Dimensions of Odour Impact Based on Odour Characteristics

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Odour Management Conference & Technology Showcase
September 14-15, 2015, Toronto, Canada

Background

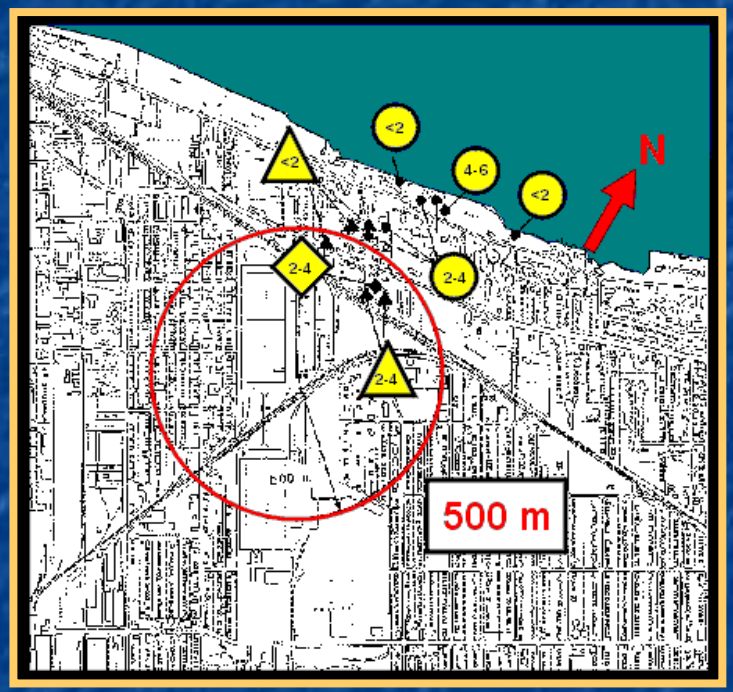
- Odours are ranked as the major generators of public complaints to regulatory agencies in North American and European communities
- Impact on physiological and psychological health, use of property, property values, etc.
- Industries and regulatory agencies lack an effective and objective basis for assessing the community impacts of odours
- Often, the lack of effective assessment methods hinders the prevention of community odour nuisances

Motivation

- An effective method is required to assess the impacts of odorous emissions on communities in order to prevent, minimize or eliminate odour nuisances
- An ideal assessment method would:
  - Be logical and simple to implement
  - Be based on quantifiable variables including: frequency, intensity, duration, offensiveness and geographical location (FIDOL) of odorous episodes
  - Provide a means for predicting potential odour impact before it is created

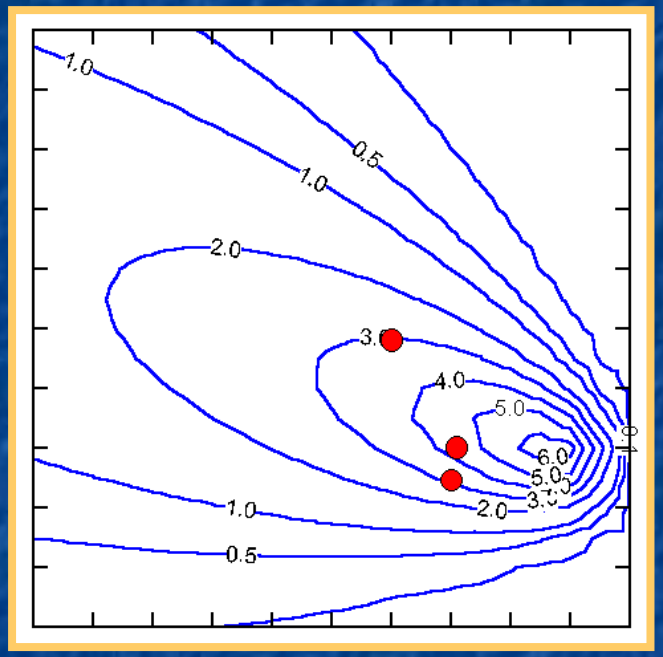
Assessments Based on the Dilution-to-Threshold Principle

- An odour is characterized by the number of dilutions (odour units, ou) required to reduce its concentration to a sensory threshold level (D_{50})
- Measurement or prediction of odour concentration at sensitive receptors: 1 ou = odour at its threshold
- Compare odour concentrations to accepted standards; e.g., 1 ou at a specified averaging time and/or frequency



Field study

Dispersion modelling



Odour concentration (C, ou)

Limitations of the Dilution-to-Threshold Approach

- Odour concentrations at selected sensitive receptors do not reflect population or regional impacts
- Thresholds do not account for the highly variable sensitivities of individuals within a population to odours
- Odour hedonics (i.e., character, offensiveness) are not considered

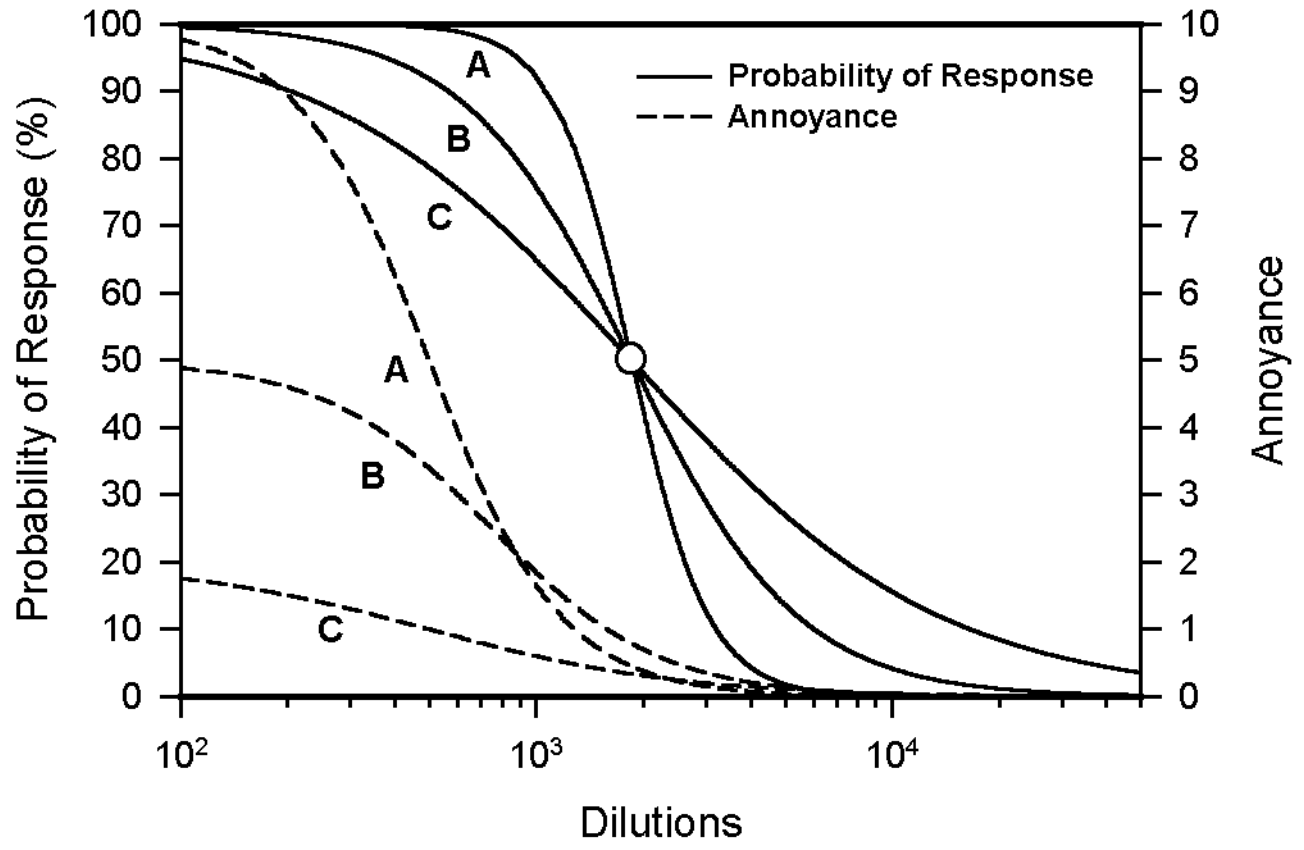
Objectives

- To characterize odours over the full range of conditions under which they can be experienced;
- To develop, test and implement methods for predicting and quantifying the effects of odorous emissions on community populations;
- To take into account odour characteristics, local meteorology and geography, land-use patterns, and population characteristics of a community; and
- To develop simple, inexpensive and flexible software to assist in the conduct of impact assessments.

