Evaluation of Long-Term Trends and Variations in the Average Total Dissolved Solids Concentrations in Wastewater and Recycled Water

Unintended Consequences

October 12, 2018
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• Technical Direction - Risk Sciences
TDS Trends Study - Synopsis

• Identify the effects of drought and water conservation measures on the long-term TDS trends in wastewater and recycled water
• Drought, water conservation measures, and other explanatory variables are auto-correlated to some degree
• Study analyzed both deterministic models and statistical models (multiple linear regression) to predict TDS in wastewater and recycled water
• Provide the science and statistical analysis to provide a framework for policy discussions
• Dovetails with CUWA’s white paper - Utilities and declining flows.
Research Question 1

• **Q:** How has indoor per capita water use changed over time? What are the water quality implications if the trend continues for the next 20 years?

• **A:** Per capita water use is generally decreasing over time, from a range of 80 to 100 gpcd to a range of 50 to 75 gpcd.

• Expect to reduce per capita water use to 55 gallons per capita per day (gpcd) by 2020 (AB-968 Section 10608.25).

• 1.2 to 1.7 mg/L increase in influent TDS for every 1 gpcd decrease in indoor water use.
Conservation Measures: Total Supply

![Graph showing total supply and population over time.]
Conservation Measures: Indoor Use

- Decline of indoor per capita water use universally.
- California 2015 state mandate is part of an overall downward trend in water use.
Research Question 2

• **Q:** How has the volume-weighted average concentration of TDS in municipal influent changed over time? What are the water quality implications if the trend continues for the next 20 years?

• **A:** A majority of the wastewater treatment plants exhibited an upward trend in TDS concentrations. Of the 26 WWTPs, 16 have an upward trend in TDS, 7 have no trend, and 3 have a downward trend in TDS.
TDS in WWTP Effluent over Time

EMWD: Moreno Valley

EMWD: Temecula Valley

EMWD: Perris Valley

IEUA: RP-1

IEUA: CCWRF

IEUA: RP-4

IEUA: RP-2/RP-6

Explanations:
- 12-Month average of effluent TDS
- Monthly effluent TDS
Research Question 6

**Q:** To what degree are fluctuations in the volume-weighted average concentration of TDS in recycled water correlated with variations in the volume-weighted average concentration of TDS in the wastewater influent?

**A:** Influent TDS and effluent TDS concentrations are generally tightly correlated.
TDS Trends Example - Temecula Valley WRF

Considerations:
• 12-mo average period
• Influent ~ Effluent
• Discharge limit based on IFU limit and absolute limits.
Research Question 7

**Q:** To what degree are fluctuations in the volume-weighted average concentration of TDS in recycled water correlated with variations in the volume-weighted average concentration of TDS in the municipal water supply?

**A:** There is a high degree of correlation between the fluctuations of source TDS and the fluctuation of influent TDS. Source TDS is one of two most important explanatory variables. According to the statistical models, the relative importance values of source TDS ranges from 34 to 99 percent with an average of 78 percent.
Multiple Linear Regression: Influent TDS

\[ y_i = b_0 + \sum_{j=1}^{n} b_j x_{ij} + e_i \]

where

- \( y_i \) = the predicted value of the response variable \( y \) for data point \( i \)
- \( b_0 \) = the model intercept coefficient
- \( b_j \) = the model slope coefficient for explanatory variable \( j \)
- \( n \) = the total number of explanatory variables in the model
- \( x_{ij} \) = the known value \( x \) of explanatory variable \( j \) for data point \( i \)
- \( e_i \) = the residual error of data point \( i \) from the fitted model
Research Question 8

**Q:** To what degree do fluctuations in the volume-weighted average concentration of TDS in recycled water correlate with long-term meteorological (drought) cycles?

**A:** Where there is a higher degree of dependence on imported water, there is a higher degree of correlation with long-term meteorological cycles. This is evident in the difference between EMWD and IEUA.
Source Supply TDS Concentrations and Drought

- Higher TDS concentration with drought periods
- EMWD greater reliance on imported water
- IEUA greater reliance on groundwater and local water supply
Research Question 9

**Q:** What effect, if any, did the state's mandatory conservation measures (2015-16), and the subsequent relaxation of these measures, have on average per capita indoor and outdoor water use?

