Evaporative effects on water isotopes in the Turkana Basin, Kenya

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Key Points:

* New measurements enhance the stable isotope hydrology record for the Turkana Basin
* Evaporation modelling provides water balance estimates under arid, closed-basin lake conditions

Abstract

Plain Language Summary

1 Introduction

Lake Turkana is the largest desert lake in the world. It is one of the African Great Lakes, situated in the northern portion of the East African Rift System. Most of the lake lies in Kenya, and the Omo River delta at the north end of the lake spans both sides of the border between Kenya and Ethiopia (Figure 1). It is a closed-basin lake with a surface area of 6,405 km2 and a drainage area of 130,860 km2, with most of its catchment in the Omo Basin and 90% of its input from the Omo River (Avery, 2012; Hopson, 1982; Nicholson, 2022). Mean annual air temperatures in the Turkana Basin are among the hottest on the planet, around 30 °C, and lake surface temperatures are ~ 3.5 °C lower (Morrissey et al., 2017; Passey et al., 2010; Yost et al., 2021). Mean annual precipitation (MAP) in the basin is ~ 200 mm/year and falls mostly in the boreal spring and autumn (Nicholson, 1996). In these extreme conditions, Lake Turkana provides food and water for communities on the lakeshore and surrounding areas. The estimated population of the Turkana region is approximately one million people, whose livelihoods are based on pastoralism, fishing, and, to a lesser extent, crop farming (Avery, 2014).

Map

Description automatically generated

**Figure 1.** Sample location map for waters collected in the Turkana Basin from 2016 to 2021.

2 Materials and Methods

Waters analyzed in this study were collected between September 2016 and January 2020 by the authors and collaborators working at the Turkana Basin Institute (TBI) Turkwel and Ileret field stations. Kale Beach, our most frequently visited Lake Turkana water sampling site, is a section of lake shore approximately 35 km south of the Omo River delta. All lake samples from Kale Beach and other sites were taken near shore, in areas where lake depth ranged from 1–2 m and within or just beyond the shore wave zone. River water samples from the Turkwel River were collected close to the river’s center line, where flow was moderate, and water was at least 0.5 m deep. The Omo River was sampled from the shore under low-flow, sediment-rich water conditions. Precipitation was collected intermittently, as rainfall sufficient to yield a ~2 mL sample is infrequent. Available containers for rainwater were checked and emptied into vials immediately after rainfall ceased in order to minimize surface evaporation from the collectors. Two of the precipitation samples were stored overnight in a vial that was loosely sealed (); when analyzed, these samples were shown to have abnormally low δD values, and thus have been excluded from the discussion due to inconsistent preparation and evident isotopic exchange with air in the collection vial. Some precipitation samples were collected from the roof gutters at TBI-Ileret and TBI-Turkwel, or from an access point where rainwater flows from the roof into the building cisterns. This style of collection implies that building roofs were saturated with rainwater, which is only possible during a heavy rain event.

With exception of the aforementioned precipitation samples, water samples were collected using 5 ml plastic syringes and filtered through 0.45 μm PTFE filters into 2 mL glass vials with plastic displacement caps for transport and storage. Vials were sealed in individual Whirl-pak bags to prevent evaporation or water loss during transport, which was replaced by parafilm upon return to the laboratory. Some samples, noted in Table S1, were not filtered in the field but contained no visible algal growth or sediment (suspended or settled). These were filtered in the laboratory before isotopic analysis.

Stable isotope ratios of oxygen and hydrogen in the filtered waters were measured in three facilities. Samples collected in 2016 were measured by TC/EA-IRMS at the Boston University Stable Isotope Laboratory in early 2017. Samples collected from 2017­–2020 were measured on a Picarro 2130i cavity ring down laser spectroscopy (CRDS) analyzer coupled to a vaporization module and Picarro autosampler in the University at Buffalo Organic and Stable Isotope Laboratory. Data was corrected using Picarro post run corrections and in-house standards according to van Geldern & Barth (2012). Samples collected in 2021 were measured at the University of Michigan Climate Change Research Group on a similar Picarro 2130i CRDS.

3 Data



**Figure 2** Water isotope measurements from this study shown with Global Meteoric Water Line and data from Levin et al., 2009. One groundwater sample had an anomalously high δ18O value (18.95‰). This sample was collected from a saline well, unlike every other sample, and is omitted from Figure 2 in order to better represent the relationship between measured values and the GMWL.



**Figure 3.** Lake water isotopes and lake height records from Global Reservoirs and Lakes Monitor (G-REALM)

4 Results



**Figure 4.** Lake evaporation models with varying input conditions

5 Conclusions

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Open Research

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