Good Practice on Air Quality Monitoring for Brownfield Projects

October 2025 (Version 1.0)

www.iaqm.co.uk

Contents

Acknowledgements

Acknowledgements: This guidance was developed by the Institute of Air Quality Management (IAQM) with the support of members of the Land Condition Community of the Institution of Environmental Sciences (IES). This 2025 guidance was produced as a result of the voluntary contribution of the members of Working Group, for which IAQM is very grateful.

Lead author: Sarah Horrocks

The members of the working group are:

- Sarah Horrocks (Chair)
- Jonathan Atkinson
- Prof Claire Holman
- Dan Maher
- David Rudland
- Dominic Young

The IAQM thanks all members who contributed to the review process. Thank you to the Berkeley Group for permission to use the case studies included in the guidance.

Disclaimer: This Guidance represents the collective view of the IAQM and IES Land Condition Community, and not necessarily those of individual members. All have commented in their personal capacities.

The Institute of Air Quality Management (IAQM): IAQM aims to be the authoritative voice for air quality by maintaining, enhancing and promoting the highest standards of working practices in the field and for the professional development of those who undertake this work. Membership of IAQM is mainly drawn from practising air quality professionals working within the fields of air quality science, air quality assessment and air quality management.

Date: October 2025

Editor: Bea Gilbert

Graphic Design: Aoife O'Connell (aoife.oconnellm@gmail.com)

Cover image: © Sarah Horrocks.
Excavated material within a brownfield remediation site in London, with housing in the background.

Contact: IAQM
c/o The Association for Laboratory Medicine
130-132 Tooley Street
London
SE1 2TU

T: +44 (0)20 3862 7484
E: info@iaqm.co.uk

1. Introduction

1.1 Brownfield development

Brownfield sites offer many opportunities for re-use of inner-city land and urban expansion and a "Brownfield First" approach is advocated in UK planning policy. This can require substantial intervention to clean up contamination (in particular, hydrocarbons and chlorinated compounds) which if left in situ, can leach into land, groundwater and surface water.

The term remediation is often used to describe the clean-up of ground contamination. In this guidance, remediation refers to the actions taken to deal with the ground or soil underlying a site, to render it suitable for future use and to prevent risks of contamination affecting health and the environment.

During remediation, the same substances affecting soil and water can be released to the atmosphere. These can have a range of effects on human health, amenity and the environment. Legislation exists to prevent such emissions, including odours; however, brownfield remediation strategies do not consistently address the full range of impacts of odours and other air pollutants. It is important that these aspects are robustly considered for any brownfield project, using good practice monitoring methods and appropriate scrutiny of the results.

Through the authors' work on several remediation sites in recent years, it has become clear that there is increasing public awareness of and concern regarding the health risks associated with air quality. While there is substantial guidance on soil, groundwater, vapour and dust monitoring, there is a gap in the available guidance for ambient air pollutant monitoring beyond that undertaken for environmental protection and land use planning frameworks. There is no standardised methodology for the monitoring of contaminants in ambient air specifically during remediation of brownfield sites, and there are limited available criteria against which the effects can be assessed. Often, the direct impacts of exposure to chemicals on site are focused on occupational health concerns, while monitoring of offsite impacts focuses on odour and dust. This can mean some potential indirect impacts on public health are overlooked.

Setting of requirements through the planning regime, and once remediation is underway, can be inconsistent due to knowledge gaps between the contaminated land and air quality disciplines; by this stage it may be too late to make material changes to the remediation strategy to limit exposure. Furthermore, planning conditions do not always cover this aspect meaning that monitoring programmes vary widely.

Box 1.1 – Why this guidance is needed

Understanding the composition of emissions from a remediation site is important so that direct human health effects can be evaluated at offsite receptors, as well as the impact of odour on amenity. This is important as chronic effects can occur at low concentrations over often long periods of remediation. Mental wellbeing aspects resulting from anxiety, which can be caused by unusual or unknown chemical odours, also need to be considered.

Such effects are likely to occur below a level that may typically have been considered an issue, either because only the strongest of odours are considered a potential nuisance, and thus are mitigated, or because continued exposure over time can result in desensitisation.

1.2 Purpose

This guidance aims to improve collaboration between those working in the air quality and contaminated land disciplines, be they consultants, developers, or regulators, and to increase understanding of interactions between topics.

It describes best practice in the monitoring of air pollutants, including individual compounds and the odours that they contribute, on remediation sites and assists in complying with the regulatory framework which governs remediation activity.

It provides suggestions for comprehensive analysis against a wider range of criteria to protect the health of communities during remediation; outlines recommendations for communicating risk to stakeholders and provides an overview of mitigation techniques.

The intention is to provide readers with examples of good practice for designing and undertaking ambient air quality monitoring on remediation sites and other types of brownfield sites. While it focuses on emissions of volatile organic compounds (VOCs), many of the principles described can be applied to other volatile airborne pollutants resulting from remediation of land contamination, which can have associated health effects and/or odours.

An overview of the stages of a remediation project and where to go for guidance within this document is provided in Figure 1.1.

There are some areas that this guidance does not cover, which are:

- Particulate matter/dust monitoring (covered by other IAQM guidance[1]);
- Occupational exposure and health and safety;
- Vapour intrusion into buildings; and
- Asbestos.

This document can be applied to different kinds of remediation projects where there may be emissions to air (e.g. sites for redevelopment in the planning system, permitted sites such as landfills, voluntary site cleanup outside the regulatory framework). It points to what good practice looks like to help specialists apply their professional judgement when designing, undertaking and/or reviewing bespoke monitoring surveys. It is intended to be scalable, giving examples of good practice rather than being prescriptive as this would not be possible given the wide range of site types. Where there is flexibility, this is intentional.

Box 1.2 – Aim of this guidance

The aim of this document is to:

- Support and encourage collaboration between air quality, contaminated land and planning disciplines;
- Help IES and IAQM members, developers, contractors and regulators understand good practice in the design, development and management of robust monitoring strategies;
- Help local authorities review planning applications, and specify monitoring surveys;
- Improve the consistency and quality of air quality surveys and their interpretation;
- Ensure direct toxicity of exposure to airborne contaminants – as well as odour – is addressed using appropriate techniques and criteria;
- Improve communication with stakeholders, support their understanding of the data and ensure important elements are not overlooked.

Understand context
Sections 2, 3, 7

- Understand the site history, why remediation is required
- What are potential impacts on air quality and odour
- What are the pollutants of interest
- What legislation and guidance exists
- Who are the main stakeholders

Assess the risk
Section 2

- Review the remediation methodology and programme
- Consider existing data e.g. ground investigation data and meteorology
- Identify sensitive receptor exposure pathways
- Consider amenity, and direct and indirect health impacts
- Consider dispersion modelling

Plan & consult
Sections 4, 5, 7

- Design survey (locations, equipment, time periods)
- Propose site action levels, assessment criteria
- Undertake baseline survey
- Prepare stakeholder communication plan
- Consult on approach with local authority

Monitor & analyse
Sections 5, 6, 8

- Undertake a robust, layered approach
- Monitor total and individual VOCs, short and long term
- Analyse data promptly, and communicate reguarly
- Identify need for / changes to mitigation
- Review the approach frequently

Communicate & mitigate
Sections 7-8

- Use data to improve site practice
- Apply mitigation hierarchy
- Respond promptly to complaints
- Continue to monitor for trends
- Report to stakeholders

Figure 1.1 – Overview of remediation project stages and document wayfinder

2. Links between land and air

This section provides an overview of the common contaminants on brownfield sites. It outlines the source-pathway-receptor concept and explains:

- How pollutants move from land to air due to volatilisation;
- The key activities on remediation sites that can lead to release of emissions to air; and
- The differences between amenity/nuisance and health effects, and direct toxicity vs anxiety.

2.1 Definition of brownfield

The term "brownfield" encompasses a wide area and range of sites yet there is no standard definition. The European Brownfield Regeneration Network[i] defines brownfield sites as those *'that have been affected by the former uses of the site and surrounding land; are derelict and underused; may have real or perceived contamination problems; are mainly in developed urban areas; and require intervention to bring them back to beneficial use'*.[2] This broadly aligns with how brownfield land is defined in England in the National Planning Policy Framework (NPPF)[3] and in the Scottish Government's National Planning Framework 4 (NPF4)[4] i.e. land which has been previously developed.

Former gasworks, petrol stations, and chemical works are just some examples of brownfield sites in urban and suburban areas that require remediation; outside of urban areas, landfills are being reclaimed and repurposed to allow for new development. In particular, former gasworks and chemical works remain a significant source of environmental contamination due to the way waste material was disposed of in the absence of appropriate environmental legislation and poor practice in past decades.

2.2 Contaminants on brownfield sites

Contaminants may be present on brownfield sites due to leaks, poor environmental practice or intentional disposal. With such a wide range of sites falling under the definition of brownfield, there are several classes of contaminant that may be present within the soils and groundwater. These contaminant classes affect different receptors in different ways and, crucially, they have different physical and chemical properties which affect their transport within the environment and potential to enter the atmosphere.

When considering the potential for odour and health effects due to exposure to compounds in the atmosphere, this guidance primarily considers non-methane volatile organic compounds (NMVOCs, referred to simply as VOCs in this document) and to a lesser extent, semi-volatile organic compounds (SVOCs). VOCs (and in the case of some SVOCs) are defined by their volatility at standard temperature and pressure. These contaminants have historically been widely used on a variety of industrial sites and their mobility, solubility and volatility make them of particular concern in the risk assessment process applied to the UK contaminated land regime.

Some commonly encountered VOCs and SVOCs are shown in Table 2.1. Subgroups of VOCs of concern due to health effects include polycyclic aromatic hydrocarbons (PAHs), one of the most volatile of which is naphthalene. Naphthalene has a distinctive odour indicative of coal tar pollution detectable at very low concentrations. Some VOCs are classified by the International Agency for Research on Cancer (IARC) as known, probable or possible carcinogens. For this reason, some such as benzene have stringent ambient air quality criteria to reduce the health risk from long term exposure (See Section 5, assessment

[i] Concerted Action on Brownfield and Economic Regeneration Network (CABERNET)

criteria). Note, this is not a comprehensive list of compounds and their sources; historical site use, ground investigation data and site monitoring data should be reviewed to identify pollutants specific to the site in question.

Table 2.1. Description of some commonly encountered VOCs/SVOCs on brownfield land

Substance	Classification^	Source	Description
Benzene*	VOC Carcinogen	Commonly found in petroleum products and solvents	Sweet odour
Toluene*	VOC	Commonly used as a solvent in paints, adhesives, and other products	Sweet odour
Ethylbenzene*	VOC Possible carcinogen	Commonly found in gasoline and other petroleum products	Sweet odour
Xylene*	VOC	Commonly used as a solvent in manufacture of rubber, plastics, and other products	Sweet odour
Naphthalene	SVOC / PAH Possible carcinogen	Byproduct of the use of coal in the production of town gas	“Mothball” odour
Styrene	VOC Probable carcinogen	Primarily used in the production of plastics, resins, and synthetic rubbers	Sweet, rubbery plastic odour
Trichloroethylene (TCE)	VOC Carcinogen	Commonly used as a solvent in industrial processes, such as metal degreasing	Sweet odour
Perchloroethylene (PCE)	VOC Probable carcinogen	Commonly used as a dry-cleaning solvent	Sweet odour
Mercaptans (thiols)	VOC / organosulphur compound	Commonly arise at old landfill sites	Rotten cabbage odour

* Collectively referred to as “BTEX”
^ Based on IARC classification[5]

2.3 Exposure pathways

An approach that is commonly used in land contamination risk management (LCRM) in the UK[6] to estimate the likelihood of exposure to pollution is the “Source Pathway Receptor” concept. This informs the Conceptual Site Model (CSM) that is often produced at an early stage of ground investigation of brownfield sites but which does not necessarily consider the potential for and timing of exposure to air emissions during remediation.

The “Source – Pathway – Receptor” concept is shown in Figure 2.1. The constituent parts are:

- **Source** – a contaminant or pollutant that is in, on or under, the land and that has the potential to cause harm or pollution;
- **Pathway** – one or more routes by which a receptor is or could be affected by a contaminant;
- **Receptor** – could be adversely affected by a contaminant, e.g. person, organism, controlled waters/water environment, ecosystem, or other receptors such as buildings, crops or animals[ii].

[ii] Environmental Protection Act 1990 Part 2A. The contaminated land regime is one of the main policy measures used to deal with the legacy of industrial sites in the UK. It provides a means of identifying and remediating land that poses a significant risk to health or the environment, where there is no alternative solution

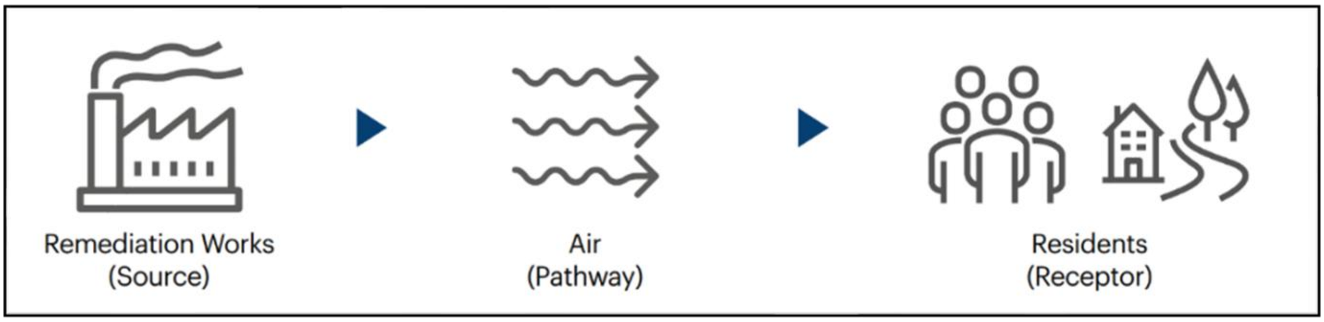


Figure 2.1 Source-pathway-receptor model

When all three of these elements are present, they form a "pollutant linkage" and thus a risk to the receptor. The UK contaminated land regime tries to address this risk by removing a source or pathway or by prohibiting exposure to a receptor with the idea of "breaking" the linkage.

Pathways linking contaminants in land and air include: evaporation from the soil followed by inhalation of contaminated air; migration from the soil into groundwater and ingestion of contaminated drinking water; direct dermal contact with contaminated soil.

This guidance is concerned with the inhalation exposure pathway in relation to sources of contamination which are in the ground and are disturbed, or sources that have been removed from the ground as part of remediation or reclamation activity and are thus subject to evaporation. Where pathways exist that link historic ground contamination with the outdoor atmosphere without any remediation work or other physical disturbance to generate vapours (i.e. vapour intrusion into buildings), this is addressed through the contaminated land framework and is not covered in this document. Similarly, individuals engaged in activities working with soils or groundwater which contain VOCs will be covered by mechanisms linked to health and safety in the workplace[iii].

Once released into the atmosphere, emissions disperse and dilute through vertical and horizontal mixing. The pathway for exposure to airborne pollutant(s) is primarily dependent on wind speed, direction, as well as temperature and the location of the receptor[iv]. The effectiveness of an exposure pathway depends on distance from and orientation between source and receptor as well as the source.

The presence of obstacles (such as buildings and barriers in between the source and receptor), meteorological factors (such as temperature, which may increase the rate of evaporation; and rainfall, which acts as a natural suppressant) may affect the dispersion pathway. For example, solid site security fences can increase concentrations in the lee of the structure, while reducing concentrations at receptors further away.

2.4 Sources of VOCs

VOCs are ubiquitous in the environment, being widely used in construction and building products, household consumer products, released from electronic devices or incomplete fossil fuel combustion processes. The presence of VOCs and

Box 2.1 – Sources of VOCs

Some examples of individual and groups of VOCs associated with different sources are:

- Short chain (C4-C7) alkanes - unburnt gasoline in exhaust
- Long chain alkanes - diesel generator/exhaust
- Alcohols - deodorant/perfume
- Pinene/cymene/limonene - deodorant/food
- Trichloroethene (TCE) - dry cleaning
- Benzene - asphalt production
- Toluene – paints and solvents

[iii] Health and Safety at Work etc. Act 1974 (legislation.gov.uk)

[iv] In the case of solid particles, size/density will also be a factor

the associated health risks inside residential and public buildings are well reported.

The IAQM has produced guidance on the assessment of indoor air quality[7] and there are published World Health Organization guidelines available for some indoor air pollutants (WHO[8],[9]) and specifically VOCs from Public Health England (PHE, now UK Health Security Agency, UKHSA)[10]).

The sources of VOCs addressed by this guidance are those related to activities undertaken outdoors to remove soils and groundwater impacted by VOCs or other chemicals of concern, from within the ground or work to separate those substances from the soil or groundwater in situ, i.e. remediation or reclamation.

Typical sources of VOC emissions to air on brownfield (and construction) sites include:

- Soil: which may be contaminated with VOCs, such as gasoline, oil, or solvents.
- Groundwater: when pumped to the surface for treatment, VOCs can be released.
- Equipment and machinery: operation of pumps, diesel generators, excavators.
- Underground infrastructure: legacy storage tanks and pipework.
- Waste disposal: if stockpiles of excavated soil are not properly managed.
- Soil vapour extraction: if the extracted vapours are not captured or properly treated.
- Chemical oxidation: injecting oxidizing agents into the soil to break down VOCs can also release VOCs into the air if the oxidizing agents are not properly contained, or may generate new odours where previously there were none.
- Breaching a clay layer, if the clay confines contaminated water;
- Emissions from infilled ground: decomposing waste materials.

Remediation activities that can generate emissions of VOCs and other compounds of concern include:

- Degassing, dewatering and desludging of old gasholders;
- Demolition and removal of buried, redundant underground infrastructure (tanks, pipework, foundations, drainage, conduits);
- Excavation of contaminated soils and groundwater for off-site disposal;
- Excavation of contaminated soils and groundwater for on-site treatment;
- Mitigation: some foams/sprays are perfumed and emit VOCs/odours; water treatment that minimises point vapour sources.

Remediation and enabling works often require physical excavation, handling, movement and storage of odorous materials on site:

- Cut and fill to remove material that is unsuitable for sensitive uses, i.e. as surface capping in gardens, but can be reused elsewhere as fill material e.g. gasholder voids
- Reduced level digs to bring the site to the required level, i.e. selectively choosing where to reduce site levels in order to target the removal of impacted soils
- Landfill mining (selective material recovery) or reprofiling closed landfill sites for stabilisation;
- Piling through treated material during the construction phase.

Each time contaminated material is disturbed (e.g. transferring an excavated bucket to a dumper, emptying dumper to a stockpile, loading to lorries) there is the potential for VOCs and odour release.

Some non-standard pathways include venting from drainage from discharge of contaminated water to foul sewer and wicking/chimney effects in buildings.

If uncontrolled, these activities could be a source of vapours and odours as well as dust. The strategy for monitoring those potential emissions during the remediation process is the focus of this guidance.

2.5 Health impacts

Emissions to atmosphere of VOCs and other compounds, even if at a low level, during what can be lengthy (several months or years) remediation phases, can pose direct and indirect impacts on health.

The direct effects to human health from VOCs can occur over short term (acute) or long term (chronic) exposure through inhalation.

The majority of VOCs are considered relatively safe if directly inhaled in trace (e.g. low parts per billion (ppb)) amounts[11]. However, some do have direct health impacts either on the respiratory system (lung irritants) or are cancer-causing agents (carcinogens) even at low concentrations, and therefore VOCs must be considered carefully. Exposure to some compounds can cause headaches, irritate the eyes and temporary wheezing. Normally, when the source is removed, the person recovers. Certain members of the population may be more vulnerable such as those with respiratory illnesses.

There are many different VOCs present in ambient air but not all undergo comprehensive toxicological studies. Where there is health information this may have been derived from only a small number of toxicological studies of the effects on animals or occupational exposure at high concentrations. This is only one element of the evidence of health effects required to establish both a causal relationship between exposure in air and a health endpoint, and a dose response relationship. A precautionary approach is advised.

VOCs also contribute to the formation of secondary pollutants such as ozone and fine particulate matter ($PM_{2.5}$), each with associated effects on human health. In fact, the focus of control of VOCs in ambient air has historically been to avoid the formation of tropospheric ozone and photochemical smog, rather than direct effects on health.

Indirect effects from exposure to VOCs can occur due to the presence of odours that may cause olfactory offence to communities in the vicinity. As a result of their volatile nature at "normal indoor" temperatures[v], many – though not all – VOCs have a characteristic odour, individually and when emitted as a group of compounds. The response that an individual has to an odour is subjective and can trigger strong reactions at a range of concentrations due to different sensitivities. The human nose has evolved to be able to detect chemicals at concentrations typically far below the threshold for toxicity. Pleasant odours can provide enjoyment and prompt responses such as appetite. However, unpleasant odours can be useful indicators to protect us from harm such as the ingestion of rotten food i.e. odours can act as a warning system.

The first reaction of local residents to a remediation site is often smelling an unfamiliar odour that raises concerns over its health effects. The presence of low concentrations of odorous compounds can affect the health of those exposed, as psychosomatic symptoms can develop in the presence of a perceived health threat. While such indirect effects are not considered an impact on human health in the Department for Environment, Food and Rural Affairs (Defra) (2012) EPA 1990 Part 2A Contaminated Land Statutory Guidance[12], such stressors are an additional consideration when considering the suitability for use of a given area of land. Therefore, it can be considered as an adverse impact in the context of the management of land affected by contamination. Such impacts should be considered in any risk communication strategy which accompanies remediation activity.

Odour annoyance can arise from repeated transient exposure; this is the case even if concentrations are only slightly above the odour detection threshold and can apply to pleasant as well as unpleasant odours.

The different routes and means of assessing remediation site pollutants and odours on and off site are summarised in Figure 2.2.

[v] Normal indoor atmospheric conditions of temperature and pressure refers to the range of conditions usually found in buildings occupied by people. Depending on the type of building and geographic location, this could be from 0 to 30 degrees Celsius and the pressure could be from sea level to the elevation of mountains. This is not to be confused with Standard Temperature and Pressure (STP). From https://www.epa.gov/indoor-air-quality-iaq/technical-overview-volatile-organic-compounds#overview

Box 2.2 – Amenity and health risks

It is important to understand the distinction between an odour that causes loss of amenity or annoyance, and the concentration in air of an odorous substance that represents a direct toxicological risk to health due to exposure of individual or a mixture of compounds associated with that odour. This difference can be understood by comparing odour detection thresholds with health-based concentration exposure criteria.

