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

[1] Disposal of Coal Combustion Residuals (CCR) from Electric Utilities Rule. 40 CFR 257 and 261 – Criteria for Classification of Solid Waste Disposal Facilities and Practices; Identification and Listing of Hazardous Waste.

Types of Evaporators

- Nozzle

- Water Atomization
  - Nozzle Injected Droplets
- Water Fracturing
  - High Speed Fan

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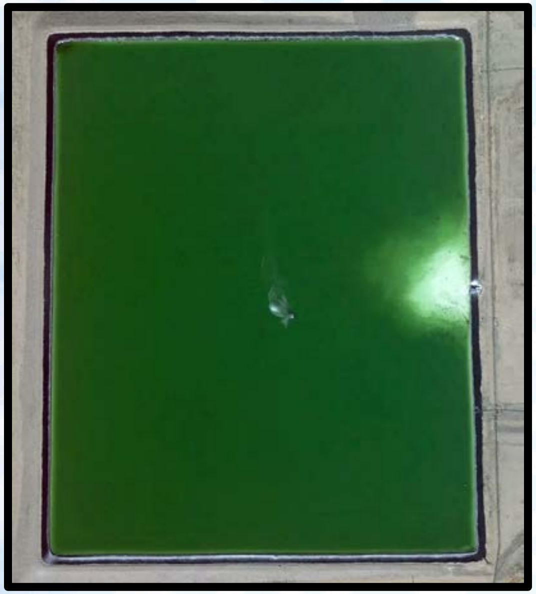
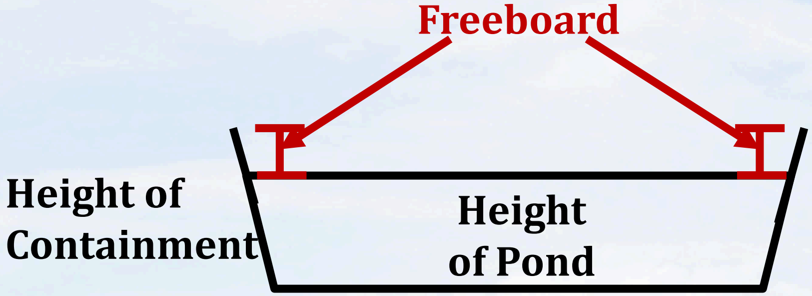
Evaporation Ponds

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





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Quantifying Emission Rates

- Big Question!
- "Typically" Treated as Cooling Towers
- Multi-Phase Emissions – Droplets & Particulate Matter
- Droplet Diameter $\geq$ 100 μm
- Particulate Matter $PM_{2.5}$, PM_{10} and TSP
- High in Total Dissolved Solids

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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 (^{o}C)
  - Relative Humidity (%)
  - Wind Speed & Direction (m/s & ^{o})
- 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

[1] Reisman, J, Frisbie, G, "Calculating Realistic PM_{10} Emissions from Cooling Towers", Environmental Process & Sustainable Energy, July 2002.

[2] Hosler, C.L, Pena, J, Pena, R, "Determination of Salt Deposition Rates from Drift from Evaporative Cooling Towers", Journal of Engineering for Power, July 1974.

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Theoretical: AP-42, Section 13.4

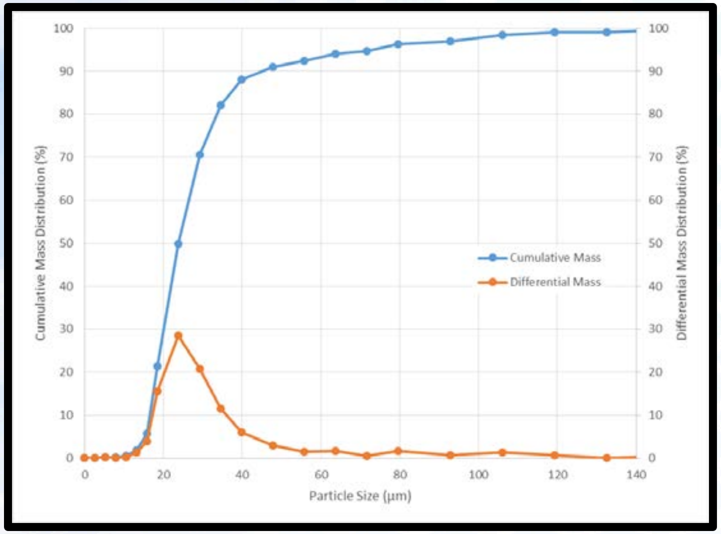
- Designed for Wet Cooling Towers
- Most Conservative (TSP = PM_{10} = $PM_{2.5}$)

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

- Assumed Inputs:
  - TDS = 41,000 mg/L
  - Drift = 100 % (Worst Case)
  - Q Rate = 80 gal/min
- Emission Rate PM_{10} = 1,600 lb/hr; 7,200 tpy

Theoretical: Reisman & Frisbie

- Designed to "Calculate Realistic PM_{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_{10} = 7.3 lb/hr; 32 tpy

