

Forensic Radiocarbon Dating of Charcoal to Help Crime Scene Investigation

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Abstract- carbon-14 dating, also called radiocarbon dating, method of age determination that depends upon the decay to nitrogen of radiocarbon (carbon-14). Carbon-14 is continually formed in nature by the interaction of neutrons with nitrogen-14 in the Earth's atmosphere; the neutrons required for this reaction are produced by cosmic rays interacting with the atmosphere. Radiocarbon present in molecules of atmospheric carbon dioxide enters the biological carbon cycle: it is absorbed from the air by green plants and then passed on to animals through the food chain. Radiocarbon decays slowly in a living organism, and the amount lost is continually replenished as long as the organism takes in air or food. Once the organism dies, however, it ceases to absorb carbon-14, so that the amount of the radiocarbon in its tissues steadily decreases. Carbon-14 has a half-life of $5,730 \pm 40$ years—i.e., half the amount of the radioisotope present at any given time will undergo spontaneous disintegration during the succeeding 5,730 years. Because carbon-14 decays at this constant rate, an estimate of the date at which an organism died can be made by measuring the amount of its residual radiocarbon. In the reference we can find accurate age of coal particle by accelerated mass spectroscopy. It is easy way to find out their age also this context this can help crime scene investigation.

Indexed Terms- Forensic Radio carbon, charcoal, Accelerated mass spectroscopy Crime scene

I. INTRODUCTION

In forensic Science Radiocarbon dating most routine as powerful tool for specimen age Carbon dating method help to forensic scientist identify the trace amount of radioactive material are present in organic remains of 500- 50,000 years Radiocarbon (14C) is produced naturally in atmosphere, by the interaction

of cosmic rays nitrogen (14) Radio Carbon dating naturally decay with half life. 5730 years allows measuring the ratio of 14C/12C for back 50,000 years ago.[1] carbon dating is only technique. that as been useful for determination approximate age of carbon based materials In 1946 American physical chemist Willard Libby Propose innovative Radiocarbon dating. Radiocarbon dating works by Comparing the three different isotopes of carbon Isotopes of a protein element have the same number of Proton in their nucleus but different number of Neutron this means that although they are similar chemically they have different mass.[2] Over time 14 C decay to nitrogen most 14C is produced in the upper atmosphere where neutron, Which Produce Cosmic rays, react with 14 Neutron Every plant and animal In $(1/2)^{t/5700}$ In e $5700K = 5700$ K will therefore have same amount of $k = \ln(1/2)/5700$

0.000125 atmosphere the 14C and 12C ratio on archeological and palaeoenvorimental at context Charcoal generally refers to microscopic material resulting from incomplete Combustion of woody plant tissue Accelerator mass Spectroscopy (AMS) is a form of mass Spectroscopy that accelerated ions to extraordinary high kinetic energy before mass analysis this allows the separation of isotopes having neighbouring masses.[3]

Charcoal is a lightweight black carbon residue produced by strongly heating wood (or other animal and plant materials) in minimal oxygen to remove all water and volatile constituents. In the traditional version of this pyrolysis process, called charcoal burning, of ten by forming a charcoal kiln the heat is supplied by burning part of the starting material itself, with a limited supply of oxygen. The material can also be heated in a closed retort. Modern "charcoal" briquettes used for outdoor cooking may contain many other additives .

e.g. coal. This process happens naturally when combustion is incomplete and is sometimes used in radiocarbon dating. It also happens inadvertently while burning wood, as in a fireplace or wood stove. The visible flame in these is due to combustion of the volatile gases exuded as the wood turns into charcoal. The soot and smoke commonly given off by wood fires result from incomplete combustion of those volatiles. Charcoal burns at a higher temperature than wood, with hardly a visible flame, and releases almost nothing except heat and carbon dioxide (One kilogram of charcoal contains 680 to 820 grams of carbon, which when combined with oxygen from the atmosphere form 2.5 to 3 kg of carbon dioxide). [4]

