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Boiled vs. Bottled: Analyzing Oxygen Isotope Signatures from Taiwanese Water to Aid Anthropological Investigations

Overview

The use of isotopic analyses has been adopted by forensic anthropology in recent years to establish migration patterns and region of origin to aid in the identification of unidentified human remains. I will use the funding received from the SARC to compare the oxygen isotopic ratios of tap and bottled water with those of drinking water in Taiwan. The goals of this research are twofold: the collection of much-needed isotopic data for the region and an examination of whether the isotopic signatures of bottled and boiled water differ significantly from tap water. In Taiwan, the preferred consumption of water varies from household to household. Therefore, this study will collect samples of hair, tap water (both boiled and unboiled), and bottled water in Taiwan to help establish isotopic signatures to aid in forensic provenancing of unidentified human remains cases.

Background

Stable isotopes are different forms of the same element and are measured in ratios of heavy to light. The ratios of oxygen isotopes ($^{18}O/^{16}O$, or denoted as simply $\delta^{18}O$) differ geographically in precipitation based on distance from large bodies of water, climate, and topography (Bartelink and Chesson 2019; Chesson et al. 2018). Isotope values are used in the formation of maps of isotopic ratios called *isoscapes*. Oxygen isotopes from drinking water become incorporated into one's body tissues, including hair (Ehleringer et al. 2008); therefore, measurements of isotope ratios in hair can be used to estimate possible regions of origin and recent travel history, known as forensic provenancing. This aids forensic anthropologists in the identification of unidentified decedents.

In forensics, the identification of immigrants can be complicated due to language barriers and distrust of the government. The need for reliable forensic methods to ensure the identification of East Asian immigrants is of particular importance with the rise in anti-Asian hate crimes in the United States since the COVID-19 pandemic. This has resulted in multiple fatalities, including mass shooting events at a Taiwanese church, in Atlanta spas, and the recent Monterey Park tragedy (Alfonseca 2023; Blankstein and Li 2022; Fausset et al. 2021). This underlies the importance of established isoscapes for East Asian countries where these immigrants are from.

However, East Asia has been largely underrepresented in isotopic research. Taiwan in particular represents one such country that lacks a defined isoscape that would allow for an understanding of the spatial and cultural distribution of isotopes in the region. The limited research that has been done in the area has focused on China, with Taiwan often grouped in with southeastern Chinese cities (Wang et al. 2022). This grouping obscures the unique geographical features of Taiwan which result in distinct $\delta^{18}O$ values compared to nearby regions (Wang and Peng 2001). Additionally, a 2014 study found that 57% of Taiwanese boiled and filtered tap water before consumption (Huang & Wang 2022). Another study, Yu et al. (2021), found that

53.3% of Taiwanese find bottled water to be more convenient than tap water and only 13.2% of respondents do not drink bottled water. Due to these variations in preferred drinking water, Taiwan represents a key area of study for how isotopic signatures imbibed into the body may differ based on individual or cultural preference.

Research Design

In May 2023 I will travel to Taiwan for 4 weeks to collect 50 hair and 250 water samples from throughout the island. I lived in Taiwan for three years, and am therefore familiar with the country, culture, and language. Hair samples will be collected from local hair salons following the example set by Tipple et al. (2019). Both hair and water samples will be taken from regions across Taiwan, including both high- and low-income areas, as well as areas with poor water infrastructure and higher numbers of indigenous peoples. This will allow for an analysis of how sociocultural and economic factors influence preferred drinking water and associated $\delta^{18}O$ values, as previously documented in other regions (Lambrigger 2022).

This study will examine how individual efforts to improve water quality via boiling and filtering could potentially alter isotopic signatures, as boiling has been shown to impact $\delta^{18}O$ values of water and human tissues (Brettell et al. 2012; Lisowska-Gaczorek et al. 2020). Therefore, I will have two groups of tap water that will be taken from each location: one that has been boiled and filtered and a control group that has not. Due to the strong national reliance on bottled water, samples of bottled water will also be collected from each location to assess comparability with isotopic ratios of consumed water. Hair samples will be transported back to the Stable Isotope Preparation Lab (SIPL) at Chico State for preparation before transferring both the water and cleaned hair samples to the University of Utah for analysis of $\delta^{18}O$ values.

This research will be overseen by my faculty mentor, Dr. Eric Bartelink, but is separate from any work done by him or the SIPL. Its design, implementation, and interpretation are my sole responsibility, and this funding is essential to the completion of my M.A. thesis. As I am nearing the end of my 2nd year of a three-year program, I will need to complete my research to graduate by May 2024. An itemized budget for this research project is provided below. I have no other funding to pay for this project; therefore, it will not be possible without assistance from the SARC. I also request a direct stipend as my research interferes with my ability to work.

Broader Impacts

The analyses of the impact of bottled water and boiled tap water on the isotopic ratios of drinking water have important global implications, as the safety of tap water is a dominant issue that has led to a reliance on treated (i.e. boiled and filtered) tap water and bottled water. This underlies the importance of not relying purely on the isotopic signatures of tap water for use in forensic provenancing, as they may not be isotopically comparable to drinking water signatures found in hair. Furthermore, the use of isotopic ratios for the estimation of region of origin in forensic anthropology requires a thorough global data set that is currently lacking in East Asia. This research will provide isotopic data for an under-represented region of the world.

As well as assessing geographic variation, this research will also address economic and sociocultural impacts on drinking water that will have broader implications globally. Examining

the relationship between income, water infrastructure, and indigeneity will speak to greater patterns of water inequality and regional isotopic variation. In addition, immigrants of Asian descent have historically been a high-risk group for violence. Therefore, this research will contribute to the development of more robust identification methods for this group of people while simultaneously addressing culturally-based alterations to isotopic ratios.

This research will allow me to gain the hands-on experience necessary for my professional development as a forensic anthropologist in the field of isotopes. In addition to these findings being disseminated through my master's thesis, I will also present this research at Chico State's Anthropology forum in the Spring of 2024, as well as the 2024 Mountain, Desert, and Coastal (MD&C) and American Academy of Forensic Sciences (AAFS) conferences. These findings will also be submitted for publication in a peer-reviewed journal, allowing for these data to be accessible to other researchers in the field.

Materials	**Cost per Unit**	**Units**	**Total**
Screw-top vials (3.7 mL)	$0.96	250	$240
Analyses	**Cost per Unit**	**Units**	**Total**
Oxygen (δ^{18}O), water	$8	250	$2000
Oxygen (δ^{18}O), hair	$28	50	$1400
Travel			**Total**
Flight (roundtrip)			$1360
Total: $5000			

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