PASSIVE MONITORING OF VOLATILE ORGANIC COMPOUNDS IN AIR AND WATER BY NEW SAMPLERS WITHOUT A MEMBRANE

By Evgeni Giller

A Thesis
Submitted to the Faculty of Graduate Studies
in Partial Fulfillment of the Requirements
for the Degree of

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PASSIVE MONITORING OF VOLATILE ORGANIC COMPOUNDS IN AIR AND WATER BY NEW SAMPLERS WITHOUT A MEMBRANE

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EVGENI GILLER

A Thesis submitted to the Faculty of Graduate Studies of the University of Manitoba in partial fulfillment of the requirements for the degree of

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ABSTRACT

A series of experiments were conducted to investigate the suitability of activated carbon cloth (ACC) and polyurethane foam (PUF) strips for diffusive sampling of volatile organic compounds in air without using a membrane. Experiments were carried out in an environmental chamber and in different indoor and outdoor air environments.

The monitors were analyzed qualitatively by liquid extraction and gas chromatography-mass spectrometry and quantitatively by gas chromatography with a flame ionization detector.

It was shown that ACC and PUF monitors can provide satisfactory quantitative data for a wide variety of volatile organic compounds in indoor air ranging in concentration from 5.0 ppb to 500 ppm in air and that the absence of a membrane (which is normally used in commercially available passive monitors) does not affect the linearity of the sampling rate. Suitability of the application of these monitors for water analysis also has been determined.

Recycling, a convenient procedure of exposure, delivery and return by postal service, as well as simple analysis all show that this passive sampler substantially reduces the cost of monitoring, thus demonstrating its benefits in the determination of the contamination source within both large industrial sites and any other buildings where such analyses may be required.

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CHAPTER I

INTRODUCTION

1.1 Introductory Remarks

"Volatile organic compounds" (VOC) is the collective name given to the carbon-based gaseous contaminants emitted from a wide range of common household or industrial products (1). VOC, often present in ambient air at 1 ppbv to 1000 ppmv (parts per billion/million based on volume) concentrations (2), may contribute to a variety of physical symptoms, such as headaches, nausea, and dizziness (3,4). VOCs consist of aromatic compounds such as toluene or benzene as well as many aliphatic compounds such as hexanes or methylbutanes (5). Therefore, air monitoring is a global concern and numerous sampling techniques of VOC have been reported (6). One of these techniques is passive sampling.

"A diffusive or “passive” sampler is a device which is capable of taking samples of gaseous vapor pollutants from the different environments at a rate controlled by a physical process, such as diffusion through static air or permeation through a membrane, but which does not involve the active movement of the air through the sampler" (7).

Diffusive sampling of VOCs is a well established technique which has the same accuracy as active monitoring (8), but does not require an expensive sampling pump. Diffusive sampler is simple, easy to use, convenient to ship and mount, and can be used by unqualified personnel.

A passive sampler typically collects the species of interest from the immediate surroundings by the process of natural diffusion or by permeation of the species into the sampler followed by retention by adsorption (9). The only disadvantage is a relatively low sampling rate which necessitates very long exposure times in order to sample low concentrations of contaminants (10). Because the diffusive permeability of each compound through the membrane affects the sampling rate, it must be known for each substance if quantitative analysis is to be achieved.

The theoretical basis for diffusive sampling is well established. The fundamental equation that describes the passive sampling mechanism is based on Fick's law of diffusion, which defines the flow of mass, N_a, as

$$N_a = \frac{m}{t} = \frac{D * S * C}{L} \qquad (1)$$

where where m is the mass collected in the time t, C is the external (airborne) concentration of the substance concerned, L and S are the diffusion length and area of the sampler respectively, and D is the diffusion coefficient in air of the gaseous substance (11).

The airborne concentration of the substance can be obtained as follows (12):

$$C = \frac{m * L}{t * D * C} \qquad (2)$$

The DS/L ratio is called the sampling rate (R) by analogy with active sampling systems and depends on the design of the sampler and the diffusivity of the pollutant in air. Using equation 1, equation 3 can be derived

$$C = \frac{m}{t * R} \qquad (3)$$

A passive sampler can be based on the principles of diffusion or permeation, or a combination of the two (9). Possible, that the use of a membrane or diffusion tube was an effective way to keep powdered sorbent materials or liquids inside the body of the monitor.

Brown *et al.* have shown (13) that removing the diffusive cap from the Perkin-Elmer type adsorbent tube does not affect the sampling rate of VOCs collected in an indoor environment. The use of a stainless steel mesh membrane with 8.02 cm^2 area (11) permitted a passive sampling rate of 50 ± 5 mL/min onto activated carbon. The effect of air velocities from 20 to 150 cm/s over the sampler oriented in different positions relative to flow direction was minimal. Ballesta *et al.* (12) showed that the simultaneous rates of uptake for the different compounds in passive sampling by an activated carbon monitor with a stainless steel mesh membrane are comparable with the rates of uptake obtained when the compounds were tested individually.

The basic idea of this thesis is that if one can find a sorbent material which is not a powder (e.g. cloth, fibers, foam plastics, etc.) the membrane or diffusion tube will not be necessary. For example, Jacob *et al.* (14) showed that an acetone extract from spruce sprouts collected in different areas of Germany reflected the actual atmospheric profile of polycyclic hydrocarbons. This indicates that the spruce can act as a passive monitor for polycyclic aromatic hydrocarbons (PAH) in air.

Srikameswaran *et al.* (15) showed that the amount of cadmium collected on polyester type foam strips from water is nearly linear and depends primarily on the time of immersion of the strips.

1.2 Literature Review

1.2.1. Application of passive samplers to the monitoring of volatile organic compounds.

The diffusion sampling technique and the permeation sampling technique both offer a set of advantages as well as limitations. Once calibrated, a diffusion sampler can be used without recalibration (18) but it is often dependent on temperature, air velocity and humidity (19). On the other hand, permeation samplers, even when calibrated, may show variation in the sampling rate because of the variations in membrane permeabilities from one sampler to the next (20).

There are several types of passive monitors that have been described. The EPA/Monsanto sampling badge has been developed for ambient air monitoring of chlorinated hydrocarbons (21, 22) and Porapak R or Tenax has been used as a thermally desorbable sorbent placed between two diffusion screens.

The most commonly employed commercially available passive monitors are the SKC passive sampler (23) and 3M Organic Vapor Monitor™ (24, 25) which have been used to analyze a number of VOC; however Coutant and Scott, (26) have found that the 3M monitor shows a large number of blank peaks and has poor sensitivity, limiting its usefulness for ambient air monitoring.

The Perkin-Elmer type tube, which is a diffusive tube with a membrane, is packed with Tenax™ (27) and requires a relatively long sampling period of four weeks to obtain reproducible results (14). It uses the method of thermal desorption for analysis to avoid a solvent extraction step.

A passive sampler using several sorbents has also been suggested (28) for the sampling of compounds with a wide range of boiling points. Based on a previous discovery (29) that medium and high boiling compounds adsorb mainly at the front part of the packing and that the low boiling point compounds adsorb at the back of the tube, the double-layer passive sampler with both Carbopack C and Carbotrap was designed (30).

A recently developed, semipermeable membrane device (SPMD), which consists of a neutral lipid (triolein) enclosed in polyethylene Layflat tubing, has been demonstrated to be a highly efficient passive sampler (31) which can sample an equivalent of the volume of the active sampler of 7 m^3 of air per day. This device readily sequesters lipophilic organic contaminants from the vapor phase, particularly PAHs in air (31) and water (32).

A solid phase microextraction (SPME) system developed at the University of Waterloo (33, 34) and marketed by Supelco (35) is an excellent passive monitor for water and possibly air. This technique employs a solvent-free sample preparation procedure in which a fused silica fiber coated with polymeric organic liquid is introduced into the headspace above a liquid sample (34) or directly into an aqueous sample (35). Since the coatings used are almost always viscous liquids, the extraction is, in effect, a liquid-liquid or gas-liquid extraction with the convenience that the organic phase is attached to the fiber. This fiber is contained in a syringe which protects it and simplifies the introduction of the fiber into the injector port of the gas chromatograph. The total analysis time is only a few minutes (36). Optical fibers are used because they are inexpensive and made from the same chemically inert fused silica which is used to make capillary columns for gas chromatography. They can be coated with different polymers, such as poly(dimethylsiloxane), of various thicknesses and can be used directly in extraction or a thermal desorption process.

Headspace and possible air analysis with the SPME technique is more complicated than extraction from the liquid phase. For example, at ambient temperatures, the headspace SPME technique can be effectively used only for three-ring aromatic hydrocarbons or more volatile compounds (34). In order to reach equilibrium with less volatile compounds, agitation of the aqueous phase or headspace is needed or an increase in sampling temperature can be used.

Application of the SPME technique to air analysis has not yet been developed, possible because of the SPME monitor has a low saturation limits.

1.2.2. Application of the polyurethane foam for the monitoring of volatile organic compounds.

Polyurethane foams (PUF) are polyesters or polyethers cross-linked by amido-linkages and foamed with carbon dioxide during the cross-linking, as described by Phillips and Parker (38). The material is a solid foam with a bulk density between 15 and 35 kg/m^3. In general, foams are chemically stable and inert. They degrade when heated between 180° and 220° C, and slowly turn brown in ultraviolet light.

Open cell polyurethane foam has been used to extract polynuclear aromatic hydrocarbons, polychlorinated biphenyls, phthalate esters and chloropesticides from water (39-43) and air (44-50) and behaves as if it was an organic solvent. Large volumes of air or water were forcibly passed through the polyurethane foam plugs which were then extracted with solvents such as petroleum ether, tetrahydrofuran, hexane or carbon disulfide. For water analysis, the water had to be removed by squeezing the foam plugs, and solvent separation prior to the extraction (41, 42). It was shown that the limits of detection and analysis of PCBs in water is presumably governed by the amount of water pulled through the foam plug. Polyurethane foam is not specific for PCBs or other types of organic compounds and it will absorb chlorinated pesticides, PAH, phthalate esters. A complex mixture collected on polyurethane foam sampler may require some additional separation prior to chromatographic analysis (39).

