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Accelerants

Definition: Any substances, most commonly ignitable liquids, used intentionally to increase the rate and spread of fires.

Significance: In a fire investigation, the primary goal is to identify whether the fire was accidental or intentional. The presence of an accelerant at a fire scene is often indicative of an intentional fire, or arson. Accelerants can be identified from fire debris through conventional forensic analysis.

Accelerants are commonly used in arson fires because they provide additional fuel in areas where the items present may not burn easily. Arsonists often pour accelerants over the areas they want to burn to ensure that their fires spread as much as possible to maximize damage and destruction. Common accelerants are commercially available ignitable liquids—such as gasoline, lighter fluid, and kerosene—that are readily accessible to the arsonist. The identification of an accelerant is significant evidence in a fire investigation because it suggests that the fire was set intentionally.

Identification at the Fire Scene

The identification of accelerants at fire scenes is often a challenge for investigators. Examination of the fire debris by various techniques can be useful in identifying the origin of a fire and any areas of potential accelerant use. After the preliminary identification of a potential accelerant source, samples can be collected and taken back to the forensics laboratory for further analysis.

The types of fire debris most likely to contain sufficient accelerant residue for analysis are porous materials, such as wood and carpet, which can trap residual liquid. Accelerant residue can also pool in the cracks in floors, where it is somewhat protected from the fire. Investigators should collect and store any debris suspected to contain accelerant residue in airtight containers, preferably metal paint cans with friction lids, to eliminate the possibility of the loss of the volatile components within the samples.

Extraction Techniques

Gas chromatography coupled with mass spectrometry is the most common technique used for the analysis of accelerants from fire debris. Before fire debris evidence can be analyzed using the dual instrument known as the gas chromatograph-mass spectrometer (GC-MS), however, the accelerant residue must first be extracted from the debris that was collected. Several techniques can be used to perform this extraction, and each has its own advantages and disadvantages.

In a solvent extraction, the fire debris is washed with a solvent that will dissolve the accelerant residue but not the debris, such as carbon disulfide. The extract can then be injected directly into the GC-MS. A drawback of solvent extraction is that large amounts of potentially hazardous solvents are required to perform an efficient extraction; in addition, this method does not concentrate the accelerant residue effectively. Although solvent extraction was at one time a popular method, it has generally been replaced by quicker, more efficient preconcentration techniques.

In passive headspace extraction, the metal paint can used to collect the debris is heated so that any accelerant present is vaporized and becomes saturated within the area above the debris in the can, which is known as the headspace. A small hole is made in the top of the can and a gastight syringe is used to draw up a sample of the vapor in the headspace, which can then be injected into the GC-MS. Passive headspace extraction is biased toward the more volatile components, but it minimizes the capacity for cross-contamination of the evidence because the accelerant residue is extracted from the same container in which the debris was collected.

A variation of the passive headspace extraction technique is adsorption/elution, in which the debris is heated in the can with a strip of activated charcoal suspended in the headspace. The accelerant vapor is trapped on the strip, from which it is dissolved by a solvent for injection into the GC-MS. Adsorption/elution is affected by the same volatility bias as the passive headspace method, but because the vapor is concentrated onto the charcoal strip, adsorption/elution greatly decreases the potential loss of low-volatility compounds.

The solid-phase microextraction (SPME) technique employs a coated fiber that is housed in a retractable apparatus. The can containing the debris is heated, and this fiber is subjected to the headspace of the can, where the accelerant vapor adsorbs onto the fiber. One advantage of SPME is that the fiber apparatus can be placed directly into the injection port of the GC-MS. The heat of the injection port causes the accelerant trapped on the fiber to desorb from the fiber so that it can be carried into the instrument for analysis. Another advantage of SPME is its potential use for on-site accelerant collection. An investigator can use the SPME fiber apparatus to adsorb accelerant vapor at the fire scene; with the fiber retracted into the apparatus, it is protected from the environment and can be transported directly to the laboratory for analysis.

