Section A-Research paper
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"Implications of Radiation Dating in Forensic Science"

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Abstract: In crime scene investigation, year of birth and death determination of unrevealed human bodies is a major factor in the examination of mass disaster cases. Due to increasing demand of C14 in forensic analysis, the identification of skeletal remains can be done. The different morphological methods are used by anthropologists in the determination of age. In this study we reviewed and compared the methods used in the identification of human remains. There are two Beta decaying devices i.e., Liquid Oscillation Counter and Gas Proportion Counting based on the count of the photon emissions resultant. Along with this, accelerated mass spectrometry is one of the best methods for radiocarbon dating. It is more precise than LOC, uses less amount of sample and gives faster results. Due to advancement in technology and innovations, recently the SCAR method has been used to save time, cut down expenses and for reliability. On the basis of the above techniques soft and hard tissues can be analyzed for the more appropriate results. This indirectly ascertains that soft and hard tissues are good indicators of C-14 in the body. Further research would examine the possibility to determine the year of death, by generating radiocarbon levels from the pupal stages of insects feeding on deceased's soft tissues postmortem.

Keywords: Radiocarbon, C-14 Dating, Forensic, Insects, Identification, Hard and Soft tissues.

INTRODUCTION

Archaeology is a field in which archaeologists' study historic and prehistoric events or remains for the purpose of unveiling myths and conceptions. Archaeologists are experts or scientists who apply their archaeological knowledge i.e., its principles, techniques etc., to unveil a historical myth or event using artifacts and tools. Forensic archaeologists unveil certain happenings for the purpose of justice like mass destruction, destruction due to disasters, nuclear attacks, tragedy etc. Forensic archaeology is itself a broad field, wherein the primary focus of this study employs carbon dating or radiocarbon dating its uses, association with forensic science, techniques used and so on.

Carbon dating is a scientific method used to determine the age of any historic, prehistoric or once existing material. This method makes use of one of the isotopes of Carbon i.e., C^{14} which is a radioactive and unstable isotope among the other isotopes i.e., C^{12} and C^{13}. This method uses radioactive isotope because of its unstable nature and also because it decays at constant rate. Its decay rate is used for the determination of substances. This carbon dating method was first used and developed by Willard Libby in 1946. There are crucially three techniques used in carbon14 dating: - Liquid Scintillation counting, Gas proportional counting and Accelerator Mass Spectrometry**.** This method can help forensic scientists to determine the birth/death of individuals, also the age of a particular individual in case of unidentified dead bodies or remains. This method is also used in finding out wildlife remains, their birth/death. They use the method to get precise results for forensic pathological or forensic entomological investigations. (Heinrich,1988)

Standard carbon-14 studies performed by archaeologists and palynologists address the radiocarbon production activity resulting from the bombardment of nitrogen by ionizing radiation in the Earth's upper atmosphere. Radiocarbon is taken up from the atmosphere and accumulated in plant tissues through plant photosynthesis. Through organic phenomena it is incorporated into all living organisms and into all food webs up to the highest level, including humans. After an organism dies, its carbon-14 content gradually decreases at a generally well-known rate, with a half-life of about 5,730 years. Archaeologists measure the number of isotopes contained in organic remains. Knowing the half-life makes it easy to calculate how long it has been since the remains had the same value as the living thing. Radiocarbon measurements can reveal organic remains about 50,000 years old. Objects older than 500 years are rarely radiocarbon dated. Natural and anthropogenic variability in radiocarbon levels in the environment means that organisms that have lived for centuries over the past 500 years may have the same levels of radiocarbon. (July 2014)

