

# Vapor Intrusion Sampling Options: Performance Data for Canisters, Badges, and Sorbent Tubes for VOCs

**Linda S. Coyne**

SKC Inc., 863 Valley View Road, Eighty Four, PA 15330

**George Havalias, Maria C. Echarte**

American Analytics Inc., 9765 Eton Ave., Chatsworth, CA 91311

## ABSTRACT

The collection of air and soil gas samples containing parts per billion levels of volatile organic compounds (VOCs) is becoming more prevalent with the recognition of the human health risks associated to vapor intrusion (VI). Vapor intrusion encompasses many areas including indoor air, ambient air and sub-slab soil gas. Canister sampling and analysis by EPA Method TO-15 has been the method of choice in most VI studies. While canisters do have advantages, they also are bulky, expensive and require extensive training. Canisters also cannot be used for the sampling of semi-volatile compounds. Sorbent tubes with battery-operated pumps have been used for many years for the collection and analysis of VOCs and are described in detail in EPA method TO-17. They are also the basis for multiple OSHA and NIOSH monitoring methods and can be used for gases as well as semi-volatile compounds.

This paper presents the results of two studies: one conducted in the state of New York, comparing the performance of passive badges and canisters and a second study, conducted in the state of California, comparing the performance of canisters and sorbent tubes. The New York study showed that correlation coefficients between canisters and an Ultra II badge packed with Anasorb GCB1 for benzene and perchloroethylene were 0.9533 and 0.9831, respectively. Toluene and xylenes also showed good correlation coefficients. The California study showed sorbent tube recoveries between 102 and 115% for the target analytes and good correlation coefficients with respect to Summa canisters.

The data in this study demonstrate that sorbent-based sampling devices can be used effectively in vapor intrusion studies and are a reliable alternative to canister sampling.

## BACKGROUND

The collection of low levels of VOCs has become more prevalent since the recognition of vapor intrusion and other indoor air quality issues.

Canisters have been used for many years and are referenced in detail in EPA Methods TO-14A and 15. The analysis of canisters is accurate but they can be expensive due to high shipping costs, recertification of cans, and extensive training. Simpler alternative

methods are desirable. Some of these methods include diffusive badges and tubes, which use solid sorbents for collection of the compounds of interest. Sorbent tubes used with battery-operated pumps have been used since the early 1970's and are considered active samplers. There are many methods that have been developed and validated by OSHA and NIOSH over the past 30 years using sorbent tubes. They are primarily used for industrial hygiene air quality monitoring and usually involve solvent extraction to remove the analyte of interest. These methods utilize many different media including activated charcoal, silica gel, XAD-2 resins and Tenax TA. Typical tubes employ both a front and a back section so that one can verify that the sample has not been saturated with the analyte of interest. When an analyte is detected in the second section of the tube, it is commonly referred to as "breakthrough". It is important to verify that the sample is valid and saturation has not occurred. Typical analysis is usually by gas or liquid chromatography. Tubes can be used to sample compounds with a wide range of vapor pressures, if the proper collection parameters are selected. EPA Method TO-17 also describes a tube-based monitoring method (active sampling) for VOCs in ambient air. However, the analyte is removed from the sorbent using thermal desorption. A table presenting information on safe sampling volumes and tube recommendations is provided in TO-17. Thermal desorption provides a dramatic increase in sensitivity, as the whole sample is usually injected into the chromatograph, instead of a very small portion of a sample extract, as is typically done with solvent extraction techniques. It is common with thermal desorption tubes to use more than one sorbent in the same tube, commonly referred to as a mixed-bed tube. This approach allows the user to sample both a gas and a semi-volatile compound at the same time with one tube. Method TO-17 requires the use of two tubes at different flow rates to ensure the integrity of the sample. This is simply not necessary because the added sensitivity of thermal desorption (as high as 1000x), requires much smaller flow rates and sample volumes. Therefore, there is low probability of breakthrough or saturation occurring. This is further verified in a paper published by the Health and Safety Executive, where they report safe sampling volumes for many compounds<sup>2</sup>.

