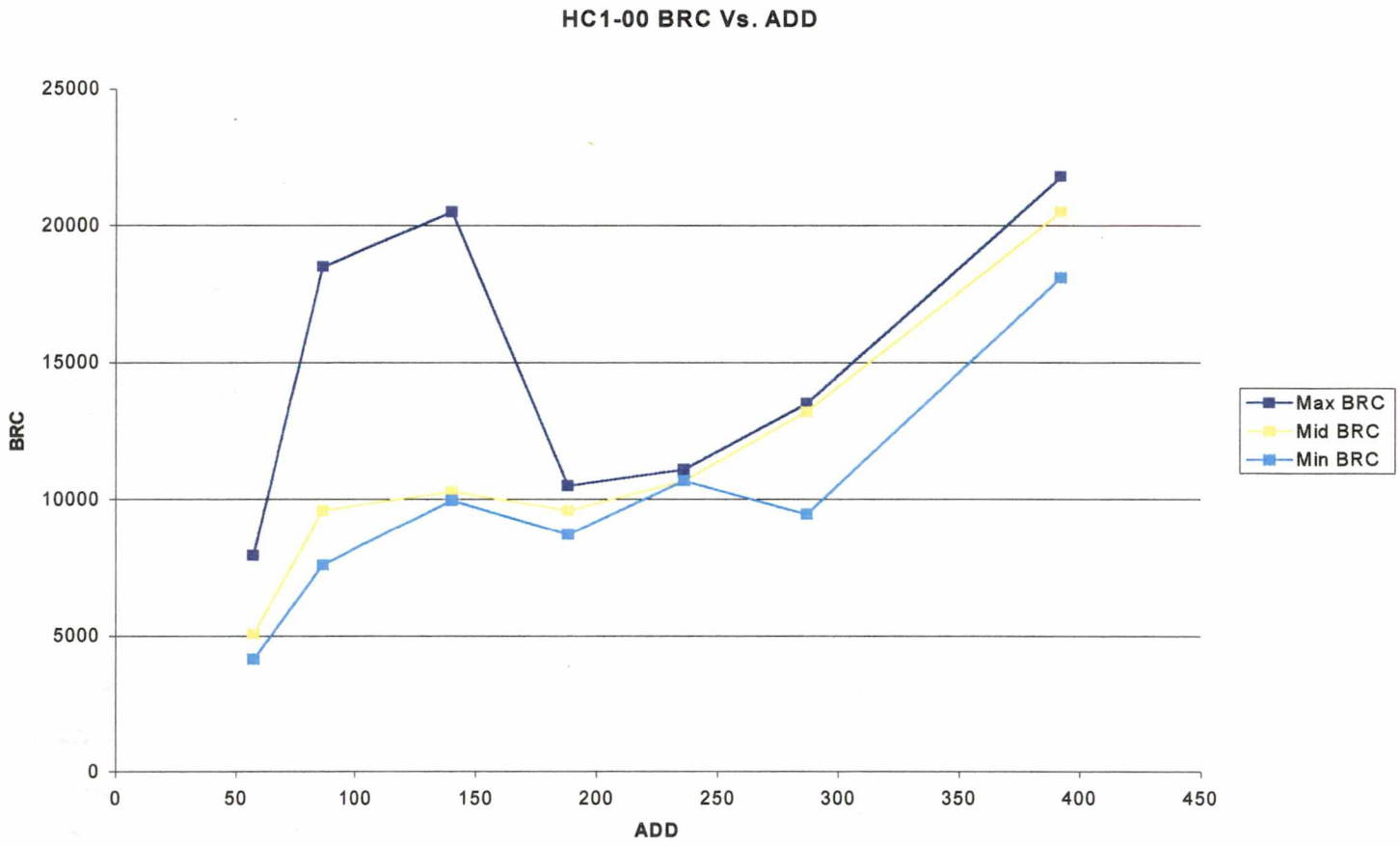


Figure 2.21. Plot of base resistance change (BRC) against accumulated degree days (ADD) for cadaver HC1-00. Each data point represents one of the three sample collected during a sampling event.

Table 2.5. Summary of Cadavers Studied.

Cadavers	Correlation of BRC to ADD				Average Daily Temperature	Sampling Period	Number of Days Studied
	Sample 1	Sample 2	Sample 3	Average			
30.99	-0.30	-0.20	0.07	-0.31	17.9	9.25.99-10.17.99	22
32.99	-0.14	-0.18	-0.09	-0.15	12.1	11.9.99-12.7.99	28
33.99	-0.16	-0.35	-0.84	-0.75	12.6	11.12.99-11.23.99	11
HC6-99	0.92	0.92	0.88	0.92	13.3	3.14.00-4.20.00	37
HC7-99	0.05	0.18	-0.02	0.08	21.6	5.12.00-5.22.00	22
3.00	0.66	0.73	0.75	0.73	15.8	3.22.00-4.20.00	29
4.00	0.82	0.82	0.84	0.84	16.0	3.24.00-4.20.00	27
5.00	0.28	0.87	0.88	0.69	15.6	3.28.00-4.20.00	23
9.00	0.74	0.72	0.68	0.73	18.3	4.21.00-5.22.00	31
11.00	-0.63	-0.60	-0.61	-0.61	26.1	6.14.00-7.17.00	33
HC01-00	0.36	0.92	0.89	0.77	26.1	8.14.00-8.29.00	15

Chapter 3

Results

The results of this study demonstrate that the aroma pattern of a decaying cadaver is constant over time, changing only in concentration. Regularity of the aroma pattern results from a lack of sample composition variation. Figure 3.1 illustrates the response of each sensor to samples collected over 22 days. Though difficult to observe in the initial samples collected, the sensors reaction to the aroma samples remains the same throughout the extended sampling interval. Figure 3.1 is an example of what is occurring with each cadaver studied. Variation in intensity of the sample collected despite identical sampling techniques indicated the amount of odor present in the body bag changed over time. Given the lack of pattern variation throughout the decomposition process, the statistical analysis focused on examining the change in odor intensity.

Statistical Analysis

Grouping the Samples

Despite the hypothesis that sample concentration is dependent on accumulated degree days and therefore not seasonally influenced, the samples were grouped by season. Fall included the months of September, October, and November. Winter included of the months of December, January, and February. Spring included of the months of March, April, and May. Summer included the months of June, July, and August. Table 3.1 shows the seasonal breakdown of the specimens and the correlation of BRC to ADD. The grouping of the specimens demonstrated that three more specimens

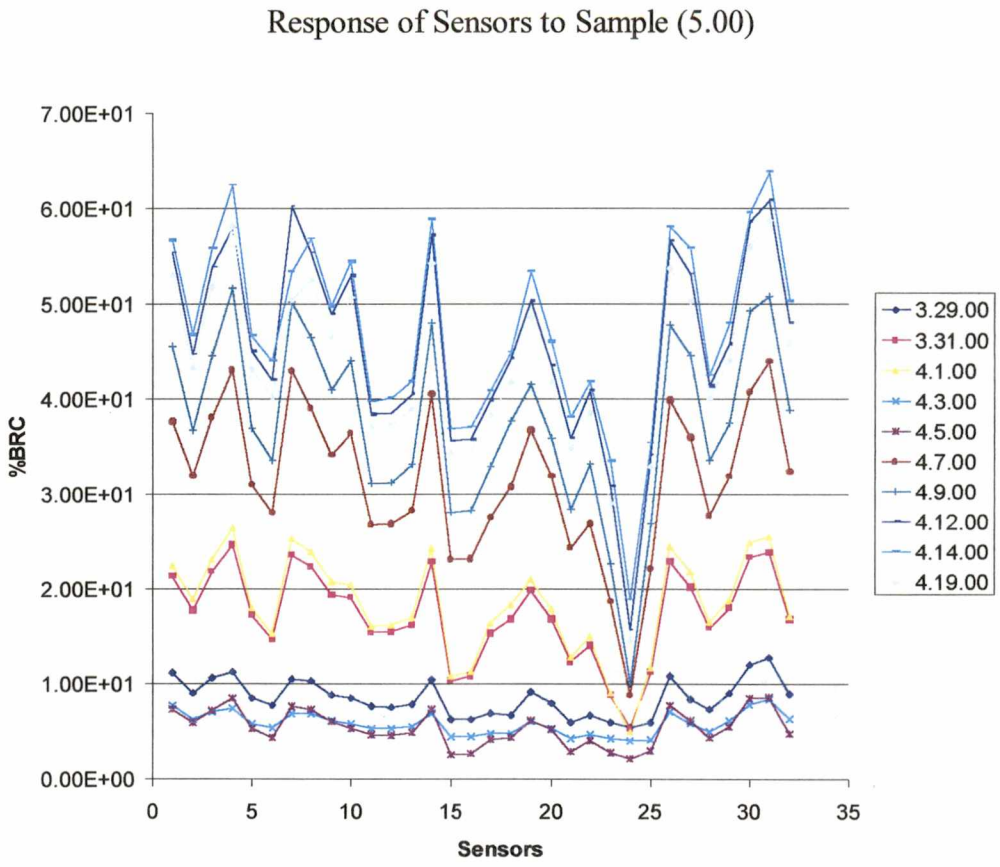


Figure 3.1. The response of each sensor to samples collected over a 22 day period for one body. Each data point represents one of the three repeat samples collected at each sampling event. The spikes and valleys of the aroma pattern remain the same throughout the sampling interval. The pattern only changes in terms of percent base resistance change (%BRC).

Table 3.1. Seasonal Grouping of Specimen Studied and Respective Correlations between BRC* and ADD**.

Specimen	Dates Studied	Season	Correlation
30.99	9/26/99-10/17/99	Fall	-0.31
32.99	11/9/99-12/7/99	Fall	-0.15
33.99	11/13/99-11/23/99	Fall	-0.75
HC6-99	3/21/00-3/20/00	Spring	0.92
3.00	3/29/00-4/20/00	Spring	0.73
4.00	3/29/00-4/20/99	Spring	0.84
5.00	3/29/00-4/20/00	Spring	0.69
9.00	4/27/00-5/22/00	Spring	0.73
HC7-99	5/1/00-5/22-00	Spring	0.08
11.00	6/18/00-7/17/00	Summer	-0.61
HC01-00	8/14/00-8/29/00	Summer	0.77

*Base Resistance Change (BRC).
**Accumulated Degree Days (ADD).

Table 3.2. Grouping of the Bodies Based on the Condition of the Body Bag and Respective Correlation between BRC and ADD.

	Cadaver	Correlation
Intact body bags	HC6-99	0.92
	HC7-99	0.21
	3.00	0.73
	4.00	0.84
	5.00	0.69
	9.00	0.73
	HC01-00	0.77
Damaged Body Bags		
	30.99	-0.31
	32.99	-0.15
	33.99	-0.75
	11.00*	-0.61

Base Resistance Change (BRC).
Accumulated Degree Days (ADD).
* 11-00 was not placed in a body bag.

were studied in spring than fall, four more specimens were studied in spring than summer, and no specimens were studied during the winter.

The negative correlation of BRC to ADD of body 11-00, which was not placed in a body bag raised question about the impact of the body bag on the temperature / sample intensity correlation. To further investigate the role of the body bag in the intensity of the odor produced during the decomposition process, the cadavers were regrouped. Sampling comments listed in Appendix 1 reveal that several of the body bags were ripped open by animal activity, including cadavers 30-99, 32-99, 33-99, and HC7-99 (Table 3.2). These three bodies were grouped with 11-00 as non body bagged cadavers. The remaining cadavers, HC6-99, HC1-00, 3-00, 4-00, 5-00, and 9-00 were grouped as body bagged cadavers.

In a further attempt to define a relationship between BRC and ADD a polynomial regression analysis was done (Table 3.3). The results show a significant relationship between ADD and BRC in all cases but one, HC7-99. Furthermore, the correlation between ADD and BRC is positive for all bodies, but continues to be stronger for bodies retained in intact body bags. Puzzling is the fact that the pattern of the relationship as shown by the varying coefficient is very different from one body to the next. In sum, the polynomial regression demonstrates a strong relationship between BRC and ADD but a single predictive model is non definable.

The Role of Humidity

The odor of decomposition is the result of water soluble volatile compounds volatilizing from the cadaver into the surrounding air. Given this fact, the concentration of the odor is hypothesized to be influenced by the level of ambient humidity. In order to investigate this assumption the total base resistance change was correlated to the ambient humidity level at the time the sample was collected. The correlation between BRC and humidity was $r = 0.08$.

Decomposition fluid collected in the undisturbed body bags indicating the humidity level within the bag remained near a constant 100%. In this environment ambient humidity levels are expected to have minimal effects on the intensity of cadaver odor. However, the samples collected from bodies in the disturbed body bags or without a body bag are expected to be influenced by fluctuating ambient humidity. To investigate

Table 3.3. Results of Polynomial Regression.

	Cadaver	Regression Formula	Standard Error of Estimation	R
Intact Body Bags				
	HC6-99	ADD=5.30E-03(BRC)+1.68E-07(BRC^2)-2.68E-12(BRC^3)+70.09	58.87	0.9
	3.00	ADD=2.83E-04(BRC)+5.92E-07(BRC^2)-1.03E-11(BRC^3)+52.28	92.48	0.77
	4.00	ADD=-4.91E-04(BRC)+5.51E-07(BRC^2)-9.27E-12(BRC^3)+47.46	71.1	0.82
	5.00	ADD=7.33E-03(BRC)+6.60E-08(BRC^2)-1.64E-12(BRC^3)-22.12	59.89	0.85
	9.00	ADD=-2.28E-03(BRC)+8.05E-07(BRC^2)-1.47E-11(BRC^3)+73.93	97.39	0.8
	HC1-00	ADD=6.68E-02(BRC)-3.42E.-06(BRC^2)+6.62E-11(BRC^3)-204.65	90.12	0.67
Damaged Body Bags				
	30.99	ADD=3.88E-02(BRC)-2.26E-06(BRC^2)+2.55E-11(BRC^3)+66.44	103.41	0.375
	32.99	ADD=8.29E-02(BRC)-6.26E-06(BRC^2)+1.32E-10(BRC^3)-115.7	94.76	0.42
	33.99	ADD=-2.14E-02(BRC)-2.95E-09(BRC^3)+717.19	227.36	0.54
	HC7-99	ADD=3.38E-02(BRC)-1.51E.06(BRC^2)+1.96E-11(BRC^3)-3.195	150	0.21
	11.00*	ADD=-9.62E-02(BRC)-3.79E-06(BRC^2)+4.44E-10(BRC^3)+997.74	185.85	0.66

Accumulated Degree Days (ADD).
Total Base Resistance Change (BRC).

this second hypothesis, the cadavers were again grouped as bagged and non bagged (see above). The correlation between BCR and humidity was calculated as r = 0.13 and r = 0.12, respectively. The results of this experiment demonstrate that humidity has relatively little effect on the intensity of the odor as it is collected using molecular sieve.

