Journal of Palaeosciences 72(2023): 55–58
2583–4266/2023
https://doi.org/10.54991/jop.2023.1855

Diet of Indus Civilization: Reinterpretations from Multi–Site Stable Isotopic Mortuary Analysis

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(Received 14 March, 2023 ; revised version accepted 31 May, 2023)

ABSTRACT

Prasanna K. 2023. Diet of Indus Civilization: Reinterpretations from Multi–Site Stable Isotopic Mortuary Analysis. Journal of Palaeosciences 72(1): 55–58.

Several insights on the identification and mobility of the Indus Civilization were provided by previous researchers based on the results limited towards archaeological context. In this study, several such published data of Mortuary samples from the major urban centre of Harappa, the eastern frontier town of Farmana, and the post–urban necropolis at Sanauli are re–evaluated in context with the modern dental samples. The results are compared to the compositional signatures found within teeth from modern humans from the USA, East Asia, Mexico and Bulgaria, which is expected to show variance in their isotopic signature depending upon regional level precipitation and diet. The results from $\delta^{18}O$ signatures from the Indus Valley point towards dependence on riverine water for drinking.

Key–words—Indus Civilization, Harappa, Sanauli, Farmana, Diet, Water.

INTRODUCTION

THE application of stable isotope analysis in the field of anthropological studies, especially in the process of identification of human remains, has become increasingly popular over the past decade (Dupras & Schwarcz, 2001; Chenery, 2003; White *et al*., 2004; Chesson *et al*., 2018). Human skeletal remains are primarily found in the form of bone, tooth enamel and hair. Unlike tooth enamel and hair tissues, which remain unchanged once they are formed, bone undergoes periodic remodelling. The stable isotopic composition of bones reflects the dietary patterns of an individual for a period ranging from several months to years prior to their death, depending on the bone type and location. Unlike permanent teeth, which develop between birth and age 12, deciduous teeth are formed at the time of gestation. Once teeth are formed, their isotopic values become fixed and remain unchanged throughout an individual's life, as teeth do not undergo remodelling. By comparing the isotopic values of teeth and bones, it is possible to infer changes in an individual's diet and migration patterns over time. Therefore, the analysis of stable isotopes in multiple tissues can provide a measurable dietary history of an individual. While the stable isotope signal from bone reflects the chemistry of diet and place of residence, enamel, on the other hand, is formed during early childhood (Price *et al*., 1994; Kohn *et al*., 1999; Budd *et al*., 2000; Hillson, 2005). The deposition of carbon in the enamel occurs in the form of carbonate ions, which are incorporated into the crystal structure of inorganic apatite or bioapatite. This incorporation happens in two ways: as "structural carbonate," which substitutes the phosphate position in the crystal structure, and as "adsorbed carbonate," which attaches to hydration layers and crystal surfaces. Both forms of carbon are influenced by the individual's diet. Carbon isotopes in bone and tooth enamel are used for reconstruction of the paleo–diet dependent upon the source of ^{13}C derived from the plants and animals ingested (Lee–Thorp *et al*., 1989; Sullivan & Krueger, 1981; Tieszen & Fagre, 1993; Cerling & Harris, 1999; Froehle *et al*., 2012). Dental enamel derives its oxygen component from the water present in the body. The isotopic make up of this body of water is influenced by the isotopic composition of the water that individuals consume from their surroundings, which in turn is determined by the local precipitation patterns. The variations in oxygen isotopes in fossils, on the surface, largely depend on the isotopic composition of the water source and in turn, on rainfall (Dansgaard, 1964; Kohn, 1996; Luz & Kolodny, 1985, 1989). Secondary influences, such as water ingested from food and atmospheric oxygen are minor. Isotopes in rainfall are determined by the relative abundance of the heavy

^{18}O isotope to lighter ^{16}O in water, due to physical processes such as evaporation and precipitation (e.g., Dansgaard, 1964). Significant factors affecting rainfall δ^{18}O values are latitude, elevation, amount of precipitation, and distance from the evaporation source (e.g., an ocean). When water evaporates over the ocean, it becomes relatively lighter isotopically (more ^{16}O) than the water left behind. As this moisture moves over land, the first precipitation accommodates more of the heavy isotope and with progressive higher elevations; the rain becomes lighter in isotopic content. Thus, oxygen isotope ratios have great potential to vary geographically and provide a tool to reconstruct human settlement and migration. In this study, we have used modern human tooth data from previously published literature where tooth enamels were analysed from samples from the diverse region across the world with different dietary habits; the USA and South East Asia (Regan, 2006), Mexico (Juarez, 2011) and, Bulgaria (Kamenov & Curtis, 2017). These baseline data were used to infer the diet and drinking water of the individuals sampled from the Indus burial sites obtained from Kenoyer *et al.*, 2013 for Harappa and Valentine, 2013 for Farnama and Sanauli as shown in Fig. 1.

