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SAMPLING AND MONITORING TOXIC GASES IN INDOOR ENVIRONMENTS

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Abstract

A brief discussion of different approaches to indoor air pollutant monitoring is presented. Indoor sampler design criteria are outlined. Grab samplers, personal samplers, passive and single-use devices, and in-situ measurement instruments are compared to novel, syringe/adsorbent tube samplers. These instruments provide automated, sequential, time-averaged collection of a variety of indoor pollutants, including hydrocarbon/halocarbon organic vapors, CO, CO2, HCOH, tobacco smoke, combustion and odorous mixtures, and particulate matter. In addition, the samplers can be used in indoor infiltration studies. The paper describes the design and operation of the new sampler in some detail. Current and potential applications are also mentioned.

Introduction

Growing concerns about the impact of indoor air pollutants on a large segment of the general population spending up to 80-90% of its time indoors, at work and at home, greatly intensify the interest of professionals involved in the sampling, monitoring and measurement of gaseous indoor pollutants. The data obtained so far provides important, yet incomplete, information on the types of species present in indoor environments, the concentration distribution, and their toxicological effects (4). In order to meaningfully interpret data from indoor pollution monitoring programs, the accuracy, reliability, and reproducibility of sampling and measuring techniques become major areas of concern. Additional demands placed on sampling programs include minimizing personnel and equipment requirements to meet specific measurement tasks, and low maintenance and replacement costs. Typical areas of interest are indoor residential and work atmospheres (6,7), industrial environments, and studies concerned with transport and fate of air pollutants. Most of the above activities require continuous monitoring of gases of interest, which include toxic or otherwise undesirable species. In this manner characterization of indoor pollution and its sources, and estimation of total exposure can be achieved.

Several approaches are utilized for indoor gas sampling. Manual grab samplers (various containers, syringes, or plastic bags) are widely used. Their advantages include simplicity and low initial cost. The drawbacks are high manpower requirements, low reliability, and unsuitability for larger studies. In some cases sampling has been semi-automated; that is, flasks or plastic bags were equipped with pumps, manifolds and timers. However, concerns about sample integrity, logistics problems and operating costs arose.

.....With the advent of new technologies in the 1970's, a number of smaller, continuous, gas analyzers appeared on the market. Some of them are suitable for in-situ measurements of a variety of gaseous species, particularly reactive gases such as ozone, nitric oxide, nitrogen dioxide, sulfur dioxide, and radon. Recently highly portable, personal monitors have been introduced (3). These instruments are used for measuring carbon monoxide, carbon dioxide, hydrogen sulfide, vinyl chloride, combustible gases, ammonia, formaldehyde, ethylene oxide, and some hydrocarbons. Presently these compact units measure only relatively few gaseous species, typically at ppm or higher concentrations. In-situ measurements of toxic contaminants are highly desirable, but frequently not feasible because of the high cost, the need for skilled personnel, complicated logistics, and limited availability to a number of users. Increased demands for indoor atmosphere characterization, including measurement of gases such as formaldehyde, and measurement of indoor/outdoor air infiltration rates led to the development of low cost passive samplers, and miniature tracer gas sources (1). Several manufacturers now provide inexpensive, single use, gas detector tubes for an approximate determination of over one hundred different gases at the ppm to % concentration.

Indoor Pollutant Sampler Criteria

.....The preferred approach to indoor sampling/monitoring uses sample collection over the desired length of time with multipurpose, versatile, automatic gas samplers. Frequently, the protocol for sampling and monitoring indoor contaminants requires sampling environments of interest at desired times and locations. Operation of a number of relatively expensive in-situ analyzers can create significant logistics problems and result in considerable expenditure of resources whereas a number of lower priced automated samplers will perform at multiple locations, 24 hours a day, with no external power or consumables such as special gases required. Subsequent sample analysis can be conveniently carried out in a central, permanently based, properly equipped and staffed analytical laboratory.

.....The main areas of concern in the sampler construction and operation are reliability, size, procurement and operating costs. Desirable characteristics of indoor toxic gas samplers are ruggedness, continuous, unattended operation capability, and flexibility in their use. One of the few limitations imposed on the automated samplers is the reactivity of sampled gases. Ozone, oxides of nitrogen, and sulfur dioxide cannot be stored for any length of time. Other gaseous species may be collected and stored in suitable containment vessels made of polymeric materials, glass, and some metals. Frequently sampling devices such as the plastic bags are not suitable for collection of indoor air samples because of contamination and permeation characteristics, difficult handling, and overall unreliability. Most types of analyses require sample size from a few millilitres to several litres. An automated, multi-station sampler utilizing suitable 20-150 ml syringes, or sample tubes containing user selectable, solid adsorbent for efficient gas vapor trapping, can collect necessary volume of samples for the analysis of indoor pollutants. An additional advantage of this type of sampler is the positive displacement mode of sample collection lending itself to convenient syringe sample analysis or thermal desorption of sample tubes.