- Common charcoal is made from peat, coal, wood, coconut shell, or petroleum.
- Sugar charcoal is obtained from the carbonization of sugar and is particularly pure. It is purified by boiling with acids to remove any mineral matter and is then burned for a long time in a current of chlorine to remove the last traces of hydrogen. It was used by Henri Moissan in his early attempt to create synthetic diamonds.
- Activated charcoal is similar to common charcoal but is manufactured especially for medical use. To produce activated charcoal, common charcoal is heated to about 900 °C (1,700 °F) in the presence of a gas (usually steam), causing the charcoal to develop many internal spaces, or "pores", which help the activated charcoal to trap chemicals. Impurities on the surface of the charcoal are also removed during this process, greatly increasing its adsorption capacity.
- Lump charcoal is a traditional charcoal made directly from hardwood material. It usually produces far less ash than briquettes. [5]
- Japanese charcoal has had pyrolytic acid removed during the charcoal making; it therefore produces almost no smell or smoke when burned. The traditional charcoal of Japan is classified into three types:
 - White charcoal is very hard and produces a metallic sound when struck.
 - Black charcoal
 - Ogatan is a more recent type made from hardened sawdust.

- Pillow shaped briquettes are made by compressing charcoal, typically made from sawdust and other wood by-products, with a binder and other additives. The binder is usually starch. Briquettes may also include brown coal (heat source), mineral carbon (heat source), borax, sodium nitrate (ignition aid), limestone (ash-whitening agent), raw sawdust (ignition aid), and other additives. [6]
- Sawdust briquette charcoal is made by compressing sawdust without binders or additives. It is the preferred charcoal in Taiwan, Korea, Greece, and the Middle East. It has a round hole through the center, with a hexagonal intersection. It is used primarily for barbecue as it produces no odour, no smoke, little ash, high heat, and long burning hours (exceeding 4 hours).
- Extruded charcoal is made by extruding either raw ground wood or carbonized wood into logs without the use of a binder. The heat and pressure of the extruding process hold the charcoal together. If the extrusion is made from raw wood material, the extruded logs are subsequently carbonized.
 - Production and utilisation of charcoal, like any use of woody biomass as fuel, typically results in emissions and can contribute to deforestation.
 - The use of charcoal as a smelting fuel has been experiencing a resurgence in South America resulting in severe environmental, social and medical problems. Charcoal production at a sub-industrial level is one of the causes of deforestation. Charcoal production is now usually illegal and nearly always unregulated as in Brazil where charcoal production is a large illegal industry for making pig iron.
 - Massive forest destruction has been documented in areas such as Virunga National Park in the Democratic Republic of Congo, where it is considered a primary threat to the survival of the mountain gorillas. Similar threats are found in Zambia.
 - In Malawi, illegal charcoal trade employs 92,800 workers and is the main source of heat and on the surface of the charcoal are also

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- Massive forest destruction has been documented in areas such as Virunga National Park in the Democratic Republic of Congo, where it is considered a primary threat to the survival of the mountain gorillas. Similar threats are found in Zambia. In Malawi, illegal charcoal trade employs 92,800 workers and is the main source of heat and
 - cooking fuel for 90 percent of the nation's population. Some experts, such as Duncan MacQueen, Principal Researcher—Forest Team, International Institute for Environment and Development (IIED), argue that while illegal charcoal production causes deforestation, a regulated charcoal industry that required replanting and sustainable use of the forests "would give their people clean efficient energy – and their energy industries a strong competitive advantage".
- Recent assessments of charcoal imported to Europe have shown that many charcoal products are produced from tropical wood, often of undeclared origin. In an analysis of barbecue charcoal marketed in Germany, the World Wildlife Fund finds that most products contain tropical wood. As a notable exception, reference is made to barbecue charcoal imports from Namibia, where charcoal is typically produced from surplus biomass resulting from bush encroachment. Radiocarbon dating (also referred to as carbon dating or carbon-14 dating) is a method for determining the age of an object containing organic material by using the properties of radiocarbon, a radioactive isotope of carbon.[8]
 - The method was developed in the late 1940s at the University of Chicago by Willard Libby. It is based on the fact that radiocarbon (^{14}C) is constantly being created in the Earth's atmosphere by the interaction of cosmic rays with atmospheric nitrogen. The resulting ^{14}C combines with atmospheric oxygen to form radioactive carbon dioxide, which is incorporated into plants by photosynthesis; animals then acquire ^{14}C by eating the plants. When the animal or plant dies, it

stops exchanging carbon with its environment, and thereafter the amount of ^{14}C it contains begins to decrease as the ^{14}C undergoes radioactive decay. Measuring the amount of ^{14}C in a sample from a dead plant or animal, such as a piece of wood or a fragment of bone, provides information that can be used to calculate when the animal or plant died.