Temperature Plateau

A common pattern in the BRC vs. ADD plots (Figure 2.11-2.21) among cadavers contained in undisturbed body bags (HC6-99, HC7-99, HC1-00, 3-00, 4-00, 5-00, and 9-00) is an increase in BRC until approximately 300 ADD. After this point the BRC appears to fluctuate independently of ADD. To statistically investigate this observation, the correlation between BRC and 0 – 300 ADD was calculated, (r = 0.53). Comparison of BRC / ≤300 ADD correlation to the BRC / total ADD correlation shows that the relationship between BRC and total ADD is stronger, (r = 0.64). Given these result, the observation of greater initial dependency of aroma concentration on accumulated degree days is not supported.

The result of the study shows that the aroma pattern, as actively sampled with molecular sieve and detected by the Aromascan®, does not change as the cadaver progresses through the decomposition process. Rather, what does occur is an increase in sample intensity throughout the decomposition process. To statistically define the relationship between accumulated degree days and concentration of odor, the sample concentration as registered by the 32 sensors was numerically summarized as total base resistance change (BRC). Comparison of ADD to BRC shows a positive correlation (r = 0.73) when a cadaver decomposes in an undisturbed body bag. However, ADD and BRC

were not positively correlated when the integrity of the body bag was destroyed by animal activity. Furthermore, the effects of humidity were hypothesized to be greater when the specimen was not enclosed in a secure body bag during the decomposition process, possibly destroying the correlation between ADD and sample concentration. This hypothesis was not supported.

Chapter 4

Discussion

The odor of decay is pungent and repulsive at best. It often lingers in the air long after the source is removed and can be carried on clothing and hair of the unfortunate who come in contact with it. Despite its negative characteristics, researchers have recently begun to explore the value of decay odor as a forensic investigative tool (Killiam 1990, Barshick et al. 1995, Love et al. 2000). Law enforcement is currently using cadaver location dogs trained to identify human decay odor in order to locate human remains. Previously in a pilot study, Barshick et al. (1995), using electronic nose technology, evaluated the odor of soil collected under a decomposing cadaver as a time since death indicator. They found a positive correlation between increased percent base resistance response of the sensors and accumulated degree days. This study follows this current trend of decay odor analysis through investigating ambient decay odor as a time since death indicator.

Experimental Design

The Body Bag

Designing a pioneer study to evaluate the correlation between decay odor changes and accumulated degree days required placing the decomposing bodies under conditions that are unlikely in actual homicides: enclosed in a body bag. Pulling aroma samples from a zipped body bag containing a nude decomposing corpse insured the sample was

either from the body, the body bag, or a combination of the two. To control for the contribution of the body bag to the odor an empty body bag was sampled at regular intervals. Comparison of the sensor response to the experimental and control samples showed the contribution of the body bag to the aroma was negligible.

Additional goals of the study design were to minimize variables while working in an unconventional outdoor laboratory and to concentrate the decay odor to potentially identify subtle aroma changes. Again, the researcher felt the best way to accomplish these goals was to enclose the body in a body bag during the decomposition process. The body bag served as a barrier to taphonomic process including carnivore, rodent, and bird activity, as well as odor dispersal due to variable winds. Given the results of the experiment, which indicate that the odor of decay is a promising time since death indicator, future research to study bodies under more realistic conditions is necessary.

Results

The Correlation

The statistical results of the study show a strong correlation between accumulated degree days and change in sensor's base electrical resistance when a body decomposes in an undisturbed body bag (Table3.3). However, this correlation is without merit unless it is compared to, and ranked with, alternative time since death estimating methods. The immediate advantage of decay odor is its longevity. Decay odor can be present from the time of death until complete skeletonization and even beyond. Therefore, the decay odor method for time since death estimation has a wide window of application.

Comparison of Various TSD Estimating Methods

During the initial stage of decomposition, a body progresses through the classic signs of death: algor, livor, and rigor mortis. As previously mentioned, researchers have investigated all three as time since death indicators. Algor mortis, like the rate of decomposition, is governed by ambient temperature, as well as, cause of death, body weight, and skin surface exposure. Recent research (Brown et al. 1985, Hutchins 1985, Henssge and Madea 1988, Madea 1993, Henssge et al. 1995) demonstrates that the body temperature drops during the initial 24 hours following death. Henssge and Madea (1988) show that the margin of error increases with postmortem interval.

Unlike algor and rigor mortis, livor mortis is less impacted by the environment in which death occurred. Traditionally, livor mortis was utilized to roughly estimate the postmortem interval as being less than 12 hours or more than 12 hours depending on whether or not livor was fixed (Henssge et al 1995, Dix and Graham 2000). Recent research has fine tuned the use of livor mortis as a time since death indicator through photometric measurement of pressure-induced blanching (Kaatsch et al. 1994), hemoglobin light absorption (Inoue et al. 1994), and use of a tristimulus color measuring system (Vanezis and Trujilla 1996). However, despite these advancements, the methods dependent on livor mortis to estimate the postmortem interval are only applicable during the initial 12 postmortem hours (Coe 1993, DiMiao and DiMiao 1996, Clark et al. 1997).

Finally, the onset and waning of rigor mortis is dependent on temperature, cause of death, and antimortem activity of the deceased. Again, recent research has fine tuned the age old rule of thumb, (rigor mortis develops over the initial 12 hour interval after death, has a duration of 12 hours, then wanes over a final twelve hour interval) (Spitz

1993, DiMiao and DiMiao 1996, Dix and Graham 2000), by breaking the onset of muscle stiffening into finite steps through electrical muscle excitability (Madea and Henssge 1988, Madea et al. 1995). Although accurate, muscle excitability is only applicable for approximately 24 hours after death (Madea and Henssge 1988, Madea et al. 1995).

Because algor, livor and rigor mortis are only applicable as time since death indicators during the interval immediately following death (approximately the first 24 hours), they are not comparable to the decay aroma method. The minimal interval after death that two aroma samples were collected was 36 hours (see Appendix 1).

The later stages of decomposition, (discoloration, bloating, and skeletonization) are governed by two methods for estimating postmortem interval: soil solution analysis (Vass et al. 1992) and entomological analysis (Kulshretha and Chandra 1987, Catts and Haskell 1990, Greenberg 1991, Hewadikaram and Goff 1991, Schoenly 1992, Haskell et al. 1997, Byrd and Castner 1999). As previously mentioned, as a body decomposes, liquefied decomposition by-products collect under a body. Vass and colleagues (1992) developed a method to correlate the concentration of the decay matter found in soil beneath a decomposing corpse to accumulated degree days. The method targets VFA's concentration, anion / cation concentration, and soil pH. Through correlating each soil component to ADD, the method provides a neat window of estimated time since deposition. The window of method application is expansive, ranging from the bloated stage to the skeletonization stage. The weaknesses of the soil solution method is its reliance on an accurate weather information and accurate estimation of the deceased antemortem weight, since the amount of decay fluid produced is directly proportionate to the body mass of the individual.

Direct comparison of the accuracy rate of the soil solution method to the aroma method is difficult because the experimental write-up of the soil solution method does not state the accuracy of the methodology beyond narrating two case studies in which it appears successful. However, the fact that the time since deposition estimates derived from the soil solution method are a result of two independent factors, VFA's and cation / anion concentration, bodes well for its accuracy (Vass et al. 1992). Furthermore, the true strength in the availability of both methods is that one is applicable when the other is not. For example if a decomposed body was found sealed in a vehicle, soil analysis would not be possible; however, aroma analysis of air surrounding a body decomposing in a high wind area would also not be practical.

Forensic entomology has an extremely long history of its use as a time since death indicator. Bergeret, a forensic investigator, is credited as the first to estimate time since death based on entomologically findings. Although incorrectly, in 1855, he estimated the postmortem interval of a mummified infant found in a bricked-up fireplace was greater than two years, exonerating the current apartment tenant (Greenberg 1991). Since this historical event, the techniques of forensic entomology have continued to evolve. Studies on human and non human remains have produced valuable information on community structure, colonization order, seasonality, synanthropy, and oviposition preferences of carrion insects (see Greenberg 1991 for review). The result of these studies is a finely tuned time since death estimation method dependent on the correlation of insect development to accumulated degree days (Rodriquez and Bass 1983, Catts and Haskell 1990, Bass 1997, Haskell et al 1997). The window of application of forensic entomology methodology is even more extensive than soil solution analysis, ranging from within the

24 hours after deposition to beyond skeletonization (Rodriquez and Bass 1983, Bass 1997). Furthermore, numerous case studies have illustrated the accuracy of insect development as a time since death indicator (Kulshretha and Chandra 1987, Catts and Haskell 1990, Greenberg 1991, Hewadikaram and Goff 1991, Schoenly 1992, Haskell et al. 1997, Byrd and Castner 1999). The short falls of forensic entomology are 1) that the body must be exposed to insect activity, and 2) the life cycle and activity of insects indigenous to the region must be defined.

Finally, several time since death estimation methods extend far beyond the skeletonization stage. As skeletal remains become entangled by invading flora, forensic botany becomes valuable in estimating minimal time since death (Willey and Heilman 1987, Hall 1997). Furthermore, research (has shown that bone weathering advances through predictable stages which are very roughly correlated to time since death Hill and Behrensmeyer 1984, Ubelaker 1997). The possible window of application of forensic botany and bone weathering is most often greater than a year. This study investigated changes in decay odor that occurred over a month interval; therefore, the aroma method is not comparable to the methods of forensic botany and bone weathering at this time.

The strength of the aroma method as a time since death indicator is the fact that odor is always present during active stages of decay. The two methods, soil solution and entomological analysis, which at this time are the most comparable TSD estimation methods to the aroma method, in terms of window of application, require specific circumstances to be applicable: deposition products must be recoverable and there must be exposure of the corpse to insects. If both circumstances fail to be met, aroma analysis is a reasonable alternative to estimate time since death. Although, the aroma method at

this time is limited in application to a body in a body bag or a similar confining situation, further studies using altered sampling methods, i.e. longer sampling time, more molecular sieve, higher pump rate, the methods applicability may be expanded to include remains found in any terrestrial environment.

The greatest advantaged gained by this study lies not with defining the value of odor as a time since death indicator, but with the continued expansion of the view that decay odor is an important investigative tool. Previously, cadaver odor was recognized as a scouting tool when used in concert with cadaver dogs, but was not valued beyond this. This study in tandem with Barshick et al.'s (1995) work has begun to experiment with alternative uses of cadaver odor.

This study attempted to evaluate decay odor through instrumentation that mirrored the mammalian response to odor. As a result the strongly electrically charged components of odors were targeted in the analysis. The electronic nose failed to distinguish aroma pattern changes throughout the decomposition process. The variations in odor compositions may be recognized using gas chromatography / mass spectrometry which targets the compositional concentration of the sample with disregard for electrical charge of the component. Further analysis of the aroma samples using GC/MS technology may demonstrate the expected changes of decay aroma.

Chapter 5

Conclusion

Accurately estimating the postmortem interval is often a crucial component of a medico-legal investigation. During the initial postmortem interval, when the body is still in the fresh stage and actively affected by livor, algor, and rigor mortis, the responsibility of estimating time since death falls on the forensic pathologist. As the postmortem interval grows and the corpse begins to enter the later stages of decay, the forensic anthropologist is called upon to estimate the postmortem interval. As postmortem time increases, so does the influence of environmental effectors on the rate of decomposition, which clouds accurate TSD estimations. In light of these difficulties, forensic scientists have strived to develop new methods to accurately estimate postmortem interval through the incorporation of environmental effectors. This study follows the research trend through evaluating decay odor as a TSD indicator through the correlation of odor pattern changes to accumulated degree days.

The Study

The Instrumentation

Advancements in electronic nose technology enable a researcher to analyze an odor in its entirety through spatial patterns reflecting the concentration of electrically charged components of the odor. Human perception of odor is not dependent on the concentration of the various components that comprise it, but rather a reflection of the concentration of electronically charged components that interact with olfactory bulbs of

the olfactory nerves (Ronhi 1996). Hence, the new electronic nose technology mirrors the human brain in its reaction to an aromatic sample. Like the various olfactory nerve endings, the multiple sensors of the polymer sensor array incorporated in the Aromascan® enables the instrument to analyze the complex composition of the aroma sample in its entirety.

The neural network capabilities of the Aromascan® enable it to identify unknown samples through aroma pattern recognition. Quantitative recognition of decay odor could serve as a powerful forensic investigative tool. The question posed in this study did not lend itself to investigating the application of the neural network to collected sample, but this easily could be done with the collected samples.

The Sample

In order to comprehensively study cadaver aroma, a representative and replicable sample of the odor was collected and transported to the ORNL laboratory. (The Aromascan® required the sample to be in 22mL vials; therefore, aroma samples could not be feed directly to the instrument from the source). The sampling method developed for this study utilized molecular sieve, a universal dryant, to collect the water soluble aromatic compounds present in the air isolated in body bags. The molecular sieve proved capable of releasing the same compounds under established analytical conditions of the Aromascan®. Containing the molecular sieve in three pipettes and simultaneously connecting them to a portable air pump enable the collection of three repeat samples over a minimal sampling interval. The end result was a representative and repeatable sample

collected under field conditions, released under analytical conditions, with minimal intrasampling error, and a short sampling interval.

The Laboratory

Working in an outdoor, nontraditional laboratory such as the Anthropology Research Facility with human remains generated many difficulties. The age, race, sex, physique, and cause of death of the remains used in the study were uncontrollable and the effects of each on the decay odor produced were indefinable. However, isolating the cadavers in body bags and exercising a stringent sample collection technique reduced sample contamination and variability. Furthermore, recording the daily temperature highs and lows enabled the changes in aroma pattern to be directly correlated to accumulated degree days.

The Results

Analysis of individual sensor reaction to the consecutive aroma samples showed that the aroma patterns did not change over time in terms of compound class concentration (see Figure 3.1). Despite the lack of pattern variation, the intensity of the sample, as registered by sensor electrical resistance change from the base level, showed a significant relationship to accumulated degree days (Table 3.3). The strength of the relationship was greater when the body decomposed in an intact body bag. The short coming of the results was that the relationship pattern between ADD and BRC was different for each body. The results of the study demonstrate a significant relationship between the intensity of decay odor and accumulated temperature. The results show that

decay odor is a promising time since death indicator that needs further study. Furthermore, the statistical analysis demonstrated that neither humidity nor seasonality affected the sample intensity when collected and analyzed with the established procedures.

Despite the stated value of decay odor as a time since death indicator, advancement could expand its applicability. Through sensitivity improvement of the sampling method and the electronic nose, decay odor may prove a valuable time since death indicator under more relaxed conditions.

In contrary to the success of this study, the greatest disappointment is the failure to detect subtle aroma pattern variations. Research currently being conducted at ORNL on the chemical make-up of decomposing tissue has shown concentration variations of aroma producing chemicals, i.e., cadaverine and putrecine, over time (Vass, personal communication). The fact that such compounds are initially absent and then become increasingly more concentration should be reflected in the decay odor through a changing aroma pattern. However, this method failed to detect this evolution of decay. Hopefully with advancements in electronic nose sensitivity and sampling techniques, these subtle aroma variations will be recognized.