Forensic scientists use carbon-14 measurements in very subtle and diverse ways. Carbon-14 in the atmosphere rose sharply in the 1950s and 1960s when the United States and several other nations tested nuclear weapons. The 1963 Nuclear Test Ban Treaty ended the period for atmospheric testing by many nuclear-weapon states. Since then, the atmospheric carbon-14 content has decreased as radiocarbon has been absorbed by the ocean and biosphere. The radiocarbon produced by a nuclear explosion is indistinguishable from normal radiocarbon, nor does it reach plants and even animal and human tissues. This has erroneously elevated carbon-14 levels in plants and organisms that have lived for the past 60 years. The criminological use of carbon-14 estimates does not rely on slow decomposition processes. Rather, carbon-14 levels in tissues are justifiably compared to abnormally rapidly evolving levels in the atmosphere. Biological information about the timing of development of selected tissues can be used to determine the year of birth or death of the organism from which the tissue originated. (July 2014)

Timeline includes:

1. 1946: Willard Libby et al. When they collected methane from Baltimore’s sewers and isotopically enriched the samples, they found that the matter contained 14C.
2. 1939: Martin and Samuel Reuben at the Berkeley Radiation Laboratory using a laboratory cyclotron accelerometer synthesized 14C.
3. Jules et al. (1995) and Wild et al. (2000): was the first investigator to propose the forensic application of bomb tips. Jules et al. (1995) focused on bone. Wild et al. (2000) measured several soft tissues and found that the 14C levels in hair lagged those in air by about a year.
4. A study by Spalding et al. (2005b) and Bhardwaj et al. (2006) For neural tissue DNA, Lynnerup et al. (2008) studies on crystal proteins in the eye lens confirmed that softer body tissues do not change once complete formation takes place. Theoretically, the radiocarbon content of these animals could also be used to estimate birth year.

5. October 10, 2016: The American Chemical Society has designated the invention of geodetic surveying at the University of Chicago a National Chemical Historic Landmark. 1955: C-14 levels in the atmosphere rise rapidly as a result of nuclear testing, but then return to natural levels.

Radiocarbon Dating of Human remains in Forensics.

Customary anthropological techniques can provide a generally exact age at death for adolescent skeletal remains, but because as it may, are less precise in grown-up or 'develop' people. Further vulnerabilities would be experienced if the remaining parts are deficient or ineffectively saved post-mortem, caused due to a lag between demise of the individual and preservation. Carbon-14 dating of human remains can give better information than other conversational techniques. (Fournier, Nichole & Ross, Ann. 2013).

Five calibration curves currently available from the tropospheric record (three north of the equator and two in the southern half of the globe) provide different estimates of natural matter from 1950 to 2011 (Hua et al. 2013). Information is typically collected in clean air, away from contamination, and significantly away from effluents from nuclear facilities and non-renewable energy sources.

Most nuclear weapons are tested north of the equator. Moving from the northern to the southern hemisphere, and consequently from high to low latitudes. During the early days of the war, large gradients in radiocarbon activity were consequently produced. All living things absorb a certain amount of 14C, and the radiocarbon levels in their bodies reflect their current air fixation rate.

The moment a person's life comes to an end, the body stops sequestering radiocarbon within the body, and this lack of binding can be used to compare 14C levels after death. It will finally reveal time after death. However, all tissues undergo a period of relaxation because it takes time for radiocarbon to penetrate plant matter through photosynthesis and fuel natural life. (Fournier, Nicole, Ross, Anne. 2013) Carbon turnover is generally faster in sensitive tissues, and time lags have been documented between atmospheric levels and human brain tissue. For adults, for blood it is 1.1 years and for lung tissue it is 1.8 years.

