Odour regulations in Europe – different approaches

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Odour measurement, control, reduction measures and monitoring in the Baltic countries

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Riga

Full title

"Odour regulations in Europe – different approaches (including, use of 'odour hour' and hourly average odour concentration for regulatory purposes) and associated assessment methods (measurements and dispersion modelling)"

Contents

- Introduction
  - Background information
  - FIDOL framework
- Odour regulation – overview
- History of odour regulation in Europe
- Dispersion modelling of odours
  - UK approach
  - Different approaches
    - Hourly average/percentile
    - ‘Odour hour’
- Odour measurements: overview
- An example of a novel approach to odour regulation

INTRODUCTION

Introduction

- We can recognise/distinguish thousands of different smells
- But we're not very good at describing them
  - Don't have names for different smells (compare - colours)
- We tend to prefer scents that we can identify correctly
- We have around 5 million olfactory receptor neurons
  - Rabbits have around 100 million
  - Dogs have around 220 million
- Our olfactory receptors are directly connected to the most ancient and primitive part of the brain
  - Linked to emotions, memories
- We can respond to odour over a 1 to 5 second interval (a single breath)
- The most odorous compound is mercaptan – used as a marker for natural gas (methane has no odour)

Factors that affect the impact of odours: FIDOL

- A framework for assessing the impact of odours

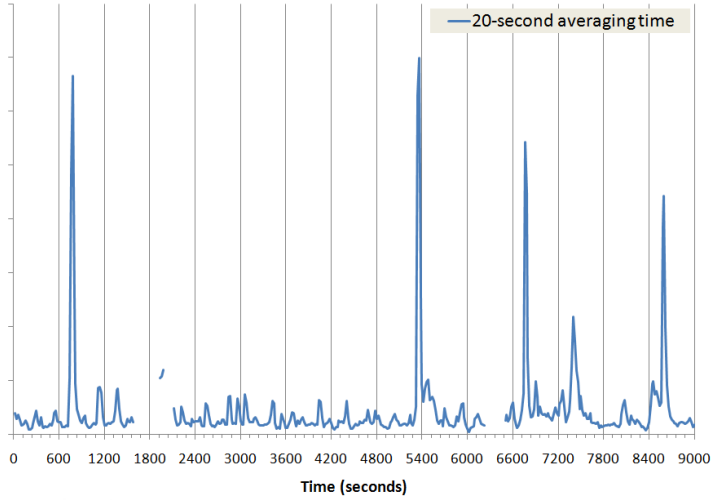
- **F**requency
- **I**ntensity
- **D**uration
- **O**dour unpleasantness / **O**ffensiveness
- **L**ocation

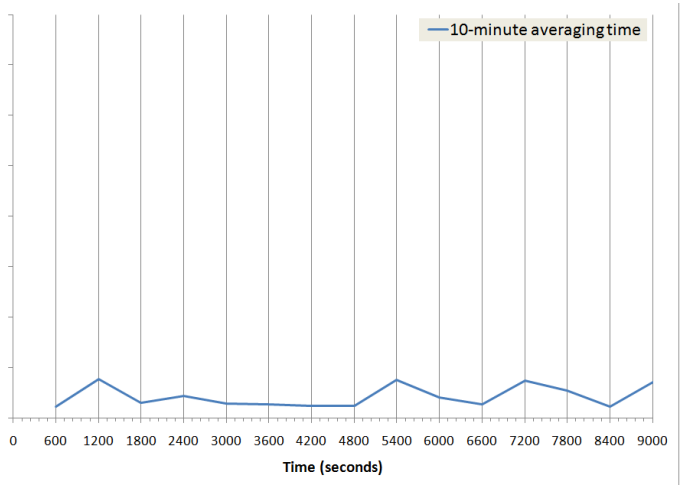
(Sometimes FIDOR, where R = receptor sensitivity)

- These are important concepts to bear in mind for odour regulation
- Will go through each of these in turn...

FIDOL: Frequency

- Frequency of detection
- How often an individual is exposed to odour
- Olfactory fatigue / adaptation:
  - An individual can get ‘used to’ the odour - unable to detect the odour after a certain period
  - But if odour has an on/off/on pattern, this is disrupted
- Assessment implications:
  - Averaging time, peak-to-mean concentrations





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FIDOL: Intensity

- The strength (concentration) of the odour
- More specifically, the *perception* of the strength of the odour
  - The relationship between a stimulus and the perceived strength is not necessarily linear (smell, noise, brightness, etc), e.g. Steven's power law / Weber-Fechner law
  - The intensity of an odour is a logarithmic function of its concentration.
- Common standard measure of odour strength: 'European odour unit' (ou_E) :
  - the quantity of a malodorous substance, which, when vaporised in one cubic metre of neutral gas, at standard conditions, induces a physiological reaction in the olfactory organs for at least half of the members of the odour evaluation panel

FIDOL: Duration

- Exposure duration
  - Hourly / daily / seasonal patterns of exposure
  - Length of particular odour ‘episode’

- Assessment implications:
  - Related to ‘frequency’
  - Hours of operation of process
  - How can this be taken into account in measurements, modelling, etc?

FIDOL: Offensiveness / Odour unpleasantness

- Mixture of the character and the hedonic tone
- The character is the description, e.g. ‘fishy’, ‘sweet’
- The hedonic tone is the ‘acceptability’
  - Is it pleasant or unpleasant?
  - Landfill *vs* baking bread
- Hedonic tone ‘scores’ are sometimes used
  - also referred to as ‘Dravnieks’.
  - Andrew Dravnieks – studied in Riga

- Assessment implications:
  - How to treat different processes?
  - What thresholds to compare model output against?

FIDOL: Location

- The nature of the surrounding area and sensitivity of nearby receptors
- Sensitivity of individuals: people have different detection thresholds
  - "Statutory nuisance uses the concept of the response of the average, reasonable person" – UK guidance
- What is the land use of the surrounding area?
  - Residential *vs* industrial
  - Urban *vs* rural
  - High population *vs* low population
- Assessment implications:
  - Careful consideration of local land use and sensitive receptors

Complicating factors - odour

- Usually complex mixtures of compounds (focus of this talk)
  - Difficult to measure
  - Synergistic effects – impact greater than the sum of its parts
  - Masking effects - impact less than the sum of its parts

- Subjective - what constitutes a ‘nuisance’?

- Sources are often complex
  - Different types of sources
  - Often fugitive
  - Often transient

ODOUR REGULATION - OVERVIEW

Odour regulation

- Three approaches of regulation:
  - Qualitative
    - e.g. Ensure no complaints
  - **Quantitative**
    - **e.g. Dispersion modelling, measurements**
  - Operational
    - e.g. Setback distances (distance between sensitive receptors and odour sources)

- Currently, the most common form of quantitative assessment is measurement of odour emissions at the source, used as input to a dispersion model

Why use dispersion modelling?