A substance which can be detected, i.e. smelt, can constitute an odour but this is different to the concentration in air which is a nuisance or injurious to health. It is equally important to recognise that the absence of odours does not mean exposure may not be harmful, for example in the case of benzene, a carcinogen with health thresholds at levels below odour detection thresholds.

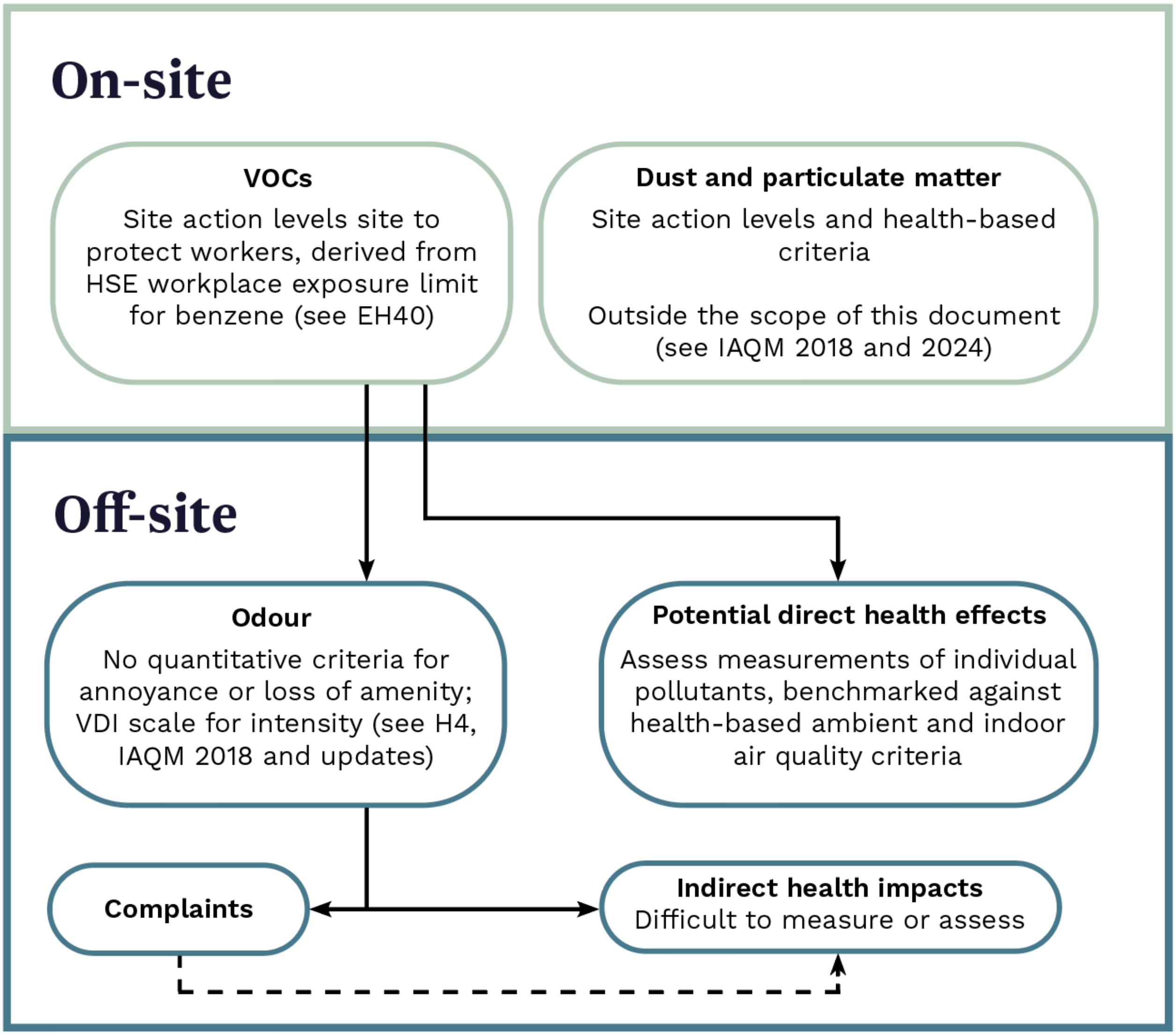


Figure 2.2 – Assessment of on- and off-site effects of emissions to air from brownfield remediation

3. Regulatory setting

This section gives a brief overview of the regulatory setting for this guidance, covering:

- Links between land contamination and air quality/odour regulation and where there are gaps
- Environmental Protection Act for controlling remediation activity and statutory nuisance
- The local air quality management regime and air quality regulations
- Planning (pre-commencement conditions, etc.) and permitting regimes
- Other sources of guidance and technical supporting documents

A list of the current (at the time of publication) regulations and websites is provided in Appendix C. Due to the changing nature of regulations, it is important to check for the latest updates online.

3.1 UK environmental regulations

Environmental legislation in the UK is primarily devolved to each of the four nations (England, Scotland, Wales, and Northern Ireland). This means that each can create their own laws. Although much environmental regulation is derived from EU and UK legislation, as time has progressed each nation has developed, and is developing, its own environmental policies and legislation to reflect national priorities. While the detail of regulations may be different, the fundamentals and principles (and often the assessment criteria applied) are essentially similar.

One example is Occupational Exposure Limits (OELs), specifically Workplace Exposure Limits (WELs), which apply to Great Britain (England, Scotland, and Wales). Northern Ireland has its own regulations, but they are often harmonised with those of Great Britain, meaning that WELs are approved for use in Northern Ireland.

3.2 Environmental Protection Act 1990

This document focuses on the UK, where regulation exists to protect people from contaminated land and nuisance through the 1990 Environmental Protection Act (EPA 1990).

3.2.1 Part 2A

The contaminated land regime under Part 2A of the EPA 1990 is one of the main policy measures used to deal with the UK's industrial legacy. It provides a means of identifying and remediating land that poses a significant risk to health or the environment, where there is no alternative solution.

Local authorities are required to proactively inspect land in their areas to identify and instigate remediation of those that pose a significant risk to health or the environment. In practice, this concerns land that is not being actively dealt with through the planning regime.

The methods for remediation are well established and regulated through this regime and are typically overseen through planning by the local authority land contamination officer who will verify that treated soils are suitable for reuse. In the UK, environmental regulators cover emissions from treatment activities covered by environmental permits, including mobile treatment plant. They are also non statutory consultees on remediation to the planning authority, but only in respect of the protection of the water environment.

3.2.2 Part III

Statutory nuisance is covered by Part III of the EPA 1990 as smoke, fumes, gases, dust, smell and noise etc. emitted from a premises.

For an odour to be defined as a statutory nuisance in the UK it must *"unreasonably and substantially interfere with the use or enjoyment of a home or* *other premises, or injure health or be likely to injure health"* (Defra, adapted from EPA 1990).[13]

A statutory nuisance includes *'any smell arising on an industrial, trade or business premises and being prejudicial to health or a nuisance'*.

The Act states that '*it shall be a defence to prove that the best practicable means were used to prevent, or to counteract the effects of, the nuisance*'. At the same time, odours may not constitute a statutory nuisance but can affect local amenity, as well as present either a perceived or indirect risk to human health, both of which can affect an individual's wellbeing.

Local authorities have a duty to investigate complaints about potential statutory nuisance. Where the local authority is satisfied that a statutory nuisance exists or is likely to occur or reoccur, an abatement notice should be served (although there can be some exceptions). This notice should set out the requirements for the abatement of the nuisance or prohibiting or restricting its occurrence or recurrence. The person served the abatement notice has 21 days to appeal. If they fail to comply with the requirements, they are guilty of an offence and can be fined.

Where a local authority decides not to instigate legal proceedings in respect of a nuisance complaint, an individual may make a complaint direct to the magistrates' court about nuisance. This might result in the court making an order prohibiting or restricting the activity generating the cause of that complaint.

Whether seeking to avoid statutory or amenity nuisance, using best practicable means (BPM) to control emissions from a brownfield remediation project is the sensible approach. How that may be defined is site-specific and relies on evidence from site assessments and showing good practice has been applied. To make a robust legal case, defendants will need to prove they have followed industry good practice and relevant guidance. The intention of this document is that it will be useful in that context.

3.3 National Air Quality standards

There are national air quality standards (NAQS) for atmospheric concentrations of one individual VOC compound, namely benzene was adopted into UK legislation from the EU Directive on Ambient Air Quality. In addition, a UK air quality objective for butadiene was introduced. These were brought in due to emissions from fuel vapours around petrol stations and unburnt fuel emissions from vehicles. These standards, expressed as annual mean concentrations not to be exceeded, have been transposed into national legislation.

Box 3.1 - Odour and nuisance

Odours associated with remediation activities can come from a variety of substances and become present in the environment via a variety of activities. Legislation (the EPA 1990) exists to prevent odours interfering with an individual's enjoyment of their property and to prevent exposures which may be "prejudicial to health".

Both of these aspects (offsite amenity and health) should therefore be addressed by the remediation strategy and monitoring programme for a brownfield remediation or reclamation project, as well as occupational exposure.

3.4 Environment Act 1995

Local authorities are responsible under the Environment Act 1995, for reviewing and assessing air quality with respect to the national air quality objectives (NAQOs). This regime, known as Local Air Quality Management (LAQM), initially addressed all regulated pollutants set out in the national air quality strategy (AQS) including benzene and 1,3-butadiene. Historically the latter were of concern around petrol stations and resulted in air quality management areas (AQMAs) being declared, although all such AQMAs have since been revoked. In recent years, LAQM monitoring and assessment has focused on nitrogen dioxide (NO_2) and to a lesser extent, inhalable airborne particulate matter (the fraction referred to as PM_{10}) as these two pollutants were found most at risk of exceeding the objectives.

The Air Quality (England) Regulations 2000 (2002 as amended), equivalent Regulations in Scotland and Wales, and 1997 Regulations in Northern Ireland, set pollutant targets which apply locally under the LAQM framework. These cover benzene and 1,3-butadiene.

However, NMVOCs are now mainly controlled under the National Emissions Ceilings Regulations at a national level, and subsequently are rarely considered by local authorities under LAQM or for planning decisions, unless they are regulated under the environmental permitting regime for industrial facilities.

3.4.1 Environment Act 2021

The Environment Act 2021 (EA2021) required the Secretary of State to set long term targets for fine particulate matter (the fraction referred to as $PM_{2.5}$) by regulation; these regulations were adopted in 2023. At the time of writing, the guidance on how to assess $PM_{2.5}$ in the planning system is yet to be provided by Defra however interim guidance has clarified that Applicants should provide evidence in their planning applications that they have identified key sources of air pollution within their schemes and taken appropriate action to minimise emissions of $PM_{2.5}$ and its precursors as far as is reasonably practicable[vi]. Local authorities are not yet under a statutory obligation to review concentrations of $PM_{2.5}$ in their area although they are encouraged to consider it in their LAQM reporting and review of planning applications. Some local authorities may adopt a position as part of a local air quality strategy, focusing on emissions reduction.

As VOCs can contribute to concentrations of secondary $PM_{2.5}$ which themselves may give rise to health effects (see Chapter 2) it is important emissions are minimised on remediation sites.

3.5 Planning

Most brownfield remediation projects, particularly those of significant scale, will be subject to planning controls and must therefore have regard to the relevant national policy framework (e.g. in England, the NPPF; in Scotland NPF4, and in Wales, Planning Policy Wales 11th edition). Planning policy decisions must consider compliance with the NAQS, and the Limit Values (derived from EU legislation and retained following Brexit), and these tend to focus on the key LAQM pollutants NO_2 and PM_{10}.

Paragraph 196 of the NPPF for England (2024) sets out that planning decisions should ensure that a site is suitable for its proposed use taking account of ground conditions and any risks arising from contamination. This includes risks arising from former activities and any proposals for mitigation including land remediation. Paragraph 199 supports opportunities to improve air quality or mitigate impacts where necessary, however the focus is on the development being consistent with local air quality action plans, which focus on NO_2 and PM_{10}. Subsequently this is the focus of most environmental impact assessment (EIA) chapters for air quality.

Planning conditions may be specified by the Local Planning Authority (LPA) to any grant of planning permission. These are used to enhance the quality of development and ensure adverse effects are mitigated. Conditions for brownfield sites often set out specific obligations in relation to how the site

[vi] Interim guidance (October 2024): https://uk-air.defra.gov.uk/pm25targets/planning

should be remediated, and the amenity of the local community (noise, dust, odour etc.) protected.

Gaps exist in the explicit requirements and expectations of an air quality assessment for planning, and for air quality management / monitoring for a brownfield site. This is exacerbated as different local authority departments will review different aspects of the developer's application with specific pollutants and pathways in mind; the air quality assessment for planning will typically focus on the LAQM-regulated pollutants NO_2 and PM_{10}, with risks of dust and odour during construction captured under amenity but not direct or indirect health considerations; the contaminated land focuses on soil, groundwater and vapour risks.

As a result, the potential for off-site health impacts of VOC exposure from this stage of the works are not fully captured either at planning stage, or approval of management plans through planning conditions.

The following example is a planning condition which covers odour/nuisance but does not explicitly mention air quality/health effects during the remediation stage and so these may not be included by the contractor in their mitigation and monitoring programme:

"The approved works shall not commence until a plan for the management of emissions from the works such as noise, dust and odour has been submitted to, and approved in writing by the Local Planning Authority. (Reason: To ensure that the proposed construction work does not cause undue nuisance and disturbance to neighbouring properties)".

Limits may be placed on emissions from specific construction site activities. In response, the developer would be expected to present to the LPA an environmental management plan covering the work in question. This might typically refer to measures to control and measure dust and odour, NRMM emissions and noise and vibration. The work would not commence until the details of the plan had been agreed with the local planning authority (LPA).

Box 3.2 – Planning conditions

A recent increase in community (and subsequently LPA) awareness of the emissions from remediation sites in London has led to the development of some more comprehensive odour management strategies that also consider these health risks. For example, some local authorities now request an outline odour management plan in advance as a pre-commencement condition prior to remediating the site. An appropriate developer's response to this may be a risk assessment to identify sources on the site and an appropriate air quality monitoring strategy that includes long-term boundary monitoring of individual VOC compounds in addition to the standard on-site checks against occupational health guidelines for short-term exposure.

The control of odours is often required as part of the environmental planning permission or permit where required to perform a remediation activity and, where remediation trials are undertaken under an exemption such as that allowed by Regulatory Position Statement (RPS) 215[vii], compliance with the RPS requires that odours are managed.

Many schemes also have limits set on the working hours to reduce the impact of building work on people living in the vicinity. These working hour limits help to reduce the time when emissions and noise from site work may be generated but do not avoid the passive release of air pollutants from continuous sources such as open excavations and stockpiles.

[vii] Environment Agency regulatory position. Treat small volumes of contaminated soil and groundwater (RPS 215)

Figure 2.2 in Chapter 2 illustrated the multi-factor air quality issues that need to be considered to protect both the amenity and health of local residents. The IAQM considers it good practice for a remediation site application to include an assessment of both air quality and odour impacts in the planning submission, with appropriate planning conditions explicitly requiring an air quality and odour management/monitoring plan (AQOMP), which may be incorporated within a Construction Environmental Management Plan or similar. This management plan should also include dust and particulate matter (outside the scope of this document). The AQOMP should be a pre-commencement requirement and approved in writing by the appropriate specialists in the local planning authority.

3.6 Environmental Permitting

The Environmental Permitting (England and Wales) Regulations 2016 (as amended) (EPR) (and equivalent permitting regimes in Scotland and Northern Ireland), are covered by the Environment Agency (and equivalent organisations) for the most complex premises, with smaller or less polluting activities permitted by local authorities. The regulations require a risk assessment of air emissions for all relevant industrial facilities, including point sources (stacks) and diffuse sources (areas, e.g. open tanks).

An Environmental Permit for an odorous industry will typically contain the following condition:

"3.3.1 Emissions from the activities shall be free from odour at levels likely to cause pollution outside the site, as perceived by an authorised officer of the Environment Agency, unless the operator has used appropriate measures, including, but not limited to, those specified in any approved odour management plan which identifies and minimises the risks of pollution from odour."

A permit is also likely to contain emission limit values where there are point sources (exhaust or vent stacks) that emit pollutants to atmosphere, either for individual pollutants or total odour.

3.6.1 Permitting guidance

The Environment Agency's risk assessment guidance (2025)[14] (which is also applied in Wales, Scotland and Northern Ireland) includes a range of ambient air assessment criteria (environmental assessment levels (EALs), see Chapter 5) for use in environmental permitting. An operator is required to select and produce an assessment against the relevant criteria to determine whether their emissions to air are potentially significant and need further investigation and/or management.

As regulators of industrial activities that can emit odorous compounds to atmosphere, the Environment Agency and Scottish Environmental Protection Agency (SEPA) publish guidance[15], [16] to support applicants in their risk assessment of the permitted activity. These documents provide useful advice on the management and assessment of odour, including the contents of an odour management plan.

The Environment Agency also provides operators with guidance[17] on ambient air monitoring techniques and standards, including VOCs and odours.

3.7 Technical Guidance

3.7.1 Land contamination guidance

The UK Government's LCRM guidance considers how risks from contaminated land can be managed through remediation to enhance health and wellbeing. It mentions the importance of managing new land and groundwater pollution, and discusses the need for odour (and dust) control during the remediation stage but does not explicitly discuss air emissions.[18]

3.7.2 IAQM guidance

Environmental Protection UK (EPUK) and the Institute of Air Quality Management (IAQM) 'Land-use Planning and Development Control: Planning for Air Quality' (2017, update due in 2026)[19] provides an approach for air quality to be considered and assessed in the planning and development control regime. It focuses on combustion emissions and provides screening criteria for deciding when further assessment is required and gives advice on how overall significance may be assessed using professional judgement. The assessment of emissions from vehicles is outside the scope of this document.

IAQM guidance on the assessment of odour for planning (2018, update due in 2026)[20] provides a framework for risk assessment of odours at the planning stage. It is for intended for assessing odour for planning purposes and not environmental protection regulatory purposes permitting although it may be used for nuisance investigations. It addresses the amenity aspects of odour rather than health impacts. It is important that for a remediation project – be that at planning stage or once on site – monitoring and management plans cover amenity and nuisance as well as potential direct and indirect effects on human health, with appropriate monitoring and management developed and updated regularly during remediation.

IAQM guidance on the assessment of dust from demolition and construction (2024)[21] describes an approach to assessment, management and mitigation of emissions from dust generated from construction. This framework for a risk-based approach to the assessment of dust emissions from demolition and construction land development schemes is widely applied. The guidance outlines options for mitigation depending on the level of 'dust risk' identified. There is accompanying IAQM (2018) guidance on air quality monitoring in the vicinity of demolition and construction sites, some of the principles of which also apply to odour (in particular, continuous monitoring, see Section 4.4).

3.7.3 Defra guidance

Defra's Local Air Quality Management Technical Guidance (2022) (LAQM.TG22)[22] describes methods concerning treatment and interpretation of monitoring data in relation to the fulfilment of duties under the LAQM regime. It is frequently applied by practitioners when undertaking air quality assessments and surveys for the purposes of supporting planning applications.

Defra's Diffusion Tubes for Ambient NO_2 Monitoring: Practical Guidance (2008)[23] is used in the absence of an international, European or UK standard method for diffusion tube monitoring of NO_2. It provides the basis for a common approach within the UK including good practice for site selection and data analysis, which is applicable to NO_2 Palmes tubes as well as other types of passive monitoring techniques.

In partnership with the British Standards Institution (BSI) Defra has developed PAS 4023:2024[24] which provides recommendations on selecting, deploying and controlling the quality of air quality sensor systems in outdoor ambient air.

4. Designing a survey

This chapter describes the key aspects of good practice when designing an air quality (VOC and odour) monitoring strategy (or supporting management plan) for a brownfield remediation project including:

- What, when, how, where and who to measure
- Contaminants of interest, odour, wind data, activity data
- Programming and timescales – before, during, after
- Range of different techniques (continuous, passive, subjective)
- Choosing relevant locations – source, boundary, receptor
- Who does what – contractor, consultant, regulator, consultation

4.1 Introduction

The measurement, management and mitigation of emissions during the remediation phase of brownfield sites is important to help developers and contractors keep concentrations of individual compounds and odours within acceptable levels for human health and nuisance. On larger sites, or those with a longer remediation phase, it is important that a specific air quality (including dust and odour) management plan be produced to give the issue due prominence with the developer, regulator and local community.

For a comprehensive and effective strategy, the developer and their contaminated land specialist(s) should collaborate with the air quality specialist(s) at an early stage e.g. when developing the remediation strategy and when preparing assessments for the planning application. This should include a discussion of the pollution sources (e.g. ground investigation findings), the types and locations of activities that are likely to be undertaken during the remediation (or reclamation) stage, potential exposure routes for atmospheric pollutants such as VOCs that could lead to public exposure and the location of sensitive receptors.

It should be clarified at the outset who is responsible for designing the survey, who will implement it, who will interpret the results and undertake quality control, who will communicate the survey findings and how often, to whom, and in what format.

Box 4.1 – Every survey is bespoke

There can be no "one size fits all" ambient air monitoring survey for a remediation project on a brownfield site. Each survey will be bespoke, based on local constraints, ground and wind conditions, duration and location of works, type of pollution sources and sensitivity of surrounding receptors.

The plan should be to gather an appropriate quality and quantity of data that is proportionate to the risk, meets commitments for communication and reporting, and allows for continual review to ensure the survey remains relevant. The plan should describe in detail how emissions to ambient air will be monitored, as well as how impacts will be managed and mitigated during the works.

This section draws on the professional experience of the authors and other monitoring best practice from published sources e.g. Defra (2008) for NO_2 diffusion tubes, Environment Agency online ambient air[25] and permitting guidance, and IAQM guidance for odour (sniff testing); IAQM for construction dust; CL:AIRE for contaminated land[26] as well as guidance from the United States (US) where several states have dealt with legacy industrial contamination.

4.2 Survey scope

The aim of an air quality monitoring survey should be to obtain results that are:

- Robust;
- Representative;
- Consistent; and
- Accessible.

When designing a survey, it is important to consider the purpose of the survey. Is it to:

- Address a planning requirement?
- Inform site management of emissions?
- Undertake an impact assessment against specific criteria?
- Alleviate concerns about amenity or health?

All of the above are equally valid motivators for designing a robust and comprehensive survey that covers the locations and pollutants of concern. This may require different forms of monitoring, reporting and communication. It is important that the survey is designed to be proportionate to the risk (including any perceived risks) but also that it allows for changes to be made in response to unexpected contamination over the course of the works.

