THE SOIL AND GROUNDWATER TECHNOLOGY ASSOCIATION

SAGTA REPORT 37–SOIL VAPOUR INTRUSION

Introduction

SAGTA's September 2009 workshop took an in-depth look at the current state-of-play on soil vapour issues.

The complexity of soil vapour intrusion processes are often not taken into account in site assessments. This may lead to risks not being properly understood or appropriately managed, and may drive unnecessary further assessment and/or remediation.

The meeting was held in advance of the publication of CIRIA's VOCs handbook (C682) which provides new guidance on managing the issues involving soil vapour and vapour intrusion. Our workshop adopted this initiative as a key note for discussion and review of current knowledge in this area.

The aim of the workshop was to promote a better understanding of soil vapour issues, including current developments, and to identify areas in which SAGTA can support initiatives and promote best practice.

KEY ISSUES AND INITIATIVES / AREAS TO PROMOTE BEST PRACTICE

Measurement techniques – Sampling of vapours is different from groundwater sampling and requires specialist protocols and techniques to ensure results are representative and comparable. There is currently much good practice in this area but little consistency. However, initiatives are underway to develop best practice guidance.

- The Energy Institute is developing standard approaches for petroleum hydrocarbons.
- Guidance from the American Petroleum Institute (API) also exists. In future this many also be covered by British Standards

Practical site-based training may also have a place and SAGTA members could support this by allowing access to appropriate sites.

Conceptual Site Model (CSM) – an appropriate CSM is always critical to risk management. The following elements were identified as particularly critical to improving management of vapour risks.

- Source Characterisation – addressed in CIRIA VOC handbook.
- Building Characteristics and Design
- Heterogeneity of sub-surface, due to geology and built structures. It is important to consider the most appropriate scale for the CSM.

Screening / Exclusion criteria – The concept is that, for some sites, VI risks can be ruled out at an early stage based on aspects of the CSM. Examples of proposed screening criteria may include characteristics of the source (for example dissolved phase as opposed to free phase, whether the contaminant of potential concern (COPC) is sufficiently volatile to present a risk, whether it has a high biodegradation rate), or the lateral or vertical distance between source and receptor. No further assessment or modelling work may be required for sites which meet certain screening criteria, allowing efforts to be focussed on sites with greater potential for risks.

Work is being done build an evidence base for these criteria and gain stakeholder acceptance. The US Environmental Protection Agency already has a database of sites and there was discussion in the meeting over using data from (for example) UK local authorities, SAGTA members and CL:AIRE to build up a UK equivalent. Considerations of data quality and consistency were identified as important to any such initiative.

Modelling - The Johnson and Ettinger (J&E) model is widely used to set risk-based guidelines for vapour, although it may in some cases overestimate vapour migration into buildings by at least an order of magnitude. The model is not flawed per se but is too often used as a "black box" without sufficient understanding of the underlying assumptions and processes. In particular:

- The model assumes buildings are constructed on a ground-bearing slab. It may not be appropriate for many UK buildings. Alternative modelling approaches are available based on the same basic theory.
- There is a growing evidence base that biodegradation in the vapour phase is an important process in reducing VI risk, particularly for petroleum hydrocarbons. The J&E model assumes biodegradation does not occur. Models such as API BioVapor may be more appropriate in some situations.
- The model assumes that buildings are located directly above source areas, whereas in reality there is often lateral separation.

Remediation

Measures to mitigate VI risks often involve attempts to intercept the pathway, by installing a vapour barrier. In the case of low permeability membranes, proper installation of the membrane is likely to be much more important than the quality of membrane material.

Acute Exposure

Disturbance of soils during remediation or redevelopment can lead to acute release of vapours. To plan effective mitigation measures it is useful to be able to predict vapour concentrations and composition. This is likely to be an area of increasing focus in the future.

Summary of Workshop Presentations

Setting the Scene

VOCs are defined as substances which are volatile under 'normal' environmental conditions and may include petroleum and halogenated hydrocarbons originating from numerous industrial operations. Where these substances are present in soil or groundwater they may generate vapours which may migrate upwards and/or laterally, and perhaps collect in buildings or enclosed spaces. In extreme cases this may lead to a risk of fire and explosion, potential human health risks from acute or chronic exposure to vapours, or concerns due to odours.

Soil vapour fate and transport is complex and influenced by many factors including geology and hydrogeology, the properties of the substances involved, weather and climate conditions, and underground pathways and obstructions. For indoor transport, factors related to building construction and state-of-repair are also important. These factors might include cracks in ground slabs, pipes and ducts, and the presence of suspended floors and cavity walls.

Many sampling and analysis techniques are in use for VI assessment. There is much good practice in this challenging area, but little consistency. Samples are commonly taken from one or more of the following locations: indoor air, immediately below a concrete floor slab (sub-slab) and/or sub-surface soil vapour (from greater depths in the unsaturated zone). All three have challenges in terms of obtaining representative concentrations for risk assessment. Human health based risk guideline values may be a similar order of magnitude (or below) detection limits for some COPCs. Short-term changes in barometric pressure, wind and ventilation can contribute to considerable variability in indoor air concentrations. Sub-slab samples may be subject to some of the same variability and may also be very disruptive to collect if the building is occupied. Sub-surface concentrations are more stable, however in order to use them for risk assessment, assumptions need to be made about attenuation along the pathway between the sample location and the receptor.

