Comparison of AERMOD and SYMOS'97 models for calculating dispersion of odors: A case study in Uttenweiler

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The experiment has already been tested;
High quantity of concentration measurements (tracer and odor intensity);
High quality data;
Representative case of real conditions (low stack).
The main objective of this work is to make a comparative study between the odor dispersion models AERMOD and SYMOS’97 for the Uttenweiler experiment.
How to characterize the odor impact?

Frequency
Intensity
Duration
Offensiveness
Location
(Nicell, 2009)

Note: There are equations that correlate this two variables (Steven’s and Weber-Fechner’s law). Other options is the use of odour hours (GOSTELOW; PARSONS; STUETZ, 2001).

\[ I = kC^n \]
\[ I = a \log C + b \]
Peak-to-Mean Rate

Fig. 1. The classic Gaussian model and short-term fluctuations.

Source: De Melo Lisboa et al. (2006).
Source types: point, area, line;
Terrain types: flat and complex;
Can simulate obstacles;
Stability classes: 5 classes (3 stable, 1 neutral and one convective) Bubnik e Koldovsky – Czech Republic;
Simulations: annual mean, hourly peak concentrations and annual particulate deposition.
Not indicated for simulating low wind conditions, the maximum indicated distance for simulations is 100 km.
Corrected the emission rate to Standard Temperature and Pressure conditions.
AERMOD description

- Source types: point, area, volume and line;
- Terrain types: simple and complex;
- Obstacles: PRIME Algorithm – Building Downwash;
- Atmospheric Stability: similarity theory;
- Simulations: mean annual concentration, maximum receptor concentration, particulate deposition, and was tested for simulating peak concentrations.
- Not indicated for simulating low wind conditions and distances beyond 50 km.
Building Downwash

\[ C_{\text{total}} = \gamma C_{\text{PRIME}} + (1 - \gamma) C_{\text{AERMOD}} \]

Source: Cunha (2009).
Description of the Uttenweiler data set

- 14 experiments - 3 cloudy days (B – O);
- 10 minute long experiments;
- Quantified parameters:
  - Wind speed and direction every 10 seconds;
  - 2 SF6 tracer measurements every 10 seconds;
  - 11/12 trained accessors noting odor intensity (escala 0-5);
  - Stack area 3,6 m²;
- Atmospheric conditions – slightly neutral and stable.
Location description
Wind tunnel experiment
Aubrun e Leitl (2003)

University of Hamburg
Escale 1:400
Experiments C, F e G
Neutral Conditions
Comparison of AERMOD x CALPUFF
VIEIRA DE MELO et al. (2012)
Wind Tunnel Simulation of the Uttenweiler experiment
26 tested experiments including Uttenweiler’s;

For the Uttenweiler’s experiment the performance of the GRAL model with the following models was compared:

- GRAL, AUSTAL2000, LASAT, GIEBL, ADMS, OENORM M9440, STERN, SCORER.
Used a peak-to-mean ratio–2,2–proposed by Freeman and Cudmore (2002).
Tested the model SYMOS’97 for simulating Uttenweiler’s odor and tracer experiments;
Flat terrain, hourly concentrations transformed into peak concentrations;
Used a fit-curve approach due to the absence of a laboratory data correlating intensity and concentration data;
Median concentration calculation for each intensity class.

Keder, Bubnik e Macoun (2003), and Keder (2008)
Median concentrations of each intensity class
Materials and Methods
## Emission rate

<table>
<thead>
<tr>
<th></th>
<th>Z50 (OU/m³)</th>
<th>Air flow (m³/h)</th>
<th>Emission rate (UO/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>B</td>
<td>1.260</td>
<td>55.100</td>
<td>19.285,00</td>
</tr>
<tr>
<td>C</td>
<td>1.225</td>
<td>55.200</td>
<td>18.738,33</td>
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<tr>
<td>D</td>
<td>1.130</td>
<td>55.200</td>
<td>17.326,67</td>
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<tr>
<td>E</td>
<td>3.000</td>
<td>55.300</td>
<td>46.083,33</td>
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<tr>
<td>F</td>
<td>3.000</td>
<td>53.700</td>
<td>44.750,00</td>
</tr>
<tr>
<td>G</td>
<td>3.000</td>
<td>54.100</td>
<td>45.083,33</td>
</tr>
<tr>
<td>H</td>
<td>2.520</td>
<td>55.000</td>
<td>38.500,00</td>
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<tr>
<td>I</td>
<td>1.220</td>
<td>56.600</td>
<td>19.181,11</td>
</tr>
<tr>
<td>J</td>
<td>1.000</td>
<td>55.700</td>
<td>15.472,22</td>
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<tr>
<td>K</td>
<td>940</td>
<td>56.700</td>
<td>14.805,00</td>
</tr>
<tr>
<td>L</td>
<td>870</td>
<td>56.100</td>
<td>13.557,50</td>
</tr>
<tr>
<td>M</td>
<td>750</td>
<td>55.700</td>
<td>11.604,17</td>
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<tr>
<td>N</td>
<td>890</td>
<td>56.400</td>
<td>13.943,33</td>
</tr>
<tr>
<td>O</td>
<td>940</td>
<td>56.400</td>
<td>14.726,67</td>
</tr>
</tbody>
</table>
AERMOD Configurations: a few tests...

