VOC and odour monitoring at remediation sites

IAQM Measuring Air Quality Conference, London, 28th March 2023

ATKINS
Member of the SNC-Lavalin Group

Definitions

Volatile organic compounds (VOCs)

- Group of chemicals with high vapour pressure/low BP, low water solubility (Koa), disperse in atmosphere
- Construction site sources include fuels, solvents, paints, building materials, cleaning products
  - *E.g. aromatic & aliphatic hydrocarbons, aldehydes, alcohols, ethers and esters*
    - *acetone, benzene, toluene, xylene, styrene, formaldehyde, tetrachloroethene*

Odours

- Can be caused by presence of VOCs in the air, complex mix of compounds which elicits a subjective response
  - *IAQM guidance "odour is not really an air pollutant at all; rather, it is the human olfactory response (perception followed by psychological appraisal) to one, or more often a complex mixture of, chemical species in the air. The chemicals are the actual pollutants and they may, or may not, have health effects at the concentrations that trigger an odour response."*
  - *All odours will (on average) be just detectable at 1 ou/m^3 but have different intensities, so at 2 ou/m^3, one may be considered "Very Weak" odour, while another "Distinct".*

What's the problem?

Residential properties, multiple sources

- Uncontrolled disposal means a lot of known unknowns
- Pollution can be very "evident" as odours
- Industrial legacy areas more deprived/poorer health

Remediation phase can last months/years

- Several hundred thousand cubic metres of earthworks
- Range of activities (degas/water/sludge, excavate, treat, transport)

Limited guidance on what where, how, when

- Planning addresses NO_2 from traffic (LAQM) and dust (EPA)
- Contractor EMP addresses occupational health and nuisance
- Contaminated land focus on groundwater/vapours

Monitoring the issue

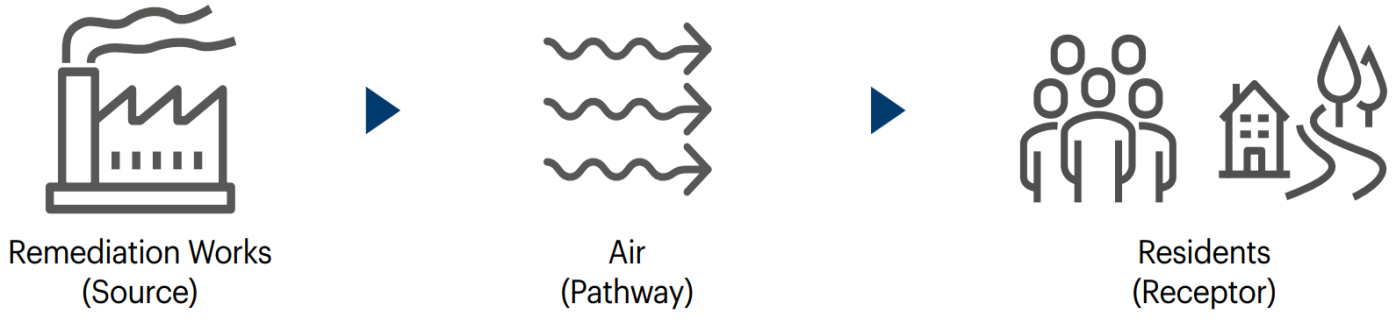
Problem - remediation of gasworks means clearing up contaminated land legacy but this can generate a new source of air pollutants which is not well understood