An effective survey may need to be multi-faceted: multiple locations, multiple parameters, multiple time periods. It should encompass an appropriate range of:

- Techniques – e.g. active, passive, continuous, subjective;
- Locations – e.g. on site, boundary, off site (receptors and ground conditions);
- Pollutants – individual compounds (e.g. benzene, naphthalene, hydrogen sulphide); sub-groups of VOCs e.g. BTEX, PAHs; total VOCs (known as TVOCs);
- Magnitudes[viii] – ppm, mg/m^3, ppb, µg/m^3;
- Thresholds – e.g. direct toxicity, acute and chronic, statutory nuisance;
- Time periods – hourly, daily, weekly, annual;
- Timing – planning, ground investigation, earthworks, construction.

The survey should be designed by a suitably qualified professional, meaning someone who has experience in designing and managing ambient air quality surveys but who also has gained an understanding of the different sources of pollution from remediation sites through consultation with a contaminated land specialist to understand what and where pollutant sources are most likely to be, and with the developer/contractor to understand when those sources are most likely to be released.

Box 4.2 – What to consider in survey design

When designing a survey consider:

- Flexibility – range of locations (with alternatives to cover changing activities and access, on and off site source influence), concentrations, exposure periods;
- Calibration and maintenance – who by, how, how often (what if replacement equipment is unavailable or site access is restricted?);
- Quality control – use of competent, accredited laboratories with standardised, transparent methods and analysis (e.g. UKAS, MCERTs); minimise data losses; regular data validation;
- Bias and uncertainty – acuity testing for odour; use of field (travel) blanks; duplicate or triplicate samples to understand accuracy and precision.

[viii] Units of air pollutants and/or assessment criteria are measured and/or expressed in parts per million or billion, or milligrams or micrograms per cubic metre. Conversion between the two units requires information on ambient temperature, pressure and molecular weight of the pollutant. For benzene, 1 ppb = 3.2430 µg/m^3 at 20°C and 1013 mb (these are the reference conditions for reporting to the EU). Several online converters are available for different pollutants and conditions.

Survey design is best thought about well in advance of remediation works commencing, not as a reactive measure once odour complaints are received. It is challenging to design a representative survey that achieves reliable and dependable results that coincide with the highest risk elements of the programme, but this can be achieved by applying the right techniques at the right time. A good monitoring strategy will allow for flexibility and should be considered a live document that is frequently reviewed, to enable a response to emerging or changing conditions.

Box 4.3 – Survey outputs

Combinations of VOCs can smell very differently to their individual component odours, and the associated odour detection threshold (ODT) can also be different between individuals, populations and experimental methods. It is important to select a monitoring approach that can accurately capture and distinguish between the different pollutants and their effects, both toxicological and odour.

By adopting a robust approach to the selection of what compounds are measured and how, the survey results should help to understand:

- Human health effects as well as odour/loss of amenity;
- Short and long term, on-site and off-site impacts and effects;
- Mitigation requirements and their effectiveness.

It should be highlighted that a good survey is one that will stand up to scrutiny in court, if a site is taken to task for causing a problem. A robust monitoring strategy, and one well carried out on the ground, should assist in making a sound defence of BPM (Section 3.2.2). To ensure the proposed strategy for managing air quality and odour is suitably robust and representative of receptor exposure, that it captures the potential sources of pollutants and the main pathways in which they could be transmitted to atmosphere, it should be developed by air quality specialists in consultation with land contamination colleagues.

The approach to analysis and reporting (Chapter 6) and communication (Chapter 7) should be established early on, as an integral component of the monitoring strategy. Communications should cover interactions between the contractor and the developer, the developer and the regulator, and the developer and members of the public.

4.3 What to measure

To understand what contaminants are likely to be released and therefore what needs to be measured before works commence, it is important to review any historic site uses and, if available, review ground investigation reports. Land condition reports in particular hold useful information on concentrations of different contaminants, particularly VOCs, in soil and groundwater samples. Consider what compounds were detected, how frequently and at what concentrations. Is the contamination widespread across the site or more likely focused in one particular area, where processing or disposal activities were historically undertaken? Are the contaminants highly volatile and therefore more likely to evaporate in air at ambient or room temperatures or are they more likely to remain in the liquid phase? Examples of pollutants that may need to be covered by the survey scope were discussed in Chapter 2.

If little is known about previous site uses, or simply where there is uncertainty regarding what the likely range of concentrations will be at the start of the works, a wider range of compounds can be analysed for until confidence has been gained regarding the focus of the survey. For example, if deploying diffusion tubes (e.g. Tenax, see Section 4.4) a "VOC analysis suite" will need to be chosen before sending to the laboratory for analysis. Laboratories should offer a range of options for this, from targeted detection of single compounds of interest to a full screen of all compounds present on the tube. A more comprehensive analysis at the start of a survey is advisable.

A screen of the Top 20 VOCs present on the tube in the highest concentrations will provide the most prevalent compounds. It is also recommended to select for specific marker compounds every time e.g. BTEX and naphthalene for former gasworks. Starting with a complete screen at the outset may be needed if there are many unknowns on site and the most common contaminants are not yet established. Note that coal tar contains potentially hundreds of hydrocarbons, including light, middle and heavy oil fractions, anthracene oil and pitch, and not all may be captured effectively in a single VOC suite for GC-MS analysis. It is appropriate to increase or decrease the suite over time; use professional judgement based on the results obtained to date and planned works to determine whether this is appropriate.

The same principle can be applied during specific activities of concern due to potential for different, or greater quantities of, pollutants to be released to air.

If the duration of works allows, the focus of the survey can be refined over time, once initial results are obtained and there is more confidence regarding potential emissions. As well as there being many different types of contaminant sources on brownfield sites, these sources of emissions may change over time, and give rise to different ranges of individual contaminants with various associated health thresholds and odours. These may be experienced by different receptors at a wide range of concentrations, with different (and valid) responses at different points of the remediation programme.

4.4 How to measure

There are several methods for measuring air pollutants and odours, including direct and indirect methods, and quantitative and qualitative (subjective) techniques. Each of these has benefits and disbenefits: price, complexity, accuracy and immediacy of the results can all be important factors that influence the choice of technique. The relevance of assessment criteria over different time periods might influence which monitoring techniques are most applicable e.g. whether there is a concern over long and/or short-term exposure.

When selecting a method, or group of methods, consider what concentration ranges may be expected on site and where. For example, emissions of VOCs during excavation of heavily contaminated soil on a former gasworks site can generate concentrations in the atmosphere spanning several orders of magnitude. At the site workface this may be several ppm while at the site boundary and beyond, concentrations will tend to decrease to ppb. It is important to understand if and how you will cover these ranges and if in doubt, apply different monitoring techniques in different locations.

The best approach for an individual site will depend on the site-specific circumstances such as the historic use, duration of the works, proximity to receptors (i.e. the risk of exposure), the type and quantity of VOCs likely to be emitted from different activities (if known), and the objectives of the measurement (e.g. the regulatory requirements, criteria being applied). If this is not yet known or fully understood, then the survey should start in an investigative and precautionary manner and be refined over time as data are received and evaluated.

4.4.1 VOCs

Direct methods for monitoring VOCs involve the use of equipment such as gas chromatographs (GC) and flame / photo ionisation detectors (FID / PIDs), to measure the concentration of VOCs in the air. Indirect methods use sensor technologies, such as electrochemical sensors or infrared cameras, to detect odours and VOCs.

Fixed units for continuous monitoring tend to be more costly to run but may provide more accurate concentrations of VOCs than handheld. As these can automatically log concentrations every minute or so, it allows activities to be monitored in real-time which enables a contractor to quickly adjust their site activity if an action level is approached, applying mitigation or stopping an activity. In contrast, passive and active monitoring by diffusion tube techniques, handheld PID and odour sniff testing are relatively cheap methods but can provide very valuable information if conducted to a consistently high standard (e.g. Defra (2022), IAQM (2018), Environment Agency (2011), Health and Safety Executive (HSE) methods for the determination of hazardous substances (MDHS [27, 28]), international standards e.g. ISO16000-6:2021[29]).

When deploying diffusion tubes, there is a time lag between completing sampling and receiving the laboratory result, which will in turn delay a response and/or application of mitigation. For this reason, a layering of monitoring techniques is recommended: a real-time device may not enable assessment of whether a health threshold is exceeded but it helps inform the management of operations to mitigate emissions; a diffusion tube can provide information on whether a long term health assessment criterion is being achieved but is of limited practical use for site management particularly on short term projects.

The most widely used methods and their main advantages and disadvantages are:

- **Continuous monitoring**: real-time equipment that continuously measures total VOC concentrations, either directly by PID or indirectly by electrochemical sensor. Works best at higher (ppm) concentrations. The equipment can be set up to operate for a specified period and can be programmed to send alerts to the site team when the concentration exceeds a pre-determined threshold (site action level, SAL). Fixed monitoring methods are less practical on a complex remediation site where there is a requirement to move units around according to activity, but they can be used over the long term on a site boundary. Whether handheld or continuous, PIDs provide useful indicative data for TVOCs. Depending on the lamp's energy, not all VOCs may be measured; some will be under-estimated while others over-estimated. The measurement precision depends on the VOC used to calibrate the PID, which is typically isobutylene. Some PIDs can be calibrated to provide estimates for individual compounds e.g. benzene.
    - **Fixed FID/PIDs** – These units can be set up on the site boundary but need a source of power (though can be run using solar or battery power); they provide a wide range of detection down to ppb, which can be set according to requirements.
    - **Handheld PIDs** are often used as a "first responder" to indicate total VOC concentrations for worker exposure, for locating emission sources and for on-site evaluation of how effective a mitigation measure is. Provide ad-hoc, indicative readings with flexibility on location. Tend to be less accurate (often with a resolution of 0.1 ppm, but can be lower).
    - **Specialised PIDs** paired with gas chromatograph (GC), which have a short column with air as carrier gas, can provide real-time readings of individual VOCs. These are relatively high cost and may not be practical on all sites.
    - **Electrochemical sensors**: provide indicative measurements of total VOCs, and when used in arrays can be useful to detect a change of state in operating conditions as a process control but are considered less useful at ambient concentrations. It is recommended to compare measurements against a PID.
- **Diffusion tube monitoring**: thermal desorption (TD) tubes provide relatively reliable data on a range of individual VOCs at low (ppb) concentrations. A commonly applied method is passive or active sampling onto a special sorbent

medium (e.g. Tenax, charcoal)[ix] followed by gas chromatography coupled with mass spectrometry (GC-MS) at a specialist laboratory to speciate individual compounds or groups of compounds of interest. The results for individual VOCs can be compared to a range of human health guidelines (see Chapter 5).

- Passive samplers can be fixed to the site boundary or at receptors and exposed for a predetermined period (typically 1-2 weeks, can be up to 4 weeks if ambient concentrations are very low), after which they are collected and sent off for analysis. This is a relatively cost-effective and flexible solution and depending on the number of locations, it can provide good spatial and temporal resolution. VOC concentrations measured passively give exposure period averages, which depend on the ambient concentrations and the limit of detection, and so should be regularly reviewed according to emerging data and site activity.

- Active (pumped) sampling uses a calibrated pump to draw a known volume of air through a thermal desorption (TD) tube. This may be typically from 10 minutes to a few hours, depending on the concentration in air (if there is a strong odour, you may choose to sample for less time, and vice versa) and health and safety considerations (use a handheld PID to check personal exposure). Typically, pump flow rates are set to 50 or 100 ml/min, which will determine the duration of monitoring and the volume of air sampled. Pumps should be calibrated by the supplier or checked using a flow regulator.[x] The sampling rate should be discussed with the laboratory supplier, to ensure it is appropriate for the likely range of sampled concentrations[xi].

Other methods, less commonly deployed and not covered further in this guidance include:

- Vacuum canister: stainless steel, pre-evacuated vessels into which air is drawn under atmospheric pressure. Collects a "whole air" sample over time periods ranging from minutes to days then analysed by GC-MS or GC-FID. Well suited to light volatiles (C2-C12 VOCs including benzene), but less so for naphthalene, styrene and other compounds in the C14-C26 range.
- Flux chamber measurement: placing a closed chamber over a small area of soil and measuring the concentration of VOCs emitted from the soil. The VOCs diffuse into the chamber, and the concentration is measured using a portable GC. The flux of VOCs from the soil can be calculated from the concentration and the diffusion coefficient of the VOCs. This method provides a measurement of VOC emissions over a small area and can be useful for characterising emissions from specific areas of concern but again may not be practical on an active site.
- Remote sensing: infrared cameras or other remote sensing techniques to detect VOC emissions from site. This can provide a quick and efficient way to detect emissions over a large area at high (ppm) concentrations, but may not provide accurate data on VOC concentrations emitted from the site and is not commonly used for remediation.

A summary of the common monitoring methods and what and where they are typically applied is presented in Table 4.1.

Photographs of passive and active Tenax monitoring equipment are provided in Figure 4.1.

[ix] It is important to discuss with the laboratory supplying the tubes what the appropriate sorbent medium would be for the pollutants of interest.

[x] Pumped sampling methods are applied as part of the BREEAM indoor air quality testing for compliance in post-construction measurement of TVOCs (BS ISO 16000-6: 2021 VOCs in air by active sampling) and in HSE's VOCs in air methodology MDHS104, e.g. a rate of 50-100ml/min for periods of up to a few hours, with concentrations in the range 0.1 to 10 mg/m^3.

[xi] Sample rates vary by the duration of monitoring, the analyte, sorbent material and type of monitoring. Problems can occur if the sample rate is not appropriate e.g. breakthrough (if concentrations are high) and insufficient contact time with the sorbent material.

Table 4.1 Common VOC monitoring methods and when they are used

Pollutant	Technique	Detection range	Averaging period	Where
Total VOCs	Continuous monitoring by PID/FID	0.01-100 ppm	1-15 mins, continuous	Site boundary, offsite receptor
Total VOCs	Continuous monitoring by electrochemical sensor	0.1-10+ ppm	1-5 mins, continuous	Site boundary
Total VOCs	Handheld PID	0.1-10+ ppm	Spot reading/ad-hoc (1-5 mins)	Workface, site boundary
Individual VOCs	TD tube (passive) followed by GC-MS	ppb	Medium to long term (1-4 weeks at a time)	Site boundary, receptors
Individual VOCs	TD tube (active pumped sampling) followed by GC-MS	ppb	Short term (e.g. 10 min to 8h)	At source/on personnel
Individual VOCs	Mobile gas chromatography	ppb	Short term (e.g. 10 min to 8h)	On site, site boundary, offsite receptor
Odour	Sniff testing	N/A	Spot reading/ad-hoc (5 mins)	Site boundary, offsite receptor
Odour	Electrochemical detector ("electronic nose")	N/A	Spot reading/ad-hoc (5 mins)	Site boundary, offsite receptor
Various pollutants	Single use gas detector tubes	ppm	Spot testing ad-hoc readings (1-15 mins)	At source/on personnel

Photo 4.1 – Passive (diffusive) Tenax tube monitoring (Note how the tube is held vertically by clip, away from interferences, with a dust cap on the end).

Photo 4.2 – Pumped (active) sampling using a Tenax tube. (Check battery life before going onto site and ensure flow regulator is provided.)

Figure 4.1 – Passive and active Tenax monitoring equipment

4.4.2 Odour

4.4.2.1 Olfactometry

The standard method for measuring odour in Europe is Dynamic Dilution Olfactometry (DDO). This involves diluting a grab sample of air in the laboratory to a point where the human testing panel can just begin to detect the odour. The standard methodology for DDO is set out in BS EN 13725:2022, which provides a common basis for evaluation of odour emissions. It specifies a method for the objective determination of the total odour concentration of a gaseous sample using human assessors. The standard also specifies a method for the determination of the emission rate of odours from stationary odour sources, in particular:

- Point sources (conveyed or ducted emissions);
- Active area sources (e.g. biofilters); and
- Passive sources.

Typically, a bag sample of air is taken from close to source, or ambient air, and sent for analysis by a panel in a certified laboratory. This type of sampling can be supported with a sample taken in parallel for individual VOC speciation e.g. by drawing a known volume of air onto a Tenax (or equivalent) tube in a laboratory by GC-MS. Note that combinations of contaminants can smell very differently to their individual odours, and their detection threshold can also be different.

4.4.2.2 Sniff testing

The quickest way to understand if odours are detectable to the public at off-site locations is to undertake sniff testing. This gives immediate, actionable information on the extent to which "site" odours are transported around and beyond the site boundary. IAQM guidance on the assessment of odour for planning (2018; update due in 2026) provides advice on how to undertake effective sniff testing. Sniff testing needs to be carried out on sufficient occasions to represent the full range of conditions and not just reactively in response to a complaint.

For site management purposes, the contractor typically undertakes sniff test surveys on a daily basis as part of the odour management plan. However, it should be recognised that those who work outdoors on site can become desensitised to or accustomed to strong odours, limiting their ability to perform the sniff test. This may then influence their ability to propose site management actions and may not be considered robust evidence to support a statutory nuisance case. To support the contractor, surveys should be verified at regular intervals by an independent sniff tester, in line with a sniff test survey plan and at a frequency agreed with the Environmental Health Officer (EHO). This is an important method of engagement with the EHO that supports regular feedback and communication.

Independent sniff testing survey should ideally be undertaken by a trained individual who has been acuity tested to understand their sensitivity to odour compared to the general population. This testing adds confidence to their findings as it indicates whether their sense of smell is likely to be representative of the majority of the community or if they are overly or less sensitive[xii]. Retesting is advised as a sense of smell changes over time and desensitisation can occur if regularly exposed to strong odours; as a minimum, testing companies recommend this be done annually.

When undertaking the sniff test, a description of the odour intensity as well as the character of the odour (offensiveness, hedonic tone – sweet, pungent, acrid, etc.) should be recorded each time, as this helps when interpreting any complaint data and when comparing with findings from GC-MS results. All odours should be recorded, not just those thought to be "site" activity related, as this can provide supporting evidence in case of complaints.

Box 4.4 – Adding value to sniff testing

The overriding experience of the authors of this document is that sniff testing alone, with or without indicative readings of total VOCs particularly when done in siloes by multiple parties, is ineffective. The survey must be undertaken transparently, consistently and robustly, in a collaborative approach between the air quality and contaminated land specialists, the developer and their contractor. This will help ensure that, for example, boundary sniff tests are timed to coincide with times of potential enhanced odour release such as when new excavation faces are created.

Using a reporting template improves consistency across different sniff testers. A template for this is provided in Appendix A.

Other observed activities underway at the time of the test should be noted (or later identified from contractor site logs). The surveyor should also note if the odour was persistent or intermittent. IAQM odour guidance (Bull et al., 2018) advises tests should ideally be undertaken for 3 to 5 minutes at each location, with odour intensity and a descriptor recorded every 10 seconds to understand if odours are identifiable (a score of 3 or more on the Verein Deutscher Ingenieure Standard (VDI 3882, Part 14)[30] scale) and their persistence.

It is helpful, though not always possible, to undertake the sniff test during meteorological conditions that represent typical working conditions as well as, for instance, during prolonged dry periods with high temperatures. It is useful to pro-actively plan offsite surveys when certain higher risk activities are due to be undertaken and/or when conditions are more likely to lead to offsite exposure e.g. relatively stable with light winds that carry odours towards sensitive receptors.

[xii] IAQM does not require that testers are within the very tight sensitivity range (between 20–80 ppb as n-butanol) that qualifies someone to act as a laboratory panellist.

4.5 When to measure

A primary objective of an ambient air quality monitoring survey is to determine if pollutant emissions generated during remediation or other site activities are increasing compared to conditions prior to works commencing, if they run the risk of approaching, or exceeding, health-based criteria in ambient air (Chapter 5) and therefore whether mitigating action needs to be taken (Chapter 8). It is also important to be able to demonstrate if concentrations have returned to pre-remediation levels after the works are complete.

Box 4.5 provides a case study for a monitoring strategy prepared at planning stage.

4.5.1 Baseline

The importance of establishing the air quality baseline should not be underestimated. This stage of monitoring should be planned prior to commencement of remediation works, and ideally before ground investigation, to understand any existing sources of contamination. This will also support future communication of risk to stakeholders (Chapter 7).

A period of baseline monitoring can assist in understanding what ambient concentrations of different pollutants are prior to the remediation works and in showing how conditions change over the course of the works, i.e. it can show whether there are contributions from existing sources to individual VOCs and odours, the range of concentrations and intensity.

The duration of a baseline survey should be commensurate to scale and risk so every site will be different; examples of good practice are:

- For long term remediation sites, three months is a reasonable time period over which to conduct a robust pre-remediation baseline survey using continuous VOC measurements (in line with IAQM guidance for PM_{10} monitoring);
- One month is the minimum recommended period for passive monitoring, as this should be sufficient to gather information on the compounds already present in ambient air and/or what odours are in the surrounding area;
- If only a short intervention is planned over a few days, active sampling baseline measurements could be taken at regular intervals in advance of works to understand natural variability in the baseline.

4.5.2 During the works

The programming of site works will normally be considered in advance of needing to commence monitoring. The programme may provide information on timing of excavations, location of stockpiles, laydown areas, and vehicle movements. This should help in determining when activities with odour/VOC potential releases will be undertaken and when and where monitoring will be needed.

During remediation works, monitoring data should be gathered during relevant activities in real time to give immediate information to the site management team on potential odour and acute health effects, as well as over longer timescales (where works are expected to last a month or more) to derive period averages for chronic health effects.

Regular (at least daily) odour sniff testing at a range of locations around the site is an efficient and cost-effective way of understanding if site emissions are arising at source and/or travelling beyond the site boundary. This enables rapid intervention to mitigate where there are noticeable site odours.

4.5.3 After completion

Continuing to monitor ambient conditions after the remediation works are complete is recommended to: a) show that concentrations are returning (where relevant) to baseline concentrations; and b) confirm that there are no issues with (for example) piling through treated material and stockpiling of treated material within the site during the construction phase.

Box 4.5 – Case study: Developing an overarching monitoring strategy

A national housing developer has established a framework air quality monitoring strategy for brownfield remediation, comprising a mix of passive, continuous and subjective VOC and odour monitoring techniques. A bespoke version of the overarching strategy is designed for each remediation site using the framework, which sets a standard from which to develop the detailed approach.