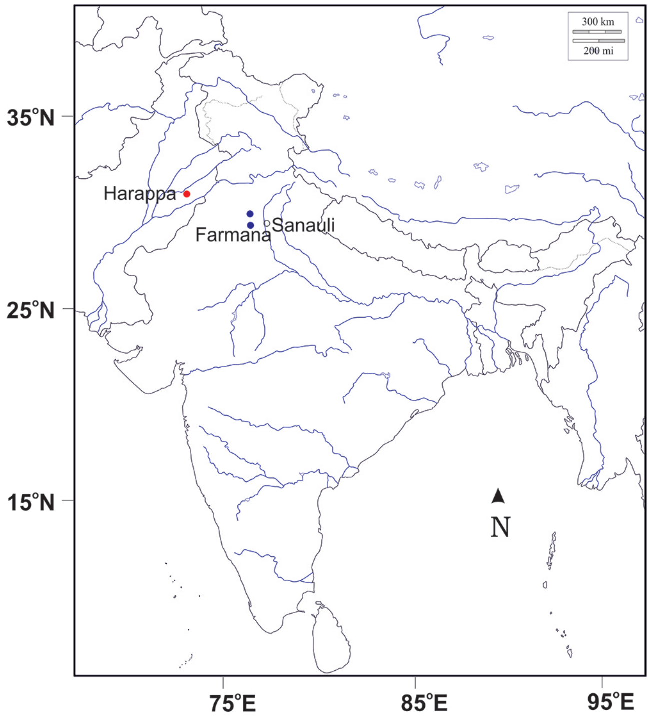

Fig. 1—Map of India showing study site Harappa (red circle), Sanauli (Green circle) and Farmana (Blue Circle) from which the stable isotope data for Indus civilisations skeletal remains were collected in the present study.

DISCUSSION

Carbon isotope signature of mammalian carbonates has been used to reconstruct diet in animals and humans (Luz *et al*., 1990; Ambrose & Norr, 1993; Passey & Cerling, 2002; Passey *et al*., 2005a, b; Stevens *et al*., 2006). As foods eaten by human/animals, δ^{13}C values in dental enamel carbonate tend to be enriched about 14‰ in comparison to primary food source (Cerling & Harris, 1999). The enrichment in ^{13}C is likely the result of fractionation during the precipitation of bioapatite minerals from dissolved inorganic carbon within the body. Thus, the δ^{13}C of human tooth enamel reflects the diet, which varies with the intake of the relative proportion of C_3vs C_4 plant diet, and the intake of meat, in the regional context. Results of previous isotopic ratios studies are shown in Fig. 2. In these studies, tooth enamels were analysed from samples retrieved from the diverse region across the world with different dietary habits; the USA and South East Asia (Regan, 2006), Mexico (Juarez, 2011) and Bulgaria (Kamenov & Curtis, 2017). The results show that the lowest δ^{13}C, i.e.–17.2‰ is inferred to be influenced by a diet of C_3 crop, i.e. rice from the population surveyed from Southeast Asia (Vietnam, Korea, Laos, Cambodia and Philippines) (Regan, 2006). The tooth samples from Bulgaria are enriched compared to that of the Southeast Asian cluster to around–11.7‰. This enrichment is inferred to be influenced by a diet rich in a mixture of C_3 (legumes) and C_4 (millets) types of vegetation. Tooth samples from the USA and Mexico have shown a higher enrichment in ^{13}C, reflecting a diet dominated by C_4 plants, such as corn or maize, sugarcane, sorghum, and millets in their region (Juarez, 2011).

The average value of δ^{13}C from Harappa is –11.85 ± 0.99 (n= 32) whereas δ^{18}O is –4.82 ± 0.94 (n= 32). From the 36 samples in Farmana, the average value is δ^{13}C –9.65 ± 2.43 and δ^{18}O is –3.17 ±1.31. From the 66 samples from Sanauli the average value is δ^{13}C –11.89 ± 1.15 and δ^{18}O is –4.33 ± 0.82 (Kenoyer *et al*., 2013; Valentine, 2013).