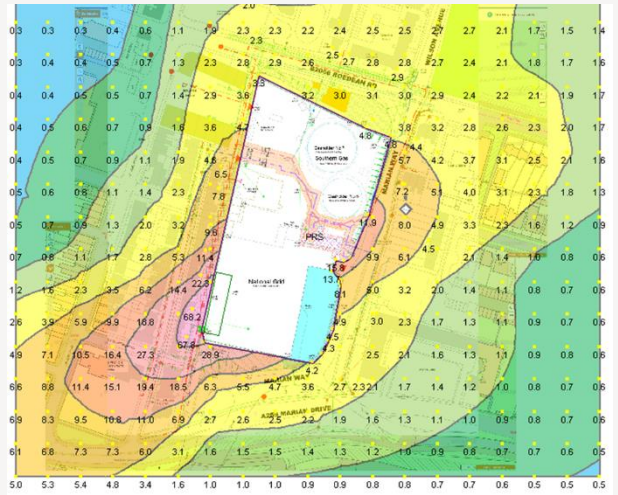
Solution – Multi-parametric air quality survey covering potential odour nuisance, direct/indirect health effects, operator EMS compliance, effective public relations

ATKINS
Member of the SNC-Lavalin Group

Assess the risk

Source > Pathway > Receptor – simple conceptual model





- Evaporation of VOCs causes odours at source, which then disperse in atmosphere, carried towards receptors
- Monitoring can be expensive (compared to NO_2 tubes at least) so needs to be proportionate
- Use hypothetical modelling to estimate areas at greater risk, inform monitoring locations, extrapolate boundary results
  - *Other factors e.g. rainfall are important, as act as a natural dust/odour suppressant*
  - *Not just one "prevailing wind", calm conditions can cause vapours to build up prior to dispersion*
  - *Consider height differences between source and receptor*

Multiple remediation site pollutants

DNAPL (dense non-aqueous phase liquids)
- E.g. transformer/ insulating oils containing PCBs, coal tar, chlorinated solvents TCE and PCE.
- Denser than and only slightly soluble in water so exist in subsurface as a separate phase

LNAPL (light non-aqueous phase liquids)
- E.g. petrol and heating oil
- Less dense than water so migrate deep below water table and dissolve into flowing groundwater.

Aromatic hydrocarbons

- Benzene, toluene, ethylbenzene, xylene
- Naphthalene, benzo[a]pyrene, styrene, phenanthrene
- Trimethylbenzenes

Aliphatic hydrocarbons

- Octane, nonane, decane

Aldehydes

- Formaldehyde

Chlorinated compounds

- Tri/tetrachloroethane
- Dichlorobenzene

Multiple sources & locations

Material handling and storage

- Excavation and treatment of impacted soil (on/off site)
- Removal of historic tanks, the unexpected
- Stockpiles and transport within/off site

Degassing, dewatering and desludging of gasholders

- Below ground contamination, from historic storage of gas

Generators, machinery, mobile plant/deliveries

- Combustion pollutants within and beyond site boundary

Even the mitigation itself

What good is monitoring?

An air quality survey – of VOCs and odour - during remediation provides:

1. Understanding of potential **direct** effects from exposure to chemicals at a complex site
    a) **Health** impacts - different techniques for short and long term exposure
2. Understanding of potential **indirect** effects from exposure to odours from range of sources
    a) **Nuisance** issues – strong odours can cause annoyance due to loss of amenity
    b) **Wellbeing** issues – continued exposure to low level odours can cause anxiety
3. Developing good client, community and regulator **relations**
    a) Satisfies **planning** requirements (if set), keeps regulators informed of risk
    b) Informs **contractor** site planning, selection of mitigation, response to changing conditions
    c) Sharing data increases **transparency** and improves credibility within community

Develop an effective strategy

Multi-faceted, multi-location, multi-parameter, multi-period!

