# USING PIDS FOR INDOOR AIR QUALITY (IAQ) SURVEYS

Time studies have repeatedly shown that in indus-trialized societies, people spend very little time outdoors. While dependent on a number of factors, the proportion of time spent outdoors is often no more than 5%. The drive for greater HVAC (Heating, Ventilation and Air Conditioning) efficiency has led to buildings that are more sealed than ever, so less fresh air makes it into these structures to dilute any airborne contaminants. Spending upwards of 95% of one's time inside a sealed high-efficiency building has led to a rise in "sick building syndrome" (SBS) complaints. According to the American Lung Association, the top five indoor air pollutants include (in alphabetical order):

- Carbon Monoxide
- Formaldehyde
- Microbial contaminants (mold, dust mites, etc.)
- Second-hand tobacco smoke
- Volatile organic compounds (VOCs)

In order to limit occupant exposure to these compounds, it is necessary to detect them so their sources can be identified and remediated.

## PIDS PROVIDE DIRECT MEASUREMENT OF THREE MAJOR IAQ CONTAMINANTS

Photoionization detectors (PIDs) provide a direct means of detecting three of these contaminants:

- Microbial VOCs (mVOCs)
- VOCs in tobacco smoke
- VOCs from construction and office activities

This makes PIDs an excellent choice for both portable IAQ surveys and permanent IAQ subsystems of a building HVAC system. PIDs provide IAQ consultants, safety and hygiene professionals and building managers with a reliable, affordable, accurate and instantaneous means of *directly* measuring VOCs so that problems can be quickly identified and fixed. Recent advances in PID technology provide parts-per-billion (ppb) resolution, providing immediate insight and diagnosis that have never been possible in IAQ surveys. Innovations such as self-cleaning optics (refer to Technical Note TN-165: Combating Drift In Portable And Fixed PIDs) reduce long-term PID drift to a manageable level and can provide the means for HVAC total VOC (tVOC) control used alone or in an array of IAQ sensors.

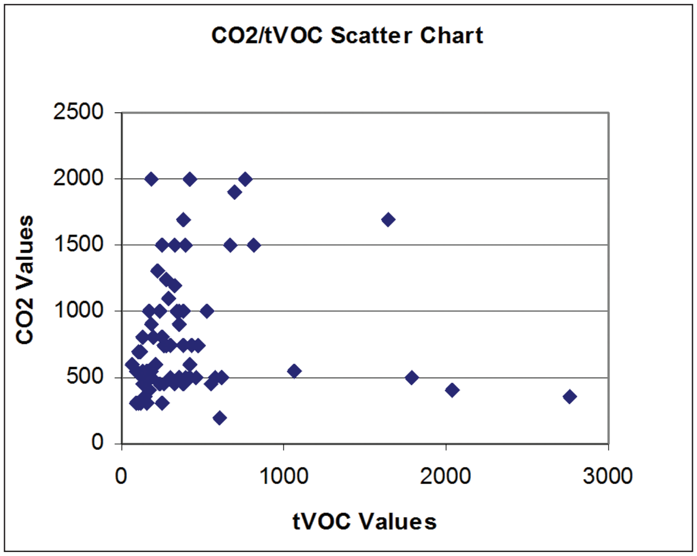
## $CO_2$: AN INDIRECT MEASUREMENT OF IAQ

Infrared (IR) carbon dioxide ($CO_2$, not to be confused with carbon monoxide or CO) monitors are among the most popular monitors for assessing the air quality of indoor environments both in portable survey instruments and permanent control systems. But $CO_2$ monitors are only a *secondary* measurement tool for IAQ. ASHRAE (American Society of Heating, Refrigeration and Air Conditioning Engineers) standards historically use $CO_2$ levels as a marker for indoor air quality. Levels of $CO_2$ in excess of 700 ppm over outdoor levels (typically 350 ppm) or usually over 1,000 ppm are an indication of "poor" indoor air quality. High levels of $CO_2$ can indicate that air is not being refreshed enough so that $CO_2$ is built up from the exhaled breath of the building occupants. But at the low levels found in IAQ, $CO_2$ is not a contaminant, only a gross indicator of possible contamination from one of the five sources listed above. If one dilutes the air enough to reduce $CO_2$ levels, it often solves the IAQ problem by diluting it away.