Odour Impact Model

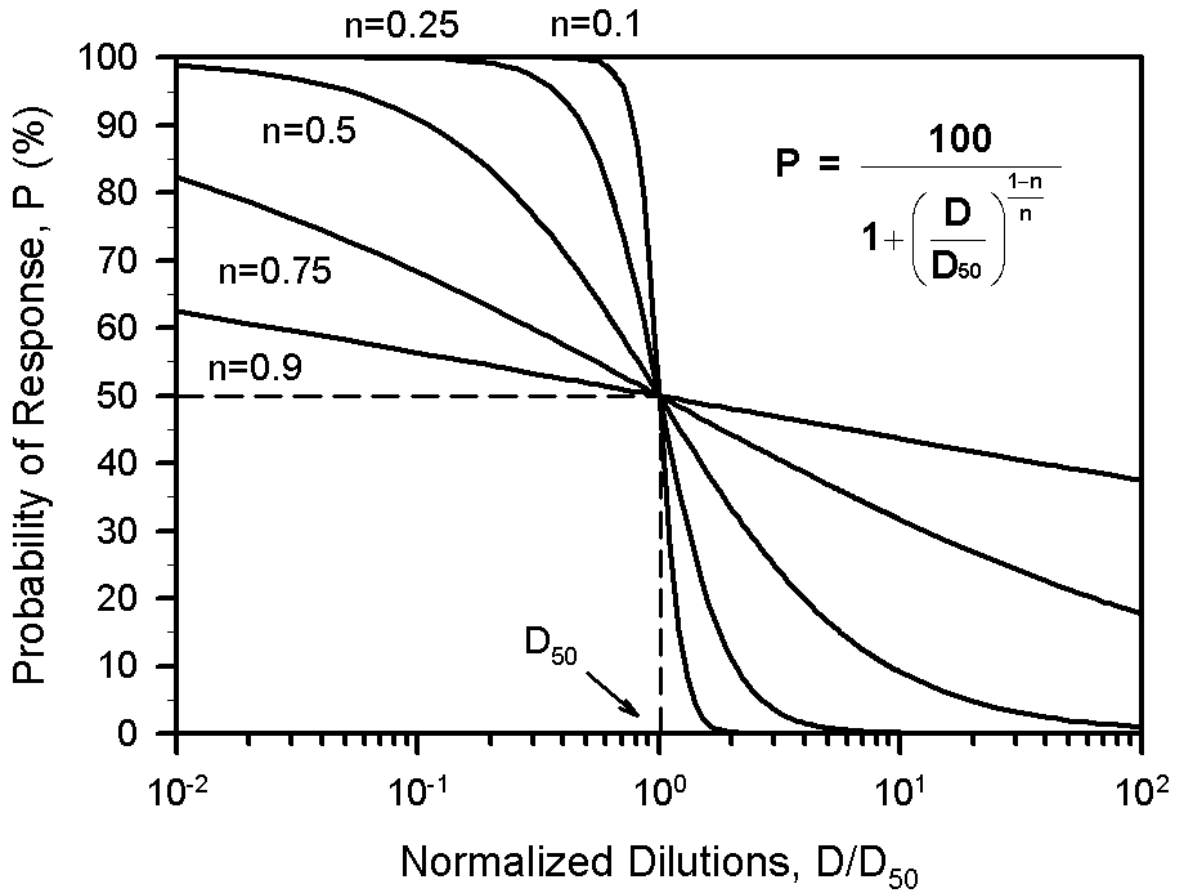
- Measurements conducted using a modified forced-choice method in conjunction with a dynamic dilution olfactometer
- Dose-response relationships are established for a population subjected to a range of dilutions of an odour sample:
  - Probability of response (i.e., detection or discrimination) versus dilutions
  - Degree of Annoyance versus dilutions

Dimensions of Odour Character



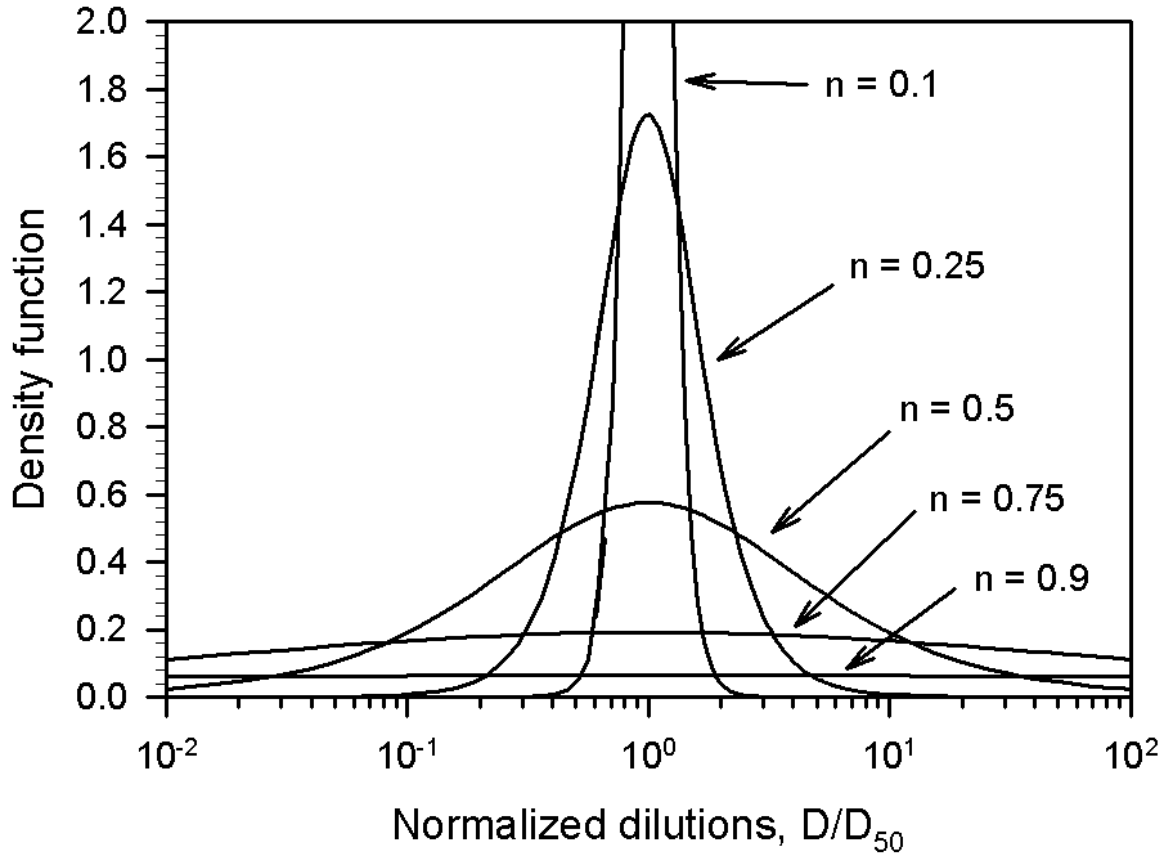
(Nicell, 2003)

Persistence of Response (n)



(Nicell, 2003)

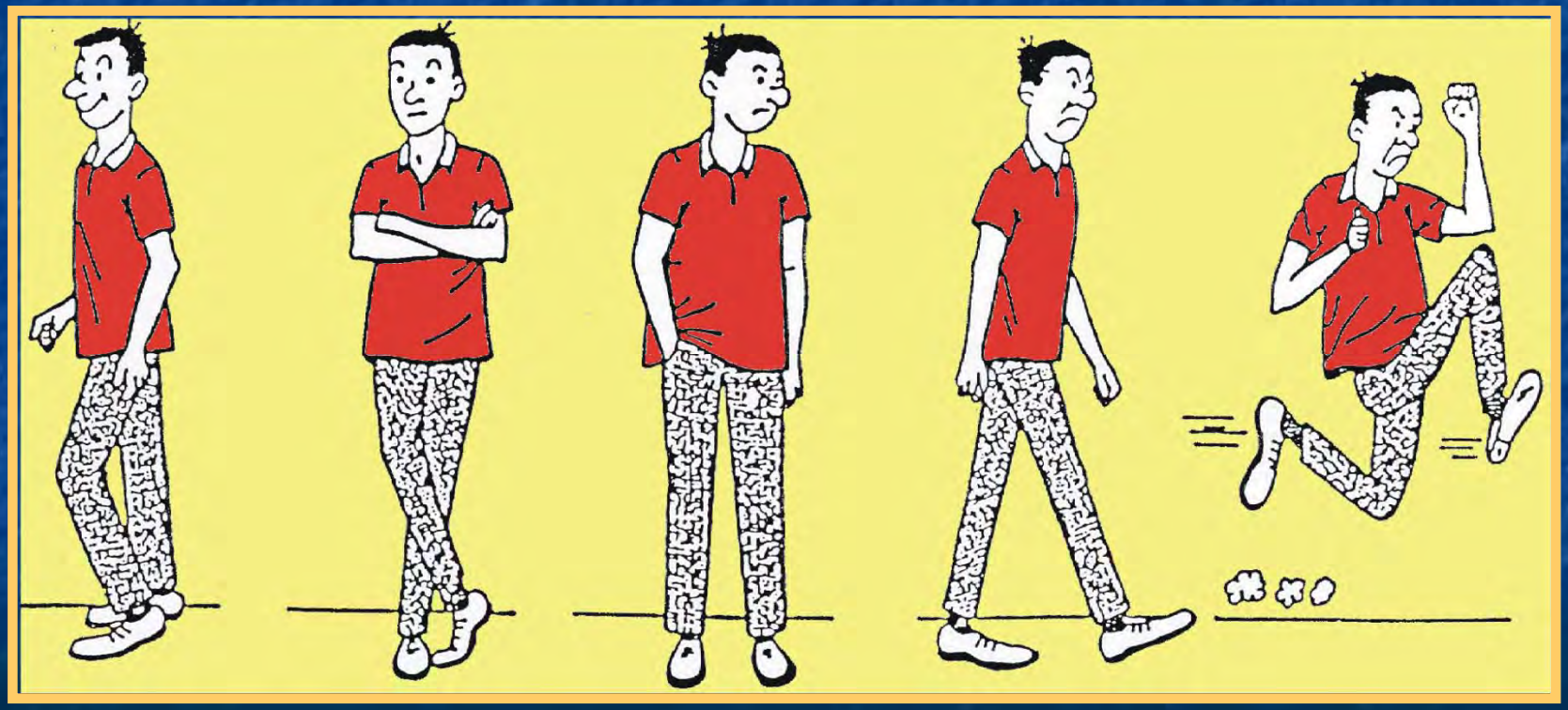
Persistence of Response (n)