In air, PUF plugs could actively draw in a high flow rate of air due to their low air resistance and can effectively trap pesticide vapors, PAH and other low-volatile organic compounds (45, 50). Therefore, PUF plugs have been used in a wide range of flow rates which permit hundreds of cubic meters of air to be sampled per day (49). However, the sampling efficiency has to be determined for each type of organic compound. For example, the greater polarity of organophosphate pesticides assists in their collection on polyether type PUF, so that acceptable trapping efficiencies (75%) are feasible for many of these compounds despite their high vapor pressure.

The results of various studies reveal that PUF can be considered a viscous organic solvent with a moderate dielectric constant. It is, however, not a universal solvent, as small molecules such as vinyl chloride, fluothane, and halothane are not significantly solubilized by PUF. It is for this reason that PUF needs to be complimented by some other material (48). The passive use of PUF plugs in water was shown to be ineffective (51) and shown to be useful when water is forcibly passed through the PUF.

1.2.3 Activated carbon cloth

Most activated carbons used in the past were activated granular carbon or activated powdered carbon, prepared from coconut shell or coal. Recently attention has been focused on activated fibrous carbon or activated carbon cloth (ACC). For practical purposes, this can be used in a variety of forms: string, woven, or unwoven. It can be prepared by direct carbonization and activation using inert gas from phenolic fabric (52) or from a viscose rayon precursor (53, 54).

Activated carbon cloth is widely used for adsorption and filtration of different organic compounds from gaseous or aqueous environments (54). Larson and Rood (55) has shown that for low levels of contaminants in the air (ppmv), activated carbon fibers (ACF Kynol) samples with lower specific surface areas actually have higher adsorption capacities, while sampling rates are approximately independent on surface area. The authors hypothesize that this is due to a micropore filling process whereby the smaller micropores are preferentially filled at lower concentrations. It was concluded that the fibers with least least amount of activation had a greater volume of small width micropores than the highly activated fibers.

It was also hypothesized that the duration of the activation acts to enlarge the micropores thus shifting the distribution of pores to a higher mean pore size.

An investigation of the adsorption of various dyes with planar aromatic fragments on activated carbon fibers from the aqueous solution and the adsorption of some organic compounds from the gas phase was carried by Kasaoka *et al.* (56). Two different models of adsorption were found to occur. In the gas phase, it was observed that planar molecules slide into pores like coins into a vending machine slot. Conversely, in the liquid phase, the planar fragments align themselves perpendicularly to the narrow dimension of the pores. The gas phase adsorption is represented as type I in Figure 1.2-1. The situation is different for the adsorption of a dye in the liquid phase, for which the critical molecular dimension is the molecular depth or minor diameter as in type II in Figure 1.2-1.

The adsorption of benzene (5) and butane (57) on activated carbon fibers shows that the sampling rates for these compounds are similar and that the saturation limits are relatively high (up to 20% of the weight of the fiber). This led to the conclusion that activated carbon cloth is an ideal passive monitor.

Numerous references include passive sampling by activated carbon which, for example, allows the measurement of xylenes at the ppb level (58). The activated carbon cloth which is employed in the present work has all of the advantages of activated charcoal including high surface area of up to 2000 m^2/g and can be used as a sampler without membrane, In addition, because of its structural and mechanical properties, the ACC monitor is easily analyzed by low

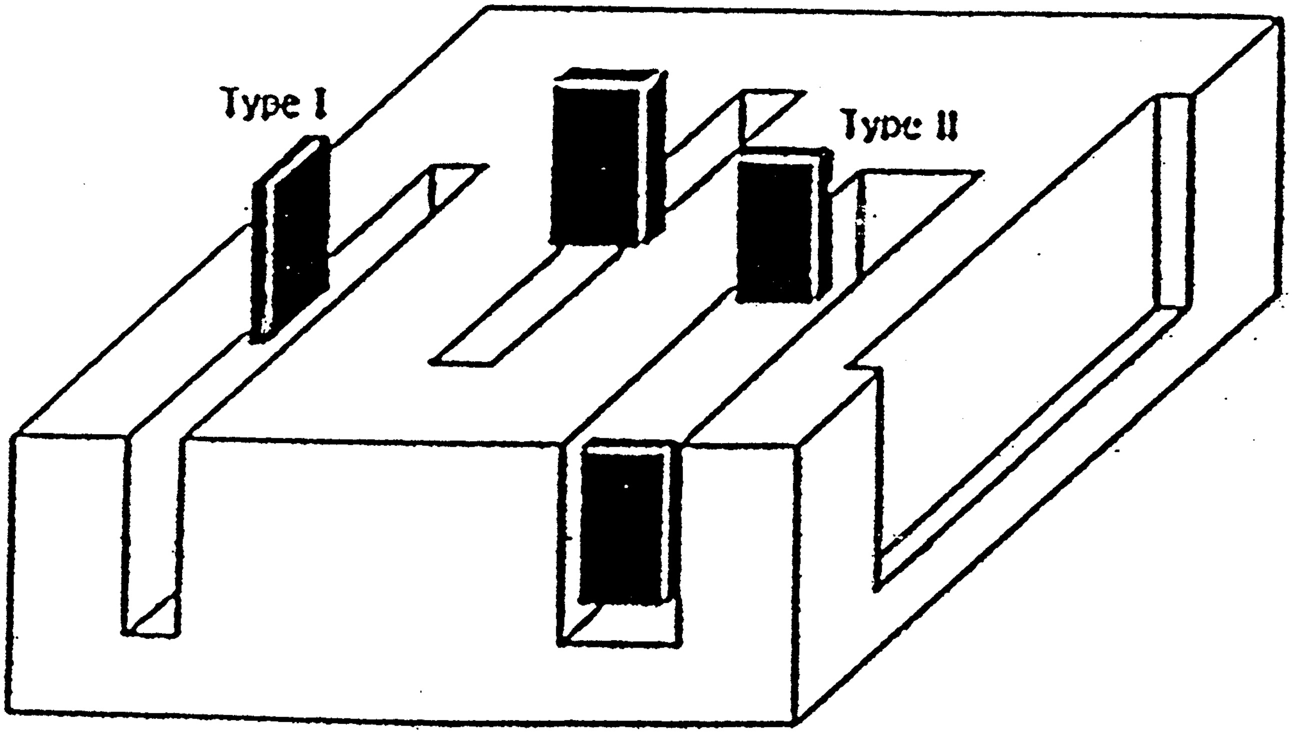


Figure 1.2-1 Schematic model for the adsorptive approach of gas-phase molecule (Type I) and liquid-phase molecule (due; Type II) to the pore opening of ACC *.

* - S. Kasaoka, Y. Sakata, E, Tanaka, R. Naitoh,

International Chemical Engineering, 1989, 29 (4), 741 volume solvent extraction or by thermal desorption.

A similar monitor with Porton-Down charcoal cloth using a membrane has been described by Bailey *et al.* (59), Broun and Trine (60) and Nelms *et al.* (61). These reports (51-62) show that activated charcoal cloth samplers are not substantially affected by ambient temperature and pressure. These samplers also have a relatively high saturation limit; however, their use with a membrane does not have an advantage over other such commercial monitors by 3M or SKC.

1.3. Objectives

The objective of this research was to develop a new passive monitor without a membrane for sampling volatile organic compounds in air and water. Specifically, the following questions were investigated:

- Is the sampling rate vs time linear for the passive monitor without a membrane in an indoor air environment?
- Which volatile organic compounds can be monitored by activated carbon cloth and which by thin polyurethane foam ribbon?
- How does the sampling rate depend on the surface area?
- Is the molar sampling rate for activated carbon cloth the same for any volatile organic compound?
- Is it possible to use the passive monitor without a membrane for the analysis of organics in water?

CHAPTER II

EXPERIMENTAL

2.1. Chemicals, Materials and Equipment

2.1.1. Chemicals

The solvents used in this study; carbon disulfide, hexane, benzene, and acetone were all obtained from Aldrich Chemical Company, P.O. Box 355, Milwaukee, WI 53201-9358, USA (spectroscopic grade purity 99+%).

O-hydroxyacetophenone and the standard kit of organic chemicals and phthalate plastisizers were obtained from Chemical Services Co. Ltd, P.O. Box 3108, West Chester, PA 19381-3108, USA (spectroscopic grade purity 99+%).

2.1.2. Materials

Activated carbon cloth

Samples of C-TEX woven, knitted and open weave with surface areas of 1200, 1300, and 1500 m^2/g respectively, were obtained from Siebe Gorman & Co. Ltd, Avondale Way, Cambran, Gwent, Wales, NP4 1TS, UK.

Samples of ACF-509 #10, #15, and #20 with a surface areas of 1000, 1500, and 2000 m^2/g respectively, produced by Nippon Kynol Inc. were obtained from American Kynol Inc., 427 Bedford Road, Suite 130, Pleasantville, NY 10570, USA.

Samples of ACC FMI/250 (1200 m^2/g) were obtained from Charcoal Cloth Limited, East Wing, Brigewater Lodge, 160 Brige Road, Maidenhead, Berkshire SL6 8DG, England.

Samples of medium activity ACC (1000 m^2/g) were obtained from Porton Down, Salisbury, Wilts SP4 0JQ, UK.

SKC activated carbon tubes purchased from SKC Inc., 334, Valley View Road , Eghty Four, PA 15330, USA and contain approximately 0.15 g of activated carbon. Each 3M Organic Vapor Monitor purshaced from 3M Canada Inc., P.O. Box 5757, London, ON N6A 4T1, contained approximately 0.2 g of activated carbon with an area of the membrane of 9.4 cm^2.

ACC strips 5.6 x 5.6 cm (weight 0.4 g for C-Tex knitted) were Soxhlet extracted for 12 h with acetone and then for 12 h in carbon disulfide and dried in a desiccator under vacuum ,using a water aspirator before use. Cleaned strips were then placed into the commercially available slide holders, and stored in made at high pressure polyethylene Ziploc™ bags (5.8 x 8.6 cm), purchased from Revere Seton Inc., P.O. Box 3307, STN Industrial Park, Marcham, ON L3R 9Z9, before being hung at the test sites (See Figure 2.1-1). Gas chromatographic analysis of the carbon disulfide extract of a ACC monitor, stored in the polyethylene bag for one month at room temperature, showed no traces of contamination.

