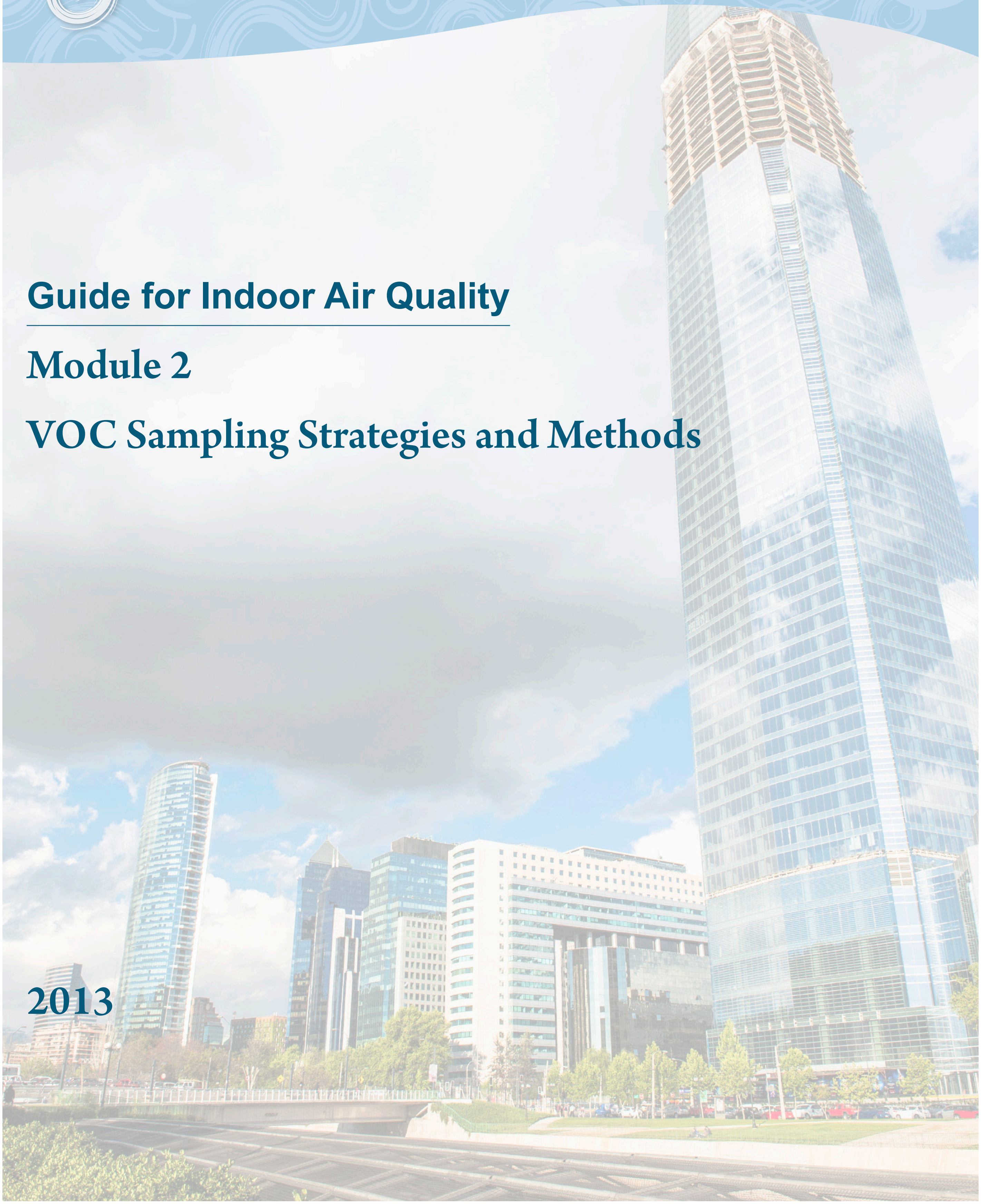
CCIAQB | Canadian Committee on Indoor Air Quality and Buildings

# Guide for Indoor Air Quality

## Module 2

## VOC Sampling Strategies and Methods

2013



# Canadian Committee on Indoor Air Quality and Buildings (CCIAQB)

## Disclaimer

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Indoor air quality is a very complex issue and there is currently a significant gap between knowledge of the effects of indoor air quality on the health of occupants and the effectiveness of various air quality technologies and solutions. User discretion is advised.

## Preamble

The objective of the CCIAQB is, ultimately, to improve indoor air quality for all Canadians in every type of building. The CCIAQB has decided that its initial focus should be on buildings where many Canadians spend time outside their home, working, learning, shopping, being entertained, etc. For the most part, these buildings have relatively complex heating, ventilating and air conditioning systems that are operated and managed by knowledgeable persons. The table below gives examples of buildings that are covered using the classification found in the National Building Code of Canada (NBC). Documents produced by the CCIAQB are primarily intended for the use of building operators and facility managers, but the information contained in the guides can be helpful to anyone seeking a general understanding of indoor air quality issues.

The Committee welcomes feedback on the documents as well as ideas for the development of new materials. Contact the CCIAQB Secretary at info@IAQforum.ca or register on the website at www.IAQ-forum.ca

| NBC Classification | Examples |
|---|---|
| Group A, Division 1 | Theatres, movie theatres and other facilities for the performing arts |
| Group A, Division 2 | Art galleries, museums, libraries, educational facilities (schools, colleges and universities), gymnasia, air and rail terminals |
| Group A, Division 3 | Arenas and swimming pools |
| Group C | Apartments, hotels, college residences |
| Group D | Offices, including medical and dental offices |
| Group E | Department stores, supermarkets, shops, retail space |

# Guide for Indoor Air Quality
# Module 2: VOC Sampling Strategies and Methods

## Table of Contents



**List of Tables and Figures**

## 1. Purpose of This Module

The purpose of this module is to give building operators and facility managers information about volatile organic compounds (VOCs) and when VOC sampling might be required. The module provides basic information to help them be knowledgeable procurers of outside resources, where sampling is required.

This document is part of a series of modules forming the CCIAQB *Guide for Indoor Air Quality* available at www.IAQForum.ca. For acronyms aand definitions, refer to *Module 1 – Introduction to Indoor Air Quality (IAQ)*.

## 2. Introduction

Building operators and facility managers face a wide range of issues in providing good indoor air quality. Indoor air quality (IAQ) complaints can be intertwined with a range of issues, such as drafts, temperature, relative humidity, stuffiness and the presence of odours. Some air quality problems may result from VOC contamination.

Sampling for VOCs encompasses a wide variety of sources, indoor environments (residential, institutional, commercial, industrial) with varied and dynamic ventilation systems, and a wide variety of objectives. No one sampling strategy or method will meet all objectives for all types of VOCs. The acceptability of a method is dependent not only on its accuracy, but on convenience, immediacy of result, its range of applicability, the availability of alternative procedures, cost and the particular objective and circumstances. The appropriate choice will also vary according to building type, occupancy, and investigative requirements.

