Isotope Ratio Mass Spectrometry - A Bright Future for Forensics

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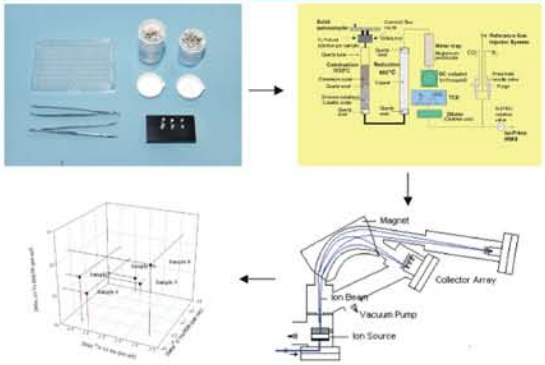
Overview

Isotope ratio mass spectrometry (IRMS) is a relatively new application in forensic science.

The technique has great importance in forensic applications due to it's enormous potential for verifying sources of materials.

Current applications of the technique include archaeology, environmental, drugs, explosives, accelerants, food research and pharmaceuticals, to name a few.



Scheme 1: How an IRMS system is used for sample analysis 1) Samples weighed into tin capsules, 2) Combustion/Pyrolysis of sample, 3) IRMS analysis, 4) d values obtained for analysis of results.

Background:

Due to the mass difference between isotopes of the same element, the ratio of those isotopes will vary in a sample. Variation in isotopic signatures occurs as a result of physical and kinetic effects.
The ratio of 'heavy' isotope to the dominant 'light' isotope of an element is used as a point for comparison with an international standard reference material. Results are given in d notation, which provides a direct comparison between sample and reference values.
Greater confidence about the origins of a material can be achieved by measuring the isotopic signatures of more than one element to produce multi-dimensional results.

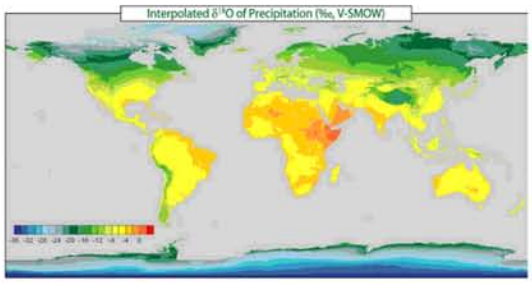


Figure 1. Diagram showing variation of delta values for isotopic abundance of oxygen-18 in rain water. [5]

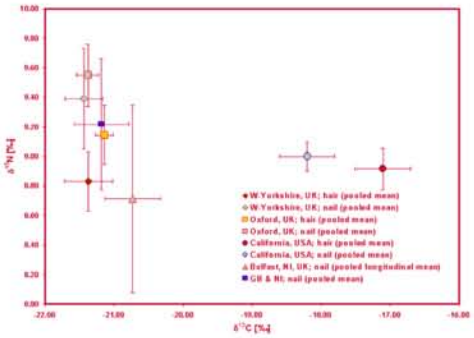


Figure 2. Comparison of carbon and nitrogen isotope ratios in hair and nail samples from donors of different regions. (Belfast, NI, UK pooled longitudinal mean represents 6 measurements taken over a period of 3 months, of people who have lived in Belfast for at least 1 year but have different ethnic origins, over a period of 3 months, all other points measured at one time) [2]

IRMS for Identification:

Carbon, nitrogen, hydrogen and oxygen isotopes are all present in the human body along with other trace elements such as strontium and lead [1]. The isotopic ratios of these elements vary depending on the region in which a person lives due to the natural global variation of isotopic ratios (Figure 1). Diet and geography affect the isotopic signatures in body tissue such as fingernails, hair, bone and teeth, providing useful data in forensic fields for the determination of geographic origin. For example the diet of a person in America is different to that of a person in Northern Europe, and therefore we would expect samples from these two individuals to have distinguishing delta values for the ratios of 'organic' elements (Figure 2). Isotopic signatures in hair may be representative of changes to environment or diet occurring in a timeframe of months, whereas isotopic signatures in bones may be representative of environment and diet years previously depending on the bone selected. Teeth provide information relating to a person's situation throughout adolescence and can therefore retain geographic information for over half a century depending on the age of the donor.