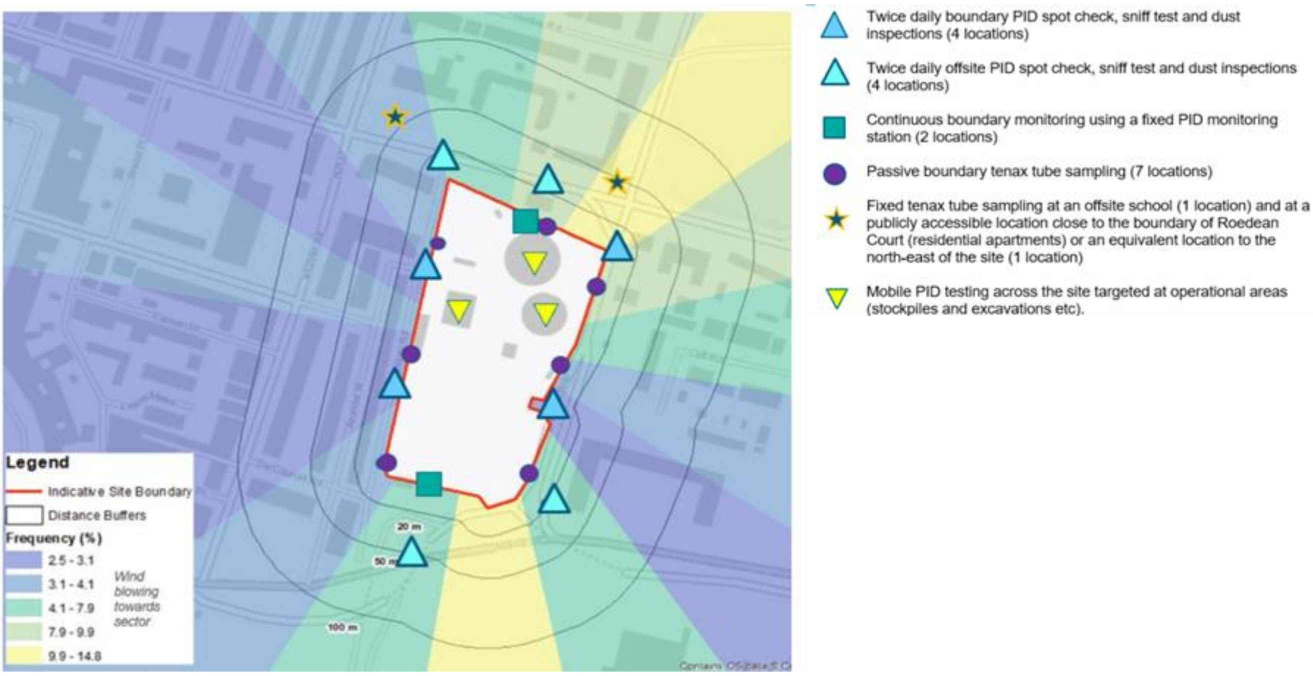
For example, on a site of 100 hectares with residential receptors within 100 m, a minimum of four Tenax tubes would be proposed at different locations around the boundary, to provide monthly concentrations of individual VOCs by passive monitoring. An accredited laboratory would undertake GC-MS analysis, and report specifically on at least the individual BTEX components and naphthalene (the latter being a key marker compound, due to its low odour detection threshold and prevalence in ground investigation reports).

Before starting, a baseline would be established including a check of the Top 20 VOCs and/or total petroleum hydrocarbons (TPH) to correlate with total VOCs. The measured concentrations during the works would be retrospectively reviewed for longer-term health risks.

Boundary monitoring of total VOCs is undertaken by deploying fixed continuous PIDs at least at two locations, typically this would be up and downwind of the prevailing wind with consideration of sensitive receptor locations. This is supported by ad hoc spot checks with handheld PID instruments. TVOCs are used for alerting site managers of the need for mitigation, in real-time.

Daily sniff tests for odour around the site boundary provide information on what VOC concentrations may translate to a discrete odour offsite. Reporting templates are filled out consistently and shared in a timely manner with site teams. The tests are performed by site-based staff who have ideally been tested for any bias in sensitivity and who are predominantly in an office; staff involved in excavations at the workface use a PID.

Findings are independently reviewed monthly to check for any loss of sensitivity due to continued on-site exposure. Reporting is provided to the site manager and a summary of results shared with the local authority.



4.6 Where to measure

Deciding where to measure air pollutants, be that as TVOCs, individual compounds or odours, on brownfield sites can be challenging for many reasons: the complexity of the mixtures of pollutants, the processes and stages involved on site, and the variability of the emission source magnitude, location and the factors affecting dispersion.

When thinking about where to set up monitoring equipment, it is important the combined professional experience of air quality and contaminated land specialists is applied. Questions that may be useful to ask are:

- Where is the source? Historical records can help but if unavailable, refer to ground investigation reports, or other existing monitoring data. Note also if there are other sources of relevant pollutants nearby.
- What are the pathways? Consider different wind directions and remember that calm conditions are also important for potentially odorous emissions. Atmospheric temperature, and pressure can also affect emissions and dispersion including through the formation of temperature inversion. The local microclimate can affect wind directions e.g. funnelling between buildings.
- What types of receptors are there and where? Residential, schools, offices are among relevant receptor types. Review if any complaints been received, and if so where from?

There may be other relevant factors to consider, depending on the site and its surroundings.

There are usually many locations where pollutant concentration measurements will provide useful information, and a sensible approach would be to cover a range of these at practical intervals i.e. close to source, on the site boundary, at a sensitive property, a background site. Closer to the source, concentrations are likely to be higher so different monitoring techniques or durations may be appropriate depending on how far the location is from the source. Setting up monitoring sites (both passive and active sampling alike) in transects can inform the understanding of whether emissions are dispersing effectively and/or whether mitigation is working well (e.g. by analysing the rate of reduction in concentrations with increasing distance from source).

Practicalities are an important factor as remediation sites regularly change shape, can be highly constrained and require careful consideration of health and safety, due to deep excavations and muddy areas to navigate around at times. This should be borne in mind before committing to monitoring at certain locations. The survey designer should think about whether it will be possible to access the same location in a months' time, if the presence of walls, buildings and other structures will impede airflow to the instrument intake (and therefore if equipment should be placed higher than breathing height) or if there may be a build-up of vapours compared to other locations (this may be of relevance so such locations should not be dismissed if there is exposure nearby).

Once the site works are underway, weather forecasts and/or data from an on-site weather station(s) should be considered to refine the monitoring locations in combination with information from the operator or contractor as to when activities will be undertaken. A local windrose may differ from the nearest publicly available data, or even from one side of the site to another; therefore, when taking ad-hoc mobile readings or sniff tests, monitoring locations should be reviewed to ensure they are representative of likely offsite exposure at the time.

Keeping informed of site activities and the works programme is important. For example, if excavation areas, stockpile locations and/or site accesses change, regular checks that the monitoring locations continue to be appropriate and are safely accessible should be undertaken.

It is not advisable to undertake monitoring inside private properties as these are uncontrolled environments containing many other sources of VOCs which may invalidate findings. There may be potentially higher concentrations of compounds not related to the site works e.g. from carpets, cleaners, air fresheners, and more importantly, smoking and heating.

4.6.1 Dispersion patterns

To inform the strategy of where it would be appropriate to monitor in advance of works commencing, a simple analysis of wind direction and frequency can be undertaken. A windrose for a local meteorological station will indicate where emissions may be carried most frequently by the wind, however, winds come from many different directions throughout the year and can be affected by many local factors. It is also important to acknowledge that calm conditions can cause vapours to build up near a source due to reduced natural dispersion effects, as discussed in the previous section.

Dispersion modelling of emissions from a site can be undertaken using a suitable computer programme, such as ADMS or AERMOD. This can help to understand in theory how pollutants and odours will dilute and disperse under local meteorological conditions. This can be helpful in the early stages of planning the strategy, to understand the receptors most at risk under different wind conditions, or when air quality monitoring data become available early on in a survey. It is important to understand the uncertainties inherent in dispersion model algorithms and in meteorological data records which are a key input.

Published emission factors can be used to estimate VOC emission rates (i.e. mass release per unit of time) from land remediation sites. Emission factors are based on the amount and type of contaminants present in the soil and estimated and are used either qualitatively (as part of a risk assessment using the source-pathway-exposure conceptual model) or quantitatively (in dispersion modelling) to illustrate the concentrations and pattern of dispersion in the surrounding area – based on wind speed, direction, surface roughness – and the rate at which concentrations decrease with increased distance from the source.

To enable a modelling study in the absence of a measured or literature emission rate, a unitised emission rate (e.g. 1 g/s) can be applied across the area of interest e.g. gasholder or excavation area. This allows a broad relationship between source, boundary and receptor concentrations to be established. Once a survey is underway and sufficient fenceline measurements of airborne concentrations are obtained, it may be appropriate to use the model to estimate receptor concentrations, where it is not practical to undertake surveys beyond the site boundary.

Dispersion modelling output can also be helpful if interpretation of boundary measurements is required, such as to identify the potential for exceedances at offsite receptors. It can also provide estimates over a larger area than can be monitored, providing a useful tool for risk assessment and site management.

5. Assessment criteria

This chapter focuses on quantitative assessment criteria for air pollutants and odours with regard to health effects. Nuisance / amenity and wellbeing are subjective matters which are not amenable to such numerical criteria and is for the EHO or health authority to determine. Records of complaints, their investigation and action should be retained in the site log and made available to the local authority on request in a timely manner.

There are many substances which may be emitted from brownfield remediation sites for which there are no regulated standards and therefore appropriate assessment thresholds need to be identified or derived from other reputable sources to allow monitoring data from the remediation site to be interpreted. This can be difficult as there is limited or no toxicological data for many chemical compounds that may be emitted into the air and a precautionary approach is recommended.

A hierarchy should be applied that reflects the applicability of the assessment threshold to the country, location and activity in question and its source. An example is provided in the following section.

5.1 Air quality criteria

5.1.1 Statutory criteria

Regulations and standards for VOCs and odorous pollutants vary by country. In Europe, standards are established by individual countries or the European Union itself e.g. the Ambient Air Quality Directive which included a limit value for benzene[31], and was subsequently adopted into UK regulations. With the exception of benzene and 1,3-butadiene annual mean air quality standards, there are no statutory UK ambient air quality criteria for individual (or total) VOCs.

In the United States, the Environmental Protection Agency (USEPA) has established standards for acceptable VOC and odour emissions, which must be met to ensure the safety and health of nearby communities.

5.1.2 Environmental permitting

The Environment Agency has developed EALs for use in environmental permitting[14] of regulated industries to demonstrate no significant environmental impact. These EALs are available for several individual VOCs including benzene, toluene, xylene, naphthalene, styrene, and chlorinated hydrocarbons; these EALs strictly apply only to assessments of permitted sites. Although not directly applicable to remediation activities (unless these require a permit, such as temporary waste operations) they can be useful when interpreting monitoring data for compounds which do not have legislated standards.

In developing these EALs, the Environment Agency explicitly excluded air quality standards (e.g. the limit values and objectives set in UK regulations) and occupational exposure limits, such as the HSE's workplace exposure limits (WELs)[32]. This is because neither is based solely on the scientific and medical evidence of human health effects, having also accounted for factors such as the technical and economic feasibility of achieving the standards. In addition, workers do not represent the general public because of the nature of their exposure (workers are exposed to much higher concentrations than in ambient settings) and their response to it (workers are assumed not to include members of the population most vulnerable to health effects).

5.1.3 Other criteria

Consultation with planners, regulators and stakeholders may raise the possibility of using other assessment criteria. The Environment Agency (2025) does not advise[33] the development of assessment criteria from human and mammalian toxicology unless it is undertaken by a suitability qualified assessor with relevant experience in toxicology.

Nevertheless, at times it is useful to put concentrations into some context especially for less frequently encountered pollutants. In this case, key sources in the Environment Agency's approach for developing EALs can be referred to, which include national statutory objectives/standards, industrial and international guidelines:

- Committee on the Medical Effects of Air Pollutants (COMEAP);
- Expert Panel on Air Quality Standards advice (NB: The panel no longer exists but guidance is still available);
- WHO guidelines for indoor and outdoor air; and
- Tolerable concentrations in air, derived from advice from government expert committees and panels and a review of existing authoritative expert opinions and evaluations.

Other sources of criteria which may be consulted for context in the absence of relevant guidelines from the above sources, but which should be applied with caution, are:

- PHE (now UKHSA) indoor air quality guidelines for VOCs[10];
- Health and Safety Executive – workplace exposure levels (WELs) for 15 mins and/or 8 hours exposure for VOCs and other compounds;
- European Chemicals Agency (ECHA) and associated REACH registration data;
- USEPA emergency response guidelines for short term exposure e.g. Acute Exposure Guideline levels (AEGLs)[34]; and
- Other international guidelines – focus on countries which have a similar level of development/ industry/regulatory history.

Table 5.1 includes a selection of health-based air quality criteria and odour thresholds which may be useful for inclusion in an air quality monitoring plan for a brownfield site where VOC emissions are expected. The criteria provide concentrations against which individual VOC measurements can be benchmarked, with interpretation where appropriate regarding different averaging periods and durations of exposure. This list is not exhaustive, and the air quality and contaminated land specialists should research and agree a range of selected criteria specific to the project in question.

The intention is that future updates of this guidance will include support on how to ensure a consistent approach is applied across different sites. For instance, it is important to understand the basis upon which certain health thresholds have been derived – was it from multiple studies at similar ambient concentrations or a single toxicological experiment at high concentrations which has then been extrapolated? Site specific criteria may need to be developed for chemicals where there are no available data; in this case, identifying chemicals with a similar structure would be a starting point to indicate the order of magnitude and whether this may be of concern. This needs specialist advice and is not covered in this guidance.

Table 5.1 – Examples of health-based air quality and odour thresholds ($\mu g/m^3$) for inclusion in an AQOMP

Determinant	EA EAL Long term^	EA EAL Short term^	PHE Indoor Guideline	WHO Guidelines	ATSDR MRL §	Odour Detection Threshold
Benzene	5 (1 year)*	30 (daily)	-	0.17 – 17 (annual ambient)	9.6 (chronic) 30 (acute)	5,000 (US ATSDR)
Toluene	260 (1 week)	8,000 (1h)	2,300 (daily)	260 (weekly indoor)	3,800 (chronic) 7,640 (acute)	1,000 (WHO 2000)
Ethylbenzene	4,410 (1 year)	55,200 (1h)	-	-	260 (chronic) 22,050 (acute)	-
m-/p-/o-Xylene	4,410 (1 year)	66,200 (1h)	100 (annual)	-	220 (chronic) 8,800 (acute)	4,776 (US ATSDR)
Naphthalene	3 (daily)	-	3 (annual)	10 (annual indoor)	3 (chronic)	7.5 to 420 (WHO)
Styrene	260 (1 week)	800 (1h)	850 (annual)	260 (weekly indoor)	850 (chronic) 21,300 (acute)	70 (WHO 2000)
Trimethylbenzenes	1,250 (1 year)	37,500 (1h)	-	-	-	-

* Value of the air quality standard for benzene set in Air Quality Standards Regulations 2010
^ Values from Environment Agency's online risk assessment guidance for permitting (2025). The ambient long-term EALs are typically daily, weekly or annual averaging periods according to the method by which they were determined and if they are threshold or non-threshold effects.
§ The United States Agency for Toxic Substances and Disease Register (ATSDR) sets Minimum Risk Levels (MRLs) for acute (1-14 days) and chronic exposure (1 year) periods, to screen environmental exposures that might harm people's health. See section 5.1.3.3.

5.1.3.1 Indoor guidelines

Indoor air quality guidelines may be used on a precautionary basis where there is a solid understanding of how they were developed. For example, the World Health Organization (WHO) and PHE (now UKHSA) indoor air quality guidelines are available and can be applied to outdoor settings, however it is important to note the guideline values may have been based on different exposure assumptions as people tend to spend more time indoors.

5.1.3.2 Workplace Exposure Levels

In the UK, there are published values for occupational exposure limits from individual VOCs, which can be found within the HSE publication, *EH40/2005 Workplace exposure limits (WELs).* The WELs presented are calculated from available toxicological data, and converted to either 15 minute, i.e. short-term, or 8 hour, i.e. long-term, exposure levels. These values are intended to represent conservative thresholds for workplace exposures and as such, the direct application of them to concentrations as encountered in, for example, a domestic property adjacent to a remediation site, may well not be appropriate. However, in the absence of other appropriate criteria, the application of WELs to results of monitoring on a remediation site is likely to ensure short term concentrations well below those thresholds in off-site locations.

5.1.3.3 Other guidelines

When reviewing other criteria including other country guidelines, non-UK sources should be used only where they are directly relevant to the protection of public health, do not rely exclusively on animal studies and are from countries with similar regulatory framework as the UK, such as the EU, USA, Canada and Australia.

In the United States, the ATSDR has established minimum risk levels (MRLs)[35] for acute and chronic exposures to indicate if concentrations have potential to harm human health and require investigation at hazardous waste sites. An MRL is described as an estimate of the amount of a chemical a person can eat, drink, or breathe each day without a detectable risk to health. MRLs are developed for health effects other than cancer. When health assessors find exposures higher than the MRLs, it means that they may want to look more closely at how a site is operated and managed.

MRLs can be established for three different exposure periods: acute (about 1 to 14 days), intermediate (from 15-364 days), and chronic (more than 364 days)]. If an exposure is below an MRL, it is not expected to result in adverse effects; if above an MRL, further evaluation is undertaken to determine if it might harm human health There is a large database of existing MRLs which may be useful to provide an indication, in the absence of other guidelines or standards, of whether a pollutant is approaching a concentration of concern.

5.2 TVOCs

The parameter TVOCs is readily measured in real-time and can help a site manager understand if there is potentially an occupational health risk in the area, or if site activity is generating elevated concentrations of contaminants in the vapour phase, and therefore if intervention is required to mitigate.

Continuous monitoring of TVOC can be undertaken relatively simply with little operator involvement following installation, so it is often used to indicate if concentrations are sustained at a high level above an agreed or indicative threshold, and whether work should be paused until a solution is found and concentrations decrease again.

Setting a site action level (SAL) (or range of levels) for TVOCs is an approach commonly applied to automatic data collection from real-time monitors. Alerts are sent to the contractor when average concentrations approach or exceed the pre-defined level, allowing action to be taken to investigate and ameliorate the source of pollution. The approach is similar to that applied on many construction sites for PM_{10} (IAQM dust monitoring guidance 2018).

There is, currently, no public health assessment criterion for TVOCs in ambient air. A generally conservative approach, in the absence of VOC speciation data and in line with the Environment Agency guidance for industrial permitting risk assessment[14], is to assume that all the VOC is represented by benzene. This is because benzene is a carcinogenic VOC which has one of the most stringent ambient air quality criteria, set in legislation as a national standard (5 $\mu g/m^3$ or 1.7 ppb).

On many sites, to protect the exposure of site workers, the contractor will apply the value of the 8 hour WEL for benzene (1 ppm) as a 15 minute SAL for TVOC. This means an alert is given when the TVOC concentration (so, all detectable compounds including benzene) exceeds the value of the WEL over a much shorter time period. This allows the contractor to take appropriate action in a timely manner to investigate the exceedance, and identify and mitigate the source of TVOC, well before benzene concentrations approach 1 ppm over the full 8 hour period over which the WEL applies.

The Environment Agency does not recommend applying WELs to assess the risk to the general public, however, the principle of the above approach can be pragmatic for brownfield sites where (as is almost always the case) monitoring data are not available immediately to allow concentrations of individual VOCs to be compared to criteria. The worked example below shows how a SAL set for TVOC over a period of 15 minutes at a value based on the WEL, should be reasonably protective of longer term, off-site public exposure to benzene. The relevant criteria for public health are a short-term (daily mean) criterion of 30 µg/m^3 and a long-term (one year) AQS of 5 µg/m^3. It is important to note that this approach relies on benzene comprising only a few percent of the TVOC component. (The working group's experience of VOC speciation data obtained from Tenax measurements at several brownfield sites, indicates this should be a reasonable starting assumption but must be verified through site-specific data where available).

The relevance of the selected SAL should be verified wherever possible through further monitoring with comprehensive GC-MS analysis – or an equivalent method that provides VOC speciation – to understand the actual composition of the VOC mixture. A more conservative value for the SAL may be needed if, for instance:

- There is a possibility that benzene comprises a much larger component of the TVOC mixture than a few percent;
- There are highly sensitive receptors close to (e.g. within 20 metres of) the site boundary;
- The potential for pollution to dilute in ambient air between the source and receptor is limited; or
- There is a high background concentration of benzene (or other pollutant of concern such as a local industry emitting solvents).

A SAL for TVOCs is unlikely on its own to be sufficient to manage the potential for odour complaints, and a more stringent or supplementary criterion may be required to address low level emissions of very odorous or distinctive compounds, such as naphthalene. In some complex and large sites with longer programmes, it may be appropriate to establish combined thresholds for offsite odours and health risk, by reviewing the findings of contemporaneous odour sniff testing at the fenceline against active Tenax tube measurements of individual VOCs and continuous monitoring data for TVOCs, for an integrated approach. These could be levels that are increasingly protective both of occupational exposure within the site, potential public health effects and loss of amenity off-site. An example of this is provided in Box 5.1 for Brighton Gasworks.

Box 5.1 – Case Study: Developing a traffic light SAL system

A “traffic light” system was set out in the air quality monitoring strategy for the former Brighton Gasworks in support of the remediation strategy submitted with the planning application. This was included in response to local concerns raised at pre-planning consultation stage. The developer proposed a range of SALs with different actions associated with each, to be undertaken in response to certain on-site and off-site concentrations and odour intensities. Initially, a check would be made that all appropriate mitigation is being applied, with further investigation then undertaken if the initial SAL continued to be exceeded. Additional fenceline monitoring or spot readings would be triggered, to understand if emissions were being carried offsite; the final stage or “red light” would be to “stop works” with no further activity until concentrations return to lower level.

Real-time reporting against alert thresholds should ensure prompt response to exceedances of precautionary short-term thresholds set using a traffic light system of action levels for VOC and odour concentrations:
- Green (proceed with caution),
- Amber (investigate and mitigate) and
- Red (stop works that are generating odour release and re-evaluate methodology and controls).

Each boundary device would have a minimum level of detection of 0.1 ppm and be programmed to sound an alarm when, for a period of more than 15 minutes:
a. An interim action level of 0.5 ppm is exceeded; and
b. An action level of 0.7 ppm is exceeded.

Photograph 5.1 – Existing gasholder frame at the former Brighton gasworks site with residential property beyond it.