- Range of techniques – subjective, active, passive, continuous
- Range of locations - to understand dispersion rate, other sources in area
- Range of pollutants - to compare to different guidelines/thresholds
  - *occupational, nuisance, direct toxicity*
- Range of timescales - GI/planning stage, earthworks/GH demolition

Multiple contractors and stakeholders

- Engage early for agreement to approach
- Safe, secure and continued access to improve data capture
- Templates for record keeping to help interpret data and react promptly
- Record activity information and PID readings to support survey data
- Communicate programme and changes to active areas/techniques

Multiple parameters

Individual VOCs

Passive sampling

- Tenax on boundary, within/beyond site
- Measurements before, during and after works
- Compare to mid / long term average criteria (week/mth/yr)
- TPH, BTEX, naphthalene etc, or full VOC suite

Active sampling

- Useful if activity v odorous and winds unfavourable.
- Up- and downwind in parallel AND at source to understand effectiveness/rate of dispersion.
- Compare to short-term (1/8/24 hour) criteria
- Compare against odour thresholds

Total VOCs

Continuous

- Real-time data on site boundary
- No direct means of interpreting against health criteria
- Shows change over time e.g. particular activities

Ad hoc

- Handheld PID readings at source
- Use to support occupational and odour alerts

Odour

Sniff testing

- Description of character, consistency, etc., VDI scale
- Multiple recordings & locations, each 5 min test
- Record all odours, not just “gasworks”, as evidence

Multiple techniques

VOCs

Total VOCs - continuous, by PID or electrochemical cell

- Non selective method, UV ionises all compounds if IE < 10eV, calibrated to IBE
  - *Handheld at workface, handheld PID, should overestimate cf. benzene*
  - *Boundary monitoring, fixed locations, more sensitive/accurate units*

Individual VOCs – non automatic*, adsorbent tubes, passive or active sampling

- Tenax ATD commonly used, sent to laboratory for GC-MS “fingerprinting”
- Compare results with a range of guidelines (chronic and acute health effects, odour)
  - *Does not give an immediate response but can detect low ppb*
  - *Apply factors to extrapolate to different exposure periods for health impacts*

Odours

- Human nose – Sniff testing to identify odours within/beyond site, **daily basis**
- Electronic nose – artificial olfactometric systems, continuous readings, calibrate first

[**Mobile GC is available but prohibitively expensive*]