Nidal et al. (1971) found a close relationship between exposure to atmospheric radiocarbon and estimates from hair and blood tests. In another extensive study, Harkness and Walton (1972) examined tissue samples from a 37-year-old woman who died in 1969 and found the highest levels of radiocarbon in parts of brain. Stenhouse and Baxter (1977) documented a long gap of 6 years in the case of bone marrow, followed by ligament and bone collagen samples. However, collagen turnover includes a wider range of parameters, including the effects of diet, presence of a disease, the bone growth stimulant Geyh (2001), stress factors, bone anatomy, and personal medications as well as age group. However, these turnover figures are less significant in forensic samples. Several studies have documented lags of 20 to 30 years or more between atmospheric radiocarbon levels and measurements of bone collagen at death in adults, regardless of age. Using the data and peak values, we can calculate the time of death and birth using soft and hard tissues. (Uberaker, Douglas, 2014)

LIQUID SCINTILLATION COUNTER

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This specialized device measures the radioactivity of a sample placed by counting the photons emitted in a particular time interval. The technique of evaluating this radioactivity is called liquid scintillation counting where the scintillator is mixed with an active material like zinc sulfide.

This technique helps in efficient counting due to the contact with scintillator and particularly detects alpha and beta particles. A scintillation counter is composed of a scintillator (generates photons in retort to the radiation), a photodetector (can even be a camera), it helps in processing the signals via electronics and converts light source into an electrical signal. These counters exclusively protect radiation and can be made economically having good efficiency for evaluation.

TECHNIQUE

Samples are immersed in a suspension containing xylene or toluene or any other less hazardous chemical which acts as a surfactant and then mixed with scintillators. Scintillators have the tendency to divide both main and subordinate phosphors using their luminescence

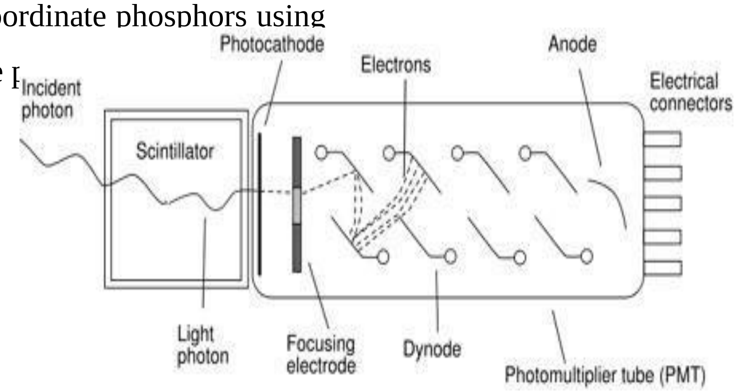

Fig. 1. Liquid Scintillation Counter Instrumentation

When a charged particle is inserted, they follow the same path but when an uncharged particle (gamma rays) is inserted in the device their energy is converted into electron using photoelectric effect or any other suitable method. The scintillators used in counting are usually of two types: organic and inorganic. The emission of Beta particles forms an aromatic ring due to energy transference, hence absorbing the emitted energy. This energized sample transfer energy until fully transferred to the primary scintillator, which then absorbs the energy by emitting the photons. Some counters also contain secondary scintillators which absorb the fluorescence of the primary and emit the photons with a longer wavelength. (Ubelaker, Douglas, 2014)

These radioactive samples and cocktail are transferred to vials which are placed inside the scintillation counter. Under ideal conditions, efficiency ranges from 30% to 100%. Some interference can be observed due to the presence of colored or some chemical compounds which can be solved through careful sample preparation. Beta particles with high energy can be counted without a cocktail by using aqueous solution replacing it which is known as Cherenkov counting. (Wild, Arlamovsky et.al., 2000)

APPLICATIONS

1. They are being used as triggers for other detectors having high voltage pulse applied.
2. They are used to determine time of flight and mass, if the information is proper and accurate like momentum.
3. Scintillators, especially inorganic ones, are used to make electromagnetic calorimeters because of their detection capacity of medium gamma rays.