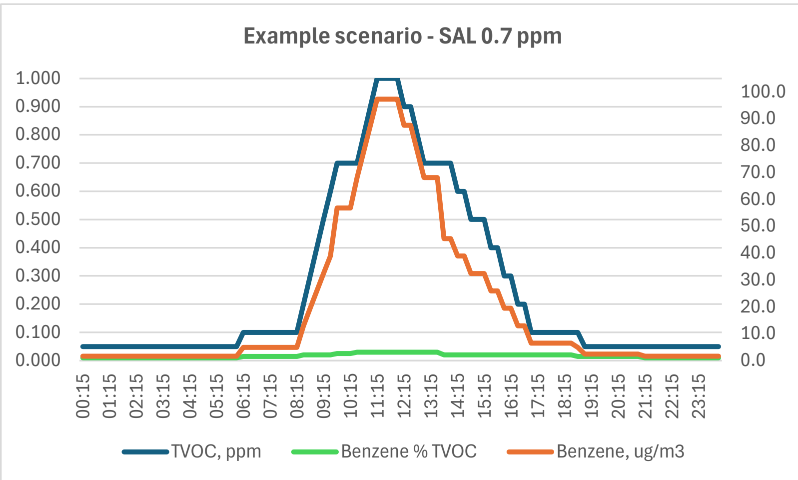
Box 5.2 – Worked example of developing a SAL

The selection of an appropriate SAL depends on many factors including baseline concentrations of individual and TVOCs at the site; the sources on site which will add to the components of individual pollutants; and the proximity to sensitive receptors. By providing this worked example, the IAQM does not advocate a specific set value to use as a SAL for TVOC, but simply aims to show how the concept can, in principle, keep annual average exposure below an AQS for human health. This is a hypothetical illustration and diurnal pollution patterns and background sources will vary each day.

If the baseline/overnight TVOC measurement is 0.05 ppm and 1 percent of this is benzene, this would give 1.6 µg/m^3 benzene (conversion rate at 20°C: 1 ppm = 3.24 mg/m^3) – this is a reasonable assumption based on long-term average benzene concentrations measured in an urban background setting. When remediation works commence, site activities e.g. excavation at a former gas works, the contribution of benzene and/or other individual VOCs, may cause a steady or sharp increase in TVOCs.

By setting a SAL of 0.7 ppm for TVOC and assuming that, during remediation, that the benzene component doubles to 2 percent of TVOC as contaminated soil is exposed, this SAL gives a benzene component of 45 µg/m^3, which is above the Environment Agency's daily mean EAL of 30 µg/m^3 and therefore justifies the need for action. If TVOC concentrations continue to remain at or above the SAL a full hour, the contractor must apply mitigation and reduce TVOC concentrations to below the SAL, ideally within an hour of the alert (setting an interim SAL at say 0.5 ppm would help apply proactive management approach, as investigation would be undertaken prior to the higher SAL being exceeded).

The illustrative graph below shows an increase from baseline to the SAL, and a steady decrease after mitigation is applied, keeping benzene concentrations to below 30 µg/m^3 over 24 hours (assuming both the concentration of TVOC and the proportion which is benzene reduce to baseline by the evening). Clearly the SAL needs to be supported by data to demonstrate the breakdown of individual VOCs at the site location.



Concentrations both of TVOC and individual VOCs need to be tracked carefully and continual improvement applied to keep TVOC concentrations well below the SAL for as much of the time as possible, to ensure over the course of a long remediation programme that benzene does not exceed the annual mean AQS objective, especially if there is relevant sensitive exposure at or just beyond the boundary. To do this, the SAL can be made more stringent for faster intervention, and/or the degree and speed of mitigation increased.

5.3 Odour

Odour can be a statutory nuisance as defined in the EPA 1990 (See Section 3.2.2). It can also cause loss of amenity and have indirect impacts on an individual's wellbeing at persistently low levels, which may not normally be considered a potential for nuisance or require mitigation.

5.3.1 Sniff testing

Consistent assessment of odours using sniff testing can be achieved by applying the VDI scale of 1 to 6:

0 - No odour

1 - Very faint odour (doubt as to presence)

2 - Faint odour (present but can't be described)

3 - Distinct odour (just recognisable)

4 - Strong odour (easily recognisable)

5 - Very strong odour (offensive and undesirable)

6 - Extremely strong odour (offensive, could induce vomiting due to strength).

The value of such surveys, if undertaken by a "non-sensitised" individual, should not be underestimated. The characteristic odour of tarry wastes, derived from the volatilisation of naphthalene, is perceptible by the human nose at very low concentrations (a few ppb), and so this may not be picked up within the site or even boundary PIDs for TVOCs which often have a detection limit of 0.1 ppm (100 ppb).

Additional information should be recorded to add value to the interpretation of sniff testing records, such as notes by the surveyor on ongoing site activity at the time (or check contractor site logs), and any off-site potential sources. Consistent recording of findings is key to being able to compare results from one survey to another.

Appendix 2 of IAQM guidance on odour for planning provides further detail of how to undertake an odour survey using sniff tests.

5.3.2 Olfactometry

The output parameter from olfactometry is an odour concentration in air (ou_E/m^3) which can be compared to various published odour detection thresholds (ODT). A value of 1 ou_E/m^3 is the level of detection of total odour under laboratory conditions.

VDI 3940 sets out that in a clean odour laboratory an ODT of 1 ou_E/m^3 represents the minimum concentration for which odours may be detectable and that the recognition threshold is generally 3-10 times higher than the odour detection threshold (i.e. 3-10 ou_E/m^3). As this is defined for a laboratory environment, it cannot be directly aligned with intensity levels in ambient air, for which odours at the ODT would typically not be detectable in the field. The Environment Agency H4 guidance for permitting does not recommend olfactometry for measuring odours in ambient conditions.

5.3.3 VOC speciation

Odour detection thresholds (ODTs) for individual VOCs are available in the literature in units of ppb or $\mu g/m^3$ (e.g. Woodfield and Hall (1994)[36], Environment Agency (2002)[37], American Industrial Hygiene Association (2013)[38], and SEPA (2025)[16]. ODTs can vary significantly at individual and population scale, and do not take account of the effects of combinations of odorous compounds.

ODTs are not readily applied to results of passive monitoring for VOCs but could be extrapolated from short-term pumped sampling to indicate whether an ODT was likely to have been exceeded. Environment Agency guidance for permitting[14] suggests values for extrapolating from daily to hourly and hourly to 15-minute averages (although note that odours can be transient, so this is to be applied with caution as part of an indicative approach).

6. Running a survey

This section outlines some of the practicalities of running a survey on complex remediation sites:

- Issues that may be encountered e.g. access to equipment, multiple sources;
- What to look out for in results – unusual patterns, correlation with activity;
- Keeping monitoring relevant – flexibility as site work evolves, reactive to issues;
- Quality control and good practice in record keeping e.g. site activity logs, calibration; and
- What and when to report, including examples of graphical presentation of data.

6.1 Practicalities

The remediation of brownfield sites often involves a lot of heavy machinery, areas of excavations, changes in site accesses or the site boundary. It is not always possible to retain monitoring instruments in the same location. This needs to be acknowledged openly with the end-users of the data (client, regulators, local communities) and allowed for where possible when setting up the survey.

Checking in advance in case there are any areas to be avoided or treated sensitively if working off-site is recommended. Planning ahead as far as possible is important but be prepared to respond to changing circumstances – expect the unexpected, consider the known unknowns, and build trust with the regulator and local community so that necessary changes to the approach (site locations, monitoring techniques) do not affect their trust in the findings in the future.

When on site, it is important to be observant, take photos (if allowed) and make notes on what is seen, heard and smelt, and what the current and recent atmospheric conditions are. Asking questions about

Box 6.1 – Tips when using Tenax tubes

The following practical pointers should help improve data collection and data quality:

- Check before leaving for site that suppliers have sent what was expected and take spares of things like holders and cable ties;
- If using pumps check these are fully charged;
- Position tubes vertically using holders and spacers, to improve airflow around the tube inlet and fit a dust cap to reduce ingress of dust particles;
- Use signage to alert site teams to the presence of monitoring equipment and reduce the potential for inadvertent losses or fencing being removed with equipment;
- Deliver a “toolbox talk” to contractors to raise their awareness;
- Log and share locations of monitoring (Tenax, sniff testing) in GPS;
- Ask for safe, secure and continued access to the site to improve consistency of measurements and avoid loss of data; enquire if your preferred monitoring location will still be accessible in a month’s time;
- Fit Tenax tube caps firmly and pack well before returning to the laboratory (if caps come off in transit the results are rendered unreliable);
- Check the tube number matches what you were expecting before sending it off; and
- Scan and keep a copy of your completed monitoring records provided by the supplier before returning to the laboratory.

what activities have been going on recently can prove useful when reviewing results, even if not obvious at the time.

6.2 Quality control

Monitoring equipment (e.g. real-time fixed units, hand-held devices, pumps) should be calibrated according to manufacturer's instructions and recommendations. Real-time monitors should undergo regular zero-checks to avoid instrument drift i.e. where concentrations creep upwards over time. Evidence should be kept of calibration and maintenance of monitoring equipment and made available on request.

Where possible, a laboratory that is accredited for the specific type of analysis to be undertaken should be selected; if not possible, ensure that standard published methods for preparation and analysis are followed for the suite of compounds under consideration.

To avoid contamination, unexposed diffusion tubes should be dispatched by the laboratory in a sealed bag with a unique identifier on each tube. A field (travel) blank should be included so that any contamination during transit can be identified. Gloves should be worn by the surveyor at all times to avoid contamination of the tubes during handling; hand sanitiser and marker pens should not be used as these may contain VOCs.

Equipment should be positioned correctly according to supplier's instructions; for Tenax tubes, typically this means with the arrow facing up. Place equipment away from the influence of non-site sources (unless you intentionally want to measure them) and ensure air flows freely around the tube or monitor inlet.

6.3 Data analysis

This section considers the desk-based review of quantitative data collected from site.

The examination of data gathered from site in a timely manner i.e. as soon as practicable upon receipt, will support a proactive approach to site management and mitigation. This should be supported on longer term surveys by analysis of comprehensive datasets and reviews of patterns and trends (temporal and spatial) over time.

While analysis of short-term datasets supports the contractor's selection and application of appropriate mitigation measures, retrospective review of long-term datasets, particularly for Tenax data, is important to compare to health criteria for chronic effects, as well as investigating any correlation with wind patterns and site activity to inform the position of monitoring sites.

Before analysis of monitoring data, check that:

- The equipment was positioned as and where intended;
- Instruments were calibrated and maintained in line with suppliers' specifications;
- Chain of custody is demonstrated between the supplier/laboratory and the contractor; and
- Data have been checked and ratified.

Sufficient time after receipt of results should be allowed to ratify the data and investigate any anomalies. Raw data should be validated for anomalous readings e.g. spikes, pollution episodes (spikes may occur during remote calibration of instrumentation or short-term emissions episodes; consider time of incident vs activity on site, duration of spike, scale of change, if one instrument or several). Upon receipt of laboratory data, query results immediately if they appear unusual without any plausible explanation based on site activity, to rule out any contamination issues, or instrument malfunction. If this is left too late, it may not be possible to query e.g. if the laboratory has already reconditioned the tubes.

Pollutant concentrations should be compared to a range of appropriate health-based criteria (see Section 5). This may require the estimation of different averaging periods e.g. weekly, monthly, rolling annual means; if doing this by applying factors then these should be clearly stated and due caution applied. Comparing results against baseline concentrations and non-site or background monitoring sites is helpful, where available. For example, Defra operates both automatic and non automatic monitoring site networks[xiii], some of which measure a range of hydrocarbons including several VOCs.

Box 6.2 – Suggestions for results analysis

When undertaking analysis of results, consider:

- Does the rate of change with increasing distance from source allow you to extrapolate boundary readings to estimate concentrations offsite?
- Do differences in Tenax and VOC readings, and odour sniff testing results in combination, help you interpret the other surveys?
- Is there a correlation of results with site activity e.g. concentrations higher during certain times of the day / excavation activities / removal off-site; do readings reduce during breaks?
- Is there a correlation between location of high values and prevailing wind direction, does this apply to both Tenax and sniff test results?
- Can you identify different sources of VOCs from the combinations of individual compounds? BTEX ratios may help to differentiate between sources
    - Toluene / Benzene <1 may indicate traffic (benzene use in petrol now restricted);
    - Toluene / Benzene >2 could indicate a non-remediation source (solvent use/paint);
    - m-p-Xylene / Ethylbenzene <3.8 may suggest a recent emission source.

If values are higher than expected (i.e. higher than baseline, or are markedly different to other monitoring periods) then check the contractor time; activity logs to see what works were going on at the time; what mitigation was being applied; were meteorological conditions unusual? Check (or ask a site-based team member to do so) the site surroundings: has something changed in the area; is there something else that may be contributing off-site to the measured concentrations?

Continuous monitoring data should be reviewed on a regular basis, even if action has not been required in response to exceedances of SALs (see Section 5.2). It can provide valuable information on trends over time and allows for proactive mitigation measures to be put in place. Openair (free, open-source tools to analyse, interpret and understand air pollution data using R programming language designed for the analysis of data) can be used with data from continuous monitoring and an appropriate meteorological station to investigate the likely source at different times of the day. An observed correlation between peaks in VOC concentrations and certain site activities may indicate if those activities intensified or came closer to a receptor, it could lead to an exceedance of a SAL; the contractor should be alerted to this and, for example, can implement checks to ensure that there is sufficient odour suppressant available, or order in additional spray systems.

Monitoring and investigating trends over time is also important when undertaking a retrospective review of longer-term average concentrations of individual compounds against long term health-based thresholds. Useful metrics are running means (to see trends without the over influence of single, short-term, high readings), site wide, individual receptor and/or area average concentrations.

Consider if the reported odour intensity (VDI scale) from sniff testing is consistent with concurrent site activity and/or VOC concentrations. Review of

[xiii] DEFRA. https://uk-air.defra.gov.uk/networks/

quantitative pollutant concentration data alongside subjective sniff test records and complaint logs can be a valuable exercise. If there is a contrast with different data sets, this may indicate an issue with the SAL, the sensitivity of sniff testers (who can become desensitised over time), a need for training in interpreting the VDI scale, or an increase in the sensitivity of the offsite receptors.

6.3.1 Record keeping

Good quality record keeping is important to allow for meaningful data collection and evaluation. Records should be legible and retained in an accessible format, with clear differentiation between raw and post-processed values.

Calculations of averages, removal of anomalies (and reasons for such) and other data ratification should be evidenced in spreadsheets. Undertake, and keep evidence of, checks of the gathered data e.g. check for transposition errors, ensure the transparent application of conversion or correction factors and assessment criteria.

Consistent and detailed record keeping is particularly important for sniff testing, which is a subjective procedure; individual surveyors and site workers may have a tendency to apply different (or interpret differently) odour intensity scales. Templates (an example is provided Appendix A) can help to improve consistency between different odour surveyors, and a similar template can also be given to members of the community or the liaison team for recording feedback and/or complaints. (Records of complaints, their investigation and action should be retained in the site log).

Audits, for example by a member of staff not regularly on the site or an independent third party (e.g. hired in by the contractor or regulator or other party), can add value to the monitoring process by providing an objective review of monitoring data, whether monitoring locations are appropriate, whether the techniques are effective and appropriate (in terms of location, sensitivity range), if there are unusual pollutants of concern whether appropriate criteria have been selected, and if mitigation measures are agreed to be performing as expected. The use of this option and the optimum frequency will depend on the complexity, risk and duration of the works. As an example, this could be done monthly over a year-long monitoring programme. The value comes from rapid feedback to the site team so any remedial action can be taken.

6.4 Reporting

There are multiple parties to whom the outcome of monitoring should be reported to, which will influence the format of the information being communicated and the timing of it. Typical audiences include the contractor/developer; the local planning authority; and the local community.

The validated results from monitoring should be shared as soon as possible with the site team, advising of anything that may be of potential concern (e.g. high values above a criterion, an increasing trend, poor data capture), and not await a more formal report. This will allow the site manager to implement relevant improvements or mitigation.

Regular reporting should be undertaken to ensure full value is obtained from the monitoring survey and proactively acted upon; it should not be left until the end of the works or the agreed monitoring period. Where a report is to be provided to those responsible for managing the site, it should be readily interpretable to enable action regarding control of operations and ongoing due diligence. Reporting against KPIs and using simple summary pages can help to highlight findings.

The frequency of reporting will vary and should be agreed through consultation with relevant parties. Monthly reports for external audiences (local planning authority, regulators, stakeholders) are a desirable and reasonable frequency for sites with high community interest and/or monitoring surveys of three month or longer duration; this takes into consideration the time lag between receiving results and undertaking any necessary validation and interpretation. Quarterly reporting may be appropriate for sites of lower risk, or shorter baseline / post remediation surveys when concentrations should be at lower risk of exceeding thresholds and less subject to variation over time.

Regular reporting should include the collation of all available data and interpretation against a range of health and odour thresholds, presenting findings of spatial and temporal analysis to examine patterns around or within the site, including trends over time, comparison with site activity logs, sniff testing results and meteorological conditions.

Selected compounds that have been consistently recorded above the limits of detection, and for which some reported concentrations at some locations during remediation are of a similar or greater order of magnitude than the relevant human health, or odour, guidelines and standards merit further investigation. A summary of the nature and significance of any exceedances (e.g. to what extent was a threshold exceeded – marginally at one location in one month, or several times over the limit, at multiple locations across the site; what is the health effect associated with the exceedance, what is the basis of the threshold) and any corrective actions undertaken or recommended is also useful to include.

If reporting numerical data this should include clearly summarised, tabulated results, highlighting minima and maxima as well as period averages, describing the range of concentrations recorded across the site, and a comparison with health-based and other relevant criteria. Graphics are also very helpful to illustrate variation around the site in relation to sources, trends over time, and comparison relative to standards, especially for a non-technical audience.

A dashboard can be useful to summarise continuous monitoring data and exceedances of Site Action Levels (SAL). Thematic mapping in GIS can be useful to illustrate more complex information from multiple surveys e.g. sniff testing results combined with activity intensity, SAL exceedances and wind patterns.

In summary, data analysis and reporting should always consider:

- Both health effects (e.g. individual VOCs) and amenity (odour);
- Both short- and (where relevant) long-term concentrations through comparison with standards covering different exposure periods;
- Review of trends over time and spatial variation;
- Cross referencing to other data collected (odour, site observations/activities, complaints);
- Recommendations for mitigation (if corrective action appropriate) and future monitoring;
- The use of digital methods such as online dashboards supports site communications and stakeholder engagement.

Figures 6.1 to 6.3 illustrate just some of the many different ways in which results for VOC concentrations and odour monitoring can be presented graphically to aid the interpretation and communication of data.

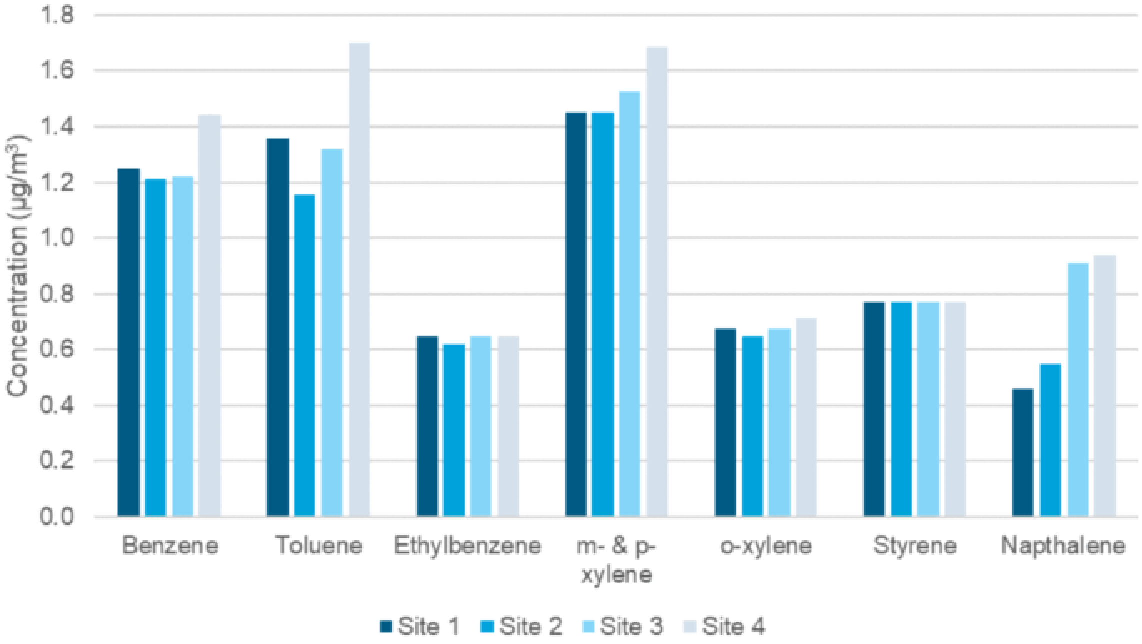


Figure 6.1 – Illustration of concentrations at four boundary Tenax monitoring locations for a range of individual VOCs, to support the interpretation of concentration patterns around the site.

