CALGARY ODOUR CONFERENCE

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Dispersion Modelling Advantages and Complexities

INTRODUCTION

- Why Conduct Modelling for Odours
- Difficulties with Odour Modelling
- Address some of the Odour Modelling Complexities
  - Meteorology
    - Examples of Complex Environment
  - Emission Rates
    - Odour complexity
    - Hydrogen Sulphide as surrogate for all odour
    - Sampling issues
  - Models
  - Area Sources
  - Assessment Criteria

WHY DISPERSION MODELLING FOR ODOURS

- Models provide quantification of odour impacts
- Objective tool in what is otherwise a very subjective process
- Most countries have odour regulation, e.g. 98^{th} - 99.9^{th} percentile, 3min - 1 hour average, 2 – 10 ou. These results can only be obtained using models.
- Modelling compliments output of Olfactometry process (which aims to quantify an odour concentration to 1 ou)
- Regulatory models developed for SO_2, NOx, PM have been adapted for use with odour
- Predict odour impacts at many points over a wide geographical area
  - Receptors are inexpensive
  - Not restricted to a few measurement points
- Evaluate the odour impact of proposed future sources
- Conduct detailed odour source contribution analyses
- Source mitigation and control scenario evaluation
  - Engineering design
  - Cost-benefit analysis

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WHY DISPERSION MODELLING FOR ODOURS

- Planning studies
  - Site selection for new facilities
  - Optimize source layout
  - Design buffer zones and fenceline locations
  - Design and optimize monitoring networks
  - Land use planning to minimize pollutant exposure to populations
- Forecast tool
  - Predict future odour impacts (e.g., 1-3 day forecasts)
  - Real-time tool for facility operators to help minimize air quality impacts by changing operations
  - Public information system (bad odour alerts)
- Emergency response planning
  - Evaluate potential worst case events for training, accident reconstruction or forecasting
  - Accidental releases, explosions, fires, upset conditions
- Data analysis
  - Fill in spatial gaps in observational coverage

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DIFFICULTIES WITH ODOUR MODELLING

- Good output requires (1) modeller skills, (2) quality meteorological data and, (3) reliable sampling and emission rates
- Can be seen as costly
- Odour complaints are usually near field, dispersion not yet occurred. Proper representation of source and OUER is important
- Poor meteorology, bad sampling, poor emissions = bad output
- Worst case odours occur on matter of seconds, beyond range of hourly time step of models, such as AERMOD
- Worst case odour dispersion - calm conditions – difficult for models
- Over or under predictions of concentrations due to model switch choice and model choice, esp. area sources
- Lots of model options, lack of understanding.
- Dispersion modelling is one of many tools to manage odour

METEOROLOGY

- Good meteorology is very important for dispersion models
- Confidence in model output increases significantly with good (on-site) data
  - On-site tower, small cost for lots of information (wind speed, dir, temp)
  - All local conditions are embedded in the data
- With nearby representative data, simple 1D model may work well. But, with no data may need 3D approach to develop met. at site
- Worst conditions for most odour sources is calm and light winds, fumigation, stagnation and re-circulation (some models intolerant to calms)
- Each application site is unique
- Uniform (steady-state) met. conditions are only applicable for a few kms, more so in flat terrain away from coast
- Even with a unit OER, good met. model input will still give accurate information on;
  - frequencies of exceedance
  - footprint of ou concentration and likely worst case
  - validate walk abouts and break out events

Level of Meteorological Data Requirements and Effort

Effort Level Little (1), Significant (3)	Level 1	Level 2	Level 3
Model	Ausplume, ISC	AERMET for AERMOD	Calmet for CALPUFF
Steady-state or non-steady state	Steady-State	Steady-State	Non-Steady State
1, 2 or 3 Dimensional meteorological data	1D	2D	3D
Single or multiple surface met stations	single	single	multiple
Single or multiple upper air stations	none	single	multiple
Applicability	< 5 km	< 10 km	0 – hundreds km
Suitability	Flat, Inland	Undulating, Inland	Complex terrain and at Coast
Nuisance Expectation	No	Minimal	Substantial
Expectation of Complaints	None	Minimal	Substantial
Source type	Single source	Single to few co-located sources	Any number of sources and, complex sources e.g. Pulp and Paper Mill