.....Experience with design and construction of automated, single to twelve station samplers used in atmospheric tracer studies (2) enabled D.S.I. to introduce a sampler meeting the above criteria for collection of indoor air samples suspected of containing toxic gases. The main advantages of DSI automated syringe/adsorbent tube samplers are the advanced design, cost-effectiveness, average reliability of 97% (8), (compared to about 60-85% for the bag samplers), compactness, and a variety of possible sampler applications.

Sampler Design and Operation

.....The DSI, commercially available, gas sampler (Figure 1.) contains an advanced timing system which allows automatic collection of twelve, sequential, time-averaged gas samples. Rack and pinion gears driven by a stepper motor mechanically actuate each syringe. In operation, the syringe plunger remains stationary while the rack and pinion drive gradually extends the syringe body. At the end of travel, the syringe needle drives into a silicone septum, and power transfers to the next syringe. Alternately, the syringe can be equipped with a multiport valve and an adsorbent tube and cycled repeatedly until desired volume of air is sampled in each sample tube.

.....A digital clock, controlled by a quartz crystal oscillator governs the operation of the sampler. The overall time accuracy is better than + 0.001% and the station-to-station sampling time reproducibility is about + 0.01%. The time base interval can be preset to 2, 5, or 6 minutes. A time-base multiplier (1 to 15) is incorporated in the control electronics. An operator can pre-program the unit up to 15 days ahead of the actual operation, locate it on a suitable site, and leave it unattended. The sampler will start collecting sequential, time-averaged samples (ranging from 2 minutes to several hours) at the pre-selected time, and upon collection of each sample, seal the syringe needle to prevent diffusion or sample contamination. The adsorbent tubes are sealed with a check valve on the inlet end and the multi-port valve at the outlet end. The unit can be very quickly turned around for another sampling cycle. A rechargeable battery, which allows up to 50 hours of continuous operation, assures portability. An optional 115/230V A/C power supply kit is available. The unit is enclosed in a sturdy aluminum case, secured with two key locks, and easily portable by one person as the overall weight is approximately 13.5 kg.

.....The automated syringe/adsorbent tube gas sampler can be readily adapted for special operating requirements. It can be used in areas inaccessible to operators because of toxic gases or other hazards. A manifold can be attached allowing sequential sample collection from a continuous gas stream. Glass or passivated stainless steel syringes are available for collection of gases which require an inert, non-contaminating, non-reactive surface for maintenance of sample integrity. Table 2. provides a listing of recommended syringe construction and adsorbent materials for sampling a variety of indoor contaminant gases. Sampler syringes can be equipped with integral shut-off valves in place of the needles. With an optional control, two to six syringes can be collected simultaneously to provide larger sample size. An impregnated membrane filter cartridge can be installed on the syringe to provide a low-volume particulate matter sampling capability. In the near future a microcomputer controlled sampler will be introduced to provide considerably enhanced sampling capabilities.

.....In the dual sampling mode the sampler is equipped with a mechanically actuated, multi-port valve attached to the syringe. A sampling tube containing a suitable solid adsorbent, or an impregnated filter cartridge is placed ahead of the valve and the syringe. The syringe acts as a small, fixed volume pump. The sampler electronics allows multiple, individual syringe actuation providing a flow of sampled air through the sampling tube during the active stroke, and exhaust of air that passed through the sampling tube, from the syringe to an optional secondary adsorbent tube, during the passive stroke. In this mode, several litres of sampled air can be pulled through each sampling tube, and the cycle can be repeated up to twelve times.

Indoor Gas Sampler Applications

.....The list of applications for the automated, syringe/adsorbent tube samplers designed to collect toxic indoor contaminants is still growing. Some organizations are using the sampler in indoor pollution studies and in determining air infiltration rates (5). Other uses include industrial and process atmosphere monitoring, plant surveys, area/traffic monitoring and tracer gas studies where reliable quantitative and qualitative data is required. Table 1. gives a summary of studies utilizing the automated, sequential, gas sampler.