Polyurethane foam (polyester type) strips 5.6 x 5.6 cm (weight 0.085 g, thickness 1 mm) of the same size as a ACC strips were cut from a bandage Mueller band roll, purchased from the sporting goods store, and were similarly treated.

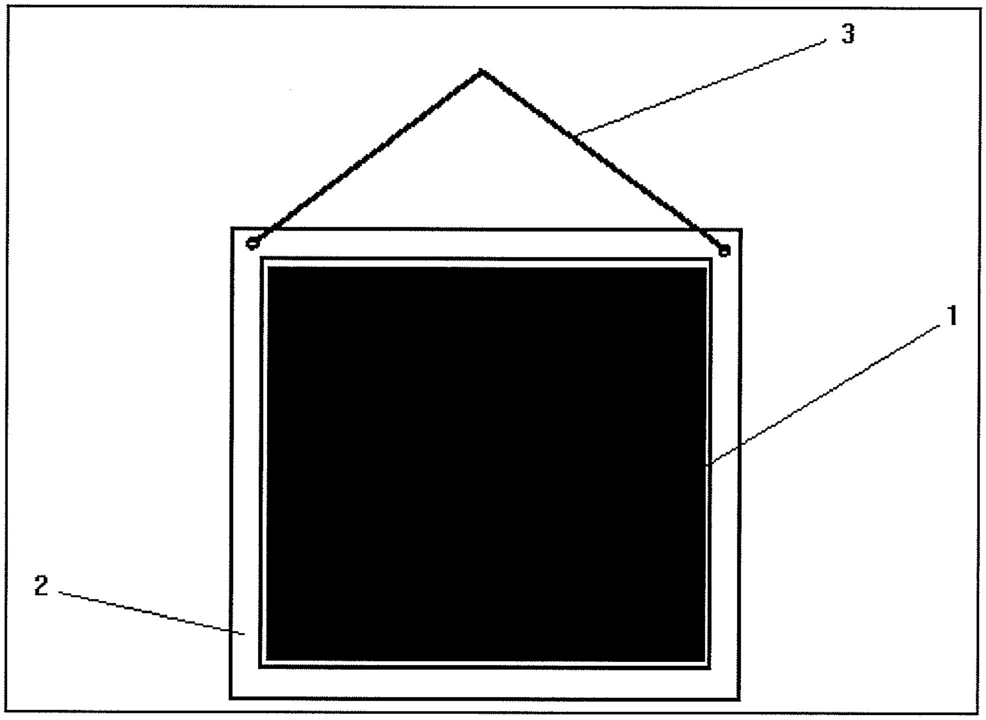
2.1.3. Analytical Equipment

Gas chromatograph

A Varian 2100 gas chromatograph with flame ionization detector was used with a Supelco 30 m, 0.25 mm i.d. capillary column coated with Supelcowax.

Operating conditions; Injector port - 150 ^{o}, detector - 150 ^{o}, column was held at 50 ^{o}C for 10 min and linearly increased to 200 ^{o} at a rate 6 ^{o}/min.

Figure 2.1-1. Activated Carbon Cloth Passive Monitor (Actual size).



1. ACC strip
2. Slide holder
3. Supportive string

Flow rates were; carrier gas (helium) 1 mL/min, make up gas (helium) 24 mL/min, hydrogen 25 mL/min and air 250 mL/min

Gas Chromatograph - Mass spectrometer

A Finnigan 800 ion trap mass spectrometer connected with a Varian 3400 gas chromatograph was used with a DB-5 30m, 0.25 mm i.d. capillary column; injector port 150 ^{o}; column 50 ^{o} for 10 min, 8 ^{o}/min to 260^{o} C.

A Gas Chromatograph-Mass Spectrometer system VG 7070E-HP 5890 was used with a DB-5 60 m, 0.25 mm i.d. capillary column. Analysis were conducted at the same conditions as analysis on the Finnigan 800 system.

UV - visible spectrophotometer

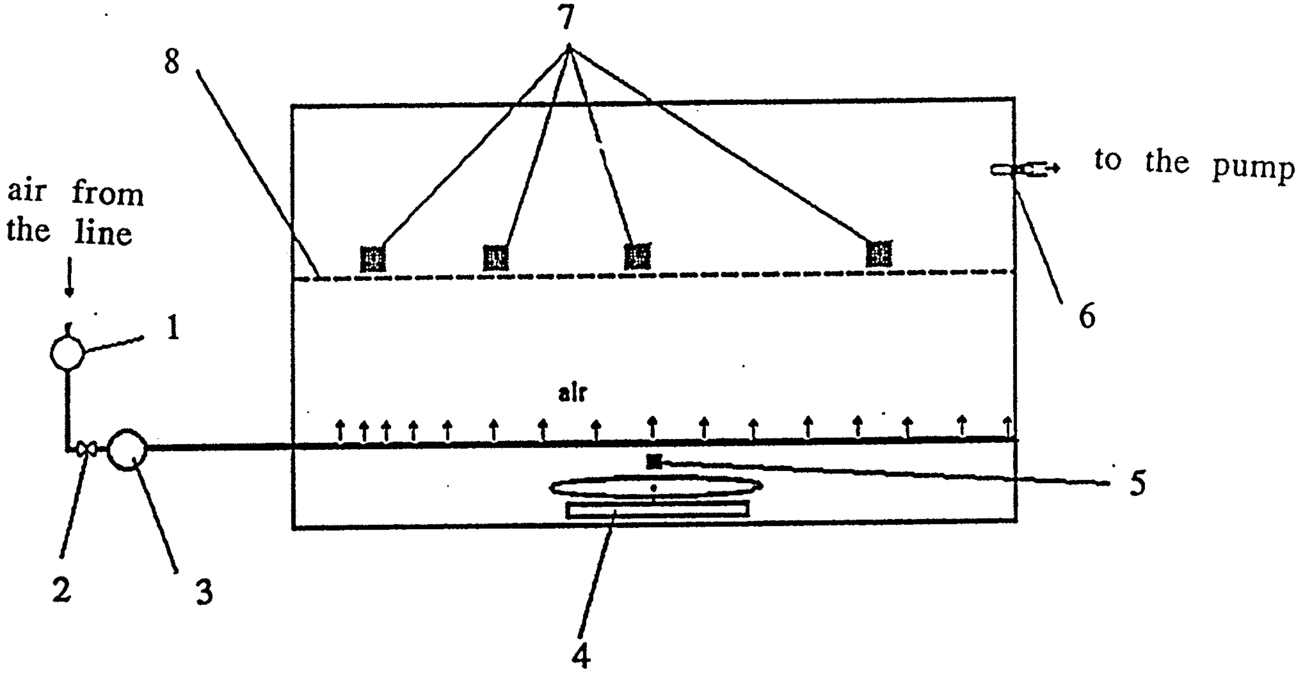
Beckman Gilford DU model 252.

Test chamber

For the accurate evaluation of the sampling rate, a test chamber with a stable concentration of VOC is necessary (See Figure 2.1-2). Air, at a flow rate of 23.5 L/h, from the laboratory air line, was purified by passage through an activated charcoal filter and introduced into the bottom of the 40 x 25 x 25 cm box through a system of holes.

Each contaminant was introduced to the air from a small vial, with a semipermiable membrane in the cap. The rate of diffusion through the membrane was constant as determined by the weight loss of the vial over time (See Table 2.1-1). A small electric fan at the bottom provided air mixing in the chamber.

Figure 2.1-2. Schematic of environmental chamber.



1. Activated charcoal filter
2. Valve
3. Pressure gauge
4. Electric fan
5. Vial for contaminants
6. SKC activated charcoal tube
7. ACC samplers
8. Supportive mesh

Table 2.1-1. Determination of the rate of benzene evaporation through the semipermeable membrane*.

Time h	Weight of the vial with benzene. g	Total weight loss g	Average weight loss per hour g/h
0.0	77.0210	0.0	0.0
5.0	76.9895	0.0315	0.0063
25.0	76.8650	0.156	0.0062
49.0	76.7180	0.303	0.0062

* - Experiment was conducted in environmental chamber at 23^0 C. The standard deviation of the balances was 0.0001 g.

2.2 Analysis

Each ACC strip (5.6 x 5.6 cm) which had been exposed to air was placed in a 30 mL glass syringe and squeezed 20 times with exactly 3 mL of carbon disulfide. The solvent and extract was weighted and spiked with approximately 0.1 g of approximately 0.1% standard solution of *o*-hydroacetophenone. A new standard solution of *o*-hydroxyacetophenone had to be prepared each week because of changes in the concentration due to solvent (carbon disulfide) evaporation.

PUF strips were treated in the same manner, but exactly 0.5 mL of carbon disulfide was used for recovery, instead of the 3 mL used for ACC monitor extraction.

SKC activated charcoal tubes were extracted in a similar manner by pumping 0.5 mL of CS_2 through each tube by means of a syringe (20 times).

For active air sampling with SKC charcoal tubes, flow rates were 0.3 - 5.0 mL/s for specified times, usually for the duration of the passive sampling period. Flow rate depended on the concentration of the contaminant.

A second extraction from ACC and PUF strips and SKC tubes did not show any additional traces of the contaminants on analysis by GC.

2.3. Specific surface measurements of the different types of the activated carbon cloth.

All measurements of surface area of the carbon cloth were performed according to the methylene blue method described by Giles (63, 64).

An aqueous solution of methylene blue was used in these measurements. A calibration plot dependence of adsorption on concentration of methylene blue in is shown in Figure 2.3-1. ACC samples of 0.04-0.14 g, depending on the specific surface area, were tumbled gently with 2-10 mL of aqueous methylene blue solution, depending on concentration. Equilibrium was achieved in 36-96 h. The rate of adsorption is plotted in Figure 2.3-2. Analysis of the methylene blue concentration was performed using UV-visible spectrophotometry (λ=610 nm). The isotherms (Figure 2.3-3) usually have a long plateau, enabling a good estimate of the monolayer capacity to be made. The long plateau enables the selection of "one-point" on a plateau beyond which the the amount of methylene blue, adsorbed on a carbon cloth remains constant.

The specific surface area of the material was calculated from the formula and the data from ref. 63:

$$S = \gamma * N * a/n \qquad (2.3.1)$$

where:

γ - is the amount of methylene blue (mmol/g) adsorbed at the plateau.