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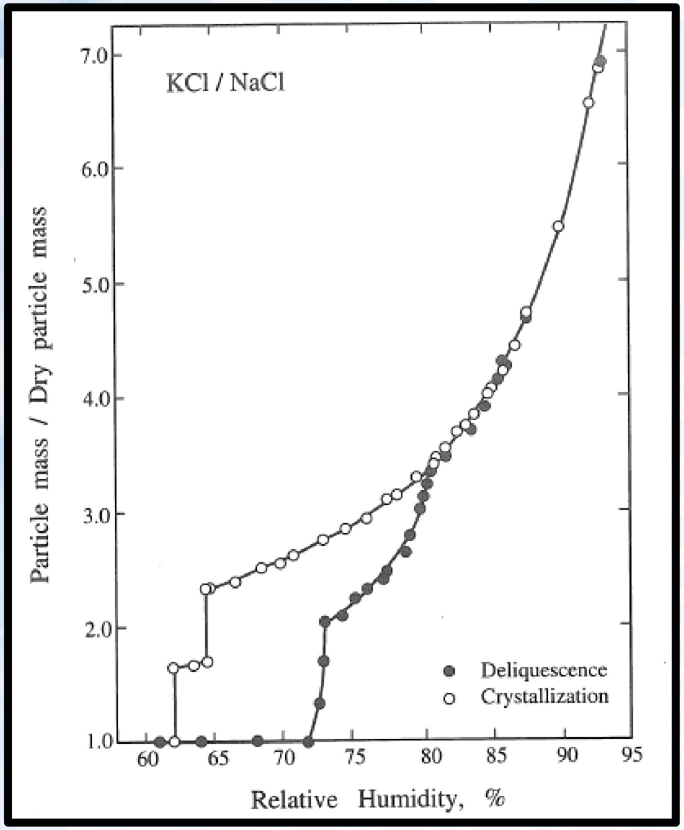
Theoretical: Dynamic Particle Model

- Requires:
  - TDS, Q Rate, Drift
  - Evaporator Type, Pressure
  - Evaporation Pond Setup
- Assumes:
  - Hygroscoptic Growth & Evaporation
  - Include Particle Deposition
- Excludes:
  - Meteorological Impacts
  - Collision/Coalescence
- Emission Rate ∝ 1/Complexity



[1] Seinfeld & Pandis, "Atmospheric Chemistry and Physics: From Air Pollution to Climate Change", Second Edition, 1997.

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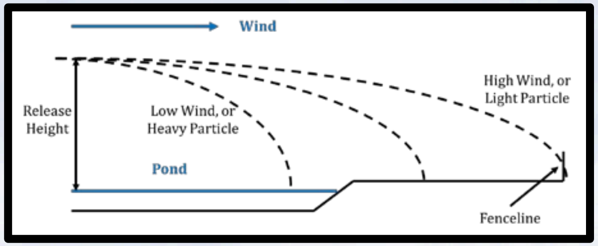
On-Site Measurement/Modeling Techniques



Mechanical Evaporator Operating Conditions

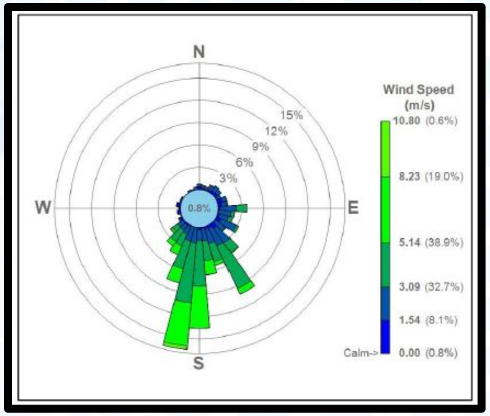
Meteorological Impacts

Collision & Coalescence

Particle Advection

Evaporation Pond System

Emission Factor



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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

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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