.....In all cases a profile of the concentrations of sampled indoor pollutant gases, as it relates to source emissions, process evolution, air exchange rates, and time-series changes, can be obtained. In addition, individual toxic gases can be identified. It is expected that new applications will develop as the users in industry, consulting firms, and regulatory agencies become aware of this novel approach to gaseous contaminant collection and monitoring.

Conclusions

.....Automated, time-averaged sampling of toxic, indoor, gaseous contaminants is gaining acceptance in industry, with consulting firms, and regulatory agencies. Inherent reliability, simplicity, efficiency, portability, and moderate cost make the automated gas sampler a versatile tool for a variety of indoor air pollution studies. Utilization of the automated gas samplers in conjunction with reliable analyzers makes the estimation of total exposure to indoor air pollutants, characterization of sources and types of pollutants possible in a timely and efficient manner. As a result, appropriate steps can be taken to prevent or significantly reduce the exposure of a large number of people to harmful indoor air pollutants.

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Table 1. Studies utilizing DSI automated, sequential samplers.

Organization	Location	Time	Application
U.S. EPA/Research Triangle Institute	Research Triangle Park, N.C.	1983/84	Air Exchange Rates/ Indoor Air Quality
U.S. EPA	RTP, N.C.	1984	Indoor Toxic Gas Meas.
Geomet Technologies/ EPRI	Gaithersburg, Maryland	1983/84	Air Exchange Rates/ Indoor Air Quality
Washington State University	Pullman, Washington	1982/84	Air Infiltration/ SF6 Tracer Studies
Exxon Research and Engineering Company	Florham Park, New Jersey	1983	SF6 Tracer Studies/ Industr. Atm. Sampling
California Institute of Technology	Pasadena, California	1983	SF6 Tracer Studies/ Indoor Air Sampling
U.S. DOI/ Bureau of Mines	Pittsburgh, Pennsylvania	1983	SF6 Tracer Studies/ Work Atm. Sampling
U.S. Army CRDC/RD	APG, Maryland	1984	Indoor Infiltration

Table 2. Suitable syringe construction and solid adsorbent materials for indoor gas pollutant collection

Type or Group of Gases to be Collected	Concentration Range (Parts: Vol./Vol.)	Recommended Syringe Material	Comments
Inert, man-made gases: SF_6, Fluorocarbons (1)	10^{-12}–10^{-3}	Polyethylene	Glass or S.S. equally suitable
Fluorochlorocarbons, Halogenated HC's (1)	10^{-10}–10^{-6}	Passivated Stainless Steel	
Hydrocarbons and Halocarbons (1)	10^{-5}–10^{-3}	Polyethylene	Glass or S.S. equally suitable
Hydrocarbons (1)	10^{-10}–10^{-6}	Passivated S.S., glass suitable	Polyethylene not recommended
CH_4, CO_2, N_2O, and most inert gases	10^{-7}–10^{-3}	Passivated S.S.	
Toxic gases (per EPA classification) (1)	10^{-9}–10^{-4}	Passivated S.S.	
Formaldehyde	10^{-7}–10^{-4}	Not applicable	Mol. sieve ads.
Tobacco smoke, odorous, combustion and other complex gas mixtures	10^{-9}–10^{-4}	Not applicable	Tenax, activated charcoal, or other adsorbents
CO, H_2, O_2, He	10^{-8}–10^{-3}	Passivated S.S.	

(1) These gases can be also adsorbed on suitable solid adsorbent materials

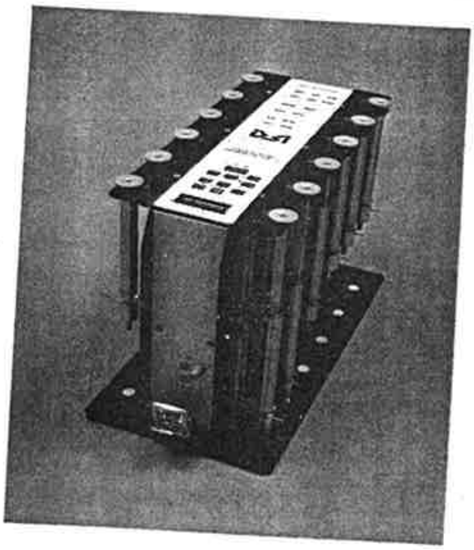

Fig. 1. DSI automated, sequential, indoor toxic gas sampler

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