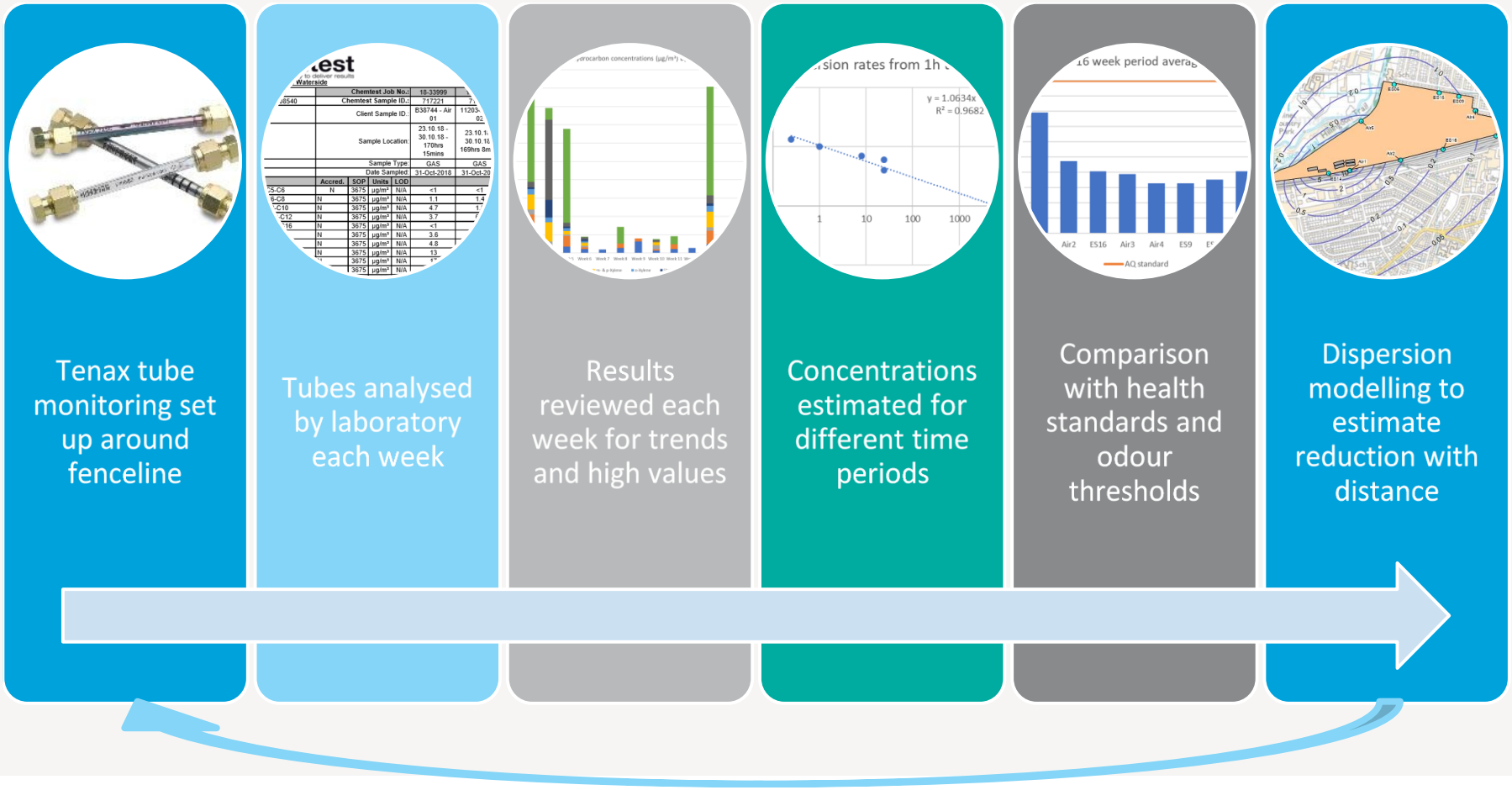
Interpreting findings

Problem – mix of pollutants, different techniques, timings, purposes

Solution – develop site specific action levels, correlate different results to identify source

ATKINS
Member of the SNC-Lavalin Group

Piecing it all together...



Assessment criteria and thresholds

Regulated air quality standards for protection of public health (off site)

- Benzene (AQS) annual mean 5 µg/m^3 , naphthalene (PHE) annual mean 3 µg/m^3
  - *Other regulatory guidelines over range of time periods, may be more appropriate (weekly/daily)*
  - *E.g. EA permitting guidance, US EPA MRL for acute benzene exposure 30 µg/m^3 , HSE, PHE*

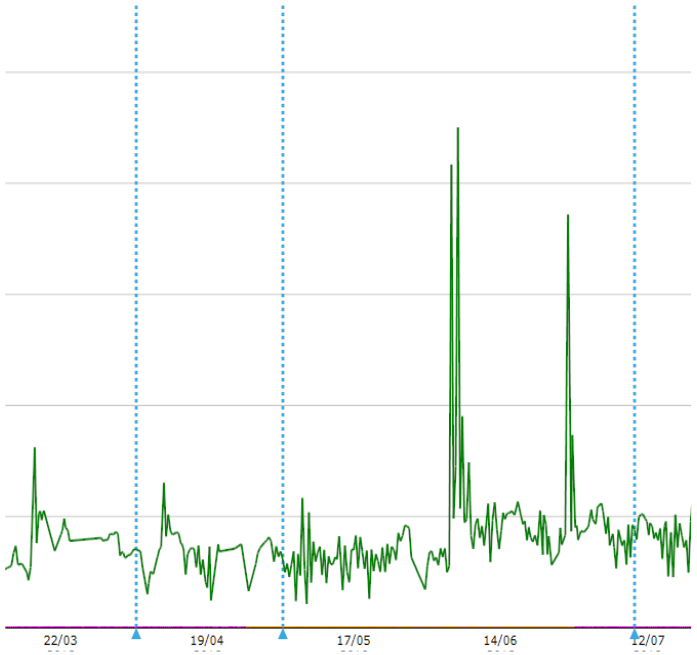
Site alert levels (SALs) – thresholds as indicators for potential health impacts