PIDs complement $CO_2$ monitors by providing a direct measurement tool for VOC contaminants. Finishes, fabrics, carpets, building materials and microbial contamination (mold, dust mites, etc.) all give off VOCs that affect Indoor air quality, yet these VOCs would never be noticed if only $CO_2$ were measured. PIDs provide a direct-reading technique to identify and locate these contaminants.

## $CO_2$ LEVELS DON'T CORRELATE WITH TVOCS

$CO_2$ levels do not correlate with total VOCs (tVOCs) in IAQ measurements. That is, high levels of $CO_2$ do not necessarily indicate high levels of tVOCs and vice-versa. In an informal study at a wide variety of sites worldwide including offices, conference rooms, hotel rooms, homes, etc., tVOCs as measured by a ppbRAE calibrated and measuring on an isobutylene scale did not significantly correlate (r= 0.11) with $CO_2$ readings taken with a RAE Systems $CO_2$ tube (p/n 10-104-20-2LL). Indoor air quality was not formally assessed in this study. That is, no judgement was made as to the indoor environment being of excellent, fair or poor quality. Therefore, it is unknown whether $CO_2$ or tVOCs are a better indicator. However, it is becoming clear that $CO_2$ as a survey tool for IAQ assessments can miss elevated VOC levels.

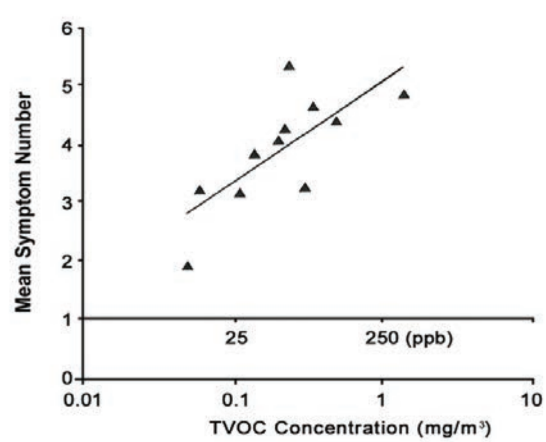



## HEALTH EFFECTS OF VOCS IN INDOOR ENVIRONMENTS

VOCs have a wide range of effects, including:

- Eye and respiratory tract irritation
- Headaches
- Dizziness
- Visual disorders
- Memory Impairment

tVOC concentration has been found to correlate with the prevalence of sick building syndrome symptoms.




Dose-response relationship between building TVOC concentrations and SBS symptom prevalence. (From Norback, D. et al., 1990. *Scand. J. Work Environ. Health.* 16:121–128. With permission.)

## WHERE DO VOCS COME FROM?

VOCs in an indoor environment can come from a wide variety of sources. They can be found in or caused by:

- Cleaning and maintenance supplies
- Carpets, fabrics, finishes and furniture
- Office equipment (copiers, printers).
- Microbial action
- Human occupancy (exhalation and perfume)
- Renovations
- Vocational training shops and art rooms
- Pesticides

### Options for Measuring VOCs

For Indoor Air Quality assessment we can use the following methods to measure VOCs (Volatile Organic Compounds) at low levels:

- **Adsorbent Media followed by GC/MS (Gas Chromatography/Mass Spectrostrophy) Lab Analysis:** Accurate, but lack real time feedback.
- **Metal Oxide Sensors (MOS)**
- **PID:** A fast, reliable, accurate detective tool for IAQ investigators.

### Adsorbent Media Followed by GC/MS Lab Analysis

To provide continuous monitoring over an entire day or portion of day, low-flow pumps are used to pull a sample through an adsorbent tube, or an evacuated stainless steel cylinder draws in the air to be sampled. These samples are sent to a lab. After analysis of these samples with GC/MS, one can tell exactly what the average concentration of chemical exposure was when the pump was used. To approximate the concentration versus the time of exposure, multiple tubes/cylinders must be run through the pump during the working day. This leads to greater complication and cost. While specific, adsorbent tubes/cylinders are reactive rather than proactive. Results can take days or weeks to return from the lab. By the time the results are available, a minor indoor air quality problem can grow into a major incident that could lead to worker slow-downs, sick-outs or even strikes.