Ultimately, the contribution of this study to the field of forensic science is far greater than the success of evaluating decay odor as a time since death indicator. It serves as a pioneer step into the study of decay odor as a forensic investigative tool. Successfully bringing the cadaver decay odor into the laboratory generates the potential for analysis utilizing many types of instrumentation. In sum, the importance of decay

odor is just beginning to be recognized and should continue to grow in concert with technological advancements.

Bibliography

Babapulle CJ, Jayasundera NPK
1993 Cellular changes and time since death. *Medicine, Science, and the Law* 33(3):213-222.

Barshick SA, Griest WH, Vass AA
1995 Electronic aroma detection technology for forensic and law enforcement applications. *SPIE* 2941:63-74.

Barshick SA, Vass AA, Sega G, Caton J, Love JC, Marks MK
2000 Measurement technologies for determining time since death. *Proceedings on American Academy of Forensic Science* 187.

Bass WM
1997 Outdoor decomposition rates in Tennessee. In *Forensic Taphonomy: The Postmortem Fate of Human Remains*, edited by WD Haglund and MH Sorg, pp. 181-186. CRC Press Boca Raton, FL.

Berne RM and Levy MN
1993 *Physiology*, 3rd edition. Mosby Year Book, St. Louis.

Brown A, Hicks B, Knight B, Nokes LD
1985 Determination of time since death using the double exponential cooling model. *Medicine, Science, and the Law* 25(3):223-227.

Catts EP, Haskell NH
1990 *Entomology and Death: A Procedural Guide.* Joyce's Print Shop, Inc Clemson, NC.

Clark MA, Worrell MB, Pless JE
1997 Postmortem changes in soft tissues. In *Forensic Taphonomy: The Postmortem Fate of Human Remains*, edited by WD Haglund and MH Sorg, pp. 151-164. CRC Press Boca Raton, FL.

Coe JI
1993 Postmortem chemistry update: emphasis on forensic applications. *American Journal of Forensic Medicine and Pathology* 14(2):92-93.

DiMiao DJ, DiMiao VJM
1989 *Forensic Pathology.* Elsevier New York, NY.

DiNunno NR, Costantinides F, Bernasconi P, Bottin C, Melato M
1998 Is flow cytometric evaluation of DNA degradation a reliable method to investigate the early post-mortem period? *American Journal of Forensic Medical Pathology* 19(1):50-53.

Dix J, Graham M
2000 *Time of Death, Decomposition and Identification: An Atlas.* CRC Press Boca Rotan, FL.

Edwards R, Chaney B, Bergman M
1987 Accumulated Degree Days. *Pest and Crop Newsletter* 2:5-6.

Galloway A
1997 The process of decomposition: a model from the Arizona-Sonoran Desert. In *Forensic Taphonomy: The Postmortem Fate of Human Remains*, edited by WD Haglund and MH Sorg, pp. 139-149. CRC Press Boca Raton, FL.

Galloway A, Birby WH, Jones AM, Henry TE, Parks BO
1989 Decay rates of human remains in an arid environment. *Journal of Forensic Science* 34(4): 607-616.

Gill-King H
1997 Chemical and ultrastructural aspects of decomposition. In *Forensic Taphonomy: The Postmortem Fate of Human Remains*, edited by WD Haglund and MH Sorg, pp. 93-108. CRC Press Boca Raton, FL.

Greenberg B
1991 Flies as forensic indicators. *Journal of Medical Entomology* 28(5):565-577.

Haglund WD
1997 Dogs and coyotes: Postmortem involvement with human remains. In *Forensic Taphonomy: The Postmortem Fate of Human Remains*, edited by WD Haglund and MH Sorg, pp. 93-108. CRC Press Boca Raton, FL.

Hall DW
1997 Forensic Botany. In *Forensic Taphonomy: The Postmortem Fate of Human Remains*, edited by WD Haglund and MH Sorg, pp. 353-363. CRC Press Baton Raton, LA.

Haskell NH, Hall RD, Cervenka VJ, Clark MA
1997 On the body: Insects' life stage presence, their postmortem artifacts. In *Forensic Taphonomy: The Postmortem Fate of Human Remains*, edited by WD Haglund and MH Sorg, pp. 415-448. CRC Press Boca Raton, FL.

Henssge C, Madea B
1988 Determination of the time since death I. Body heat loss and classical signs of death. An integrated approach. *Acta Medical Legal Society* 38(1):71-89.

Henssge C, Knight B, Krompecher T, Madea B, Nokes, L
1995 *The Estimation of the Time Since Death in the Early Postmortem Period.* Edward Arnold Boston, MA

Hewadikaram KA, Goff ML
1992 Effect of carcass size on rate of decomposition and arthropod succession patterns. *The American Journal of forensic Medicine and Pathology* 12(3):235-240.

Hill AP, Behrensmeyer AK
1984 Disarticulation pattern of some modern East African mammals. *Paleobiology* 10:366-376.

Hirvonen J, Huttunen P
1996 Postmortem changes in serum noradrenaline and adrenaline concentrations in rabbit and human cadavers. *International Journal of Legal Medicine* 109(3):143-146.

Hodgins D, Simmonds D
1995 The electronic NOSE and its application to the manufacture of food products. *Journal of Automatic Chemistry* 17(5):179-185.

Hutchins GM
1985 Body temperature is elevate in the early postmortem period. *Human Pathology* 16(6):560-561.

Inoue M, Suyana A, Matuoke T, Inoue T, Okada K, Irizawa Y
1994 Development of an instrument to measure postmortem lividity and its preliminary application to estimate the time since death. *Forensic Science International* 65(3):185-93.

Junqueira CL, Carneiro J, Kelley RO
1991 *Basic Histology.* Appleton and Lange Norwalk, CT.

Kaatsch HJ; Schmidtke E; Nietsch W
1994 Photometric measurement of pressure-induced blanching of livor mortis as an aid to estimating time of death. Application of a new system for quantifying pressure-induced blanching in lividity. *International Journal of Legal Pathology* 106(4):209-214.

Killiam EW
1990 *The Detection of Human Remains.* Illinois: CC Thomas.

Knight B
1996 *Forensic Pathology*, 2nd edition. Arnold, London

Kulshretha P, Chandra H
1987 Time since death: An entomological study on corpses. *The American Journal of Forensic Medicine and Pathology* 8(3):233-283.

Lange N, Swearer S, Sturner WQ
1993 Human postmortem interval estimation from vitreous potassium: an analysis of original data from six different studies. *Forensic Science International* 66(3):159-174.

Lyman RL
1984 Bone density and differential survivorship of fossil classes. *Journal of Anthropological Archaeology* 3:259-299.

Love JC, Marks MK, Barshick SA
2000 The Odor of Decay, a Sampling Method. *Proceedings for American Academy of Forensic Sciences*, 188.

Madea B, Henssge C
1988 Determination of the time since death II. Electrical excitability of skeletal muscles. Current state and recent development. *Acta Medical Legal Society* 38(1): 91-108.

Madea B
1992 Estimating time of death from measurement of the electrical excitability of skeletal muscle. *Journal of Forensic Science Society* 32(2):117-129.

Madea B, Krompecher T, Knight B
1995 Muscle and tissue changes after death. In *The Estimation of the Time Since Death in the Early Postmortem Period.* Edited by Henssge C, Knight B, Krompecher T, Madea B, Nokes, L pp. 138-171, Edward Arnold Boston, MA

Manhein M
1997 Decomposition rates of deliberate burials: A case study of preservation. In *Forensic Taphonomy: The Postmortem Fate of Human Remains*, edited by WD Haglund and MH Sorg, pp. 469-482. CRC Press Boca Raton, FL.

Mann RW, Bass WM, Meadows L
1993 Time since death and decomposition of the human body: Variables and Observations in Case and Experimental Field Studies. *Journal of Forensic Sciences* 35(1): 103-111.

Marks MK, Love JC, Elkins SK
2000 Time since death: a practical guide to physical; postmortem events. *Proceedings on American Academy of Forensic Sciences* 181-182.

Mello de Oliveira JA, Santos-Martin CC
1994 Enzyme histochemistry of the liver in autopsy material at different post-mortem times. *Medicine, Science, and the Law* 35(3):201-206.

Micozzi MS
1997 Frozen environments and soft tissue preservation. In *Forensic Taphonomy: The Postmortem Fate of Human Remains*, edited by WD Haglund and MH Sorg, pp. 171-180. CRC Press Boca Raton, FL.

Mikami H, Terazawa K, Takatori T, Tokudome S, Tsukamoto T, Haga K
1995 Estimation of time of death by quantification of melatonin in corpses. *International Journal of Legal Medicine* 107(1):42-51.

Moy L, Tan T, Gardner J
1994 Monitoring the stability of perfume and body odors with and "Electronic Nose". *Perfumer and Flavorist* 19:11-16.

O'Brien OC
1997 Movement of bodies in Lake Ontario. In *Forensic Taphonomy: The Postmortem Fate of Human Remains*, edited by WD Haglund and MH Sorg, pp. 559-567. CRC Press Boca Raton, FL.

Persaud KC
1995 The sammon mapping technique. *SPIE* 2937:47-51.

Reed HB
1958 A study of dog carcass communities in Tennessee, with special references to the insects. *American Midland Naturalist* 34(3): 213-245.

Rhine S, Dawson JE
1997 Estimation of time since death in the Southwestern United States. In *Forensic Osteology: Advances in the Identification of Human Remain.* Edited by Kathleen Riechs pp.145-159 Charles C. Thomas Springfield, IL.

Robertson MD, Drummer OH
1997 Postmortem distribution and redistribution of nitrobenzodiazepines in man. *Journal of Forensic Science* 43(1):9-13.

Rodriguez WC, Bass WM
1983 Insect activity and its relationship to decay rates of human cadavers in East Tennessee. *Journal of Forensic Science* 28(2): 423-32.

Rodriguez WC
1997 Decomposition of buried and submerged bodies. In *Forensic Taphonomy: The Postmortem Fate of Human Remains*, edited by WD Haglund and MH Sorg, pp. 459-482. CRC Press Boca Raton, FL.

Ronhi AM
1996 Tracing scents to an odor map. *American Chemical Society.* http://education.llnl.gov/msds/ScanDbase/smell-CEN-12-23-96.html.

Sammon Jr. JR
1970 Interactive pattern analysis and classification. *IEEE Trans. on Computers* 19(7):594-616.

Schoenly K
1994 A statistical analysis of success ional patterns in carrion-arthropod assemblages: Implications for forensic entomology and determination of the postmortem interval. *Journal of Forensic Science* 37(6):1489-1513.

Spitz WU
1993 *Medicolegal Investigation of Death – Guidelines for the Application of Pathology to Crime Investigation*, 3rd edition. Charles C.Thomas Publisher, Springfield, IL

Tobbin AJ, Morel RE
1997 *Asking About Cells.* Saunders College Publishing Fort Worth, TX.

Ubelaker D
1997 Taphanomic Applications in Forensic Anthropology. In *Forensic Taphonomy: The Postmortem Fate of Human Remains*, edited by WD Haglund and MH Sorg, pp. 77-90. CRC Press Boca Raton, FL.

Vanesiz P, Trujillo O
1996 Evaluation of hypostasis using a colorimeter system and its application to assessment of the postmortem interval (time of death). *Forensic Science International* 78(1):19-28.

Vass AA, Bass WM, Wolt JD, Foss JE, Ammons JT
1992 Time since death determinations of human cadavers using soil solution. *Journal of Forensic Science* 37(5):1236-53.

Willey P, Heilman A
1987 Estimation time since death using plant roots and stems. *Journal of Forensic Science* 32(5): 1264-1270.

Wyler D, Marty W, Bar W
1994 Correlation between the post-mortem cell content of cerebrospinal fluid and time of death. *International Journal of Legal Medicine* 106(4):209-214.

Yonemitsu K, Pounder DJ
1993 Postmortem changes in blood tranylcypromine concentrations: competing redistribution and degradation effects. *Forensic Science International*59(2):177-184.

Zanoni MM, Morria A, Messer M, Martinez R
1998 Forensic Evidence Canines: Status, Training, and Utilization. Paper presenter at the *American Academy of Forensic Sciences* www.prusik.com.

Zugibe FT, Costello JF
1993 "The Iceman Murder"-One of a series of contract murders. *Journal of Forensic Sciences* 38:1404-1408.

Appendix

ID#	Date	Time	Temp (C)	H Temp (C)	Time of H Temp	Date of H Temp	L Temp (C)	Time of L Temp	Date of L Temp	Humidity	H Hum
30.99	9.25.99		4.4	4.4			4.4				
30.99	9.26.99	1520	29.0	35.0			19.4			36	97
30.99	9.27.99	1715	27.2	29.1	1415	9.27.99	19.5	0621	9.27.99	65	88
30.99	9.28.99	1650	27.8	27.8	1735	9.27.99	20.6	0828	9.28.99	76	97
30.99	9.29.99	1646	21.4	27.0	1714	9.28.99	20.9	1505	9.28.99	97	97
30.99	9.30.99	1611	19.3	21.4	1702	9.29.99	10.0	0812	9.30.99	39	97
30.99	10.1.99	1724	22.5	21.8			10.2			31	
30.99	10.2.99	1659	24.8	24.8	1702	10.2.99	10.7	0812	10.2.99	40	97
30.99	10.3.99	1705	22.8	25.7	1457	10.3.99	12.9	0633	10.3.99	78	97
30.99	10.4.99	1841	20.9	24.7	1615	10.4.99	16.9	0802	10.4.99	68	97
30.99	10.5.99	1753	19.7	20.9	1844	10.4.99	12.2	0731	10.5.99	48	94
30.99	10.6.99	1703	22.8	23.0	1648	10.6.99	10.2	0652	10.6.99	40	97
30.99	10.7.99	1723	23.5	23.7	1623	10.7.99	10.6	0811	10.7.99	46	
30.99	10.9.99	1424	18.8	26.2	1537	10.8.99	11.7	0829	10.8.99	97	97
30.99	10.10.99	1413	20.5	20.5	1417	10.10.99	18.4	0009	10.10.99	97	97
30.99	10.11.99	1604	23.7	24.1	1526	10.11.99	17.9	0728	10.11.99	70	97
30.99	10.12.99	1743	23.4	25.6	1635	10.12.99	14.8	0628	10.12.99	76	97
30.99	10.13.99	1737	20.9	23.2	1745	10.12.99	15.5	0637	10.13.99	94	97
30.99	10.14.99	1658	19.8	20.9	1741	10.13.99	14.3	0816	10.14.99	74	97