- Total VOCs 1 ppm over 15 minutes (1ppm = 8 hour WEL for benzene, so highly conservative)

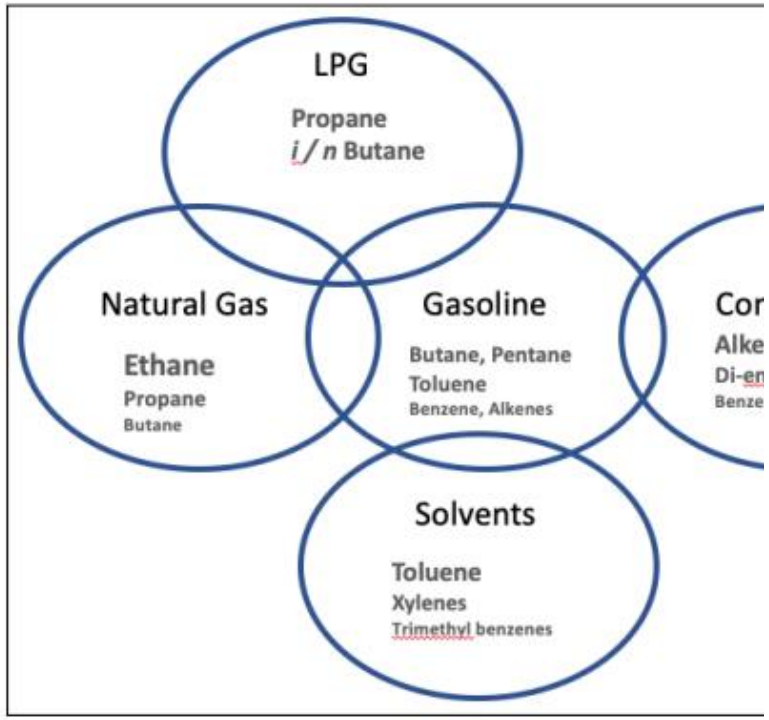
Odour VDI intensity

- Odour intensity of 4 indicates strong odour, action required if 4 at/beyond boundary so 3 is precautionary
- Odour annoyance can arise from transient exposure. Extrapolate Tenax concentration data to evaluate odour complaints, using a factor to approximate short-term concentrations to compare to odour detection thresholds (ODT) (roughly an order of magnitude to estimate a ~ 10 minute average from a 1 week measurement).
  - *E.g. naphthalene > 3 µg/m^3 as a 1 week average may indicate odour identifiable beyond boundary at sensitive receptors, given a lowest published ODT of 40 µg/m^3*