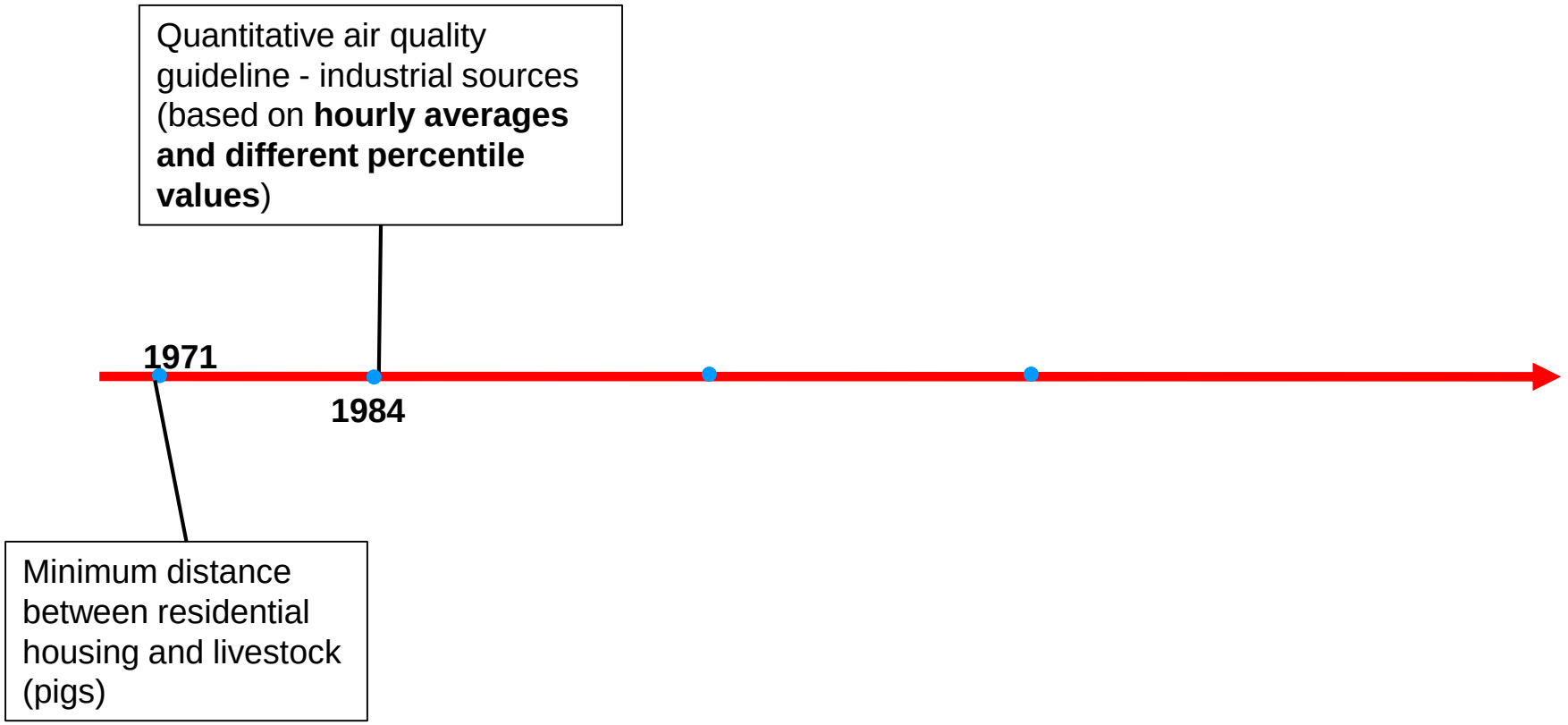
- Ambient odours are difficult to measure
  - Human nose is highly effective at measuring odour
    - Sensitive, fast and can distinguish a wide range of compounds
  - Olfactometry is an important tool in odour assessment
    - Air samples ‘measured’ by a panel of selected human assessors
  - But olfactometry can only be used for determining odour emissions, not ambient concentrations
  - Direct measurements cannot usually be made at receptor locations – concentrations too low
  - (‘Electronic noses’ – improving technology but still not widely used)
- Useful at the planning and permitting stage of potentially odorous processes - the source is not yet present
- Can investigate possible mitigation measures – abatement, etc

HISTORY OF ODOUR REGULATION IN EUROPE

Odour regulation - history

- First odour regulations in Europe were in the 1970s
  - e.g. minimum setback distances for agriculture
- During the 1980s, countries in Europe began developing standards of olfactometry
- Some of the standards developed and published include:
  - France AFNOR X-43-101
  - Germany VDI 3881, Parts 1-4
  - Netherlands NVN 2820

Timeline – the Netherlands

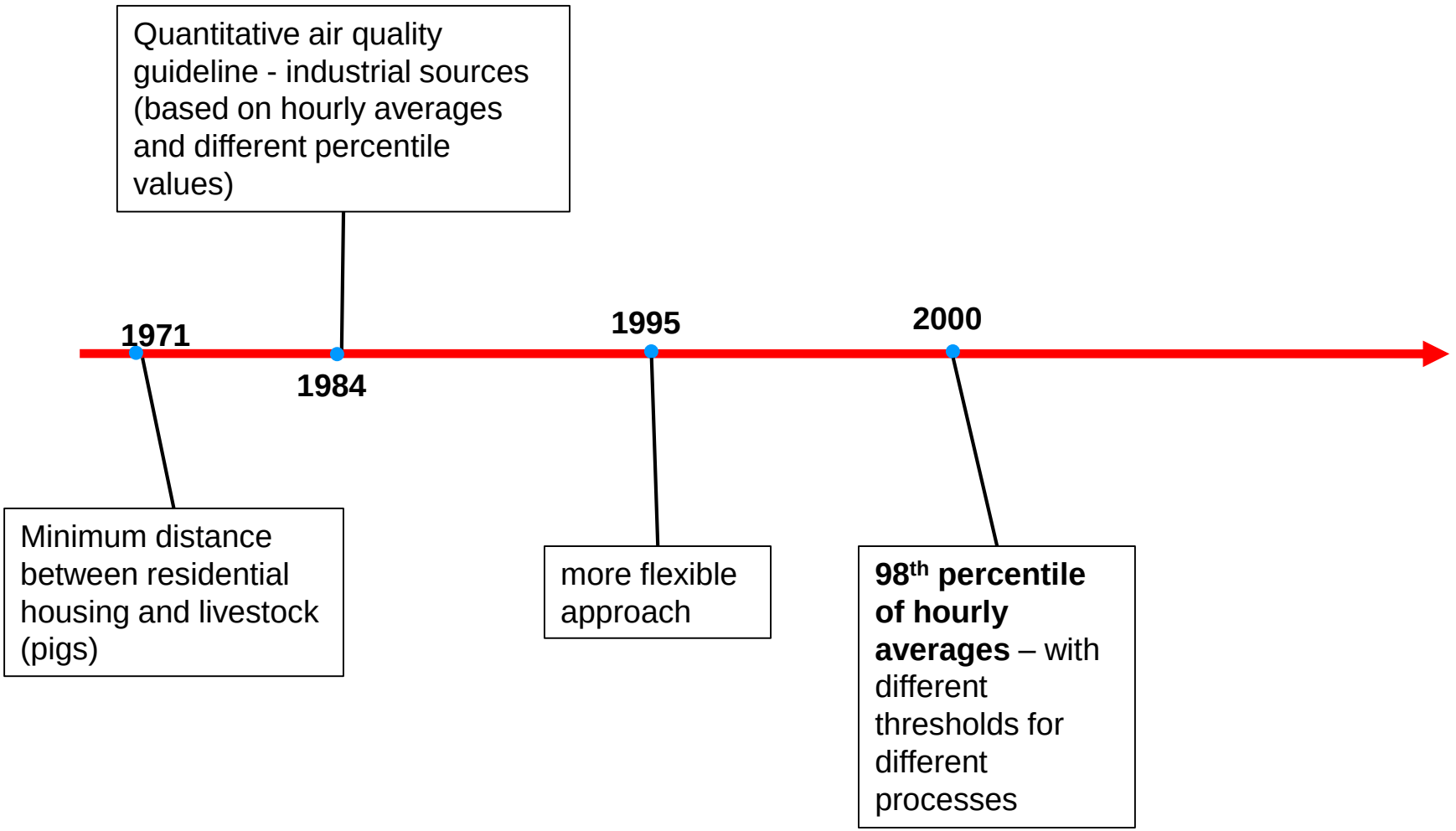


The Netherlands - 1984

Percentile (hourly averages)	Source	Receptors
99.5	New installations	Residential, schools, hospitals, etc
98	existing installations	Residential, schools, hospitals, etc
95	-	Isolated residential houses located on industrial estates
99.9	Short duration, high impact emissions (e.g. loading/unloading)	Residential, schools, hospitals, etc