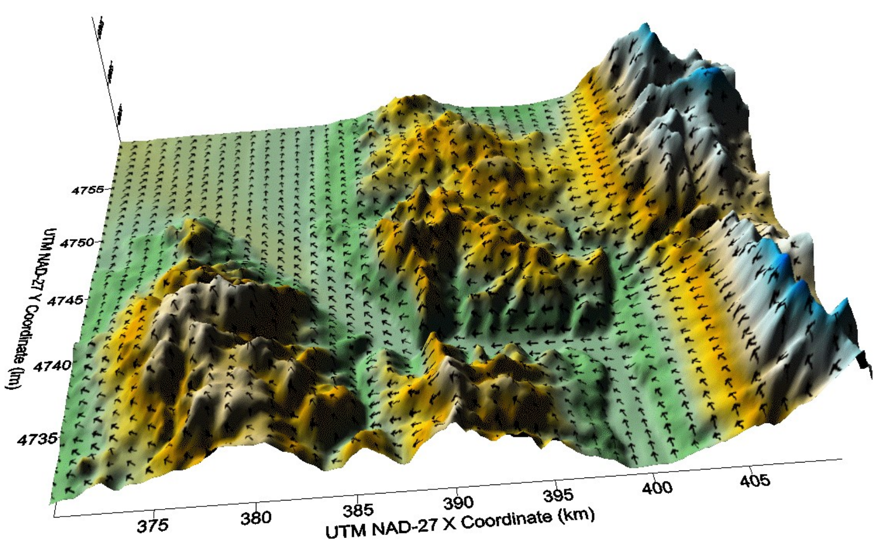
METEOROLOGY – COMPLEX ENVIRONMENT & SOURCES REQUIRES 3D MET

EXAMPLES OF COMPLEX FLOW SITUATIONS

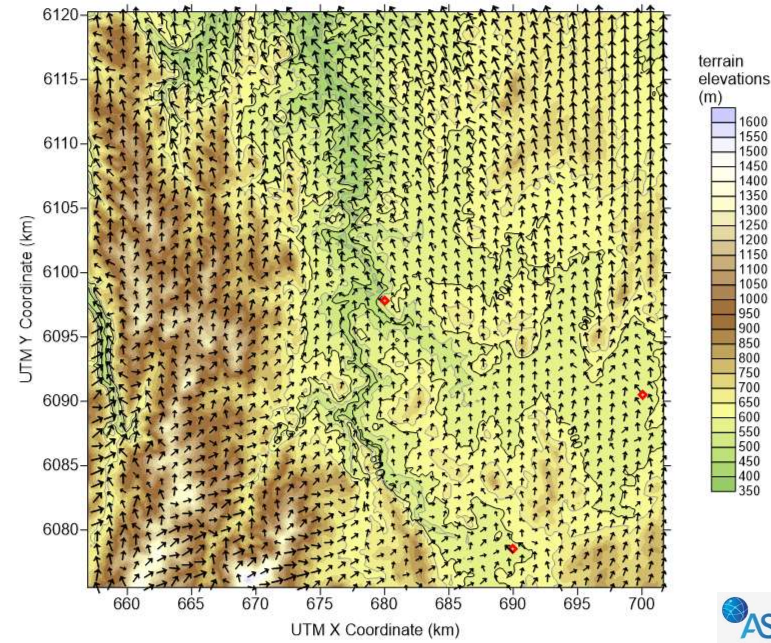
Defined as conditions when steady-state (uniform) criteria are not met

