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INDOOR AIR POLLUTION EVALUATION BY TRACER GAS TECHNIQUE

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Abstract

A tracer gas technique has been used for evaluation and characterization of air flow pattern of contaminants penetrating into buildings. As a tracer, sulfur hexafluoride (SF_6) was used and detected by a gas chromatograph equipped with an electron capture detector. SF_6 was released at suspected points of contaminant origin at a constant flowrate and was detected quantitatively in the room or laboratory of concern. A dilution factor concept was established which can be used to estimate room contaminant levels and to calculate the level of contaminant in a laboratory hood exhaust system which will result in any given level in the make-up air system or room supply system. In all cases, the tracer gas method was successful and proved to be an effective method for the characterization and the investigation of the contaminant flow pattern. The sensitivity of the SF_6 gas detection, the low toxicity, and the specificity of the tracer gas make this procedure a very useful tool for this type of study.

Introduction

Polluted air in office or laboratory buildings may cause serious illnesses among workers. Therefore, the indoor air quality in these areas has become the subject of much attention. The levels of indoor air contaminants can be determined by air sampling techniques. Qualitative information may be estimated by use of smoke tubes. A measurement of ventilation rate may be used for identification of air quality. However, these methods are limited to the immediate office or laboratory area and may not provide sufficient information outside the immediate area or as to the source of the contaminant. The use of a tracer gas can provide this information. The tracer gas can be released at suspected points of contaminant origin and detected quantitatively in the room or laboratory of concern.

To accomplish this, some necessary conditions must be met:

- o The tracer should be specific and different from pollution compounds to avoid interference with the contaminants.
- o The tracer should be chemically stable and it should not react with the constituents in the test area.

- o The tracer should be detectable at low concentration with a high sensitivity and accuracy.
- o The tracer should not be harmful to the worker.

Numerous tracer compounds have been used to the tracer technique. Generally, there are two basic groups of tracers: radioactive and non-radioactive. The groups are shown in Table 1. The tracer technique has been used in several applications, such as evaluation of meteorological studies, terrain pollutant studies, mining ventilation, plume tracking, infiltration rate measurements in building structures of residences, hospitals, plants and hood efficiency evaluation. The list of tracers or applications certainly is not complete, however, it should demonstrate the feasibility of this technique.

Table 1. List of Tracers

<u>RADIOACTIVE</u>	<u>NON-RADIOACTIVE</u>	
Xenon	Fluorescent	Carbon Dioxide
Krypton	Sodium Chloride	Helium
Argon	Rhodamin	Nitrous Oxide
Methanes	Uranine	Freons
	Diocetylphthalate	
	Sulfur Hexafluoride	

The National Institute for Occupational Safety and Health (NIOSH) has recently used the tracer technique for evaluation and characterization of contaminant air flow pattern in several buildings. Among tracers, sulfur hexafluoride (SF₆) seemed to meet all requirements specified above and was selected as the most suitable tracer for our investigation. SF₆ is a colorless gas chemically inert, stable up to 500°C(1). It is non-explosive, non-flammable and non-toxic(2,3). SF₆ may be easily detected. The lower detection limit of SF₆ concentration is approximately 10⁻¹² parts per one part air, i.e., 0.001 ppb by a gas chromatograph provided with an electron capture detector (ECD). Generally, SF₆ can be considered as a unique gas not normally occurring in ambient air(4).

Apparatus - Method

For SF₆ measurement, a gas chromatograph (Baseline Industries, Model 1030A) equipped with ECD was used. The chromatographic column was a 183 cm (6 ft) long, 0.32 cm (1/8 inch) OD stainless-steel tubing packed with Molesieve 5A 60/80. To allow continuous on-the-spot sampling, the gas chromatograph was provided with a multi-functional valve. A built-in microprocessor provided an automatic repetition of the sampling cycle. A prepurified nitrogen was selected as a suitable carrier gas. Both the carrier

gas and air sample flow rates were constantly maintained at 50 ml/min (0.0018 ft³/min). The ECD operating temperature was 180°C, while the column was set at 70°C.

Since this method does not require an isokinetic sampling, the sampling probe used was a simple L-shaped, 0.32 cm (1/8 inch) ID stainless-steel tube. The sampling line was connected with the gas chromatograph via a glass fiber filter to protect the chromatographic column against contamination by particulate aerosol.

The SF₆ was continuously discharged from a cylinder at a given constant flow rate until a quasi-equilibrium concentration of SF₆ was obtained at the point of detection. Then the SF₆ discharge was stopped and a decay rate of the SF₆ concentration was measured for evaluation of ventilation or infiltration rate.

Due to variety of the investigations, it may be difficult to establish a standard discharge location for all ventilation systems. However, some general techniques can be established. SF₆ can be discharged either in the air conditioning or laboratory hood exhaust duct under investigation or into open air next to the suspected point of the contaminant origin. If discharged into the duct, it is recommended to discharge SF₆ upstream of a duct blower which accelerates the SF₆ dispersion and contributes to the accuracy of the method.

To quantify the contaminant penetration rate, a dilution factor has been established and was defined as follows:

$$D = \frac{\text{SF}_6 \text{ Stack Concentration}}{\text{SF}_6 \text{ Concentration Found at Ventilation System Supply}} \quad (1)$$

The dilution factor is applicable in all cases to the contaminant level in the exhaust. This level will be a function of all laboratory operations and the system filtration efficiency. Then, the total vaporous contaminant emission rate from the hood, which would result in the permissible exposure level (PEL) of that contaminant in the air supply, may be calculated by:

$$\sum_{i=1}^n d_i = \frac{\text{TLV}}{1000} \frac{\text{MW}}{24.45} D \cdot Q \left(\frac{1}{1-\eta} \right) \quad (2)$$

where d_i = contaminant emission rate, [g/min] from individual hood (i) in use at 25°C and 760 mm Hg

MW = contaminant molecular weight

TLV = ACGIH TLV limit, [ppm]

Q = stack actual air flowrate at 25°C and 760 mm Hg, [m³/min]

D = dilution factor

η = filter efficiency.