Examining total VOCs



Check timing of total VOC peaks to see if correlates with site activity



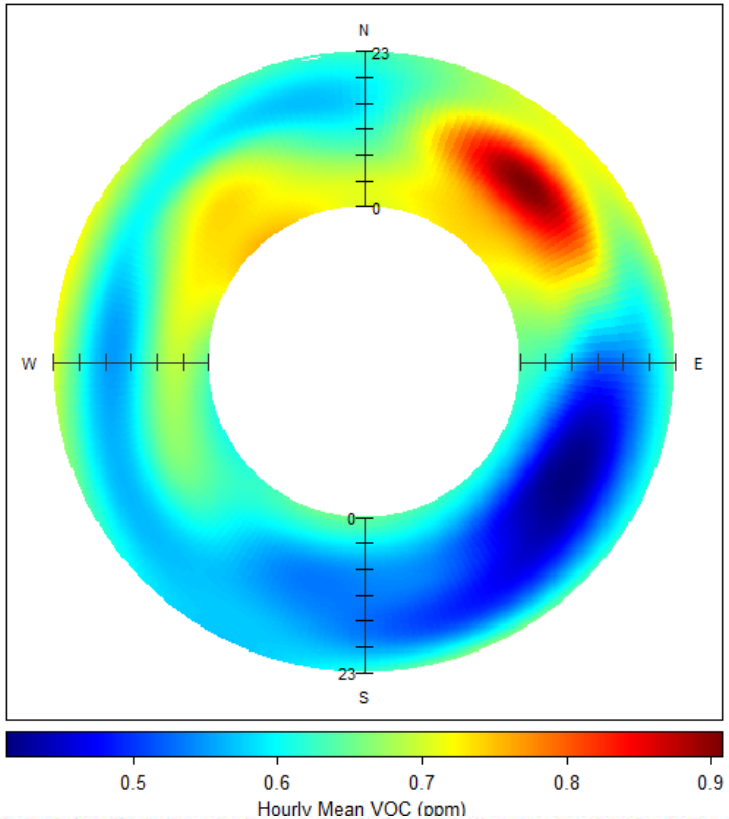


Figure 1. Some major contributing emission sourc current Defra automatic network. Overlapping sectors indicates where VOCs that are common to multiple sources exist, and size of text indicates relative magnitude of emission from that source for each VOC.

What's the source?

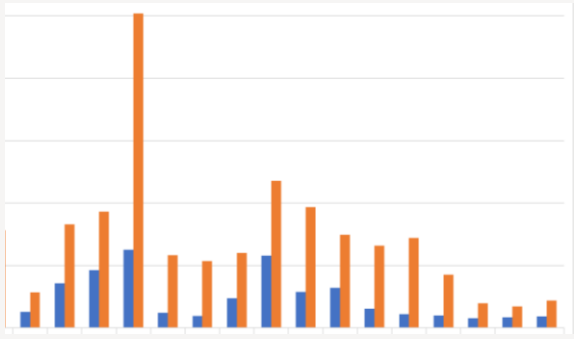
Examine differences by location, time period, pollutant, odour records

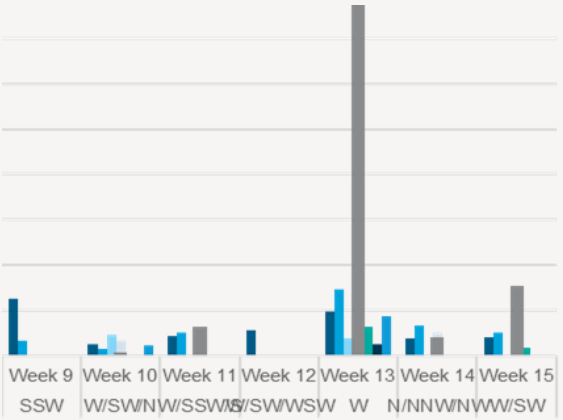
BTEX ratios

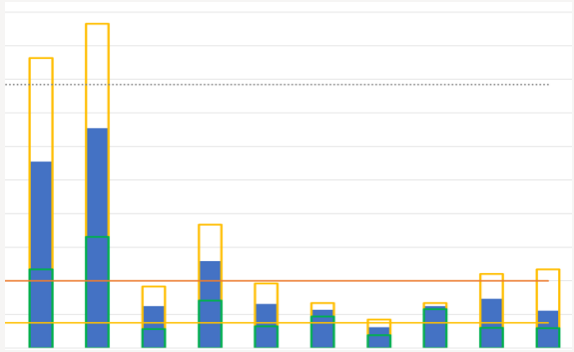
- T / B <1 likely traffic (benzene use is restricted)
- T / B >2 other source (industry/solvent use/paint)
- m-p-X / E <3.8 suggests recent emission source