- Widely-applied
- Highlighted the need to have standard, reproducible measurements of odour

Timeline – the Netherlands



Hourly mean approach: 98th percentile of hourly averages

- The odour threshold value can be exceeded 2% of the time (of the hours in a year)
- 2% of 8760 = 175 hours of exceedence

- Widely used in Europe

‘Odour hours’ approach

- Germany has air pollution control regulations: ‘Technical Instructions on Air Quality Control’
  - commonly known as the ‘TA Luft’
- Uses ‘odour hours’ approach - aims to take into account the short-term peaks in concentration (within the hour)
- ‘Odour hour’ definition:
  - Hours which have recognisable odour for at least 10% of the time (6 minutes)
- Odour assessment: the number of occurrences of ‘odour hours’ within a year

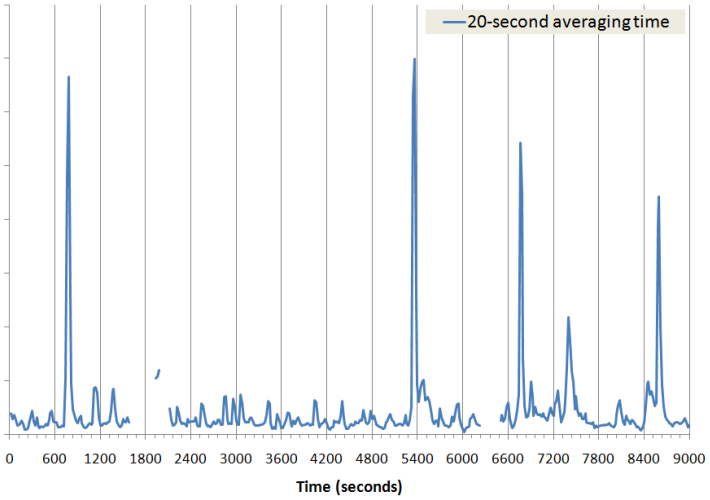
Current situation in Europe

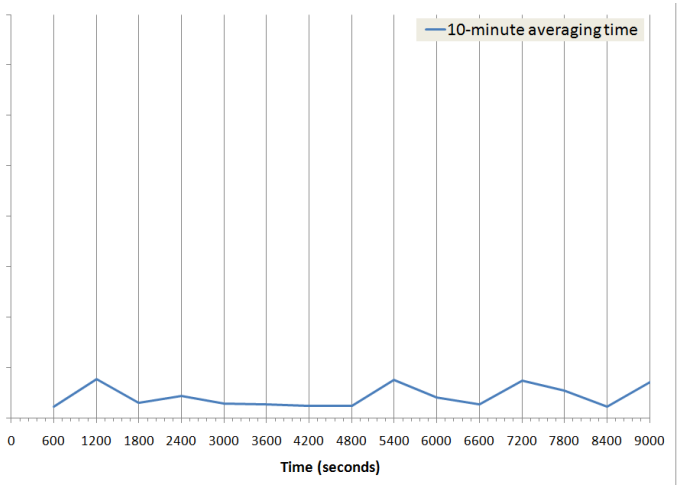
- Most European countries tend to use the hourly mean (percentile) approach (e.g. Netherlands, France, Italy (regional), Ireland, UK)

- Some countries (e.g. Germany and Austria) use an ‘odour hour’ metric approach to try to account for short-term peaks

Why do some countries apply the ‘odour hour’ approach?

- Reflects the short-term peaks in odour concentrations
- Attempts to account for the ‘frequency’ aspect of the FIDOL framework
- Rapid response of human nose (few seconds)





Why do many countries apply the 'hourly average' approach?

- Simple concept
- Straightforward methodology
- Tried and tested
  - Many studies have found good correlation between the 98th percentile results and annoyance
  - The percentile approach has been used in many different practical situations such as planning applications
  - Has been the subject of many legal challenges – scrutiny
  - *"Odour assessment methodology, as it has developed in Europe and UK over the last 35 years, has become well-established. The predictive, quantitative approach involves obtaining estimates of the odour source emission rate, use of the emissions in a dispersion model to predict 98th percentile concentrations at sensitive receptors and comparison of these with criteria that have evolved from research and survey work.* ***At the present time, this remains an accepted technique and the IAQM supports this****"*

Institute of Air Quality Management (IAQM) odour guidance, 2014.

DISPERSION MODELLING OF ODOUR

Modelling: UK approach

- Various guidance and approaches for odour assessment
  - Different purposes (e.g. planning, permitting)
  - Different sectors (e.g. waste water treatment, composting)
  - Different regions within UK (England, Scotland, Northern Ireland, Wales)
- Examples of guidance:
  - Environment Agency: ‘H4’ document
    - https://www.gov.uk/government/collections/horizontal-guidance-environmental-permitting
  - Guidance produced in 2014 by a voluntary working group:
    - Institute of Air Quality Management (IAQM)
    - Good overview of odour regulations, assessment and guidance
    - http://iaqm.co.uk/guidance/
- The 98th percentile of hourly average metric is consistent throughout

Modelling: UK approach

- 98th percentile of hourly average concentrations
- 175 exceedences allowed in a year

"But exceedences of **what value**?"

- Threshold values (ou_E/m^3):
  - 1.5 for most offensive odours
  - 3 for moderately offensive odours
  - 6 for less offensive odours

  (plus others – e.g. 5 in waste water industry)

"But **how offensive** is my source?"

Most offensive: decaying animal remains, landfill, some waste water treatment processes

Moderately offensive: intensive livestock, some food processing, composting

Less offensive: Brewery, coffee roasting, bakery

"But **where** do these threshold values apply?"

Modelling: UK approach

Receptor sensitivity	Surrounding land where:	Examples
High	Users can expect enjoyment of a high level of amenity Users present continuously/regularly for extended periods	Residential Hospitals Schools Tourism
Medium	Users can expect reasonable enjoyment of a high level of amenity Users not present continuously/regularly for extended periods	Workplaces Commercial/retail Playing fields
Low	The enjoyment of amenity not reasonably expected Transient exposure	Industrial Farms Footpaths Roads

Modelling: UK approach - Combining FIDOL factors

- Example – UK guidance (IAQM):

Location

Table 6: Proposed odour effect descriptors for impacts predicted by modelling

Odour Exposure Level C_{98}, ou_E/m^3	Receptor Sensitivity		
	Low	Medium	High
≥10	Moderate	Substantial	Substantial
5-<10	Moderate	Moderate	Substantial
3-<5	Slight	Moderate	Moderate
1.5-<3	Negligible	Slight	Moderate
0.5-<1.5	Negligible	Negligible	Slight
<0.5	Negligible	Negligible	Negligible

When compiling this table, it has been assumed, on a conservative basis that the odour in question is at the offensive end of the spectrum.

