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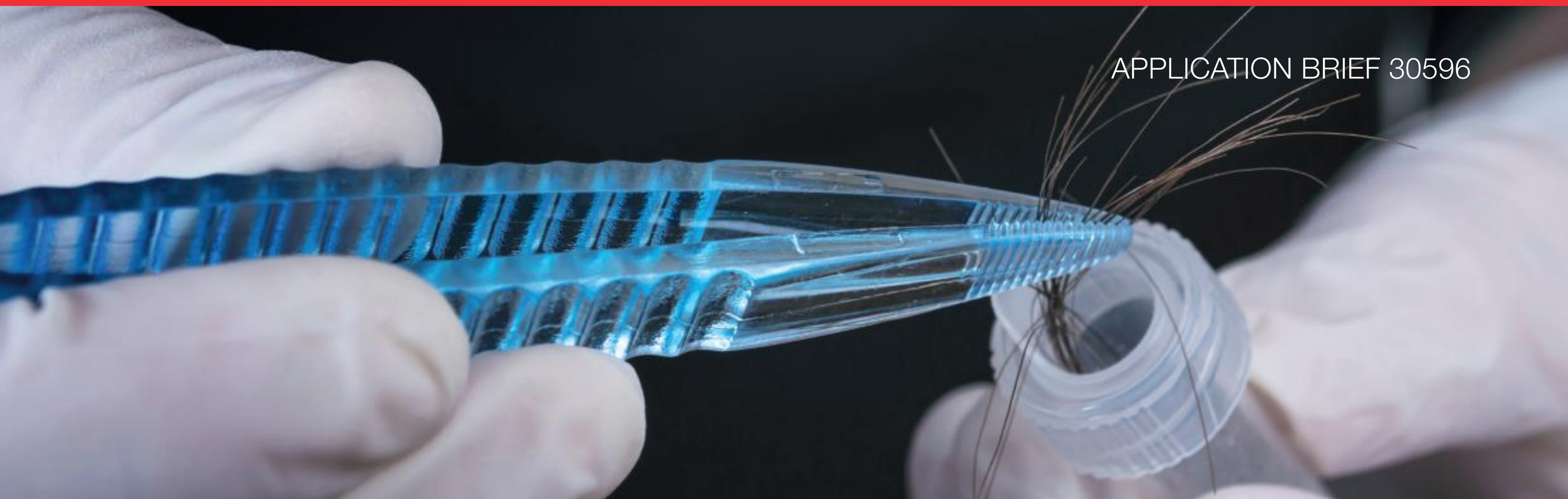
APPLICATION BRIEF 30596



EA-IRMS: Tracing human provenance using hydrogen and oxygen isotope fingerprints

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Keywords
Criminal forensics, Hair, Human provenance, Isotope fingerprints, Origin, Oxygen,

Goal

Illustrate how isotope fingerprints can help identify human provenance and movements through analysis of oxygen isotopes in hair.

Introduction

One investigation area that is part of criminal forensics is human provenance: where has a person been and what were their movements? This is a critical question that sometimes cannot be answered completely with traditional evidence gathered by law enforcement agencies. In such instances, stable isotope analysis, or isotope fingerprinting, has been shown to provide vital important additional evidence that has been able to successfully trace human movements and even bring clarity to homicide cases. Generally, this is achieved by being able to detect the oxygen isotope fingerprints locked in the hair, teeth and bones of humans, which has a strong relationship with local drinking water. By extension, the same concept can be applied to anthropological studies.

This application note is a summary of the work by Ehleringer et al (2008)[1] on the relationship between isotope fingerprints in human hair and local tap drinking water. Specifically, it focuses on the isotope fingerprint data from the human hair and tap water analyzed therein. Further data and data analysis, alongside the full analytical procedures used are presented by the authors in detail in their publication[1].

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Isotope fingerprints of human hair

The hydrogen and oxygen isotope fingerprints (δ^2H and $\delta^{18}O$ values) of human hair can be utilized to help with human provenance, tracing where a human has been based on their dietary intake of water, either via drinking water or water consumed within food stuffs. The primary protein in hair is keratin and during keratin synthesis in the hair follicle, the protein δ^2H and $\delta^{18}O$ values should be influenced by several factors, including dietary (water intake), atmospheric oxygen, and water derived from metabolism. In this study it was hypothesized that variations in the nonexchangeable δ^2H and $\delta^{18}O$ values in human keratin could provide insights into water and human diet across geographical regions if the hydrogen and/or oxygen isotopes from these tap water sources were recorded in the keratin of human hair.

Local tap water fundamentally carries a local-regional fingerprint primarily derived from the hydrological cycle, which is directly associated with local-regional snowfall or rainfall[1,2,3], but can also be influenced in arid regions by water transferred across basins[3]. The oxygen and hydrogen isotope fingerprints change in rainfall as you move further inland from the coast and with increasing altitude because the heavier isotopes are the first to be released from the clouds[3,4]. Consequently, there is a variation in δ^2H and $\delta^{18}O$ values across geographical regions, which subsequently relates to local-regional tap water. The consequence of this is that the δ^2H and $\delta^{18}O$ values in human hair are highly correlated with tap water, providing a strong framework for human provenance research.

Sample collection and analytical configuration

In this study by Ehleringer et al[1], human hair samples were collected as discarded, trash clippings from the floor and garbage containers in barbershops from 65 geographically distributed cities, or towns, from 18 different states, across the United States of America. In each location, 25-ml vials of tap water were also collected.