Sampling may also be prone to variation due to factors including difficulties in detecting leakage (in above ground sampling equipment or annular seals), potential for equipment contamination or sorbent onto equipment,

The Johnson and Ettinger (J&E) model is generally used to set risk-based guidelines for vapour (including SGVs) but it is widely thought to be conservative, with a large variation between measured and predicted concentrations. Detailed QRA requires high level specialist expertise. Remediation techniques are not confined to source removal but often also include pathway interception and/or receptor management.

Industry concerns include:

- Public perception after several high-profile VI cases worldwide
- Complexity of assessment, with implications for time and cost.
- Good practice methods exist, but are not consistently applied.

Current Developments

CIRIA guide C665 *Assessing risks posed by hazardous ground gases to buildings* has been an industry reference for some time and deals mainly with so-called 'bulk' gases such as methane. CIRIA has now developed a further guide, C682 *The VOCs Handbook. Investigating, assessing and managing risks from inhalation of VOCs at land affected by contamination* –November 2009. This aims to provide guidance on methods for investigating, assessing and managing risks to human health from VOCs, specifically via inhalation of vapours. An assessment framework is proposed (similar to CLR11), moving through the stages of Preliminary Risk Assessment, Generic Quantitative Risk Assessment and Detailed Risk Assessment towards (if required) Remediation Options. It was noted that there are key differences between halogenated and non-halogenated hydrocarbons and this should be taken into account when designing the assessment. There is much evidence that shows that use of soil and groundwater data to predict concentrations of petroleum hydrocarbons in soil gas is conservative. It is important to understand the complexity of the VI pathway. Factors such as large cracks in foundation slabs may not be taken into account in models but can make a big difference to the significance of VI.

Modelling vs Actuals

An 'exclusion criteria' approach was suggested as a means of screening out sites at which VI is unlikely to be a risk. Criteria may be based on factors such as the lateral and/or vertical distance between source and receptor and differentiation of source type (NAPL vs free phase). Biodegradation in the vapour phase is an important factor, which is not considered in the Johnson & Ettinger model.

The applicability of the Johnson and Ettinger (J&E) model for UK conditions was considered. The Johnson and Ettinger model was developed in the USA to estimate vapour migration into buildings. It has been incorporated into many software tools that are commonly used in the UK for contaminated land risk assessment (eg CLEA, RISC, RBCA). Unfortunately many practitioners use the model and software without fully understanding how the equations were derived and how the "black box" is modelling the flow of ground gas or vapours into buildings. There are several key factors that make the use of the model invalid for many of the new buildings being constructed in the UK (for example buildings in the UK tend to have suspended floor slabs with a ventilated void space beneath them whereas the model assumes buildings are constructed on a ground bearing slab).

An alternative simple modular approach is proposed that uses common equations to model phase partitioning, vapour transport and dilution mechanisms. The equations used to define these mechanisms are derived from the same basic theory. The approach is more appropriate to many new buildings being constructed in the UK and can be used to model the effect of introducing protection measures to reduce vapour migration into a building. It is commonly accepted that the Johnson and Ettinger model over estimates vapour migration into buildings by at least an order of magnitude. The proposed approach will reduce this effect and provide a more realistic assessment of risk due to the inhalation of vapours.

Case Studies

A SAGTA member described a study to look at acute emissions of vapours when disturbing soils which are impacted with hydrocarbons, for example during remediation work. A fugacity model was used to estimate partitioning of hydrocarbons between free phase, soil, groundwater, and air. It was determined that the hydrocarbon composition, rather than the volume of free phase, was key in predicting the vapour concentration.

A second case study related to a remediation project which was driven by vapour intrusion to residential properties. There were a number of unusual aspects to this project: sources were positioned laterally with respect to buildings, and the risk driver was a semi-volatile compound, which provided challenges for risk screening. A reference value for the potential contaminant needed to be developed by a 3rd party and agreed. Indoor air monitoring was carried out within residential properties. It took approximately 15 months to collect indicative data, and this time delay presented challenges in terms of stakeholder management. Local variations in geological conditions were found to influence vapour intrusion to a great extent, and it was therefore important that the Conceptual Site Model was done at the right scale (in fact 15 'neighbourhood' CSMs were developed).

Remediation

In risk assessments it is often assumed that impermeable membranes used in new developments will 'break' the vapour pathway. Whilst this is likely to be effective for 'bulk' gases such as methane, there is much less data on the permeability of membranes to VOCs and it may be higher. Proper installation of the membrane is likely to be much more important than the quality of membrane material, and yet membrane installation is often left to non-specialist construction contractors and not checked for integrity. A floor slab, especially if cast in situ, is likely to be as important a barrier as a membrane. CIRIA document C665 provides guidance on membrane validation