(Nicell, 2003)

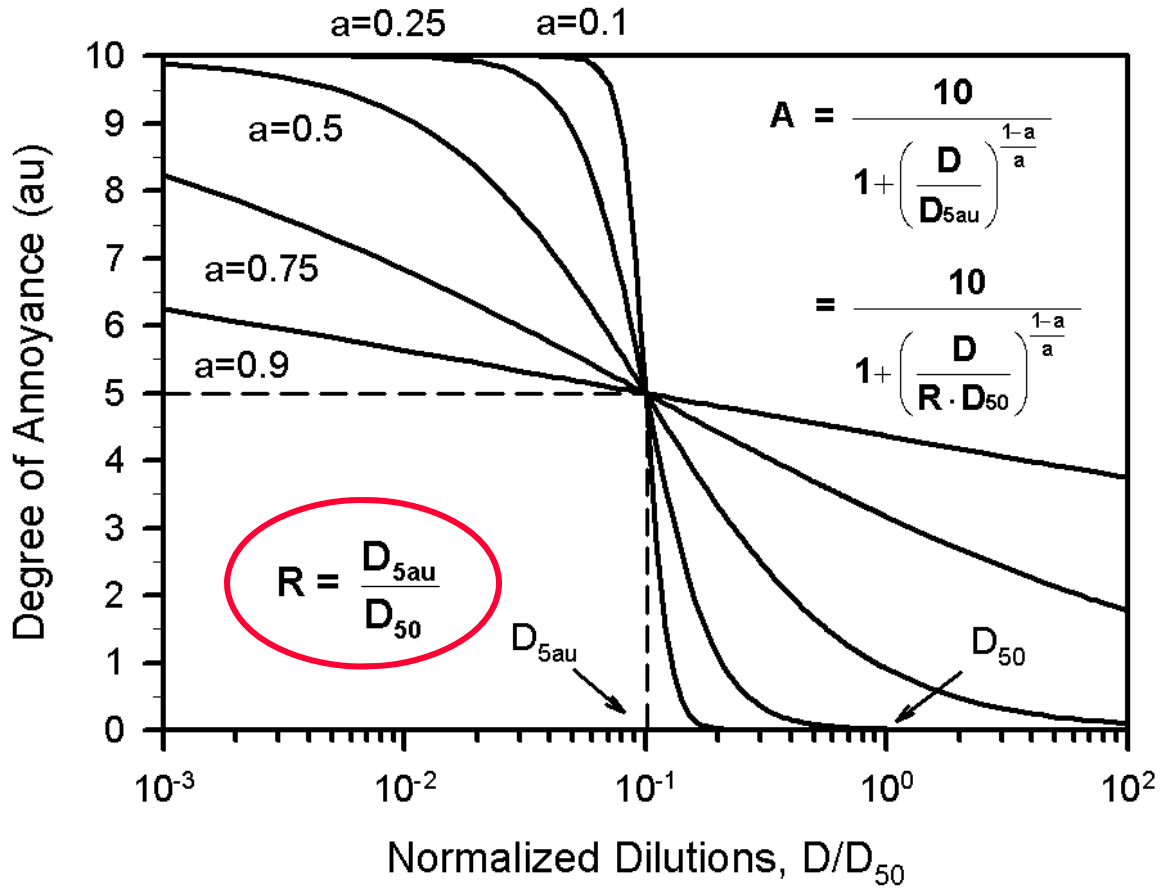
Degree of Annoyance

Tolerable (0 to <2)	Unpleasant (2 to <4)	Very unpleasant (4 to <6)	Terrible (6 to <8)	Unbearable (8 to 10)



(Nicell, 1994)

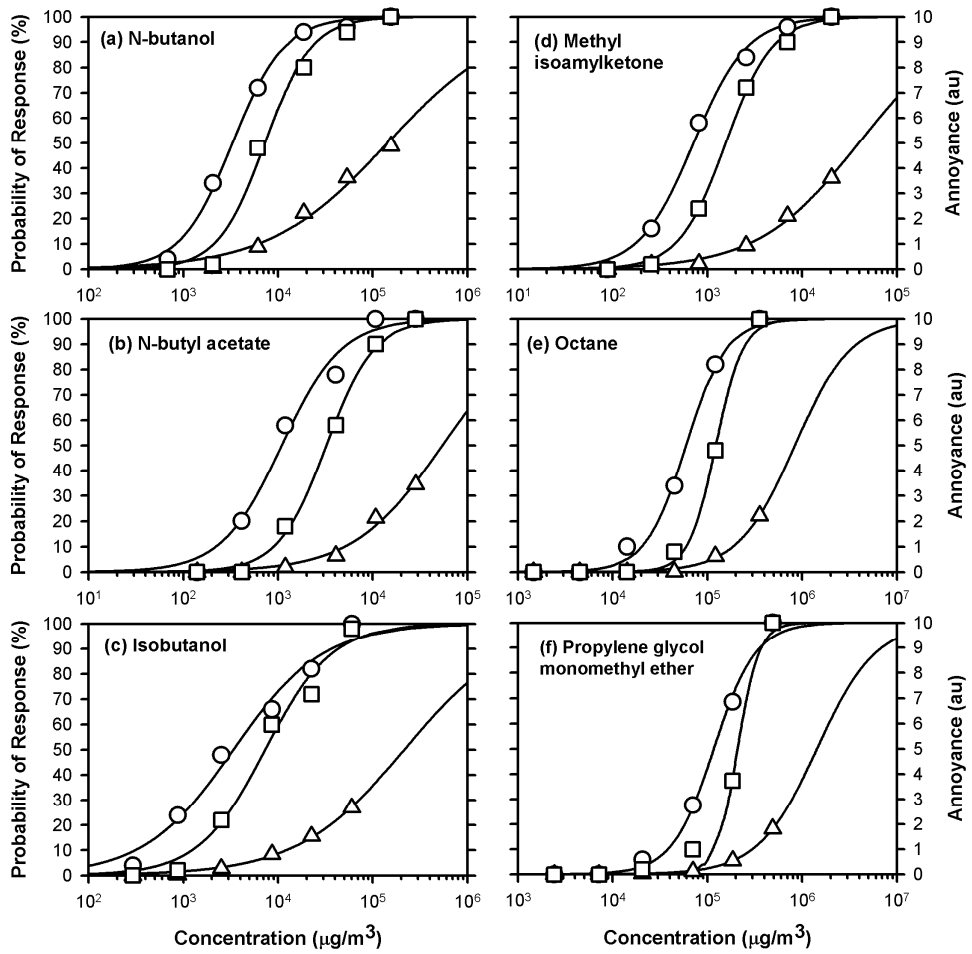
Persistence of Annoyance (a)



(Nicell, 2003)