- Cup anemometer x sonic anemometer;
- Surface data (onsite data + Laupheim airport data);
- Onsite data: Wind speed and direction + temperature - every 10 seconds (sonic anemometer);
- Laupheim surface data (22 km from site): cloud cover and pressures,
- Sounding (3 per day): Schnarrenberg 84 km from site.
AERMOD Configurations

- Albedo: 0.18;
- Bowen Ration: 0.4;
- Surface roughness length: 0.01 m
- Corrected wind speed and direction because the model rounds this variables;
- Standard deviation of the horizontal wind - SAnn (degrees) and the Standard deviation of the w component of the wind - SWnn (m/s);
- No corrections were made to the emission data rate, we used Standard Ambient Temperature and Pressure (SATP) conditions.
BIAS;
FB (fractional BIAS);
NMSE (normalised mean square error);
R (correlation);
MG (geometric mean bias);
VG (geometric variance);
FAC2 (factor of two).
Statistical Indices

\[ BIAS = \overline{C_0} - \overline{C_p} \]  \hspace{1cm} (1)

\[ FB = \frac{\overline{C_0} - \overline{C_p}}{0.5(\overline{C_0} + \overline{C_p})} \]  \hspace{1cm} (2)

\[ NMSE = \frac{(\overline{C_0} - \overline{C_p})^2}{\overline{C_0} \cdot \overline{C_p}} \]  \hspace{1cm} (3)

\[ R = \frac{(\overline{C_0} - \overline{C_0})(\overline{C_p} - \overline{C_p})}{\sigma_{C_p} \sigma_{C_0}} \]  \hspace{1cm} (4)

\[ MG = \exp \left( \ln\overline{C_0} - \ln\overline{C_p} \right) \]  \hspace{1cm} (5)

\[ VG = \exp \left[ (\ln\overline{C_0} - \ln\overline{C_p})^2 \right] \]  \hspace{1cm} (6)

\[ FAC2 = \text{fração dos dados que satisfaz } 0.5 \leq \frac{C_p}{C_0} \leq 2, \]  \hspace{1cm} (7)
Tracer dispersion experiment
SF6
Factor of 2 - Keder (2008)

![Graph showing the relationship between model SF₆ peak concentration and measured short-term SF₆ maximum concentration with different data quality categories.]

Legend:
- Data of a good quality
- Data of an ordinary quality
- Data of a poor quality

FA2 = 57.7%
Observed x Predicted Concentrations

Factor of two

FAC2 = 23.1%
OBSERVADO X SIMULATED
PM 6,6
Observed x Predicted Concentrations
Factor of two

Model SF6 peak concentration
AERMOD (ug/m³)

Máxima concentração de SF6 observada (ug/m³)

FAC2 = 53.8%
<table>
<thead>
<tr>
<th></th>
<th>AERMOD PM 2.2</th>
<th>AERMOD PM 6.6</th>
<th>SYMOS’97 PM 2.2</th>
<th>Perfect Model (CHANG; HANNA, 2005)</th>
<th>Boundaries (CHANG; HANNA, 2005)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BIAS</td>
<td>19.34</td>
<td>-1.63</td>
<td>6.08</td>
<td>0.0</td>
<td>&lt;0.3</td>
</tr>
<tr>
<td>FB</td>
<td>0.96</td>
<td>-0.05</td>
<td>0.18</td>
<td>0.0</td>
<td>&lt;0.3</td>
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<tr>
<td>NMSE</td>
<td>1.64</td>
<td>0.77</td>
<td>0.60</td>
<td>0.0</td>
<td>&lt;1.5</td>
</tr>
<tr>
<td>R</td>
<td>0.67</td>
<td>0.67</td>
<td>0.74</td>
<td>1.0</td>
<td>Close to 1</td>
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<tr>
<td>MG</td>
<td>4.35</td>
<td>1.45</td>
<td>0.88</td>
<td>1.0</td>
<td>0.7&lt;MG&lt;1.3</td>
</tr>
<tr>
<td>VG</td>
<td>53.66</td>
<td>7.11</td>
<td>1.02</td>
<td>1.0</td>
<td>&lt;4</td>
</tr>
<tr>
<td>FAC2 (%)</td>
<td>23.1</td>
<td>53.8</td>
<td>57.7</td>
<td>100.0</td>
<td>&gt;50</td>
</tr>
</tbody>
</table>
Comparação do AERMOD com outros modelos para o experimento do traçador SF6