In many circumstances, VOC contamination can either be ruled out as an issue or can be mitigated without the need for VOC sampling and analysis. In other circumstances, such sampling and analysis may be essential. The identification of potential sources of VOCs and improvement of air quality through the control of sources is, in most situations, more informative and cost-effective than indoor air quality testing and comparison of measured values to quantitative guideline values.

## 3. Volatile Organic Compounds

Volatile organic compounds are chemicals that contain carbon, hydrogen and oxygen and are gases at room temperature. The volatility, polarity, water solubility, and reactivity of a VOC affect the choice of sampling methods.

To assess the influence or relevant importance of various factors in determining the indoor VOC concentrations it is helpful to use a "source-pathway-receptor" conceptual model. The source is the cause of the presence of the VOC. The pathway is the route the VOC takes to a receptor and a receptor is a person, animal, plant, property or eco-system that is exposed to the VOC. Each factor plays a role in determining the final VOC concentration within the indoor air environment.

In general this conceptual model will also help identify any VOC control strategies that may ultimately be required. Indoor VOC concentrations may be controlled by three basic strategies:

- Source control is the avoidance or elimination of materials that emit VOCs;

- Ventilation is the lowering of VOC concentrations by replacing air in specific spaces with air (fresh air) that has a lower concentration of VOC (for example, dedicated exhausts in garbage rooms or the pressurization of public corridors);
- Cleaning includes filtration and ultra (UV) radiation. Filtration is the physical capture and disposal of VOCs. Ultraviolet radiation is the chemical alteration of a VOC compound with the intention of creating different and less harmful compounds.

A sampling program may be required to demonstrate the effectiveness of any control measures that have been implemented.

## 4. Determining When VOC Sampling Is Required

VOC sampling can be expensive so careful consideration should be given to determining if it is needed. The purpose of VOC sampling can generally be placed into one or more of the following four categories:

- Building commissioning;
- Best management practices (including assessment / control during renovation or construction activities);
- Compliance with regulatory requirements; and
- Complaint investigation.

There are many factors that may affect the concentration and distribution of VOCs in indoor environments and hence the choice of VOC sampling methodology. These factors include: VOC type and location, building type and size, occupant type and activity, and type and extent of ventilation (mechanical / natural). Figure 2-1 shows a process for helping decide if VOC sampling is needed.

### 4.1. Building Commissioning

Building commissioning is a quality control process for achieving, verifying, and documenting that the performance of facilities, systems, and assemblies meet the defined objectives and criteria. When VOC sampling is included in the commissioning process, the baseline data can be used for comparison purposes later. Examples of commissioning protocols are Leadership in Energy and Environmental Design (LEED) [www.usgbc.org] and the Building Owners and Managers Association's Building Environmental Standards (BOMA Best) [www.bomabest.com].

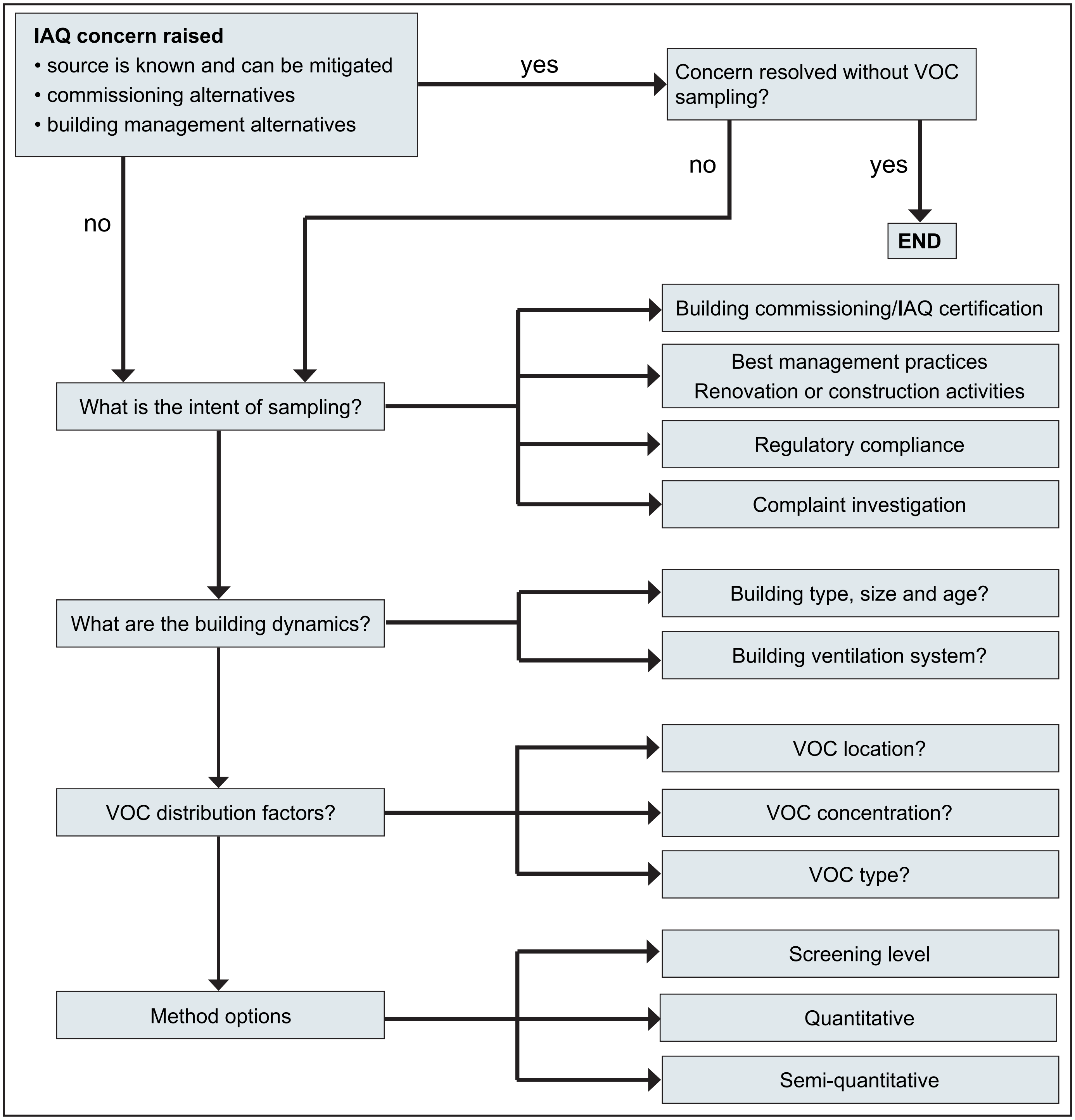
Commissioning may include on-site verification of equipment, components and procedures, or air quality testing, including VOC sampling. For example commissioning procedures for the LEED and BOMA programs typically require testing prior to occupation to demonstrate that total VOCs (TVOCS), and some specific VOCs (e.g., formaldehyde, 4-Phenylcyclohexene), are below a threshold value or, during construction activities, to demonstrate control management plans are in place and effective.

