Isotope Isolation
Using Stable Isotope Analysis to Quantify Non-Stormwater Flow Sources

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woodplc.com
Overview of Dry-Weather Flow Reduction Program

1. Flow monitoring
2. “Data to Doorsteps” Outreach & Education
3. Quantify flows using Isotopes
Purpose of Study

• **Why conduct this study?**
  – San Diego Regional MS4 Permit requirements
  – Dry weather flow reduction goals:
    • “reduce controllable flows”
Purpose of Study

• Why conduct this study?
  – San Diego Regional MS4 Permit requirements
  – Dry weather flow reduction goals

Potential flow sources:
• Over-irrigation (local, tap, recycled)
  • Residential
  • Agricultural
  • Commercial (golf course)
• Groundwater infiltration
• Wastewater/Sewage (RV dumpage)
• Pool draining
• Water utility operations (flushing, dewatering)
Purpose of Study

• **Why conduct this study?**
  – San Diego Regional MS4 Permit requirements
  – Dry weather flow reduction goals

• **General questions for this study**
  – Is MS4 flow from local rain/groundwater or municipal tap water?
  – Can isotopic methods help *quantify* these sources?
**Scientific Background**

**Isotopes** are variants of an element with **same number of protons** but **varying number of neutrons**.

Ex.: Oxygen has 8 protons, and 8,9,10 neutrons

= 16O, 17O, 18O

Greek: “iso” = same, “topos” = place

→ same place in periodic table of elements
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Scientific Background

**Isotopes** are variants of an element with **same number of protons** but **varying number of neutrons**

Ex.: Oxygen has 8 protons, and 8, 9, 10 neutrons = $^{16}$O, $^{17}$O, $^{18}$O

Greek: “iso” = same, “topos” = place

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Types of Isotopes

- **Stable Isotopes**
  - Protium
  - Deuterium
  - Tritium

- **Radioactive Isotopes**
More neutrons = More mass

physical property leads to spatial patterns of isotopic composition of rainfall
Scientific Background (cont)

More neutrons = More mass

**physical property** leads to **spatial patterns** of isotopic composition of rainfall

“Heavy”

More $^{18}$O

http://web.sahra.arizona.edu/programs/isotopes/oxygen.html
Scientific Background (cont)

More neutrons = More mass

physical property leads to spatial patterns of isotopic composition of rainfall

1. Ocean to Continent

http://web.sahra.arizona.edu/programs/isotopes/oxygen.html
Scientific Background (cont)

More neutrons = More mass

**Physical property** leads to **spatial patterns** of isotopic composition of rainfall

1. Ocean to Continent
2. Elevation

"Heavy"  "Light"

More $^{18}$O  Less $^{18}$O

http://web.sahra.arizona.edu/programs/isotopes/oxygen.html
Scientific Background (cont)

More neutrons = More mass

**physical property** leads to **spatial patterns** of isotopic composition of rainfall

Storms mostly move from west to east

More 18O

Less 18O

Kendall and Coplen, 2001
More neutrons = More mass physical property leads to spatial patterns of isotopic composition of rainfall

San Diego imports water from Colorado River
CO River water is depleted in O18

“Heavy”  “Light”

More 18O
Less 18O

Kendall and Coplen, 2001
Analytical Approach

Isotopic End-Member Mixture Analysis (IEMMA)

![Graph showing isotopic analysis](image)

- δD and δ18O values for Colorado River water and ocean (desalination) water.
- The graph illustrates the difference in isotopic composition between light and heavy isotopes.

Colorado River water is shown on the light side of the graph, while ocean (desal) water is on the heavy side.

A presentation by Wood.
Analytical Approach (cont)

Isotopic End-Member Mixture Analysis (IEMMA)

Isotopic End-Member Mixture Analysis (IEMMA)

- Local water $\delta_L$
- Tap water $\delta_T$
- Colorado River water
- Ocean (desal)

$\delta D$

$\delta^{18}O$
Analytical Approach (cont)

Isotopic End-Member Mixture Analysis (IEMMA)

- Water sample from study area (e.g. MS4)
- Mostly local
- Mostly tap
- Tap water $\delta T$?
- Colorado River water
- Local water $\delta L$
- Ocean (desal)
- $\delta^18O$
- $\delta D$
- Light
- Heavy
- Mostly local
- Mostly tap
Analytical Approach (cont)

**Isotopic End-Member Mixture Analysis (IEMMA)**

\[
\text{%TAP} = 100 \times (\delta_S - \delta_L) (\delta_T - \delta_L)
\]

- **%TAP** = percent tap water
- **δL** = δ18O of local water
- **δS** = δ18O of sample
- **δT** = δ18O of tap water
Isotopic End-Member Mixture Analysis (IEMMA)

....with Evaporation

\[
\text{% TAP} = 100 \times (\delta S - \delta L) (\delta T - \delta L)
\]

% TAP = percent tap water
\(\delta L = \delta^{18}O\) of local water
\(\delta S = \delta^{18}O\) LEL/MixLine
\(\delta T = \delta^{18}O\) of tap water
Where might IEMMA *not* work?

- Light
- Heavy
- δD
- δ18O

- Local water δL
- Tap water δT
- Colorado River water
- Ocean (desal)
- GMWL
- Mixing line
Where might IEMMA *not* work?