Instrumental Analysis

Although many techniques have proven useful in accelerant identification, gas chromatography (GC) is by far the most commonly used technique in the forensics laboratory for fire debris analysis. GC is a separation technique that is capable of isolating the numerous individual compounds present in typically complex accelerants. The result of a GC analysis is a chromatogram, which is essentially a chart in which all the components are represented as individual peaks. The pattern of these peaks does not change for a substance and thus is characteristic of that substance. Therefore, when an accelerant residue is examined by GC, its peak pattern can be matched to the peak pattern of a known sample of the same accelerant analyzed for comparison.

When GC is coupled with mass spectrometry (MS), the chemical composition of a sample can be identified conclusively. The pairing of GC and MS allows the identification of individual peaks within the peak pattern and thus is the standard convention for accelerant identification. It should be noted that accelerant identification is considered class evidence because it cannot be individualized to one source. For example, if an accelerant is identified to be gasoline, the pump or even the service station from which it was purchased cannot be determined because of the inherent variation in the process of refining crude oil.

The American Society for Testing and Materials (ASTM), an organization that generates and maintains standards for procedures and materials in a wide array of fields, has developed standard accelerant classes for the identification of accelerants in court. The ASTM classification system for ignitable liquids provides a standardized method of accelerant description for forensic scientists. In this system, nine classes of ignitable liquids are subdivided into three boiling point ranges (light, medium, and heavy). The nine classes—gasoline, petroleum distillates, isoparaffinic products, aromatic products, naphthenic-paraffinic products, normal alkane products, dearomatized distillates, oxygenated solvents, and a final miscellaneous grouping—and their subdivisions provide standard guidelines for the identification of ignitable liquids based on chemical composition.

Difficulties in Identification

Although chromatographic pattern matching is the convention for the identification of accelerants in a forensics laboratory, some factors can alter chromatographic patterns and make it difficult for investigators to identify conclusively any accelerant that may be present. Most common accelerants contain refined petroleum products, which are mixtures of hydrocarbons, and several of these hydrocarbons are found in everyday household products. For example, basic carpeting such as that found in many homes contains compounds similar to those found in common accelerants. This overlap presents a problem for a scientist attempting to identify an accelerant that soaked into a carpet before it was burned.

An efficient extraction technique, such as adsorption/elution or SPME, can separate an accelerant from the fire debris itself. Investigators can also use a data-processing technique called extracted ion chromatography (EIC)—in which specific characteristic peaks can be isolated from other peaks—to understand the data more fully. Because of the potential problem of interference, fire investigators should collect several debris samples, including samples in which no accelerant is expected to be found, in order to understand which chromatographic peaks correspond to the debris and which peaks correspond to an actual accelerant.

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See also: Arson; Bureau of Alcohol, Tobacco, Firearms and Explosives; Burn pattern analysis; Column chromatography; Fire debris; Gas chromatography; Mass spectrometry; National Church Arson Task Force.

Accident investigation and reconstruction

Definition: Collection and analysis of evidence at the scenes of transportation accidents to create models explaining what happened.

Significance: In determining responsibility for motor vehicle and other kinds of transportation accidents, forensic scientists attempt to reconstruct what happened during these events by analyzing the available evidence. The testimony of accident investigators often plays a role in criminal and civil proceedings that stem from accidents.

In the United States, transportation accident investigation and reconstruction are usually carried out by police departments. Some accident investigations, however, fall under federal jurisdiction. The National Transportation Safety Board (NTSB), formed in 1967 as part of the U.S. Department of Transportation, replaced the Civil Aeronautics Board and expanded the role of the federal government in accident investigation and reconstruction. The NTSB became an independent agency in 1975; its duties include the investigation of all civil aviation accidents in the United States as well as all major railroad, highway, marine, and pipeline accidents and any transportation accidents that involve the release of hazardous materials. Private companies also offer accident investigation and reconstruction services.

Accident Investigators

When transportation accidents occur, law-enforcement agencies, insurance companies, manufacturers of the vehicles involved, and the persons involved, including those injured, all have interests in understanding the causes of the accidents and in assigning responsibility. Police officers normally are the first individuals to investigate traffic accidents. Typically, when a serious accident has taken place, the police deal first with any injured people and any hazardous situations created by the accident; they then record information that will allow them to assess how the accident occurred. Most police officers in the United States receive at least brief training in accident investigation; some receive additional specialist training. The accuracy and completeness of the evidence collected by the police at an accident scene affects the degree of accuracy of the accident reconstruction.