Sampling followed by GC/MS testing is like a 35mm camera. While they both produce excellent results, you must wait for the film to be developed! In addition, lab analysis is expensive.

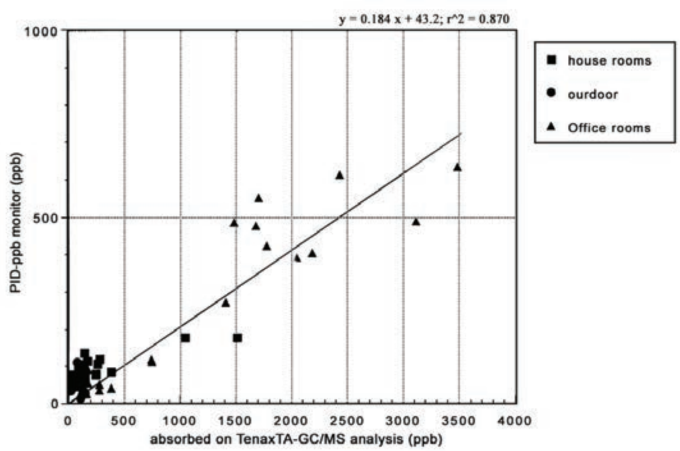



Fig. 4 Comparison between absorbed on TenaxTA-thermal desportion-GC/MS analysis, and PID-ppb monitor (RAE Systems Inc.) obtained in buildings, houses and outdoor in 2000.

In his study *Comparison Among Three Volatile Organic Compounds Measuring Methods*, Kunio Hara found "significant correlation" between samples tested with a TenaxTA-thermal desorption-GC/MS and a RAE Systems ppbRAE.

### Metal Oxide Sensors

Semiconductor or Metal Oxide Sensors (MOS) are among the oldest and least expensive measurement technologies used in portable and fixed IAQ monitors. While MOS sensors are inexpensive and can detect a very wide range of contaminants, they have number of shortcomings that limit their effective use, including:

- They have limited sensitivity.
- They respond positively to moisture, temperature and $CO_2$.
- They are slow to react (relative to a PID).

## PIDS AS A POWERFUL IAQ TOOL

PIDs measure up to 0 to10,000 ppm with resolution down to 1 ppb, and therefore are a very appropriate means of measuring VOCs (and other toxic gases and vapors) at extremely low levels. The advantage of the PID is that while it is not selective, it is a small, continuous monitor that can provide instantaneous feedback (less than 3 seconds). This instant feedback is critical because it provides users with the ability to deal with an IAQ problem instantly, rather than letting the problem build while lab results come back.

### Applying a PID in IAQ

PIDs provide a direct means of quickly assessing IAQ. The urgency and complexity of the problem of sick building syndrome triggered search of practical (time/cost-effective) assessment method using tVOC levels as practical standards (Godish, 1995). Such "total component" concept has already gained acceptance in other health-related disciplines, such as TSP (total suspended particles) and TdB (total decibel) as screening standards for particle and sound pollution, respectively. Pioneer works on using tVOC level as practical overall standard are not complete (Seifert, 1990; Molhave, 1991) and require further epidemiological research. Even so, tVOCs are emerging as a more direct approach of surveying indoor environments for contamination.

## TVOCS AS A MEANS OF DIRECTLY IDENTIFYING MICROBIAL CONTAMINATION

Preliminary data indicate that tVOCs are a good indicator not only for traditional contaminants (off-gasing products) but also for microbial actions (chemical releases from molds, fungi, etc.). Recent studies on chemistry of VOCs in indoor air (secondary emission and reactive species) and effects of microbiological VOCs (Wolkoff, 2000; Salthammer, 2000; Hess, 2001) call for further research. Until complete understanding is reached, researchers (Seifert, 1999; Salthammer, 2000; Kara 2000) are refining the tVOC approach as a practical screening method for exposure risk assessment to total VOCs in working and living environments.