ACCELERATION MASS SPECTROMETRY

It is a specific of mass spectrometry which is done prior to mass analysis which accelerates ions to gain insanely high kinetic energy. This type of spectrometry has its own tendency to differentiate the isotopes (^{14}C and ^{12}C). It also can suppress molecular isobars, even sometimes atomic isobars which help in long-lived isotope detection. This is mostly used in carbon dating and related methods for decay evaluation, where determining half-life is sufficient. (Huels., Pensold et.al. 2017)

HISTORY

- L.W. Alvarez and Robert Cornog were experimenting on the stability of ^{3}He using cyclotron. They used this accelerator as a mass spectrometer along with cyclotron.

- Richard A. Muller realized efficiency and proposed that modern accelerators can be used to accelerate ions separating the background and published all his findings in a seminal paper.
- K.Purser and colleagues, Berkeley and French teams published their successful experimentation on same (acceleration of radioactive ions). Berkeley and French team also reported the use of this technique in geology.
- The use of these accelerators became sensitive and scientists started using this device along with several other methods. Then the concept of using this technique for radiocarbon dating came to help archaeologists, also forensic archaeologists to serve their purpose.

TECHNIQUE

In an ion source, negative ions are generated which already suppress some number of unwanted isobars. These ions are passed on to two different devices (mass spectrometer and electrostatic tandem accelerator) where they are separated.

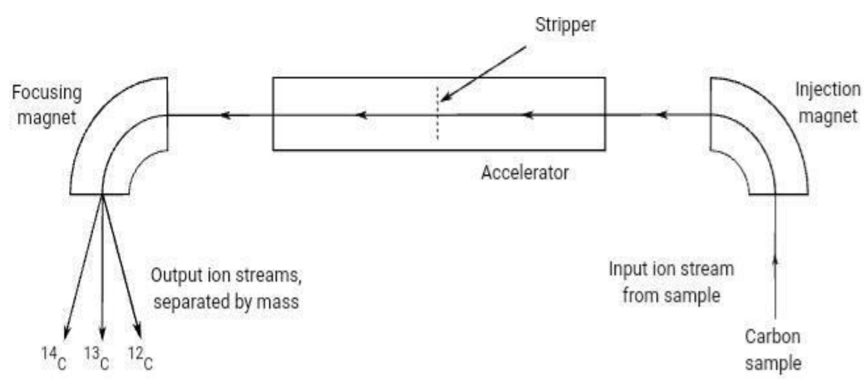

Fig. 2. Acceleration Mass Spectrometry (AMS)

At a connecting point, the ions are converted to positively charged ions and are allowed to oscillate away after the suppression of molecular isobars. Due to like nature the ions are repelled off and are oscillated away from the strips in the second half of accelerator which leads to their way out of accelerator with speed increased insanely. In the second stage, the ions are allowed to pass through velocity selectors having both electric and magnetic fields where the final suppression takes place.

The ions emitted are counted using the spectrometer individually and background isobar identification can also be done using nuclear charge determination. (Zoppi, Skopec, et.al., 2004) Not all AMS adopt the same procedure, the result achievement is done in other ways also, but they all work on same mass selectivity and specificity improvement by raising kinetic energy.

APPLICATIONS

1. Archaeologists use this technique in support with radiocarbon dating, to determine the age of articles by examining ^{14}C concentration.
2. This spectrometer is used along with other spectrometers due to its complete isobar suppression ability.
3. In bone resorption measurement also, AMS is useful and is being widely used in biomedical research.

SCAR

SCAR stands for Saturated absorption cavity ring-down. This is a compact cavity ring-down spectrometer that focuses on the trace amounts of radiocarbon (14C) in biomedical samples. Rapid sampling is required for huge scale studies. Discovered 30 years after the discovery of radiation optical method, this technique has benefited in both cavity ring down and saturation spectroscopy. It encompasses more than 5 magnitude orders and has a wider range than AMS. It enhances the intensity and sensitivity of samples by molecular absorption saturation followed by saturation spectrometric analysis. (Richardin, Coudert, Gandolfo, Vincent, 2013)