In accidents that fall under the jurisdiction of the NTSB, the NTSB becomes the lead investigative agency. In such a case, the role of the local police department initially is to handle any casualties and hazards caused by the accident and then to preserve the scene to the greatest degree possible. NTSB specialists are experienced investigators with strong academic backgrounds in forensic science, physics, structural engineering, aeronautical engineering, and similar fields. NTSB investigators are qualified to serve as expert witnesses in court.

Insurance companies often have their own accident investigators. These investigators, as well as independent investigators hired by attorneys and other interested parties, often enter the accident and reconstruction process after much of the debris from the accident has been cleared away. They may have the opportunity to examine the damaged vehicles, but in attempting to reconstruct the accident they usually must depend on other evidence collected by the police at the accident scene.

Some disagreement exists among experts in accident reconstruction concerning the degree of training and education necessary to qualify an individual as an accident and reconstruction specialist and as an expert witness. Since 1991, the Accreditation Commission for Traffic Accident Reconstruction (ACTAR) has promoted voluntary standards for traffic accident investigators in order to encourage accuracy, consistency, and professionalism in accident investigation and reconstruction. These standards have not been universally adopted, however.

At the highest level, accident reconstruction specialists hold university degrees in engineering, mathematics, physics, or similar fields and have years of experience related to crash analysis and reconstruction. In the United States, the National Academy of Forensic Engineers is empowered by the Council of Engineering and Scientific Specialty Boards to certify accident investigation and reconstruction specialists as "diplomate forensic engineers." This is the highest level of certification, the engineering equivalent of being a board-certified medical specialist. The International Institute of Forensic Engineering Sciences also awards diplomate status to qualified forensic engineers and forensic science professionals.

At the other end of the spectrum, individuals who do not even have high school diplomas can enroll in vocational training programs that focus on accident investigation and reconstruction. These programs call their graduates "certified accident reconstructionists," although many lack the background to do necessary mathematical analyses of accident scenes. Some courts in the United States have begun to reject certified accident reconstructionists as expert witnesses, requiring those who provide expert testimony on accidents to have higher levels of education and expertise.

The Investigation Phase

After immediate needs involving injuries and hazards have been attended to at the scene of an accident, the investigation phase begins. In collecting evidence at an accident scene, the investigators perform some or all of the following tasks: taking witness statements, photographing damage to vehicles and property, measuring and recording tire (skid) marks, recording paint and gouge marks, recording the postcrash locations of all vehicles involved, and recording the positions of all pieces of debris from the accident with photographs and measurements. Using this information, the investigators create a grid map of the crash scene that shows, with measurements, where each skid mark, vehicle, and piece of collision debris and damaged property is located in relation to all others.

Primary accident investigators also use a Haddon matrix to record situational evidence relative to the accident. This tool, developed around 1970 by Dr. William Haddon, the first head of what later became the National Highway Traffic Safety Administration, is a grid on which investigators record information about various conditions before, during, and after the accident at the accident scene. The most common Haddon matrix used for traffic accidents has three rows and three columns, creating nine cells. The rows represent events occurring before the crash, during the crash, and after the crash, respectively, and the columns identify the following factors that could have affected the accident in each time period: human factors (for example, impaired vision, precrash alcohol consumption, speeding, failure to wear a seat belt), vehicle and equipment factors (for example, failed brakes, nonfunctioning lights, malfunctioning air bags, poorly designed fuel tanks that leaked or exploded), and physical, social, and economic factors (for example, missing road signs, nonfunctioning traffic signals, absence of or poorly designed guardrails, cultural attitudes toward alcohol consumption or speeding, interference with or delayed emergency services response).

Electronic Evidence Improves Precision and Confidence

Many new automobiles are equipped with crash data recorders (CDRs) or event data recorders (EDRs). These recorders store data about cars' speed and handling that can provide crucial evidence in accident cases. In November, 2004, Danny Hopkins was convicted of second-degree manslaughter for causing the death of Lindsay Kyle in a car acci- dent. The event data recorder in Hopkins's car had shown that the vehicle was traveling at 106 miles per hour just four seconds before it crashed into the back of Kyle's car, which was stopped at a red light. If Hopkins's car had not been equipped with an event data re- corder, a forensic investigation of the physical evidence, such as skid marks and crash damage, could have been used to estimate the speed of the car. The recorder's data evidence, however, provided better precision, increasing the investigators' confidence that the driver's speed was 106 miles per hour at the time of impact.