sample is, the less ^{14}C there is to be detected, and because the half-life of ^{14}C (the period of time after which half of a given sample will have decayed) is about 5,730 years, the oldest dates that can be reliably measured by this process date to approximately 50,000 years ago, although special preparation methods occasionally make accurate analysis of older samples possible. Libby received the Nobel Prize in Chemistry for his work in 1960.

- Research has been ongoing since the 1960s to determine what the proportion of ^{14}C in the atmosphere has been over the past fifty thousand years. The resulting data, in the form of a calibration curve, is now used to convert a given measurement of radiocarbon in a sample into an estimate of the sample's calendar age. Other corrections must be made to account for the proportion of ^{14}C in different types of organisms (fractionation), and vary single velsof ^{14}C throughout the biosphere (reservoir effects). Additional complications come from the burning of fossil fuels such as coal and oil, and from the above-ground nuclear tests done in the 1950s and 1960s. Because the time it takes to convert biological materials to fossil fuels is substantially longer than the time it takes for its ^{14}C to decay below detectable levels, fossil fuels contain almost no ^{14}C . As a result, beginning in the late 19th century, there was a noticeable drop in the proportion of ^{14}C as the carbon dioxide generated from burning fossil fuels began to accumulate in that atmosphere. Conversely, nuclear testing increased the amount of ^{14}C in the atmosphere, which reached a maximum in about 1965 of almost double the amount present in the atmosphere prior to nuclear testing. [9]
- Measurement of radiocarbon was originally done by beta-counting devices, which in the sample and not just the few that happen to decay during the measurements; it can therefore be used with

much smaller samples (as small as individual plant seeds), and gives results much more quickly. The development of radiocarbon dating has had a profound impact on archaeology. In addition to permitting more accurate dating within archaeological sites than previous methods, it allows comparison of dates of events across great distances. Histories of archaeology often refer to its impact as the "radiocarbon revolution". Radiocarbon dating has allowed key transitions in prehistory to be dated, such as the end of the last ice age, and the beginning of the Neolithic and Bronze Age in different regions.

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Measurement of radiocarbon was originally done by beta-counting devices, which counted the amount of beta radiation emitted by decaying C atoms in a sample. C atoms in the sample and not just the few that happen to decay during the measurements; it can therefore be used with much smaller samples (as small as individual plant seeds), and gives results much more quickly. The development of radiocarbon dating has had a profound impact on archaeology. In addition to permitting more accurate dating within archaeological sites than previous methods, it allows comparison of dates of events across great distances. Histories of archaeology often refer to its impact as the "radiocarbon revolution". Radiocarbon dating has allowed key transitions in prehistory to be dated, such as the end of the last ice age, and the beginning of the Neolithic and Bronze Age in different regions.

The phenomenon of Adsorption is a widely used as an effective physical method for elimination or lowering the concentration of wide range of dissolved pollutants (organic and inorganic) in an effluent. Activated carbon (AC) is the best adsorbent that can be used effectively for removal of broad spectrum of pollutants from air, soil and liquids. Activated carbon is prepared by carbonization and activation of a large number of raw materials of organic origin such as wood, coal, coconut shell and lignite (Zhonghuo, et al, 2001). Characteristics of the ACs depend on the physical and chemical properties of the raw materials as well as the methods of activation (Lua, et al, 2001). The carbonization process enriches the carbon content and introduces the porosity in the char while activation further develops the porosity and creates some ordering in the structure.[11]