In a recent murder case, IRMS was employed to assist detectives with the identification of the victim's origin. After DNA analysis failed to match a potential relative of the victim, the question of whether the victim originated from Northern Ireland became a key focus in the investigation. Police and scientists used the data comparing bone and hair samples to rule out the possibility that the victim originated from Northern Ireland and further determined the approximate origin of the body as a location in Eastern Europe. Further to this a potential timeline was ascertained from comparisons of water at the suspected origin (location X), water in Northern Ireland and water in the victims hair, suggesting that the victim had arrived in Northern Ireland approximately 10-20 days before their death (Figure 3). [2]

IRMS was also employed in the case of 'Adam', the torso found in the Thames River in London. Samples of Adam's bones were used to determine ratios of strontium isotopes. The signature indicated rocks older than 2,500m years and narrowed the search area to West African regions including large areas of Nigeria. Adam's origin was determined to be within a corridor of Nigeria stretching 100miles by 50 miles. [3] [4]

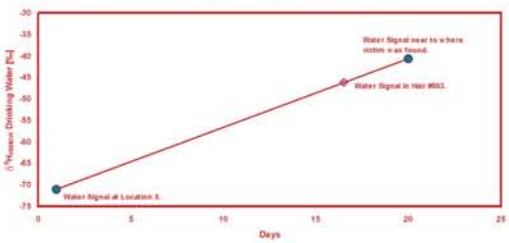


Figure 3. Potential timeline from hair giving an indication of how long the victim had been in Northern Ireland. [2]

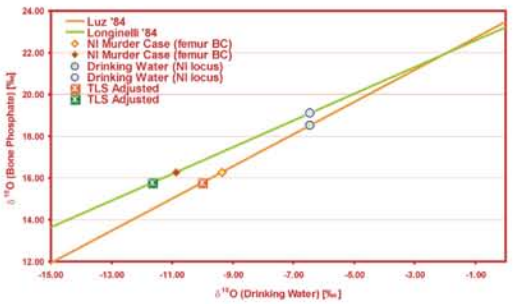


Figure 4. Intelligence on geographical origin based on water signal recorded in bone. Application of Luz and Longinelli correlations confirmed origin was not in Northern Ireland. Approximation of trophic level shift (TLS) placed the origin further away from Northern Ireland.

FIRMS Network:

The Forensic Isotope Ratio Mass Spectrometry network was established in 2002, uniting researchers, end users, instrument manufacturers, police and legal representatives in the task of developing this powerful technique and raising awareness in the scientific community. The network has three working groups in the fields of explosives, drugs, and general forensics. Members are kept up to date with international progress through the network website and newsletter.

The 'FIRMS 2005' workshop and conference is scheduled for March 2005 and aims to encompass practical experience, research and forensic applications of IRMS instrumentation.

The website address is:
http://www.forensic-isotopes.rdg.ac.uk/

The network co-ordinator can be contacted at:
Firms@dstl.gov.uk

Summary:

IRMS is a technique with the promise of delivering valuable forensic information regarding sources of a wide variety of sample types. The technique has been applied in a number of forensic cases and is routinely used to determine authenticity of rare foods and materials as well as provide evidence of geographic origins of asylum seekers (Australia). Future research will reveal the full potential of this technique.

Forensic laboratories among others are undertaking the task of gathering information about factors influencing the isotopic signatures of samples in order to understand more about the origins of samples. IRMS will provide forensic science with a unique tool allowing the ability to determine relationships between samples, perpetrators, their environment and chemical treatment for a variety of evidence types.

References:

[1] "Forensic applications of 'Isotope DNA'". Discussion document written for NCF. Wolfram Meier-Augenstein, Environmental Engineering Research Centre, Queen's University Belfast.
[2] "Forensic Applications of Stable Isotope Technologies". Conference presentation. Wolfram Meier-Augenstein, Environmental Engineering Research Centre, Queen's University Belfast.
[3] "Torso in the Thames, Scientist helps murder case" Cambridgeshire Constabulary Press Release (http://www.cambs.police.uk/camops/press_releases/press_releases.asp?ID=1028)
[4] RedNova News 08 August 2003. (http://www.rednova.com/news/stories/2/2003/08/08/story102.html)
[5] "Spatial distribution of d18O in meteoric precipitation." Bowen, G. J. and Wilkinson, B. (2002) Geology 30 (4): 315 - 318.

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