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Review Article

Air Sampling : Past to Present
การเก็บตัวอย่างอากาศ : จากอดีตถึงปัจจุบัน

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Abstract : **P. Kongtip. 1994. Air Sampling : Past to Present. Thai J Hlth Resch 8(1): 43-48**

Air sampling techniques have been divided into two groups; instantanious sampling and integrated sampling. Instantanious sampling devices could be evacuated flasks, detector tubes, plastic bags, canisters etc. Integrated sampling devices include adsorbers containing liquid adsorbents, solid adsorbent tubes and passive sampling units. The development, advantages and limitations of each device will be discussed.

Key word : Air sampling.

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เทคนิคการเก็บตัวอย่างอากาศแบ่งเป็น 2 ประเภทคือ การเก็บตัวอย่างอากาศในขณะนั้น (Instantanious sampling) และการเก็บตัวอย่างแบบรวบรวม (Integrated sampling) การเก็บตัวอย่างอากาศในขณะนั้นสามารถใช้แก้วคนโทสุญญากาศ หลอดตรวจ หาถุงพลาสติกสำหรับเก็บอากาศ และกล่องโลหะคานิสเตอร์ การเก็บอากาศแบบรวบรวม สามารถใช้ภาชนะบรรจุตัวจับสารที่เป็นของเหลว หลอดบรรจุตัวจับสารที่เป็นของแข็ง และเครื่องมือเก็บอากาศที่ให้สารซึมผ่านเยื่อเมมเบลน เป็นต้น ประโยชน์และข้อจำกัดของเครื่องมือแต่ละชนิด และ การพัฒนาเครื่องมือสำหรับ เก็บตัวอย่างอากาศ จะได้บรรยายต่อไป

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Introduction

The need for sampling air in workrooms and ambient environments is to ensure a safe atmosphere which will not cause any diseases. Air sampling is defined as the collection of air from an atmosphere, followed by transfer of these volumes to the place and into the form in which the analysis can be made (Weurman, 1974). Air sampling can be taken for several purposes: (1) assurance of adequate health protection for all workers by initial and ongoing assessment of risk for developing occupational diseases; (2) establishment of historical records of exposure levels for epidemiologic and worker's compensation purposes; (3) compliance with governmental standards; (4) evaluation of new types of equipment, process and control and (5) correlation of environmental conditions with medical findings in order to establish threshold limit value. The type of contaminants occurring in a workplace depends on the process employed. It can be particulate matter, gases, vapours, mists or mixtures. This overview is focused only on air sampling for gases and vapours.

Air Sampling

The decision to sample an atmostphere for particular contaminants is often based on the results of preliminary surveys. Surveys are sometimes initiated as a result of complaints received from workers, neighbors or other sources suggesting that a harzardous or annoying air contamination exists.

Air sampling devices for industrial purposes have been divided into two groups, one called "instantaneous" or "grab" samples, and the other integrated or continuous samples (Silverman, 1956).

Instantaneous sampling

Butterfield (1909) developed an instantanious sampling device to collect air for the assessment of moisture, carbon dioxide, methane or other combustible gases. The sampling device used was a narrow-mouthed bottle of about 56 ml, with a well-fitting glass stopper. A piece of rubber tubing was used to draw air into the bottle; one end of the tube being attach to the bottom of the bottle, the other was put in the mouth of investigator. A full inspiration of air was taken, thus drawing the air of the room into the bottle, following which the bottle was stoppered.

Instantaneous samples could be collected by means of evacuated flasks, with volumes ranging from a few milliliters to 300 ml. These flasks were constructed of glass, metal or plastic. In practice, the evacuation was done in the laboratory or the flask was purged in the field by pump. Bottles were commonly used to collect grab samples. In one instance, the bottles had a mercury pool at the bottom to form an air-tight seal over the porcelain stopper when the bottles were inverted during transportation. Instantaneous sampling devices also included direct reading instrumentation for air contaminants. These devices collected gases and vapours on a solid adsorbent, impregnated papers or cellulose. The adsorbents used were either granular adsorbent gels, such as activated alumina or silica gel, or inert granules, such as pumice or sand coated with the detecting materials. Detector tubes or impregnated papers became popular devices (Silverman, 1956).