Activated charcoal is an insoluble powder produced by pyrolysis of organic material. It is able to adsorb a wide variety of drugs and toxic agents onto its surface. The capacity of charcoal to bind chemicals has been recognised for centuries and the first systematic studies of charcoal as an antidote were

performed in the early 1800s. During the following hundred years, several studies on activated charcoal were published, but in many countries and in many hospitals its use as an antidote has not been accepted until recently. One reason for this neglect has been the lack of suitable formulations, a situation which has prevented the use of activated charcoal in adequate amounts. Furthermore, until the 1980s there have been only a few experimental or clinical human studies on the antidotal effect of high doses of activated charcoal. The effect of high single and repeated doses of charcoal on the absorption and elimination of various drugs has been studied intensively during the last 10 years. Various aspects of the antidotal use of activated charcoal have been reviewed lately (Cooney 1980; Levy 1982; Neuvonen 1982; Olkkola 1985a; Park et al. 1986; Pond 1986; Spector et al. 1986). As a result, the initial management in particular of intoxicated patients has changed.[12]

Single-dose activated charcoal should not be administered routinely in the management of poisoned patients. Based on volunteer studies, the administration of activated charcoal may be considered if a patient has ingested a potentially toxic amount of a poison (which is known to be adsorbed to charcoal) up to one hour previously. Although volunteer studies demonstrate that the reduction of drug absorption decreases to values of questionable clinical importance when charcoal is administered at times greater than one hour, the potential for benefit after one hour cannot be excluded. There is no evidence that the administration of activated charcoal improves clinical outcome. Unless a patient has an intact or protected airway, the administration of charcoal is contraindicated. A review of the literature since the preparation of the 1997 Single-dose Activated Charcoal Position Statement revealed no new evidence that would require a revision of the conclusions of the Statement.

Activated charcoal can be prepared from one of a variety of carbon-containing materials. Wood pulp with a low ash content, coal, lignite and rye starch are some examples of sources. Once the charcoal (nearly pure carbon) is obtained through chemical means, it is broken down into a fine granular form. To activate it, a further process of treating it with steam, oxygen,

carbon dioxide, certain acids and other chemicals is undertaken. This activating process removes impurities and creates fine, small granules. As a result, currently used activated charcoal has a surface area of about 1,000 m² per gram, while experimental activated charcoal with surface areas of up to 3,500 m² per gram has been manufactured.⁷ Activated charcoal will adsorb most drugs and toxins,^{8,9} but not all compounds are well adsorbed [13]

Charcoal for medicinal use is created by the controlled pyrolytic decomposition of carbon-based compounds, such as coconut shells or peat. Thereafter, 'activation' with gases at high temperature removes previously adsorbed substances and further reduces particle size, resulting in an exceptionally porous final product. Indeed, some 'superactivated' charcoal preparations have a surface area of up to 3500 m² g⁻¹, or about 175 000 m² per 50 g bottle (For perspective, the area of a large football pitch is about 10 000 m².) This allows the adsorption of drugs and toxins through weak intermolecular forces, with non-ionized, organic compounds binding more avidly than dissociated, inorganic ones

Activated carbon has been used in purification schemes for centuries because of its remarkable adsorption properties. While these properties are certainly related to the porous nature of the carbon, the detailed mechanism of adsorption remains rather speculative at the present time. In the case of non-electrolytes, physical or 'specific' adsorption takes place at the solid-liquid interface, whereas with electrolytes a chemical or 'non-specific' adsorption takes place in the electrical double layer surrounding each carbon surface.

II. CARBON EXCHANGE RESERVOIR

- Simplified version of the carbon exchange reservoir, showing proportions of carbon and relative activity of the ¹⁴C in each reservoir
- Carbon is distributed throughout the atmosphere, the biosphere, and the oceans; these are referred to collectively as the carbon exchange reservoir, and each component is also referred to individually as a carbon exchange reservoir. The different elements of the carbon exchange

reservoir vary in how much carbon they store, and in how long it takes for the ¹⁴C generated by cosmic rays to fully mix with them. This affects the ratio of ¹⁴C to ¹²C in the different reservoirs, and hence the radiocarbon ages of samples that originated in each reservoir. The atmosphere, which is where ¹⁴C is generated, contains about 1.9% of the total carbon in the reservoirs, and the ¹⁴C it contains mixes in less than seven years. The ratio of ¹⁴C to ¹²C in the atmosphere is taken as the baseline for the other reservoirs: if another reservoir