Alternatives to testing such as flush-out prior to occupancy are often impractical but available. Most VOC off-gassing from new building materials and furnishings occurs when they are newly installed. Hence, whenever occupancy is delayed and or ventilation is increased, exposure may be reduced.

### 4.2. Best Management Practices

Best management practices (BMPs) for indoor air quality are procedures implemented during the planning, construction and operation of buildings to reduce exposure and emission of pollutants. For example, many building operators have established BMPs for maintenance (e.g., air-handling unit filter changes) intended to ensure good IAQ.

**Figure 2-1 Flow chart for VOC sampling**



BMPs may require VOC sampling in order to determine suitable occupancy or re-occupancy timeframes (e.g., during renovations when VOC levels may be elevated due to the introduction of new materials or prior to occupancy). The appropriate VOC sampling method depends on the source-pathway-receptor scenario for each case. The methods would generally include screening or semi-quantitative methods when quick results and monitoring of control measures are required; and quantitative results when occupancy criteria or certification is required.

BMPs have been issued by various authorities, primarily by federal, provincial and municipal agencies. Examples are listed in Table 2-1.

**Table 2-1 Examples of some building best management practices**

| Authority | Comment | Reference |
|---|---|---|
| Health Canada | Tools for schools | Go to: http://www.hc-sc.gc.ca/ Search for: Tools for schools action kit |
| Canadian Mortgage and Housing Corporation (CMHC) | CMHC: Indoor Air Quality | Go to: http://www.cmhc-schl.gc.ca/ Search for: Indoor air quality |
| National Research Council Canada (NRC) | Indoor Air Quality Guidelines and Standards | Go to: http://archive.nrc-cnrc.gc.ca/eng/ibp/irc.html Search for: Indoor air quality guidelines |
| British Columbia Ministry of the Environment | Environmental Best Management Practices for Urban and Rural Land Development in British Columbia:Air Quality BMPs and Supporting Information | Go to: http://www.env.gov.bc.ca/ |
| Better Buildings Partnership - Toronto | Better Buildings Partnership (BBP) is a City of Toronto program that works with building owners, managers and builders to ensure that buildings achieve high energy performance and low environmental impact. BBP provides knowledge, resources and financial assistance to maximize the outcomes of a wide range of energy efficiency and renewable energy projects. | Go to: http://bbptoronto.ca/ |

## 4.3. Regulatory Requirements

Regulatory requirements for indoor VOCs vary depending on occupancy (residence or workplace), type of workplace or residence and by province or territory. In jurisdictions without specific legislation for indoor air quality issues, a “general duty clause” applies. This clause, common to all Canadian occupational health and safety legislation, states that an employer must provide a safe and healthy workplace.

Table 2-2 provides examples of federal, provincial and territorial occupational health and safety regulations.

Health Canada Guidelines are often referenced, particularly where regulations do not exist.

For industrial settings, exposure to chemicals and designated substances is regulated under provincial health and safety regulations. Occupational health and safety criteria and protocols for VOCs are typically intended for the protection of industrial workers.

**Table 2-2 Sample occupational health and safety regulations**

| Jurisdiction | Go to: | Search for |
|---|---|---|
| Alberta | http://employment.alberta.ca/ | Occupational Health and Safety Code |
| British Columbia | http://www2.worksafebc.com/ | OHS Regulation: Part 4 General Conditions |
| Manitoba | http://safemanitoba.com/ | Workplace Health and Safety Regulations: Part 4 General Workplace Requirements |
| New Brunswick | http://www.gnb.ca/0062/PDF-regs/91-191.pdf | Occupational Health and Safety Act |
| Newfoundland and Labrador | http://www.assembly.nl.ca/legislation/sr/regulations/rc120005.htm#701 | Occupational Health and Safety Regulation 5/12 |
| NWT & Nunavut | http://www.justice.gov.nt.ca/PDF/REGS/SAFETY/General_Safety.pdf | Safety Act: General Safety Regulations |
| Nova Scotia | http://www.gov.ns.ca/just/regulations/regs/ohsgensf.htm | Occupational Safety General Regulations |
| Ontario | http://www.search.e-laws.gov.on.ca/en/isysquery/8a873f6c-46e6-4f97-a02d-38a7706b1106/2/doc/?search=browseStatutes&context=#hit1 | Occupational Safety Act: Regulation 833 Control of Exposure to Biological or Chemical Agents |
| Prince Edward Island | http://www.gov.pe.ca/law/regulations/pdf/O&01G.pdf | Occupational Health and Safety Act: General Regulations |
| Quebec | http://www.canlii.org/en/qc/laws/regu/2001-goq-2-3888/latest/2001-goq-2-3888.html | Regulation respecting occupational health & safety 2001 GOQ 2, 3888 |
| Saskatchewan | http://www.qp.gov.sk.ca/documents/English/Regulations/Regulations/O1-1R1.pdf | The Occupational Health and Safety Regulations, 1996 |
| Yukon | http://www.wcb.yk.ca/Media/documents/Occupational_Health_Regs.pdf | Yukon Occupational Health Regulations |
| Canada | http://laws-lois.justice.gc.ca/eng/acts/L-2/index.html | Canada Labour Code: Part II Occupational Health and Safety |

Building managers and facility operators should be aware of the impact of VOC sources from neighbouring industrial sites on their buildings. In addition, while some building uses or classifications may not be industrial, they could include activities that generate specific VOCs. For example, alcohol and disinfectants would be prevalent in medical buildings; acetone in beauty parlours, or formaldehyde in undertaking premises.

The appropriate occupational health and safety method for specific VOCs is often defined by provincial legislation or recognized authorities such as U.S. National Institute for Occupational Safety and Health (NIOSH), U.S. Occupational Safety and Health Administration (OSHA), or the American Conference of Governmental Industrial Hygienists (ACGIH).

Their sampling methods are usually well-defined and intended to assess personal exposure of human receptors. However, additional sampling and modifications to the methods may be required to determine source and pathways in some circumstances. For example, worker exposure to VOCs in one unit in a commercial plaza may be impacted by a source within a neighbouring unit such as a paint booth or beauty parlour, and additional sampling may be required to resolve source pathway relationships. While VOC sampling method choices are well defined under provincial legislation and recognized authorities, screening, long-term, or more sensitive methods may be required to resolve occupant complaints, odour issues, or to assess exposures below permissible levels.

Vapour intrusion refers to VOCs that volatize from the surface of the aquifer, migrate through the unsaturated soil and enter the building via openings in the foundation. The presence of specific VOCs may indicate that a former industry was on the site (e.g., aromatic hydrocarbons from gas stations, tetrachloroethylene from dry cleaners, etc.).