For solid contaminants, the equation is reduced to:

$$\sum_{i=1}^n d_i = \frac{TLVs}{1000} D \cdot Q \left(\frac{1}{1-\eta} \right) \quad (3)$$

where TLVs = ACGIH TLV limit, [mg/m³]

For evaluation of infiltration or ventilation rate, a standard ASTM method was used. This method calculates the ventilation rate from the logarithmic decay rate in tracer gas concentration with respect to time⁽⁵⁾. By plotting natural logarithm of SF₆ concentration against time, a straight line should be obtained (Figure 1). Then, the ventilation rate is given by the difference of natural logarithm of SF₆ at 60 minutes and 0 minute.

Several buildings have been investigated by this method. At the U.S. Department of Justice Building in Washington, D.C., origination and flow-pattern of contaminants intruding the offices was solved by this technique. At the Rutgers University in Newark, New Jersey, a study was conducted to investigate a potential re-entry of contaminants from animal laboratories into a building's fresh air intakes. At the Rosswell Park Memorial Institute in Buffalo, New York, a potential re-entry of contaminants being emitted from laboratory hood exhausts and from a power plant stack into fresh air intakes at several buildings was identified. In this case, the dilution factor combined with combustion factors, determined by the U.S. Environmental Protection Agency (EPA), were used to estimate a minimum concentration of combustion contaminants from the stack to pollute the building's fresh air supplies to the contaminant PEL level. The combustion contaminant concentration in a fresh air room supply was calculated as follows:

$$C = \frac{1000 d_c \cdot 24.45}{(MW) \cdot D_c \cdot Q_c} (1 - \eta) \quad (4)$$

Where C = contaminant concentration, ppm
 d_c = total combustion contaminant emitted from the stack at 25°C, 760 m/m Hg, (g/min)
 D_c = dilution factor
 Q_c = stack flow rate, at 25°C, 760 m/m Hg, m³/min
 MW = combustion contaminant molecular weight
 η = filter efficiency

For evaluation of d_c values, pollutant emission factors, as defined by EPA (EPA Report AP-42, 1977) were used.

At a NIOSH facility, a study was performed to evaluate a potential re-entry of contaminants from a carcinogen laboratory exhaust stack. In this case, the SF₆ was also measured outside the building to investigate the pollution rate in the neighborhood of the building. The measurements were conducted at several wind conditions downstream the wind direction. An example of the dilution factors obtained is shown in Figure 2.

In all cases, the tracer gas method, using SF₆ was successful and proved to be an effective method for the characterization and the investigation of the contaminant flow pattern. The sensitivity of the SF₆ gas detection, the inertness, the low toxicity, and the specificity of the tracer gas, make this procedure a very useful and powerful tool for this type of study.

References

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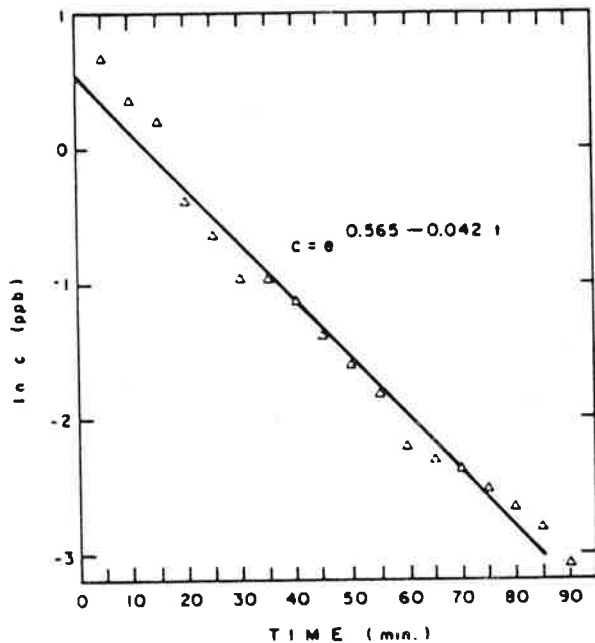
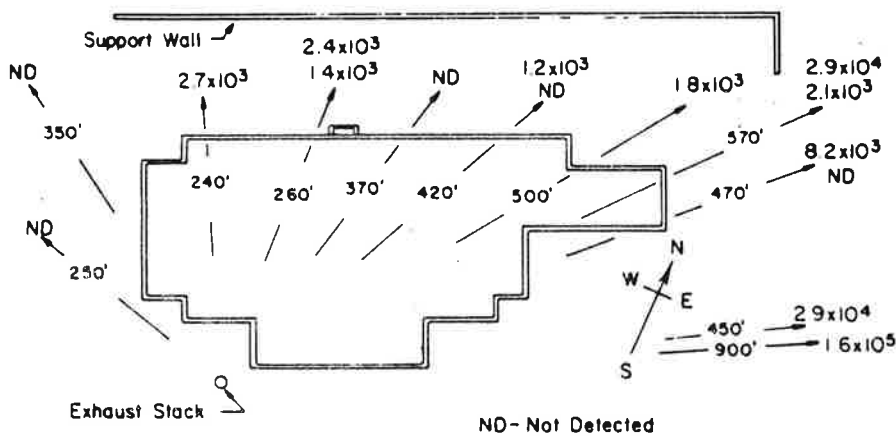


Figure 1. SF₆ concentration vs. time.



DILUTION FACTORS FOUND OUTSIDE NIOSH BUILDING

Figure 2

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