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The Reconstruction Phase

During the reconstruction phase, accident investigators apply their knowledge of the laws of physics to the evidence to determine such elements as the speeds of the vehicles involved, the angle of initial impact, the occurrence of secondary impacts, mechanical failures that may have caused the accident, and environmental factors that may affect responsibility for the accident. Damage-based reconstruction is one of the oldest and simplest forms of accident reconstruction. In this approach, the reconstructionist looks at the damage done by and to vehicles and property.

By using information from vehicle manufacturers and applying knowledge of the laws of physics and structural analysis, the reconstructionist is able to determine the approximate rates of speed of the vehicles and their angle of impact. Damage-based reconstruction requires many assumptions and simplifications. For example, car manufacturers provide the results of crash tests for reconstruction engineers, but in using such results, a reconstructionist must assume that the vehicle involved in the accident had the same structural properties as a new vehicle of the same model that was used in the crash tests.

Ideally, damage-based reconstruction should be done in conjunction with trajectory-based reconstruction, which is based on the principle that momentum (speed multiplied by mass) is conserved in a crash. Starting with where the vehicles and debris ended up after a crash, reconstructionists work backward to determine the speed of each vehicle at impact. This method must also take into account forces such as friction of tires on the road, which reduces momentum, and whether the road was wet or dry. The mathematics required to perform trajectory-based reconstruction can be complex, and software programs are available to help with these calculations.

Ultimately, the reconstruction of an accident is only as good as the original information provided by those who measured and recorded the accident scene. All reconstructions involve assumptions, simplifications, and interpretations. Good reconstruction engineers are able to explain their analyses and provide scientific justifications for their conclusions that will stand up to expert examination in a court of law.

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See also: Crime scene measurement; Crime scene reconstruction and staging; Cross-contamination of evidence; Direct versus circumstantial evidence; Flight data recorders; Hit-and-run vehicle offenses; ValuJet Flight 592 crash investigation.

Acid-base indicators

Definition: Substances that show the acidity or alkalinity of solutions within a narrow range.

Significance: Among the tools forensic scientists use to identify unknown substances are acid-base indicators, also known as pH indicators. Such indicators can also enable scientists to detect the presence of contaminating chemicals in solutions, and their use in the analysis of human tissues can provide clues to cause of death.

The acidity or alkalinity of a substance is indicated by its pH, which is a measure of the concentration of hydrogen ions (H^+) in a solution. The pH scale is logarithmic and ranges from 0 to 14. The lower the pH, the more acidic the solution, and the higher the pH, the more alkaline, or basic, the solution; pH 7.0 is neutral and is the pH of pure water.

Acid-base indicators are organic dyes that change color depending on the concentration of hydrogen ions present in a solution. The change does not become visible at a precise point; rather, it happens within a fairly narrow pH range. Many different acid-base indicators are available, and they change colors within different pH ranges. For example, phenolphthalein is colorless at a pH of 8.2 but turns red at a pH of 10. Methyl orange is red at a pH of 3.2 but turns yellow at a pH of 4.4.

The most common acid-base indicator is litmus paper. It comes in two forms, red and blue. When dipped into a solution, blue litmus paper turns red if the pH of the solution is 4.5 or below, indicating the solution is acidic. If the pH of the solution is 8.2 or above, blue litmus paper remains its original blue color. Conversely, red litmus paper remains red when dipped into an acidic solution but turns blue when dipped into a basic solution.

Most often, acid-base indicators are used with a technique called titration. Titration allows analytical chemists to make quantitative determinations of how much acid or alkaline material is in a solution. In the titration of an acid solution, a known quantity of base is added until the correct acid-base indicator changes color. The chemist then measures how much base was used and can calculate how much acid is in the solution. The procedure is reversed with a basic solution.

When investigating an unknown substance such as a confiscated drug, a forensic technician may dissolve a small amount of the substance in water and then test its pH. Conversely, if the substance has been identified and the pH of that substance in pure form is known, the technician may dissolve a small amount of the substance in water to see if the pH varies from the known pH. If it does, this suggests that the substance is contaminated with another chemical.