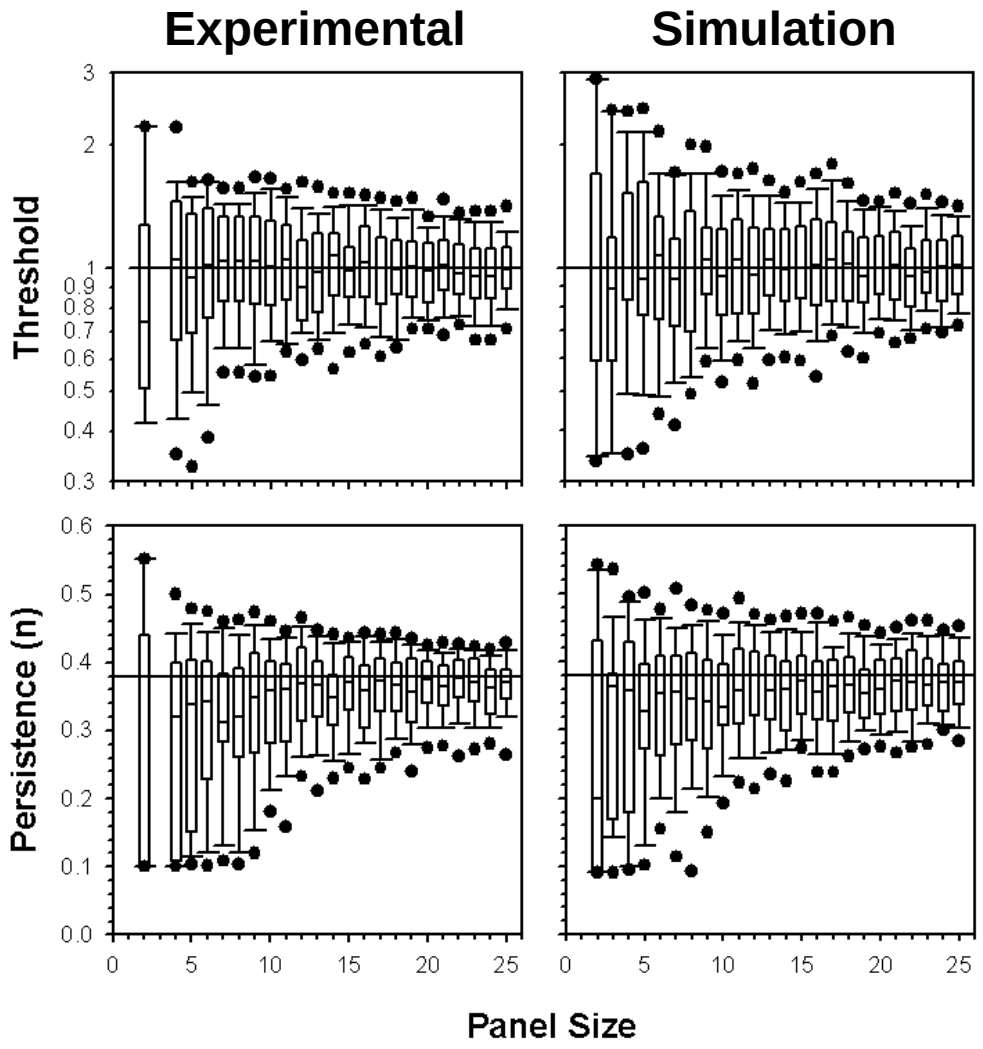
Application to Pure Chemicals

(○) Detection, (□) Discrimination, (△) Annoyance



(Nicell, 2003)

Application to Olfactometry



Effect of panel size on the reproducibility of thresholds and persistence; e.g., n-butanol

Use to:

- Optimize olfactometer design
- Optimize experimental protocols

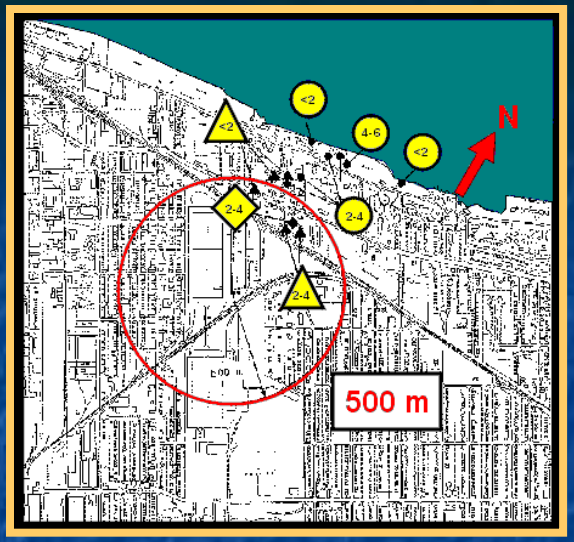
Application to Impact Assessment

- Extract thresholds and best-fit parameters of *n, a* and *R* from Odour Impact Model data
- Use dispersion modelling to predict spatial and temporal variations in odour concentration, probability of response, and degree of annoyance using

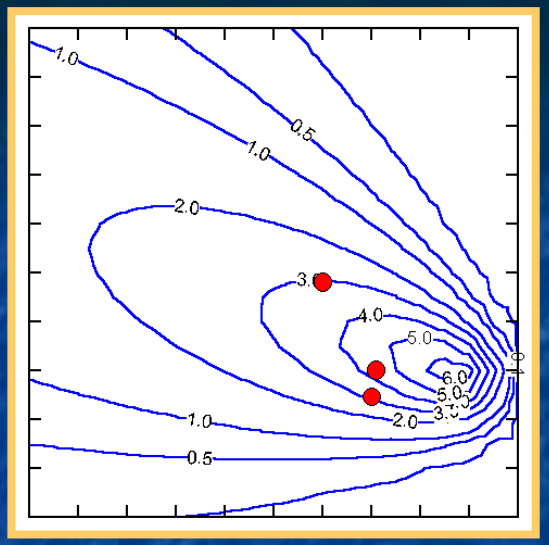
$$P = \frac{100}{1 + (C)^{\frac{n-1}{n}}} \qquad A = \frac{10}{1 + (C \cdot R)^{\frac{a-1}{a}}}$$

- Evaluate parameters that logically reflect the nature and magnitude of odour impact

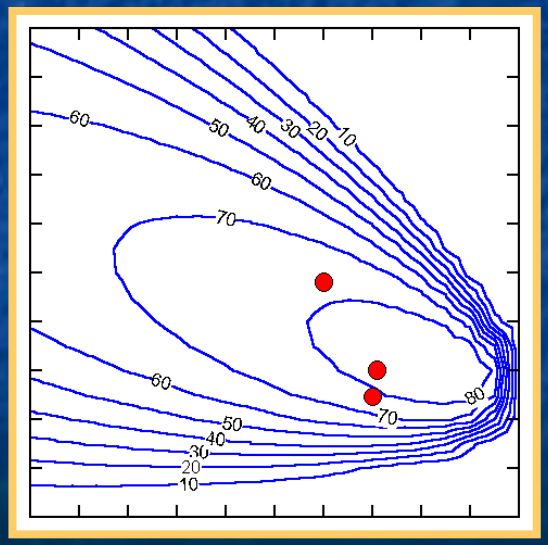
Field study



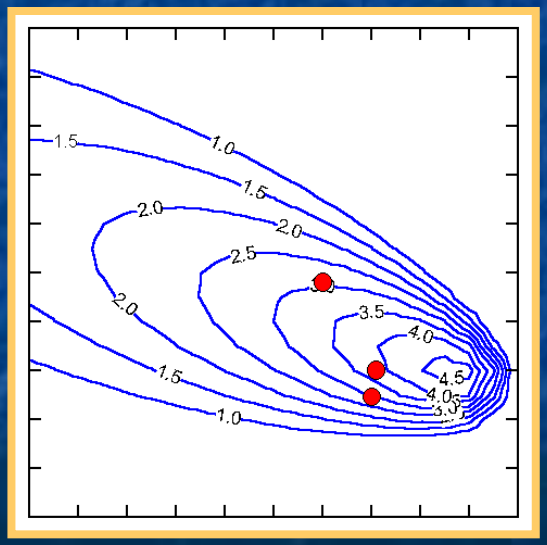
Dispersion modelling



Concentration, C (ou)