If warranted by historical research, drilling through the basement slab may be required to confirm the source and composition of the contamination and to develop a remediation plan. Regulations for limiting sub-surface vapour intrusion should be considered.

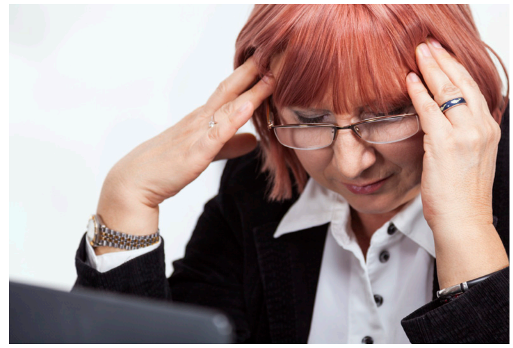
### 4.4. Complaint Investigations

Complaints by occupants about air quality may require building operators and facility managers to respond with an IAQ assessment that includes VOC sampling. The first step is to use interviews and walk-through inspections to determine symptoms, odours, timing, related activities, as well as building conditions and operation of the heating, ventilation and air-conditioning (HVAC) sytem.

When assessing complaints it is important to note that feelings of discomfort and illness may be related to health conditions (e.g., the common cold or influenza) or to building issues such as noise levels, thermal comfort (temperature, humidity, and air movement), lighting, and ergonomics and many non-building issues or pre-existing medical conditions.

Poor air quality would be suspected if occupants develop symptoms within a few hours of being in the building and feel better after leaving the building, or after a weekend or vacation. It would also be suspected if several people report similar symptoms, or if all of the people reporting symptoms are in the same area of a building or HVAC zone. VOC exposure symptoms may include:

- Eye, nose, and throat irritation
- Headaches
- Allergic skin reaction like a rash



- Difficulty breathing
- Nausea and/or vomiting
- Nosebleeds
- Fatigue
- Dizziness
- Loss of coordination
- Confusion

If the initial investigation indicates the possibility that health or odour complaints are related to VOC sources, the sampling method will initially depend on whether the VOC source is known or unknown. Sampling may be needed if further information on the pathway or receptor is required, or if mandated by regulatory concerns or orders. Examples of sources of VOCs are provided in Table 2-3.

**Table 2-3 Commonly-encountered VOCs and sources***

| **Chemical** | **Source** |
|---|---|
| Acetone | Paint, coatings, finishers, paint remover, thinner, caulking |
| Aliphatic hydrocarbons (octane, decane, undecane hexane, isodecane, mixtures, etc.) | Paint, adhesive, gasoline, combustion sources, liquid process photocopier, carpet, linoleum, caulking compound |
| Aromatic hydrocarbons (toluene, xylenes, ethylbenzene, benzene) | Combustion sources, paint, adhesive, gasoline, linoleum, wall coating |
| Chlorinated solvents (dichloromethane or methylene chloride, trichloroethane) | Upholstery and carpet cleaner or protector, paint, paint remover, lacquers, solvents, correction fluid, dry-cleaned clothes |
| n-Butyl acetate | Acoustic ceiling tile, linoleum, caulking compound |
| Dichlorobenzene | Carpet, moth crystals, air fresheners |
| 4-Phenylcyclohexene (4-PC) | Carpet, paint |
| Terpenes (limonene, a-pinene) | Deodorizers, cleaning agents, polishes, fabrics, fabric softener, cigarettes |
| Formaldehyde | Furniture, cabinets and building materials made from particleboard, medium density fibreboard and certain moulded plastics; consumer products, including some latex paints, wallpapers, cardboard and paper products, dishwashing liquids, fabric softeners, shoe-care agents, carpet cleaners, glues, adhesives, lacquers and some cosmetics, such as nail polish and nail hardener; some permanent press fabrics (e.g., certain curtains, sheets, clothing, etc.), medical laboratories.<br>Hand sanitizers; sterilization (medical /dental) |

* Information in this table is from multiple sources including Health Canada.

For example, the receptor is often known for odour complaints, but the source or pathway may not be fully understood and additional investigative VOC sampling may be required to resolve a complaint. In other words, the building operator or facility manager is either asking the question "what is this smell and where is it coming from?" or "this smells like something known and how did it get here?"

The investigation generally starts at the receptor and most often with screening level methods to confirm the source-pathway-receptor relationship. The need for more intensive semi-quantitative or quantitative methods will depend on the type of VOC and whether the goal is mitigation of the source or assessing occupant exposure. Additional challenges of odour-related VOC sampling are:

- Odours may not be due to VOC's (for example inorganic sulphurous or ammonia compounds);
- Odours may be detected by smell at lower concentrations than can be readily measured by a sampling and analysis program;
- People have different sensitivities to odourous compounds; and,
- Sources and pathways may not be continuous.

When the source is not known, an investigative phase will be necessary. A typical approach would include a screening survey for TVOCs using direct read instrumentation, followed by sampling for open characterization of VOCs based on the survey, and then possibly more quantitative sampling for specific VOCs. Compared to targeted sampling, open characterization is quite expensive and the results may be difficult to interpret.

Additional information on addressing IAQ problems and communicating with building occupants can be obtained from the following guides available on the IAQforum website: *Module 4 – Recognizing and Addressing IAQ Problems* and *Module 7 – Communicating with Tenant Organizations and Individual Occupants.*

Guidance on approaches for addressing occupant complaints is also available from national (e.g., Health Canada) and international (e.g., European Community) bodies. Table 2-4 lists examples.

| **Table 2-4 Examples of guidelines for managing VOC pollutants** | |
|---|---|
| **Authority/** | **Go to:** |
| Health Canada<br>Air Quality Guidelines | http://www.hc-sc.gc.ca/ewh-semt/air/in/index-eng.php |
| Canadian Centre for Occupational Health and Safety – Indoor Air Quality | http://www.ccohs.ca/oshanswers/chemicals/iaq_intro.html |
| US EPA<br>An Introduction to Indoor Air Quality (IAQ)<br>Volatile Organic Compounds (VOCs) | http://www.epa.gov/iaq/voc.html |
| WHO Guidelines for Indoor Air Quality: Selected pollutants | http://www.euro.who.int/en/what-we-do/health-topics/environment-and-health/Housing-and-health/publications/2010/who-guidelines-for-indoor-air-quality-selected-pollutants |

| **Table 2-4 Examples of guidelines for managing VOC pollutants** | |
|---|---|
| European International Collaborative Action Indoor Air Quality & Its Impact On Man - Environment and Quality of Life - Report No 19 Total Volatile Organic Compounds (TVOC) in Indoor air Quality Investigations | http://www.buildingecology.com/iaq/useful-publications/european-collaborative-action-on-urban-air-indoor-environment-and-human-exposure-reports-1/ |

## 5. VOC Sampling

### 5.1. When to Sample VOCs

Sampling for VOCs should only be done after source elimination has been considered as a first step. If this is not possible, or too expensive, sampling could then be considered. The source-pathway-receptor relationship will have characteristics that will influence the sampling method and duration. Table 2-5 shows how VOC sampling can be tailored to suit various complaint patterns.