Frequency

Duration

Intensity

Offensiveness

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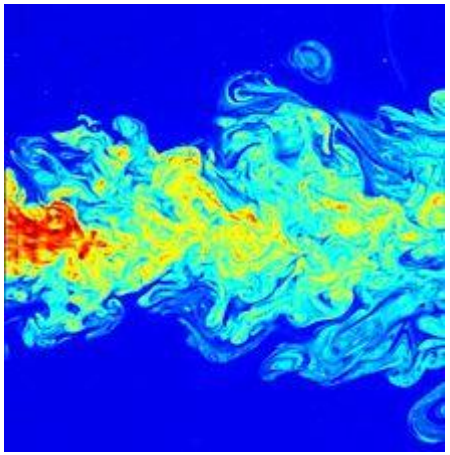
Dispersion effects

- We can think of ‘dispersion’ in the atmosphere as being made up of two main processes: Advection and turbulent processes

  - ‘Advection’: the pollutant (odour) is transported along in the main direction of the wind
    - ‘external effects’ constant
    - Constant meteorological conditions

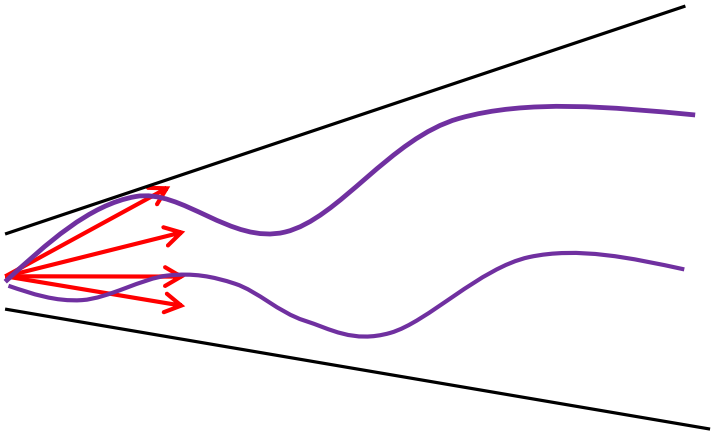
  - ‘diffusive’ processes: the pollutant (odour) is moved and mixed due to fluctuations in the wind, and chaotic smaller-scale movements of eddies



Spreading of pollutant plumes

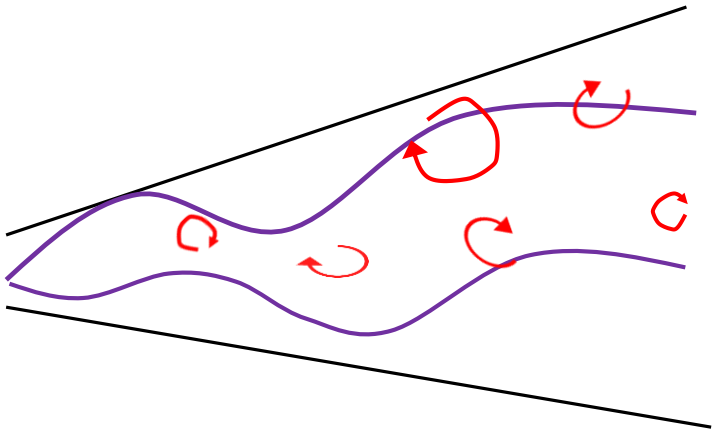
- On timescales on less than around an hour, plumes will fluctuate and spread due to two main mechanisms:

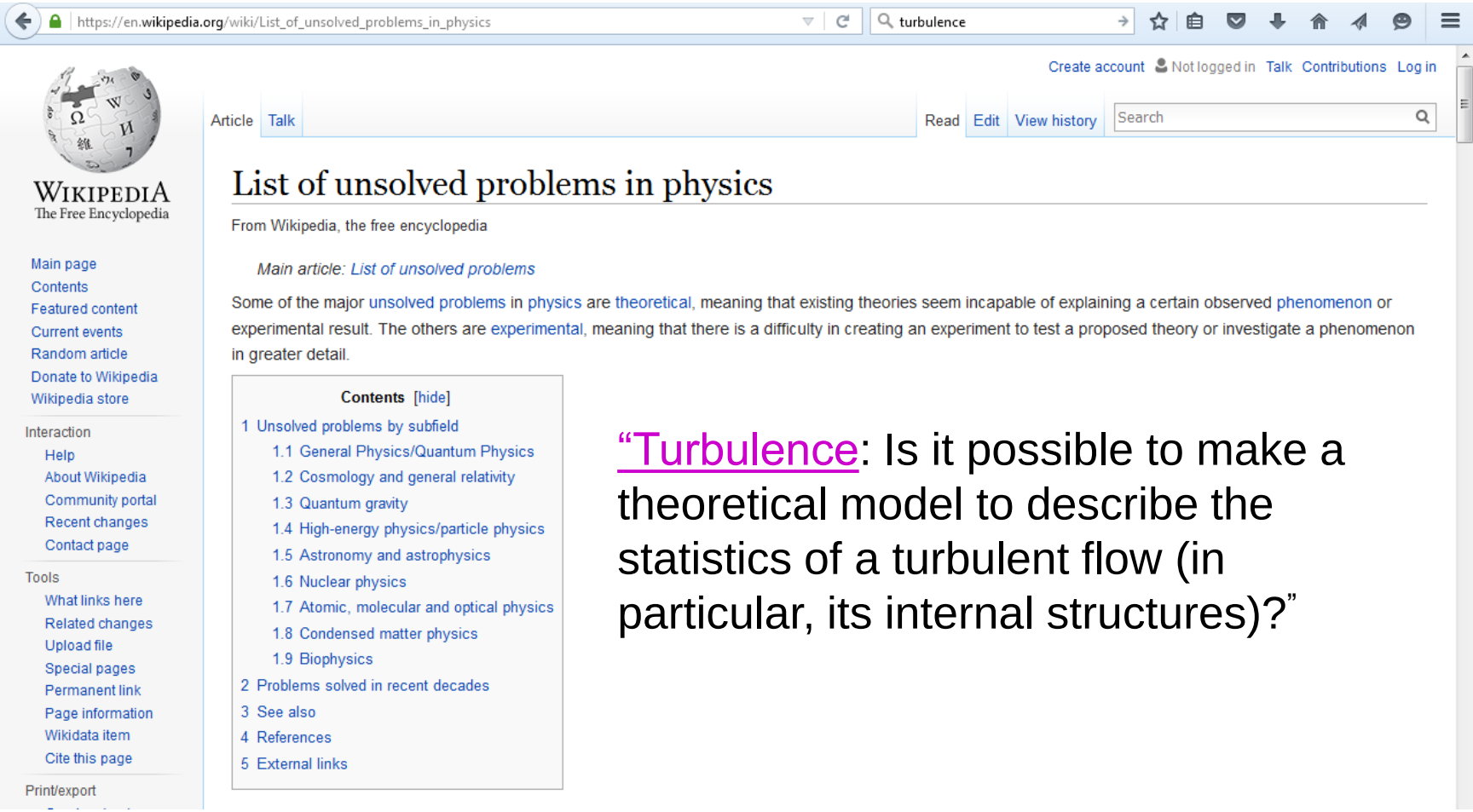
a) Large-scale turbulence and changes in the direction of the wind



b) Small-scale turbulence

- ‘Eddy diffusion’
- On different scales
- Generally small timescales
- Timescales less than an hour
- Prevailing wind conditions unchanged



