



COMPARISON OF ISCST3 AND AERMOD AIR DISPERSION MODEL TO PREDICT DIOXIN DEPOSITION FROM AN INCINERATOR IN MIDLAND, MICHIGAN

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Introduction and Objectives

A new air dispersion model, AERMOD was promulgated by the United States Environmental Protection Agency (US EPA) to replace the Industrial Source Complex Short Term model, ISCST 3. The new model incorporates air dispersion based planetary boundary concepts, advanced building downwash algorithms, atmospheric profiling for several variables (temperature, wind, turbulence). AERMOD is different from ISCST 3 as it requires more extensive data inputs such as surface characteristics (Bowen ratio, albedo, roughness length), building downwash parameters, and longer computer running time. However, the two models are very similar in model setup as they use almost the same keywords and input file structure. We applied both AERMOD and ISCST 3 air dispersion models to predict deposition of dioxin associated particles from a historic incinerator, which presumably is the only dioxin source to soil in Midland, Michigan.

OUR STUDY OBJECTIVES ARE TO:

- Compare the dioxin deposition field (extent) using both models
- Estimate the soil TEQ_{DF/WHO-200} values using spatial statistical models
- Assess the impact of emission strength, particle size and meteorological data quality on the predictive outcomes

Methods

- The deposition models were used in accordance with the specifications detailed in the User's Guide for the ISCST 3 and AERMOD model (US EPA 1995, 2004) and with the model setup described in Goovaerts et al. (2008). A grid of 261x261 receptor nodes with spacing of 50 m was specified. Model outputs are dry and wet deposition fluxes of dioxin associated particles at each receptor node.
- The geostatistical tools used are detailed in Goovaerts et al. (2008). Briefly, they include the following steps: normal score transform of 53 available field data (soil TEQs); regression of 53 normal scores versus wet and dry deposition to obtain a TEQ spatial trend estimate over the receptor grid; computation and modeling of variogram of regression residuals; Sequential Gaussian simulation using trend model kriging, yielding 100 realizations of TEQ value maps; and average point simulated values within each census block.
- Three emission scenarios were evaluated:
 - Scenario 1 (ISCST3):
 - Dioxin emission rate, 0.012 grams TEQ/year (Goovaerts et al. 2008)
 - Meteorological data from 1987-1991. The data format is compatible for using in the ISCST 3 model
 - Particle size categories: 1.3, 6.8 and 21.5 micron. The mass fractions of dioxins associated with the particles are 0.9, 0.05 and 0.05 (Goovaerts et al., 2008)
 - Scenario 2 (AERMOD):
 - Same inputs as scenario 1
 - Meteorological data from 2001-2005 are in the right format for AERMOD model, which requires different types of meteorological input files (surface and upper air) and with more variables than that of ISCST 3.
 - Scenario 3 (AERMOD):
 - Emission rate: 0.033 gram TEQ/year (US EPA stack test, 1992);
 - Particle size categories of 0.13, 0.76, 4.24, and 31.61 micron with corresponding mass fractions of 0.38, 0.42, 0.15 and 0.05 (calculated based on field data from Chao M. R et al., 2003)
 - Vapor/particulate ratio (V/P = 0.32, calculated based on data of Eitzer and Hites, 1989). The V/P ratio is partitioning of total emission into vapor and particulate phases.
 - Meteorological data from 2001-2005 as in scenario 2.
- The model comparison was conducted between scenarios 1 & 2, and was based on the following metrics:
 - Ratio of ISCST3 and AERMOD model for dry and wet dioxin associated particle deposition fluxes (pg/m³-yr)
 - Scatter plots of 53 M-DEQ measured soil TEQ concentrations (normal score transformations) versus predicted dry and wet deposition fluxes of dioxin associated particles.
 - Quantile-Quantile plots (Q-Q plots) of ISCST3 and AERMOD predictions of wet and dry particle fluxes at the 53 sampling locations
- Predicted TEQs at census block levels from all model results (scenarios 1-3)

Results

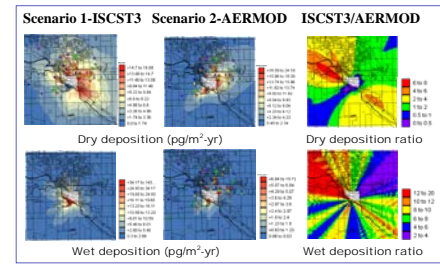


Figure 1: 5-year dry and wet deposition values predicted by the dispersion model. Dots depict the 53 soil TEQ concentrations, while the outlines of census blocks are displayed in background. Ratio of model predictions of dry and wet depositions are on the right.

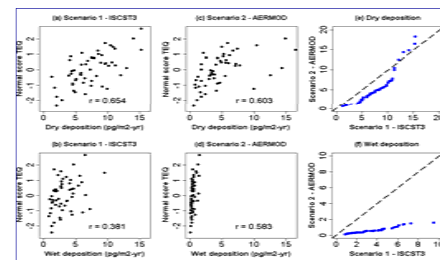


Figure 2: Scatter plots of soil TEQ normal scores versus 5-year dry (a)&(c) and wet deposition values (b)&(d) predicted by the dispersion model ISCST and AERMOD. Q-Q plots of dry (e) and wet deposition (f) predicted in the two scenarios at 53 sampling locations.

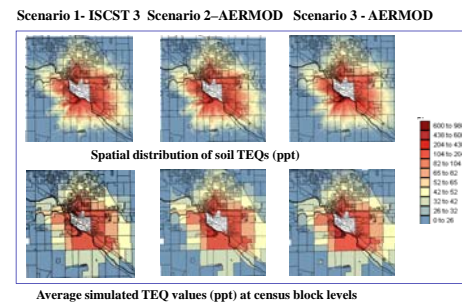


Figure 3: Mean values of simulated soil TEQs over 100 realizations (upper row) and average simulated soil TEQs at census block levels (lower row) predicted by geostatistical model, following deposition predicted by ISCST3 (scenario 1) and AERMOD (scenario 2 & 3).

Conclusions

- The AERMOD-based dioxin deposition plume is more focused and unidirectional downwind (north-east) from the incinerator, as compared to ISCST3 (Figure 1).
- Dry deposition is the main transport pathway of dioxin according to the AERMOD predictions, in contrast to the ISCST3 results (Figure 1).
- Both ISCST3 and AERMOD predict similar results for dry deposition fluxes of particle-associated dioxins (Figure 1).
- Both ISCST3 and AERMOD predict that dry deposition fluxes are correlated with the 53 field soil TEQs (Figure 2).
- Both dry and wet deposition fluxes predicted by AERMOD are correlated with the soil TEQs (Figure 2).
- The geostatistical simulations, which use deposition plumes as model inputs, predict similar TEQs in soil in both the ISCST3 model based scenario 1 and the AERMOD model based scenario 2 (Figure 3).
- Geostatistical simulations using the AERMOD model based scenario 3, which incorporates the measured dioxin emission rate, predicts higher soil TEQ values south of the incinerator.

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