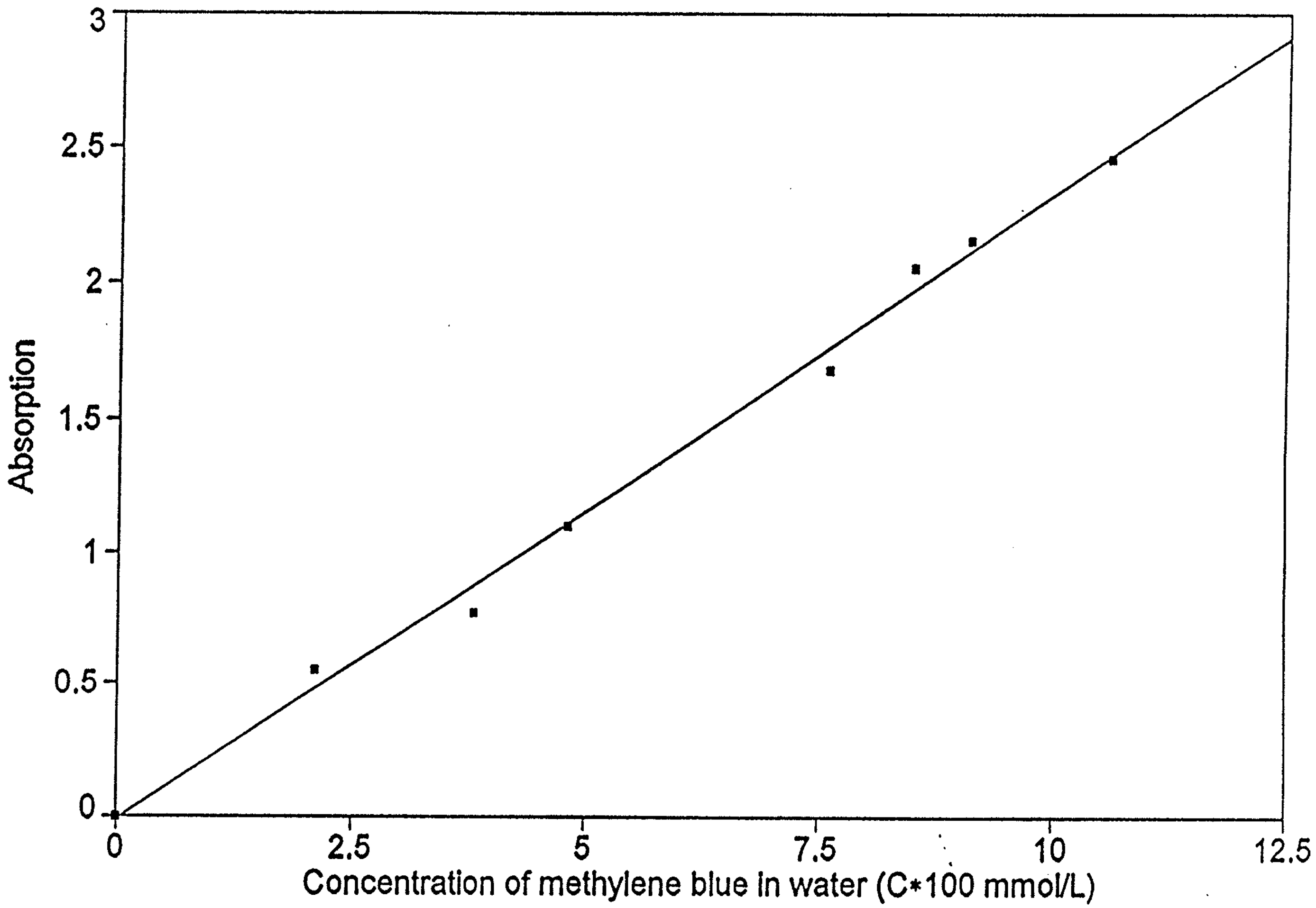
N - Avogadro's number

a - the molecular area of methylene blue (63) $a = 120\ \text{Å}^2$

n - is the aggregation number, representing the average number of dye color ions in the adsorbed micelle (63) $n = 2$

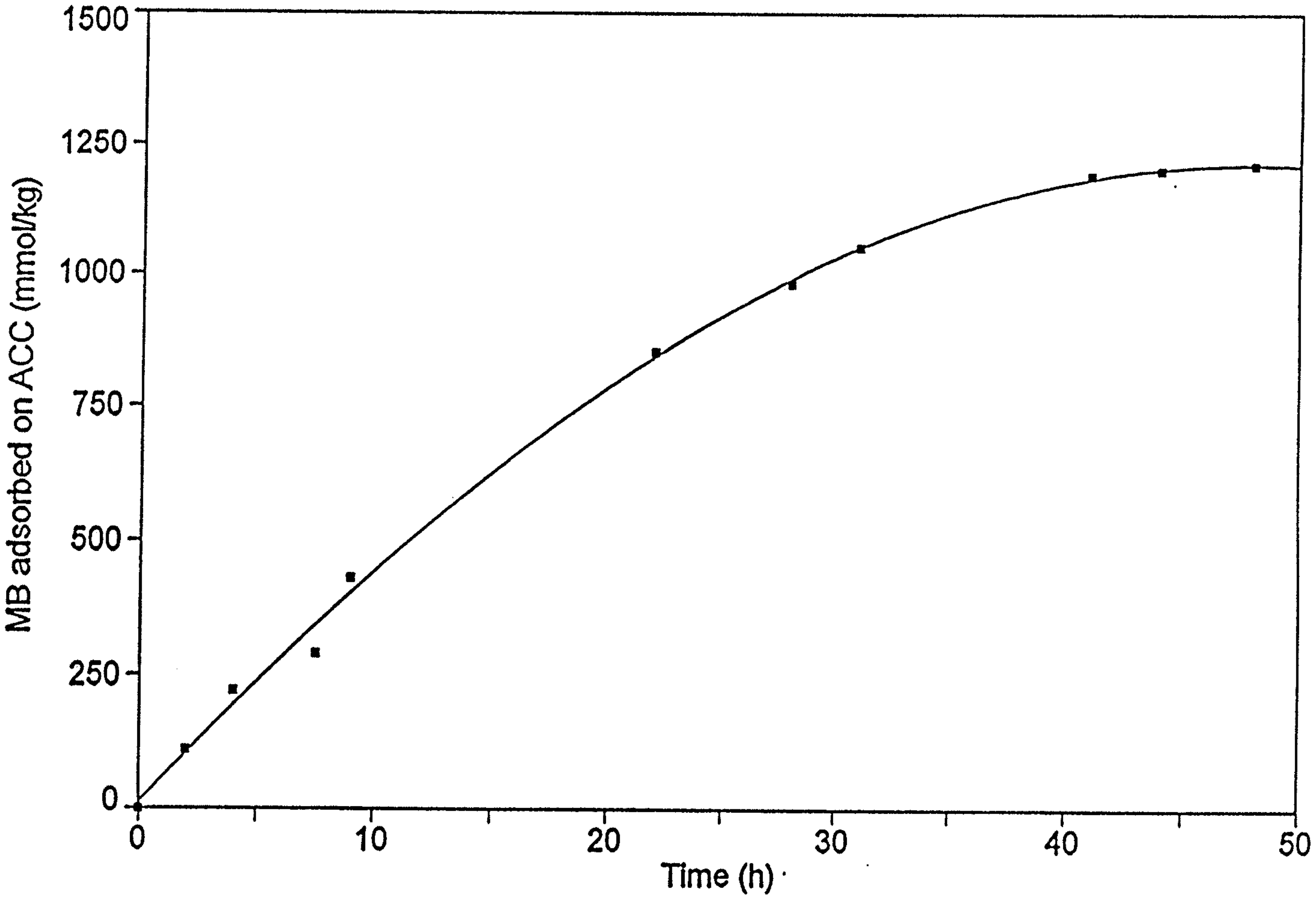
A number of the samples of activated carbon cloth from the various manufacturers was studied. All of them were analyzed for

Figure 2.3-1. Calibration plot. Dependence of absorption on concentration of methylene blue in water solution.*



* - Analysis conducted at λ=610 nm in 1.0 cm cell at 20 ^{0}C. Substrate ACC C-TEX knitted.

Figure 2.3-2. Typical adsorption of methylene blue from water solution*.



* - Analysis conducted at λ=610 nm in 1.0 cm cell at 20 ^{0}C. Substrate ACC C-TEX knitted.