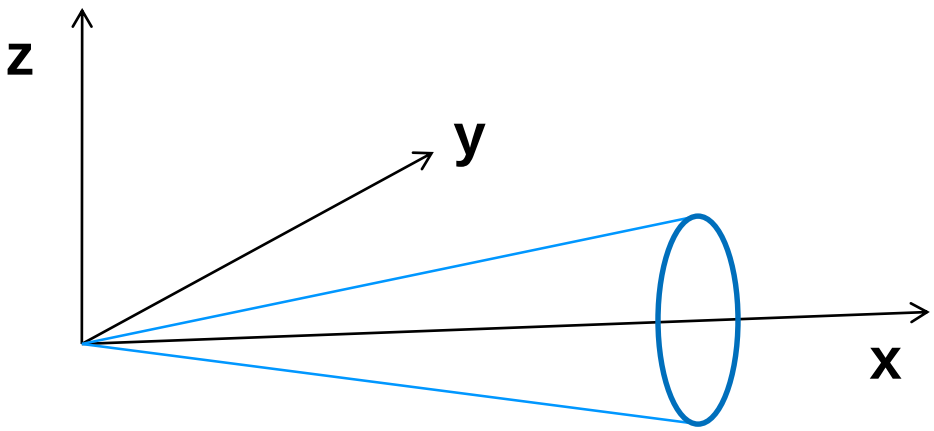


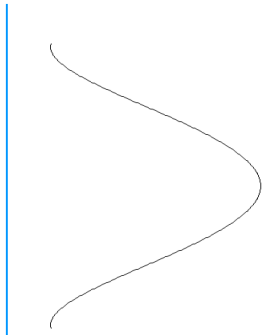
"Turbulence: Is it possible to make a theoretical model to describe the statistics of a turbulent flow (in particular, its internal structures)?"

Concentration fluctuations and ‘odour hours’

- To calculate ‘odour hours’, need to determine the peak concentrations, which depend on the turbulence in the flow
- Turbulence and dispersion are best considered as random / stochastic phenomena
- This implies a statistical / probability approach
- Various methods for this:
  - Probability-based fluctuation ‘modules’ in Gaussian plume models
  - Lagrangian model (e.g. AUSTAL2000G in Germany)
  - Applying a fixed peak-to-mean factor to hourly mean values (e.g Austrian Odour Dispersion Model (AODM)
    - $F = C_p / C_m$

Gaussian plume models





Normal distribution

- Often misconceptions: “can’t model complex effects” (terrain, low wind speeds, coastlines, short-term concentrations)
- Detailed treatment of meteorological parameters
- *Advanced* Gaussian plume models – e.g. ADMS, AERMOD include refinements, such as:
  - Terrain effects
  - ‘Calms’ module: Accounts for the variable wind directions during low winds
  - Coastline module
  - Fluctuations module

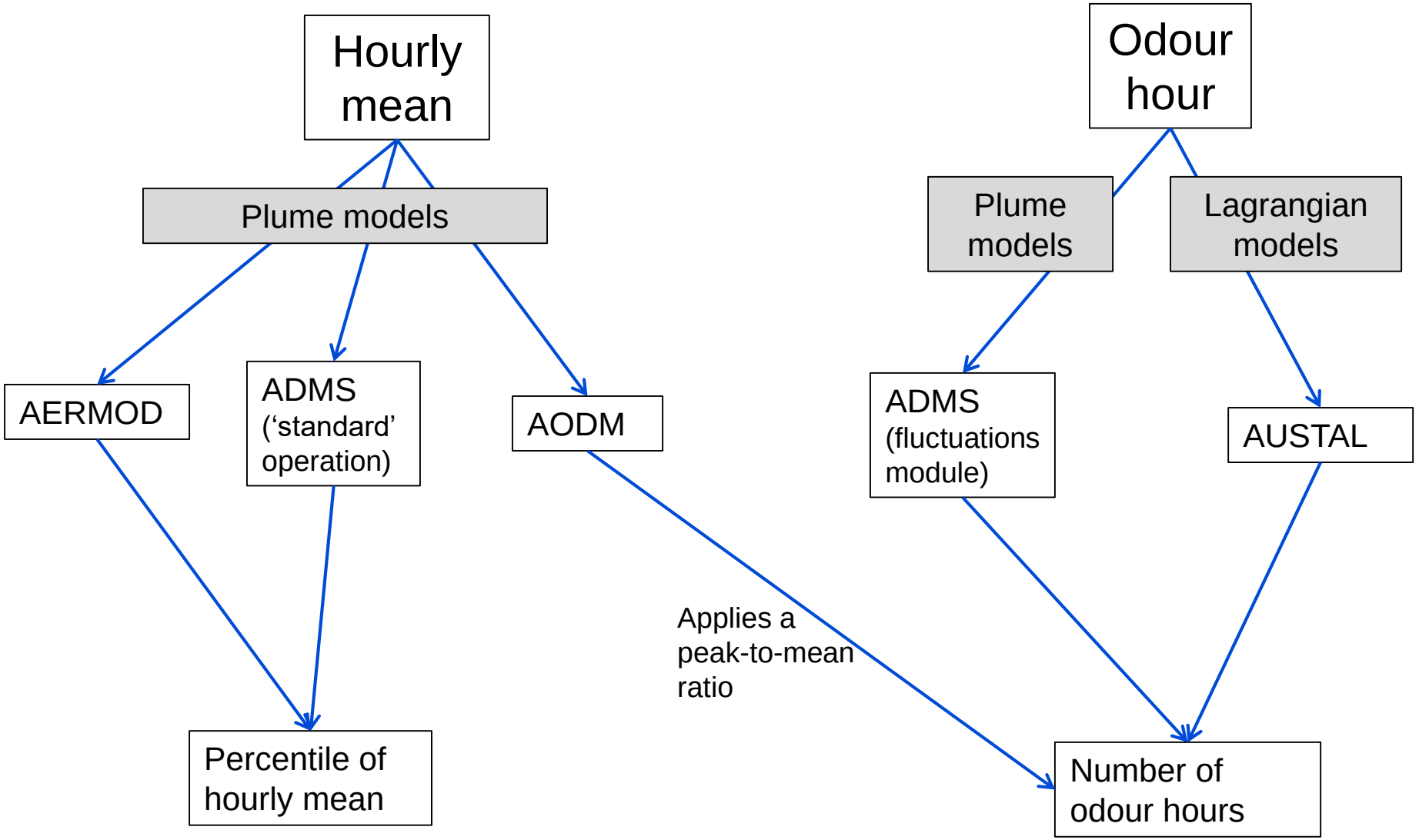
Fluctuations module in ADMS

- An advanced module within ADMS
- Calculates the probability that a certain concentration will be exceeded
- Produces statistics of fluctuations in concentration
- The user specifies an averaging time (e.g. 6 minutes)

Lagrangian models

- Often called ‘random walk’ models
- The observer follows individual plume ‘particles’ or ‘puffs’ (parcels) as they move through the atmosphere
- Statistics of concentrations derived from trajectories of particles or puffs