In comparison to the modern samples mentioned above, Harappa and Sanauli both have mean δ^{13}C of–11.9‰, whereas the mean value at Farmana is–10.0‰ suggesting millets or other C_4 crops were consumed by individuals in the mortuary populations of Sanauli and Harappa, but millets contributed significantly to diet at Farmana. According to the archaeobotanical data (Bates *et al*., 2018), it was inferred that millets comprised a significant portion of the crop remains at all Harappan sites. The diversity of foodstuffs discovered in the archaeobotanical analysis (Weber & Kashyap, 2016) suggests the possibility that dietary choices may have been guided in part by group affiliation. The overall assemblage of plants revolved around cereals and pulses and incorporated both summer and winter crops. There is the combined use of Southwest Asian cereals, like barley and wheat with indigenous millets.

The $\delta^{18}O$ value found in meteoric water differs depending on the region, and is influenced by various climatic parameters such as latitude, altitude, distance from the coastline, and temperature. Despite relatively large standard deviations within the same locations, due to our understanding of the several metabolic fractionations in the human body that influences the $\delta^{18}O$ values. Linear equations between the drinking water oxygen isotopes ($\delta^{18}O_w$) values and of dental carbonate oxygen isotopes ($\delta^{18}O_c$) can be drawn. These equations are region specific, for example, the Middle East was defined by Posey (2011), the relationship for the USA was established by Ehleringer *et al*., (2010) (based on the human tooth). For Europe Longinelli (1984) established a relationship based on phosphate remains in the tooth enamels. The slope and intercept from these plots may vary due to the various factors like sources of drinking water ingested and metabolic effect.

In this study, the relationship (Equation 1) between the ionic forms of oxygen (phosphate oxygen and structural carbonate) in archaeological human dental enamel between dental carbonate by Chenery *et al*., (2012) was used. This equation allows direct comparison of data produced by the different methods and allows drinking water values to be calculated from structural carbonate data with confidence.

$$\delta^{18}O_{Drinking\ Water}(VSMOW) = 1.509(\pm 0.105) \times \delta^{18}O_{Carbonate}(VSMOW) - 48.635 \quad (1)$$

Based on this relationship between drinking water $\delta^{18}O$ and apatite carbonate the estimated environmental water values in Harappa would be–7.39 ± 1.55 ‰ with a minimum of–12.27‰ and a maximum of–4.08‰ at Harappa. However, ~80% of the samples are between–6 to–10‰ which is the seasonal variation of the $\delta^{18}O$ for the river Ravi–11.2‰ for summer and–6‰ for winter seasons (Ajaz & Jan, 2002). Similarly in Sanauli, the environmental water estimated would be –6.60 ± 1.35 ‰, –10.31 and –2.27. Here ~86% of the samples are between –5 to –9‰ which is similar to the seasonal variation of the $\delta^{18}O$ for the river Yamuna which is –6.2 to –10.3‰ (Dalai *et al*., 2002). Whereas, in Farmana the average $\delta^{18}O$ is –4.99 ± 1.29‰ with a minimum of –7.68‰ and a maximum –2.93‰ where ~88% of the samples shown in Fig. 2 are between –3 to –7‰ which is enriched compared to Sanauli and Harappa due to the absence of any riverine source of drinking water indicating stored water for drinking.

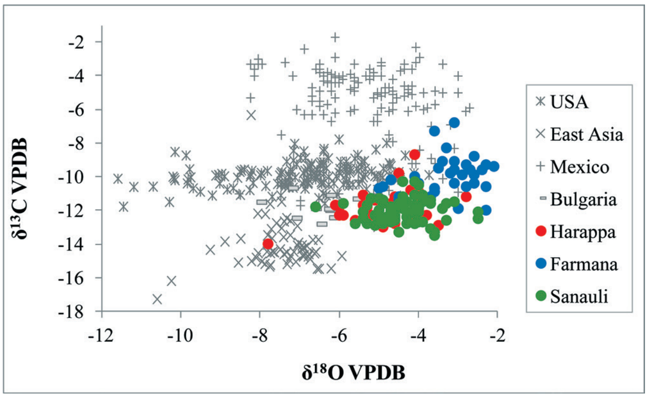

Fig. 2—$\delta\ ^{13}C$ vs $\delta\ ^{18}O$ of plot of the retrieved data of modern human dental isotopes from Mexico, USA and Bulgaria. Note that the Southeast Asian samples show lower $\delta\ ^{13}C$ and followed by Bulgaria and subsequently by USA and Mexico.