The analysis of δ^2H and $\delta^{18}O$ was carried out by weighing around 150 µg of hair into silver capsules and introducing them to the pyrolysis reactor of the EA-IRMS, held at 1400˚C, to produce H_2 and CO. For water, 40 µl were injected in a separate analysis into the same reactor system. All samples were bracketed by in-house laboratory standards: hair from Florida (isotopically heavy end member) and Utah (isotopically light end member).

Water samples were analyzed by using University of Utah manufactured ‘‘zero’’ water (heavy end member) and deionized tap water (light end member). The 2σ precisions of δ^2H and $\delta^{18}O$ analyses for water samples were 0.9‰ and 0.2‰, respectively, and for hair samples were 4‰ and 0.4‰, respectively.

Detecting human movements across the USA

Figure 1 shows modelled isoscapes for hydrogen (Figure 1a) and oxygen (Figure 1b) isotope fingerprints of human scalp hair, which are based on waters from nearly 500 locations across the USA. This model is used to predict the δ^2H and $\delta^{18}O$ values in human hair associated with a location. The isotope fingerprint data unlocked from the human hair correlate with local tap water data (Figure 2), which illustrated that the primary factor influencing the δ^2H and $\delta^{18}O$ values of the keratin in human hair is local drinking water, likely derived from water, beer, milk, tea, coffee, soft drinks, with a much lesser impact from dietary water contributions, such as fruit and vegetables. As an individual travels from place to place, hair from that individual faithfully records the stable isotope composition of water from those regions at a hair growth rate of about one centimeter per month. Thus, hair becomes a “tape recorder” of an individual’s travels.

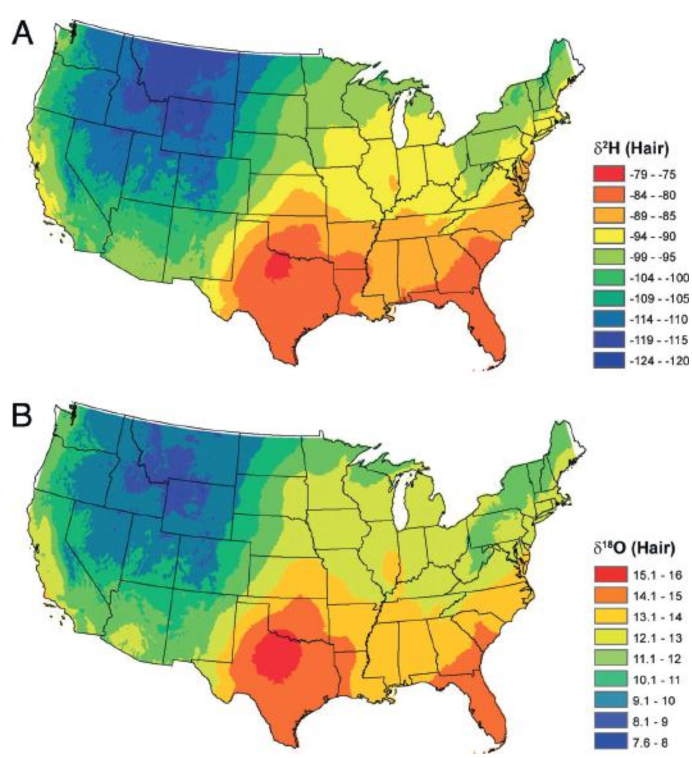

Figure 1. Predicted average H isotope ratios (δ^2H) (A) and average O isotope ratios ($\delta^{18}O$) (B) of human scalp hair across the USA based on a correlation of local tap drinking water and hair.

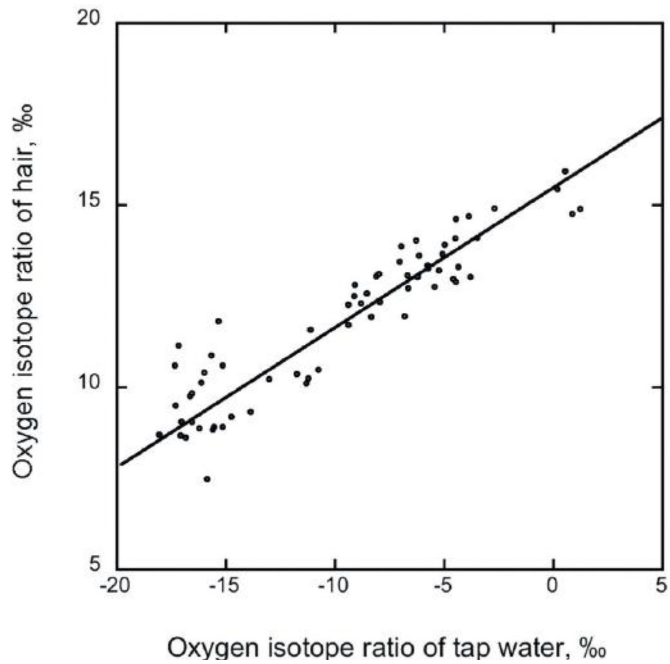

Figure 2. A plot of oxygen isotope ratios in local tap drinking water versus human scalp hair from 18 states across the USA.

Summary

Ehleringer et al[1] have shown, using hydrogen and oxygen isotope fingerprints, that a sufficiently strong correlation exists between local tap drinking water and human hair. Despite the potential dietary influences that may affect δ^2H values, the overall relationship provides a framework to understand human movements. This by extension has implications for contribution further evidence to criminal forensic cases, such as homicide, and for anthropological studies looking at ancient humans.

This study has shown the powerful contribution that isotope fingerprints can make to human provenance studies. These data presented are based on bulk measurements of hydrogen and oxygen using Elemental Analysis Isotope Ratio Mass Spectrometry, such as the Thermo Scientific™ EA IsoLink™ IRMS System (a former model was used in this study).

References

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