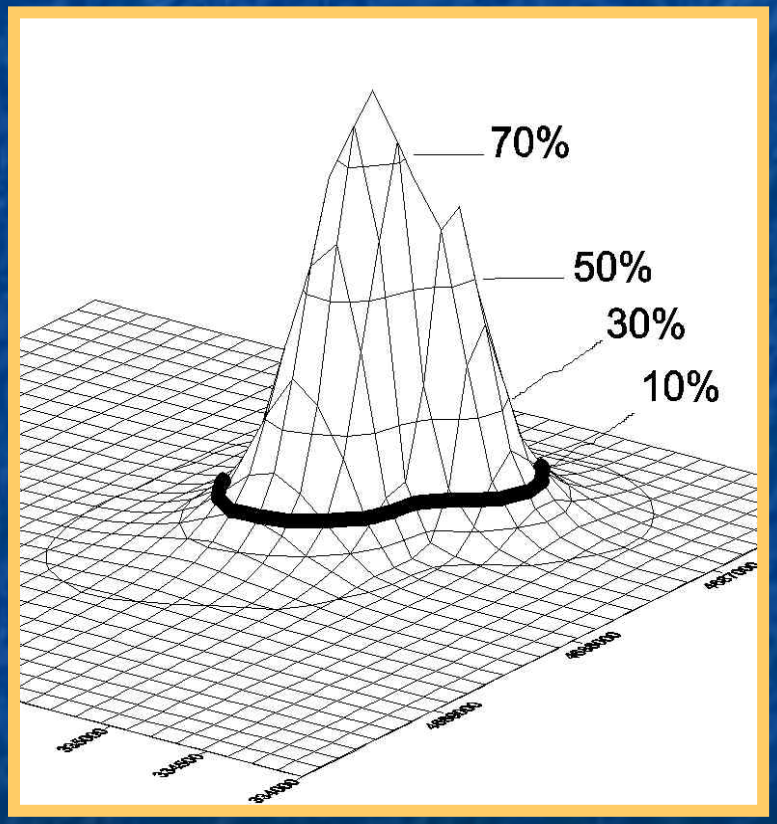
Probability of response, P (%)



Annoyance, A (au)

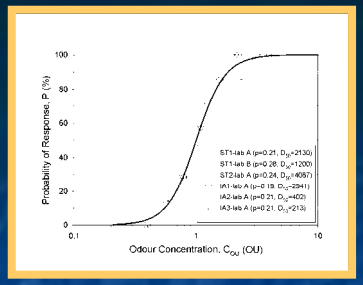
Dimensions of Odour Impact

- 1-D parameters:
  - Peak C, P or A at selected sensitive receptors or most-impacted receptor
- 2-D parameters:
  - Footprint areas inside selected contours
- 3-D parameters:
  - Footprints weighted by C, P or A
  - Population inside selected contours of C, P or A
  - Number of persons responding



(Henshaw et al, 2002; Henshaw et al, 2006)

Concentration
(C, ou)



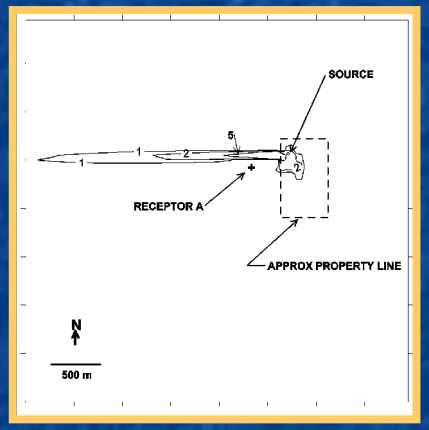
Response
(P, %)

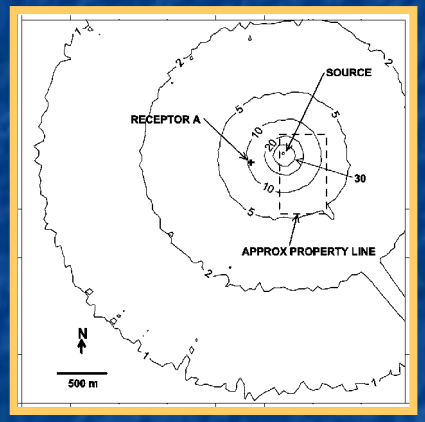
Single peak hour (over 5 years)

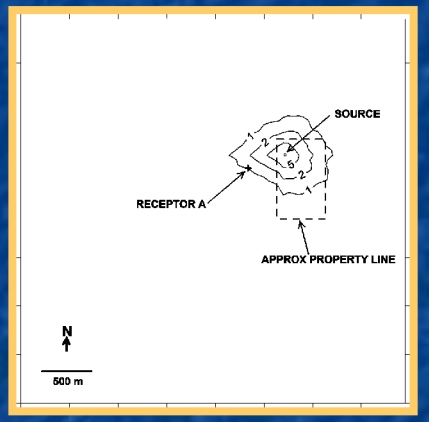
All 1-hour peaks (over 5 years)

99th percentile of 1 hour peaks (over 5-years)

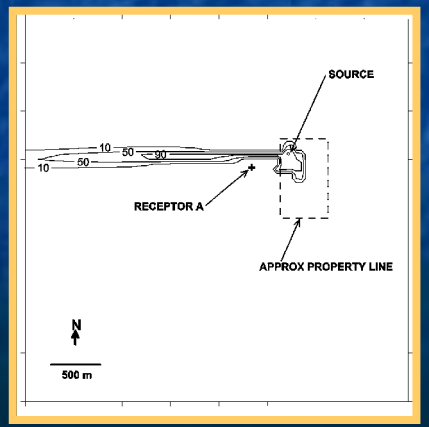
C

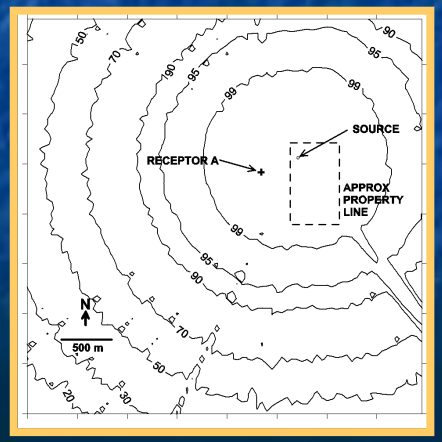


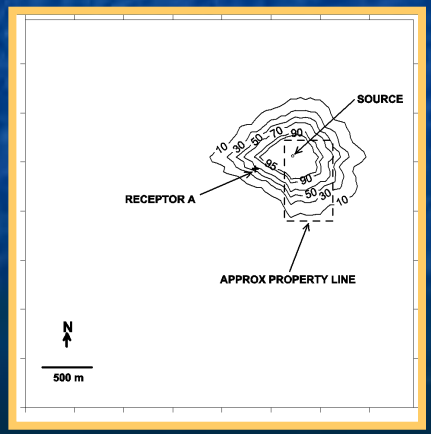




P

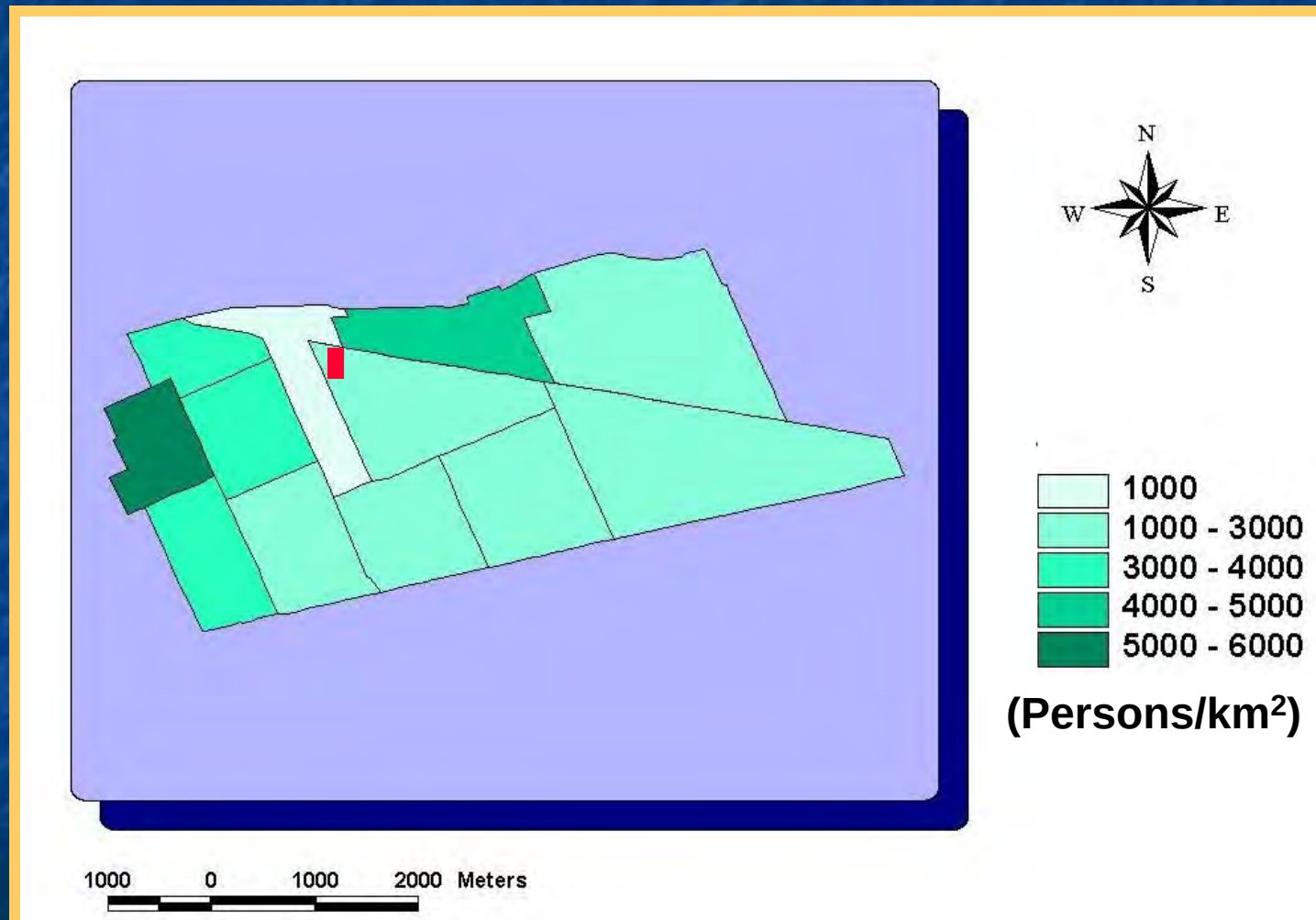






(Henshaw et al, 2006)