## GENERAL GUIDELINES OF PID USE IN IAQ

Global consensus has resulted in the emergence of preliminary guidelines for tVOC standards for IAQ (Australian NHMRC, 1993; Finnish Society of IAQ, 1995; Seifert, 1999; Hong Kong EPA, 1999; Japan MoH, 2000). Depending on location (home, school, etc.), recommended levels range from 200 to 1300 ug/m3 or about 50 to 325 ppb (Toluene units) or approximately 100 to 650 ppb isobutylene units. By all accounts, the IAQ tVOC threshold for normal environments should not exceed 500 ppb (0.5 ppm) toluene units, which is equivalent to 1000 ppb (1 ppm) isobutylene units. Field experience suggests the following guide for the use of PIDs to assess indoor environments:

- <100 ppb isobutylene units: normal outdoor air
- 100-400 ppb isobutylene units: normal indoor air
- 500+ ppb isobutylene units: indicates potential of IAQ contaminants

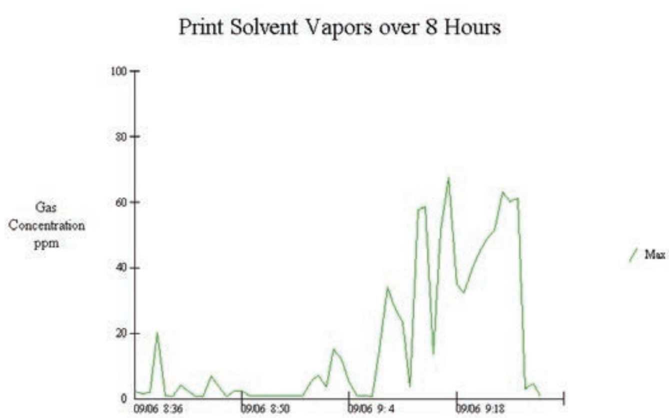
## PIDS SOLVE PAINT ODOR PROBLEM

In a situation where building tenants are complaining about paint odor the PID is very useful:

1. The PID can be used like a Geiger counter to lead investigators to the source of the paint odor.
2. Building maintenance can be interviewed to identify the paint(s) used.
3. The chemical formulas on most paint and glue containers allow you to quickly identify the chemicals.

4. Texts like the NIOSH *Pocket Guide to Chemical Hazards* help you to quickly find the safe levels for chemicals.
5. PID Correction Factors let users set the scale of the PID to the chemical of interest so that the reading is accurate.
6. Using the PID scaled with the right Correction Factor, you can quickly and accurately measure the level of the paint fumes.
7. If fumes are at safe levels, the PID can help prove that it is safe for the occupants to stay in the building. It might be necessary to explain the difference between odor threshold and toxicity to building occupants. For example, the odor threshold for toluene is 0.16 to 37 ppm while the 8 hour NIOSH TWA is 100 ppm.
8. If the fumes are at unsafe levels, then the PID provides evidence that the building needs to be ventilated.

The PID provides a fast and dependable "ruler" so that IAQ investigators can measure chemical vapors and quickly make decisions. In the politically charged situations posed by many indoor air quality complaints, a fast measurement tool like a PID is invaluable.  It can save time, money and headaches.




## DATALOGGING PIDS DOCUMENT EXPOSURE VERSUS TIME

Adsorptive tests may show that workers were safe on average over an 8-hour day, yet elevated levels of chemical may be missed by the averaging effects of adsorptive testing. For example, consider an office building with a small print shop in the basement. During the winter, the building manager decided to save money by decreasing the amount of outside ("fresh") air introduced into the HVAC system so that the air in the building was recirculated. Over the course of a workday, the solvent vapors from the print shop built up in the building until they reached high levels. Workers in the building didn't smell the vapors because they had grown accustomed to them over the workday (olfactory fatigue). Low print solvent exposure in the morning coupled with the high exposure in the afternoon provided an average exposure that was acceptable. However, exposure versus time datalogging with a PID showed that while there were no VOCs in morning, there were high levels in the afternoon. By adding the high morning concentrations to the low afternoon concentrations, adsorptive techniques missed this situation. If we were to plot the time versus exposure for adsorptive tests it would just be a straight line for the 8-hour workday.