If the timing of a source is well known it may be used to define the source-pathway-receptor relationship and possibly eliminate or reduce the amount of VOC sampling required. For example, if odour or health complaints can be correlated with building conditions, occupant/neighboring activities, weather, or ventilation system status, then it may be possible to determine the source or pathway, and mitigate the problem without sampling or to adjust the sampling program.

**Table 2-5 Complaint patterns and sampling methodology**

| **Description** | **Sampling / Analysis Considerations** |
|---|---|
| Short-term | Complaints that occur at specific times should result in sampling that occurs at those times. To allow for pre-concentration prior to analysis short-duration, whole-air sampling followed by VOC characterization may be appropriate. |
| Continuous | When complaints are received continuously, short duration sampling followed by VOC characterization (e.g., Austen Method (AM) 1.2) would be appropriate. |
| Seasonal | Complaints that occur seasonally should be assessed by comparing VOC profiles for both the complaint and non-complaint periods. |
| Periodic | Complaints that occur periodically should result in sampling that occurs at those times, sampling duration should be appropriate for event duration. |
| Erratic | Erratic complaints are most problematic and may require sampling close to complaint areas and providing a means for affected people to quickly advise of reoccurrences of symptoms. |

The duration of sampling should provide data that it is representative and meaningful. How the data will be interpreted should be considered. Timing factors may also be defined by legislation such as determining short-term exposure or time weighted average exposure for workers. Where timing is not defined by legislation, occupants should be interviewed or asked to complete a questionnaire to gain an understanding of when exposure may be occurring. It is important to note that complainants may not always be objective when providing information.

## 5.2. Where to sample for VOCS

### 5.2.1. Building Factors

Buildings contribute a wide variety of factors that may be critical in determining an appropriate sampling methodology and are frequently associated with the timing factors mentioned previously. The type of building will often define the receptor and hence the method choice.

Building age and construction are also possible factors. New buildings tend to be more air-tight for energy conservation, but may have more sophisticated ventilation systems or may be constructed using more environmentally friendly materials (i.e., low-VOC paints). Table 2-6 shows how a VOC sampling strategy might be adjusted depending on building age.

The physical extent of the area of concern should be considered in conjunction with other building factors. For example, investigations of complaints that occur in a section of a building served by a single air handling unit should consider whether the air handling unit is acting as a pathway and/or source.

The environment surrounding the building should also be given due consideration. On-site and external sources may contribute to indoor VOC concentrations and the impact of such sources may be influenced by local weather conditions. The geographical location of the building may influence factors including building construction and proximity to external sources.

### 5.2.2. Receptor Factors

Since the intent of sampling is often to determine exposure or potential exposure to receptors, sampling methodology will be influenced by the type, location, and exposure duration of receptors. For example, an investigation of the long-term impact on building materials in a museum may require sensitive and long term sampling methods, whereas assessing the exposure of the general public may require short term sampling methods of varying sensitivity. Receptor factors generally fall into five categories:

- Healthy adult worker
- Healthy adult
- The general public
- Sensitive individuals
- Building materials or articles

In general, the more sensitive the receptor the more sensitive the methodology required.

### 5.2.3. Building Ventilation

The building ventilation system is likely to play an important role as a pathway and may also be linked to timing factors; for instance, odours that are only observed during operation of an air handling system.

| Table 2-6 Effect of building age on sampling methodology | |
|---|---|
| **Description** | **Sampling / Analysis Considerations** |
| Less than 10 years, constructed with low-VOC materials | External or occupant related sources are more probable sources than building materials for problems within recently constructed buildings built using carefully-selected, low-VOC emitting materials.<br>Microbial VOCs may be present where water infiltration has occurred or in case of inappropriate storage / disposal of organic materials. |
| Less than 10 years, constructed with standard construction materials | Off-gassing from building materials represents a possible source within recently constructed buildings built using typical materials. Consideration should be given to determining formaldehyde concentrations (Method DM1.3, Method DM1.4, Method SM2.1, or Method SM2.2) prior to VOC characterization.<br>Microbial VOCs may be present where water infiltration has occurred or in case of inappropriate storage / disposal of organic materials. |
| More than 10 years | In the absence of renovations/additions, off-gassing from building materials is unlikely to be a significant source of VOCs.<br>Microbial VOCs may be present where water infiltration has occurred or in case of inappropriate storage / disposal of organic materials. |

| Table 2-7 Effect of site factors on VOC sampling and analysis | |
|---|---|
| **Factor Description** | **Sampling / Analysis Considerations** |
| Presence of new construction / refurbishments | New construction / refurbishments may act as a source of VOCs from building materials (e.g. paints, adhesives, pressed wood products) and may introduce additional sources into the building.<br>Renovation activity may release contaminants to atmosphere from older building materials (e.g. formaldehyde from UFFI). Screening methods (e.g. Method DM1.1) may be used to assess potential sources and pathways. |
| Presence of known external on-site (property) sources. | For new building assess potential impact of on-site sources (e.g. emergency generators, parking garages).<br>For older buildings careful consideration should be given to determining whether changes have resulted in a pathway allowing contaminants from known on-site sources to enter the building envelope. |
| Presence of known off-site sources | Careful consideration should be given to determining potential pathway(s) allowing contaminants from known off-site sources to enter the building envelope. |

The operation and maintenance of building components such as air handling, plumbing, and solid waste handling systems may influence one or more of the source-pathway-receptor links associated with the area of concern. Unnecessary expense may be incurred by commissioning a VOC sampling and analysis strategy before ensuring that critical building components are operating as intended.

Where complaints are associated with all areas served by the ventilation system, sampling should focus on the ventilation system as a possible source and/or pathway. Where complaints are not consistently associated with areas served by the system, internal source-pathway links are likely. Where complaints are associated with areas served by multiple ventilation systems, the sampling strategy should consider possible external source impacting the air intakes of the ventilation systems.

Table 2-7 shows how VOC sampling might be affected by on- and off-site factors.

# 6. Sampling Strategies

## 6.1. General Considerations

Indoor air sampling for VOCs encompasses a wide variety of sources, indoor environments (residential, institutional, commercial, industrial) with varied and dynamic ventilation systems, and a wide variety of objectives (e.g., chronic assessment for health effects, trend analysis or background assessments; regulatory compliance, occupant complaint response, design or testing of mitigation measures). No one sampling strategy or method will meet all objectives for all types of VOCs. The acceptability of a method is dependent not only on its accuracy, but on convenience, immediacy of result, its range of applicability, the availability of alternative procedures and the particular objective and circumstances. The sampling strategy will depend on:

- The purpose of sampling (background assessment, occupant complaints, regulatory requirements, mitigation, etc.) [see Section 4. Determining When Sampling Is Required]
- The type of VOC; and,
- The type of indoor environment.