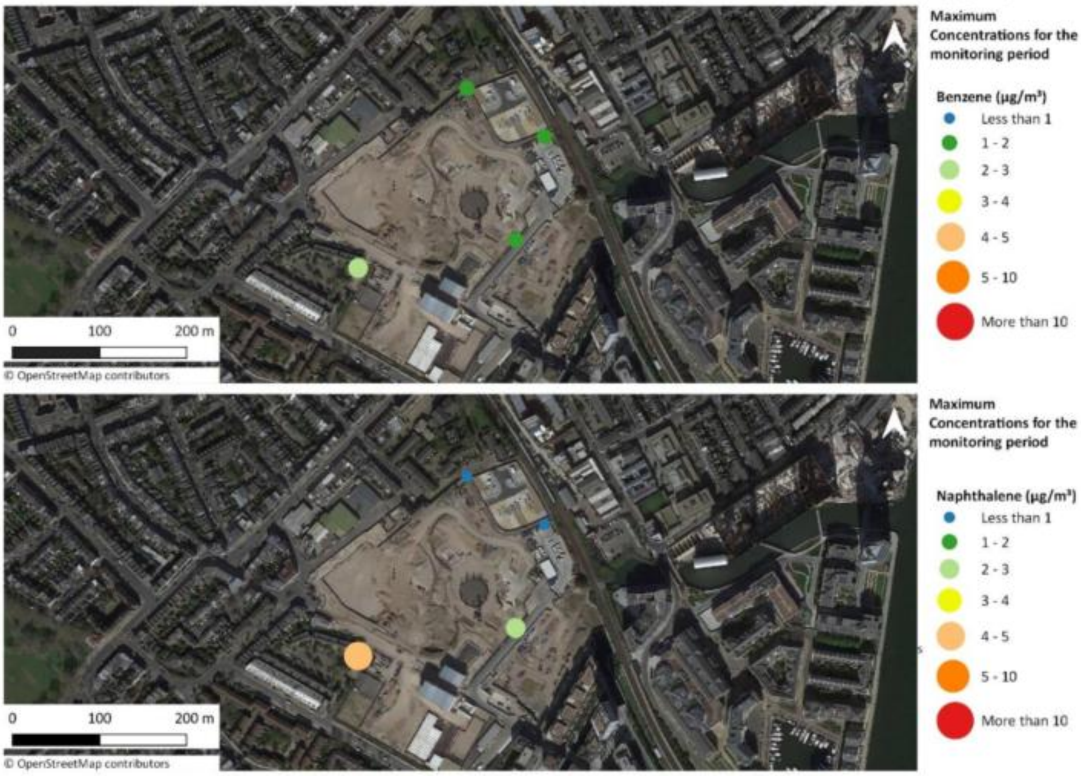


Figure 6.2 – Comparison of benzene and naphthalene concentrations using thematic mapping in GIS software, using colour and size to differentiate between concentration ranges (could also apply to odour intensity results)

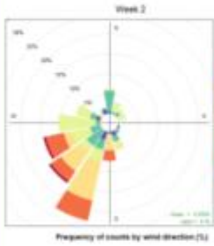
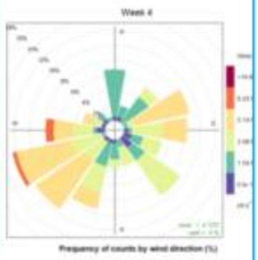
		Period 1	Period 2	Period 3	Period 4
Dates		07.01.21 - 14.01.21	14.01.21 - 21.01.21	21.01.21 – 28.01.21	28.01.21 – 04.02.21
Exposure time (hrs)		171	165	171	168
Missing data		None	None	None	None
Period Wind Rose					
Benzene (µg/m³)	Range	1.2 – 1.7 (Max: Site 4)	1.3 – 1.4 (Max: Site 2)	1.4 – 1.9 (Max: Site 4)	1.3 – 2.1 (Max: Site 4)
	Site ave	1.5	1.3	1.6	1.6
Naphtha -lene (µg/m³)	Range	0.3 – 1.0 (Max: Site 3)	0.5 – 0.8 (Max: Site 1 & 3)	0.3 – 2.3 (Max: Site 3)	0.5 – 4.9 (Max: Site 4)
	Site ave	0.6	0.7	1.0	1.8
Toluene	Max (µg/m³)	3.1 (Site 4)	1.5 (Site 4)	2.7 (Site 1)	2.6 (Site 4)
Ethyl-benzene	Max (µg/m³)	0.8 (LOD all sites)	0.9 (LOD all sites)	0.8 (LOD all sites)	0.9 (LOD all sites)
m- & p-Xylene	Max (µg/m³)	2.7 (Site 4)	1.7 (LOD all sites)	1.7 (LOD all sites)	2.4 (Site 4)
o-Xylene	Max (µg/m³)	1.1 (Site 4)	0.9 (LOD all sites)	0.8 (LOD all sites)	0.9 (LOD all sites)
Styrene	Max (µg/m³)	1.0 (LOD all sites)	1.1 (LOD all sites)	1.0 (LOD all sites)	1.1 (LOD all sites)

Figure 6.3 – Summary of weekly Tenax readings of individual VOCs, including the range, average and maxima alongside a windrose to help identify potential correlation between results

Box 6.3 – Case study: Auditing an air quality and odour monitoring strategy

An Air Quality and Odour Monitoring Strategy was produced for a long-term (approximately three years) remediation project of a former gasworks in central London. To support the strategy, independent auditing of the effectiveness of the strategy was undertaken. The air quality auditor reviewed the contractor's monitoring data and reports, undertook a monthly site visit to observe progress and verify the effectiveness of mitigation, including an independent boundary odour sniff test; discussed future work areas with the contractor and advised the client on potential improvements or changes to the monitoring and reporting.

Prior to the audit, an information pack was produced by the site contractor / monitoring subcontractor for review, including:

- Environmental Monitoring Report, with weekly air quality monitoring data from site boundary locations, any exceedances of SALs and their significance;
- Summary of meteorological conditions for the previous week, and forecast conditions for the next week;
- Summary of activities undertaken in the previous week, with any corrective actions applied;
- Any complaints received, their nature, location of complainant, actions taken (or to be implemented) and communications to be followed up;
- Activities to be undertaken in the next four weeks, with any new mitigating actions proposed;
- Boundary air quality monitoring data (based on weekly reports), with information on any exceedances, their significance and any corrective actions undertaken;
- Monthly summary of any complaints received; and
- A list of actions that to be closed out and the party responsible.

Each month, a summary audit report was produced including a "RAG" table (red, amber, green) summarising the contractor's performance in the required areas supported by photographs to demonstrate changes to the site and the observations made on site such as mitigation applied.

Table 2 – Summary of Audit Findings

REF	DESCRIPTION	COMPLIANCE		FINDING	RISK RATING	ACTION / RECOMMENDATION	TARGET DATE
		K	S				
1.	**GENERAL CONDITIONS AND OBSERVATIONS DURING THE SITE VISIT**						
1.1	Conditions on the day and during the site visit	N/A	N/A	Sunny and dry with very calm condition and sporadic light north to north-west winds with average speed of 2 m/s and average temperature 11°C. Windrose and detailed wind direction during the visit is provided in Figure 2.	N/A	N/A	N/A
1.2	Physical site walkover and work in progress	N/A	N/A	Work in progress: - Advanced sheet piling works around GH3, GH4 and GH5 parallel to Vauxhall Rd, and a localised excavation at the centre of the site; - Excavation works at GH3, GH4 and GH5 mostly completed; - Advanced excavation activities in the surrounding of GH1 with restricted access to the gasholder itself; - Continued backfilling of GH1 to the required level;	N/A	Exposed pipes to be addressed on a precautionary basis (see below) Construction vehicles should be switched off while not in use on site [ref. EMMP, Appendix A, AQDMP Table 3].	N/A

7. Communication

This chapter covers the key stages of communication with stakeholders, including regulators and the local community:

- Risk communication is very important in early discussions with stakeholders to educate, inform and build trust and should be carefully planned.
- Sharing information from monitoring proactively with site team is important for better understanding of any potential issues requiring mitigation
- Sharing results to communicate risk (before, during, after works) externally and internally helps improves site management
- Communication should be an iterative process – reacting to events, improving practices and building trust.

7.1 Introduction

Remediation of brownfield sites needs to be carefully planned and managed and regularly monitored to mitigate potential impacts on the local community. It is also paramount that the local community and other stakeholders are engaged and informed at key stages before, during and after the remediation works through an effective communication strategy.

Risk, and its acceptability to that stakeholder, is often related to a sense of control and perceived benefit, both of which can be enhanced by timely, well planned and well-prepared communication material and events, carefully tailored to the specific receiving group. The extent of communication and its timing will depend on the site history, planning requirements and the developer's overarching communications strategy.

Brownfield development can be especially associated with negative perceptions, more so than equivalent greenfield development. Proximity to remediation and construction works can cause anxiety and distress to those living and working in neighbouring properties. In particular, concerns over unfamiliar odours can be personal and subjective. Odour can cause annoyance, but it may also impact on wellbeing by raising concerns over health, especially if relating to a chemical with a complex name, or an uncertain/invisible source of pollution.

Effective communication with different individuals and groups (collectively referred to as stakeholders) is crucial to ensure all parties understand the key issues and concerns, to enable effective decision making and build trust between different parties. This is especially important as far as it relates to designing and undertaking monitoring surveys, sharing data and acting upon results.

The developer/contractor must commit to engagement with the community at an early stage and continue with regular and proactive communication throughout the works. Communications should follow these principles:

- Proactive community liaison, listening carefully to people's concerns;
- Contact with stakeholders throughout, ensuring a two-way flow of information;
- Complaints investigated and responses provided as quickly as possible;
- Senior management included in communication;
- Information about meetings made available well in advance; and
- Communication with all stakeholders using clear and unambiguous language.

Some extracts from relevant SNIFFER (2010)[39] and Defra (2018)[40] guidance are provided in Box 7.1.

Box 7.1 – Guidance on communication

The SNIFFER (2010) guidance on communicating understanding of contaminated land risks sets out very clearly the benefits of good risk communication and how to go about it. The benefits cited include:

- Reduce unnecessary anxiety for potentially and actually affected parties and misunderstanding;
- Establish a good working relationship with key stakeholders and members of the public and a degree of mutual trust, which is also beneficial for effective communication;
- Avoid a "crisis management" approach of belatedly addressing communities who feel they have not been consulted with or listened to; and
- Reduce the potential for unnecessary delays.

The Defra Science Advisory Council (2018) communicating risk report describes four interactive tasks in the risk management process:

- Characterise the risks;
- Characterise disputes or controversies;
- Identify and evaluate communication aims and methods; and
- Identify the 'informed' public.

7.2 Stakeholders

Establishing and maintaining clear, transparent and accessible ways of communicating with stakeholders in the local community, will help to enable the right information to be shared and discussed openly, building trust and credibility, help address concerns early on regarding the potential risks health and minimise disruption.

Establishing clear flows of information is also central to the management of the works, both in terms of the site and contractors. As well as the developer and main contractor, there will likely be multiple subcontractors working on remediation sites, and potentially different local stakeholders that they need to engage with.

Individual stakeholders will have an interest in different impacts of brownfield development; each will have different expectations of measurements and monitoring with varying grasps of the technical issues involved. Each will decide on the relevance of the information presented to them and perceived risk from the brownfield remediation activities.

The key stakeholders for a remediation project are shown in Figure 7.1. These may differ from project to project, depending on scale, location, type of remediation activity. For more substantial and long-term projects, a contacts list should be established and timing and nature of communications to the relevant stakeholders agreed.

Stakeholders on all sides – developers, regulators and the public – must have confidence in the findings of monitoring data and reports. Regulators may choose to engage an independent third party to conduct a technical review of the developer's emissions management strategy and/or air quality monitoring data to help build trust.

Figure 7.1 – Key stakeholders for remediation projects

7.3 Communication Strategy

Establishing a communication strategy early on, before site activity commences, and continuing to keep it relevant throughout the set-up, monitoring and remediation phases, will help to provide the necessary reassurance that the health of communities around the site is a priority to the developer. This in turn can support trust among local stakeholders and reduce the level of anxiety within the community. If a strategy is not in place, this can not only undermine the value of the monitoring survey but can put unnecessary pressure on the team managing engagement and those undertaking and communicating the findings of the monitoring.

By involving nearby communities, developers and contractors can establish trust and transparency, helping to minimise the potential for disruption. Ideally, engagement should involve sharing information with residents about the proposed works including the remediation process, how the strategy was defined, what may be expected and when, why it needs to be done, what is being done to manage and mitigate potential health impacts, both current, during works and for the future, and how will this be monitored. Close neighbours should be contacted via multiple routes e.g. mailshots, website and liaison group meetings, to raise awareness of works and the communications plan.

Engaging with local education providers and supply of informational material and educational programmes can help raise awareness of a brownfield development, how it interacts with the environment around them and how sustainable development can ameliorate legacy issues of past contamination. Engaging with local educational establishments at all levels may also encourage future green skills career paths.

The importance of communication with and between site staff and technical specialists, be they main contractors, sub-contractors, consultants or monitoring teams, should also not be overlooked. Site teams need to be aware of the on-site and off-site risks and the importance of mitigation and monitoring of VOCs and odours, and on early reporting of any issues. Monitoring teams should be kept up to date of changes to the site working area, the type of activities undertaken and if any concerns have been raised. The communications strategy should be shared, including messages they should or should not talk about “outside the gates”. Toolbox talks on who is doing what and who to engage with through external messaging are vital for clear communications with external parties.

Prior to the commencement of work on-site, a detailed communication plan should be developed and discussed with the key stakeholders (Figure 7.1). This is important to ensure a two-way process, to understand the type of information that stakeholders would like to receive and the timeframes and means by which they wish to be kept informed. This should include air quality reporting, and the type of information that will be shared (frequency, detail). The plan should be a ‘live document’, to be updated as and when necessary, as the works progress. More information on this is provided in Appendix A.

Although not covered in this guidance, it is important that relevant data protection regulations are observed when sharing material that may include personal information e.g. contact lists of residents, complaints response forms. (Consent is only valid for the particular purpose it was gained for e.g. consent to use someone's address to send them a newsletter, does not mean you have consent to use this information for other purposes).

Box 7.2 – Good practice for communication of air quality monitoring data

- Engage with regulators and stakeholders to discuss the approach and listen to what they need e.g. monitoring in certain locations of community interest;
- Communicate the programme and future active areas/new monitoring techniques;
- Be open about monitoring techniques' advantages and disadvantages, potential uncertainties and data gaps and anomalies, and explain why they can occur;
- Share results openly (using graphics to aid understanding) and respond to complaints in a timely manner with an appropriate level of detail to explain findings; and
- Circulate templates for record keeping, to support community participation and help the client to react promptly to any concerns including updating monitoring plans.

7.4 Responding to Concerns

It is imperative that residents and other members of the public can raise concerns about site activities relating to health, odour, dust, noise and other relevant matters through an official route and that they receive a swift response. That response should set out how their complaint will be dealt with and thereafter keeping them informed throughout the follow-up process, including the outcome of any corrective actions.

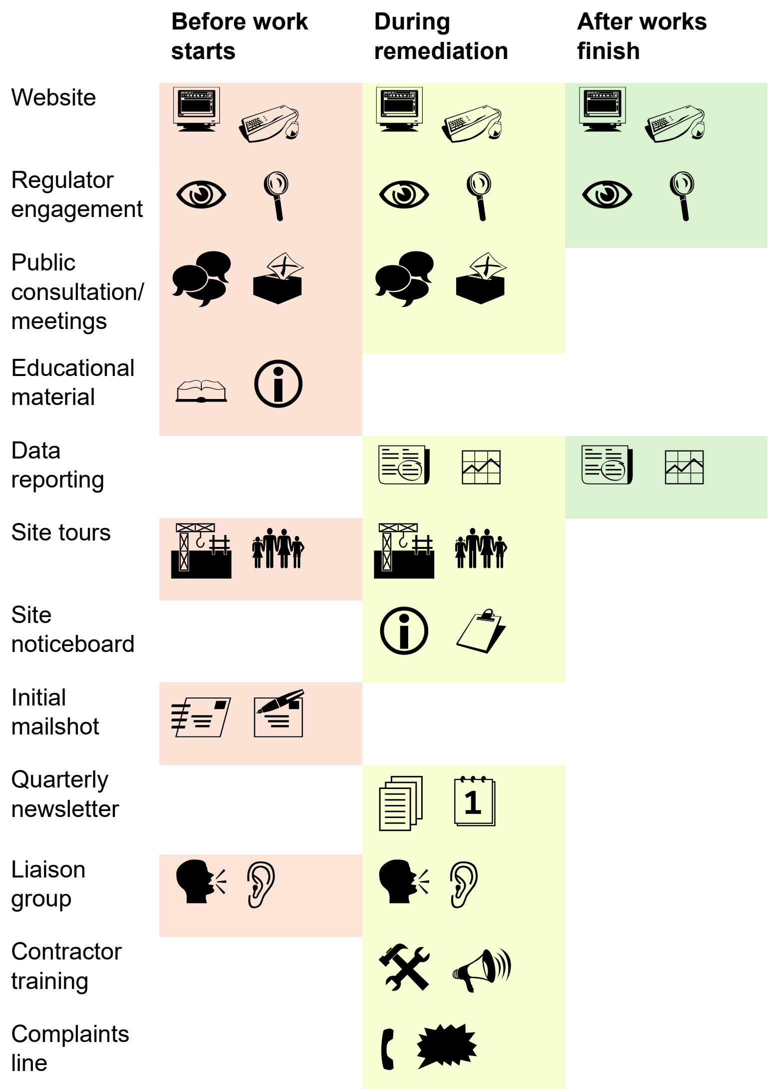
Likewise, the more information that the public can provide about their concerns, the more effective any necessary corrective action may be. Residents can be asked to keep their own odour diaries and share them with the site manager. An example of an Odour Diary template is provided in Appendix A. Providing training in how this is completed, and providing a template, will help ensure full supporting information is gathered in feedback. This may also help with communication of different types of odour sources, understanding the subjective nature of odour and the importance of quality records.

A dedicated feedback/complaints line and website will, in the case of larger/long running remediation projects, be established by the developer and advertised via leafleting/notices. Site contact details should be made available online, posted on a sign at the site itself, and circulated by post to all neighbouring properties. All complaints should be assigned a unique reference number and complainants ideally contacted within 24 hours, (other than on Sundays/Bank Holidays), and local residents and the regulator kept informed of actions.

A summary of any complaints, communications and corrective actions should be shared with the Site Manager or equivalent. The Local Authority Environmental Health Officer and/or Regulatory Case Officer should be kept informed of any relevant issues on a recurring basis.

Box 7.3 – Case study: Brighton Blackrock Communications Strategy

The developer produced a comprehensive communications strategy in support of the Air Quality and Odour Management Plan submitted with the remediation strategy at planning stage to demonstrate their commitment. At pre-planning consultation stage, stakeholder meetings were held with the local authority, Council officers and Councillors, where information was presented on the planned remediation and construction works, the principles of air quality and odour mitigation and monitoring, and the communication strategy. The proposed activities are summarised below.



8. MITIGATION

This document focuses on providing guidance on how to undertake a monitoring survey, which can inform the selection, timing and effectiveness of mitigation techniques on brownfield sites. This chapter provides an overview of some common and some emerging air pollutant control and mitigation techniques and technologies, focusing on emissions from the contaminated land itself[xiv].

This chapter describes:

- The "mitigation hierarchy" to control emissions from brownfield sites;
- An overview of mitigation techniques;
- The importance of developing a site-specific; strategy with the developer/contractor; and
- Engaging with the community.

8.1 MITIGATION HIERARCHY

The primary aim when designing a remediation strategy should be to avoid or, where that is not possible, reduce the potential for emissions to be released into the environment i.e. contain or control at source.

The control of air emissions from brownfield sites should involve a variety of methods, developed in line with the principles of the '**Avoid, Reduce, Mitigate'** hierarchy:

- Avoid emissions to air by carefully and proactively designing the remediation strategy to avoid exposing potential odour and air pollution sources;
- Reduce emissions to air as far as practicable by planning ahead for air polluting/odorous activities, where emissions cannot be avoided or designed out;
- Reduce public exposure to pollutant emissions as far as practicable, where it cannot be avoided; and
- Make provision for reactive mitigation of emissions, where they cannot be prevented at source.

There is some overlap in the mitigation measures used to control emissions of dust and particulate matter with those used for odour and VOC emissions; but there are also specific measures aimed at reducing odour and VOC emissions.

8.2 MITIGATION TECHNIQUES

A brownfield site remediation project will require a bespoke emissions mitigation strategy. It is not the intention of this guidance to describe all available techniques. The most appropriate techniques for a specific site will depend on a range of factors, such as the type and extent of contamination, the location of and proximity to receptors, and the timeline for the project. These techniques should be selected in line with the hierarchy and proportionate to the risk.

8.2.1 Planning ahead

Consideration should be given at an early stage of the remediation strategy to the potential for different activities to generate pollution and odours and when these will be undertaken. Where these activities are necessary, it is important to consider their position within the site relative to offsite sensitive receptors and dispersion pathways, and the likely prevailing weather conditions.

Although it may not be possible to programme works to entirely avoid working under unfavourable meteorological conditions, consideration of likely conditions at certain times of year by reviewing a local windrose can allow sensitive areas that are

[xiv] Other sources of VOCs on brownfield sites include vehicle/plant emissions (controlled through vehicle standards and non-road mobile machinery (NRMM) legislation) and paint/solvent use.

potentially more frequently at risk of windblown emissions from the site to be identified in advance. The inclusion of an anemometer(s) on site will help the contractor to continue considering the impacts of weather conditions to ensure mitigation is proactively applied.

Where practicable, specific works that are likely to be odorous and in proximity to sensitive properties should be planned in colder/wetter months, when residents are more likely to keep windows closed.

Phasing the remediation so that works commence in a less contaminated area will allow more time for the full set of mitigation controls to be put in place while communications with residents are being established.

8.2.2 Reducing the source

Reductions in the source strength can be achieved through making proactive modifications to the remediation strategy, such as planning for contaminated material to be treated offsite at a specialist facility rather than treating in-situ; however, these techniques have time and cost implications that will need to be considered by and discussed with the contractor.

Simple approaches can be applied to reduce the source strength such as the implementation of a carefully phased approach to excavation (only exposing small areas of a few square metres of ground at a time or keeping the cover on a gasholder while it is dewatered). This serves to reduce the surface area of exposed odorous materials and hence the area in contact with the atmosphere.

Stockpile management plans can specify that odorous material should not be stored in proximity to the boundary, especially if there are sensitive receptors present, and to keep stockpiles covered with impermeable material or foam to reduce emissions when not in regular use (including overnight).

If odorous material is excavated and exposed to air, the handling and agitation/shaking of that material should be minimised to avoid volatilisation. It should be done where practicable at a suitable distance from sensitive properties. Strongly odorous material should ideally be loaded directly into trucks for offsite treatment, rather than left on site.

8.2.3 Mitigating emissions

Spraying odorous material, either simply with water or with a neutraliser, during excavation and when being stored, will reduce the potential for an effective exposure pathway. These reactive measures have co-benefits in that they will also reduce potential dust emissions (but note, use of water is not always possible for reasons of sustainability, water pollution and material quality). They should therefore be considered as a secondary measure in line with the hierarchy.

Misting sprays for odour and dust suppression can inadvertently interfere with certain types of dust monitoring equipment as the droplets created by certain odour suppression sprays (the fine droplets or the high humidity generated by the spray can be misread as particles by optical sensors). If a deodorant is added to sprays, it is important to check off site that this does not result in too strong a concentration, as the spray may become a nuisance itself or be perceived as a danger to health.

The use of air pollution control equipment, such as scrubbers, adsorption systems, and thermal oxidisers, can be an effective treatment method where emissions cannot be avoided. These technologies capture and destroy VOCs and other pollutants before they are released into the atmosphere. While this may be achievable on small area/volume sources which can be enclosed e.g. by retaining the lid on gasholders when degassing, or erecting a tent over buried tanks, it may not be practical for large open areas on remediation sites.

Enclosing odorous source material introduces occupational health risks to workers that require use of respiratory protective equipment, which is undesirable. However, in some cases it may be the only feasible option to contain odours and VOCs. In this case, the enclosed unit should be as airtight as possible, kept under negative pressure with air drawn out through an appropriately sized and maintained scrubber to remove the bulk of VOCs.

Photo 8.1 – Foaming soil with a neutral odour suppressant can reduce odour potential

Photo 8.2 – Covering over stockpiles of residual odorous material is good practice

8.3 Monitoring effectiveness

An effective air quality monitoring strategy should go hand in hand with the mitigation strategy. It should be used to inform the contractor how effective different mitigation techniques are. The VOC and odour monitoring data should be regularly reviewed to check there is a continued need for – or an increase in – mitigation (see Section 6.3). Both the monitoring and mitigation strategies should be iterative, in recognition of the "known unknowns" on brownfield sites. The regular updating of both strategies allows them to evolve over time as the remediation works progress, e.g. as new areas of contamination are uncovered, and mitigation is applied in new areas so the monitoring can be adjusted to provide relevant information.