## PID PROVIDES INSTANTANEOUS RESPONSE TO TRANSIENT EXPOSURES

Adsorbent tubes respond slowly to changes in concentration. This means that they can miss, or grossly underestimate some exposures. For example, suppose a nail salon is located in a storefront under a law office. Odors periodically filter into the law office with every new nail salon customer. These transient exposures may affect the law office workers, but the slow response of adsorptive sampling techniques, coupled with their averaging, would completely miss this exposure. A PID can datalog these quick, high transient responses and help IAQ investigators quickly identify and solve this problem.

## PIDS IDENTIFY COPIER ODORS

A school district had many older photocopies in operation using liquid toner. The liquid toner had an exposure limit of 100 ppm. Heavy copier use released significant concentrations of toner vapor in the small copier rooms where there was little ventilation. A PID was used to initially identify the problem and subsequently to help "tune" the new ventilation system to vent the copier odor away from workers.

## PIDS: A MAGNIFYING GLASS FOR IAQ "DETECTIVES"

IAQ investigators need a number of detection technologies to track down contaminants. PIDs provide IAQ investigators with a fast and effective way of identifying and then quantifying a VOC problem.  If the PID shows any reading, then the investigator knows to look for VOCs. Once the VOCs are identified, then the PID can be instantly scaled to that chemical so that the investigator knows at the scene the exact VOC concentration. This not only saves time for the IAQ investigator, but it also can prevent a small IAQ incident from "blowing up" into a major political incident.

For further information on how PIDs work and how to use them, reference Application Note AP-211: PIDs for Continuous Monitoring of VOCs.

## RAE MONITORS FOR IAQ

### ppbRAE Plus PID

Breakthrough technology to measure VOCs and other ionizable compounds in parts per billion (ppb). The ppbRAE provides unsurpassed accuracy, capable of continuous detection down to 1 ppb. For IAQ applications, the ppbRAE can detect VOCs at or below the olfactory threshold. Advanced comparitor circuitry in the ppbRAE Plus' sensor allows it to be set to zero out background VOCs so that the operator can see the rise in VOCs above the current background level.


### MiniRAE 2000 PID

The MiniRAE 2000 is our best detection or survey instrument.


- **Linear from 0 to 10,000 PPM with 3-Second Response.**
- **Quick Lamp and Sensor Access:** Access the lamp and sensor in seconds without tools. Other PIDs have quick lamp access, but what is the point if you can't clean the sensor? Cleaning the lamp without cleaning the sensor is like taking a shower and then putting on the same sweaty clothes.
- **Nickel Metal Hydride Drop-in Battery:** No memory effects, unlike NiCD batteries.
- **Intelligent:** User-friendly screens make it easy to take advantage of the sophisticated options in the MiniRAE 2000, including 100 Correction Factors in memory.
- **Rugged Rubber Boot.**
- **Bags Samples:** For IAQ the standard sample bagging attachment of the MiniRAE 2000 lets you bag unknown positive results for further lab testing.

### MultiRAE IR:

Combines a PID with NDIR $CO_2$ sensor, $O_2$, LEL and one toxic sensor like CO in one compact monitor to accurately provide a warning that threshold levels (ppm) of organic solvents (and other toxic gases) are about to be exceeded. The MultiRAE has one specific toxic sensor socket that can accept 10 specific toxic sensors. This allows IAQ consultants to quickly reconfigure the MultiRAE IR for different customers. The MultiRAE IR can run continuously when on its wall charger. This, and its large memory, allows it to datalog continuously for up to a week so that long term Indoor Air Quality trends can be spotted.


### ToxiRAE II Pocket PID

This instrument is for those who want the sensitive broad-band capabilities of the PID/VOC detector in our MultiRAE Plus, but they already have a four-gas monitor. ToxiRAE II is the most affordable PID in the world.


### RAE Systems Gas Detection Tubes:

While RAE Systems is known for innovative, high-tech gas monitoring solutions, we also offer money-saving gas detection tubes. RAE Systems has many of the most commonly used IAQ tubes.

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