Plastic bags of varying chemical composition sometimes are used for the collection of air samples. This is the preferred method for sampling gases and high vapour pressure compounds which have low breakthrough volumes for adsorption methods. A variety of bags have been used, such as aluminized, Halar^{R}, Saran^{R}, Tedlar^{R}, Teflon^{R}, and Mylar^{R}. Possible sources of loss of substances from such bags include adsorption of the analyte on the walls of the bags, chemical reactions among the collected substances and permeation of the substances through walls of the bag (Tombe *et al.*, 1991). Posner and Woodfin (1986) performed a study on the losses of butene and 1, 3-butadiene with time on some of the gas bags. Tedlar bags appeared to be the best choice for short term storage although Tedlar bags have been found to contaminate air samples with acetaldehyde and acetone (Tombe *et al.*, 1991). Tedlar bags have been used to collect gases and vapours for the exposure assessment of firefighters (Trietman *et al.*, 1980; Jankovic *et al.*, 1991) and for source emission sampling (Pau *et al.*, 1991).

Another type of instantaneous sampling uses a canister. Miller *et al.* (1976) used partially evacuated steel containers, Vacu-Samplers, for collecting gases and vapours. Recently, the SUMMA passivated stainless steel canister has been the recommended sampling method by U.S. Environmental Protection Agency (EPA) for the collection of volatile organic compounds in ambient air. These devices provided very satisfactory performance for aliphatic and aromatic hydrocarbons (C_1-C_{12}). The inertness of the SUMMA canister surface has been demonstrated by storing parts per trillion (ppt) levels of trace gases for several months or longer without any appreciable losses of the stored substances (Tombe *et al.*, 1991). The advantages of canister use in monitoring volatile organic compounds (VOCs) in ambient air include easy cleanup procedure, repeated or multiple analysis, good storage stability, no breakthrough of target compounds and no electrical power needed for filling canister (McClenny *et al.*, 1991; Hsu *et al.*, 1991). However, the canisters are costly, bulky and have limited sampling volumes and are not generally applicable to polar compounds (McClenny *et al.*, 1991). The analysis of VOCs collected by the canisters is difficult and costly.

Integrated sampling

Initially, integrated sampling used adsorbers containing collecting agents, such as water, acid, alkali or organic solvent, to trap contaminants. Adsorbers for gases and vapours varied in characteristics depending upon the gas and vapour encountered. Simple wash bottles with ground glass joints or with multihole dispensers were used for collecting readily soluble adsorbed gas and vapours. For poorly adsorbed gases and vapours, sintered micro-gas washing flasks or midget impinger flasks fitted with a glass-filter stick were used. These filters dispersed the gas into fine bubbles or spread the liquid onto a large surface area. The pumps used for drawing air contaminants into adsorbers could be an aspirator (bottle), a hand pump or a motor-driven pump. The flow rate of contaminants in air could be drawn through adsorbers ranging from 0.5 to 15 liters per minute (Silverman, 1956).

At present, liquid adsorbents and impingers, may be useful for some reactive gas and vapours such as formaldehyde and ammonia. The spill-proof impinger for personal samples is also available (Heitbrink and Doemeny, 1979).

When collected contaminants are insoluble or non-reactive vapours, adsorption or condensation is the method of choice. Adsorbents commonly used in practice include: (1) activated charcoal, (2) silica gel and (3) special impregnated gels which contained a reactant for specfic gases. Sometimes, highly volatile contaminants must be condensed at low temperature with a mixture of dry ice and acetone (Silverman, 1956).

Rushing (1958) proposed methods coordinating the process of sampling on adsorbents and subsequent gas chromatographic analysis (cited by Reid and Halpin, 1968). Reid and Halpin (1968) used small glass tubes containing activated charcoal to collect organic vapours. Sampling was accomplished by drawing vapour-containing air, at desired flow rate, through these tubes. Altshuller *et al.* (1962) and Feldstein *et al.* (1967) did essentially the same thing except that a silica gel adsorbent was employed. They desorbed contaminants by solvent desorption and analyzed by gas liquid chromatography.