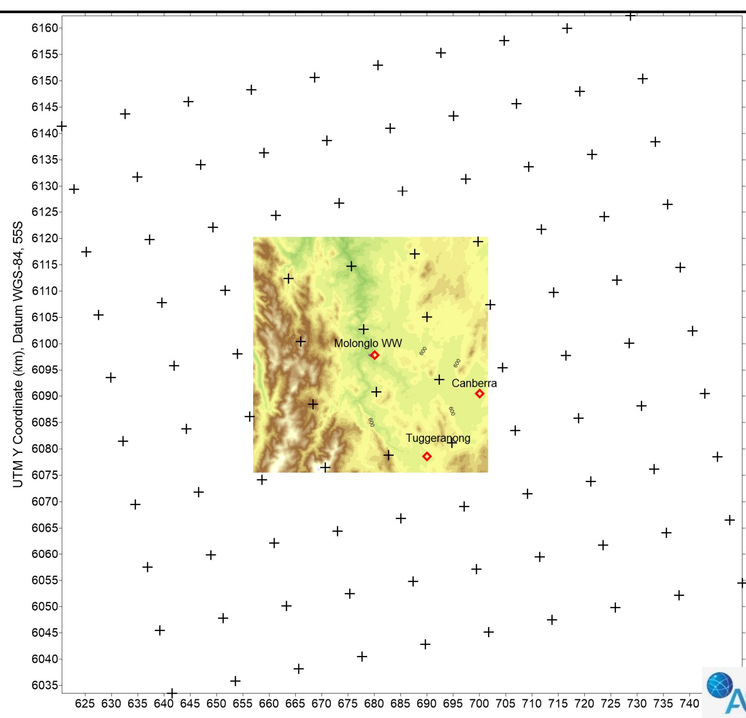
- Complex terrain
- Coastal regions/ land-water boundaries
- Overwater transport
- Inhomogeneous dispersion conditions
  - Changing Land use
  - Distance (> 10-20 km)
- Stagnation
  - Light wind speed dispersion, calm conditions
- Flow reversals
  - Land-sea breeze
  - Upslope/downslope, valley flows
- Recirculation

TERRAIN CHANNELED FLOW



10m WINDS IN A COMPLEX VALLEY SYSTEM





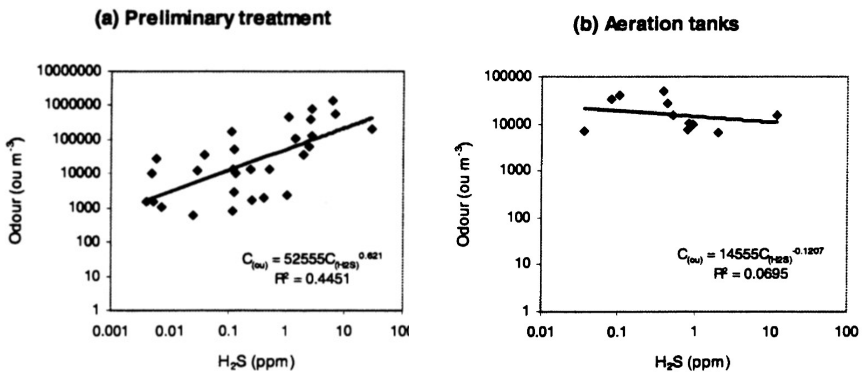
ODOUR COMPLEXITY

- Mixture of compounds picked up by Olfactory cells. Olfactory nerve is connected to the Limbic system and **closely linked to emotions**.
- Most odours are a complex mixture of **chemical and VOC** compounds.
- The perception of intensity v.s. concentration is **a logarithmic relation**, not linear (increase conc. 10x = perceived intensity of a small amount)
- Interactions between mixtures of odours can occur – e.g., one odour can **mask or disguise** another (sunlight, O_3)
- As the conc. dilutes, the nature of the **odour may change** where a different compound can dominate (e.g. mushroom compost, pulp and paper mill)
- The perceived odour intensity is, in general, **not equivalent to the sum of the intensities** of each individual odour. It may be greater or less.
- Exposure can lead to **desensitization** - i.e., no longer detect the odour even if constantly present. Conversely, individuals may be highly sensitive through acute exposure or repeated exposure.
- 1 ou is the concentration of odorous gas that will elicit a D_{50} physical response of a panel under laboratory conditions

ODOUR AND HYDROGEN SULPHIDE

- Common misconception that odour from facilities is due to one compound
  - Perception that sewage treatment facilities / or landfill odour is only or mostly due to hydrogen sulphide
  - Many odour control facilities designed on H_2S alone resulting in poor performance
- Many studies have been done on the correlation between odour and hydrogen sulphide.
- Hydrogen sulphide and odour are linked for some process unit / types – but in some cases not at all.