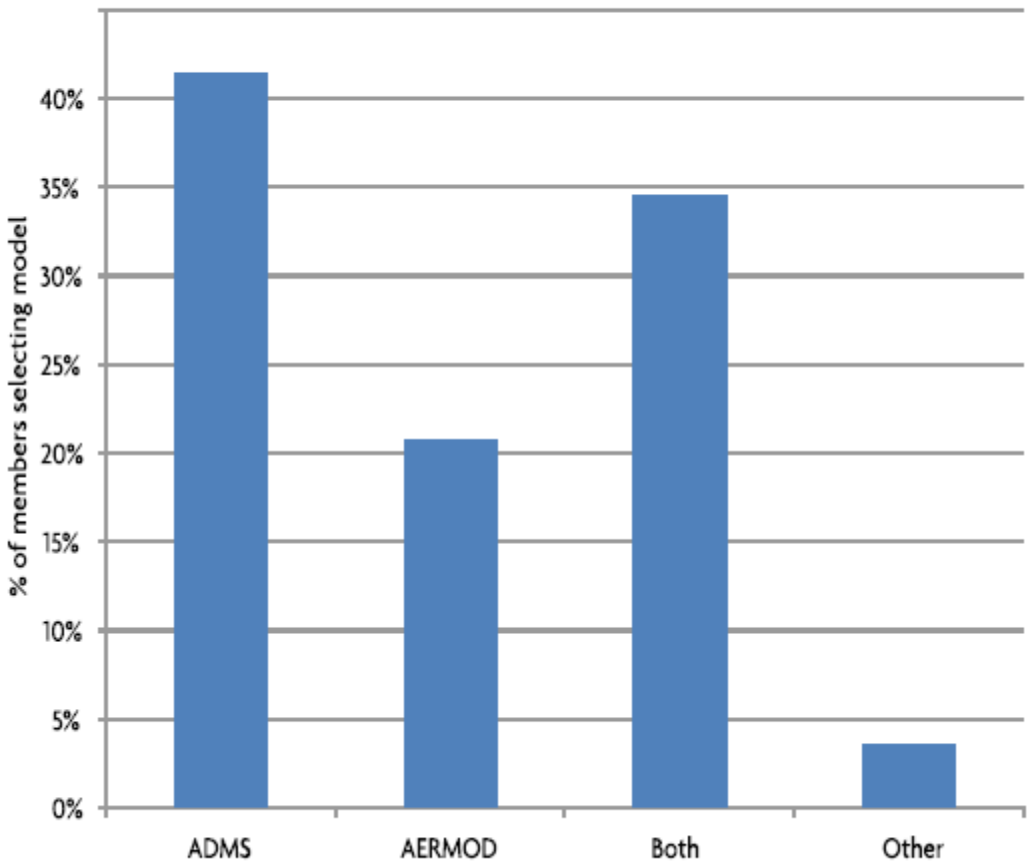
Different modelling approaches - examples



Modelling: UK approach –type of model

- IAQM guidance:
  - "In a recent survey in preparation for this guidance, members were asked which model they would select for an odour assessment"
  - "Odour assessments are almost exclusively undertaken in the UK using the AERMOD or ADMS models"
- Note: no prescribed model type

Figure 3: Percentage of IAQM members selecting each dispersion model option.



MEASURING ODOUR

Odour measurements

- *"**Did you ever try to measure smell? Can you tell whether one smell is just twice as strong as another? Can you measure the difference between one kind of smell and another?** It is very obvious that we have very many different kinds of smell, all the way from the odour of violets and roses up to asafoetida. But **until you can measure their likeness and differences you can have no science of odour**"*

- Alexander Graham Bell - Inventor of the telephone - 1914

Assessing ambient concentrations

- Human nose is highly sensitive to odour – sensitive, fast and wide range
- ∴ Olfactometry is an important tool in odour assessment.
  - Collection of gaseous samples, followed by assessment by human assessors
- **But** is used for emission, not ambient concentrations
  - i.e. Used at the source, not at the receptor
  - (Are now *some* ambient olfactometry measurements - more later)
- CEN working group – European Committee for standardization
  - EN13725 standard introduced in 2003
- Many different approaches in Europe (and the world) until the introduction of the EN13725 standard
- Key elements of the EN13725 standard are the quality criteria for accuracy and precision (repeatability).

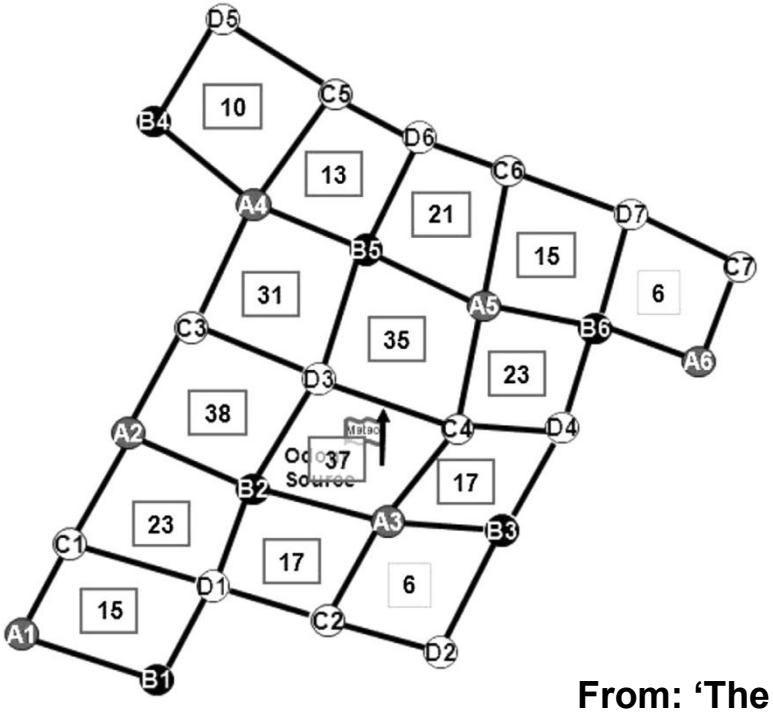
Ambient measurements: Future European standards

- A new European Standard is being drafted by the Technical Committee (CEN/TC 264/WG 27)
- Determination of odour in ambient air
- Selected and trained human panel members
- Two different methodologies of field inspection:
  - Grid measurement
  - Plume measurement

e.g: 'The future European standard to determine odour in ambient air by using field inspection' Guillot *et al*. Water Science and Technology.

CEN/TC 264/WG 27 – Grid method

- "The grid method is a statistical survey method which should be applied over a sufficiently long period of time (e.g. half a year or one year), to provide a representative map of the exposure of the population to recognisable odours."