TECHNIQUE

The entire system is tested for reproducibility, linearity, sensitivity, and contamination and memory effects of random sampling methods. System performance variability is still limited but is primarily due to tiering and other systematic effects. Some biomedical samples, such as urine and faeces, have been analyzed with 14C concentrations greater than 10-fold their natural abundance during manufacturing. Comparing the results of the technique with those of liquid scintillation

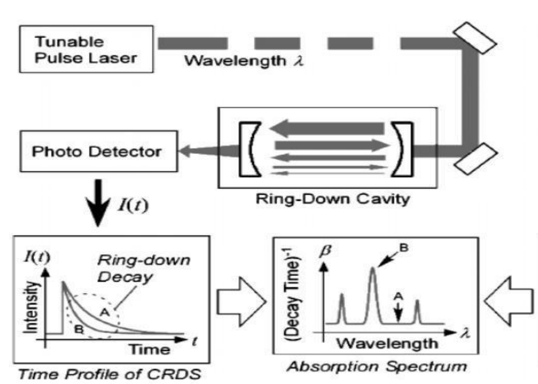

Fig. 3 SCAR instrumentation (T. Iguchi, 2014)

counting systems, it has improved the sensitivity exponentially. (Handlos, Svetlik, 2018)

APPLICATIONS

1. It can be used for spectrometric applications of the hyper fine structure of CO2 due to its sensitivity which is high and frequency precision.
2. SCAR can be combined with tunable radiation delivering source to calculate the trace amounts of gas. (Quarta, D'Elia, Braione, 2019)

DISCUSSION

Radiocarbon (Carbon 14) is a radioactive isotope of the element carbon. So far, we have mentioned it's properties and nature, talking about the various methodologies and principles being used for identification of estimated year of birth and death of an unidentified human remains. These techniques of 14C dating have been described in former sections. Initially, methods like Gas proportional counting and liquid scintillation counting were prevalent. Further enhancement in the field gave rise to Accelerator Mass Spectrometry (AMS), which proved to be one of the most efficient and reliable techniques to overcome the conventional limitations. Throughout the years,14C dating technique has been proliferating, with better mechanisms to work out the process easily and effectively. Hence, an advanced and sophisticated instrument, known as SCAR (Saturated Absorption cavity Ring-down) was developed. This instrument is capable of serving expected results in about 2 hours, with an advantage of suitable size and expense parameters, as compared to that of AMS. Not all substances are datable, organic substances and few of the inorganic ones can be traced for their 14C content, wherein Oxalic Acid 2 is used as a standard. A lot is yet to be discovered in this field, the roots of the 14C dating technique are well established in the archaeological and historical discipline; research in forensic science – the dead remains of humans is still a developing subject. Several established institutes have been conducting studies, considering it a milestone and successfully collaborating science, archaeology and forensics for various cases involving unknown identities, mass destruction and skeletal remains for gathering information about the origin and death of the same.

CONCLUSION

The review research paper encircling the importance of carbon isotope 14C in human bodies is a collaboration of the dating technique for age and death estimations and forensic science for law enforcement. There are a number of methods working on the radiocarbon dating principle and research has proved that it can be of use in cases involving unidentified human remains yielding good results about the approximate lifespan of a corpse. The human body has specific amounts of 14C levels, which after death are subject to constant decay. The content can be analyzed through efficient AMS and SCAR instruments, through carbon dating. This can not only speed up the process of identifying unknown cadavers in homicidal cases, but also helps in getting through unsolved investigations. Since the 1960s, the levels of carbon 14 isotope have been affected rapidly, which makes it prone to decrease in next few decades. Although, with growing advancement and evolutionary alternatives, anything is possibly achievable. A practical approach combined with deep knowledge about the necessary facts can be fruitful. The subject requires a lot of research and experimentation. If we manage to work out things in the right direction, radiocarbon dating can speed up criminal and civil investigations up to several folds. Time is an essential benefactor, and the existing resources need to be tamed gradually and effectively.

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