The use of small charcoal tubes connected to a small portable pump was introduced in 1970 (White *et al.*, 1970). Charcoal has gained the status of the almost universal adsorbent because of the large surface area, microporous structure, high adsorption capacity and high degree of surface reactivity. Many types of raw materials are used for industrial-scale production of activated charcoal such as wood, coal, lignite, coconut shell and peat. Granular activated charcoal is the type of charcoal commonly used for the adsorption of gases and vapours. Nutshell charcoal tube sampling was the recommended method for organic solvents in air in 1974. The National Institute for Occupational Safety and Health (NIOSH) adapted this technique to more than one hundred individual chemicals including compounds with low exposure limits such as acrylonitrile, benzene and vinyl chloride in 1977. Activated charcoal has some limitations, including sensitivity to humidity and low sensitivity due to solvent desorption. These limitations have led to the

development of other adsorbents, such as porous polymers. The use of sampling tubes packed with porous polymer adsorbents, such as Porapak Q, Tenax GC or Chromosorb 101, 102 or 103, offered an excellent means for trapping organic contaminants present in air (Tanaka, 1978). Subsequently, the contaminants are thermally desorbed into a gas chromatograph for analysis. The advantages of thermal desorption include high sensitivity, the absence of a solvent peak in a gas chromatographic analysis and the reuse of the adsorbent. However, thermal desorption does not permit multiple analysis of a single sample. Tenax GC has been widely used porous polymers for the assessment of VOCs in ambient environment (Crisp, 1980).

The approach of using more than one adsorbent to enhance the adsorption for low molecular weight compounds has been studied. The Oil Companies' International Study Group used a sampling system composed of two types of solid sorbents for monitoring gasoline vapour. The sampling tube consisted of a front bed of Chromosorb^{R} 106 and a back bed of charcoal. The low molecular weight hydrocarbons passed through the front bed and were trapped on the charcoal. The tube was thermally desorbed in the reverse direction from that used for collection (Coke *et al.*, 1989). The Ontario Ministry of Environment (MOE) currently uses a sorbent tube of Carbotrap/Carbosieve that has been found to be very effective for retaining C_2 to C_{12} components (Tombe *et al.*, 1991). Multi-sorbent samplers containing a series of Tenax, Ambersorb XE-340 and activated charcoal have been used to increase the breakthrough volume of low-boiling compounds. With a 10-L collected sample volume, limits of quantitation were < 1 ppb (Hodgson *et al.*, 1989). In a field study evaluating the ability of a multi-sorbent sampling tube to identify organic contaminants in 12 Canadian homes, the results indicated that the recoveries were more than 70%, with the precision being better than 15% (Chan *et al.*, 1990). The integrated sampling techniques need an aspirator or a pump to draw air into the sampling device. This sampling technique is called active sampling.

In 1973, Palmes introduced a passive sampling unit for monitoring sulfur dioxide based on the molecular diffusion of a gas through an orifice into a small chamber containing mercuric chloride (Palmes and Gunnison, 1973). This approach was intended to obviate the need for pumps and flow control devices as parts of the sampler. This sampling principle could be applicable to any gaseous airborne contaminant. Another passive sampling unit for nitrogen dioxide, containing stainless steel grids coated with triethanolamine, was developed in 1976 (Palmes *et al.*, 1976). Similar passive sampling devices have been developed for organic vapour monitoring because they were small and light, simple in structure and required no source of power. Examples were the Walden GASBADGE^{TM} dosimeter for industrial pollutants (Tompkins and Goldsmith, 1977); the Abcor GASBADGE^{TM} for acrylonitrile (Silverstein, 1977); the 3M monitor for mercury vapour (McCammon and Woodfin, 1977); and the Porton diffusion sampler for volatile organic substances (Evans *et al.*, 1977). The passive samplers were initially developed for monitoring relatively high-level time-weighted average (TWA) exposures because the Occupational Safety and Health Administration (OSHA) was promulgating the threshold limit value for TWA of employee exposure to toxic substances in that period. The development of passive sampling increased dramatically because of the simplicity of sampling without a personal pump. The technique was commonly applied using charcoal or porous polymer adsorbents to the collection of organic vapours. With charcoal adsorbents, the adsorbed vapours were eluted with solvent, usually carbon disulfide. If a porous polymer adsorbent was employed, the analyte could be efficiently desorbed by thermal techniques. This technique could also be used for low sample loadings such as short-term exposure and low concentration monitoring of organic vapours. Such passive samplers require validation before use in analyzing low concentrations of organic vapours in indoor air.

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