**A:** Between 2004 and 2010 there was a general decrease in per capita indoor water use. Between 2010 and 2015, per capita indoor water use remained constant at around 60 gpcd. In May 2015, per capita indoor water use began to decline again down to 55 gpcd in 2016.
Multiple Linear Regression: Influent TDS

- Variables:
  - STDS: Source TDS
  - IGPCD: Influent per capita water use

- $R^2 = 0.98$

- Relative Importance (%)
  - STDS: 88.2
  - IGPCD: 11.8
Multiple Linear Regression: Influent TDS

- **Variables:**
  - STDS: Source TDS
  - IGPCD: Influent per capita water use

- **R-squared = 0.75**

- **Relative Importance (%):**
  - STDS: 67.2
  - IGPCD: 32.8
TDS Statistical Model Matrix

• Using the statistical models, matrices were developed to predict the effects of conservation and changes in source water TDS. Much of this variation was due to climatic factors such as drought.

• EMWD Example: During the peak of the drought, source water quality was approximately 500 mg/L and indoor per capita water use was 55 gpcd. The estimated water quality entering a WWTP would be approximately 750 mg/L.
Research Question 10

• **Q:** What effect, if any, did the 2015-16 changes in average per-capita indoor water use have on the average concentration of TDS in wastewater influent and recycled water?

• **A:** This study estimates that for every 1.0 gpcd decline in indoor water use, TDS increases by 1.7 mg/L for the EMWD service area. The state’s mandatory conservation measure may have contributed to the estimated 8.5 mg/L added to the system during this time period.
Research Question 11

- **Q:** Based on water quality correlations with drought and conservation, what are the implications for the trends in per capita water use and TDS in recycled water if precipitation patterns over the next 20 years are drier than normal?

- **A:** Using the statistical models, matrices were developed to predict the effects of conservation and changes in source water TDS. Much of this variation was due to climatic factors such as drought.
## EMWD Statistical Model Matrix for Influent TDS

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</tbody>
</table>

Every 1 gpcd decrease amounts to 1.7 mg/L increase in TDS.
Multiple Linear Regression: Influent TDS

Variables:
- STDS: Source TDS
- IGPCD: Influent per capita water use

R-squared = 0.98

Relative Importance (%)
- STDS: 88.2
- IGPCD: 11.8
Long-term rolling averages

• How does the volume-weighted average TDS concentration in recycled water, and the related increment of use, vary using a range of rolling averaging periods (e.g., 1, 5, 10, and 15 years)?

• Longer-term rolling average periods smooth out annual variations of effluent trends. 10 year averages account for seasonal cyclicity.
TDS Trends Example - Temecula Valley

Considerations:

• Rolling average period
• Discharge limits based on Management Zone Water Quality Objectives
• Long term trends
• Sessional cyclicity (drought vs wet years)
TDS Trends Example - Temecula Valley

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Considerations:

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• Long term trends
• Sessional cyclicity (drought vs wet years)

- 5-year rolling average

Basin discharge permit limit: 750 mg/L

Source TDS

Influent TDS

Effluent TDS

TDS (mg/L)

1991 1993 1995 1997 1999 2001 2003 2005 2007 2009 2011 2013 2015 2017
TDS Trends Example - Temecula Valley

Considerations:

- Rolling average period
- Discharge limits based on Management Zone Water Quality Objectives
- Long term trends
- Sessional cyclicity (drought vs wet years)
Summary

• Longer rolling averages (>5-years) minimize the influence of drought cycles. Long-term upward trends in TDS will still be present.

• Statistical modeling suggests that for every 1.0 gallon per capita per day that is conserved there will be an increase in TDS concentrations to the WWTPs of 1.2 mg/L to 1.7 mg/L

• Unintended consequences from water conservation measures
  o lower water quality (higher TDS)
  o less quantity of recycled water
  o less revenue
  o infrastructure O&M
  o Less energy uses
  o Less GHG emissions
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