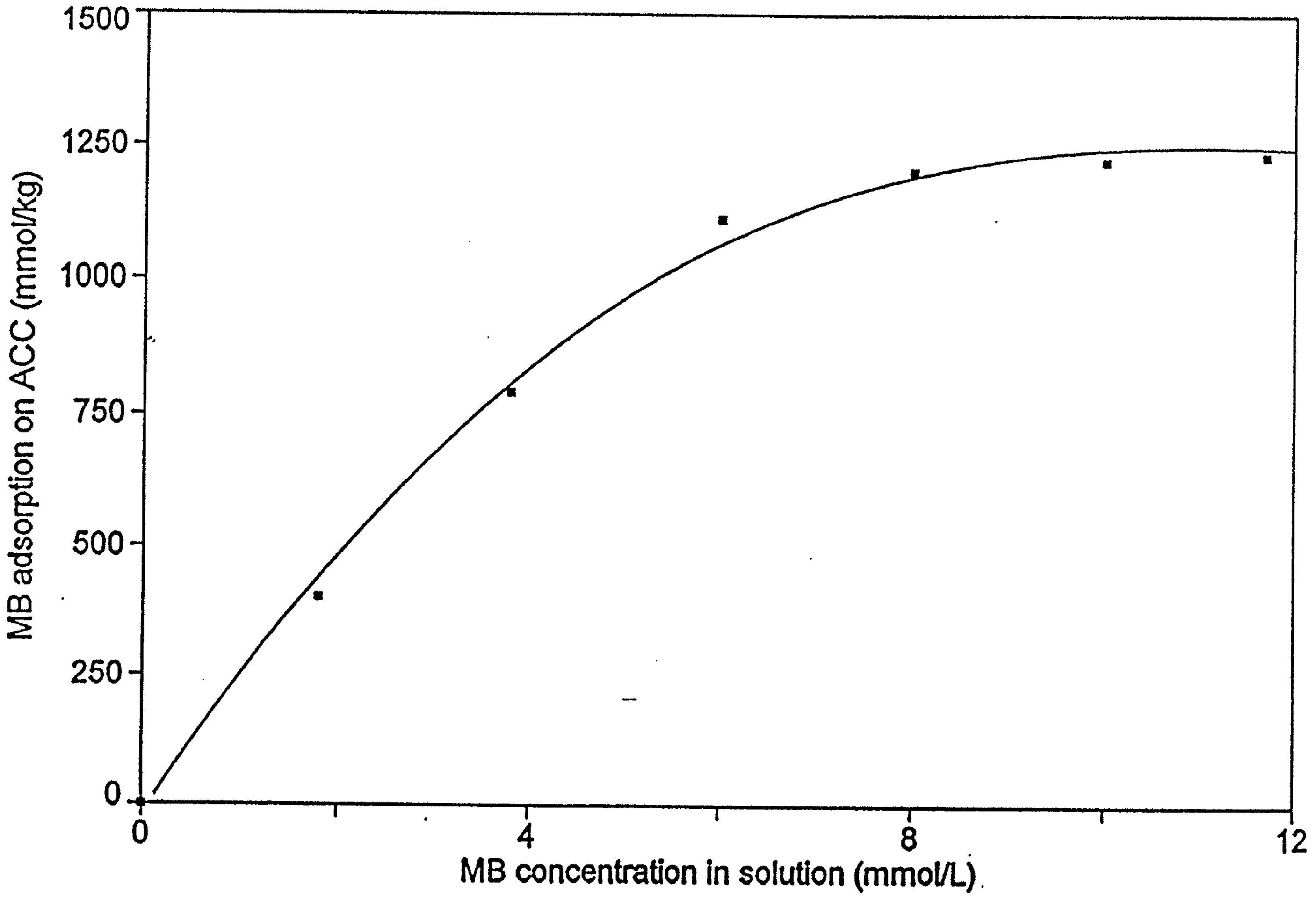
the presence of residue after carbon combustion. A weighed ACC strip was exposed to air in an open furnace at 650 °C for 6 h. The residue was then weighted (See Table 2.3-1).

Surface measurements of the activated carbon from the SKC active monitors were done using the above technique and showed the active surface area to be $1.5*10^3$ m^2/g.

Surface measurements by B.E.T. method was preformed at the AECL facilities in Pinawa, MB. Two samples of carbon cloth were investigated. ACC C-TEX knitted had a surface area of 1324.3± 4.3 m^2/g with the average pore size of 20.0 Å measured by the Langmuir method (See Appendix A). Nippon Kynol ACC 5092-10 had a surface area of 1189.7± 17.2 m^2/g with the average pore size of 14.5 Å measured by the Langmuir method. Comparison of the data obtained by B.E.T, method with that reported by the manufacturer and the data obtained by methylene blue adsorption method (see Table 2.3-1) shows that the methylene blue adsorption method actually gives a good estimation of the surface area.

Medium activity ACC was also analyzed to determine the concentration of inorganic impregnates. After boiling with water for 2 h to remove inorganic salts the weight loss was 3.15%. The ACC strip was then dried after boiling with water, and was placed into the quartz tube and heated to 800 ° under the vacuum. A metallic mirror was deposited on the walls of the tube and the additional weight loss of the ACC sample was 4.9%. It shows that not all the inorganic compounds were removed completely by boiling with water. Combustion of the ACC without impregnates (after vacuum pyrolysis) showed a residue of 2.9%. Total weight loss was

Figure 2.3-3. Typical isotherm for methylene blue adsorption from water*.



* - Analysis conducted at λ=610 nm in 1.0 cm cell at 20 ^{0}C. Substrate ACC C-TEX knitted.

Table 2.3-1. Surface analysis of the different samples of ACC.

Manufacturer and type	Specific surface area measured*	Specific surface area reported by manufacturer	Residue**
	$(m^2/g)*10^{-3}$	$(m^2/g)*10^{-3}$	%mass
Seibe Gorman & Co Ltd.			
1. Standard woven C-TEX	1.1	1.2	9.93
2. Standard Knitted C-TEX†	1.3	1.3	14.2
3. Standard open weave C-TEX	1.4	1.5	17.9
Charcoal Cloth Limited			
4. ACC FMI/250	1.1	1.2	6.9
Porton Down			
5. Medium activity ACC	1.1	1.0	8.3
Nippon Kynol Inc.			
6. ACC - 5092-10††	1.1	1.0	3.7
7. ACC - 5092-15	1.5	1.5	3.3
8. ACC - 5092-20	1.8	2.0	1.7

* - measured by methylene blue adsorption method

** - after combustion in open furnace at 650 °C

† - surface area of $1.3*10^3$ m^2/g measured by B.E.T. method

†† - surface area of $1.2*10^3$ m^2/g measured by B.E.T. method

approximately 10.9%, compared to the mass loss of 8.3% for the same cloth without pretreatment. The differences in the material balance were associated with the mechanical destruction of ACC during the processing.

CHAPTER 3.
RESULTS AND DISCUSSION

3.1. Environmental chamber test.

Calibration of benzene and toluene uptake.

After establishing that there was a steady benzene concentration in the environmental chamber by gas chromatographic analysis of the air, five activated carbon cloth monitors were placed on a perforated platform. Each monitor was removed after a certain time, extracted with carbon disulfide and analyzed by means of a gas chromatograph with a flame ionization detector using the internal standard method (See Chapter 2). The exact concentration of benzene in the air was determined to be 17.5 ± 1.5 mg/m^3 by pulling the air from the chamber through the SKC activated carbon tube with an air flow rate of 2.35 L/h, which was 10% of the air flow rate into the chamber.

Concentrations of the volatile organic compounds in the air were calculated from the formula:

$$C(\text{in the air}) = 1000 \bullet M(\text{in the extract})/(t \bullet K)$$

where

C (in the air) - is the concentration of the compound in air in $\mu g/m^3$

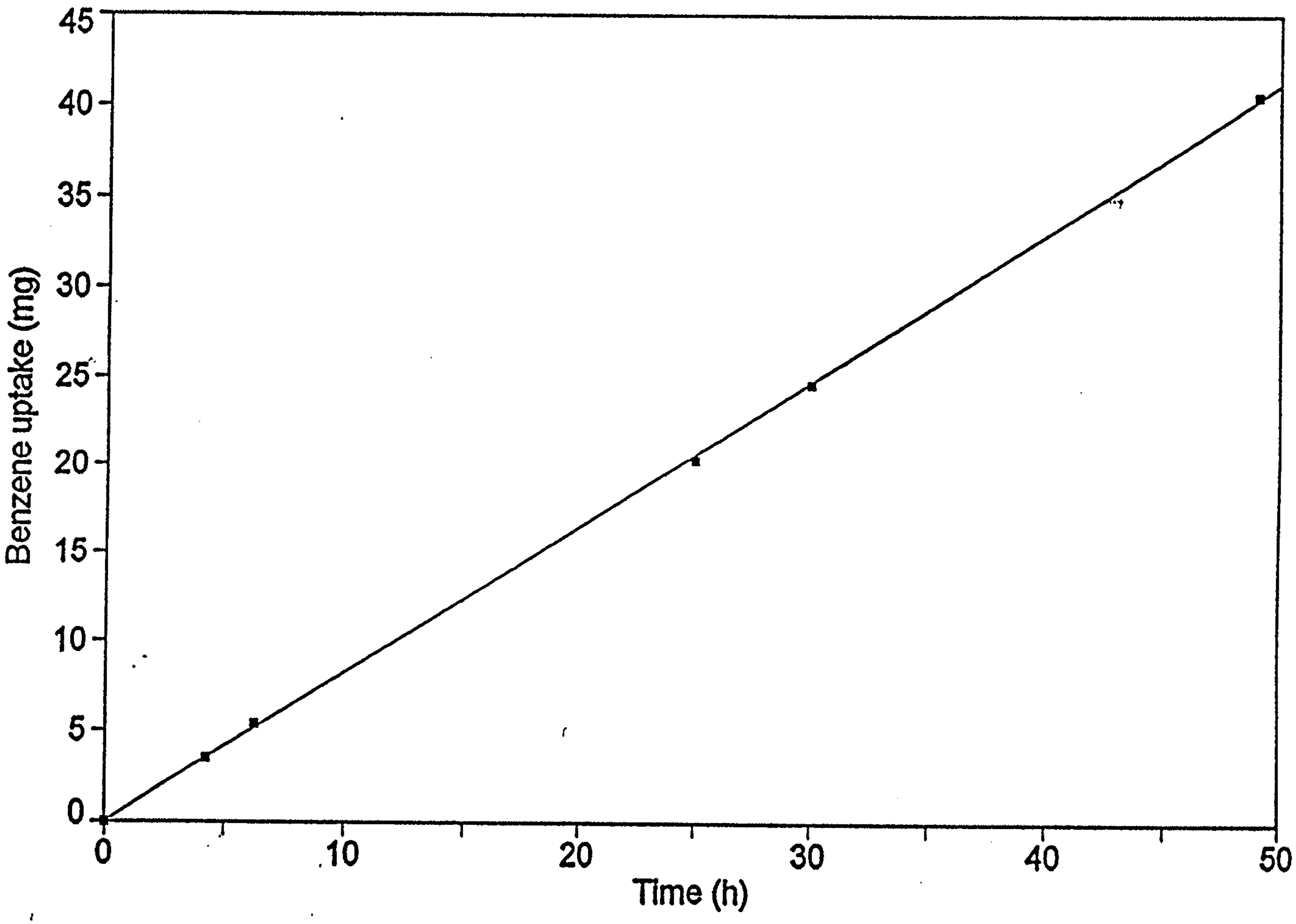
M (in the extract) - total mass of the compound in the extract in μg (calculated assuming that the residual extractant remaning on the cloth has the same concentration of organic compound)

K - sampling rate L/h

t - time of exposure h

The results of the analysis are presented in the Figure 3.1-1 and clearly show a linear dependence of the uptake of benzene onto the ACC monitor for up to 50 h exposure. The rate of benzene uptake

Figure 3.1-1. Rate of benzene uptake for ACC monitor*.