ID#	Date	Time	Temp (C)	H Temp (C)	Time of H Temp	Date of H Temp	L Temp (C)	Time of L Temp	Date of L Temp	Humidity	H Hum
30.99	9.25.99		4.4	4.4			4.4				
30.99	9.26.99	1520	29.0	35.0			19.4			36	97
30.99	9.27.99	1715	27.2	29.1	1415	9.27.99	19.5	0621	9.27.99	65	88
30.99	9.28.99	1650	27.8	27.8	1735	9.27.99	20.6	0828	9.28.99	76	97
30.99	9.29.99	1646	21.4	27.0	1714	9.28.99	20.9	1505	9.28.99	97	97
30.99	9.30.99	1611	19.3	21.4	1702	9.29.99	10.0	0812	9.30.99	39	97
30.99	10.1.99	1724	22.5	21.8			10.2			31	
30.99	10.2.99	1659	24.8	24.8	1702	10.2.99	10.7	0812	10.2.99	40	97
30.99	10.3.99	1705	22.8	25.7	1457	10.3.99	12.9	0633	10.3.99	78	97
30.99	10.4.99	1841	20.9	24.7	1615	10.4.99	16.9	0802	10.4.99	68	97
30.99	10.5.99	1753	19.7	20.9	1844	10.4.99	12.2	0731	10.5.99	48	94
30.99	10.6.99	1703	22.8	23.0	1648	10.6.99	10.2	0652	10.6.99	40	97
30.99	10.7.99	1723	23.5	23.7	1623	10.7.99	10.6	0811	10.7.99	46	
30.99	10.9.99	1424	18.8	26.2	1537	10.8.99	11.7	0829	10.8.99	97	97
30.99	10.10.99	1413	20.5	20.5	1417	10.10.99	18.4	0009	10.10.99	97	97
30.99	10.11.99	1604	23.7	24.1	1526	10.11.99	17.9	0728	10.11.99	70	97
30.99	10.12.99	1743	23.4	25.6	1635	10.12.99	14.8	0628	10.12.99	76	97
30.99	10.13.99	1737	20.9	23.2	1745	10.12.99	15.5	0637	10.13.99	94	97
30.99	10.14.99	1658	19.8	20.9	1741	10.13.99	14.3	0816	10.14.99	74	97

ID#	Date	Rain (cm)	Comments
30.99	9.25.99		
30.99	9.26.99	0.00	Individual died 9.25.99 in Chattanooga. Brought to facility 9.26.99. Some abdominal bruising and subclavian needle
30.99	9.27.99	0.00	fresh
30.99	9.28.99	0.00	fresh
30.99	9.29.99	0.00	fresh
30.99	9.30.99	0.00	fresh
30.99	10.1.99	0.00	Powerloss. Lost temp and hum high and low. Odor of body noticeable in building.
30.99	10.2.99	0.00	Fluids collection btw legs in bottom of body bag.
30.99	10.3.99	0.00	Body disturbed by animals overnight. Body bag unzipped, r tibia chewed on. Rezipped bag and took sample. GC/MS sample taken.
30.99	10.4.99	0.00	More aninmal activity, zipper broken can only flap body body bag closed.
30.99	10.5.99	0.00	Animal activity. R and L gasterocnemus chewed. Small amount of decomp fluid in pipet B.
30.99	10.6.99	0.72	Animal activity. Flies very active in upper torsal. Small maggot in pipet C..
30.99	10.7.99	0.00	Animal activity.
30.99	10.9.99	0.02	Raining while sampling--dizzle. Noticed a different odor on 10.7.99 continues. Water in tip of all the pipets, a few balls wet.
30.99	10.10.99	0.83	Raining while sampling. Body white in color. Odor remains. Water in all pipets. Main hose came off pump, think it happened when picking up pump after sampling complete.
30.99	10.11.99	0.00	collected under head and chest and in chest cavity. Control taken in body bag in building.
30.99	10.12.99	0.00	No change in body since yesterday.
30.99	10.13.99	0.00	Pipet C broke during sampling.
30.99	10.14.99	0.00	Fly activity heavier than any day last week. No visible maggot activity. Bag still being pulled open but femur no longer being disturbed

ID#	Date	Time	Temp (C)	H Temp (C)	Time of H Temp	Date of H Temp	L Temp (C)	Time of L Temp	Date of L Temp	Humidity	H Hum
30.99	10.15.99	1415	21.4	21.4	1417	10.15.99	10.1	0751	10.15.99	58	95
30.99	10.17.99	1406	23.4	23.6	1722	10.16.99	11.7	0815	10.16.99	52	97

ID#	Date	Time of H Hum	Date of H Hum	L Hum	Time of L Hum	Date of L Hum	ADD	AHD	MAX BRC	MID BRC	MIN BRC
30.99	10.15.99	0935	10.15.99	49	1706	10.14.99	376.2	1274.5	6850	6850	6690
30.99	10.17.99	1032	10.17.99	49	1623	10.16.99	393.85	1347.5	10200	10100	9920

ID#	Date	Rain (cm)	Comments
30.99	10.15.99	0.00	Fly activity slightly less than yesterday.
30.99	10.17.99	0.00	Moderate fly activity. Foam forming around legs and torso. Remains relatively dry.

ID#	Date	Time	Temp (C)	H Temp (C)	Time of H Temp	Date of H Temp	L Temp (C)	Time of L Temp	Date of L Temp	Humidity	H Hum
32.99	11.9.99	1025	15.6	26.5			11.8			94	97
32.99	11.10.99	1517	22.8	25.5	1428	11.9.99	10.5	0517	11.10.99	49	97
32.99	11.11.99	1547	21.1	23.1	1326	11.11.99	14.2	0700	11.11.99	37	86
32.99	11.12.99	1548	21.4	22.3	1452	11.12.99	8.6	0729	11.12.99	44	97
32.99	11.13.99	1548	22.2	22.6	1424	11.13.99	8.6	0603	11.13.99	44	97
32.99	11.14.99	1513	24.3	24.3	1511	11.14.99	9.9	0445	11.14.99	45	97
32.99	11.15.99	1515	14.4	24.3	1527	11.14.99	7.1	0833	11.15.99	31	70
32.99	11.16.99	1607	11.7	14.6	1552	11.15.99	1.1	0734	11.16.99	34	96
32.99	11.17.99	1458	11.8	11.8	1456	11.17.99	-0.6	0756	11.17.99	36	96
32.99	11.18.99	1612	15.4	17.1	1428	11.18.99	-1.1	0737	11.18.99	37	97
32.99	11.19.99	1158	14.8	15.3	1609	11.18.99	1.2	0726	11.19.99	47	97
32.99	11.22.99	1544	22.0	22.1	1537	11.22.99	8.5	0733	11.20.99	65	97
32.99	11.23.99	1612	21.9	22.9	1351	11.23.99	8.8	0558	11.23.99	55	97
32.99	11.24.99	1544	18.1	22.2	1635	11.23.99	11.6	0616	11.24.99	92	97
32.99	11.25.99		15.8	19.1			10.2				

ID#	Date	Time of H Hum	Date of H Hum	L Hum	Time of L Hum	Date of L Hum	ADD	AHD	MAX BRC	MID BRC	MIN BRC
32.99	11.9.99			34			19.15	65.5	5180	4800	3390
32.99	11.10.99	0614	11.10.99	43	1458	11.9.99	37.15	135.5	5900	5190	3530
32.99	11.11.99	0717	11.11.99	33	1431	11.11.99	55.8	195	6680	6550	6370
32.99	11.12.99	0938	11.12.99	36	1635	11.11.99	71.25	261.5	10200	9900	7560
32.99	11.13.99	1023	11.13.99	40	1424	11.13.99	86.85	330	24000	23100	21600
32.99	11.14.99	0934	11.14.99	43	1543	11.13.99	103.95	400	18700	15200	3910
32.99	11.15.99	0755	11.15.99	33	2249	11.14.99	119.65	451.5	27200	12900	9470
32.99	11.16.99	0806	11.16.99	26	1553	11.15.99	127.5	512.5	7500	7430	2850
32.99	11.17.99	0804	11.17.99	34	1615	11.16.99	133.1	577.5	18600	16100	14200
32.99	11.18.99	0909	11.18.99	99	1438	11.18.99	141.1	675.5	5600	5190	5150
32.99	11.19.99	0914	11.19.99	36	1610	11.18.99	149.35	742	25700	9090	
32.99	11.22.99	1035	11.22.99	39	1403	11.19.99	164.65	810	11600	8620	5220
32.99	11.23.99	1032	11.23.99	48	1617	11.22.99	180.5	882.5	6860	6150	
32.99	11.24.99	1232	11.24.99	53	1632	11.23.99	197.4	957.5	9500	8390	6170
32.99	11.25.99						212.05				

ID#	Date	Rain (cm)	Comments
32.99	11.9.99	0.00	White Male 98, COD pneumonia. DOD 11.9.99, 0400
32.99	11.10.99	0.00	No noticeable odor, no fly activity, a few bees. No signs of decomp.
32.99	11.11.99	0.00	Heavy fly activity. Small amount of decomp fluid collected between the legs. Maggot mass visible inside the mouth. Control sample taken.
32.99	11.12.99	0.00	Fly activity heavy especially in abdomen cavity. Animal activity. Hole punctured in R arm and L cheek adjacent to mouth. A lot of maggot eggs in mouth and abdomen cavity--no maggot activity. No noticeable odor.
32.99	11.13.99	0	Heavy fly activity. Dry weather since he arrived only fog in the morning. Egg masses have begun to hatch. Noticeable odor.
32.99	11.14.99	0	Body bag flapped closed between sampling, Zipper broken by animals. Animal activity--ate muscle off R forearm. Heavy fly activity. Noticeable odor. Maggot activity on head intense.
32.99	11.15.99	0	Maggot activity continues on face and abdomen. No more noticeable animal activity. Bowels have been pulled out of the abdomen but only a small amount. Definite odor, greasy. Few flies present
32.99	11.16.99	0	Maggot activity continues-abdominal skin black and greasy. R arm chewed by animals. Noticeable odor.
32.99	11.17.99	0	Body bag flapped open. Maggot activity less but continues. Still greasy smell.
32.99	11.18.99	0	Maggot mound located both in face and abdomen area, Maggots age getting fat. Still smells greasy.
32.99	11.19.99	0	Maggots continue, maybe slightly less in number. Smell--greasy.
32.99	11.22.99	0.00	Maggot activity remains but only in thorax and pubic area. Odor is strong and greasy. Decomp soup has formed.
32.99	11.23.99	0.00	Maggot activity continues in pubic area, thorax, and face. Greasy smell.
32.99	11.24.99		Rained lightly today. Rain gage upset-- didn't record it. Odor smells different-more decomp, less greasy. Maggot activity continues, not great. Pump stopped during sampling.
32.99	11.25.99		No sample taken

ID#	Date	Time	Temp (C)	H Temp (C)	Time of H Temp	Date of H Temp	L Temp (C)	Time of L Temp	Date of L Temp	Humidity	H Hum
32.99	11.26.99		13.6	19.1			7.8				
32.99	11.27.99		12.2	19.4			6.2				
32.99	11.28.99		14.0	21.8			7.0				
32.99	11.29.99		12.8	18.6			7.4				
32.99	11.30.99		7.2	11.0			7.4				
32.99	12.1.99		8.4	16.6			6.2				
32.99	12.2.99	1626	12.0	18.1	1518	11.28.99	4.3	0744	12.2.99	65	97
32.99	12.3.99		10.4	15.2			3.2				
32.99	12.3.99	1106	8.2	12.8	1628	142.2.99	1.6	0707	12.3.99	53	91
32.99	12.5.99	1337	21.7	22.5	1332	12.5.99	3.3	0656	12.5.99	40	97
32.99	12.6.99		15.6	16.8			2.1			40	97
32.99	12.7.99	1607	10.1	10.3	1504	12.7.99	-3.1	0726	12.7.99	43	97

ID#	Date	Time of H Hum	Date of H Hum	L Hum	Time of L Hum	Date of L Hum	ADD	AHD	MAX BRC	MID BRC	MIN BRC
32.99	11.26.99						225.5				
32.99	11.27.99						238.3				
32.99	11.28.99						252.7				
32.99	11.29.99						265.7				
32.99	11.30.99						274.9				
32.99	12.1.99						286.3				
32.99	12.2.99	1057	11.28.99	36	1557	11.15.99	297.5	1024	9580	6870	4140
32.99	12.3.99						306.7				
32.99	12.3.99	0806	12.3.99	34			313.9	1086.5	11600	9260	7820
32.99	12.5.99	1052	12.5.99	35	1524	12.3.99	326.8	1152.5	7730	7070	6940
32.99	12.6.99			36			336.25	1219			
32.99	12.7.99	1025	12.7.99	40	1522	12.7.99	339.85	1287.5	8050	6680	5400

ID#	Date	Rain (cm)	Comments
32.99	11.26.99		No sample taken
32.99	11.27.99		No sample taken
32.99	11.28.99		No sample taken
32.99	11.29.99		No sample taken
32.99	11.30.99		No sample taken
32.99	12.1.99		No sample taken
32.99	12.2.99		New pump charger. Odor strong. Animal activity seems to have stopped.
32.99	12.3.99		No sample taken
32.99	12.3.99		Odor slightly less than yesterday. Visual changes stopped.
32.99	12.5.99	3.00	Strong odor. Visually, same as yesterday.
32.99	12.6.99		No sample taken
32.99	12.7.99		Strong odor. Visually, the same.

ID#	Date	Time	Temp (C)	H Temp (C)	Time of H Temp	Date of H Temp	L Temp (C)	Time of L Temp	Date of L Temp	Humidity	H Hum
33.99	11.12.99		4.4	4.4			4.4				
33.99	11.13.99	1625	22.2	23.6			9.7			44	97
33.99	11.14.99	1540	24.3	24.3	1511	11.14.99	9.9	0445	11.14.99	45	97
33.99	11.15.99	1535	14.4	24.3	1527	11.14.99	7.1	0833	11.15.99	31	70
33.99	11.16.99	1639	11.7	14.6	1552	11.15.99	1.1	0734	11.16.99	34	96
33.99	11.17.99	1527	11.8	11.8	1456	11.17.99	-0.6	0756	11.17.99	36	96
33.99	11.18.99	1630	15.4	17.1	1428	11.18.99	-1.1	0737	11.18.99	37	97
33.99	11.19.99	1215	14.8	15.3	1609	11.18.99	1.2	0726	11.19.99	47	97
33.99	11.20.99		16	18.2			1			50	97
33.99	11.21.99		19.3	21.6			6.2			52	97
33.99	11.22.99	1602	22.0	22.1	1537	11.22.99	8.5	0733	11.20.99	65	97
33.99	11.23.99	1630	21.6	22.9	1351	11.23.99	8.8	0558	11.23.99	55	97

ID#	Date	Time of H Hum	Date of H Hum	L Hum	Time of L Hum	Date of L Hum	ADD	AHD	MAX BRC	MID BRC	MIN BRC
33.99	11.12.99						4.4				
33.99	11.13.99			42			21.05	69.5	5490	4560	5410
33.99	11.14.99	0934	11.14.99	43	1543	11.13.99	38.15	139.5	5650	5390	5200
33.99	11.15.99	0755	11.15.99	33	2249	11.14.99	53.85	191	4950	4950	4880
33.99	11.16.99	0806	11.16.99	26	1553	11.15.99	61.7	252	4880	4700	4410
33.99	11.17.99	0804	11.17.99	34	1615	11.16.99	67.3	317	5010	4910	4790
33.99	11.18.99	0709	11.18.99	33	1433	11.18.99	75.3	382	5530	5310	4390
33.99	11.19.99	0914	11.19.99	36	1610	11.18.99	83.55	448.5	5160	3340	2900
33.99	11.20.99			34			93.15	514			
33.99	11.21.99			38			107.05	581.5			
33.99	11.22.99	1035	11.22.99	39	1403	11.19.99	122.35	649.5			
33.99	11.23.99	1032	11.23.99	48	1617	11.22.99	138.2	722	4640	4500	3140

ID#	Date	Rain (cm)	Comments
33.99	11.12.99		Body in Morgue cooler
33.99	11.13.99		W-F-94 Died approx. 1900 11.12.99 picked up11.13.99@11:00.
33.99	11.14.99		Fly activity heavy. No maggots. Abdomen patches of green. No noticeable odor except when broads were open.
33.99	11.15.99		No fly activity. No visible maggot masses green discoloration same as yesterday. No noticeable odor. Both top and bottom body bag flap closed--may have picked up slight odor from 32.99 white positioning pipette-doubt it.
33.99	11.16.99		No fly activity. Maggot egg mass observable in vestibule of nose. Signs of decomp remain the same. No noticeable odor.
33.99	11.17.99		Signs of decay remain to be minimal. Same maggot egg. Discoloration may increases on R side of abdomen. No noticeable odor.
33.99	11.18.99		We forgot to put cage back over body so animal activity. Both abdomen and thoracic rib open left open. Body bag flipped closed for sample few flies.
33.99	11.19.99		Very small amount of maggot in nose just hatched. Noticeable odor. Temperature has raised a bit and there is a noticeable increase in fly activity around both 32.99 &33.9.The flies can't seem to get into the cage despite the large screen openings. I wonder if this is effecting the odor. I will leave the top off so the flies can get access.
33.99	11.20.99		no sample taken
33.99	11.21.99		no sample taken
33.99	11.22.99		no sample taken
33.99	11.23.99		Fly activity heavy. Buzzards ate off skin and muscles of face and thorax. Will cover cage tonight. Noticeable odor. Pump stopped during sampling.