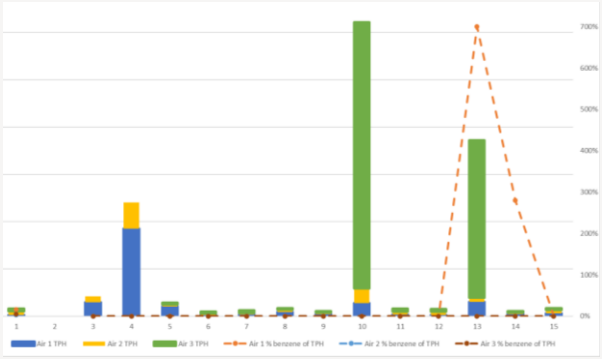
Non-gasworks

- C4-C7= Unburnt gasoline in exhaust
- Long chain alkanes = Diesel generator
- Alcohols = deodorant/perfume
- Pinene/cymene/limonene = deodorant/food
- TCE = dry cleaning
- Benzene = asphalt production









Interpreting health effects

Individual VOCs

Ambient / indoor guidelines

- Compare to weekly/monthly samples, concentrations over a year *typically* lower
- Do boundary concentrations dilute with distance
- Check regional data for seasonal effects
- Indoor air guidelines are conservative approach

Acute effects criteria

- Hourly / daily standards for acute effects
- Use for pumped sampling findings
- Extrapolate from weekly measurements
- Use WELs and derive safety factor

Total VOCs

- Examine daily trend for clues as to emissions source
  - *E.g. 5am local industry? 7am traffic? 9am site?*
- Anomalous spikes (e.g. remote calibration) vs build up over time? Can significantly influence daily average
- SAL for an early warning e.g. 15min <1ppm (8h benzene WEL) or more conservative e.g. 0.5-0.7 ppm
- Assume all benzene for highly conservative approach or look at Tenax VOC suite to determine a fraction e.g. 1%

Odours

- Review findings alongside information on site activities
- Aromatic/sweet/acrid/rubber etc, can match to individual VOCs from Tenax findings to confirm source
- Correlate over time with wind direction, rainfall, temperature

Bespoke criteria to inform mitigation

Individual VOCs

- Tenax tubes give information after the event, but can still help confirm source, risk, future mitigation needs
- Workplace exposure standards give ballpark, derive factors to identify potential for public health effects
  - *International standards e.g. Germany, Canada, Japan may also be available*
- Work out what concentrations correlate with complaints – important for a sensitised population

SALs for early warnings

- Use real-time total VOC data as a relative indicator of change from a baseline
  - *E.g. increase at 9am, drop off at breaktime - a source being disturbed, may require mitigation*
- Daily visual/olfactory checks on-site and at boundary for dust and odour,
  - *Proactively use to mitigate - if strong odours at source, stop before discrete odours reach off-site*

Summary - pragmatic, proactive and responsive

- Multiple factors to consider, so plan carefully
  - *Dispersion modelling to estimate at risk, most sensitive areas*
  - *Regularly review to ensure right thing, right time, right place*
- Raise profile of monitoring with contractor and regulator
  - *Plan strategy in advance, start engaging early with all parties*
  - *Clear signage, ask for warning of excavations/fence moving*
- Sites are unpredictable, be prepared to change approach
  - *Sampling period, locations, programme, chemicals, SALs*
  - *Encourage proactive and responsive mitigation and reporting*

Always expect the unexpected!

Q&A

This presentation was based on ~5 years experience on several sites

There's a gap in guidance for best practice and no level playing field – do you agree?

IAQM and IES Land Condition Community support the need for cross-discipline guidance for practitioners in air quality and contaminated land

What is your experience?

- Are you coming across more planning officers asking questions/setting conditions for VOCs?
- If conditions are set, does the requirement for CEMP/EMP go beyond odour?
- What kind of VOC/odour monitoring techniques are you applying/specifying?
- What criteria do you use? What pollutants, time periods?
- What existing guidance do you refer to, if any? E.g. IAQM, EA, CLAIRE, CIRIA, BRE?

Acknowledgments

Thanks to:

Developers

Contractors

Regulators

Equipment suppliers

Colleagues, past and present

Royal Holloway MSc student