* - Monitor contained 0.4 g ACC C-TEX knitted. Benzene concentration was 17.5 mg/m^3.

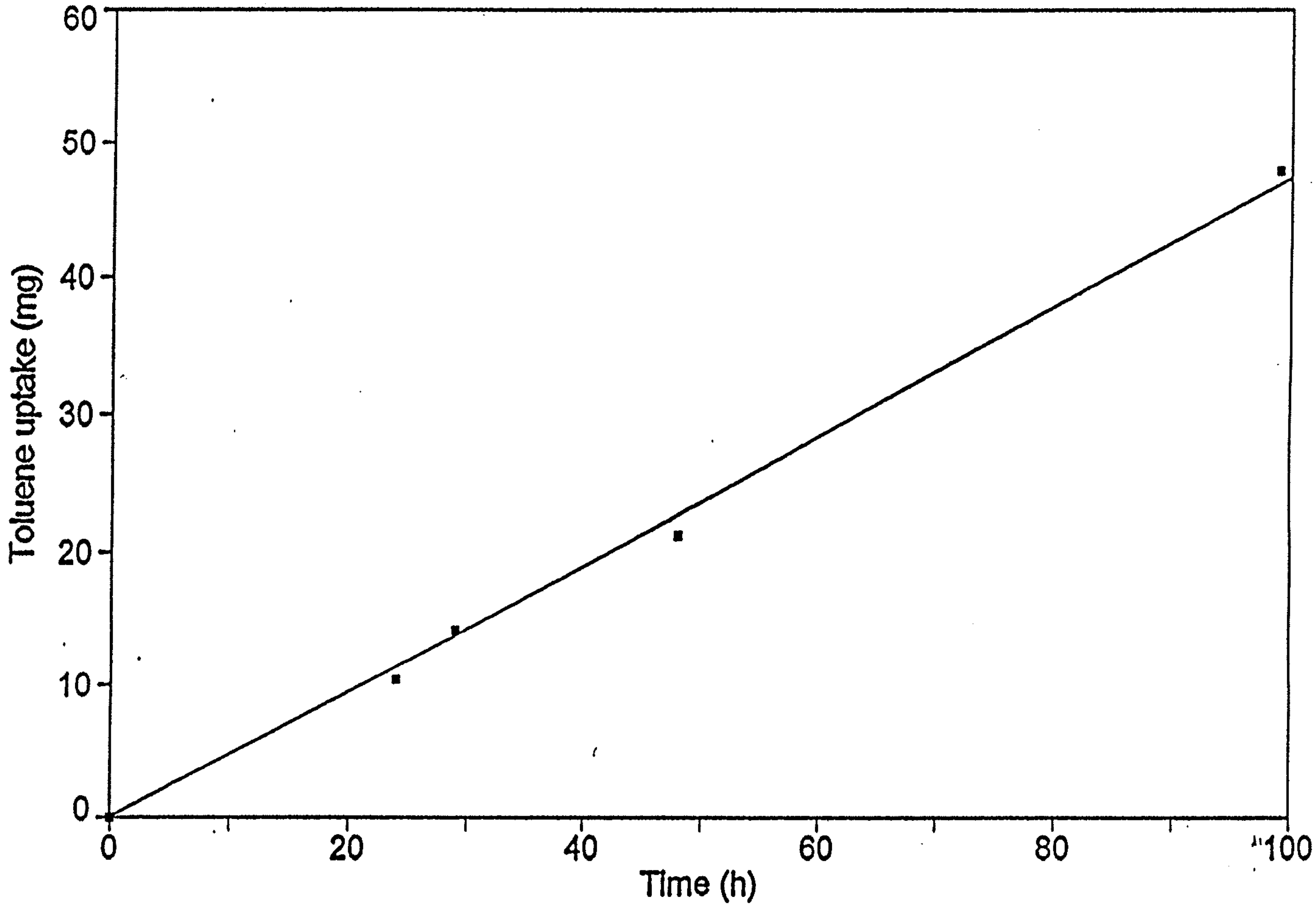
was 0.824 mg/h for a standard (i.e. 5.6 x 5.6 cm contained 0.4 g ACC C-TEX knitted) monitor. From this data, the sampling rate of the ACC monitor for benzene was 47.0 L/h.

A similar set of data has been obtained for toluene (Figure 3.1-2) using the same air flow rates through the chamber and SKC activated carbon tube, which gave 9.5 ± 1.0 mg/m^3 toluene concentration in the air. The sampling rate of ACC monitor for toluene was 44.7 L/h.

Five ACC monitors with different types of carbon cloth were exposed for 24 h in the environmental chamber with a toluene concentration of 9.5 ± 1.0 mg/m^3. The toluene uptake was calculated relative to the nominal area of each monitor, active surface area and weight of each monitor (See Table 3.1-1). The above results do not show any significant correlation between the relative sampling rate and the surface areas of different ACC samples. For example, the relative sampling rate of Kynol 10 with surface area of 1000 m^2/g was 177.1 $L/h/g_{ACC}$, while the relative sampling rate of C-TEX knitted with surface area of 1300 m^2/g was 100.9 $L/h/g_{ACC}$. These inconsistencies may have been caused by differences in the pore sizes, impregnation of the ACC samples by different inorganic compounds, the adsorption of several toluene molecules into one megapore, the ratio between micro- and megapores, and the experimental deviation.

A more detailed examination of the physical properties of the various ACC may result in a more conclusive correlation.

Figure 3.1-2. Rate of toluene uptake for ACC monitor*.



* - Monitor contained 0.4 g ACC C-TEX knitted. Toluene concentration was 9.5 mg/m^3.

Table 3.1-1. Characteristics and sampling rates of some activated carbon cloth[a].

#	Source of ACC	Density[b]	Mass of ACC sample	Surface area[b]	Toluene on sample	Toluene per nominal area	Toluene per surface area	Toluene per ACC weight	Relative sampling rate
		g/m^2	g	m^2/g	mg	g/m^2	µg/m^2	mg/g	L/h/g_{ACC}
1	C-TEX knitted	130	0.41	1300	9.4	3.0	17.6	23.0	100.9
2	C-TEX open weave	95	0.30	1500	9.9	3.2	22.0	33.0	144.7
3	PD medium activity	120	0.38	1000	8.9	2.8	23.4	23.4	102.6
4	Kynol 20	95	0.30	2000	9.1	2.9	15.2	30.3	132.9
5	Kynol 10	135	0.42	1000	11.2	3.6	26.7	26.7	117.1

[a] - Monitors (5.6 x 5.6 cm) were exposed for 24 h in chamber where toluene concentration was 9.5 mg/m^3

[b] - Reported by manufacturer

3.2. Comparison of the air pollutants absorbed on the polyurethane foam and activated carbon cloth.

3.2.1. Outdoor air analysis.

An analysis of samples exposed outdoors in the backyard of a house in Winnipeg for 29 days was performed for both activated carbon cloth and polyurethane foam strips. Both materials were extracted with carbon disulfide and analyzed by GC-MS method as described in Chapter 2.2 (see Table 3.2-1 for ACC sample). The chromatogram of these extracts obtained on a gas chromatograph HP 5890 which was connected to a mass spectrometer VG 7070 showing the total ion current chromatogram shown in Figure 3.2-1. All compounds were identified using the standard MS library software. Also, all chlorinated compounds were identified by using isotopic ratios of M^+, $(M+2)^+$ ions, which gave a characteristic peak intensities ratios of 3:1 for chlorinated compounds.

The analysis of the CS_2 extract from the polyurethane foam strip showed small traces of the same hydrocarbons found in the ACC extract. An additional compound identified in this extract was 9-octadeceneamide. This is a commercially available compound but its origin is unknown.

It was assumed that the identified hydrocarbons originated from car exhaust. To confirm this, an ACC strip was exposed near the exhaust pipe of an idling car for 20 minutes. GC-MS analysis of the CS_2 extract showed the presence of similar compounds (See Table 3.2-2 and Figure 3.2-2a). Because of the variety of the gasoline types and differences in a car emissions there was a great deal of