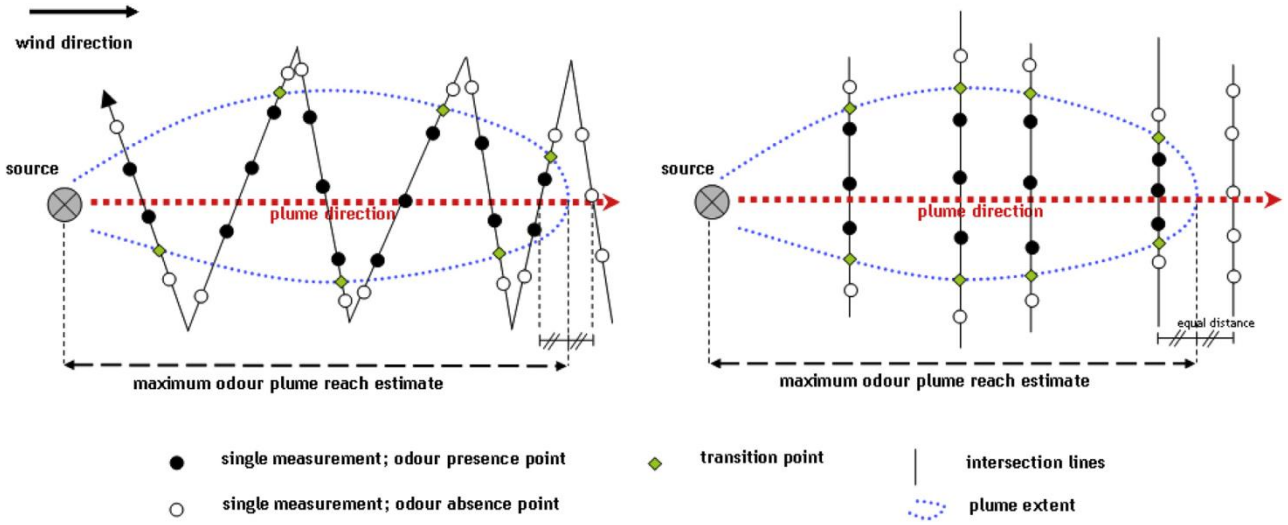


From: 'The future European standard to determine odour in ambient air by using field inspection' Guillot et al.

Odour measurement, control, reduction measures and monitoring in the Baltic countries

CEN/TC 264/WG 27 – plume method

- The plume method is used to determine the area in which the plume can be perceived under specific meteorological conditions.
- The odour plume extent is described by points where a transition from absence to presence of the odour under occurs.
- Results used to
  - determine a plausible extent of potential exposure to odours, or
  - to estimate the total emission rate using reverse dispersion modelling (useful where sampling at source is not practical)



Ambient odour measurements

- Field measurement techniques
- - “sniff tests”
- Use of the human nose as a sensor
  - With or without an instrument to help
  - ‘field olfactometers’
- Electronic noses
  - Devices
  - Arrays of sensors and pattern recognition
- More about this in later talks

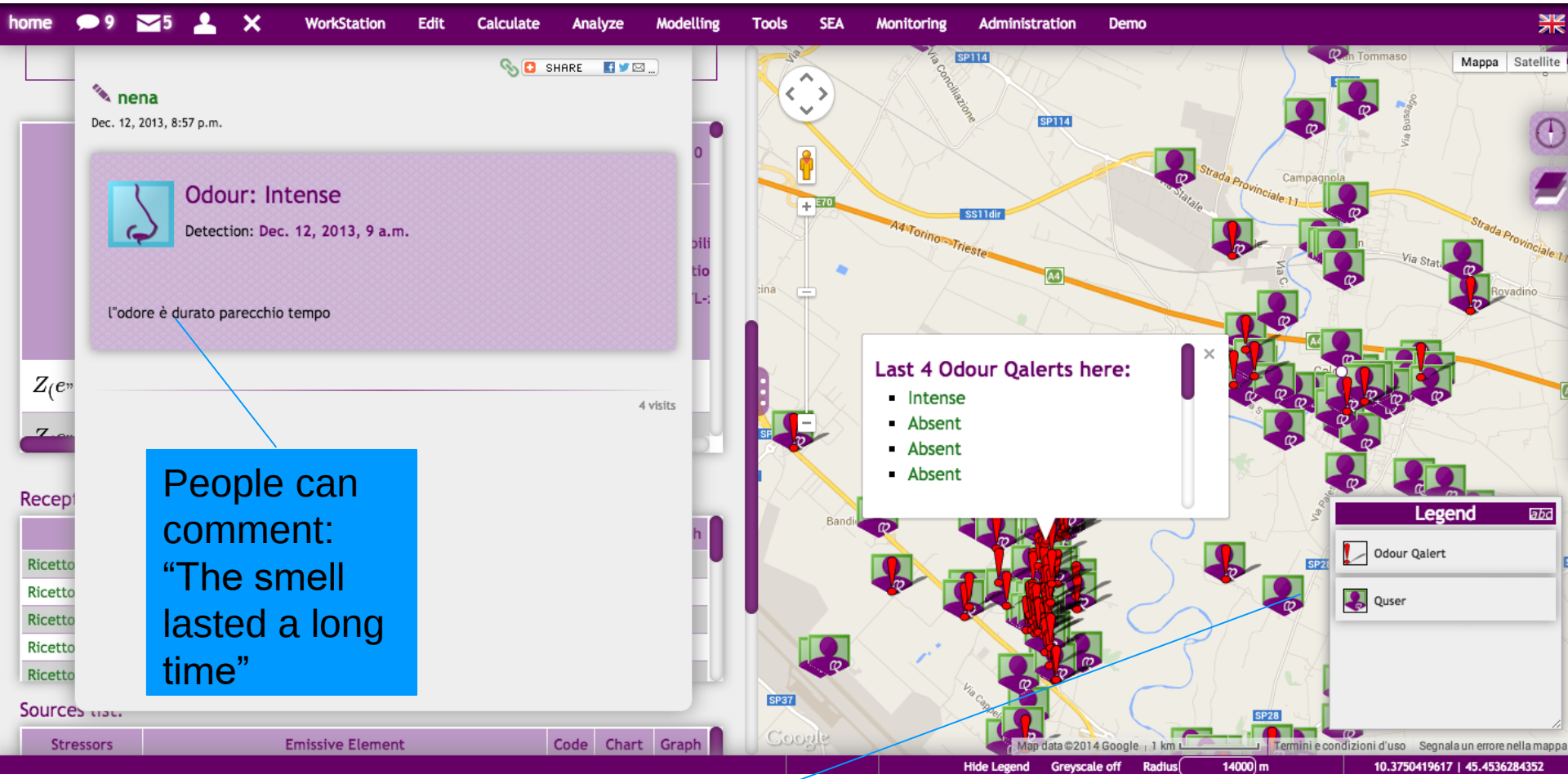
AN EXAMPLE OF A NOVEL APPROACH TO ODOUR REGULATION

Crowd sourcing of odour episodes in Italy

- Q-Cumber - an innovative combination of crowd-sourcing, social networking and environmental tools, combining data from heterogeneous sources into a user-friendly query framework (developed by Algebra)

- QCumber combines
  - Crowd-sourced data on odour nuisance
  - Official data on possible sources of odour
  - Near-real-time official data (meteorology)
  - Modelling (ADMS)
- These can identify likely sources of odour nuisance
- Modelling can be used for odour source apportionment