Diffusive badges pose different issues than sorbent tubes. A diffusive sampler is a device which samples the atmosphere at a rate which is controlled by the physical process of diffusion. It does not involve the active movement of air through the device, as is seen with a sorbent tube and pump and thus it is commonly referred to as a passive sampler. Some of the main concerns are reverse diffusion and low or high wind velocities. Reverse diffusion, or loss of analyte from the badge, is usually due to the selection of a weak sorbent for the analyte of interest and is related to the exposure profile. It occurs when the vapor pressure of the analyte at the sorbent surface is greater than the external concentration, thus creating a situation where the analyte tends to desorb from the media. Ambient air velocity can affect the performance of a badge because it can influence the diffusion path length. Under conditions of low external wind speeds, the diffusion path may be increased while under conditions of high external wind speeds, the effective diffusion path may be decreased. Both of these phenomena must be tested out prior to usage in the field. There are many validation reports now that demonstrate that diffusive badges can perform well under these conditions and can accurately sample volatile organic compounds in the workplace<sup>3,4,5</sup>. Most of these studies were conducted at higher

levels and also at velocities much higher than those found in indoor air. Contamination of the sample is always a concern. Studies at SKC indicated Tenax TA and Anasorb GCB1 can be stored, in bulk form, for 4 months in the freezer with no change in the background. Off-gassing from badge housings can occur and takes place over time. By simply removing the sorbent from the badge into another holding vessel (tube or vial) after sampling, this problem is eliminated. In a study by the Health and Safety Executive, 20 compounds spiked on Tenax tubes remained stable over an eleven month period at ambient temperatures<sup>2</sup>.

The purpose of this paper is to show side-by-side comparisons between diffusive badges and tubes against the Summa canister (reference method) and to provide some possible alternatives to canisters. We studied the use of badges for the collection of indoor air samples and thermal desorption tubes for soil gas sampling.

## **EXPERIMENTAL**

A field study was coordinated by SKC and other companies, in several homes in the state of New York to investigate the presence of compounds such as perchloroethylene, benzene, xylenes, and toluene at ppb levels. The test sites were being investigated for vapor intrusion by VOCs in ground water from a dry-cleaning establishment and a gas station.

The sampling methods consisted of Summa-type stainless steel canisters and the SKC Ultra II diffusive badges packed with Tenax TA and Anasorb GCB1. The canisters were analyzed by EPA Method TO-15 for full-scan VOC list and a method reporting limit of 1 microgram per cubic meter for a 24-hour 6-liter sample. The Ultra II badges were analyzed using EPA method TO-17 (thermal desorption) with select ion monitoring. The reporting limits for the badges ranged from 0.005 to 0.06 micrograms per cubic meter for a 24-hour sample. The Ultra II badge has a screw-cap vial adapter which allows for easy transfer of sorbent into and out of the badge. This design helps lessen the chance of any type of contamination. Indoor air was sampled at 2 locations in each home, with one location selected for the correlation study of the badges and canisters. Usually the basement was used and the badges and canisters were attached to a 5-ft sampling stand.

A field study was also conducted, by American Analytics, in the state of California to investigate the use of sorbent tubes for monitoring soil gas. A preliminary laboratory study was conducted initially to validate sampling volumes for the field work for aromatic hydrocarbons and chlorinated compounds. For the laboratory study, samples were prepared in Tedlar bags by diluting a certified 1 ppm standard to a final concentration of 10 ppbv. In order to collect the samples into the canister and tubes, the Tedlar bag containing 1 liter of sample was connected to an orifice capable of restricting the flow rate to approximately 150 mL/min, followed by a vacuum gauge fitted with a female quick connect. Sampling was initiated by attaching the canister to the gauge and continued until a gauge pressure of approximately - 5 inches of mercury was achieved. The sorbent tubes were tested by connecting the tube to the bag, followed by the orifice and a vacuum gauge equipped with a quick disconnect fitting. A cleaned canister was

then connected to the gauge and was used to pump the sample from the bag onto the sorbent tube. After sample collection, the tubes were thermally desorbed with nitrogen at 300°C and analyzed by EPA Method TO-15.