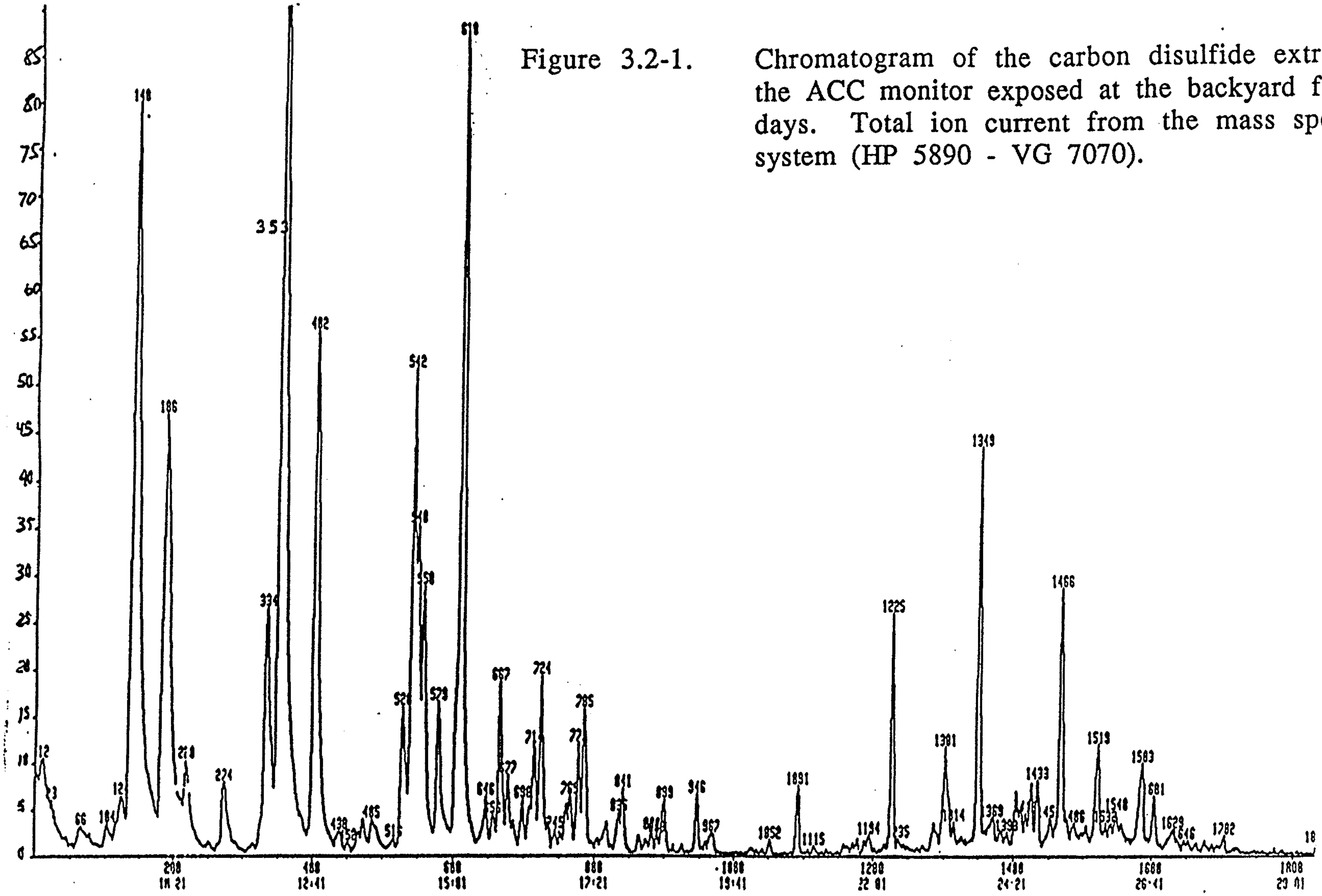


Figure 3.2-1. Chromatogram of the carbon disulfide extract from the ACC monitor exposed at the backyard for 29 days. Total ion current from the mass spectrometer system (HP 5890 - VG 7070).

TABLE 3.2-1. Results of GC-MS analysis of CS_2 extract from ACC strip sample exposed at a backyard for 29 days.

#	Scan time	Compound	Fit
1	140	Toluene	935
2	186	4,4-Dimethyl-2-pentene	859
3	334	Ethylbenzene	899
4	353	1,4-Dimethylbenzene	891
5	402	1,3-Dimethylbenzene	944
6	542	1-Ethyl-4-methylbenzene	928
7	548	1-Ethyl-2-methylbenzene	886
8	558	1,3,5-Trimethylbenzene	908
9	579	1-Methylethylbenzene	854
10	610	1,2,4-Trimethylbenzene	961
11	667	1-Ethyl-3-methylbenzene	883
12	724	1,3-Diethylbenzene	880
13	785	4,7-Dimethylundecane	844
14	1225	2,4,6-Trimethyloctane	882
15	1466	2,6,11-Trimethyldodecane	942

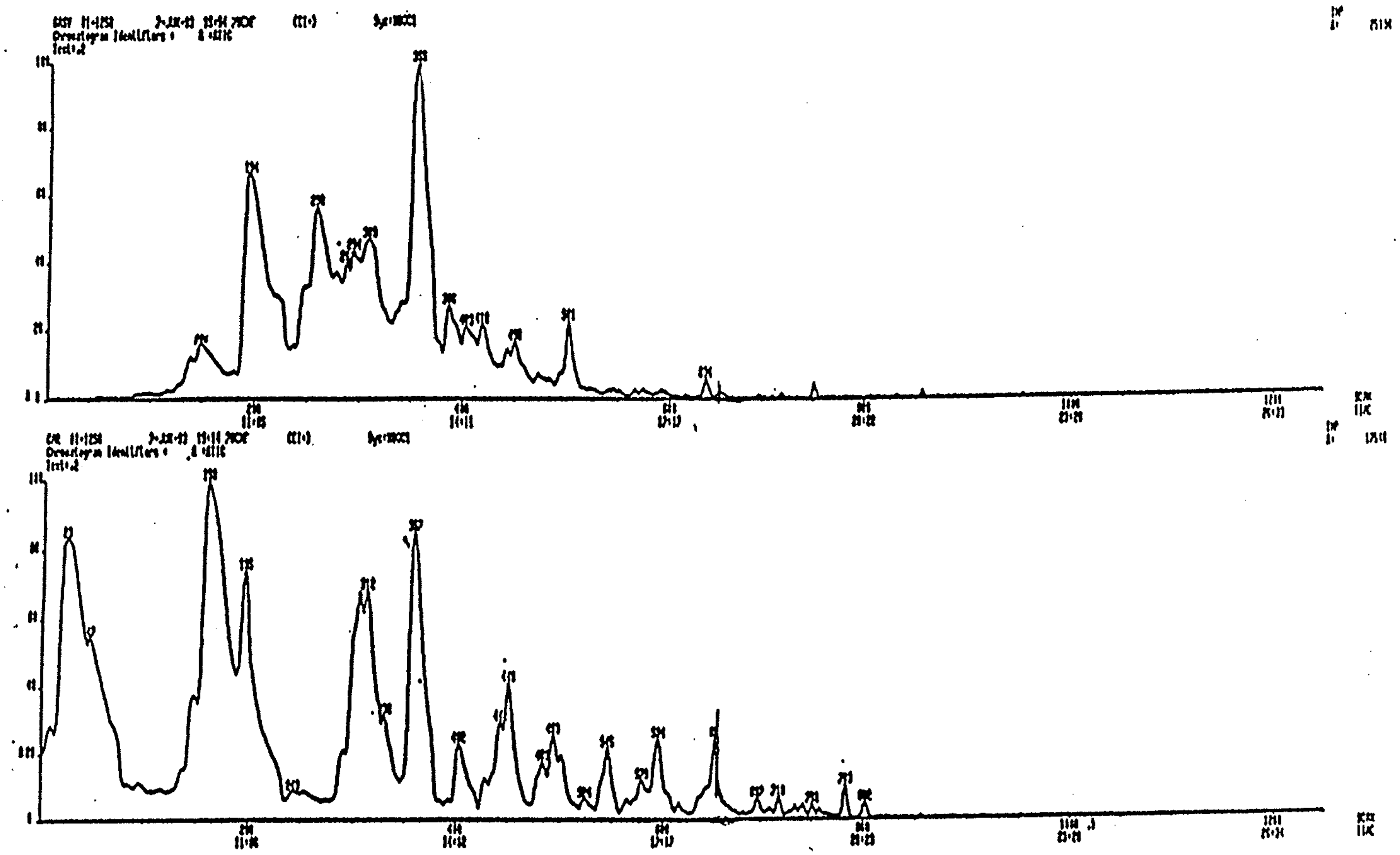


Figure 3.2-2. Chromatogram of the carbon disulfide extract from the ACC monitor exposed over a) gasoline, b) car exhaust pipe. Total ion current from the mass spectrometer system (HP 5890 - VG 7070).

Table 3.2-2. Results of analysis of car exhaust with ACC strip.

#	Compound	Retention time	Fit
1	Benzene	23	961
2	Toluene	34	948
3	1,3-Dimethylbenzene	195	906
4	1-Ethyl-3-methylbenzene	314	944
5	1,3,5-Trimethylbenzene	361	888
6	1,2,4-Trimethylbenzene	402	928
7	1,3-Diethylbenzene	449	944
8	1-Ethyl-2,4-dimethylbenzene	493	899
9	1,2,3,4-Tetramethylbenzene	545	870
10	1,2,3,5-Tetramethylbenzene	550	914
11	2,3-Dihydro-5-methylindene	594	896
12	Naphthalene	651	961
13	1-Methylnaphthalene	783	940

Table 3.2-3. Results of analysis of the ACC strip exposed over liquid gasoline for 8 h.

#	Compound	Retention time	Fit
1	5,6-Dimethylundecane	148	961
2	4-Methylundecane	194	878
3	1-Tridecanol	258	888
4	2-Ethyl-1-decanol	275	888
5	6-Methyltridecane	309	912
6	Decane	355	838
7	1-Chlorohexadecane	477	862
8	2-Methyltridecane	501	931
9	2,6,11-Trimethyldodecane	634	906
10	4,7-Dimethylundecane	752	922
11	2,4,6-Trimethyloctane	856	940

variability. Another ACC strip was exposed for 8 h over liquid gasoline and subsequent analysis showed that nonaromatic compounds were prominent in the gasoline vapor (See Table 3.2-3 and Figure 3.2-2b).

Compounds 3 and 4 which are identified as alcohols, may have been misidentified by the library search and may thus be hydrocarbons. For example, library search for compound 3 favors 1-tridecanol with the fit of 888, but the second choice is 5-methylundecane with the fit of 880. However, the origin of chlorohexadecane in the gasoline is unknown.

Results from Tables 3.2-2 and 3.2-3 show that the car exhaust contains more aromatic compounds, despite the fact the gasoline vapor contains more straight chain hydrocarbons. This most likely occurs due to the enrichment of aromatic compounds because of the more complete combustion of the aliphatic hydrocarbons or because of the high temperature reactions in the engine cause the formation of the aromatics.