- has a lower ratio of ¹⁴C to ¹²C, it indicates that the carbon is older and hence that either some of the ¹⁴C has decayed, or the reservoir is receiving carbon that is not at the atmospheric baseline. The ocean surface is an example: it contains 2.4% of the carbon in the exchange reservoir, but there is only about 95% as much ¹⁴C as would be expected if the ratio were the same as in the atmosphere. The time it takes for carbon from the atmosphere to mix with the surface ocean is only a few years, but the surface waters also receive water from the deep ocean, which has more than 90% of the carbon in the reservoir. Water in the deep ocean takes about 1,000 years to circulate back through surface waters, and so the surface waters contain a combination of older water, with depleted ¹⁴C, and water recently at the surface, with ¹⁴C in equilibrium with the atmosphere. Creatures living at the ocean surface have the same ¹⁴C ratio as the water they live in, and as a result of the reduced ¹⁴C/¹²C ratio, the radiocarbon age of marine life is typically about 400 years. Organisms on land are in closer equilibrium with the atmosphere and have the same ¹⁴C/¹²C ratio as the atmosphere. These organisms contain about 1.3% of the carbon in the reservoir; sea organisms have a mass of less than 1% of those on land and are not shown in the diagram. Accumulated dead organic matter, of both plants and animals, exceeds the mass of the biosphere by a factor of nearly 3, and since this matter is no longer exchanging carbon with its environment, it has a ¹⁴C/¹²C ratio lower than that of the biosphere. [14]

III. METHODOLOGY

- SAMPLES FOR CARBON DATING

A. Suitability of Materials

In order to be suitable for use in carbon dating, materials commonly derived from biological systems must contain Carbon that was initially able to exchange with the atmosphere. Samples collected for Carbon dating must be changed into suitable forms for measuring the ^{14}C content: which means depending on the measurement technique to be used for dating, the sample is converted to gaseous, liquid, or solid forms accordingly. Before that, the sample must be treated to remove any contamination and any unwanted components.

Charcoals are very much preferred for carbon dating because of their high carbon content which does not get replaced by other carbon sources. However, soil-buried charcoal can easily absorb considerable amounts of soluble soil humic substance mainly formed in-situ especially in seasonally wet soil rich in organic matter. Treating charcoal's exhaustively with a mixture of 0.1M NaOH helps. Charcoals are very much preferred for carbon dating because of their high carbon content which does not get replaced by other carbon sources. However, soil-buried

Charcoals can easily adsorb considerable amounts of soluble soil humid substances, mainly formed in-situ especially in seasonally wet soil rich in organic matter. Treating charcoals exhaustively with a mixture of 0.1M NaOH : 0.1M NaOH helps to remove such contamination [15]

- Sampling charcoal for Radiocarbon Dating
sampling of macroscopic charcoal from archeological site and soil sedimentary sequence is relative & bright and fragments can be handpicked from the sedimentary matrix wrapped in solvent-washed aluminum foil and sealed in a labelled plastic bag.
Charcoal : to separate charcoal from sediment matrix use tweezers for micro tweezers for large pieces of charcoal that are not coarse in a lot of days you can use water floatation. Dry charcoal samples at temperature less than 70°C for 12-24 hours prior to shipping. In AMS the sample is first changed to a

solid graphite by conversion to CO_2 followed by graphitization in the presence of a metal catalyst these samples placed. On a disc along with the reference which are then fixed on a target wheel and analyzed sequentially. Ions are fired at the target wheel using

generally negatively charged carbon ions which are accelerated to the positive terminal of the tandem Accelerator After an AFTS. Data collected is the number and quantity of various isotopes of carbon from the values concentration ratio of these isotopes can be determined to allow evaluation of the level of fractionation. While collection of samples, the spot and region from where it is collected, and the relationship between the original sample and the event to be dated should be noted. Older samples collected are often put through thermal diffusion column to increase the amount of ^{14}C present.

But it is seldom done in practice as it is a time-consuming process and it needs large sampling size. However, it extends the limit of maximum age that can be accurately calculated by giving precise measurement of the $^{14}\text{C}/^{12}\text{C}$ ratio in old samples collected. Once samples are decontaminated, depending on the measuring technology to be used, they must be transformed

into a suitable form accordingly. Carbon must be in liquid form (benzene) for Liquid Scintillation technique. Solid Carbon (graphite) targets are the more typical for Accelerator Mass Spectrometry, although gaseous CO_2 can also be used.