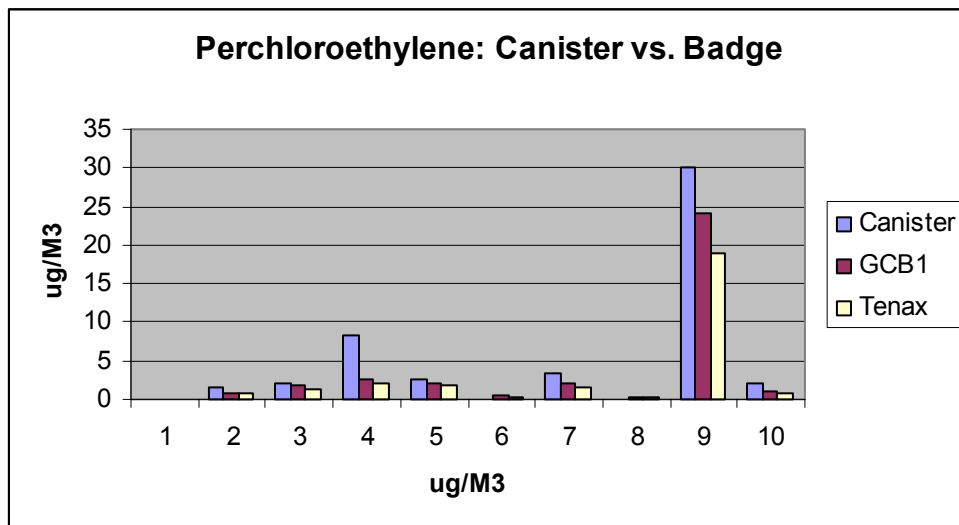
The field study with Summa canisters (0.4 and 1.6 liter) and sorbent tubes was conducted in an area with a known historical soil gas concentration of chlorinated compounds and petroleum hydrocarbons. A Summa canister and a sorbent tube sampling train were connected to the same soil gas probe through a manifold assembly. The Summa was equipped with a pressure gauge and flow control restrictor set for 150 mL/min. The tube sampling train consisted of two tubes in series, a flow restrictor, a pressure gauge and a second Summa canister. This canister served as a pump for the sorbent tube. After sample collection, the tubes were thermally desorbed with nitrogen at and analyzed by EPA Method TO-15.

## RESULTS

### Diffusive Badges and Canisters

Correlation data for benzene, toluene, xylene, and perchloroethylene are shown in Figures 1 through 4. Results for trichloroethylene and dichloroethenes yielded mostly non-detectable results, which made it difficult to show side-by-side comparisons. The correlation data for perchloroethylene with canisters and diffusive badges is shown in Figure 1.

**Figure 1.** Concentration Results for Perchloroethylene



The correlation coefficients for perchloroethylene were 0.9831 and 0.9837 for passive badges containing Anasorb GCB1 and Tenax TA, respectively. The field data using an Alnor velocity meter indicated that the highest velocity reading in the homes was 2 feet per minute, with many readings indicating zero velocity. Additional laboratory work was performed to study sampling rates for the badges in stagnant air or at zero velocity. The data indicated that sampling rates for the badges read approximately 60 percent on

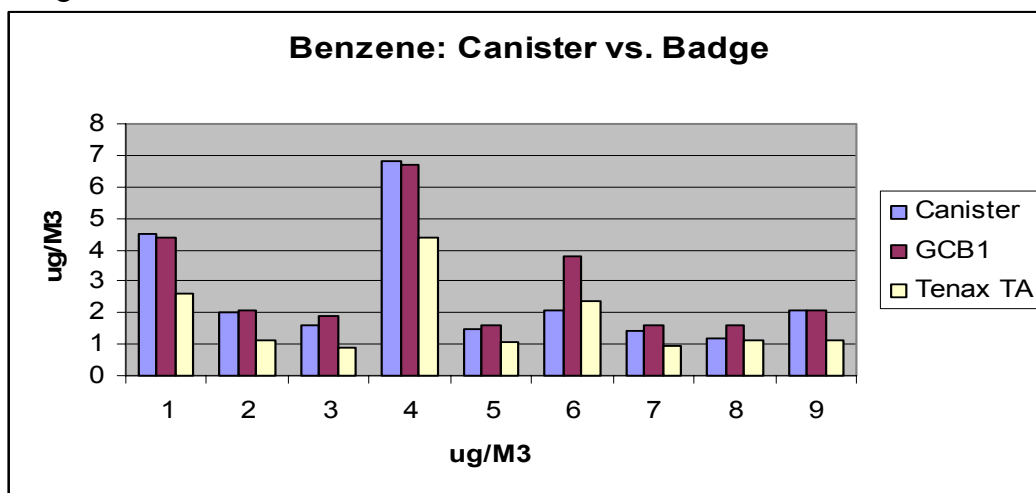
average of the sampling rate listed in the original validation studies. These rates are in Table 1. The sampling rate at the lower velocity was used to calculate the results in the field study.