Population Density



(Henshaw et al, 2002)

Evaluation of Impact Parameters

Impact Parameters	Peak	99th Percentile	95th Percentile
1-D: Maximum concentration at a receptor (C_{max}, ou)	3.94	2.92	2.37
1-D: Maximum probability at a receptor (P_{max}, %)	96.1	92.4	88.2
2-D: Footprint area inside 10% contour ($F_{10\%}$, km^2)	16.0	2.50	1.10
3-D: Probability weighted footprint area (PWFA, km^2)	6.34	1.20	0.49
3-D: Population responding (N, persons)	9070	2010	824

(Henshaw et al, 2002)

Effects of Emission Rate and Persistence on Impact Parameters

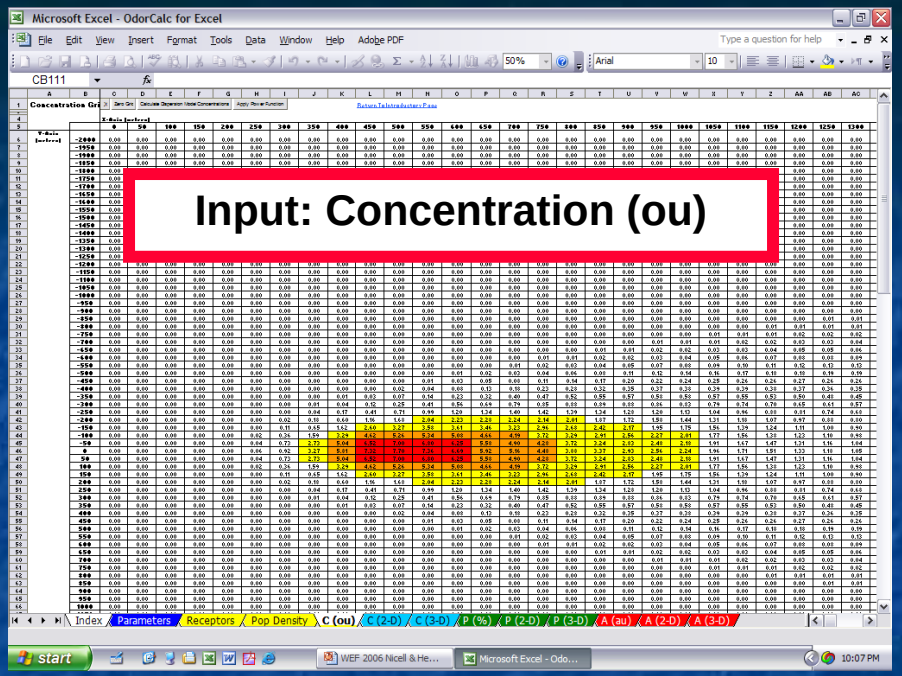
(using 99th percentile of 1-hour concentrations)

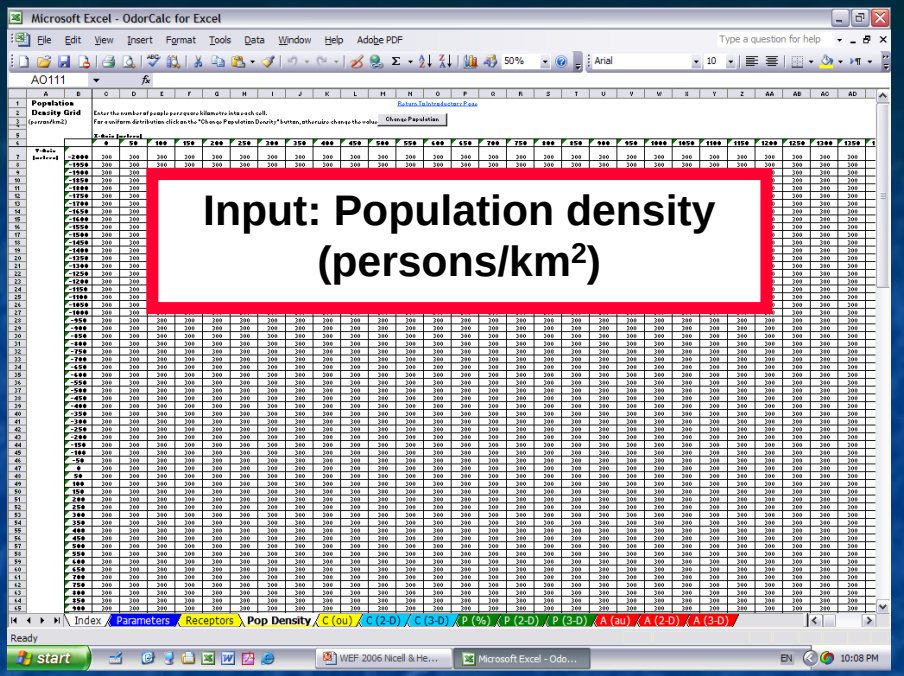
Parameter	Modelled Scenarios					
Emission rate	100%	100%	100%	**90%**	**50%**	**10%**
Persistence	**0.3**	**0.2**	**0.4**	0.3	0.3	0.3
C_{max} (ou)	2.92	2.92	2.92	2.63	1.46	0.29
P_{max} (%)	92.4	98.6	83.3	90.5	70.7	5.35
$F_{10\%}$ (km^2)	2.50	1.50	5.80	2.20	0.97	0.00
PWFA (km^2)	1.20	0.80	2.03	1.03	0.41	0.01
N (persons)	2010	1350	2980	1770	717	26

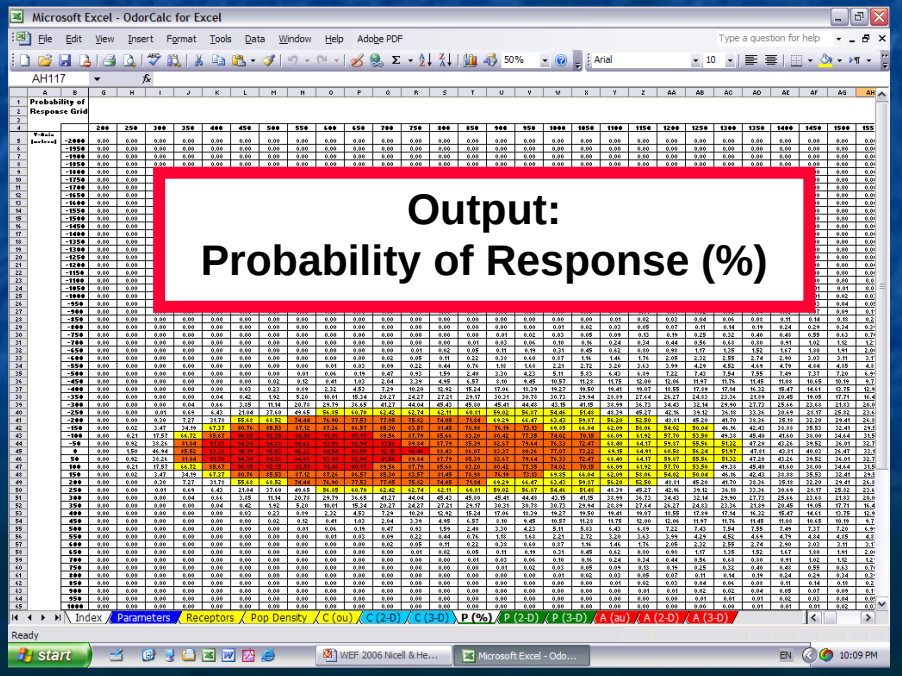
(Henshaw et al, 2002)