Figure 2-2 on page 14 is a flowchart showing the effect of these variables on appropriate test methods. Descriptions of the test methods follow the flowchart.

## 6.2. Effect of VOC type on sampling strategy

The volatility, polarity, water solubility, and reactivity of a VOC are critical in the choice of the sampling and analytical methods. Generally, VOCs may be broadly classed into four categories based on these physical and chemical characteristics. The transition between categories is best given as a range rather than sharp limits. An understanding of the chemical properties, potential sources and final analytical techniques of the target VOCs is important in developing a meaningful sampling strategy, transportation and storage of samples, and correct interpretation of results.

The categories of VOCs are:

- Very volatile organic compounds (VVOCs) are present primarily in the gas phase in air at room temperature and atmospheric pressure. Due to their high vapor pressures, VVOCs are generally more difficult to collect and retain on sorbents than other VOCs.

- Volatile organic compounds (VOCs) are present in the gas phase in air at room temperature and atmospheric pressure.
- Semivolatile organic compounds (SVOCs) may be present in both the vapor and particulate phases at room temperature and atmospheric pressure.
- Microbial volatile organic compounds (MVOCs) are organic compounds emitted by different species of fungi during their growth on contaminated materials.

### 6.3. Effect of type of indoor environment on sampling strategy

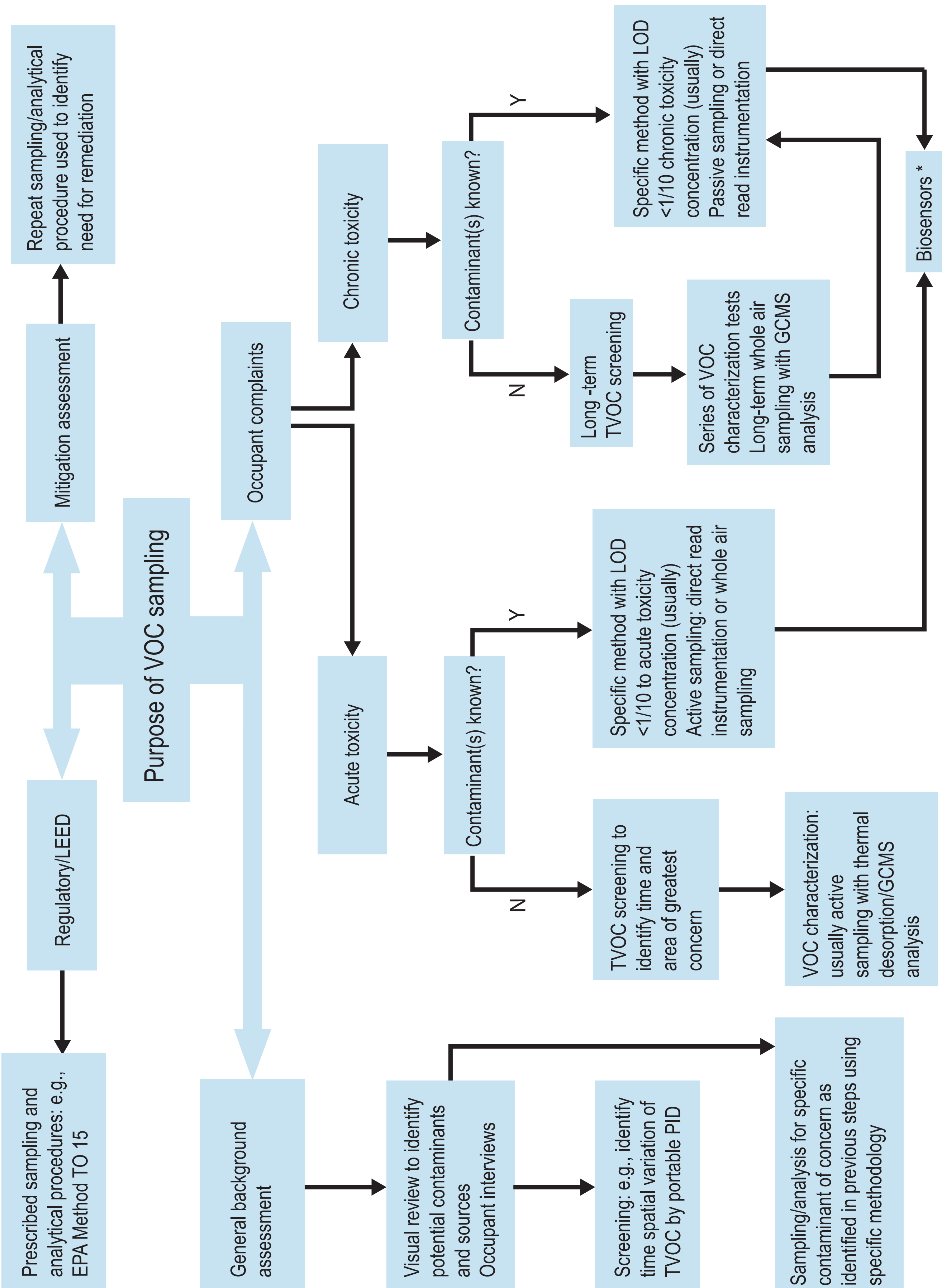
Sampling strategy should be tailored to how the building operates. Concentrations will vary depending on the type of indoor space, the emission characteristics of the sources therein, occupant behaviour and ventilation conditions. The large variety of VOC sources and the diversity of their emission characteristics within the wide range of ventilation conditions and air circulation patterns can result in a highly dynamic sampling environment.

Prior to each sampling event a pre-building investigation should be conducted to identify conditions that may affect or interfere with the proposed testing. The investigation should evaluate the type of structure, floor layout, physical conditions, and airflows of the building(s) being studied. In addition, potential sources of chemicals of concern should be evaluated within the building by conducting a product inventory and review of occupant activities. The primary objective of the product inventory is to identify potential air sampling interference by characterizing the occurrence and use of chemicals and products throughout the building, keeping in mind the goal of the investigation and site specific contaminants of concern. In some cases, the goal of the testing is to evaluate the impact from products used or stored in the building. If the goal of testing is to determine whether products are an indoor volatile chemical contaminant source, then removing these sources does not apply. The pre-sampling investigation should consider the presence of subsurface, indoor and outdoor sources with the overall sampling program objectives. It may be difficult to separate the relative contribution of each.

In some cases the initial assessment may clearly identify a potential source-pathway-receptor system whose chain can easily be broken by eliminating, reducing or diluting the sources or pathways. In such cases VOC sampling may not be necessary. However, it is important to consider the building and its ventilation system prior to making any changes in order to avoid creating new problems or worsening the situation. For example, blocking one pathway without eliminating or reducing a source may create a new pathway or allow the build-up of VOCs in other areas.

