Effective Evaporation as a Water Reduction Solution

Mine Design, Operations & Closures Conference

Montana Tech

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APPLIED H_2O SOLUTIONS

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Biological via “Chlor”

Rare Colorado salt water Crocodile.

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Regional Haze

Rule 40 CFR 51.300:

"visibility impairment that is caused by the emission of air pollutants from numerous sources located over a wide geographic area.

This visibility impairment is a result of particles and gases in the atmosphere that scatter and absorb light, thus acting to reduce overall visibility.

The primary cause of atmospheric haze is light extinction (scattering and absorption) by particulate matter (PM).

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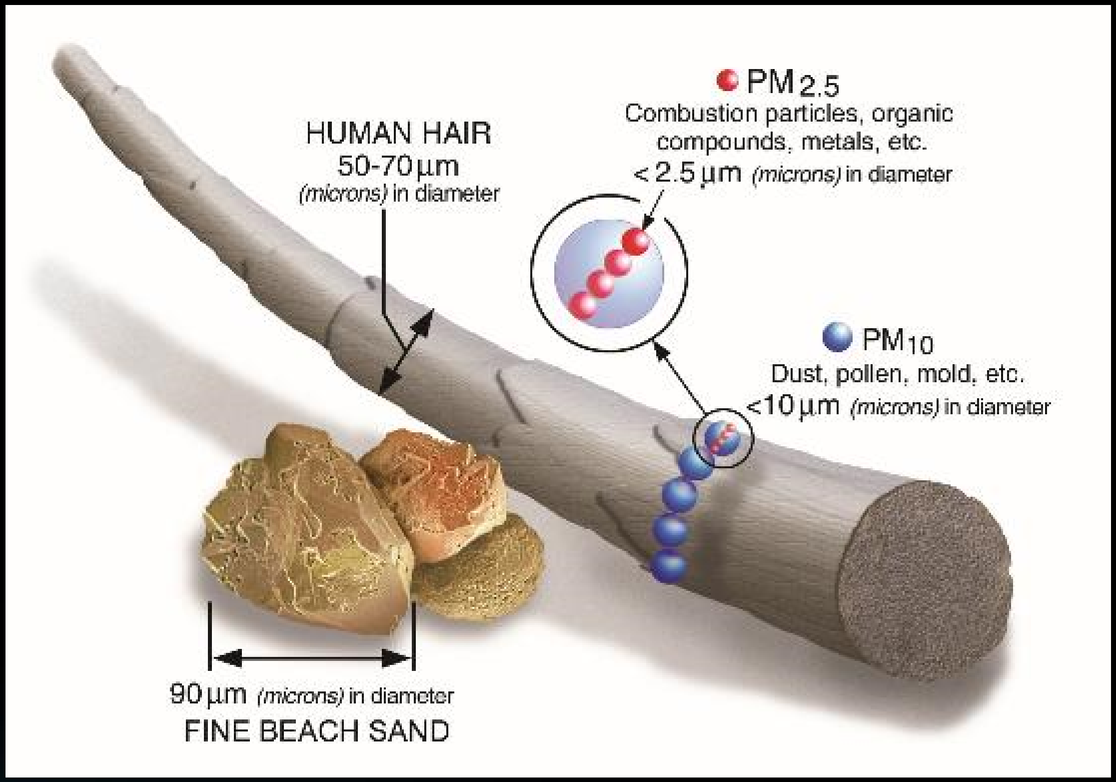

US EPA

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Mechanically Enhanced Evaporation

THE GOOD

- Creates additional surface area for evaporation
- Enhances speed of evaporation rates
- Successfully removes large volumes of water

The Bad

- Potential for Plume is large
- Can create an environmental risk
- Space constraints can limit enhancement potentials

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- Actual Vapor Pressure (e)
  - The density of water vapor within the air.
- Saturation Vapor Pressure (es)
  - The limit to the density of water vapor which may be contained in the air, at temperature.
- Relative humidity
  - e/ es
- Saturation Deficit or Vapor Pressure Deficit (VPD)
  - es-e, or the amount of water that can be held in the air at temperature.

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$$E_{\text{mass}} = \frac{mR_n + \rho_a c_p \left(\delta e\right) g_a}{\lambda_v \left(m + \gamma\right)}$$

Penman equation

where:

- m = Slope of the saturation vapor pressure curve (Pa K−1)
- R_n = Net irradiance (W m−2)
- ρ_a = density of air (kg m−3)
- c_p = heat capacity of air (J kg−1 K−1)
- g_a = momentum surface aerodynamic conductance (m s−1)
- δe = vapor pressure deficit (Pa)
- λ_v = latent heat of vaporization (J kg−1)
- γ = psychrometric constant (Pa K−1)

$$E_{\text{mass}} = \frac{mR_n + \gamma * 6.43\,(1 + 0.536 * U_2)\,\delta e}{\lambda_v\,(m + \gamma)}$$

Shuttleworth Simplification

- where:
- Emass = Evaporation rate (mm day−1)
- m = Slope of the saturation vapor pressure curve (kPa K−1)
- Rn = Net irradiance (MJ m−2 day−1)
- γ = psychrometric constant = (kPa K−1)
- U2 = wind speed (m s−1)
- δe = vapor pressure deficit (kPa)
- λv = latent heat of vaporization (MJ kg−1)

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$$E = 0.0306 A F_a (P - P_a)$$

John W. Lund Evaporation Equation

- Where:
- E = Evaporation Rate (Gallons/Day)
- A = Impoundment Surface Area (ft^2)
- F = Activity Factor (1 for open water)
- P = Water's Vapor Pressure (mmHG) at Ambient Temperature
- P_a = Water's Vapor Pressure (mmHG) at Dew Point Temperature

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- Unit placement
- Unit parameters audit
  - Maximize evaporation per unit specific to site
  - Maximize evaporation specific to available support utilities
- Energy Balance management for efficiency gains
  - Pumps brought shallow
  - Brine Stratification management

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Thank you

Questions

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