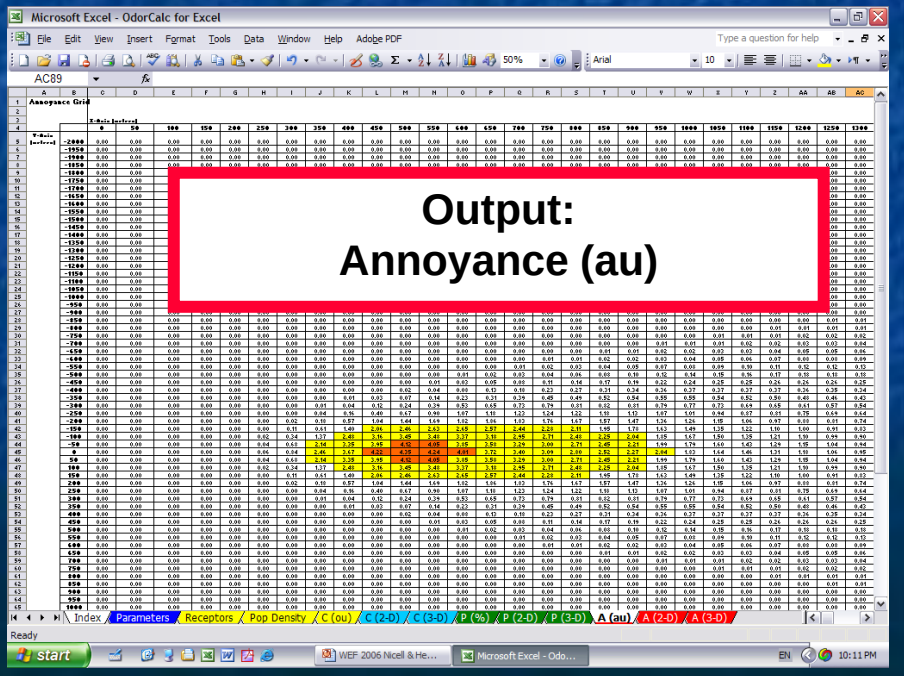
Tool Development

- Post-processing software for dispersion model results included: spreadsheet, GIS, and a contouring program with mathematical functionality for contour integration
- Many hours of work were required to extract a very limited sub-set of possible odour impact parameters
- Users would benefit from simple, user-friendly, flexible and readily accessible (inexpensive) software to assist in analyses
- Software called *OdorCalc (for Excel)* has been developed


Microsoft Excel - OdorCalc for Excel
Input: Concentration (ou)

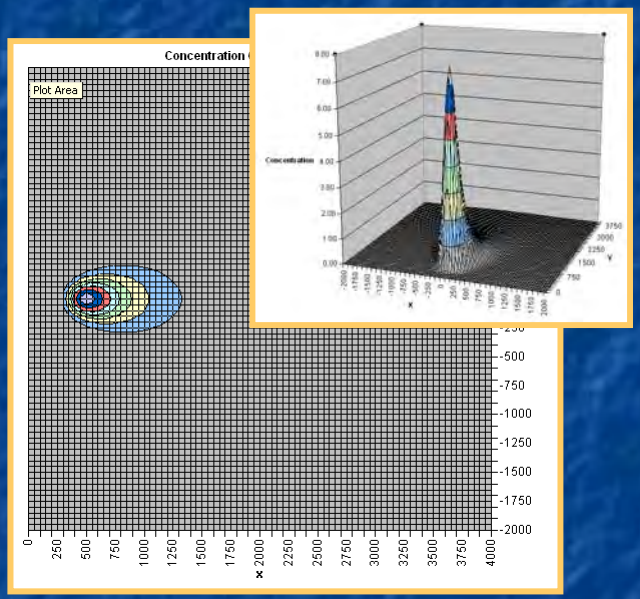

Microsoft Excel - OdorCalc for Excel
Input: Population density (persons/km²)


Microsoft Excel - OdorCalc for Excel
Output: Probability of Response (%)

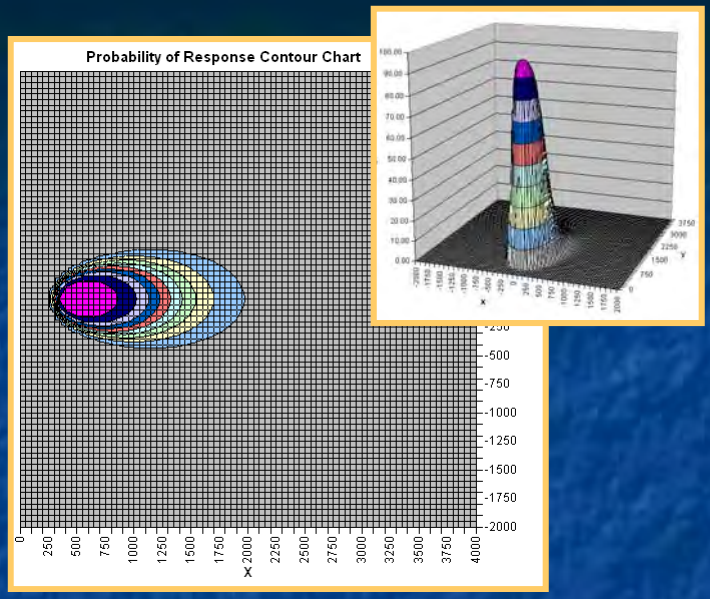

Microsoft Excel - OdorCalc for Excel
Output: Annoyance (au)

OdorCalc (for Excel)

$$P = \frac{100}{1 + (C)^{\frac{n-1}{n}}}$$

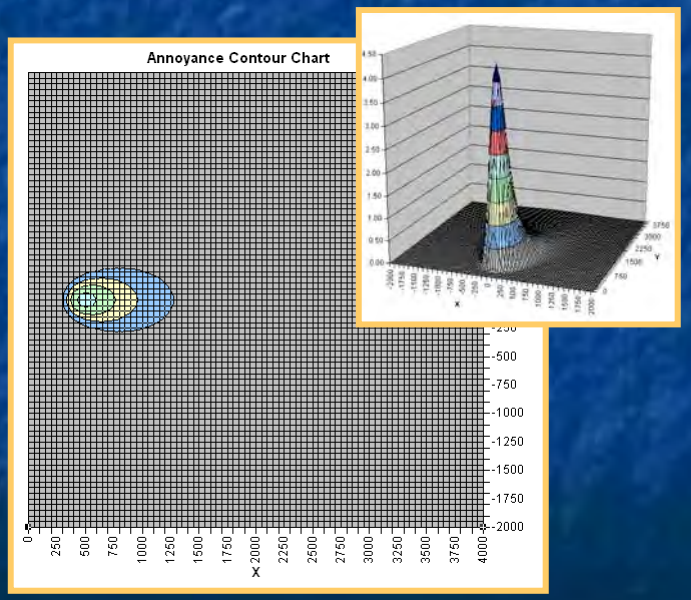


Concentration (C, ou)