On longer duration projects, the monitoring approach should be revisited at least at before each core phase of the remediation works, to identify in advance and plan the location of monitoring and mitigation of specific activities that may result in emissions.

8.4 Community engagement

Involving the local community (see Chapter 7 and Appendix A) is a key element to consider when developing, applying and reviewing a mitigation strategy. Forewarning residents of potentially odorous activities being planned and explaining how the Contractor is proposing to monitor and manage them and, importantly, when the activity is likely to be finished, can help to reduce local anxiety about the odour.

This is especially important when noticeable mitigation techniques such as misting sprays may be applied on the boundary (note, the use of perfume agents to suppress odours is not recommended as these can introduce a new source of odour that may be offensive to local populations if too concentrated, or create alarm i.e. a new, unknown source of odour).

It is also important to communicate that some odours may still be noticeable during the construction phase, for example when piling through ground containing treated material or where there is a risk of finding residual areas of contamination.

Box 8.1 - Case study: Oval Village Gasholder Demolition Mitigation Strategy

The successful gasholder demolition contractor designed a comprehensive odour/VOC mitigation scheme in support of the remediation strategy for a former gasworks site in Central London. The contractor adapted an existing mitigation approach used within the pharmaceutical industry to aid the containment of vapours during the dismantling and degassing of gasholders. To reduce the risk of fugitive emissions due to the presence of hydrocarbon-contaminated sludges and other historical contamination within the gasholders, an odour control unit filled with activated carbon was used to exchange 50,000 cubic metres of air per hour. Small holes were cut into the crown (cover) of the gasholder to increase the gas capture rate. The system in this case was designed for general control of VOC odours but would be effective for mercaptans, hydrogen sulphide and other contaminants in waste treatment.

Small aperture in gasholder crown

Extraction to odour control unit

9. Summary

9.1 Purpose of the guidance

This guidance was conceived by the IAQM and IES LCC to promote consistent and proportionate approaches to air quality monitoring on brownfield remediation projects. The principal aim is to support effective collaboration between the contaminated land and air quality sectors, ensuring that air quality considerations are integrated throughout the project lifecycle and that the outputs are appropriate to inform the protection of health and wellbeing of communities potentially affected by brownfield remediation activities.

This document has described the background to, and the key stages and steps involved in, the planning, monitoring, evaluation, mitigation and communication of air quality – including odour – during the remediation of brownfield sites. It provides a framework for good practice in design and implementation of proportionate monitoring strategies; it encourages early and integrated consideration of monitoring within project design and management; and aims to improve transparency, consistency, and stakeholder confidence in the interpretation of monitoring results.

Figure 9.1 provides a high-level summary of the contents of this good practice guide and the likely parties undertaking each of the activities; it is, however, to be expected that some projects will differ in approach. It is essential that this document is read as a whole to ensure the detail of good practice in this complex technical field is not overlooked.

9.2 Core principles

Five core principles underpin the good practice described within this document:

1. Clear objectives: monitoring should be designed with well-defined purposes, such as baseline characterisation, compliance verification, health protection, and/or community reassurance.
2. Considered design: the spatial and temporal design of the monitoring programme should reflect site-specific sources, meteorological influences, and the proximity of sensitive receptors.
3. Robust methodology and quality assurance: monitoring and analytical techniques should be fit for purpose, traceable to recognised standards, and supported by appropriate quality assurance and control procedures.
4. Proactive management: monitoring should inform real-time decision-making, with clear response protocols in light of elevated pollutant concentrations or threshold exceedances.
5. Transparency and communication: results and analysis should be communicated clearly to regulators, stakeholders, and the public, using accessible formats and consistent terminology.

9.3 Implementation

9.3.1 Pollutants of concern

VOCs are the primary pollutants of interest for most brownfield remediation activities on gasworks sites, which form the focus on this guidance. However, the principles for monitoring and analysis are applicable to other pollutants such as chlorinated compounds and other gaseous phase, odorous pollutants. The selection of monitoring parameters should be justified based on contaminant profiles, remediation methods, and identified exposure pathways.

9.3.2 Monitoring design

Monitoring programmes should include:

- Baseline surveys prior to intrusive or remediation works to establish existing ambient conditions;

- Operational phase monitoring to assess emissions during active remediation, with both upwind and downwind sampling where feasible;
- Verification monitoring following completion of works to confirm that pollutant levels have returned to baseline conditions; and
- Monitoring frequency and duration should capture the expected variability in site emissions and relevant meteorological conditions.

9.3.3 Assessment criteria

Data interpretation should be based on ambient air quality or health-based benchmarks, rather than occupational exposure limits. Both short-term and longer-term exposure should be evaluated, taking account of potential cumulative effects and analytical uncertainty.

9.3.4 Mitigation and response

A monitoring strategy should set out the actions to be taken when elevated concentrations or odours are detected. Mitigation may include operational adjustments, containment or suppression, or modification of remediation methods. The effectiveness of these interventions should be reviewed regularly and documented.

9.3.5 Stakeholder engagement

Effective communication with local communities, regulators, and other stakeholders is essential. This should include:

- Clear explanation of monitoring objectives and planned activities;
- Regular updates on monitoring results and their interpretation;
- Clear reporting of any exceedances or corrective actions taken; and
- Transparency and openness in communication, to maintain confidence in the monitoring process.

9.3.6 Documentation and reporting

Monitoring programmes should be documented within the site management or remediation plan. This should include:

- Monitoring objectives, locations, and methods;
- Quality assurance and control measures;
- Data records and calibration details; and
- Results interpreted in relation to baseline conditions and project activities.

Reports should clearly demonstrate how monitoring outcomes have influenced site management decisions and the overall risk assessment process.

9.4 Continual improvement

Air quality monitoring for brownfield remediation projects is an essential component of land-use planning and public health protection. When planned and implemented in accordance with the principles outlined in this guidance, air quality monitoring can provide robust evidence to support safe, effective, and sustainable site redevelopment.

The IAQM and IES encourages practitioners, developers, and regulators to maintain an open dialogue and to share lessons learned as monitoring technologies, analytical methods and mitigation techniques continue to evolve. The principles set out in this guidance should therefore be regarded as a basis for continual improvement, supporting the long-term objective of delivering regeneration projects that are both environmentally responsible and protective of human health.

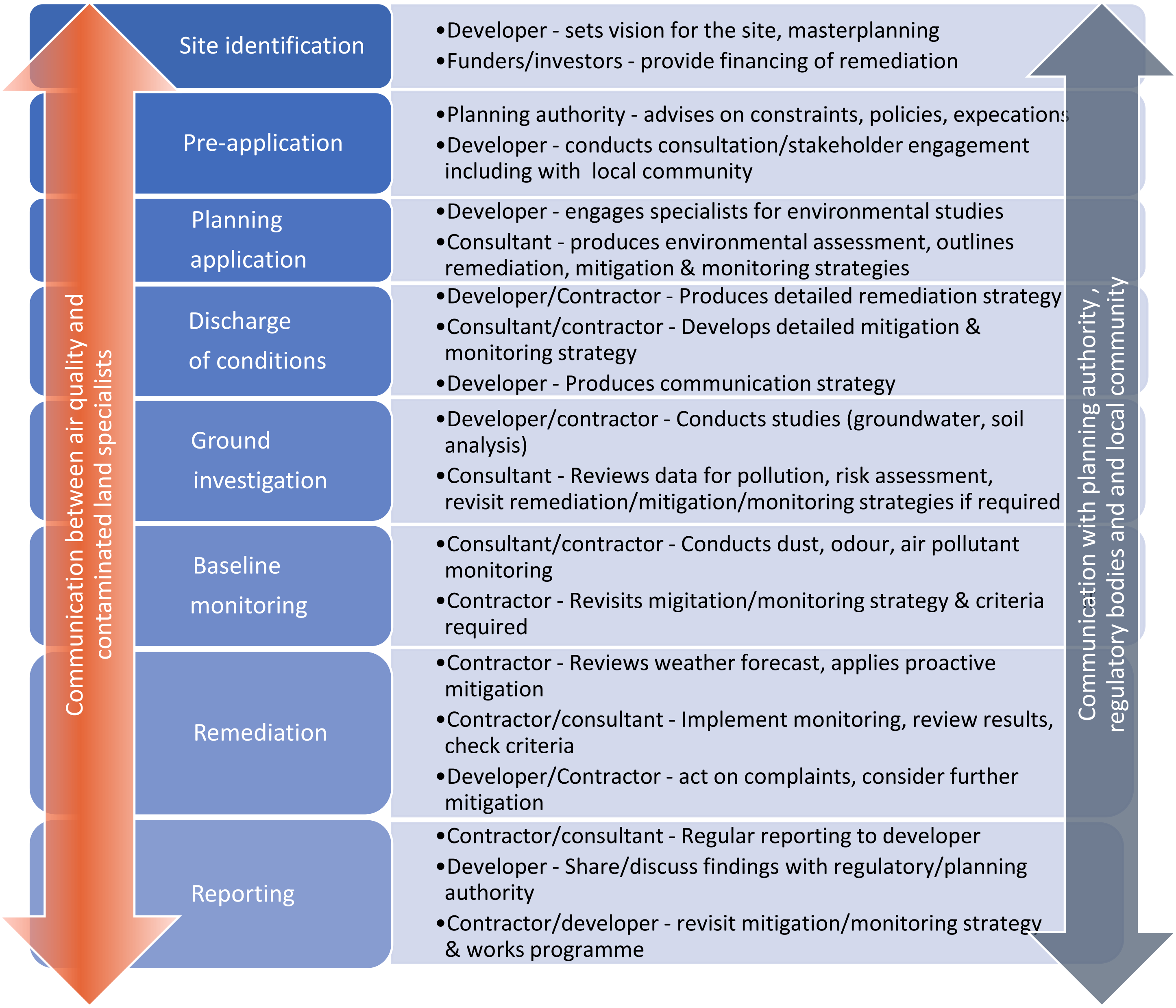


Figure 9.1 - Key stages in planning, monitoring, evaluating, mitigating and communicating data

Appendix A. Information Sharing

A.1 External communication

Sharing clear information externally can help manage community concerns, expectations and awareness of key events or operations. Site noticeboards explaining site activities, with the basic information, regular updates, newsletter and data presentation on air quality can be helpful to inform and help local communities understand works as they progress. Noticeboards can be static, paper based, simple screen based or fully digital and interactive. Websites can also help update and keep communities informed. Blogs or vlogs can be added to show key operations, emission controls and how contamination will be handled.

Brownfield projects are complex and there is a need to be iterative in communications, as well as managing site issues such as an unexpected discovery of contamination. Communications must be kept up to date, as out of date information, poor data or careless reporting will quickly lose trust and make communities suspicious of events and activities, reported air quality data and potential health impacts. Therefore, keeping communications live throughout a project is vital.

Different levels of detail and format of information are required by different stakeholders, at different times, including prior to, throughout and after the works. The sections below outline some of the means of information sharing between various parties.

A.2 Information for employees and contractors

Employees and contractors working on a remediation site should be briefed on their requirements and available actions to avoid, reduce and mitigate air pollution and odour emissions. This should be conducted with reference to contractor method statements which implement the air quality and odour management strategy. Toolbox talks should be rolled out to all site staff to familiarise with the site-specific monitoring techniques and criteria to apply, good practice in sniff testing, and mitigation measures. This may be done initially by the air quality specialist, then any updates/refresh by the environmental manager or site manager or other appropriately informed party.

A.3 Information for stakeholders

Residents, local authority officers and members, regulatory bodies and other stakeholders may wish to engage in different ways, at different times. In undertaking early engagement on the communications plan, the various parties can be made aware of the different ways in which they can receive information, and can opt in, or opt out at different times. Key throughout, will be to ensure two-way communication, to listen and be responsive to concerns and suggestions and to be clear in the information provided in return.

The following actions are considered best practice for public engagement:

- Initial mailshot: Residents, workplaces, schools and businesses contacted via post/e-mail to alert them to the works, access to website and contact details; ask if they want to be included in more regular communications (and how).

- Quarterly newsletter, to keep residents informed of progress on-site and mitigation covering:
  - (i) Anticipated programme of works;
  - (ii) Progress with works activities against programme timeline;
  - (iii) Summary of monitoring results, corrective measures adopted or proposed, what will be done to manage emissions over the forthcoming period;
  - (iv) Contact details for further information.
- Dedicated website providing a range of information, including:
  - (i) Clear signposting to contact details and complaints procedure;
  - (ii) Supporting information on the proposed activities and programme, and the benefits the end result is expected to bring to them and the local area;
  - (iii) Online updates (frequency depending on intensity of activities): activities scheduled for the coming period, working methods, odorous activities and their likely duration, mitigation plans, reminder of the complaints procedure;
  - (iv) Frequently Asked Questions (updated as the work progresses).
  - (v) Quarterly newsletters by mailshot.
- Face to face meetings, which may comprise:
  - (i) A public consultation event, (timed with an initial mailshot) to proactively provide information about the works and the mitigation and controls that will be in place. The consultation event will enable familiarisation with the works and programme, provide an understanding of the activities that will be undertaken, their likely duration, the mitigation methods that will be employed, opportunities for further engagement and contacts;
  - (ii) Walkover tours, arranged at intervals throughout the works for members of the public, the local authority and/or regulators to understand the site and provide comments;
  - (iii) Liaison group – an opportunity to build up trust and develop relationships with the local community, best done at an early stage. Short, regular monthly meetings between the developer/operator and residents' representatives to discuss activities, monitoring findings and any concerns;
  - (iv) Meetings with local authority and regulators – as required, to discuss monthly reports and respond to any concerns.

A.4 Example odour diary template

Reporter name(s)	
Date (day/month/year)	
Time of test	
Location of test (Street name – not house name or number)	
Weather conditions (delete as appropriate or add other)	sunny, dry, light rain, heavy rain, fog, snow
Temperature (delete as appropriate or enter in degrees)	very warm, warm, mild, cold, freezing
Wind strength (delete as appropriate)	none, light, steady, strong, gusting
Wind direction (e.g. blowing from west)	
Intensity out of a score of 6 (see below, e.g. 0, 3-6, 2-3, 4-6 etc.) Record every 10-20 seconds	
Duration of test (e.g. 5 mins)	
Constant or intermittent odour?	
Frequency of detection during monitoring period (e.g. never, once, every 30 secs, every 60 secs etc)	
What does it smell like? (e.g. is the smell offensive?)	
Sensitivity of location (see below, low, medium, high)	
Any other comments or observations (e.g. PID reading, notes on other activities nearby)	
Intensity (German Standard VDI 3882, Part 14) 0 - No odour 1 - Very faint odour (doubt as to presence) 2 - Faint odour (present but can't be described) 3 - Distinct odour (just recognisable) 4 - Strong odour (easily recognisable) 5 - Very strong odour (offensive and undesirable) 6 - Extremely strong odour (offensive, could induce vomiting due to strength)	Location sensitivity (where odour is detected) Low – footpath, road) Medium – industrial or commercial workplaces High – housing, pub/hotel etc.

A.5 Example odour feedback form

Reporter name(s)	
Time & date feedback received *(day/month/year)*	
Name & address of observer, and contact no.	
Time & date of observed odour	
Location of observed odour *(if not same as above)*	
Weather conditions *(delete as appropriate or add other)*	*sunny, dry, light rain, heavy rain, fog, snow*
Temperature *(delete as appropriate or enter in degrees)*	*very warm, warm, mild, cold, freezing*
Wind strength *(delete as appropriate)*	*none, light, steady, strong, gusting*
Wind direction *(e.g. blowing from SW/NE etc)*	
Complainant's description of odour intensity *(see below)*	
Complainant's description of smell *(e.g. oil, petrol, paint, smoke, drain?)*	
Constant or intermittent odour?	*Use VDI scale*
Any other comments or observations ***(E.g. notes on** ongoing activities, **site noise etc.)***	
Remedial action required? *(to be determined by project team)*	
Date follow up to be provided	

Appendix B. Acronyms, abbreviations & definitions

Acronym or Abbreviation	Term	Further information
AEGL	Acute exposure guideline level	Concentrations of airborne chemicals at which health effects may occur. Used by emergency planners and responders worldwide as guidance in dealing with rare, usually accidental, releases of chemicals into the air. Designed to protect the elderly and children, and other individuals who may be susceptible
AMCT	annual mean concentration target	New regulatory air quality target introduced in England in 2023 for $PM_{2.5}$ (see also PERT)
AQMA	Air quality management area	An area in the UK declared by a local authority where it considers there to be a risk of exceedances of an NAQO
AQS	Air quality strategy	See NAQS
AQOMP	Air quality and odour management/monitoring plan	A document that sets out the proposed plan for managing, mitigating and monitoring air pollutants and odour during a construction/remediation project
ATSDR	Agency for Toxic Substances and Disease Register	Federal, non-regulatory, environmental public health agency overseen by the US Department of Health and Human Services. Lead body for determining, preventing, and mitigating the effects of exposure to hazardous substances
BPM	Best Practicable Means	Measures to control emissions of substances which may result in a statutory nuisance under EPA 1990
BREEAM	Buildings Research Establishment Environmental Assessment Method	Standardised assessment method and certification scheme for evaluating the procurement, design, construction and operation of a development against a range of targets based on performance benchmarks
BTEX	Benzene, toluene, ethylbenzene and xylenes	A group of VOCs comprising aromatic hydrocarbons with associated odours, commonly found together on some types of brownfield sites e.g. former gasworks
CoPC	Compound of potential concern	A contaminant that is present at a site in an amount that creates a potentially unacceptable exposure risk to workers or the public, based on the planned site activities
COMEAP	Committee on the Medical Effects of Air Pollutants	Committee advising the UK Government on all matters concerning the health effects of air pollutants
CSM	Conceptual site model	Term used in land contamination risk assessment to describe an illustrative representation of the ground conditions and the physical, chemical and biological processes that control the generation, transport, migration and potential impacts of mine gas to receptors

Acronym or Abbreviation	Term	Further information
DDO	Dynamic dilution olfactometry	BS EN 13725:2022 provides a common basis for evaluation of odour emissions by DDO. It specifies a method for the objective determination of the total odour concentration of a gaseous sample using human assessors
Defra	Department of the Environment, Food & Rural Affairs	UK Government department with oversight of environmental matters including air quality and contaminated land regulation and policy
DNAPL	Dense non-aqueous phase liquid	Compounds that are denser than and only slightly soluble in water so exist in a subsurface as a separate phase e.g. transformer/ insulating oils, coal tar, and chlorinated solvents (TCE, PCE)
EAL	Environmental Assessment Level	Term used by Environment Agency to describe assessment criteria for environmental permitting including guidelines for use in air quality risk assessment
ECHA	European Chemicals Agency	A public body, funded by both the European Union and administrative fees from chemical companies registering under REACH
EHO	Environmental Health Officer	Local authority role to protect the safety, health and wellbeing of citizens and the environment through compliance and enforcement activities
EIA	Environmental Impact Assessment	Required for major building or development projects in the UK to assess their impact on the environment. Considers the direct and indirect significant impact of a project based on a wide range of environmental factors including air, soil, water, climate and biodiversity
EPA 1990	Environmental Protection Act 1990	Makes provision for the improved control of pollution arising from certain industrial and other processes. Defines matters that constitute a statutory nuisance and requires local authorities to inspect complaints. Sets out the structure and authority of waste management and emissions control in England, Wales, and Scotland
EPAQS	Expert Panel on Air Quality Standards	The expert panel no longer exists but guidance that it produced is still available
EPR	Environmental Permitting Regulations	Regulatory regime controlling certain industrial processes in England and Wales (with similar regimes in Scotland and Northern Ireland), requiring the operator to apply for an environmental permit
EU	European Union	Sets directives or legislative acts that set out a goal that EU countries must achieve. It is then up to the individual countries to devise their own laws on how to reach these goals. Air Quality Standards Regulations are retained EU-derived domestic legislation under s.2 of the European Union (Withdrawal) Act 2018. The Directive itself is not retained but is still relevant for the purposes of interpreting the Air Quality Standards Regulations and other relevant retained legislation

Acronym or Abbreviation	Term	Further information
FAQ	Frequently asked question	A question in a list of questions and answers intended to help people understand a particular subject
GC-MS	Gas chromatography - mass spectrometry	Analytical method that combines two techniques to identify the concentrations of individual VOCs and other compounds
GI	Ground investigation	Exploration and recording of the location and characteristics of the subsurface. Specialist intrusive investigation on a site with the associated monitoring, testing and reporting. May comprise boreholes, trial pits, penetration tests, laboratory tests and geophysical methods
GIS	Geographical Information System	Software that brings together maps and data for analysis. Can help to create, manage, and analyse information about a location or area
IAQM	Institute of Air Quality Management	Professional body representing specialists in indoor and outdoor air quality assessment, monitoring, management and mitigation
IARC	International Agency for Research on Cancer	Specialised agency of the WHO focusing on cancer research. Publishes monographs which identify environmental factors that are carcinogenic hazards to humans
ISO	International Standards Organisation	Independent, non-governmental, international standard development organisation
LAQM	Local air quality management	Framework under Part IV of the Environment Act 1995 whereby air quality is managed by England's local authorities
LCRM	Land contamination risk management	Applies in England, Wales and Northern Ireland. Framework to assess risks from land contamination, assess what remediation options are suitable, to plan and carry out remediation and verify that remediation has worked. It can be used in a range of contexts e.g. voluntary remediation, planning, assessing liabilities or under the Part 2A contaminated land regime
LNAPL	Light non-aqueous phase liquid	Compounds that are less dense than water so migrate deep below the water table and dissolve into flowing groundwater e.g. petrol and heating oil
LPA	Local planning authority	Responsible for deciding whether a proposed development should be approved
MCERTS	Monitoring certification scheme	Environment Agency's monitoring certification scheme used to approve people, instruments and laboratories for the testing of air, soils and other materials
mg/m^3	milligrams per cubic metre	Concentration of a pollutant expressed as the mass of a gaseous compound per cubic metre of ambient air
NAQO	National air quality objective	Objective for pollutant concentrations in ambient air set under the UK air quality strategy
NAQS	National air quality strategy	First published in 1997 it set out a framework of standards and objectives for the air pollutants of most concern in the UK. The aim was to reduce the air pollutant impact on human health and the natural environment by reducing airborne concentrations