ID#	Date	Time	Temp (C)	H Temp (C)	Time of H Temp	Date of H Temp	L Temp (C)	Time of L Temp	Date of L Temp	Humidity	H Hum
HC6-99	3.14.00		4.4	4.4			4.4				
HC6-99	3.15.00		4.4	4.4			4.4				
HC6-99	3.16.00		4.4	4.4			4.4				
HC6-99	3.17.00		4.4	4.4			4.4				
HC6-99	3.18.00		4.4	4.4			4.4				
HC6-99	3.19.00		4.4	4.4			4.4				
HC6-99	3.20.00		4.4	4.4			4.4				
HC6-99	3.21.00	1215	17.6	20.2			6			45	97
HC6-99	3.22.00	1300	18	20.4	1716	3.21.00	5	655	3.22.00	45	97
HC6-99	3.23.00	1356	21.5	21.5	1342	3.25.00	5.9	656	3.23.00	34	97
HC6-99	3.24.00	1400	25.4	25.4	1359	3.24.00	7.4	644	3.24.00	34	97
HC6-99	3.25.00	1630	20.8	28.1	1343	3.25.00	13.1	309	3.25.00	71	97
HC6-99	3.26.00	1300	22.6	23.6	1524	3.26.00	15	720	3.26.00	97	97
HC6-99	3.27.00	1316	13.1	23	1702	3.26.00	8.1	244	3.27.00	97	97
HC6-99	3.28.00	1451	18.4	19.6	1705	3.27.00	4.1	439	3.28.00	20	97
HC6-99	3.29.00	1355	13	18	1451	3.28.00	0.6	627	3.29.00	35	89
HC6-99	3.30.00	1610	17	18.6	1334	3.30.00	6.4	117	3.30.00	60	97
HC6-99	3.31.00	1240	19.6	19.9	1236	3.31.00	6.1	700	3.31.00	34	97
HC6-99	4.1.00	1154	22.9	23	1658	3.31.00	6.4	639	4.1.00	40	92
HC6-99	4.2.00	1207	19.9	26.8	1508	4.1.00	13.9	508	4.2.00	97	97
HC6-99	4.3.00	1230	16.6	21.6	1805	4.2.00	14.6	732	4.3.00	97	97
HC6-99	4.4.00	1416	12.6	17.7	1710	4.3.00	6.7	910	4.4.00	37	97
HC6-99	4.5.00	1230	12.5	13.1	1521	4.4.00	-0.7	727	4.5.00	35	97
HC6-99	4.6.00	1430	23.4	23.4	1426	4.6.00	11.2	2200	4.5.00	39	56
HC6-99	4.7.00	1400	24.7	26.3	1757	4.6.00	11.2	620	4.7.00	41	93
HC6-99	4.8.00		13.2	21.12			4.2			39	95
HC6-99	4.9.00	1330	12.5	26.2	1758	4.7.00	-0.3	704	4.9.00	36	97
HC6-99	4.10.00		23.3	23.8	14.57	4.10.00	3.9	528	4.10.00	25	80
HC6-99	4.11.00		18	23.3	15.15	4.10.00	8.1	715	4.11.00	55	86
HC6-99	4.12.00	1600	19	19.1	1603	4.12.00	10.1	930	4.12.00	46	97

ID#	Date	Time of H Hum	Date of H Hum	L Hum	Time of L Hum	Date of L Hum	ADD	AHD	MAX BRC	MID BRC	MIN BRC
HC6-99	3.14.00						4.4				
HC6-99	3.15.00						8.8				
HC6-99	3.16.00						13.2				
HC6-99	3.17.00						17.6				
HC6-99	3.18.00						22				
HC6-99	3.19.00						26.4				
HC6-99	3.20.00						30.8				
HC6-99	3.21.00			34			36.8	65.5	5080	2170	2070
HC6-99	3.22.00	900	3.22.00	36	1722	3.21.00	49.5	132			
HC6-99	3.23.00	849	3.23.00	34	1344	3.23.00	63.2	197.5	5280	4610	3530
HC6-99	3.24.00	851	3.24.00	31	1728	3.23.00	79.6	261.5	5430	5430	4560
HC6-99	3.25.00	1502	3.25.00	31	1600	3.24.00	100.2	325.5	5150	4810	4200
HC6-99	3.26.00	918	3.26.00	21	1545	3.26.00	119.5	384.5	9130	8970	8170
HC6-99	3.27.00	1314	3.27.00	22	1750	3.26.00	135.05	444	9890	5460	5010
HC6-99	3.28.00	1423	3.27.00	18	1431	3.28.00	146.9	501.5	5830	5100	4910
HC6-99	3.29.00	820	3.29.00	20	1458	3.28.00	156.2	556	21900	19800	15800
HC6-99	3.30.00	1029	3.30.00	32	1523	3.29.00	168.7	620.5	21900	14800	12200
HC6-99	3.31.00	845	3.31.00	33	1244	3.31.00	181.7	685.5	22700	19700	15900
HC6-99	4.1.00	705	4.1.00	22	1720	3.31.00	196.4	742.5	24300	22600	20100
HC6-99	4.2.00	1121	4.2.00	32	1524	4.1.00	216.75	807	22900	18200	6370
HC6-99	4.3.00	12.36	4.3.00	75	1808	4.2.00	234.85	893	22400	13800	9120
HC6-99	4.4.00	855	4.4.00	35	1350	4.4.00	247.05	959	21500	20600	19700
HC6-99	4.5.00	900	4.5.00	31	1703	4.4.00	253.25	1023	20400	19700	17300
HC6-99	4.6.00	816	4.6.00	26	1622	4.5.00	270.55	1064	40700	38000	34000
HC6-99	4.7.00	635	4.7.00	36	1800	4.6.00	289.3	1128.5	35700	35600	31600
HC6-99	4.8.00			36			301.96	1194			
HC6-99	4.9.00	1024	4.8.00	36	1321	4.9.00	314.91	1260.5			
HC6-99	4.10.00	616	4.10.00	24	1513	4.10.00	328.76	1312.5			
HC6-99	4.11.00	735	4.11.00	24	1648	4.10.00	344.46	1367.5			
HC6-99	4.12.00	740	4.12.00	45	1604	4.12.00	359.06	1438.5	52200	49800	48200

ID#	Date	Rain (cm)	Comments
HC6-99	3.14.00		Body in Morgue cooler
HC6-99	3.15.00		Body in Morgue cooler
HC6-99	3.16.00		Body in Morgue cooler
HC6-99	3.17.00		Body in Morgue cooler
HC6-99	3.18.00		Body in Morgue cooler
HC6-99	3.19.00		Body in Morgue cooler
HC6-99	3.20.00		Body in Morgue cooler
HC6-99	3.21.00		fresh
HC6-99	3.22.00		No sample taken
HC6-99	3.23.00		fresh
HC6-99	3.24.00	0	externally-fresh
HC6-99	3.25.00	4	discoloration, definate odor, rained briefly but hard before sampling
HC6-99	3.26.00	0	discolored
HC6-99	3.27.00	7	bloated
HC6-99	3.28.00	3	bloated intense fly activity
HC6-99	3.29.00	0	bloated intense fly activity
HC6-99	3.30.00	0	Foul Smell
HC6-99	3.31.00	0	foul smell-bowel
HC6-99	4.1.00	1	Intense marbling-stage bloated
HC6-99	4.2.00	0	Slight rain overnight. bloat and liquefy. Small maggots in chest.
HC6-99	4.3.00	3	Raining during sampling. Scrotum balloon overnight. Bloated.
HC6-99	4.4.00	7	Bloated and discolored. Pump quit during sample
HC6-99	4.5.00	0	Pump weak. Foul smell from the body bag.
HC6-99	4.6.00	0	Bloated and marbling, cranium skeletonized.
HC6-99	4.7.00	0	Maggots in A,B,& C. Decomp fluid in B & C, a lot in B, a little in A.
HC6-99	4.8.00	0	No sample taken
HC6-99	4.9.00	4	No sample taken
HC6-99	4.10.00	0	No sample taken
HC6-99	4.11.00	0	no sample pump broken.
HC6-99	4.12.00	1	New pump. Strong NH4 odor. Decomp fluid spilling from bag. DF and mags in all pipettes

ID#	Date	Time	Temp (C)	H Temp (C)	Time of H Temp	Date of H Temp	L Temp (C)	Time of L Temp	Date of L Temp	Humidity	H Hum
HC6-99	4.13.00	1400	9.9	19.7	1632	4.12.00	7.4	840	4.13.00	97	97
HC6-99	4.14.00	1400	20.6	20.6	1347	4.14.00	8.7	522	4.14.00	59	97
HC6-99	4.15.00		17.2	20.6			12.6			60	97
HC6-99	4.16.00		21.2	20.6			12.6			60	97
HC6-99	4.17.00	1300	23.4	27	1705	4.16.00	12.2	747	4.16.00	60	97
HC6-99	4.18.00	1630	14.7	23.5	1240	4.17.0	11	913	4.18.00	73	97
HC6-99	4.19.00	1300	20.2	20.2	1250	4.19.00	8.7	713	4.19.00	56	97
HC6-99	4.20.00	1530	28.6	28.7	1521	4.20.00	11	656	4.20.00	37	97

ID#	Date	Time of H Hum	Date of H Hum	L Hum	Time of L Hum	Date of L Hum	ADD	AHD	MAX BRC	MID BRC	MIN BRC
HC6-99	4.13.00	1356	4.13.00	43	1707	4.12.00	372.61	1508.5	44200	42400	36700
HC6-99	4.14.00	1055	4.14.00	57	1349	4.14.00	387.26	1585.5	47700	46000	45600
HC6-99	4.15.00			46			403.86	1657			
HC6-99	4.16.00			46			420.46	1728.5			
HC6-99	4.17.00	1012	4.17.00	34	1716	4.16.00	440.06	1794	54100	51700	50300
HC6-99	4.18.00	1001	4.18.00	47	1746	4.17.00	457.31	1866	48500	48400	45800
HC6-99	4.19.00	1006	4.19.00	54	1247	4.19.00	471.76	1941.5	45900	45600	28300
HC6-99	4.20.00	934	4.20.00	34	1249	4.20.00	491.61	2007	37300	36200	35900

ID#	Date	Rain (cm)	Comments
HC6-99	4.13.00	5	raining during sampling. Maggots and df in all 3 pipettes.
HC6-99	4.14.00	2	non-bloated. Maggots and DF in 3 pipets. Pipet B has a ton of maggots.
HC6-99	4.15.00	0	no sample taken
HC6-99	4.16.00	0	no sample taken
HC6-99	4.17.00	0	body almost complete skeleton. Tiny amount of DF in all pipets
HC6-99	4.18.00	1	Little bit of fluid in pipet c
HC6-99	4.19.00	1	Big maggots in A&C, pump laboring.
HC6-99	4.20.00	0	complete skeleton, large maggot in A, small maggots in B

ID#	Date	Time	Temp (C)	H Temp (C)	Time of H Temp	Date of H Temp	L Temp (C)	Time of L Temp	Date of L Temp	Humidity	H Hum
HC7-99	5.1.00	1500	22.3	27.2			16.9			29	97
HC7-99	5.2.00	1300	16.9	22.5	1541	4.27.00	11.5	749	4.28.00	77	97
HC7-99	5.3.00	1230	21.1	21.7	1735	4.28.00	9.8	700	4.28.00	40	97
HC7-99	5.4.00	1200	19.4	22.1	1305	4.29.00	8	719	4.30.00	43	97
HC7-99	5.5.00	1630	26.3	27.2	1458	5.1.00	9.5	723	5.1.00	33	97
HC7-99	5.6.00	1800	25.2	26.2	1702	5.2.00	16.9	542	5.2.00	56	86
HC7-99	5.7.00	1530	27.8	27.8	1521	5.3.00	15.4	727	5.3.00	48	97
HC7-99	5.8.00		29.2	29.5	1509	5.7.00	18.7	632	5.8.00	40	93
HC7-99	5.9.00	1530	26.8	28.2	1710	5.3.00	15.9	737	5.5.00	50	97
HC7-99	5.10.00	1500	27.7	27.8	1421	5.6.00	16.4	722	5.6.00	47	97
HC7-99	5.11.00	1600	29.4	29.4	1445	5.7.00	17.3	733	5.7.00	35	97
HC7-99	5.12.00	1430	29.2	29.5	15	5.7.00	18.7	632	5.8.00	40	93
HC7-99	5.13.00		27.8	30.5	1505	5.13.00	12.9	700	5.11.00	50	95
HC7-99	5.14.00	1430	23.7	29.5	1542	2.8.00	18.1	1452	5.8.000	45	97
HC7-99	5.15.00		21.6	29.1	1426	5.13.00	12.6	710	5.15.00	33.3	73
HC7-99	5.16.00		18.4	26.2			10.9			42	97
HC7-99	5.17.00	1330	27.8	30.5	1505	5.12.00	12.9	700	5.11.00	50	95
HC7-99	5.18.00		26.2	30.8			19.2			45	92
HC7-99	5.19.00	1400	21.6	29.1	1426	5.13.00	12.6	710	5.15.00	33	73
HC7-99	5.20.00		22.9	16.3			19.2			97	97
HC7-99	5.21.00	1621	22.6	26.2	1653	5.16.00	10.9	713	5.16.00	65	82
HC7-99	5.22.00	730	15.8	30.8	1609	5.18.00	15.7	713	5.22.00	97	97