Following successful elimination, reduction, or dilution of a source and/or elimination of a pathway, the situation should be re-evaluated. VOC sampling may be required regardless of its elimination in order to demonstrate compliance with legislation (e.g., worker exposure) or due diligence in the effectiveness of mitigation measures. It may also be worthwhile to determine VOC concentrations to establish risk or exposure levels prior to any mitigation.

Figure 2-2 Objective-based sampling strategy




* Biosensors: potentially provide direct measurement of toxicity. As direct toxicity assessment allows for the determination of synergitic effects, the method has advantages over chemical measurement. Presently, few biosensors are available.

## 7. VOC Sampling Methods

This section is intended to give building managers basic knowledge about the types of sampling methods that might be used to solve indoor air quality problems or verify that regulatory requirements are being met. Sampling methods may be divided into three basic categories:

- Real time sampling;
- Active sampling for subsequent analysis (including whole air sampling);
- Passive sampling for subsequent analysis.

In general, active and passive sampling approaches involve later off-site analysis. The following sections provide descriptions of typical sampling methods.

### 7.1. Real Time Monitoring

Historical real-time screening techniques include several portable VOC sampling instruments that can give instant results for TVOCs as well as individual VOCs. Although their precision and detection limits are generally not as good as equivalent analytical laboratory instruments, portable instruments provide the advantage of real time measurements for projects requiring on-site decisions, rapid capture of temporal variations, or involving large survey areas.

***Colorimetric indicator tubes (e.g. Drager, Gastec)(portable)***

Screening or semi-quantitative analysis may be obtained for a variety of VOCs by drawing a known volume of air through a colorimetric indicator tube. Samples are usually collected by use of a simple hand pump supplied by the manufacturer of the indicator tubes. The presence of analyte is indicated by a color change to reagent within a glass indicator tube. Indicator tubes are available for a variety of VOCs, often covering detection ranges of several orders of magnitude (ppm to %).

Colorimetric tubes are generally suitable for use in environmental conditions associated with indoor air, with restrictions on use identified by the manufacturer. Tubes are often only semi-specific with cross-interference common, manufacturer data identifying potential types and degree of cross-interference may be available.

***Flame ionization detection (FID) (portable / stationary)***

FID involves the detection of VOCs resulting from the combustion of hydrocarbons. As “stand-alone” equipment, FID is unable to differentiate between VOCs. Operating as a “carbon counter”, FID can function under most indoor environmental conditions and is not subject to significant cross-interference provided oxygen content is stable. FID may be combined with separation techniques (e.g., gas chromatography) and allows qualification of specific hydrocarbons based on retention time.

***Photo ionization detection (PID) (portable)***

A PID uses an ultraviolet light to ionize a chemical. It can accurately measure gases at low ppmv or even ppb levels, however it cannot differentiate between chemicals. The electrically charged gas produces a current that is amplified and displayed as a concentration.

PID can be operated under most indoor environmental conditions, cross-interference is limited however different analytes provide different responses precluding accurate interpretation of results obtained from gases containing mixed analytes. Portable GC systems with PID detectors provide some separation of VOC for improved identification and quantification.

***Sensor technology (portable)***

Different sensor systems have been used to provide continuous on-site monitoring of VOCs. Most field sensors rely either on electrochemical, mass sensitive, or optical transducers. Typical sensitivities are in the ppm range but ranges may be extended by coupling sensors with a analyte enrichment method. Acceptable environmental conditions and susceptibility to cross-interference is sensor specific.

***Metal oxide sensors (portable / stationary)***

Metal oxide sensors measure the change in conductivity in the presence of oxidizing and reducing gases and are capable of providing real-time measurements.

***Proton transfer reaction – mass spectrometer (PTR-MS) (stationary)***

The detection principle of the PTR-MS is based on reactions to most of the common VOCs but not with the components of clean air. PTR-MS has potential for on-site detection of VOCs with the advantages of rapid response and high sensitivity without sample pretreatment. PTR-MS can be operated in most indoor environmental conditions.

***Ion mobility spectrometry (IMS) (portable / stationary)***

IMS is an analytical technique used to separate and identify ionized molecules in the gas phase based on their mobility in a carrier buffer gas. Related ionization MS techniques include desorption electrospray ionization (DESI) electrospray laser desorption ionization (ELDI), direct analysis in real time (DART) and atmospheric pressure solids analysis probe.

***SIFT-MS – (stationary)***

SIFT-MS is an analytical technique that uses chemical ionisation to analyse for VOCs in a whole air sample and can be used for real-time quantification. SIFT-MS is suitable for moist / humid samples and is routinely utilized for analysis of human breath without need for sample conditioning.

***Photo-acoustic spectroscopy (PAS) – (stationary)***

A PAS system includes: a chamber to contain the gas sample, a light source, some means of modulating the light, a detector to measure the sound, and a method of processing the signal. The intensity of sound emitted by a sample depends on the nature and concentration of the substance and the intensity of the incident light (the photo-acoustic effect). Combining with FTIR allows identification of unknowns and their concentrations.

Advantages include infrequent calibration of the microphone; and linear response to gas concentration over a wide dynamic range (1 ppm to 103 ppm). The major disadvantage is the potential for interference between two gases of similar structure due to overlap of absorption bands. PAS is operable under typical indoor environmental conditions.

***Infra-red spectroscopy (IR) (portable / stationary)***

The majority of hydrocarbons absorb energy when contacted by IR light, giving rise to a spectrum that can act as a ‘fingerprint’ that can be used to identify and quantify a contaminant. While IR analysis can provide instantaneous measurements, both contaminant identification and quantification may be subject to interference should air contain a mixture of contaminants.

An advantage of IR is the system stability allowing consistent results to be obtained over extended periods with minimal quality assurance checks. Water vapour can impact IR analysers; sample conditioning is therefore required for analysis of high humidity samples.

### 7.2. Active Sampling

A predetermined volume of air is sampled at a controlled flow rate onto a sorbent material or into a solvent where the VOC of interest is trapped either by physical adsorption or chemical reaction. Sorbent material is subsequently desorbed by thermal desorption or solvent extraction in the laboratory for quantification and identification of VOCs. Samples collected in solvents may be pre-concentrated or analyzed directly. This is a widely used, well- established technique with many validated methods available.

The variety of sorbents/solvents currently available allows the sampling of gaseous compounds from VVOCs to SVOCs. However, none of the existing sorbents/solvents is capable of retaining all compounds, so either a combination of adsorbents with different characteristics (multi - bed tubes) or one sorbent/solvent specially chosen for the actual analytical problem has to be used.