Members of the public report odour problems



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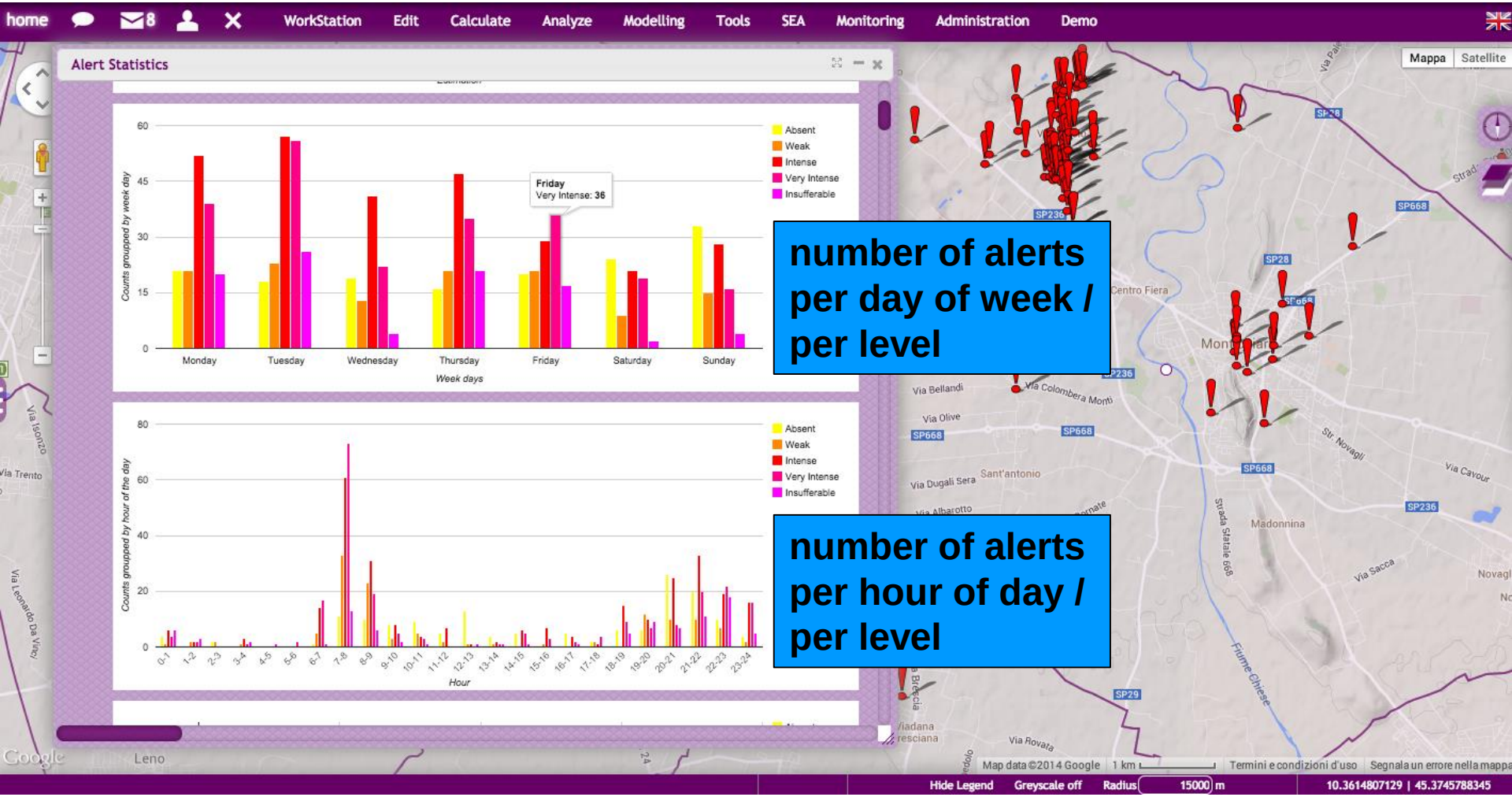
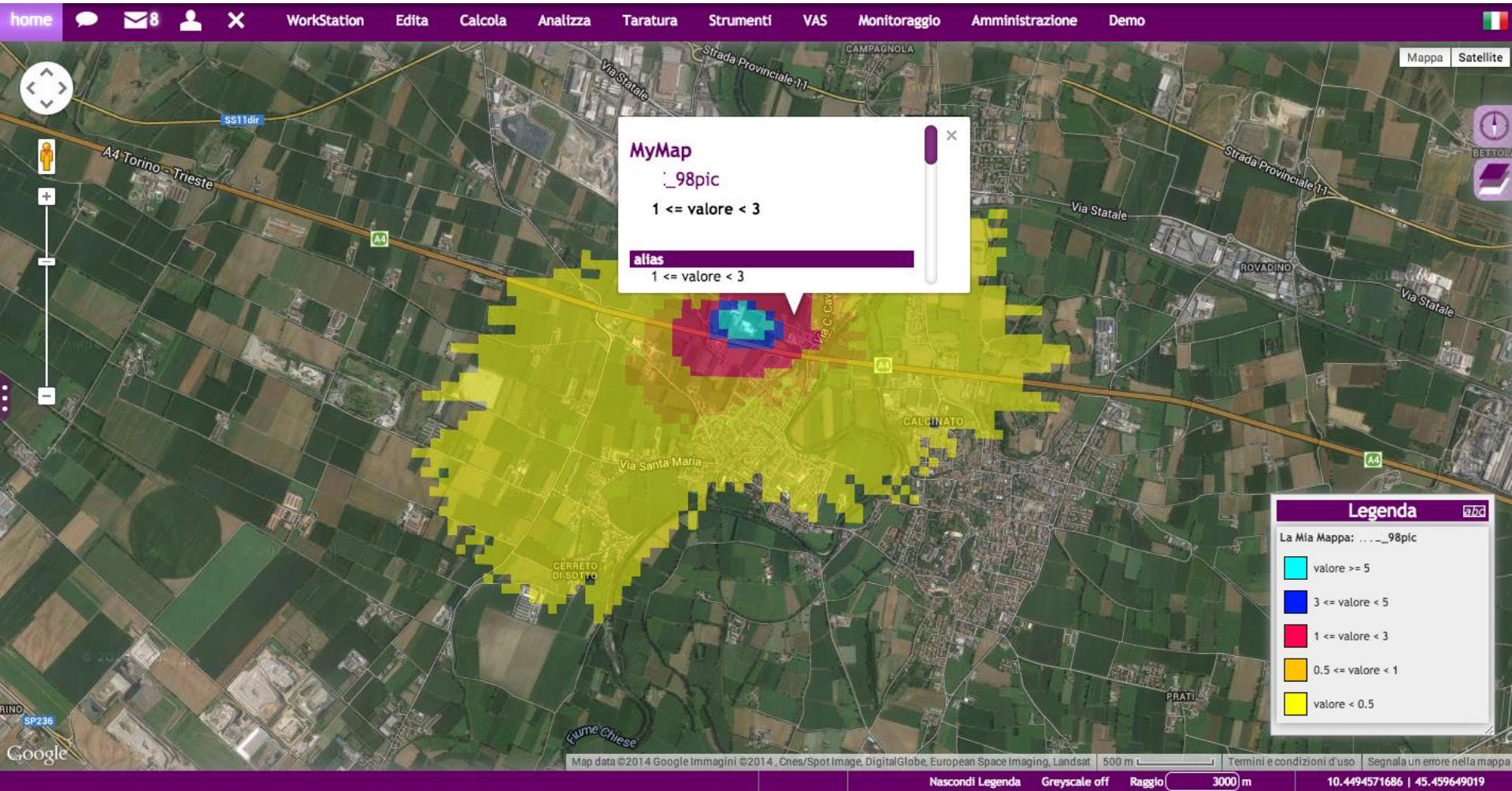
Data can be analysed



Odour contour plot

98th percentile



Today's meeting

- Today's program includes a wide variety of interesting presentations:
  - Experience of odour regulations, frameworks and control in Latvia, Estonia and Lithuania
  - Odour regulations and monitoring techniques
  - Practical experience – six case studies
  - Opportunity for discussion – panel

Many thanks for your attention