ID#	Date	Time of H Hum	Date of H Hum	L Hum	Time of L Hum	Date of L Hum	ADD	AHD	MAX BRC	MID BRC	MIN BRC
HC7-99	5.1.00			26			22.05	61.5	30800	30800	27400
HC7-99	5.2.00	749	4.28.00	27	1550	4.27.00	39.05	123.5	6680	6300	6250
HC7-99	5.3.00	920	4.29.00	38	1227	4.29.00	54.8	191	7330	6570	6490
HC7-99	5.4.00	1029	4.30.00	32	1307	4.29.00	69.85	255.5			
HC7-99	5.5.00	902	5.1.00	26	1810	4.30.00	88.2	317	31300	9780	5360
HC7-99	5.6.00	544	5.2.00	34	1754	5.1.00	109.75	377	31300	23300	17100
HC7-99	5.7.00	959	5.3.00	48	1522	5.3.00	131.35	449.5	39700	27800	22300
HC7-99	5.8.00	710	5.8.00	32	1512	5.7.00	155.45	512	43200	31100	20900
HC7-99	5.9.00	1040	5.5.00	44	1547	5.3.00	177.5	582.5			
HC7-99	5.10.00	1001	5.6.00	42	1438	5.6.00	199.6	652	28000	23100	20400
HC7-99	5.11.00	904	5.7.00	32	1432	5.7.00	222.95	716.5			
HC7-99	5.12.00	710	5.8.00	32	1512	5.7.00	247.05	779			
HC7-99	5.13.00	616	5.11.00	42	1432	5.11.00	274.85	829	36900	35100	34500
HC7-99	5.14.00	1002	5.10.00	37	1452	5.8.00	298.55	874			
HC7-99	5.15.00	9.24	5.15.00	32	1350	5.15.00	320.15	907.3	30200	23400	3240
HC7-99	5.16.00			45			338.55	949.3			
HC7-99	5.17.00	616	5.11.00	42	1432	5.11.00	366.35	999.3	13300	13000	8580
HC7-99	5.18.00			40			392.55	1044.3			
HC7-99	5.19.00	9.24	5.15.00	32	1350	5.15.00	414.15	1077.3			
HC7-99	5.20.00			29			437.05	1174.3			
HC7-99	5.21.00	858	5.16.00	25	1757	5.15.00	459.65	1239.3			
HC7-99	5.22.00	723	5.22.00	32	14.18	5.12.00	475.45	1336.3	13300	13000	8580

ID#	Date	Rain (cm)	Comments
HC7-99	5.1.00	0	facility 5.1.00 1730 abdomin discolored lower r quadrant
HC7-99	5.2.00	6	continues to discolor
HC7-99	5.3.00		discolored
HC7-99	5.4.00		no sample
HC7-99	5.5.00		discolored
HC7-99	5.6.00		begins to bloate r side of belly
HC7-99	5.7.00		continues to bloat, skin slippage, lot of liquid in bag
HC7-99	5.8.00		full bloate, skin slippage increases, marbling begins
HC7-99	5.9.00		no sample
HC7-99	5.10.00		complete bloate mandible and mid face skeletonized
HC7-99	5.11.00		no sample
HC7-99	5.12.00		no sample
HC7-99	5.13.00	0	Full body complete maggot cover
HC7-99	5.14.00	0	no sample
HC7-99	5.15.00	0	bloating in abdomin continues to skeletonized extensive maggots
HC7-99	5.16.00		no sample
HC7-99	5.17.00	0	body continues to skeletonize no bloating
HC7-99	5.18.00		no sample
HC7-99	5.19.00	0	no sample
HC7-99	5.20.00		no sample
HC7-99	5.21.00	0	no sample
HC7-99	5.22.00		body skeletonized except for legs, bag ripped open by animals.

ID#	Date	Time	Temp (C)	H Temp (C)	Time of H Temp	Date of H Temp	L Temp (C)	Time of L Temp	Date of L Temp	Humidity	H Hum
3.00	3.22.00	1300	18	20.4	1716	3.21.00	5	655	3.22.00	45	97
3.00	3.23.00	1356	21.5	21.5	1342	3.25.00	5.9	656	3.23.00	34	97
3.00	3.24.00	1400	25.4	25.4	1359	3.24.00	7.4	644	3.24.00	34	97
3.00	3.25.00	1630	20.8	28.1	1343	3.25.00	13.1	309	3.25.00	71	97
3.00	3.26.00	1300	22.6	23.6	1524	3.26.00	15	720	3.26.00	97	97
3.00	3.27.00	1316	13.1	23	1702	3.26.00	8.1	244	3.27.00	97	97
3.00	3.28.00	1451	18.4	19.6	1705	3.27.00	4.1	439	3.28.00	20	97
3.00	3.29.00	1355	13	18	1451	3.28.00	0.6	627	3.29.00	35	89
3.00	3.30.00	1610	17	18.6	1334	3.30.00	6.4	117	3.30.00	60	97
3.00	3.31.00	1240	19.6	19.9	1236	3.31.00	6.1	700	3.31.00	34	97
3.00	4.1.00	1154	22.9	23	1658	3.31.00	6.4	639	4.1.00	40	92
3.00	4.2.00	1207	19.9	26.8	1508	4.1.00	13.9	508	4.2.00	97	97
3.00	4.3.00	1230	16.6	21.6	1805	4.2.00	14.6	732	4.3.00	97	97
3.00	4.4.00	1416	12.6	17.7	1710	4.3.00	6.7	910	4.4.00	37	97
3.00	4.5.00	1230	12.5	13.1	1521	4.4.00	-0.7	727	4.5.00	35	97
3.00	4.6.00	1430	23.4	23.4	1426	4.6.00	11.2	2200	4.5.00	39	56
3.00	4.7.00	1400	24.7	26.3	1757	4.6.00	11.2	620	4.7.00	41	93
3.00	4.8.00		13.2	21.12			4.2			39	95
3.00	4.9.00	1330	12.5	26.2	1758	4.7.00	-0.3	704	4.9.00	36	97
3.00	4.10.00		23.3	23.8	14.57	4.10.00	3.9	528	4.10.00	25	80
3.00	4.11.00		18	23.3	15.15	4.10.00	8.1	715	4.11.00	55	86
3.00	4.12.00	1600	19	19.1	1603	4.12.00	10.1	930	4.12.00	46	97
3.00	4.13.00	1400	9.9	19.7	1632	4.12.00	7.4	840	4.13.00	97	97
3.00	4.14.00	1400	20.6	20.6	1347	4.14.00	8.7	522	4.14.00	59	97
3.00	4.15.00		17.2	20.6			12.6			60	97
3.00	4.16.00		21.2	26.12			12.55			60	97
3.00	4.17.00	1300	23.4	27	1705	4.16.00	12.2	747	4.16.00	60	97
3.00	4.18.00	1630	14.7	23.5	1240	4.17.0	11	913	4.18.00	73	97
3.00	4.19.00	1300	20.2	20.2	1250	4.19.00	8.7	713	4.19.00	56	97
3.00	4.20.00	1530	28.6	28.7	1521	4.20.00	11	656	4.20.00	37	97

ID#	Date	Time of H Hum	Date of H Hum	L Hum	Time of L Hum	Date of L Hum	ADD	AHD	MAX BRC	MID BRC	MIN BRC
3.00	3.22.00	900	3.22.00	36	1722	3.21.00	12.7	0	4910	2840	2670
3.00	3.23.00	849	3.23.00	34	1344	3.23.00	26.4	65.5	5280	3580	2400
3.00	3.24.00	851	3.24.00	31	1728	3.23.00	42.8	129.5			
3.00	3.25.00	1502	3.25.00	31	1600	3.24.00	63.4	193.5	4950	4870	2160
3.00	3.26.00	918	3.26.00	21	1545	3.26.00	82.7	252.5			
3.00	3.27.00	1314	3.27.00	22	1750	3.26.00	98.25	312	11600	8100	4630
3.00	3.28.00	1423	3.27.00	18	1431	3.28.00	110.1	369.5	13200	11800	8070
3.00	3.29.00	820	3.29.00	20	1458	3.28.00	119.4	424	26700	25300	23200
3.00	3.30.00	1029	3.30.00	32	1523	3.29.00	131.9	488.5			
3.00	3.31.00	845	3.31.00	33	1244	3.31.00	144.9	553.5	26700	24000	19800
3.00	4.1.00	705	4.1.00	22	1720	3.31.00	159.6	610.5	49700	30200	12200
3.00	4.2.00	1121	4.2.00	32	1524	4.1.00	179.95	675	49000	42500	26500
3.00	4.3.00	12.36	4.3.00	75	1808	4.2.00	198.05	761			
3.00	4.4.00	855	4.4.00	35	1350	4.4.00	210.25	827	31400	25900	25600
3.00	4.5.00	900	4.5.00	31	1703	4.4.00	216.45	891	9940	9910	9190
3.00	4.6.00	816	4.6.00	26	1622	4.5.00	233.75	932	28000	22600	15800
3.00	4.7.00	635	4.7.00	36	1800	4.6.00	252.5	996.5			
3.00	4.8.00			36			265.16	1062			
3.00	4.9.00	1024	4.8.00	36	1321	4.9.00	278.11	1128.5			
3.00	4.10.00	616	4.10.00	24	1513	4.10.00	291.96	1180.5			
3.00	4.11.00	735	4.11.00	24	1648	4.10.00	307.66	1235.5			
3.00	4.12.00	740	4.12.00	45	1604	4.12.00	322.26	1306.5	49700	46600	45500
3.00	4.13.00	1356	4.13.00	43	1707	4.12.00	335.81	1376.5	47300	44700	44400
3.00	4.14.00	1055	4.14.00	57	1349	4.14.00	350.46	1453.5	47100	45500	44000
3.00	4.15.00			46			367.06	1525			
3.00	4.16.00			46			386.395	1596.5			
3.00	4.17.00	1012	4.17.00	34	1716	4.16.00	405.995	1662	39300	38700	38100
3.00	4.18.00	1001	4.18.00	47	1746	4.17.00	423.245	1734	37400	36300	27200
3.00	4.19.00	1006	4.19.00	54	1247	4.19.00	437.695	1809.5	29900	27000	19600
3.00	4.20.00	934	4.20.00	34	1249	4.20.00	457.545	1875	37400	31700	31200

ID#	Date	Rain (cm)	Comments
3.00	3.22.00		fresh
3.00	3.23.00		fresh
3.00	3.24.00	0	no sample
3.00	3.25.00	4	fresh
3.00	3.26.00	0	no sample
3.00	3.27.00	7	discolored-face
3.00	3.28.00	3	discolored-face
3.00	3.29.00	0	bloated
3.00	3.30.00	0	no sample
3.00	3.31.00	0	bloated
3.00	4.1.00	1	no comment
3.00	4.2.00	0	Bloated
3.00	4.3.00	3	no sample
3.00	4.4.00	7	FD spilled out of body bag. Skeletonizing
3.00	4.5.00	0	Weak pump. Thick DF spilling from bag
3.00	4.6.00	0	A lot of DF flowing from bag
3.00	4.7.00	0	no sample taken
3.00	4.8.00	0	no sample
3.00	4.9.00	4	no sample taken
3.00	4.10.00	0	no sample
3.00	4.11.00	0	no sample
3.00	4.12.00	1	no comment
3.00	4.13.00	5	good sample little moisture
3.00	4.14.00	2	no longer bloated-gooing greatly
3.00	4.15.00	0	no sample
3.00	4.16.00	0	no sample
3.00	4.17.00	0	body nearly complete skeleton great maggots decomp foam in pipets
3.00	4.18.00	1	a lot of foam and foul smell
3.00	4.19.00	1	foam, not much odor
3.00	4.20.00	0	continues to foam

ID#	Date	Time	Temp (C)	H Temp (C)	Time of H Temp	Date of H Temp	L Temp (C)	Time of L Temp	Date of L Temp	Humidity	H Hum
4.00	3.24.00	1400	25.4	25.4	1359	3.24.00	7.4	644	3.24.00	34	97
4.00	3.25.00	1630	20.8	28.1	1343	3.25.00	13.1	309	3.25.00	71	97
4.00	3.26.00		22.6	23.6	1524	3.26.00	15	720	3.26.00	97	97
4.00	3.27.00	1316	13.1	23	1702	3.26.00	8.1	244	3.27.00	97	97
4.00	3.28.00	1451	18.4	19.6	1705	3.27.00	4.1	439	3.28.00	20	97
4.00	3.29.00	1355	13	18	1451	3.28.00	0.6	627	3.29.00	35	89
4.00	3.30.00		17	18.6	1334	3.30.00	6.4	117	3.30.00	60	97
4.00	3.31.00		19.6	19.9	1236	3.31.00	6.1	700	3.31.00	34	97
4.00	4.1.00	1154	22.9	23	1658	3.31.00	6.4	639	4.1.00	40	92
4.00	4.2.00	1207	19.9	26.8	1508	4.1.00	13.9	508	4.2.00	97	97
4.00	4.3.00	1230	16.6	21.6	1805	4.2.00	14.6	732	4.3.00	97	97
4.00	4.4.00	1416	12.6	17.7	1710	4.3.00	6.7	910	4.4.00	37	97
4.00	4.5.00	1230	12.5	13.1	1521	4.4.00	-0.7	727	4.5.00	35	97
4.00	4.6.00	1430	23.4	23.4	1426	4.6.00	11.2	2200	4.5.00	39	56
4.00	4.7.00	1400	24.7	26.3	1757	4.6.00	11.2	620	4.7.00	41	93
4.00	4.8.00		13.2	21.12			4.2			39	95
4.00	4.9.00	1330	12.5	26.2	1758	4.7.00	-0.3	704	4.9.00	36	97
4.00	4.10.00		23.3	23.8	14.57	4.10.00	3.9	528	4.10.00	25	80
4.00	4.11.00		18	23.3	15.15	4.10.00	8.1	715	4.11.00	55	86
4.00	4.12.00	1600	19	19.1	1603	4.12.00	10.1	930	4.12.00	46	97
4.00	4.13.00	1400	9.9	19.7	1632	4.12.00	7.4	840	4.13.00	97	97
4.00	4.14.00	1400	20.6	20.6	1347	4.14.00	8.7	522	4.14.00	59	97
4.00	4.15.00		17.2	20.6			12.6			60	97
4.00	4.16.00		21.2	26.12			12.55			60	97
4.00	4.17.00	1300	23.4	27	1705	4.16.00	12.2	747	4.16.00	60	97
4.00	4.18.00	1630	14.7	23.5	1240	4.17.0	11	913	4.18.00	73	97
4.00	4.19.00	1300	20.2	20.2	1250	4.19.00	8.7	713	4.19.00	56	97
4.00	4.20.00	1530	28.6	28.7	1521	4.20.00	11	656	4.20.00	37	97