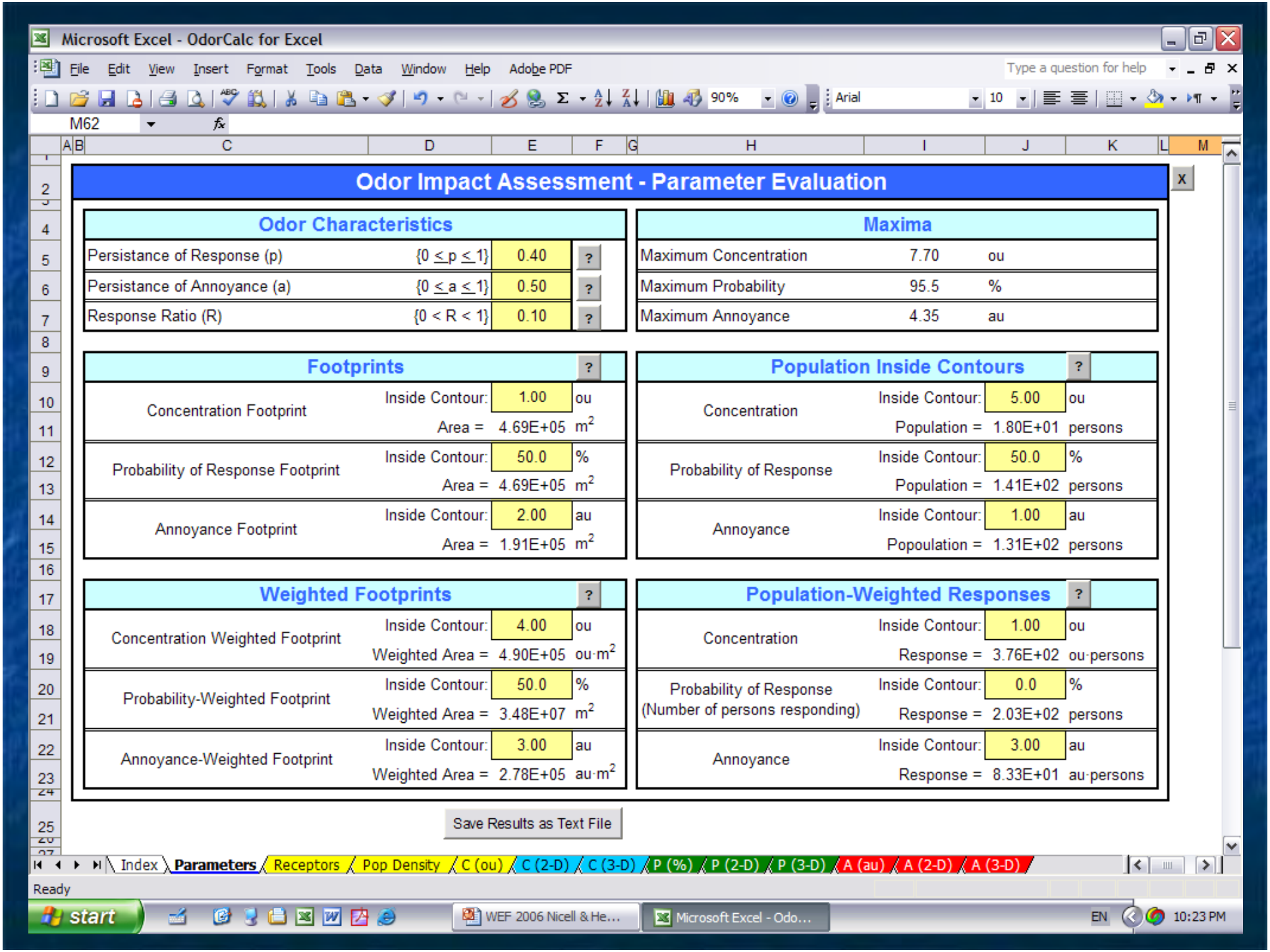


Response (P, %)

$$A = \frac{10}{1 + (C \cdot R)^{\frac{a-1}{a}}}$$



Annoyance (A, au)


Microsoft Excel - OdorCalc for Excel
File Edit View Insert Format Tools Data Window Help Adobe PDF
Type a question for help
M62
Odor Impact Assessment - Parameter Evaluation
Odor Characteristics
Persistance of Response (p) {0 ≤ p ≤ 1} 0.40 ?
Persistance of Annoyance (a) {0 ≤ a ≤ 1} 0.50 ?
Response Ratio (R) {0 < R < 1} 0.10 ?
Maxima
Maximum Concentration 7.70 ou
Maximum Probability 95.5 %
Maximum Annoyance 4.35 au
Footprints ?
Concentration Footprint Inside Contour: 1.00 ou
Area = 4.69E+05 m²
Probability of Response Footprint Inside Contour: 50.0 %
Area = 4.69E+05 m²
Annoyance Footprint Inside Contour: 2.00 au
Area = 1.91E+05 m²
Population Inside Contours ?
Concentration Inside Contour: 5.00 ou
Population = 1.80E+01 persons
Probability of Response Inside Contour: 50.0 %
Population = 1.41E+02 persons
Annoyance Inside Contour: 1.00 au
Popoulation = 1.31E+02 persons
Weighted Footprints ?
Concentration Weighted Footprint Inside Contour: 4.00 ou
Weighted Area = 4.90E+05 ou·m²
Probability-Weighted Footprint Inside Contour: 50.0 %
Weighted Area = 3.48E+07 m²
Annoyance-Weighted Footprint Inside Contour: 3.00 au
Weighted Area = 2.78E+05 au·m²
Population-Weighted Responses ?
Concentration Inside Contour: 1.00 ou
Response = 3.76E+02 ou·persons
Probability of Response (Number of persons responding) Inside Contour: 0.0 %
Response = 2.03E+02 persons
Annoyance Inside Contour: 3.00 au
Response = 8.33E+01 au·persons
Save Results as Text File
Index Parameters Receptors Pop Density C (ou) C (2-D) C (3-D) P (%) P (2-D) P (3-D) A (au) A (2-D) A (3-D)
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start
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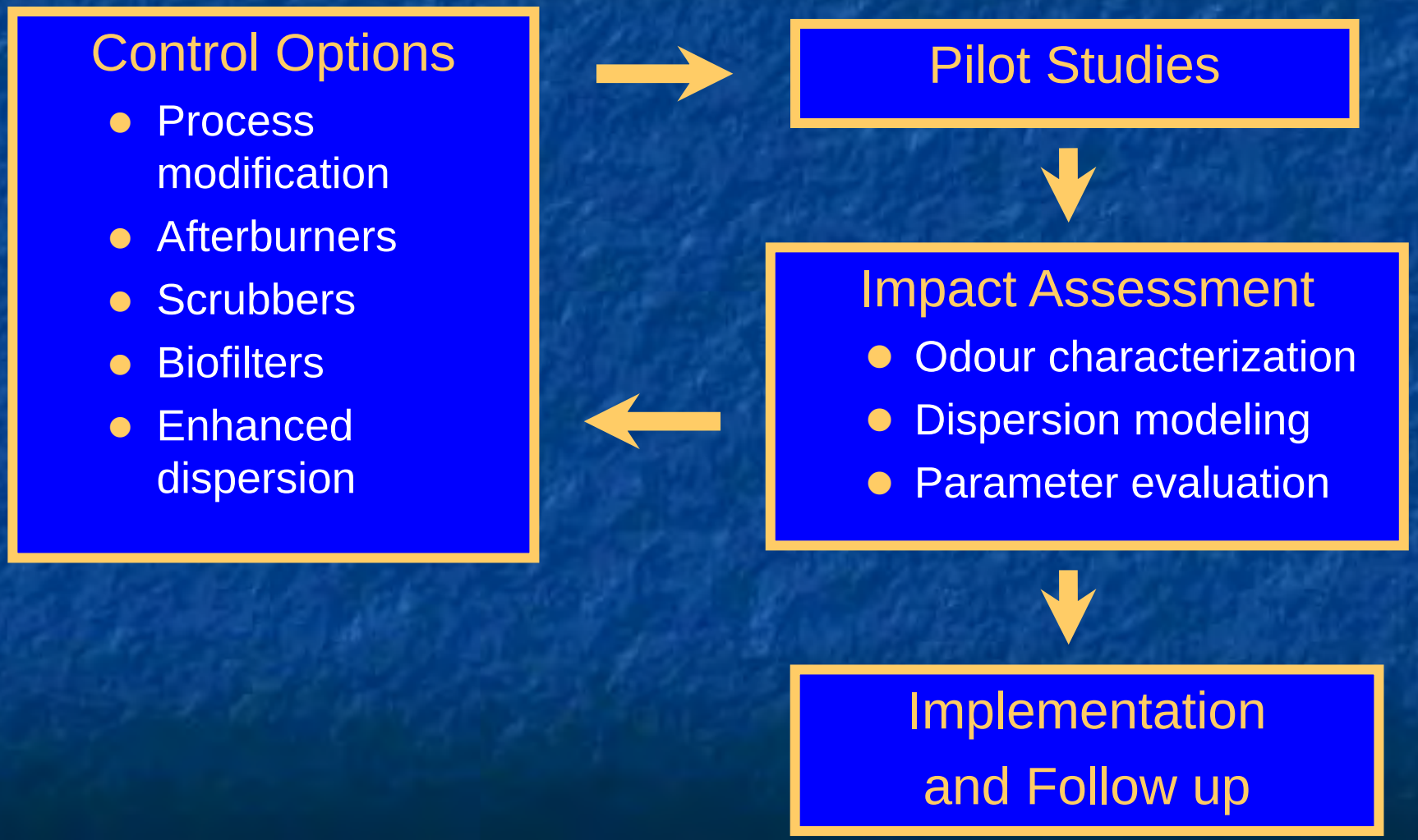
Assessment of Control Options



Conclusions

- Quantitative dimensions of odour character and impact have been developed and demonstrated.
- Approaches to odour impact assessments are proposed that represent improvements on current methods by:
  - including dose-response relationships and community and source characteristics into impact estimates;
  - allowing the prediction of the impact of new facilities, new processes, and process modifications;
  - providing a means for evaluating the effectiveness of odour control alternatives.

References

Nicell, J.A. (2009) Assessment and regulation of odour impacts. *Atmospheric Environment*, 43, 196-206.

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Henshaw, P., J.A. Nicell, A. Sikdar (2006) Odour impact parameters for an industrial facility. *Atmospheric Environment*, 40, 1016-1029.

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