In the early 20th century, the most notable way to measure the activity of ^{14}C decay was to measure the radioactivity that can be defined as "the number of decay events per unit mass per time period, of the sample." This method was called Beta counting as number of particles emitted from ^{14}C was counted. In the late 20th century, an alternative method called Acceleration mass spectrometry (AMS) was introduced which directly counted the number of atoms of both ^{14}C and ^{12}C presenting a given sample, hence formulating the ratio. Initially, beta counting was more accurate. However, AMS has become more error-free with advancement of the

apparatus. The sample size needed for AMS is smaller than needed for β counting and it is much faster.

A Geiger counter is an instrument which detects ionizing radiation such as α particles, β particles, and rays using the ionization eject produced in a Geiger tube. Libby designed his own Geiger counter covering the inner surface of a cylinder with Carbon from his sample converted to soot. The placing of this cylinder into the counter was such that there was nothing between the counting wire and the sample- the wire being inside the sample. The tube was conducted

Electrical charge when a particle or photon of incident radiation made the gas conductive by ionization and produced detectable pulse [16]

In this method, Carbon in the sample is converted into gaseous form (carbon dioxide, methane, or acetylene), which is then introduced into a proportional counter to measure β -particle emissions. To exclude background cosmic radiations or other radioactive emissions, the counters are shielded by lead or steel. Additionally, anti-coincidence detectors which record events outside the counter, and all events recorded simultaneously inside and outside the counter are regarded as nonessential events and hence ignored. Liquid Scintillation Counting.

It is the measurement of radioactive activity of a sample using the technique of mixing the active material with a liquid scintillate (exhibiting the property of luminescence - e.g. zinc slide), and counting the resultant photon emissions" Libby's anti-coincidence counter. The purpose is to allow more accurate counting due to the intimate contact of the activity with the scintillate.

This method also uses anti-coincidence counters to shield from background radiation.

As we know the number of β particles detected in given time period for Beta Counting in the given sample, we can convert it to a standard measure of activity in units of either counts per minute per gram of carbon (cpm/g C), or Becquerel's per kg (Bq/kg C, in SI units). We also need to measure the activity of a

blank sample and a sample with a standard activity using the measuring device to subtract background radiation and compare results

Accelerator mass spectrometry (AMS) is a form of mass spectrometry that accelerates ions to extraordinarily high kinetic energies before mass analysis." This allows the separation of isotopes having neighboring masses [17]

IV. OBSERVATIONS

AMS gives result in the form of ratio of isotopes of carbon that is ^{12}C , ^{13}C , ^{14}C ratio are used to calculate Fm the Fraction modern calibration curve. Varieties of method and statistical approaches based on new improved values collected from tree rings were used to publish numerous calibration curves over the next few decades.

V. CALIBRATION CURVE

Varieties of method and statistical approaches based on new improved values collected from tree rings were used to publish numerous calibration curves over the next few decades.

Modern methods of calibration take the original normal distribution of radiocarbon age

Ranges and use it to develop a histogram showing the relative probabilities for calendar ages." Calibration curve cannot be formulated, thus it is done numerically. Programs like Ox Cal and CALIB perform these calculations and produce probabilistic output as a table as well as in graphical form. In the blue curves give tree ring measurements (\pm standard deviation) and along the y-axis the red curve gives the sample radiocarbon concentration. The grey histogram represents all the possible ages for the sample.

Calculated age of a sample in Radiocarbon years "along with an associated range of error of plus or minus one standard deviation (denoted by the symbol \pm), can be transformed into a range of the sample's calendar ages using calibration curves (See figure 14 - the solid line is the calibration curve, and the dotted lines on either side represent the range of standard

error"). The calibration curve has an associated error term by itself. Thus the \pm error term can be calculated as:

CONCLUSION

Radiocarbon dating of charcoal for investigation purpose it is quite challenging. It is essential that carbon dating applied on carbon relevant object. Reading this paper it tells importance of Forensic carbon dating and how we applied. On a charcoal, and most How useful in crime.

Scene investigation.

RESULT

This article on the motto behind the article was to know carbon dating charcoal which will help solve the cases we told to take simple method. For the analysis which will help crime scene investigation.

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