Mechanical Evaporator Emission Factor Development Studies

2017 International Emissions Inventory Conference

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Evolution of Trinity Consultants

1974
> One person, one office
> Air quality specialty

2017
> Over 500 employees
> 50+ offices in North America, the UK, the Middle East, and China
> Serve more than 1,800 clients annually
> EHS consulting services with a focus on air quality
> ISO 9001 quality management system, certified in Dallas HQ
Mechanical Evaporators (ME)

- Who, Where and Why?
- Types?
- Evaporation Ponds?
- How to Quantify Emissions?
Industrial Drivers (Who, Where & Why)

> Mining Industry
  - Tailings Ponds
    - Water Level Reduction/Maintaining Freeboard
    - High Metal Concentrations Prohibits Discharge to POTW

> Power Industry
  - Cooling Tower Blow Down
  - Dehydrating Ash Ponds in Response to CCR Rule\(^1\)

> Facilities With Brine Ponds
  - Brine Generated from Reverse Osmosis
  - High Salt Concentrations Prohibits Discharge to POTW

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Types of Evaporators

- Nozzle

- Water Atomization
  - Nozzle Injected Droplets

- Water Fracturing
  - High Speed Fan
Evaporation Ponds

- Large Volume of Water
- System of ME’s
- Designed to Maintain Freeboard
- Evaporate Water
Quantifying Emission Rates

- Big Question!
- “Typically” Treated as Cooling Towers
- Multi-Phase Emissions - Droplets & Particulate Matter
  - Droplet Diameter \( \geq 100 \, \mu m \)
  - Particulate Matter PM\(_{2.5}\), PM\(_{10}\) and TSP
- High in Total Dissolved Solids
Variables That Influence Air Emissions

> Total Dissolved Solids (TDS) content (mg/L) of Water
> Mechanical Evaporator Setup
  ❖ Type of Evaporator
  ❖ Droplet Size Distribution (dN/dlogD_p)
  ❖ Rate Capacity (gpm)
  ❖ Nozzle Diameter (m)
  ❖ Nozzle Pressure (psi)
> Ambient Meteorological Conditions
  ❖ Temperature (°C)
  ❖ Relative Humidity (%)
  ❖ Wind Speed & Direction (m/s & °)
> Evaporation Pond Design
  ❖ Distance from Pond Edge (m)
  ❖ Pond Freeboard (m)
  ❖ Pond Berm Height (m)
Estimating Emission Rates

> Theoretical Techniques
  - AP-42, Section 13.4 Wet Cooling Towers
  - Reisman & Frisbie, (2002)¹
  - Hosler et al., (1974)²
  - Dynamic Particle Model

> On-Site Measurement/Modeling Techniques
  - Customized Field Study
  - Model the Plume

Theoretical: AP-42, Section 13.4

> Designed for Wet Cooling Towers
> Most Conservative (TSP = PM$_{10}$ = PM$_{2.5}$)

\[
ER \left( \frac{lb}{hr} \right) = TDS \left( \frac{mg}{L} \right) \times \frac{Drift(\%)}{100 \%} \times Q \text{ Rate} \left( \frac{gal}{min} \right) \times 3.78 \left( \frac{L}{gal} \right) \times \frac{2.2lb}{10^6mg} \times \frac{60min}{hr}
\]

> Assumed Inputs:
- TDS = 41,000 mg/L
- Drift = 100 % (Worst Case)
- Q Rate = 80 gal/min

> Emission Rate PM$_{10}$ = \textbf{1,600 lb/hr; 7,200 tpy}
Theoretical: Reisman & Frisbie

- Designed to “Calculate Realistic PM\textsubscript{10} Emission From Cooling Towers”
- Less Conservative due to Droplet/Particle Size Distribution
- Assumes a Droplet to Mass Distribution

- Assumed Inputs:
  - TDS = 41,000 mg/L
  - Drift = 100 % (Worst Case)
  - Q Rate = 80 gal/min
- Emission Rate PM\textsubscript{10} = 7.3 lb/hr; 32 tpy
Theoretical: Dynamic Particle Model

- Requires:
  - TDS, Q Rate, Drift
  - Evaporator Type, Pressure
  - Evaporation Pond Setup

- Assumes:
  - Hygroscopic Growth & Evaporation
  - Include Particle Deposition

- Excludes:
  - Meteorological Impacts
  - Collision/Coalescence

- Emission Rate $\propto \frac{1}{\text{Complexity}}$

On-Site Measurement/Modeling Techniques

- Mechanical Evaporator Operating Conditions
- Evaporation Pond System
- Meteorological Impacts
- Emission Factor
- Particle Advection
- Collision & Coalescence

Diagram showing wind direction, release height, and particle behavior (heavy vs. light), as well as wind speed distribution.
Methodology Overview

Steps:
- Customized Plan for the Site/Evaporators
- Measurement Period (PM and Meteorology)
- Wind Sector Analysis
- Concentration Profiles are Developed
- Reverse Model to Determine Emission Rate Based on Concentration Profile
- Apply Emission Rates
Methodology

> Light Scattering Photometer
  - Determines Mass Concentration of PM in Real-Time
  - Advantage Over Gravimetric Filter Methods

> Meteorological Tower
  - Determines the Ambient Meteorological Conditions During Sampling
  - Use in Wind Sector Analysis
  - Minimum: Temperature, Relative Humidity, Wind Speed and Direction
Wind Sector Analysis

> Upwind and Downwind Monitors are Relocated based on Wind Direction
> Location is Assessed/Compared to Wind Sector
> Data is Excluded if Outside of Sector
> Generally Compare 15 min of Data
Modeling Strategy

> Combine Concentration \((\mu g/m^3)\) and Meteorological Profiles

> Reverse Model Evaporator to Determine Emission Rate \((lb/hr)\) or Emission Factor \((lb/gal)\)
Monitoring Technique Results

Based on Studies Conducted to Date:

<table>
<thead>
<tr>
<th>Evaporator Type</th>
<th>TDS Concentration (mg/L)</th>
<th>Emission Rate (lb/hr)</th>
<th>Emission Rate (lb/1000 gal)</th>
<th>Emission Rate (tpy)</th>
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</thead>
<tbody>
<tr>
<td></td>
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<td>PM$_{2.5}$</td>
<td>PM$_{10}$</td>
<td>PM$_{2.5}$</td>
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</table>

- Emission Rate PM$_{10}$: 0.07 to 0.61 lb/hr; 0.3 to 2.7 tpy
- Emission Rate PM$_{2.5}$: 0.05 to 0.52 lb/hr; 0.2 to 2.3 tpy
# Comparison of Results

<table>
<thead>
<tr>
<th>Method</th>
<th>TDS Concentration (mg/L)</th>
<th>Emission Rate (lb/hr)</th>
<th>Emission Rate (tpy)</th>
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<td>PM₁₀</td>
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</table>
Conclusions

- Mechanical Evaporators are Widely Used
- Existing Theoretical Methods Significantly Overestimate Emission Factors/Rates
- More Complex Theoretical Models Can Get Closer Estimates
- Customized Emission Factor Studies Can Provide the Most Representative Emission Rate

Approved by:
- New Mexico Environmental Department (NMED)
- Arizona Department of Environmental Quality (ADEQ)
- Maricopa County Air Quality Department (MCAQD)
Thank You

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