- Isotopic composition of Tap ($\delta T$) too similar to Local ($\delta L$)

**Example**
Desal water added to water supply will shift Tap water to isotopically resemble Local water by enriching $^{18}O$ and $D$. 

![Diagram showing isotopic composition of water sources](image)
Where might IEMMA not work?

- Isotopic composition of Tap (δT) too similar to Local (δL)
- Spatial or Temporal variability in Water District

Diagram:

- Heavy
- Light
- δD
- δ18O
- Tap water δT
- Local water δL
- Ocean (desal)
- Colorado River water
- GMWL
- Mixing line
Where might IEMMA not work?

- Isotopic composition of Tap ($\delta_T$) too similar to Local ($\delta_L$)
- Spatial or Temporal variability in Water District

![Graph showing isotopic composition of water sources](image)
1. Do Local and Tap end-members vary in space and time?

2. Are Local and Tap end-members isotopically different enough for IEMMA?

3. What fraction MS4 discharge is Local water vs Tap water?
**Sampling Design**

- **Sampling May 1-Oct 1, 2018**
  - 50 MS4 outfalls sampled in May, Aug, Oct (n=3)
  - 20 Priority MS4 sampled bi-weekly (n=10)
  - 4-10 streams sampled bi-weekly (n=10)
  - 24 tap water sampled bi-weekly (n=10)

**Study Sites**

10 water districts sampled

~60 miles

- **MS4Outfalls**
  - =50

- **RefStreams**
  - =4-10

- **TapWater**
  - =24
Q1: Do Local and Tap end-members differ isotopically in SPACE and time?

Local endmember values vary with elevation (space)...

Local water at high elevations can be similar to Tap water...

...not as good for reference....

... but hard to find good reference sites at lower elevations
Q1: Do Local and Tap end-members differ isotopically in SPACE and time?

Local endmember values vary with elevation (space)...

→ Need to calculate “Elevation-specific” local reference (δL) based on regression and/or mean or range of low-elevation sites

Local water at high elevations can be similar to Tap water...

...not as good for reference....

... but hard to find good reference sites at lower elevations
Q1: Do **Local** and **Tap** end-members differ isotopically in space and **TIME**?

...but **Local** water endmembers are mostly stable over time.
Q1: Do Local and Tap end-members differ isotopically in space and time?

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TAP water sources appear to have changed during the summer for some districts...

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[Graph showing isotopic variability over time for different districts]
Q1: Do Local and Tap end-members differ isotopically in space and time?

TAP water sources appear to have changed during the summer for some districts...

→ Is the variability important for calculation of %TAP?

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Q2: Are Local and Tap end-members isotopically different enough for IEMMA?

Answer: Yes and No

6 water districts good (blue), 4 districts moderate/bad for IEMMA (red)
Q3: What fraction MS4 discharge is local water vs tap water?

Tap water % (no evaporation)

A presentation by Wood.
Q3: What fraction MS4 discharge is local water vs tap water?

Tap water % (no evaporation)

20-25% Tap

Some sharp peaks, also some Low-Moderate baseflow

Indicates local water intrusion
Q3: What fraction MS4 discharge is local water vs tap water?

Tap water % (no evaporation)

- 57-80% TAP

Why not 100% TAP though?
Q3: What fraction MS4 discharge is local water vs tap water?

Tap water % (with evaporation)

**LEL** = **Local Evaporation Line**

Corrects for evaporative enrichment of 18O (lighter O16 evaporates)

Shows SDR-064 is 100% TAP

LEL correction introduces uncertainty
Conclusions

Research Questions

1. Do Local and Tap end-members vary in space and time?

   Local reference samples varied:
   a) Space: Yes, predictable with elevation
   b) Time: No

   → Need reference sites at same elevation as sites of interest, biweekly
Conclusions

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   Local reference samples varied:
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   Tap reference vary over:
   a) Space: among but (usually) not within water districts
   b) Time: for some districts. Reflects changing water supply?
   → 2-3 tap sites in each district ok, but need ~biweekly sampling
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   → 2-3 tap sites in each district ok, but need ~biweekly sampling

2. Are Local and Tap end-members isotopically different enough for IEMMA?

   Local and Tap endmembers sufficiently different
   → calculate % TAP in 8/10 districts
   → 40/50 MS4 sites are in good/moderate water districts
Conclusions

Research Questions

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   Local reference samples varied:
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2. Are Local and Tap end-members isotopically different enough for IEMMA?
   Local and Tap endmembers sufficiently different
   → calculate % TAP in 6/10 districts

3. What fraction MS4 discharge is Local water vs Tap water?
   TAP % varies widely: 0-100%. Why?
Thank you!

**Special thanks to:**
Wood field staff

County of San Diego:
Joanna Wisniewska and Ryan Jensen

San Diego State University:
Dr. Trent Biggs, Dr. Chun-Ta Lai, and Hannah Carney
Some next steps

Autosampler at 2 sites

Not much correlation with flow?
Multiple Ordered Lines of Evidence (MOLE)

1. Flow Data

2. Isotopes

3. Geochemistry

4. Indicators

FLOW SOURCES?