Estimating the Potential for Plume Fogging from Wet Scrubbed Electric Power Plants

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Purpose of Study

Large numbers of electric power plants will install Flue Gas Desulfurization (FGD) systems to comply with:

- Consent Orders
- CAIR
- CAMR
- Future ozone and PM2.5 SIP requirements

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Purpose of Study

- Each FGD system will increase the emissions of water vapor and liquid water from its exhaust stack.

- This raises the potential for plume-induced ground-level fogging/icing in the vicinity of the plant.

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Purpose of Study

•Such fogging and icing may cause considerable local community complaints requiring potentially costly changes to the FGD subsystem and plant operating practices

Purpose of Study

•There are no existing U.S. EPA-approved air quality models for fogging and icing

Purpose of Study

Develop way to evaluate the potential for fogging and icing from power plant exhaust stacks with FGD systems

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OVERVIEW OF APPROACH

1. We applied the U.S. EPA Guideline Model, AERMOD, to predict ground-level concentrations of water vapor from the power plant FGD system

OVERVIEW OF APPROACH

2. We predicted whether ground level fogging/icing occurred using basic principles of condensation formation

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PLANT/FGD SYSTEM PROFILE

1. Coal-fired power plant exceeding 1500 MW in river valley with complex terrain

2. 850 foot GEP Stack based on physical modeling study

3. Several nearby communities mainly in river valley

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DATA INPUT

1. **Develop the water vapor emissions inventory**:

- 12.9% water vapor by volume in the stack exhaust
- 252,062 grams/second water vapor at 100% operating load

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DATA INPUT

2. **Develop the water droplet emissions inventory**

- The liquid water carryover from the mist eliminators is estimated at 378 grams/second.

- Conclusion: Water droplet emissions are insignificant compared to emissions of water vapor. Exclude from further analysis.

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DATA INPUT

3. **Assemble Meteorological Data**

- 5 years hourly surface and upper air data from closest National Weather Service station

Note: on-site data always preferred if available

DATA INPUT

3. **Assemble Meteorological Data**

- AERMET meteorological pre-processor used to process the data required for AERMOD.

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DATA INPUT

4. Determine Land Use within 3 km of the National Weather Service Station

	Fractional Land Use	
Land Use Type	**Sector 1 (15^o – 270^o)**	**Sector 2 (270^o – 15^o)**
Urban	0.75	0.10
Deciduous	0.20	0.85
Grassland	0.05	0.05
Total % Land Use	**1.00**	**1.00**

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DATA INPUT

5. Select AERMOD default mode input parameters by land use type and season of year:

- Albedo
- Bowen Ratio
- Surface Roughness

Source: AERMET User's Guide

DATA INPUT

6. **Calculate the land-use weighted average values of default input parameters by season and direction from plant**

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Sector 1 (15^o-270^o)

Albedo				
	Winter	Spring	Summer	Autumn
Urban	0.2625	0.105	0.12	0.135
Deciduous	0.1	0.024	0.024	0.024
Grassland	0.03	0.009	0.009	0.01
Total	**0.393**	**0.138**	**0.153**	**0.169**
Bowen Ratio - Wet Conditions				
	Winter	Spring	Summer	Autumn
Urban	0.375	0.375	0.75	0.75
Deciduous	0.1	0.06	0.04	0.08
Grassland	0.025	0.015	0.02	0.025
Total	**0.500**	**0.450**	**0.810**	**0.855**
Surface Roughness				
	Winter	Spring	Summer	Autumn
Urban	0.75	0.75	0.75	0.75
Deciduous	0.1	0.2	0.26	0.16
Grassland	0.00005	0.0025	0.005	0.0005
Total	**0.850**	**0.953**	**1.015**	**0.911**

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DATA INPUT

7. Select Receptors:

RECEPTOR GRID CENTERED AT PLANT			
Grid	**Size**	**Receptor Spacing**	**Number Receptors**
Inner	1x1 km	100 meters	100
Middle	5x5 km	250 meters	400
Outer	10x10 km	500 meters	400
TOTAL			**900**