ODOUR AND HYDROGEN SULPHIDE



ODOUR SAMPLING AND EMISSION RATE (OER)

Know the operation - both normal and abnormal operations

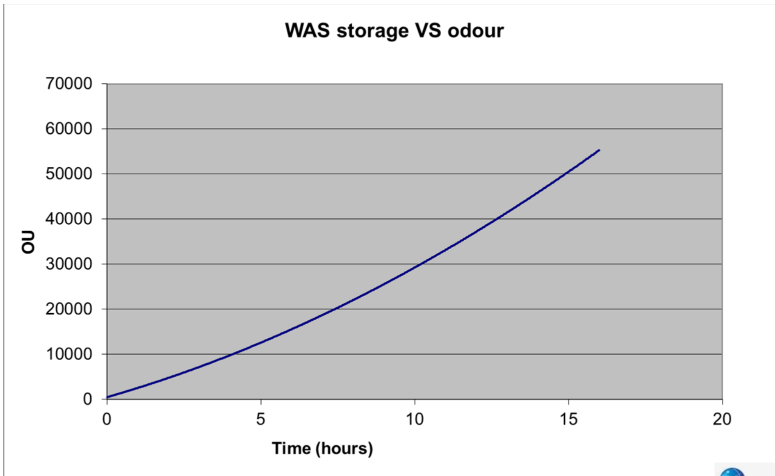
Know the workers – do they operate the plant differently

- Selection of sources
  - Audit the facility
    - Decide upon your sources
    - Don't rely upon other people to tell you what does or doesn't smell
    - Do measure the airflows and directions
- Be representative
  - Don't sample the v worst – or v best point of a vessel, try and get a representative sample
  - Know diurnal variations
  - Know how your process odour changes over time e.g. sludge storage
  - Take enough samples to verify the emissions. (One or two samples per process unit is statistically worthless leading to under design and inaccurate modelling)
  - H_2S and total VOC should be sampled and logged on a continuous basis for 7 days

Stantec, Odour Course, Brisbane March, 2018

ODOUR SAMPLING - VARIABLE EMISSIONS

- Bio solids processing, bio solids conveyance and bio solids cake storage all have ability to have temporally variable emission rates



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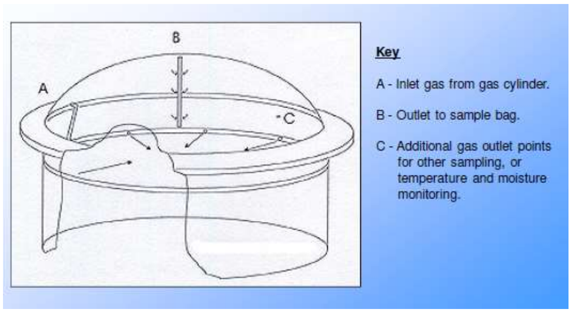
ODOUR SAMPLING - VARIABLE EMISSIONS

- Odour associated with dewatered sludge significantly higher than fresh WAS

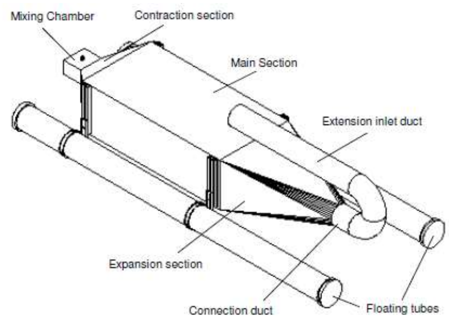
Parameter	Fresh WAS	Dewatered WAS	Dewatered WAS - 4 days
Hydrogen Sulphide	ND[1]	4.1	19
Mercaptans	ND[1]	2.5	12
Ammonia	ND[1]	0.91	ND
VOC	0.6	0.3	0.2
DMS	0.5	0.92	4.9

WAS – waste activated sludge
Stantec, Odour Course, Brisbane March, 2018

AREA SOURCE SAMPLING



Flux Hood
better for stable conditions



Wind Tunnel

can be adjusted for actual wind speeds and fetch lengths of the area sources.