ID#	Date	Time of H Hum	Date of H Hum	L Hum	Time of L Hum	Date of L Hum	ADD	AHD	MAX BRC	MID BRC	MIN BRC
4.00	3.24.00	851	3.24.00	31	1728	3.23.00	16.4	64	4900	4660	4550
4.00	3.25.00	1502	3.25.00	31	1600	3.24.00	37	128	5100	4990	3120
4.00	3.26.00	918	3.26.00	21	1545	3.26.00	56.3	187			
4.00	3.27.00	1314	3.27.00	22	1750	3.26.00	71.85	246.5	6570	5790	4940
4.00	3.28.00	1423	3.27.00	18	1431	3.28.00	83.7	304	7300	4950	4260
4.00	3.29.00	820	3.29.00	20	1458	3.28.00	93	358.5	20600	18500	7940
4.00	3.30.00	1029	3.30.00	32	1523	3.29.00	105.5	423			
4.00	3.31.00	845	3.31.00	33	1244	3.31.00	118.5	488			
4.00	4.1.00	705	4.1.00	22	1720	3.31.00	133.2	545			
4.00	4.2.00	1121	4.2.00	32	1524	4.1.00	153.55	609.5	23100	21300	15500
4.00	4.3.00	12.36	4.3.00	75	1808	4.2.00	171.65	695.5	20300	18900	17900
4.00	4.4.00	855	4.4.00	35	1350	4.4.00	183.85	761.5	29400	25900	25200
4.00	4.5.00	900	4.5.00	31	1703	4.4.00	190.05	825.5	29200	13600	13100
4.00	4.6.00	816	4.6.00	26	1622	4.5.00	207.35	866.5	30600	27900	27600
4.00	4.7.00	635	4.7.00	36	1800	4.6.00	226.1	931	36800	34000	24000
4.00	4.8.00			36			238.76	996.5			
4.00	4.9.00	1024	4.8.00	36	1321	4.9.00	251.71	1063	42000	40400	25000
4.00	4.10.00	616	4.10.00	24	1513	4.10.00	265.56	1115			
4.00	4.11.00	735	4.11.00	24	1648	4.10.00	281.26	1170			
4.00	4.12.00	740	4.12.00	45	1604	4.12.00	295.86	1241	36400	36400	36200
4.00	4.13.00	1356	4.13.00	43	1707	4.12.00	309.41	1311	36200	34400	34300
4.00	4.14.00	1055	4.14.00	57	1349	4.14.00	324.06	1388	37000	35900	34400
4.00	4.15.00			46			340.66	1459.5			
4.00	4.16.00			46			359.995	1531			
4.00	4.17.00	1012	4.17.00	34	1716	4.16.00	379.595	1596.5	44300	38600	38600
4.00	4.18.00	1001	4.18.00	47	1746	4.17.00	396.845	1668.5	33000	29800	29600
4.00	4.19.00	1006	4.19.00	54	1247	4.19.00	411.295	1744	38100	35600	25800
4.00	4.20.00	934	4.20.00	34	1249	4.20.00	431.145	1809.5	29700	27200	25800

ID#	Date	Rain (cm)	Comments
4.00	3.24.00	0	fresh
4.00	3.25.00	4	discolored
4.00	3.26.00	0	no sample
4.00	3.27.00	7	discolored animals eating arm
4.00	3.28.00	3	discolored animals eating arm
4.00	3.29.00	0	discolored animals eating arm
4.00	3.30.00	0	no sample
4.00	3.31.00	0	no sample
4.00	4.1.00	1	
4.00	4.2.00	0	no bloating massive cranial maggots
4.00	4.3.00	3	massive cranial maggots. Sampled near abdomen
4.00	4.4.00	7	pump stopped during sampling
4.00	4.5.00	0	weak pump
4.00	4.6.00	0	no comment
4.00	4.7.00	0	DF collecting in body bag. Body never bloated.
4.00	4.8.00	0	no sample
4.00	4.9.00	4	pump stopped during sampling
4.00	4.10.00	0	no sample
4.00	4.11.00	0	no sample
4.00	4.12.00	1	Body smells minty maggot activity continues but slow
4.00	4.13.00	5	Good sample
4.00	4.14.00	2	body never bloated, dry decay
4.00	4.15.00	0	no sample
4.00	4.16.00	0	no sample
4.00	4.17.00	0	raining hard during sample
4.00	4.18.00	1	dry decomp odd smell
4.00	4.19.00	1	lots of beetles
4.00	4.20.00	0	pipets fell out of bag while sampling.

ID#	Date	Time	Temp (C)	H Temp (C)	Time of H Temp	Date of H Temp	L Temp (C)	Time of L Temp	Date of L Temp	Humidity	H Hum
5.00	3.28.00	1451	18.4	19.6	1705	3.27.00	4.1	439	3.28.00	20	97
5.00	3.29.00	1355	13	18	1451	3.28.00	0.6	627	3.29.00	35	89
5.00	3.30.00	1610	17	18.6	1334	3.30.00	6.4	117	3.30.00	60	97
5.00	3.31.00	1240	19.6	19.9	1236	3.31.00	6.1	700	3.31.00	34	97
5.00	4.1.00	1154	22.9	23	1658	3.31.00	6.4	639	4.1.00	40	92
5.00	4.2.00	1207	19.9	26.8	1508	4.1.00	13.9	508	4.2.00	97	97
5.00	4.3.00	1230	16.6	21.6	1805	4.2.00	14.6	732	4.3.00	97	97
5.00	4.4.00	1416	12.6	17.7	1710	4.3.00	6.7	910	4.4.00	37	97
5.00	4.5.00	1230	12.5	13.1	1521	4.4.00	-0.7	727	4.5.00	35	97
5.00	4.6.00	1430	23.4	23.4	1426	4.6.00	11.2	2200	4.5.00	39	56
5.00	4.7.00	1400	24.7	26.3	1757	4.6.00	11.2	620	4.7.00	41	93
5.00	4.8.00		13.2	21.12			4.2			39	95
5.00	4.9.00	1330	12.5	26.2	1758	4.7.00	-0.3	704	4.9.00	36	97
5.00	4.10.00		23.3	23.8	14.57	4.10.00	3.9	528	4.10.00	25	80
5.00	4.11.00		18	23.3	15.15	4.10.00	8.1	715	4.11.00	55	86
5.00	4.12.00	1600	19	19.1	1603	4.12.00	10.1	930	4.12.00	46	97
5.00	4.13.00	1400	9.9	19.7	1632	4.12.00	7.4	840	4.13.00	97	97
5.00	4.14.00	1400	20.6	20.6	1347	4.14.00	8.7	522	4.14.00	59	97
5.00	4.15.00		17.2	20.6			12.6			60	97
5.00	4.16.00		21.2	26.12			12.55			60	97
5.00	4.17.00	1300	23.4	27	1705	4.16.00	12.2	747	4.16.00	60	97
5.00	4.18.00	1630	14.7	23.5	1240	4.17.0	11	913	4.18.00	73	97
5.00	4.19.00	1300	20.2	20.2	1250	4.19.00	8.7	713	4.19.00	56	97
5.00	4.20.00	1530	28.6	28.7	1521	4.20.00	11	656	4.20.00	37	97

ID#	Date	Time of H Hum	Date of H Hum	L Hum	Time of L Hum	Date of L Hum	ADD	AHD	MAX BRC	MID BRC	MIN BRC
5.00	3.28.00	1423	3.27.00	18	1431	3.28.00	11.85	57.5	11300	8550	8530
5.00	3.29.00	820	3.29.00	20	1458	3.28.00	21.15	112			
5.00	3.30.00	1029	3.30.00	32	1523	3.29.00	33.65	176.5	17900	17200	15000
5.00	3.31.00	845	3.31.00	33	1244	3.31.00	46.65	241.5	19400	19000	18200
5.00	4.1.00	705	4.1.00	22	1720	3.31.00	61.35	298.5	87400	14700	
5.00	4.2.00	1121	4.2.00	32	1524	4.1.00	81.7	363	74400	7270	5910
5.00	4.3.00	12.36	4.3.00	75	1808	4.2.00	99.8	449	18100	11500	11500
5.00	4.4.00	855	4.4.00	35	1350	4.4.00	112	515	16800	14900	14900
5.00	4.5.00	900	4.5.00	31	1703	4.4.00	118.2	579	21800	21100	16700
5.00	4.6.00	816	4.6.00	26	1622	4.5.00	135.5	620	31200	28700	
5.00	4.7.00	635	4.7.00	36	1800	4.6.00	154.25	684.5	38300	36700	
5.00	4.8.00			36			166.91	750			
5.00	4.9.00	1024	4.8.00	36	1321	4.9.00	179.86	816.5	45200	40600	
5.00	4.10.00	616	4.10.00	24	1513	4.10.00	193.71	868.5			
5.00	4.11.00	735	4.11.00	24	1648	4.10.00	209.41	923.5			
5.00	4.12.00	740	4.12.00	45	1604	4.12.00	224.01	994.5	35500	27100	26900
5.00	4.13.00	1356	4.13.00	43	1707	4.12.00	237.56	1064.5	46700	41900	27300
5.00	4.14.00	1055	4.14.00	57	1349	4.14.00	252.21	1141.5	49400	47400	31100
5.00	4.15.00			46			268.81	1213			
5.00	4.16.00			46			288.145	1284.5			
5.00	4.17.00	1012	4.17.00	34	1716	4.16.00	307.745	1350	51100	48600	45500
5.00	4.18.00	1001	4.18.00	47	1746	4.17.00	324.995	1422			
5.00	4.19.00	1006	4.19.00	54	1247	4.19.00	339.445	1497.5	43500	43100	
5.00	4.20.00	934	4.20.00	34	1249	4.20.00	359.295	1563	39000	35200	33400

ID#	Date	Rain (cm)	Comments
5.00	3.28.00	0	fresh-rat gnawing on left arm and eye.
5.00	3.29.00	0	no sample taken
5.00	3.30.00	0	discolored
5.00	3.31.00	0	discolored
5.00	4.1.00	1	discolored odor of bowel
5.00	4.2.00	1	bloat
5.00	4.3.00	0	odor like bowel raining during sampling
5.00	4.4.00	3	foul odor
5.00	4.5.00	7	bloating and green
5.00	4.6.00	0	many flies in body bag.
5.00	4.7.00	0	Fluid in B
5.00	4.8.00	0	no sample taken
5.00	4.9.00	0	no comment
5.00	4.10.00	4	4.10.00 no sample taken
5.00	4.11.00	0	4.11.00 no sample
5.00	4.12.00	0	heavy DF spilling from bag. B lost MS Few maggots in pipets
5.00	4.13.00	1	Raining during sample lots on maggots
5.00	4.14.00	5	strong smell of NH4 body still bloated
5.00	4.15.00	2	no sample taken
5.00	4.16.00	0	no sample taken
5.00	4.17.00	0	reduced bloating. Lots DF spilling from bag Maggots in all pipets
5.00	4.18.00	0	no sample taken
5.00	4.19.00	1	Many flies and DF from bag.
5.00	4.20.00	1	foul odor

ID#	Date	Time	Temp (C)	H Temp (C)	Time of H Temp	Date of H Temp	L Temp (C)	Time of L Temp	Date of L Temp	Humidity	H Hum
9.00	4.21.00		4.4	4.4			4.4				
9.00	4.22.00		4.4	4.4			4.4				
9.00	4.23.00		4.4	4.4			4.4				
9.00	4.24.00		4.4	4.4			4.4				
9.00	4.25.00		4.4	4.4			4.4				
9.00	4.26.00		4.4	4.4			4.4				
9.00	4.27.00	1500	22.3	4.4			4.4			29	97
9.00	4.28.00	1300	16.9	22.5	1541	4.27.00	11.5	749	4.28.00	77	97
9.00	4.29.00	1230	21.1	21.7	1735	4.28.00	9.8	700	4.28.00	40	97
9.00	4.30.00	1200	19.4	22.1	1305	4.29.00	8	719	4.30.00	43	97
9.00	5.1.00	1630	26.3	27.2	1458	5.1.00	9.5	723	5.1.00	33	97
9.00	5.2.00	1800	25.2	26.2	1702	5.2.00	16.9	542	5.2.00	56	86
9.00	5.3.00	1530	27.8	27.8	1521	5.3.00	15.4	727	5.3.00	48	97
9.00	5.4.00		21.8	17.5			17.5			49	97
9.00	5.5.00	1530	26.8	28.2	1710	5.3.00	15.9	737	5.5.00	50	97
9.00	5.6.00	1500	27.7	27.8	1421	5.6.00	16.4	722	5.6.00	47	97
9.00	5.7.00	1600	29.4	29.4	1445	5.7.00	17.3	733	5.7.00	35	97
9.00	5.8.00	1430	29.2	29.5	15	5.7.00	18.7	632	5.8.00	40	93
9.00	5.9.00		25.1	29.6			20.3			43	97
9.00	5.10.00	1430	23.7	29.5	1542	2.8.00	18.1	1452	5.8.000	45	97
9.00	5.11.00		20.6	29			11.4			47	97
9.00	5.12.00		22.9	30.5			21.4			47	95
9.00	5.13.00	1330	27.8	30.5	1505	5.12.00	12.9	700	5.11.00	50	95
9.00	5.14.00		19	23.5			14.2			41.5	80
9.00	5.15.00	1400	21.6	29.1	1426	5.13.00	12.6	710	5.15.00	33	73
9.00	5.16.00		18.4	26.2			10.9			49	77
9.00	5.17.00	1621	22.6	26.2	1653	5.16.00	18.1	713	5.16.00	65	82
9.00	5.18.00		26.2	31.7			19.2			70	75
9.00	5.19.00		26.8	31.8			21.4			73	95
9.00	5.20.00		22.9	32.6			19.2			80	97

ID#	Date	Time of H Hum	Date of H Hum	L Hum	Time of L Hum	Date of L Hum	ADD	AHD	MAX BRC	MID BRC	MIN BRC
9.00	4.21.00						4				
9.00	4.22.00						8.4				
9.00	4.23.00						12.8				
9.00	4.24.00						17.2				
9.00	4.25.00						21.6				
9.00	4.26.00						26				
9.00	4.27.00			26			30.4	61.5	6080	5280	5060
9.00	4.28.00	749	4.28.00	27	1550	4.27.00	47.4	123.5	6490	6270	5920
9.00	4.29.00	920	4.29.00	38	1227	4.29.00	63.15	191	7000	6770	3570
9.00	4.30.00	1029	4.30.00	32	1307	4.29.00	78.2	255.5	7600	6940	5720
9.00	5.1.00	902	5.1.00	26	1810	4.30.00	96.55	317	7090	6490	5410
9.00	5.2.00	544	5.2.00	34	1754	5.1.00	118.1	377	7030	6270	5930
9.00	5.3.00	959	5.3.00	48	1522	5.3.00	139.7	449.5	14100	13100	5700
9.00	5.4.00			46			157.2	521			
9.00	5.5.00	1040	5.5.00	44	1547	5.3.00	179.25	591.5	41400	39100	35500
9.00	5.6.00	1001	5.6.00	42	1438	5.6.00	201.35	661	49200	48900	42200
9.00	5.7.00	904	5.7.00	32	1432	5.7.00	224.7	725.5	42300	37500	34800
9.00	5.8.00	710	5.8.00	32	1512	5.7.00	248.8	788	38400	38000	32500
9.00	5.9.00			35			273.75	854			
9.00	5.10.00	1002	5.10.00	37	1452	5.8.00	297.55	921	36000	31000	5410
9.00	5.11.00			40			317.75	989.5			
9.00	5.12.00			39			343.7	1056.5			
9.00	5.13.00	616	5.11.00	42	1432	5.11.00	365.4	1125	37900	36000	32300
9.00	5.14.00			42			384.25	1186			
9.00	5.15.00	9.24	5.15.00	32	1350	5.15.00	405.1	1238.5	39500	34900	33300
9.00	5.16.00			29			423.65	1291.5			
9.00	5.17.00	858	5.16.00	25	1757	5.15.00	445.8	1345	37700	34600	33400
9.00	5.18.00			28			471.25	1396.5			
9.00	5.19.00			35			497.85	1461.5			
9.00	5.20.00			32			523.75	1526			