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DATA INPUT

8. Determine receptor elevations

- AERMAP terrain processor
- Digital elevation data files

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MODELING Task 1

- Apply AERMOD to predict water vapor concentrations for each hour of 5 years at 900 receptors

900 x 5 x 8760=**39,420,000 predictions**

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MODELING Task 1

- **Problem 1:** AERMOD Model does not address terrain-induced downwash yet highest upwind terrain exceeds stack height

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MODELING Task 1

- **Solution:** Physical modeling study of plant showed the highest 10-minute “measured” concentration using the actual complex terrain was **1.93 times** the highest 10-minute measured concentration with flat terrain

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MODELING Task 1

- **Problem 2:** AERMOD Model does not predict the maximum 10-minute concentration within each hour although 10 minutes of fogging could trigger community complaints

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MODELING Task 1

Observations of maximum plume centerline concentrations and averaging times show the maximum concentration per period varies inversely with averaging time raised to between the 0.17 and 0.2 power

Source: Turner, D.B., Workbook of Atmospheric Dispersion Estimates, U.S. EPA, Research Triangle Park, NC, 1970.

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MODELING Task 1

Solution:

$$Cmax10 = C60*(60/10)^{0.2}$$

The highest 10-minute concentration each hour equals $(60/10)^{0.2}$ = **1.43 times** the predicted hourly average concentration

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MODELING Task 1

Combining the two solutions, each predicted hourly concentration was multiplied by 1.93 times 1.43 = **2.76** to predict the maximum 10-minute concentration each hour

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MODELING Task 2

Calculate the plume water vapor mixing ratio from the predicted 10-minute plume water vapor concentration C_{max10} (ug/m3) :

$\mathbf{R_{plume}} =$ grams plume water vapor/grams air

$= C_{max10} (2.8706 \times 10^{-9} T)/ P$

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MODELING Task 3

Calculate the ambient water vapor mixing ratio

$\mathbf{R_{ambient}}$ = grams ambient water vapor/grams air

= R_s x Relative Humidity

where $\mathbf{R_s}$ is the Saturation Mixing Ratio

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MODELING Task 3

Calculate the ambient water vapor mixing ratio

$\mathbf{R_s} = (0.622)e_s/(P - e_s) \times \text{Relative Humidity}$

where $\mathbf{e_s}$ is saturation vapor pressure and **P** is atmospheric pressure in millibars

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MODELING Task 4

Calculate the Total Mixing Ratio:

$$R_{total} = R_{plume} + R_{ambient}$$

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MODELING Task 5

Compare the Total Mixing Ratio (R_{total}) to the Saturation Mixing Ratio (R_s):

If $R_{total} \geq 0.995\ R_s$,

ground-level fogging is assumed to occur

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MODELING RESULTS

- There were **no 10-minute periods** when the plume water vapor combined **with** the ambient moisture caused ground-level **condensation/fogging**

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MODELING RESULTS

- The highest plume water vapor mixing ratios predominantly occur during **summer afternoons**, under relatively **warm temperatures** (80+ degrees F) and **dry relative humidities** (20-40%)

MODELING RESULTS

- Under these conditions, the addition of plume moisture is not nearly sufficient to raise the ambient mixing ratio to the saturation point

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CONCLUSIONS

- We developed a way to evaluate the potential for plume fogging that is **generally applicable to wet scrubbed electric power plants**

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CONCLUSIONS

We applied this procedure to a large coal-fired power plant in complex terrain using an FGD system with 12.9% water vapor emissions by volume and a GEP stack.

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CONCLUSIONS

Prediction results indicated that this plant **did not** produce incidents of ground level fogging

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CONCLUSIONS

Caution:

Wide variations in relative humidity are common especially in areas of complex terrain

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CONCLUSIONS

Caution:

Such terrain effects may lead to more hours per year of atmospheric saturation or near-saturation than would normally occur with flat terrain **raising the potential for plume-induced fogging episodes**

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CONCLUSIONS

Caution:

There is considerable benefit to collecting and using site-specific meteorological data in evaluating the potential for plume fogging especially for plants located in complex terrain

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