**Table 1.** Sampling Rates for Ultra II Badges

Compound	Sampling Rate (mL/min) 10-200 cm/sec	Sampling Rate (mL/min) < 5 cm/sec
Acetone	20.3	5.79
Benzene	16.0	10.1
1,1-dichloroethene	12.3	9.74
cis-1,2-dichloroethene	14.8	10.67
trans-1,2-dichloroethene	14.8	10.2
Ethyl benzene	12.9	7.83
Hexafluorobenzene	12.99	7.77
Hexane	14.3	9.59
Methylethyl ketone	16.88	6.27
Methylene chloride	14.7	9.61
Perchloroethylene	13.1	9.4
Toluene	14.5	8.58
p-Xylene	12.8	7.57
Trichloroethylene	14.9	10.2

Correlation coefficients and concentrations results for benzene, toluene, and m,p-xylene are shown in Figures 2 ,3, and 4.

Figure 2 Concentration Results for Benzene



The benzene data in Figure 2 showed correlation coefficients of 0.953 and 0.944 for Anasorb GCB1 and Tenax TA, respectively. The toluene data in Figure 3 showed correlation coefficients of 0.9863 for Anasorb GCB1 and 0.9798 for Tenax TA,

respectively. Similar results are observed for m,p-xylene. In almost all cases, badges containing Anasorb GCB1 gave higher results than those containing Tenax. This could be attributed to better adsorptive properties for GCB1 compared to Tenax TA. Anasorb GCB1 is comparable to Carbo-pack B.

Figure 3 Concentration Results for Toluene

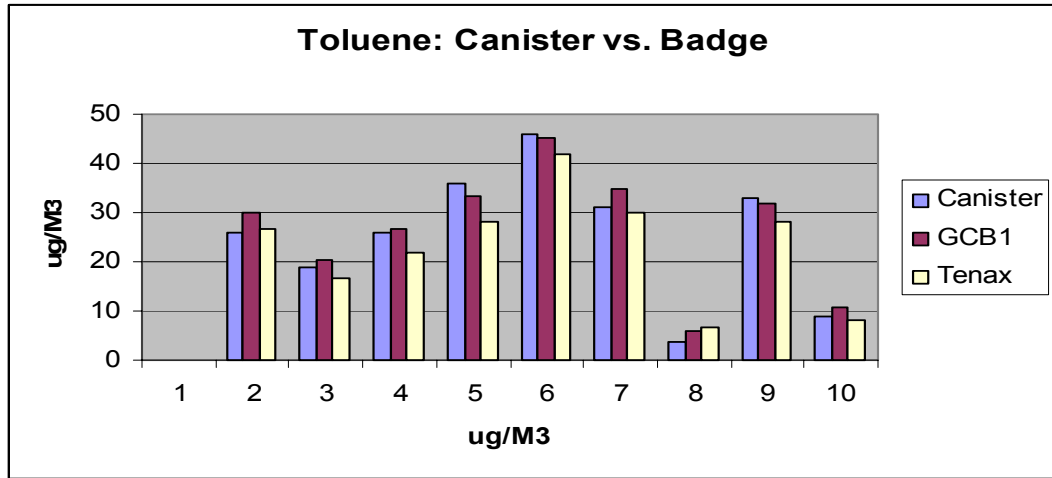
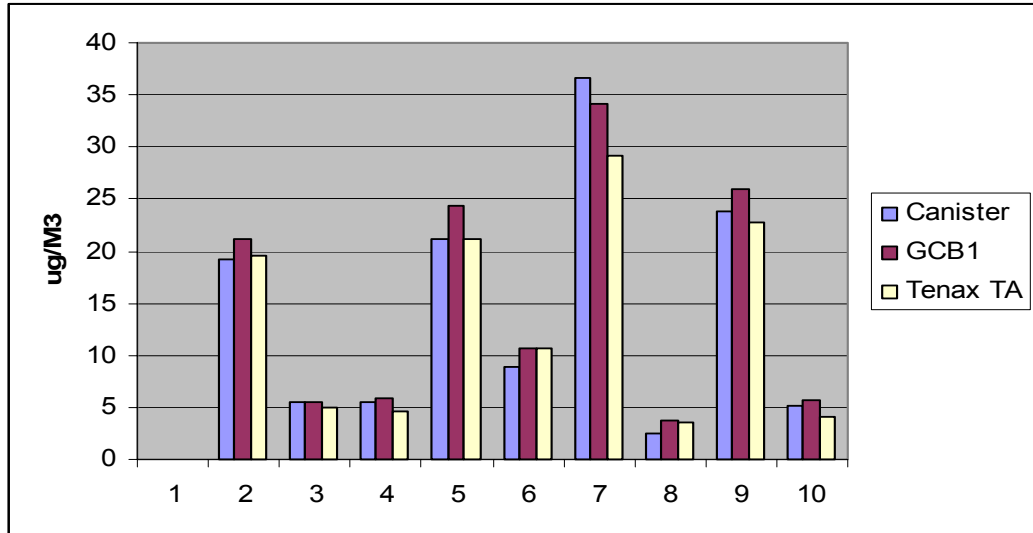