ID#	Date	Rain (cm)	Comments
9.00	4.21.00		Morgue Cooler
9.00	4.22.00		Morgue Cooler
9.00	4.23.00		Morgue Cooler
9.00	4.24.00		Morgue Cooler
9.00	4.25.00		Morgue Cooler
9.00	4.26.00		Morgue Cooler
9.00	4.27.00	0	TOD 2009 on 4.21.00 facility 4.27.00 w-f-43 possible drug overdose
9.00	4.28.00	6	fresh-no maggots
9.00	4.29.00	0	fresh-more fly activity
9.00	4.30.00	0	fresh
9.00	5.1.00	0	r arm beginning to marble intestines beginning to discolor
9.00	5.2.00	0	face bloated abdomen slightly are continues to marble odor
9.00	5.3.00	0	body bloated marbling organs liquefying
9.00	5.4.00		no sample
9.00	5.5.00		body significantly more bloated-small maggots-intestines ballooning
9.00	5.6.00		body still severely bloated great odor
9.00	5.7.00		many maggots along zipper of bag
9.00	5.8.00		body still bloated maggot pop increasing leg skin darkening
9.00	5.9.00		no sample
9.00	5.10.00	0	body still bloated
9.00	5.11.00		no sample
9.00	5.12.00		no sample
9.00	5.13.00	0	motor quit running during sampling extensive maggots. Body bloated
9.00	5.14.00		no sample
9.00	5.15.00	0	bloating declining
9.00	5.16.00		no sample
9.00	5.17.00	0	bloating absent...skeletonizing
9.00	5.18.00		no sample
9.00	5.19.00		no sample
9.00	5.20.00		no sample

ID#	Date	Time	Temp (C)	H Temp (C)	Time of H Temp	Date of H Temp	L Temp (C)	Time of L Temp	Date of L Temp	Humidity	H Hum
9.00	5.21.00		22.9	25.7			17.1			97	97
9.00	5.22.00	719	15.8	30.8	1609	5.18.00	15.7	713	5.22.00	97	97

ID#	Date	Time of H Hum	Date of H Hum	L Hum	Time of L Hum	Date of L Hum	ADD	AHD	MAX BRC	MID BRC	MIN BRC
9.00	5.21.00			35			545.15	1592			
9.00	5.22.00	726	5.22.00	32	1418	5.18.00	568.4	1656.5	39700	37500	35200

ID#	Date	Rain (cm)	Comments
9.00	5.21.00		no sample
9.00	5.22.00	0	body no longer decomposed, collected in pile of goo.

ID#	Date	Time	Temp (C)	H Temp (C)	Time of H Temp	Date of H Temp	L Temp (C)	Time of L Temp	Date of L Temp	Humidity	H Hum
1100	6.14.00		4.4	4.4			4.4				
1100	6.15.00		28.4	32.9			23.6			97	97
1100	6.16.00		25.1	27.9			22			95	97
1100	6.17.00		26.8	31.3			21.4			97	97
1100	6.18.00	1600	25.2	26.5	1234	6.18.00	20.9	745	6.18.00	97	97
1100	6.19.00	700	21.3	26	1826	6.18.00	21.4	652	6.19.00	97	97
1100	6.20.00		26.2	29			23.1			97	97
1100	6.21.00	700	22	29.7	1531	6.20.00	21.5	726	6.19.00	97	97
1100	6.22.00		25.6	29			22			95	97
1100	6.23.00		26.2	31.8			19.7			97	97
1100	6.24.00	700	22.3	32.9			19.5			92	97
1100	6.25.00	1400	29.6	31.8	1653	6.24.00	21.7	610	6.25.00	66	92
1100	6.26.00		27.3	31.3			22.5			68	95
1100	6.27.00	1700	27.1	31.6	1453	6.26.00	22.3	740	6.27.00	71	93
1100	6.28.00		25.6	27.4			23.1			97	97
1100	6.29.00		24	27.4			19.7			95	95
1100	6.30.00	700	17.7	28.2	1731	6.27.00	17.7	715	6.30.00	96	97
1100	7.1.00		24.5	30.1			18.1			86	92
1100	7.2.00		24.5	31.3			17.5			95	95
1100	7.3.00		26.8	32.4			20.8			66	97
1100	7.4.00		27.3	33.5			22.5			75	97
1100	7.5.00	1800	28.6	32.2	1454	7.3.00	17.7	718	6.30.00	71	97
1100	7.6.00		28.4	32.9			17.9			68	95
1100	7.7.00	1430	30.6	31.9	1656	7.6.00	21.6	658	7.7.00	47	97
1100	7.8.00		27.3	32.9			21.4			60	92
1100	7.9.00	1800	32.6	33.5	1455	7.9.00	20.5	643	7.8.00	58	95
1100	7.10.00		30.1	34.6			22.3			55	97
1100	7.11.00	1500	34	34.3	1508	7.10.00	22.5	835	7.11.00	53	97
1100	7.12.00		27.3	30.7			22.4			48	97

ID#	Date	Time of H Hum	Date of H Hum	L Hum	Time of L Hum	Date of L Hum	ADD	AHD	MAX BRC	MID BRC	MIN BRC
1100	6.14.00						4.4		8220	7050	6080
1100	6.15.00			81			32.65	81			
1100	6.16.00			85			57.6	180			
1100	6.17.00			80			83.95	268.5			
1100	6.18.00	1600	6.18.00	81	1253	6.18.00	107.65	357.5	14400	14000	11300
1100	6.19.00	700	6.19.00	83	1919	6.18.00	131.35	447.5	15000	15000	11300
1100	6.20.00			84			157.4	538			
1100	6.21.00	432	6.20.00	68	1450	6.20.00	183	620.5	5050	4870	4780
1100	6.22.00			79			208.5	708.5			
1100	6.23.00			68			234.25	791			
1100	6.24.00			72			260.45	875.5	5390	5180	4710
1100	6.25.00	936	6.24.00	42	1744	6.24.00	287.2	942.5	6190	5000	4760
1100	6.26.00			45			314.1	1012.5			
1100	6.27.00	312	6.27.00	50	1553	6.26.00	341.05	1084	4910	4710	3740
1100	6.28.00			68			366.3	1166.5			
1100	6.29.00			52			389.85	1240			
1100	6.30.00	1310	6.29.00	43	1933	6.29.00	412.8	1310	5030	4760	4700
1100	7.1.00			52			436.9	1382			
1100	7.2.00			46			461.3	1452.5			
1100	7.3.00			49			487.9	1525.5			
1100	7.4.00			35			515.9	1591.5			
1100	7.5.00	855	6.30.00	33	1612	7.2.00	540.85	1656.5	5110	4650	4340
1100	7.6.00			39			566.25	1723.5			
1100	7.7.00	826	7.7.00	46	1432	7.7.00	593	1795	4930	4900	2430
1100	7.8.00			46			620.15	1864			
1100	7.9.00	815	7.9.00	46	1443	7.7.00	647.15	1934.5	4870	4640	4340
1100	7.10.00			42			675.6	2004			
1100	7.11.00	929	7.11.00	32	1439	7.10.00	704	2068.5	5160	4840	4780
1100	7.12.00			35			730.55	2134.5			

ID#	Date	Rain (cm)	Comments
1100	6.14.00		COD heart problems, obese, died 6.14.00, received 6.15.00, first sampled 6.18.00, 40F at morgue, sample taken outside body bag.
1100	6.15.00		no sample
1100	6.16.00		no sample
1100	6.17.00		no sample
1100	6.18.00	0	heavy rain earlier, body bloated, marbled, skin slippage, maggot activity, odor, lack abd. Dis.
1100	6.19.00	0	bloated, skin slippage, heavy maggots mild odor
1100	6.20.00		no sample
1100	6.21.00	0.63	body black, bloated, greasy, extreme maggots and odor
1100	6.22.00		no sample
1100	6.23.00		no sample
1100	6.24.00		body bloated, face skeletonized, foul odor
1100	6.25.00	0	bloated, marbled, face skeletonized, odor
1100	6.26.00		no sample
1100	6.27.00	0	bloating decreasing in legs and arms, odor
1100	6.28.00		no sample
1100	6.29.00		no sample
1100	6.30.00	0.09	maggot activity decreased, bloating gone, slight odor, slowed decomp
1100	7.1.00		no sample
1100	7.2.00		no sample
1100	7.3.00		no sample
1100	7.4.00		no sample
1100	7.5.00	0.04	decomp stopped, no odor
1100	7.6.00		no sample
1100	7.7.00	0.08	body unchanged pump not working
1100	7.8.00		no sample
1100	7.9.00	0	body same, greasy odor
1100	7.10.00		no sample
1100	7.11.00	0	body same, abd more sunken, no odor
1100	7.12.00		no sample

ID#	Date	Time	Temp (C)	H Temp (C)	Time of H Temp	Date of H Temp	L Temp (C)	Time of L Temp	Date of L Temp	Humidity	H Hum
1100	7.13.00		26.8	31.3			21.3			54	97
1100	7.14.00		26.8	31.3			20.7			53	97
1100	7.15.00		26.2	30.7			20.6			52	97
1100	7.16.00		25.6	30.1			19.6			58	97
1100	7.17.00	1300	28.2	34.2	1642	7.11.00	18.7	638	7.17.00	52	97

ID#	Date	Time of H Hum	Date of H Hum	L Hum	Time of L Hum	Date of L Hum	ADD	AHD	MAX BRC	MID BRC	MIN BRC
1100	7.13.00			42			756.85	2204			
1100	7.14.00			32			782.85	2268.5			
1100	7.15.00			34			808.5	2334			
1100	7.16.00			38			833.35	2401.5			
1100	7.17.00	1325	7.14.00	34	1821	7.16.00	859.8	2467			

ID#	Date	Rain (cm)	Comments
1100	7.13.00		no sample
1100	7.14.00		no sample
1100	7.15.00		no sample
1100	7.16.00		no sample
1100	7.17.00	1.34	body same no odor

ID#	Date	Time of H Hum	Date of H Hum	L Hum	Time of L Hum	Date of L Hum	ADD	AHD	MAX BRC	MID BRC	MIN BRC
HC01-00	8.14.00						4				
HC01-00	8.15.00	841	8.15.00	33	1734	8.14.00	29	67	7950	5070	4150
HC01-00	8.16.00	651	8.16.00	37	1815	8.15.00	56.95	133.5			
HC01-00	8.17.00	826	8.17.00	40	1827	8.16.00	85.85	209	18500	9610	7600
HC01-00	8.18.99	342	8.18.00	43	1515	8.18.00	113.1	296			
HC01-00	8.19.00			44			139.75	380.5	20500	10300	9970
HC01-00	8.20.00			44			164	467			
HC01-00	8.21.00	524	8.21.00	42	1748	8.19.00	188.45	564	10500	9600	8730
HC01-00	8.22.00			44			211.95	652			
HC01-00	8.23.00	900	8.22.00	46	1755	8.22.00	235.8	738.5	11100	10700	10700
HC01-00	8.24.00			52			262.35	831			
HC01-00	8.25.00	708	8.25.00	57	1508	8.24.00	287.25	928	13500	13200	9460
HC01-00	8.26.00			46			312.65	1015.5			
HC01-00	8.27.00			54			337.85	1105.5			
HC01-00	8.28.00			57			365.25	1198			
HC01-00	8.29.00			62			391.8	1292.5	21800	20500	18100

ID#	Date	Time	Temp (C)	H Temp (C)	Time of H Temp	Date of H Temp	L Temp (C)	Time of L Temp	Date of L Temp	Humidity	H Hum
HC01-00	8.14.00		4	4			4				
HC01-00	8.15.00	1800	32.5	32.6	1753	8.15.00	17.4	735	8.15.00	39	95
HC01-00	8.16.00	1800	33.5	34.8	1538	8.16.00	21.1	751	8.16.00	41	92
HC01-00	8.17.00	1900	33.1	35.3	1652	8.17.00	22.5	740	8.17.00	54	97
HC01-00	8.18.99	900	21.2	34.1	1512	8.18.00	20.4	735	8.19.00	85	89
HC01-00	8.19.00	1800	21.5	32			21.3			75	94
HC01-00	8.20.00		22.9	28.2			20.3			76	97
HC01-00	8.21.00	700	17	29.9	1600	8.19.00	19	700	8.21.00	97	97
HC01-00	8.22.00		23.4	29.5			17.5			79	97
HC01-00	8.23.00	800	26.2	29.3	1542	8.22.00	18.4	727	8.22.00	76	97
HC01-00	8.24.00		26.7	30.6			22.5			88	97
HC01-00	8.25.00	700	19.8	30	1401	8.24.00	19.8	657	8.25.00	97	97
HC01-00	8.26.00		25.6	32.2			18.6			78	97
HC01-00	8.27.00		25.1	29			21.4			86	94
HC01-00	8.28.00		27.3	33.4			21.4			88	97
HC01-00	8.29.00		26.7	33.4			19.7			92	97

ID#	Date	Rain (cm)	Comments
HC01-00	8.14.00	0	W/M/ DOD 8.14.00~1700 rec'v 8.15.00
HC01-00	8.15.00	0	Fresh
HC01-00	8.16.00	0	no sample
HC01-00	8.17.00	0.05	Abdomen Discolored
HC01-00	8.18.99	0	no sample
HC01-00	8.19.00	0	Adominal discoloration
HC01-00	8.20.00	0.16	no sample
HC01-00	8.21.00	0	Skin slippagge, heavy maggots
HC01-00	8.22.00	0	no sample
HC01-00	8.23.00	0.04	discolored, skin slippage, heavy maggots
HC01-00	8.24.00	0	no sample
HC01-00	8.25.00	0	discolored, skin slippage, heavy maggots
HC01-00	8.26.00	0	no sample
HC01-00	8.27.00	0.24	no sample
HC01-00	8.28.00	0	no sample
HC01-00	8.29.00	0	maggot activity heavy, sot tissue being consumed

Vita

Jennifer C. Love was born in Pittsburgh, Pennsylvania on August 24, 1971. She received her Bachelor's of Arts in Anthropology from the Pennsylvania State University in May of 1994. She received her Master's of Arts in Anthropology from The University of Tennessee in May of 1999. Jennifer received her Doctorate of Philosophy in Anthropology from the University of Tennessee in August of 2001.