CONCLUSION

The study conducted on the remains of humans buried in Harappa, Sanauli and Farmana burials aimed to determine the average diet and water intake of the people living in the region. The findings indicate that millets or other C_4 crops were consumed by individuals in the mortuary populations of Sanauli and Harappa, but millets contributed significantly to diet at Farmana. This can be inferred from the presence of these crops in the archaeological assemblage and the fact that millets were the most commonly utilized crop in the region.

Moreover, the study also revealed that the people of Harappa ingested water from rivers such as Ravi. This suggests that these rivers played a crucial role in providing water to the local population and supporting their livelihoods. The utilization of river water for drinking purposes also sheds light on the resourcefulness of the Harappan people in adapting to the environmental conditions of the region. The people of Sanauli ingested water from rivers such as the river Yamuna. People of Farmana may have stored water for drinking.

Acknowledgements*—Author is grateful to the Director, Birbal Sahni Institute of Palaeosciences, Lucknow for providing the necessary facilities and permission to publish this manuscript. He is also grateful to Prof Jonathan M Kenoyer for permitting the use of the data from his manuscript.*

REFERENCES

Ajaz K & Jan V 2002. Water balance of the Indus River Basin and moisture source in the Karakoram and western Himalayas: Implications from hydrogen and oxygen isotopes in river water. Journal of. Geophysical Research–Atmosphere 107: ACH 9–1–ACH 9–12.

Ambrose SH & Norr L 1993. Experimental evidence for the relationship of the Carbon Isotope ratios of whole diet and dietary protein to those of Bone Collagen and Carbonate. *In*: Lambert JB & Grupe G (Editors)– Prehistoric Human Bone: Archaeology at the Molecular Level. Springer Berlin Heidelberg, Berlin, Heidelberg:1–37.

Bates J, Petrie C & Singh R 2018. Cereals, calories and change: exploring approaches to quantification in Indus archaeobotany. Archaeological and Anthropological Sciences 10: 1703–1716.

Budd P, Montgomery J, Evans J & Barreiro B 2000. Human tooth enamel as a record of the comparative lead exposure of prehistoric and modern people. Science of the Total Environment 263: 1–10.

Cerling TE & Harris JM 1999. Carbon isotope fractionation between diet and bioapatite in ungulate mammals and implications for ecological and paleoecological studies. Oecologia 120: 347–363.

Chenery C 2003. Amesbury Archer may have come from Central Europe. TrAC Trends in Analytical Chemistry 22: III–III

Chenery CA, Pashley V, Lamb AL, Sloane HJ & Evans JA 2012. The oxygen isotope relationship between the phosphate and structural carbonate fractions of human bioapatite. Rapid Communication in. Mass Spectrometry 26: 309–319.

Chesson LA, Tipple BJ, Youmans LV, O'Brien MA & Harmon MM 2018. Forensic identification of human skeletal remains using isotopes: A brief history of applications from archaeological dig sites to modern crime scenes. *In*: Latham KE, Bartelink EJ & Finnegan M (Editors)–New Perspectives in Forensic Human Skeletal Identification, Academic Press: 157–173.

Dalai TK, Bhattacharya SK & Krishnaswami S 2002. Stable isotopes in the source waters of the Yamuna and its tributaries: Seasonal and altitudinal variations and relation to major cations. Hydrological Processes 16: 3345–3364.

Dansgaard W 1964. Stable isotopes in precipitation. Tellus 16: 436–468.

Dupras TL & Schwarcz HP 2001. Strangers in a strange land: Stable isotope evidence for human migration in the Dakhleh Oasis, Egypt. Journal of Archaeological Science 28: 1199–1208.

Ehleringer JR, Thompson AH, Podlesak DW, Bowen GJ, Chesson LA, Cerling TE, Park T, Dostie P & Schwarcz H 2010. A framework for the incorporation of isotopes and isoscapes in geospatial forensic investigations. *In*: Isoscapes: Understanding Movement, Pattern, and Process on Earth through Isotope Mapping. Springer Netherlands, pp. 357–387.

Froehle AW, Kellner CM & Schoeninger MJ 2012. Multivariate carbon and nitrogen stable isotope model for the reconstruction of prehistoric human diet. American Journal of Physical Anthropology 147: 352–369.