Acronym or Abbreviation	Term	Further information
NMVOC	Non methane volatile organic compound	A VOC other than methane
NPPF	National Planning Policy Framework	Sets out the Government's economic, environmental and social planning policies for England and how these should be applied. Similar regimes apply in Wales, Scotland and Northern Ireland
NRMM	Non Road Mobile Machinery	Any mobile machine, transportable equipment, or vehicle, not intended for carrying passengers or goods on public roads, that is equipped with a combustion engine. Exhaust emissions can contain VOCs
ODT	Odour detection threshold	The lowest concentration of an odorant that can be detected reliably. For populations, the ODT refers to the concentration where 50% of the population can detect an odour is present (under controlled conditions). ODT values in the literature can show wide differences due to different experimental methods
PAHs	Polycyclic aromatic hydrocarbons	A subgroup of hydrocarbons containing more than one benzene ring including benzo[a]pyrene, naphthalene, styrene and phenanthrene
PCE	perchloroethylene	Chlorinated solvent used in dry cleaning and industrial processes
PERT	Population exposure reduction target	New target introduced in England in 2023 for $PM_{2.5}$ (see also AMCT)
PHE	Public Health England	Replaced by UKHSA in 2021. Works to prevent, prepare for and respond to infectious diseases and environmental hazards
PID	Photoionisation Detector	A gas detection device that gives instantaneous readings of VOCs and other gases. Can operate continuously, commonly used as detectors for laboratory-based GC or as hand-held portable instruments. Typically uses a lamp (10.6eV) to emit high-energy UV photons that break molecules into positively charged ions
PM	Particulate matter	PM_{10} – refers to suspended particles of diameter up to 10 micrometers (µm) $PM_{2.5}$ – refers to suspended particles of diameter up to 10 µm
ppb	Parts per billion	The volume of a gaseous compound per billion volumes of ambient air i.e. number of units of mass or volume of a contaminant per 1000 million units of total mass or volume. A concentration of 1 ppb means that for every billion (10^9) units of air, there is one unit of pollutant present
ppm	Parts per million	Similarly to ppb, but the number of units of mass or volume of a contaminant per million units of total mass or volume
QA	Quality assurance	The process for assuring the reliability of monitoring and measurement data, by planning, assessment, and improvement efforts to meet end-use data quality requirements

Acronym or Abbreviation	Term	Further information
QC	Quality control	The routine application of procedures for attaining prescribed standards of performance in the monitoring and measurement process
REACH	Registration, Evaluation, Authorisation and Restriction of Chemicals.	European Union regulation, which entered into force in June 2007, designed to improve the protection of human health and the environment from the risks that can be posed by chemicals, while enhancing the competitiveness of the EU chemicals industry
RPS	Regulatory Position Statement	Environment Agency guidance on the regulatory requirements associated with certain regulated operations. The RPS explains when a permit is not required for certain regulated activities
SAL	Site action level	The concentration of a contaminant or group of contaminants, established for site use to protect health of workers and/or offsite receptors. Also referred to as a trigger level for when mitigating action should be taken
SVOC	Semi-volatile organic compound	The organic compounds which elute after n-hexadecane, on the GC column, as specified in BS EN16516:2017
TCE	trichloroethylene	Chlorinated solvent used in industrial metal degreasing
TD	Thermal desorption	Technique used in the analysis of VOCs by GC-MS. Involves heating a sorbent tube (containing Tenax or similar) to desorb the organic compounds
TPH	Total petroleum hydrocarbons	Describes any mixture of hydrocarbon compounds that are found in crude oil
TVOC	Total volatile organic compound	The sum of the concentrations of the identified and unidentified VOCs, as specified in BS EN16516:2017
$\mu g/m^3$	micrograms per cubic metre	Concentration of a pollutant expressed as the mass of a gaseous compound per cubic metre of ambient air
UK	United Kingdom	United Kingdom of Great Britain and Northern Ireland. Refers to the areas and legislative frameworks for England, Scotland, Wales and Northern Ireland
UKAS	United Kingdom Accreditation Service	National accreditation body for the UK that assesses and accredits testing, calibration, validation and verification services
UKHSA	United Kingdom Health Security Agency	Government Agency, responsible since April 2021 for public health protection and infectious disease capability in England (replaces PHE)
UKHSE	United Kingdom Health and Safety Executive	British public body responsible for the encouragement, regulation and enforcement of workplace health, safety and welfare. Provides advice and standards for occupational health
USEPA	United States Environmental Protection Agency	Regulatory body in the United States responsible for permitting and setting environmental standards
VDI	Verein Deutscher Ingenieure	Association of German Engineers. Sets a standard for odour sniff testing in VDI 3882

Acronym or Abbreviation	Term	Further information
VOC	Volatile organic compound	A chemical with high vapour pressure/low boiling point, low water solubility, indicated by its octanol-water partitioning coefficient (K_{oa}). The organic compound eluting between and including n-hexane and n-hexadecane on the GC column, as specified in the British Standard[41] BS EN16516:2017. Construction/industrial site sources of VOCs 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 **See also: NMVOC, SVOC, TVOC and VVOC**
VVOC	Very volatile organic compound	The organic compound eluting before n-hexane on the gas chromatographic column.
WEL	Workplace exposure limit	Occupational air quality standard for the protection of site workers
WHO	World Health Organization	International body which sets guidelines for the protection of health including for indoor and outdoor air quality
Other definitions	**Term**	**Further information**
	air monitoring	The identification and quantification of airborne contaminants to determine the need for mitigation using direct-reading instruments and/or laboratory analysis of air samples
	aliphatic	straight and branched chain hydrocarbons, including alkanes and alkenes
	aromatic	Hydrocarbons containing one or more benzene rings, including BTEX and PAHs
	brownfield	Developed land, that is, or was previously, occupied by a permanent structure
	criterion	General term applied to an environmental assessment guideline, objective, standard, or threshold
	desorption	The release of gas where it has been stored on the surface of another material
	diffusion	Movement of a gas or fluid from an area of higher concentration to an area of lower concentration. The material mix until the different phases are evenly distributed
	direct-reading instruments	Instruments for detecting and measuring exposures to gases, vapours, aerosols, and fine particulate matter suspended in air, in real-time or near real-time
	dust	Solid particles that are suspended in air, or have settled out onto a surface after having been suspended in air. The terms dust and particulate matter (PM) are often used interchangeably, although in some contexts

Acronym or Abbreviation	Term	Further information
		one term tends to be used in preference to the other. Note: this is different to the definition given in BS 6069, where dust refers to particles up to 75 µm in diameter
	earthworks	The processes of soil-stripping, ground-levelling, excavation and landscaping
	field blank	A conditioned sorbent tube from the batch used for the sampling exercise, subjected to the same handling procedure in the field as the sample tubes, including removal and replacement of storage caps, but not used for sample collection
	groundwater	Water present in the cavities and spaces in soils and rocks
	nuisance	Often used in a general sense when describing the impact on amenity of dust and odour but with specific meanings in environmental law: (a) Statutory nuisance, as defined in S79(1) of the EPA 1990. (b) Private nuisance, arising from substantial interference with a person's enjoyment and use of land. (c) Public nuisance, arising from an act or omission that obstructs, damages or inconveniences the rights of the community. Each of these applying in so far as the nuisance relates to the unacceptable effects of emissions. It is recognised that a significant loss of amenity may occur at lower levels of emission than would constitute a statutory nuisance. Note: as nuisance has a specific meaning in environmental law, and to avoid confusion, it is recommended that the term is not used in a more general sense in remediation strategies.
	odour	The human olfactory response (perception followed by psychological appraisal) to one, or more often a complex mixture of, chemical species (such as VOCs) in the air. The chemicals are the pollutants, and they may or may not have health effects at the concentrations that trigger an odour response
	olfactometry	A common method used to quantify the concentration of odour. A standardised way to quantify odour concentrations was adopted across Europe in 2003 through EN 13725:2003, *Determination of odour concentration by dynamic olfactometry*
	passive instruments	Sampling techniques that collect air pollutants without using a mechanical pump but instead relies on the natural diffusion of air pollutants to a sorbent material
	piling	Construction of deep foundations by driving a preformed pile (usually concrete or steel) into the ground or by casting concrete in a pre-bored shaft which may be cased or uncased

Acronym or Abbreviation	Term	Further information
	pathway	The route by which a source of pollutant travels through the environment before encountering a receptor. Routes could be air, ground, water
	receptor	A location that may be affected by emissions during remediation/construction/operation. Human receptors include locations where people spend time and where property may be impacted by emissions to air. Ecological receptors are habitats that might be sensitive
	remediation	Describes the process of removing ground contamination. In this guidance, it refers to the actions taken to deal with the ground or soil underlying a site, to render it suitable for future use and to prevent risks of contamination affecting health and the environment
	risk	The combination of the severity of an event (e.g. the impact of exposure to a chemical hazard) and the likelihood (or probability) of that event occurring. A risk can have a negative impact (harm) or positive impact (benefit)
	risk assessment	The formal process of identifying, assessing and evaluating the health and environmental risks that may be associated with a hazard
	site investigation	The overall process of determination of the physical characteristics of sites as they affect design, construction and stability of neighbouring ground or structures
	source	The origin of a pollutant in or prior to its release into the environment
	speciation	The identification of individual compounds in a mixture of compounds such as VOCs. A specific type of chemical analysis that can be requested

Appendix C. Legislation and Policy

C.1 Acts

UK Parliament. Environmental Protection Act 1990. c.43. Available at: https://www.legislation.gov.uk/ukpga/1990/43/contents (Accessed 16/10/2025)[xv]

UK Parliament. Environment Act 1995. c.25. Available at: https://www.legislation.gov.uk/ukpga/1995/25 (Accessed 16/10/2025)

UK Parliament. Environment Act 2021. c.30. Available at: https://www.legislation.gov.uk/ukpga/2021/30 (Accessed 16/10/2025)

UK Parliament. European Union (Withdrawal) Act 2018. SI2018/16. Available at https://www.legislation.gov.uk/ukpga/2018/16/contents (Accessed 16/10/2025)

C.2 Regulations

UK Government. The Air Quality Standards (England) Regulations 2000 (as amended 2002). Available at: https://www.legislation.gov.uk/uksi/2000/928/contents/made (Accessed 16/10/2025)

UK Government. The Air Quality (Scotland) Regulations 2000. SSI2000/97. Available at: https://www.legislation.gov.uk/ssi/2000/97/made (Accessed 16/10/2025)

UK Government. The Air Quality (Northern Ireland) Regulations 2003. https://www.legislation.gov.uk/nisr/2003/342/contents/made (Accessed 16/10/2025)

UK Government. The Air Quality Standards Regulations 2010. SI 2010/1001. Available at: https://www.legislation.gov.uk/uksi/2010/1001/contents (Accessed 16/10/2025)

UK Government. The Air Quality Standards (Wales) Regulations 2010 (Accessed 16/10/2025)

UK Government. The Air Quality Standards (Northern Ireland) 2010 (Accessed 16/10/2025)

UK Government. The Air Quality Standards (Scotland) Regulations 2010 (Accessed 16/10/2025)

[xv] "c." stands for chapter, so for EPA 1990, c.: Stands for chapter; 43 is the specific chapter number of that year's Acts.

UK Government. Environmental Permitting (England and Wales) Regulations 2016. SI 2016/1154. Available at: https://www.legislation.gov.uk/uksi/2016/1154/contents (Accessed 16/10/2025)

UK Government. National Emissions Ceiling Regulations (2018) Available at: https://www.legislation.gov.uk/uksi/2018/129/contents (Accessed 16/10/2025)

The Environmental Targets (Fine Particulate Matter) (England) Regulations 2023. SI2023/96. Available at: https://www.legislation.gov.uk/uksi/2023/96/contents/made (Accessed 16/10/2025)

C.3 European legislation

Directive 2008/50/EC of the European Parliament and of the Council of 21 May 2008 on ambient air quality and cleaner air for Europe. Available at: https://www.legislation.gov.uk/eudr/2008/50/contents (Accessed 16/10/2025)

C.4 Policy

Department for Levelling Up, Housing and Communities. National Planning Policy Framework. (2024). Available at: https://www.gov.uk/government/publications/national-planning-policy-framework--2 (Accessed 16/10/2025)

Welsh Government (2024) Planning Policy Wales Edition 12 https://www.gov.wales/sites/default/files/publications/2024-07/planning-policy-wales-edition-12.pdf (Accessed 16/10/2025)

Scottish Government (2023) National Planning Framework 4 Available at: https://www.gov.scot/publications/national-planning-framework-4/ (Accessed 16/10/2025)

Department for Environment, Food and Rural Affairs in partnership with the Scottish Executive, Welsh Assembly Government and Department of the Environment Northern Ireland (2007) The air quality strategy for England, Scotland, Wales and Northern Ireland: Volume 1. Available at: https://www.gov.uk/government/publications/the-air-quality-strategy-for-england-scotland-wales-and-northern-ireland-volume-1

Air Quality Strategy for England, Scotland, Wales and Northern Ireland (2007) Volume 1. Available at: https://assets.publishing.service.gov.uk/media/5a758459ed915d731495a940/pb12654-air-quality-strategy-vol1-070712.pdf

The air quality strategy for England (2023). Available at: https://www.gov.uk/government/publications/the-air-quality-strategy-for-england (Accessed 16/10/2025).

The Clean Air Plan for Wales (2020). Available at: https://www.gov.wales/clean-air-plan-wales-healthy-air-healthy-wales (Accessed 16/10/2025)

At the time of publication (October 2025), in Northern Ireland and Scotland, the Air Quality Strategy (Volume 1) remains in force.

Appendix D. References

[1] Institute of Air Quality Management (2018) *Guidance on Monitoring in the Vicinity of Demolition and Construction Sites - version 1.1.* Available at: https://iaqm.co.uk/text/guidance/guidance_monitoring_dust_2018.pdf (Accessed 7 September 2025).

[2] Oliver L. et al. (2005) The scale and nature of European brownfields, Proceedings of CABERNET 2005: The International Conference on Managing Urban Land, pp. 274–281. Nottingham: Land Quality Press.

[3] National Planning Policy Framework (2024) Available at: https://www.gov.uk/government/publications/national-planning-policy-framework--2 (Accessed 14 September 2025)

[4] Scottish Government (2023) National Planning Framework 4 Available at: https://www.gov.scot/publications/national-planning-framework-4/

[5] International Agency for Research on Cancer – Monographs on the identification of carcinogenic hazards to humans. Available at: https://monographs.iarc.who.int/agents-classified-by-the-iarc/ (Accessed 7 September 2025)

[6] Environment Agency (2025) *Land Condition Risk Management - Stage 1 risk assessment.* Available at: https://www.gov.uk/government/publications/land-contamination-risk-management-lcrm (Accessed 14 September 2025)

[7] Institute of Air Quality Management (2021) *Indoor Air Quality Guidance: Assessment, Monitoring, Modelling and Mitigation - version 1.0.* Available at: https://iaqm.co.uk/wp-content/uploads/2013/02/iaqm_indoorairquality.pdf (Accessed 7 September 2025).

[8] World Health Organization (2010) *Guidelines for Indoor Air Quality*. Available at: https://www.who.int/publications/i/item/9789289002134 (Accessed 7 September 2025).

[9] World Health Organization (2000) *Air Quality Guidelines for Europe, Second Edition.* Available at: https://www.who.int/publications/i/item/9789289013581 (Accessed 7 September 2025).

[10] Public Health England (2019) *Air quality: UK guidelines for volatile organic compounds in indoor spaces.* Available at https://www.gov.uk/government/publications/air-quality-uk-guidelines-for-volatile-organic-compounds-in-indoor-spaces (Accessed 7 September 2025).

[11] Air Quality Expert Group (2020) *Non-methane Volatile Organic Compounds in the UK.* Available at: https://uk-air.defra.gov.uk/assets/documents/reports/cat09/2006240803_Non_Methane_Volatile_Organic_Compounds_in_the_UK.pdf (Accessed 7 September 2025).

[12] DEFRA (2012) *Contaminated Land Statutory Guidance*. Available at: https://www.gov.uk/government/publications/contaminated-land-statutory-guidance (Accessed 10 October 2025)

[13] Department for Environment, Food and Rural Affairs (2015) *Nuisance smells: how councils deal with complaints*. Available at: https://www.gov.uk/guidance/nuisance-smells-how-councils-deal-with-complaints (Accessed: 7 September 2025)

[14] Environment Agency and Department for Environment, Food and Rural Affairs (last updated July 2025) *Air emissions risk assessment for your environmental permit*. Available at: https://www.gov.uk/guidance/air-emissions-risk-assessment-for-your-environmental-permit (Accessed: 7 September 2025).

[15] Environment Agency (2011) *H4 Odour Management - how to comply with your environmental permit*. Available at: https://www.gov.uk/government/publications/environmental-permitting-h4-odour-management (Accessed: 7 September 2025).

[16] Scottish Environmental Protection Agency (2025) *Odour guidance 2025 – Version 1*. Available at: https://www.sepa.org.uk/media/h4ocmt2z/sepa-odour-guidance-2025.docx (Accessed: 7 September 2025).

[17] Environment Agency (2024) *Monitoring ambient air: techniques and standards*. Available at: https://www.gov.uk/guidance/monitoring-ambient-air-techniques-and-standards (Accessed 7 September 2025)

[18] Environment Agency (2023) *Land contamination risk management (LCRM): How to assess and manage the risks from historic land contamination*. Available at: https://www.gov.uk/government/publications/land-contamination-risk-management-lcrm (Accessed 7 September 2025).

[19] Moorcroft and Barrowcliffe. et al. (2017) *Land-use Planning and Development Control: Planning for Air Quality - version 1.2*. Available at: https://iaqm.co.uk/text/guidance/air-quality-planning-guidance.pdf. (Accessed 7 September 2025; due for update in 2026).

[20] Bull et al. (2018) *IAQM Guidance on the assessment of odour for planning - version 1.1*. Available at: https://www.iaqm.co.uk/text/guidance/odour-guidance-2014.pdf (Accessed 7 September 2025; due for update in 2026).

[21] Institute of Air Quality Management (2024) *Guidance on the assessment of dust from demolition and construction - version 2.2*. Available at: http://iaqm.co.uk/wp-content/uploads/2013/02/Construction-Dust-Guidance-Jan-2024.pdf (Accessed 7 September 2025).

[22] Department for Environment, Food and Rural Affairs (2022) *Local Air Quality Management Technical Guidance (TG22)* Available at https://laqm.defra.gov.uk/wp-content/uploads/2022/08/LAQM-TG22-August-22-v1.0.pdf (Accessed: 7 September 2025).

[23] Targa, Loader and Defra Working Group on Harmonisation of Diffusion Tubes (2008) *Diffusion Tubes for Ambient NO_2 Monitoring: Practical Guidance*, AEAT/ENV/R/2504 Issue 1a. Available at: https://uk-air.defra.gov.uk/library/reports?report_id=499 (Accessed: 7 September 2025).

[24] British Standards Institution sponsored by Defra (2023) *Selection, deployment and quality control of low-cost air quality sensor systems in outdoor ambient air – Code of Practice (PAS 4023:2023)*. Available at:

https://knowledge.bsigroup.com/products/selection-deployment-and-quality-control-of-low-cost-air-quality-sensor-systems-in-outdoor-ambient-air-code-of-practice (Accessed: 14 September 2025).

[25] Environment Agency (2024) *Monitoring ambient air: monitoring strategy*. Available at: https://www.gov.uk/guidance/monitoring-ambient-air-monitoring-strategy (Accessed: 7 September 2025).

[26] CLAIRE (2015) *Soil and Groundwater Remediation Technologies for Former Gasworks and Gasholder Sites*. Available at: https://claire.co.uk/component/phocadownload/category/22-important-industry-documents?download=476:gasworks-remediation-innovation-project (Accessed: 7 September 2025).

[27] Health and Safety Executive (2016) *Volatile organic compounds in air. Laboratory method using diffusive solid sorbent tubes, thermal desorption and gas chromatography.* Available at: https://www.hse.gov.uk/pubns/mdhs/pdfs/mdhs80.pdf (Accessed: 3 August 2025).

[28] Health and Safety Executive (2016) *Volatile organic compounds in air: Laboratory method using solid sorbent tubes, thermal desorption and gas chromatography. MDHS104.* Available at: https://www.hse.gov.uk/pubns/mdhs/pdfs/mdhs104.pdf (Accessed: 3 August 2025).

[29] International Organization for Standardisation (ISO) (2021) *ISO 16000 Indoor air Part 6: Determination of organic compounds (VVOC, VOC, SVOC) in indoor and test chamber air by active sampling on sorbent tubes, thermal desorption and gas chromatography using MS or MS FID*

[30] Verein Deutscher Ingenieure (VDI) (Association of German Engineers) Standard VDI 3882 Olfactometry - Determination of hedonic odour tone.

[31] European Union Directive (EU) 2024/2881 of the European Parliament and of the Council of 23 October 2024 on ambient air quality and cleaner air for Europe (recast)

[32] Health and Safety Executive (2020) *EH40/2005 Workplace exposure limits*. Available at: http://www.hse.gov.uk/pubns/priced/eh40.pdf (Accessed: 7 September 2025).

[33] Environment Agency (2025) *Methodology for the scientific derivation of Environmental Assessment Levels*. Available at https://www.gov.uk/government/publications/methodology-for-the-scientific-derivation-of-environmental-assessment-levels (Accessed: 7 September 2025)

[34] United States Environmental Protection Agency. Acute Exposure Guideline Levels. Available at: https://www.epa.gov/aegl/about-acute-exposure-guideline-levels-aegls (Accessed: 7 September 2025)

[35] United States Agency for Toxic Substances and Disease Registry (ATSDR) Minimum Risk Levels for Professionals. Available at: https://www.atsdr.cdc.gov/minimal-risk-levels/php/about/index.html (Accessed: 7 September 2025).

[36] Woodfield and Hall (1994) Odour measurement and control: an update. AEA Technology for Department of the Environment.

[37] Environment Agency (2002) Draft Horizontal Guidance for Odour Part 1 – Regulation and Permitting. Available at: https://www.sepa.org.uk/media/61325/ippc-h4-1-odour-pt-1-draft-for-consultation-2002.pdf (Accessed: 7 September 2025).

[38] American Industrial Hygiene Association (2013) Odour Thresholds for Chemicals with Established Occupational Health Standards, 2nd edition

[39] SNIFFER (2010) Communicating understanding of contaminated land risks. Project UKLQ13. Document produced by ArupScotland and Ray Kemp Consulting Ltd.

[40] Defra (2018) Science Advisory Council: Communicating risk report. Available at: https://www.gov.uk/government/publications/science-advisory-council-communicating-risk-report (Accessed: 7 October 2025)

[41] British Standards Institute (2020) *Construction products: Assessment of release of dangerous substances. Determination of emissions into indoor air.* BS EN 16516:2017. Published 31 Aug 2020.