Figure 4 Concentration Results for m,p-Xylene



This field study indicates that diffusive badges can be used as a screening tool and a potential predictor of concentrations inside homes involved in vapor intrusion studies. This is just one field study and more studies need to be done to further substantiate these findings. Their small size and ease of operation makes them a cost-effective tool for this type of study.

## Sorbent Tubes and Canisters

This field study used a multi-bed tube, the SKC 226-349, containing both Anasorb GCB1 and Carbon Molecular Sieve and the Summa canister for soil gas sampling.

A preliminary laboratory study was conducted to evaluate the performance of the tubes under moist sample conditions, as this was anticipated at the field location. Some of the laboratory results are shown in Table 2.

Table 2 Recovery Comparisons between Canisters and Tubes

Compounds	Tedlar Bag	Summa 2-70		Tube 2-70	
	Conc (ppbv)	Conc (ppbv)	Recovery %	Conc (ppbv)	Recovery %
Dichlorofluoromethane	8.21	7.87	96	9.14	111
Trichlorofluoromethane	7.67	7.33	96	8.48	111
1,1-Dichloroethylene	7.7	7.56	98	8.55	111
1,2-Dichloroethane	7.7	7.4	96	8.82	115
Vinyl chloride	6.99	6.09	87	7.44	106
Benzene	8.05	7.03	87	8.51	106
Trichloroethylene	7.83	7.6	97	9.0	115
Toluene	7.92	6.74	85	8.27	104
Tetrachloroethylene	8.24	7.69	93	9.06	110
Ethyl benzene	7.75	5.63	73	7.89	102
m,p-Xylene	7.45	5.31	71	7.58	102
o-Xylene	7.55	5.36	71	7.73	102

The results suggest comparable recovery values from the tube and the Summa canister, with slightly higher values observed for the tube. More studies are needed, however, to confirm this observation.

The field study for the soil gas determination was conducted in Southern California where the soil has been impacted by both chlorinated volatile organic compounds and petroleum hydrocarbons. Two soil gas monitoring wells, SG23 and SG13, were selected for this study. The wells had been installed onsite during a previous site assessment. The wells consist of ¼ inch high-density polyethylene perforated near the bottom, to facilitate the flow of gases. The data from the field studies are shown in Figures 5 and 6.