Hillson S 2005. Teeth (2nd Edition, Cambridge Manuals in Archaeology). Cambridge: Cambridge University Press.

Juarez, C 2011. Geolocation: A pathway to identification for deceased undocumented border crossers. University of California–Santa Cruz, ProQuest Dissertations Publishing, 3452521.

Kamenov GD & Curtis JH 2017. Using Carbon, Oxygen, Strontium, and Lead Isotopes in Modern Human Teeth for Forensic Investigations: A critical overview based on data from Bulgaria. Journal of forensic sciences 62(6): 1452–1459.

Kenoyer JM, Price TD & Burton JH 2013. A new approach to tracking connections between the Indus Valley and Mesopotamia: initial results of strontium isotope analyses from Harappa and Ur. Journal of. Archaeological Science 40: 2286–2297.

Kohn MJ 1996. Predicting animal $\delta^{18}O$: Accounting for diet and physiological adaptation. Geochimica & Cosmochimica Acta 60: 4811–4829.

Kohn MJ, Schoeninger MJ & Barker WW 1999. Altered states: effects of diagenesis on fossil tooth chemistry. Geochimica & Cosmochimica Acta 63: 2737–2747.

Lee–Thorp J, Sealy J & van der Merwe N 1989. Stable Carbon Isotope ratio differences between bone collagen and bone apatite and their relationship to diet. Journal of Archaeological Science: 585–599.

Longinelli A 1984. Oxygen isotopes in mammal bone phosphate: A new tool for paleohydrological and paleoclimatological research? Geochimica & Cosmochimica Acta 48: 385–390.

Luz B, Cormie AB & Schwarcz HP 1990. Oxygen isotope variations in phosphate of deer bones. Geochimica & Cosmochimica Acta 54: 1723–1728.

Luz B & Kolodny Y 1985. Oxygen isotope variations in phosphate of biogenic apatites, IV. Mammal teeth and bones. Earth and Planetary Science Letters 75: 29–36.

Luz B & Kolodny Y 1989. Oxygen isotope variation in bone phosphate. Applied Geochemistry 4: 317–323.

Passey BH & Cerling T 2002. Tooth enamel mineralization in ungulates: Implications for recovering a primary isotopic time–series. Geochimica & Cosmochimica Acta 66: 3225–3234.

Passey BH, Cerling TE, Schuster GT, Robinson TF, Roeder BL & Krueger SK 2005a. Inverse methods for estimating primary input signals from time–averaged isotope profiles. Geochimica & Cosmochimica Acta 69: 4101–4116.

Passey BH, Robinson TF, Ayliffe LK, Cerling TE, Sphonheimer M, Dearing MD, Roeder BL & Ehleringer JR 2005b. Carbon isotope fractionation between diet, breath CO_2, and bioapatite in different mammals. Journal of Archaeological Science 32: 1459–1470.

Posey RG 2011. Development and validation of a spatial prediction model for forensic geographical provenancing of human remains. Unpublished PhD dissertation, University of East Anglia55.

Price TD, Johnson CM, Ezzo JA, Ericson J & Burton JH 1994. Residential mobility in the Prehistoric Southwest United States: A preliminary study using Strontium Isotope Analysis. Journal of Archaeological Science 21: 315–330.

Regan LA 2006. Isotopic Determination of region of origin in modern peoples: Applications for identification of U.S. War–Dead from the Vietnam conflict. University of Florida108.

Stevens RE, Lister AM & Hedges REM 2006. Predicting diet, trophic level and palaeoecology from bone stable isotope analysis: a comparative study of five red deer populations. Oecologia 149: 12–21.

Sullivan CH & Krueger HW 1981. Carbon isotope analysis of separate chemical phases in modern and fossil bone. Nature 292: 333.

Tieszen LL & Fagre T 1993. Carbon Isotopic variability in modern and archaeological maize. Journal of Archaeological Science 20: 25–40.

Valentine BT 2013. Immigrant Identity in the Indus Civilization: A Multi–Site Isotopic Mortuary Analysis. University of Florida 86.

Weber S & Kashyap A 2016. The vanishing millets of the Indus civilization. Archaeological and Anthropological Sciences 8: 9–15.

White CD, Spence MW, Longstaffe FJ & Law KR 2004. Demography and ethnic continuity in the Tlailotlacan enclave of Teotihuacan: The evidence from stable oxygen isotopes. Journal of Anthropological Archaeology 23: 385–403.