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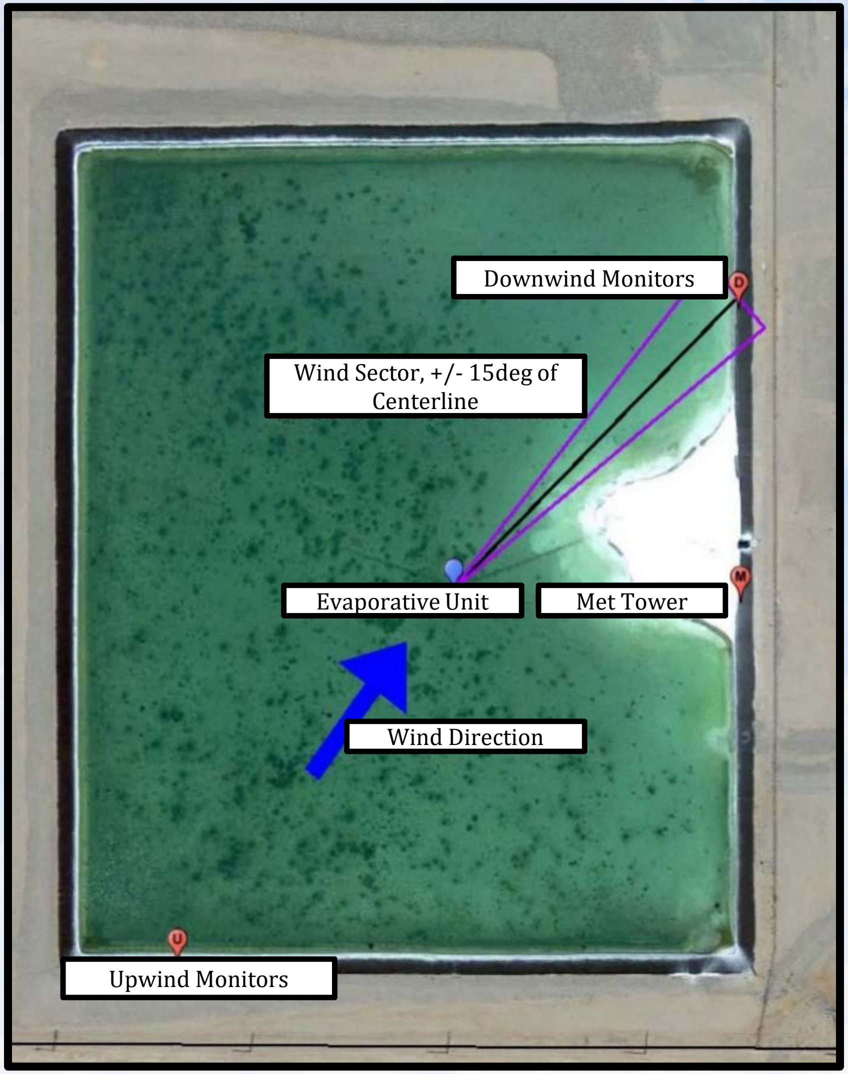
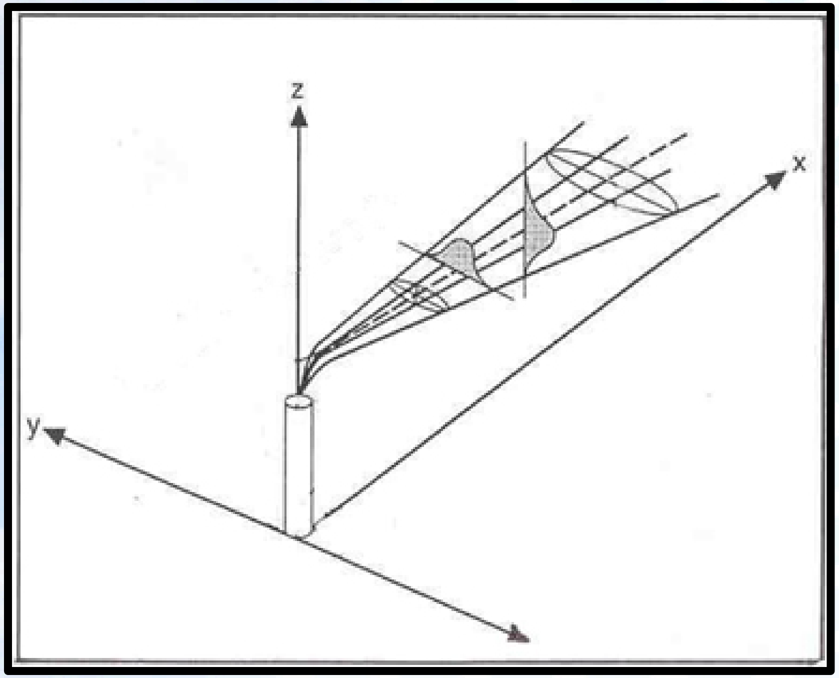
Wind Sector Analysis



- 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 (µg/m^3) and Meteorological Profiles
- Reverse Model Evaporator to Determine Emission Rate (lb/hr) or Emission Factor (lb/gal)



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Monitoring Technique Results

- Based on Studies Conducted to Date:

Evaporator Type	TDS Concentration (mg/L)	Emission Rate (lb/hr)		Emission Rate (lb/1000 gal)		Emission Rate (tpy)	
		$PM_{2.5}$	PM_{10}	$PM_{2.5}$	PM_{10}	$PM_{2.5}$	PM_{10}
Fracture	12,000	0.52	0.61	0.11	0.13	2.29	2.67
Atomizer	41,000	0.05	0.07	0.01	0.02	0.22	0.32
Atomizer	41,000	0.05	0.11	0.01	0.02	0.20	0.47
Atomizer	41,000	0.08	0.10	0.02	0.02	0.35	0.43
Atomizer	110,000	0.18	0.47	0.05	0.12	0.79	2.04
Atomizer	110,000	0.18	0.50	0.05	0.13	0.79	2.19

- 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

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Comparison of Results

Method	TDS Concentration (mg/L)	Emission Rate (lb/hr)		Emission Rate (tpy)	
		$PM_{2.5}$	PM_{10}	$PM_{2.5}$	PM_{10}
AP-42	41,000	1637	1637	7168	7168
Reisman & Frisbie	41,000	0.00	7.34	0.00	32.13
Measurement Technique	41,000	0.08	0.11	0.35	0.47

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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)

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Thank You

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