The use of solid sorbents in combination with thermal desorption and gas chromatographic separation is a preferred method due to the sensitivity, selectivity, convenience of use and the reliability that has been proven over the years. The sampling tubes are glass or stainless steel tubes of various lengths and outer diameters with the central portion packed with > 200 mg of solid adsorbent material(s). The choice of sorbent depends on absorption and desorption efficiencies for the target compounds, the stability of adsorbed compounds and the sorbent capacity (sorbent mass).

A sampling protocol needs to define for each target compound:

- The type and amount (suitability) of sorbent;
- Limits on environmental conditions (humidity and temperature);
- Limits of sampling flow rate and times;
- Storage requirements; and,
- Recommended analytical technique.

Background sampling and quality control are also required as many analytical methods require a background subtraction using the same media batch. Typically, sealed samples are held at ambient temperature (thermal desorption tubes) or kept cold (sorbents requiring solvent extraction) for immediate transport to the lab and analysed within 30 days. Some specific analytes may require additional handling.

### 7.3. Passive sampling

Passive sampling relies on the unassisted molecular diffusion of VOCs through a diffusive surface onto an adsorbent. After sampling, the adsorbed analytes are desorbed by solvent or thermal desorption for analysis. Passive sampling provides time-integrated concentrations with continuous time coverage. The averaging time is determined by the period of sampler exposure to ambient air (which can be daily, weekly, monthly, etc.). The choice of sorbent must be appropriate for the sampling (humidity and temperature) and analysis conditions (thermal or solvent desorption).

***Whole Air Sampling***

To collect a whole air sample a sufficient quantity of air is drawn or pumped into a container such as a polymer bag (Tedlar, Teflon or Mylar) or a passivated stainless steel canister (Summa® or silocan) and then transported to the laboratory for analysis. Container sampling has advantages over sorbent methods. Whole air sampling samples offers a relatively simple and rapid collection method providing the opportunity to monitor for the presence of a wide variety of VOCs from one sample, the ability to carry out replicate analysis, and not have sample break through. Other advantages include:

- no thermal or solvent desorption necessary;
- multiple aliquots for replicate analysis, and
- time-integrated samples can be obtained by using flow controllers or-pumps.

Additional advantages of passivated canisters include:

- rugged and safe to use;
- no field calibration necessary;
- sample stability for weeks or months depending on the nature of the sample;
- consistent recoveries;
- passive grab or time-integrated sampling is possible, and
- no electrical power needed to fill canisters to atmospheric pressure.

Disadvantages include: possible sample instability by adsorption onto the walls of the container; surface reactions on the walls of metal containers; sample permeation in or out of the container in the case of bags; the volume of the air sample is limited by the size of the container (except for metal containers which can be pressurized); no exclusion of non-target compounds which may lead to sampling matrix effects or analytical interferences; condensation; adsorption of target compounds onto particles collected onto the prefilter, and bulkiness.

***Canisters (e.g., Summa®)***

Typically, sealed samples are transported directly to the lab at room temperature (should not be cooled). Storage times of up to thirty days have been demonstrated for many of the VOCs. Pressure checks or evidence of leaking are reported on receipt at the laboratory.

The principle disadvantages of using canisters are the high initial cost and complex analytical techniques. Very volatile compounds, such as chloromethane and vinyl chloride can display peak broadening and co-elution with other species if the compounds are not delivered to the GC column in a small volume of carrier gas. Refocusing of the sample after collection on the primary trap, either on a separate focusing trap or at the head of the gas chromatographic column, mitigates this problem.

***Polymer Bags (e.g., Tedlar®)***

The general principles of whole air sampling that apply to canisters also apply to polymer bags. Bags may be filled by use of a sampling pump. If there are concerns with respect to introducing contaminants from the pumping system a lung sampler may be used to draw an air sample into the bag. With polymer bags compounds may not remain stable for more than 24–48 hours and may be permeable to certain chemicals resulting in losses if stored for prolonged periods. Polymer bags can also allow humidity to diffuse when relative humidity levels differ between inside and outside.

A double-layer polymer bag has been designed with a drying agent between the two films to limit the impact of external humidity on a low-humidity sample. Whole air samples collected in bags must be protected from the light. The main disadvantages of Tedlar bags are that passive sampling is not possible and samples may not be stable for more than 24–48 hours. Cleaning and re-use of Tedlar bags is not recommended.

***Bottles-Vacs***

Whole air samples may also be taken in glass bottles treated with a deactivation process and equipped with a specially designed valve used to collect VOCs over short time periods (seconds to minutes). Samples are collected passively via the pressure differential of the evacuated container.

## 8. Laboratory and Consultant Qualifications

### 8.1. Choosing a Consultant

There is currently no accreditation process for persons offering air quality services in Canada. Although not a regulatory requirement, some clients require sign-off by a certified industrial hygienist (CIH) when occupational health and safety issues are involved. Most of the criteria used to select an IAQ professional are similar to the ones that would be used for other consultants:

- Experience in similar problems, including the training and experience of the individuals responsible for the work;
- Knowledge of local codes and regional climate conditions;
- The quality of the consultant interview and proposal;
- Reputation and references;
- Cost relative to the services to be provided;
- Education of project staff, e.g., chemist, scientist, industrial hygienist, or engineer; and,
- Proof of insurance coverage.

It may be helpful to ask for a report the consultant provided for a similar project.

### 8.2. Laboratory Accreditation

Laboratories should be accredited by a body that requires audits and participation in programs with inter-lab comparisons and on-site assessments based on international standards. Table 2-8 (page 20) lists accreditation commonly used by Canadian laboratories.

## 9. Sources of Additional Information

- EPA, An Introduction to Indoor Air Quality (IAQ), Volatile Organic Compounds (VOCs):http://www.epa.gov/iaq/voc.html
- EPA, Volatile Organic Compounds (VOCs) - Technical Overview: http://www.epa.gov/iaq/voc2.html

| Table 2-8 Accreditations commonly used by Canadian laboratories | | |
|---|---|---|
| **Accrediting Authority** | **Description** | **Link** |
| Standards Council of Canada (SCC) Program for the Accreditation of Laboratories/ Canada (PALCAN) | Accredits and recognizes the competence and reliability of laboratory organizations' facilities through its Program for the Accreditation of Laboratories/Canada (PALCAN). Also offers accreditation of testing and calibration laboratories against ISO/ IEC 17025, Proficiency Testing (PT) provider accreditation against ISO/IEC 17043, and Good Laboratory Practice (GLP) recognition. | http://www.scc.ca/en/programs-services/laboratories |
| The Canadian Association for Laboratory Accreditation Inc. (CALA) | Not-for-profit Canadian laboratory accreditation body | http://www.cala.ca/index.html |
| American Industrial Hygiene Association (AIHA) in the Industrial Hygiene Laboratory Accreditation Program (IHLAP) | AIHA IHLAP is the largest industrial hygiene laboratory accrediting program of its kind in the world and has been in operation since 1974. | http://www.aihaaccreditedlabs.org/AccredPrograms/IHLAP/Pages/default.aspx |