AREA SOURCE SAMPLING

Comparison of wind tunnel hood vs isolation flux hood for a WWTP

WWTP source	Wind Tunnel Hood	Isolation Flux Hood	WT/IFH ratio
1	1.359	0.062	21.9
2	3.054	0.065	47.2
3	1.747	0.050	34.8
4	3.090	0.129	24.0
5	3.682	0.129	28.6
6	6.965	0.977	7.1
7	5.675	2.035	2.7
8	9.471	1.139	8.3
9	3.527	1.456	2.4

(from T Schulz, AWA Odour Master Class, Sydney 2013)

Up to 4-fold differences between isolated flux hood and tunnel hood

FUGITIVE EMISSIONS

REGULATORY MODELS FOR ODOURS

Plume Models	Lagrangian Puff Model
AERMOD – US EPA guideline model for near field applications (< 50km) (November 9, 2005) Appendix W 2017 also recognizes “AERMOD is limited”	CALPUFF – US EPA guideline model for all far-field applications (> 50km) and, all near-field applications in complex environments where the steady state assumption does not apply (April 15, 2003) CALPUFF – (Version 5.85) Removed from US EPA, Appendix W guideline model (January, 2017) Appendix W (2017) - states. The use of CALPUFF in the near field as an alternative model for situations involving complex terrain and complex winds **has not changed** by the removal of CALPUFF as a preferred model in Appendix A

REGULATORY STATUS OF ODOUR MODELS

- *Guideline Models* are pre-approved for designated uses in regulatory applications.
- *Guideline models* undergo an extensive, multi-year model assessment and evaluation process:

  - Evaluation of model performance relative to observations.
  - Requirements on model documentation, access and codes.
  - Open public review process at public hearings in Washington, DC.
  - Formal peer review committees created US EPA, professional organizations such as the A&WMA and private industry groups such as API and EPRI.

The amount of resources invested by the US EPA AQMG to persist with a model to guideline status **was large and was an effort beyond the means of modelling communities in almost all other countries around the world**

MODEL APPLICABILITY
STEADY-STATE (AERMOD) VS NON-STEADY-STATE (CALPUFF)

Feature	Steady State AERMOD	Non Steady State CALPUFF
Causality effects considered?	No – plume extend to infinity	Yes
Spatial variability of surface characteristics	Land use variability allowed in wind sectors centered at met. station	Full variability
Horizontal wind variability	None. Single station and uniform winds	Full variability
Calm winds	Not treated –	Calm winds treated
Mass accumulation during stagnation. Memory?	No. No memory of pollutants emitted during previous hours	Retains previous hours emissions
Coastal effects, fumigation, complex terrain	No coastal TIBL or fumigation algorithm, not suitable complex terrain	Full coastal effects Suitable Complex terrain

ASSESSMENT CRITERIA

- Averaging time, 3 mins to 1 hour
  - 3 minute avg time requires scaling 1-hour concentrations by 1.82
- Assessment criteria – 2 – 10 ou
- Maximum, 99.9% (9th highest), 99.5%(44th highest)
- Apply a peak to mean ratio that
  - Differs for a wake or non-wake affected stack
  - Differs according to stability
  - Is applied to all receptors downwind

CONCLUSIONS

•There are no disadvantages to modelling odours, but, there are difficulties

•Objective rather than Subjective

•Skilled odour personnel – as much about understanding community engagement as it is about technical abilities and modelling

•Dispersion modelling compliments other odour techniques (walk abouts, odour management plant, complaints etc)

•Quality of the output really depends on good input data – don't use model as a black box

•Essential for;

- •Odour assessment criteria at specific percentile limit
- •Design criteria, planning studies, buffer zones, site selection, optimize source layout, forecast tool