Acid-base indicators are useful but crude analytical tools. To complete most chemical analyses, forensic scientists usually need to employ more precise analytical tools.

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See also: Crime scene screening tests; Quantitative and qualitative analysis of chemicals; Reagents.

Actuarial risk assessment

Definition: Formation of judgments and predictions regarding dangerous behavior through the application of formulas to particular variables and statistics in preparation for the adoption of necessary preventive measures.

Significance: Forensic psychologists use numerous factors to evaluate the likelihood that particular persons will be involved in violent and dangerous behavior. Predictions based on actuarial risk assessment influence many decisions made in the criminal justice system.

Actuarial risk assessment is one of the many tools that forensic psychologists use to evaluate the likelihood of future violent and dangerous behavior on the part of certain persons. Other methods include clinical predictions, which are based on evidence derived from counseling and experience, and anamnestic predictions, in which psychologists analyze the behavior of specific persons in the past in similar situations. The scientific community has demanded greater reliability in predictions than either clinical or anamnestic methods can provide, and an outcome of this demand has been the use of mathematical formulas to make predictions of risk. Actuarial risk assessment thus employs many of the tools of statistical analysis.

Uses of Risk Assessment

Many people and organizations rely on forensic psychologists and similar experts to make predictions of human behavior. For example, officials in the U.S. criminal justice system rely on risk assessment in making decisions concerning sentencing—for example, in deciding whether to impose probation as a sentence instead of incarceration or whether to sentence a violent offender to death rather than life in prison. A psychologist's prediction concerning a given individual's risk of violent or inappropriate behavior could support the issuance of a restraining order in a domestic dispute or abuse case. Risk assessment may also be used in child-custody decision making and in decisions concerning whether child visitation by a parent should be supervised. Some companies use risk assessment to evaluate the potential for violent behavior in the workplace by terminated employees, and some educational institutions use risk assessment to predict the likelihood of school violence.

Experts also use actuarial risk assessment to predict the potential for recidivism in determining whether to parole prisoners from correctional facilities and in considering the release of offenders who have been confined to mental health facilities. One area of risk assessment that has seen substantial growth concerns the prediction of sexual offending. Predictions in this area may influence whether particular released prisoners must register as sex offenders with their local communities.

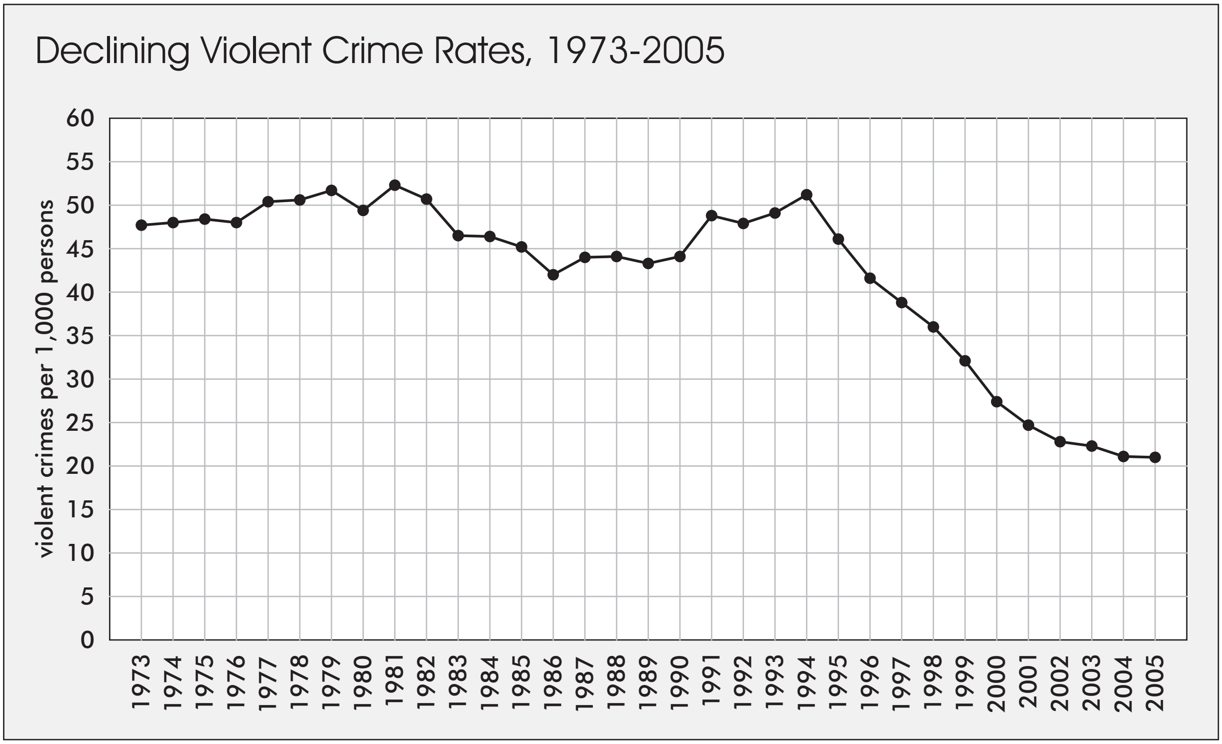
Forensic psychologists may also be called upon to predict the likelihood that certain persons will attempt suicide. In addition, psychologists may have a legal obligation to warn others of any potential danger of harm from any persons they are treating. In some cases, the goal of risk assessment is to determine whether to commit persons to mental health facilities involuntarily because of the likelihood that they may cause serious harm to themselves or others. Risk assessment is also used to decide whether persons who have been involuntarily confined to mental health facilities have become stable enough in their behavior that they are no longer dangerous and can be released.