Figure 5 Canister and Tube Results for SG 23

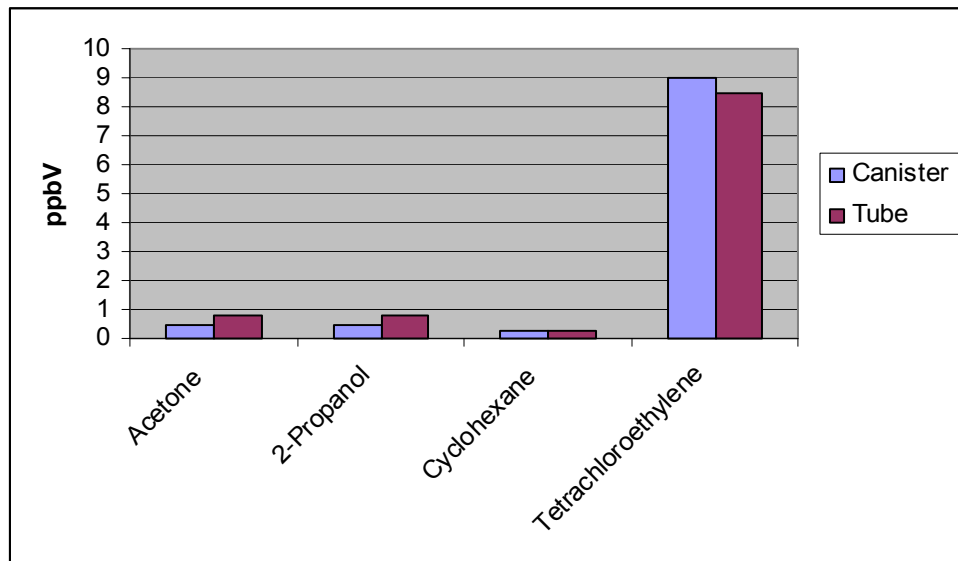
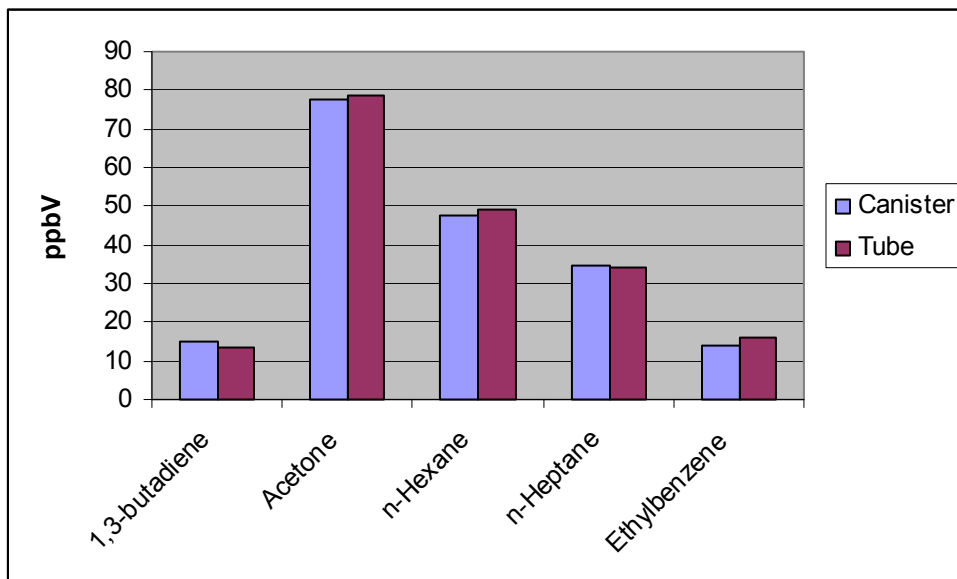


Figure 6 Canister and Tube Results for SG13



Good agreement was observed between the concentrations measured in the samples collected with the Summa canisters and the multi-bed sorbent tubes. The correlation coefficients between the tubes and the canisters, for the SG23 and SG13 field studies were 0.9992 and 0.9987, respectively. The data indicate good correlation between the two sampling methods. More studies are in progress.

## CONCLUSION

The results of the New York field study indicate that diffusive badges packed with Anasorb GCB1 or Tenax TA correlate well with Summa-type canisters. Data also demonstrate that Ultra II diffusive badges have adequate sensitivity to detect low ppb levels of VOCs and can be used as a screening tool and a potential predictor of concentration inside homes in vapor intrusion studies. Field studies with thermal desorption tubes indicate their potential for monitoring VOCs in soil gas studies. They also correlated well with canisters. Both sampling techniques, badges and tubes, are simple to operate, and require the same analytical methods employed with Summa canisters.

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