<table>
<thead>
<tr>
<th>Model</th>
<th>NMSE</th>
<th>FB</th>
</tr>
</thead>
<tbody>
<tr>
<td>SYMOS’97</td>
<td>0.6</td>
<td>0.18</td>
</tr>
<tr>
<td>AERMOD</td>
<td>0.77</td>
<td>-0.05</td>
</tr>
<tr>
<td>AUSTAL2000</td>
<td>0.8</td>
<td>-0.1</td>
</tr>
<tr>
<td>GRAL 12.5/level2</td>
<td>1</td>
<td>0.1</td>
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<tr>
<td>GRAL 12.5/level1</td>
<td>1</td>
<td>-0.3</td>
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<tr>
<td>LASAT</td>
<td>1.1</td>
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<tr>
<td>AERMOD – 2.2</td>
<td>1.64</td>
<td>0.96</td>
</tr>
<tr>
<td>OENORM M9440</td>
<td>1.8</td>
<td>0.5</td>
</tr>
<tr>
<td>GRAL 12.5</td>
<td>2.6</td>
<td>0.7</td>
</tr>
<tr>
<td>STERN</td>
<td>3.6</td>
<td>0.8</td>
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<tr>
<td>ADMS 3.1</td>
<td>5.8</td>
<td>1.3</td>
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<tr>
<td>GIEBL</td>
<td>9.1</td>
<td>1.1</td>
</tr>
<tr>
<td>SCORER</td>
<td>21.3</td>
<td>1.6</td>
</tr>
</tbody>
</table>
Swine Odor dispersion experiment
AERMOD fit curve for this work

Concentration to Intensity equation

\[ I = 2,378.0^{0.3223} \]

Outlier

![Graph showing the concentration to intensity equation with data points and an outlier.](attachment:image)
Comparison among fit curves

\[ I_{od} = 2.378 (C_{od})^{0.3223} \quad \text{this article;} \]

\[ I_{od} = 1.086 (C_{od})^{0.464} \quad \text{(Keder, Bubnik, and Macoun 2003);} \]

\[ I_{od} = 1.57 (\log_{10} C_{od}) - 0.466 \quad \text{(Nicolai et al., 2000);} \]
## AERMOD – Fit Curves

<table>
<thead>
<tr>
<th></th>
<th>SOUZA</th>
<th>KEDER</th>
<th>Perfect Model (CHANG; HANNA, 2005)</th>
<th>Boundaries (CHANG; HANNA, 2005)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BIAS</td>
<td>0.73</td>
<td>1.34</td>
<td>0.0</td>
<td>&lt;0.3</td>
</tr>
<tr>
<td>FB</td>
<td>0.30</td>
<td>0.63</td>
<td>0.0</td>
<td>&lt;0.3</td>
</tr>
<tr>
<td>NMSE</td>
<td>2.47</td>
<td>1.08</td>
<td>0.0</td>
<td>&lt;1.5</td>
</tr>
<tr>
<td>R</td>
<td>0.59</td>
<td>0.55</td>
<td>1.0</td>
<td>Close to 1</td>
</tr>
<tr>
<td>MG</td>
<td>1.91</td>
<td>0.74</td>
<td>1.0</td>
<td>0.7&lt;MG&lt;1.3</td>
</tr>
<tr>
<td>VG</td>
<td>2.79</td>
<td>22.48</td>
<td>1.0</td>
<td>&lt;4</td>
</tr>
<tr>
<td>FAC2 (%)</td>
<td>66.7</td>
<td>45.3</td>
<td>100.0</td>
<td>&gt;50</td>
</tr>
</tbody>
</table>
Further validating studies are necessary, specially under low wind conditions, when the odor concentrations gets higher;

- AERMOD under estimated the concentrations for the Uttenweiler’s experiment;
- The fit curve approach isn’t the most adequate once it tries to correct part of the model mistakes;
- A better peak to mean approach was able to improve AERMOD’s performance;
- Both gaussian models, SYMOS’97 and AERMOD, reached good results for FB and NMSE, although this indices aren’t so sensible to low values witch is the case of Utteweiler’s experiment.