Risk Assessment Factors

Actuarial risk assessment involves looking at statistical relationships between variables to make judgments and predictions about future behavior. Risk assessment involves a delicate balance between protecting society from physical harm and ensuring that the rights and liberties of the persons subjected to risk assessment are not unduly restricted. Forensic psychologists look at various behavioral characteristics and other factors to increase the accuracy of their scientific approaches to risk assessment. These factors are derived from research involving large groups of people who have exhibited risky or violent behavior in the past and from data gathered by professional clinicians. Some of the factors or variables considered in risk assessment are specifically associated with one behavior, whereas others are predictive across the entire array of potentially risky or dangerous behaviors.

One of the most significant factors considered in risk assessment is the presence or absence of a history of violent behavior. Other risk factors include static predictors such as psychological and physiological characteristics of the person and the person's personal and family history.

Higher risk is associated with relationship and employment instability, education maladjustment, a history of drug and alcohol abuse, and being young. Dynamic characteristics—that is, characteristics that change over



Source: U.S. Bureau of Justice Statistics, 2008. Data represent aggregate violent victimization rates for murder, rape, robbery, and assault.

time—that are associated with higher risk include a lack of insight about personal behavior, the inability to control hostile and impulsive behavior, negative emotions in response to treatment, and ongoing psychotic symptoms such as hallucinations.

Finally, in assessing risk, the person's potential living environments and social networks must be considered, as well as the person's ability to harm others in the future.

Research has found that actuarial risk assessment is more accurate than clinical assessment. Jurors, however, tend to believe the testimony of clinicians over that of actuarial experts, as jurors perceive that clinicians have stronger relationships with and thus more knowledge of the persons being assessed. Despite the scientific basis of actuarial risk assessment by forensic scientists, the prediction of human behavior is very difficult, and significant criticism has been directed toward actuarial risk assessment.

Research has shown that a person's behavior changes over time and that actuarial prediction has an accuracy rate of little more than 50 percent.

Actuarial risk assessment continues to gain acceptance among members of the scientific and legal communities, however, and as risk factors and formulas are enhanced through research, the accuracy rates of this technique should also improve in the future.

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See also: Alcohol-related offenses; Child abduction and kidnapping; Child abuse; *Daubert v. Merrell Dow Pharmaceuticals*; Forensic psychology; Psychological autopsy; Sexual predation characteristics; Suicide; *Tarasoff* rule.

Adipocere

Definition: Naturally occurring substance produced by dead bodies under certain conditions from the hydrolysis of body fat and a sufficient amount of water or moisture.

Significance: Also called grave wax, corpse wax, and mortuary wax, adipocere is commonly formed by the bodies of human beings or animals with sufficient body fat when they lie under wet or moist conditions. The presence of this substance on a human body may help or hinder forensic scientists in estimating the postmortem interval.

