The Use of Stable Isotopic Tracers in Earth and Environmental Science Research

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Outline

• Environmental Problems
• Science Questions
• Stable Isotopic Tracers
• Several Case Studies:
  – Sea Level Rise
  – Lake Level Change
  – Evaporative Enrichment
  – Partition of Stream Waters
Is the Earth getting sick?
Extreme Climate - Prolonged Drought

Lake Elephant Butte, New Mexico (2004)

Southwest China (2010)
Extreme Climate- Floods

Hurricane Katrina (2005)

Western Lake Erie (2003)

(Landsat from Ohio View)
Harmful Algal Blooms

(Toledo Blade)
Acid Mine Drainage

• Ohio has 1,300 miles of streams affected by acid mine drainage – (ODNR)
Two Science Questions

• Climate change- natural climate variability: How has the climate changed over time?

• Evaluating the anthropogenic impacts: How much disturbances have been made by human beings?
Hydrogen and Oxygen Isotopes

- $^{16}\text{O}$ (99.762%), $^{17}\text{O}$ (0.038%) and $^{18}\text{O}$ (0.200%)

- $^{1}\text{H}$ (99.985%) and $^{2}\text{H}$ or D (0.015%)

- Water molecules: HH$^{16}\text{O}$, HD$^{16}\text{O}$, HH$^{18}\text{O}$
δ - notation

\[ \delta^{18}\text{O} = \left( \frac{R_{\text{spl}}}{R_{\text{std}}} - 1 \right) \times 10^3 \text{ (‰, SMOW)} \]

where \( R \) is the ratio of the heavy to light isotope

\[ R = \frac{^{18}\text{O}}{^{16}\text{O}} \]
$\delta$ - notation

$$\delta D = \left( \frac{R_{spl}}{R_{std}} - 1 \right) \times 10^3 \text{ (‰, SMOW)}$$

where $R$ is the ratio of the heavy to light isotope

$$R = \frac{D}{H}$$
Oxygen Isotope Fractionation

-13‰ Vapour
-3‰ Rain
-15‰ Vapour
-5‰ Rain
-17‰ Vapour

Ocean
$\delta^{18}O = 0‰$

Continent
Relationship of $\delta^{18}$O and $\delta^2$H

$\delta D = 8 \delta^{18}O + 10$

(Craig 1961)
Case I: Planetary Ice Volume
Sulu Sea

(Linsley, 1996)
Case II: Lake Level Fluctuations

(Trenberth et al., 2006)
Walker Lake

(Yuan et al., 2004)
Walker Lake

(Yuan et al., 2004)
Case III: Evaporative Enrichment
Chen Co, a Tibetan Lake
Relationship of $\delta^{18}O$ and $\delta^{2}H$
Case IV: Partition of Stream Water
Relationship of $\delta^{18}O$ and $\delta^{2H}$

GMWL: $\delta D = 8\delta^{18}O + 10$
Relative Contributions to River Water
Summary

• Isotopic tracers ($\delta^{18}$O and $\delta^2$H) can be used as a powerful indicator of
  – Earth’s surface temperature (not shown here)
  – planetary ice volume and sea level
  – a lake’s hydrologic balance
  – evaporative water loss
  – partition of stream water from different sources