The production of adipocere by a body generally requires an anaerobic surrounding (that is, one without free oxygen), a sufficient quantity of body fat (that is, adipose containing connective tissue with lipids present), and any of a variety of bacteria that take oxygen away from other compounds and thus assist in the hydrolysis of the fats. The material was first recognized and described in the seventeenth century, when Sir Thomas Browne wrote in *Hydriotaphia, Urne Buriall* (1658) of encountering the substance while relocating previously buried individuals from an English cemetery. The process of adipocere formation is called saponification, which literally means "soap making" (in times past, soap was made with a combination of animal fat, water, and lye, which produced a grayish-white material that was similar to adipocere in appearance and texture). Because adipose, or body fat, can be either white or brown, adipocere may appear grayish-white or tan in color. It was not until the use of microscopes became widespread during the seventeenth century that scientists began to understand the chemical process of saponification.

Adipocere is an artifact of the decomposition process, and because its formation requires that lipids (fats) be present, it is more commonly seen among animal remains containing comparatively high levels of fat. Among humans, this means that adipocere is found most frequently on the bodies of women, infants, and obese individuals of either sex. In addition, fatter individuals contain more moisture, and fats contain fatty acids that have an affinity to attach to sodium or potassium from the environment. Water assists in this process, and, indeed, adipocere is most often found among tissues that have been kept damp or moist, or even submerged.

It has been suggested that the formation of adipocere on a body may be useful as a guide for forensic scientists in estimating the length of time since death (the postmortem interval, or PMI), much like the appearance of algor, rigor, and livor mortis. However, because adipocere results from a chemical process, the speed with which the substance is formed is temperature-dependent, and, as is true for all other PMI indicators, the rate of formation varies. It appears that the formation of adipocere is speeded up by warmth, but temperature extremes, whether too warm or too cold, impede formation. In addition, because saponification produces a more durable substance than do other processes associated with decomposition, the formation of adipocere can result in a body's retaining facial and other anatomic features well after death.

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See also: Algor mortis; Decomposition of bodies; Forensic entomology; Livor mortis; Mummification; Rigor mortis; Taphonomy.

Air and water purity

Definition: Extent to which natural water and air supplies are free of harmful forms of contamination.

Significance: Various forms of chemical and biological contaminants that pollute air and water supplies are responsible for death, disease, climate shifts, and the alteration of fragile ecosystems around the world. Techniques used to investigate the nature and causes of pollution are allied with forensic toxicology.

Although challenges to air and water purity have always existed, the assault has taken on forbidding aspects since the advent of the industrial age. So ubiquitous are the sources of air and water pollution that they have become woven into the fabric of everyday modern life. However, it is important to note that although much pollution comes from the processes of industry and commerce, pollution is also a product of natural biological and geographic processes. It should also be kept in mind that purity and pollution are relative. For example, although oxygen is necessary to animal life, it is highly toxic to certain organisms that flourish in an atmosphere of methane, which would be lethal to human beings.

Human-made pollutants come from the combustion of fuels that power ships, aircraft, motor vehicles, factories, and power-generating plants. Natural pollutants come from the discharges of wildfires and volcanoes. Pollutants also come from chemical discharges and landfill outgassing as well as military operations that generate nuclear fallout, pathogens, and toxic gases. Pollutants even ride the wind in the form of dust.

A notorious example of the damage inflicted when human activities alter the air's chemistry comes in the form of chlorofluorocarbons (CFCs), which find wide applications as refrigerants, insulating foams, and solvents. CFCs eventually make their way into the stratosphere, where the ultraviolet (UV) rays of sunlight break the CFCs' chemical bonds and release their chlorine atoms. As one chlorine atom is capable of breaking apart 100,000 ozone molecules, damage to Earth's ozone layer is great. The ozone layer protects Earth's surface from the damaging UV rays of the sun; without its protection, human beings are vulnerable to immune disorders, skin cancer, and cataracts. Additionally, increased UV radiation can reduce crop yields and cause serious dislocations in the marine food chain.

Water Quality

The quality of naturally occurring freshwater may be degraded through natural sources such as bedrock salts or sediment containing organic material. Additional degradation of water