3.2.2. Analysis of the air from a coffee factory.

The air in a coffee roasting facility was taken as an example of indoor air analysis. Sampling was carried out by exposing PUF and ACC strips monitors for a week (7 d). Both strips were extracted with carbon disulfide, 0.5 mL for PUF and 3 mL for ACC strip. The results of the GC-MS analysis of both extracts are presented in the Tables 3.2-4 and 3.3-5 and samples of the chromatograms are in Figures 3.2-3 and 3.2-4. Extracts were also analyzed on the gas chromatograph equipped with a capillary column and a flame

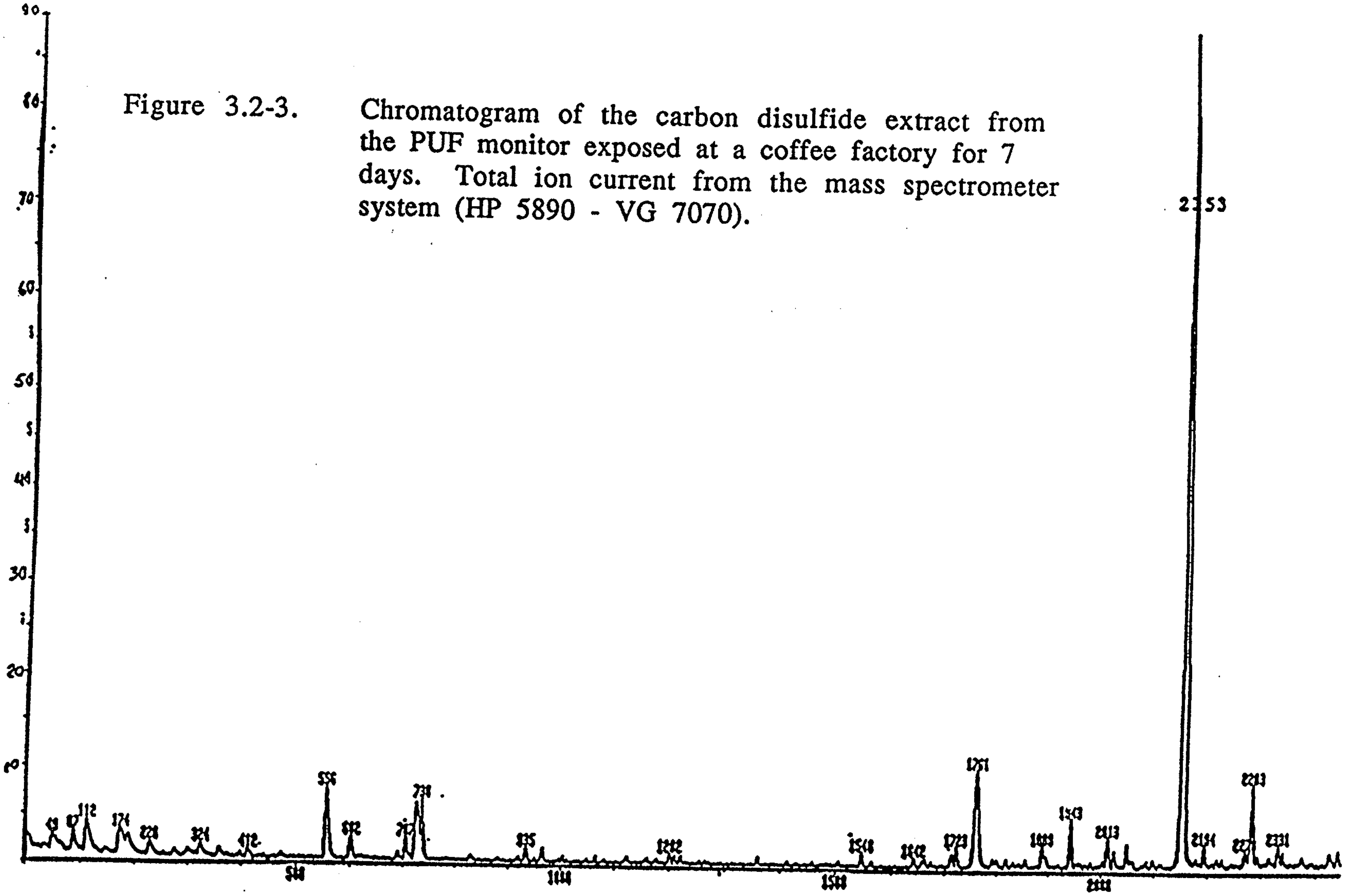


Figure 3.2-3. Chromatogram of the carbon disulfide extract from the PUF monitor exposed at a coffee factory for 7 days. Total ion current from the mass spectrometer system (HP 5890 - VG 7070).

TABLE 3.2-4. Results of GC-MS analysis of the extract from PUF strip exposed at a coffee factory for 7 days.

#	Retention time	Compound	Fit
1	112	Tetrachloroethylene	940
2	556	1,4-Dichlorobenzene	946
3	728	*n*-Methyl-1-octadecanamine	817
4	738	Nonanal	847
5	1761	2,2-Diethyl-1,1-biphenyl	763
6	2153	Caffeine (main)	951
7	2283	Butyl-2-methylpropyl-1,2-benzendicarboxylic acid	899

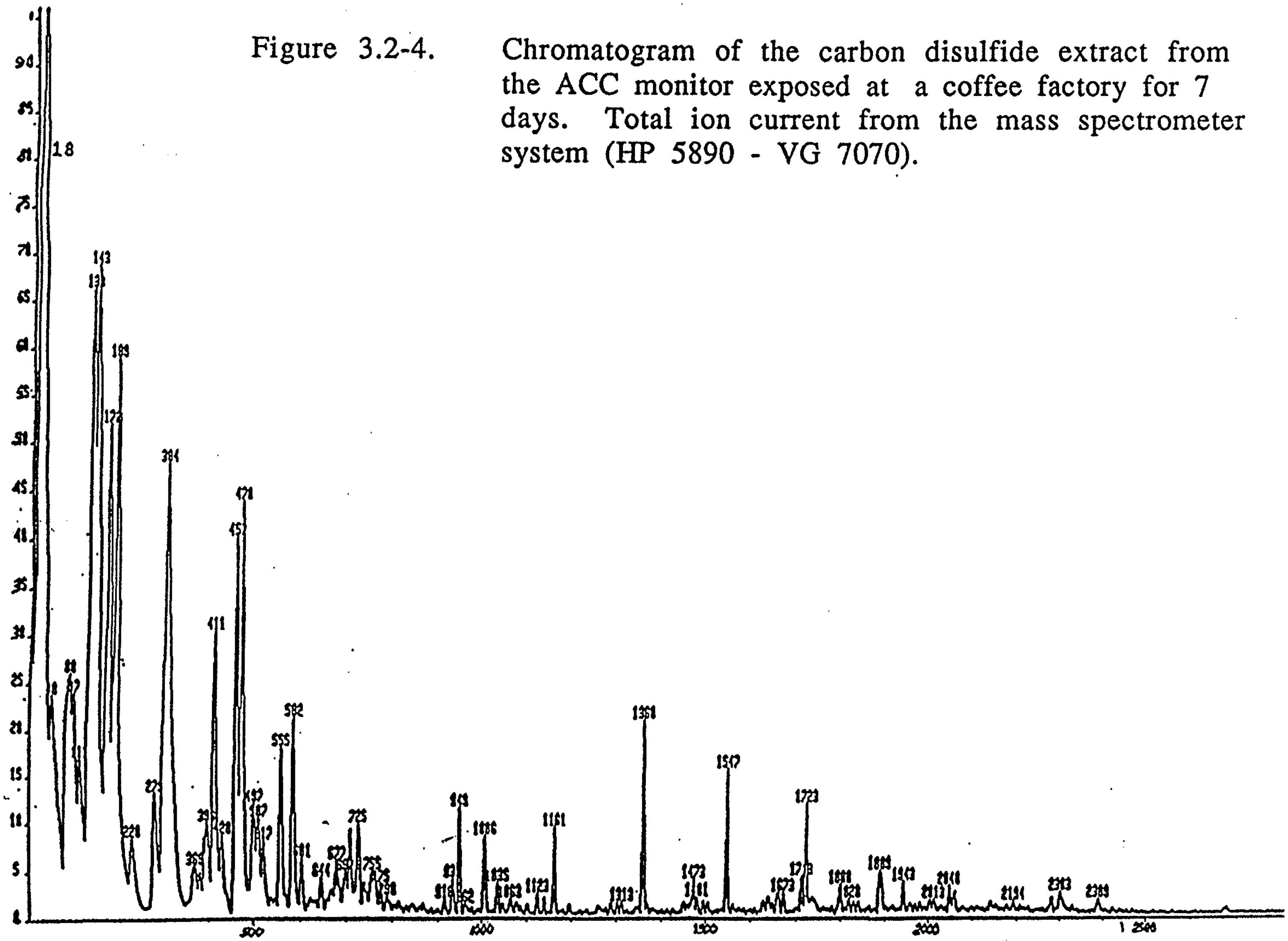


Figure 3.2-4. Chromatogram of the carbon disulfide extract from the ACC monitor exposed at a coffee factory for 7 days. Total ion current from the mass spectrometer system (HP 5890 - VG 7070).

TABLE 3.2-5. Results of GC-MS analysis of the extract from ACC strip exposed at a coffee factory for 7 days.

#	Retention time	Compound	Fit
1	18	Dimethyldisulfide	880
2	111	Tetrachloroethylene	889
3	133	2-Methylpirimidine	932
4	143	3,5-Dimethyl-1-purazole	753
5	172	2-Furanmethanol	904
6	189	1,2-Ethandiol, diacetate	948
7	304	2,6-Dimethylpyrazine	948
8	411	5-Methyl-2-furancarboxaldehyde	927
9	458	Dimethyltrisulfide	974
10	470	2-Furanmethanol, acetate	967
11	555	1,4-Dichlorobenzene	948
12	582	d-Limonene	929
13	725	2,4,6-Trimethyloctane	882

ionization detector. The compounds with a low boiling point could not be identified by GC - MS system because of the necessity to cut off the solvent peak. Two of these contaminants were identified on gas chromatograph with a flame ionization detector by known retention times: formaldehyde and benzene.

Methylsulfide, and several aldehydes and esters have been reported to be found in the coffee beans (65).

3.2.3. Samples of qualitative air analysis.

Indoor air was monitored in a Winnipeg school classroom by using two different techniques. Air was passed through activated carbon filled glass tubes (SKC) for specified time and known flow rate and the second one was by passive monitoring the same area with a polyurethane foam strip. Both samples were then extracted by carbon disulfide. The results of the qualitative GC-MS analysis and parameters of the library search are shown in the Tables 3.2-6 and 3.2-7. All compounds presented in these Tables are in the sequence of decreasing peak areas and show the confidence of the assignment.

The precise meanings of Purity, Fit and Reverse Fit are given in Appendix C.

From the comparison of the data, one can see that all the components are different for each of the monitors. Also, it is obvious from Tables 3.2-6 and 3.2-7 that the probability in matching the library with the components is lower for the PUF monitor than for the SKC tubes. It was probably because of the lower concentrations of organic compounds adsorbed on PUF strip, due to the relatively

Table 3.2-6. Data for the analysis of the SKC carbon tube monitor from the classroom. Volume of air sampled was 12.5 m^3.

#	Compound	Search parameters		
		Purity	Fit	Reverse fit
1	Toluene	899	979	911
2	2,5,9-Trimethyldecane	838	928	838
3	1,2-Dichlorobenzene	795	992	795
4	*o*-Decyl hydroxylamine	729	943	731

Table 3.2-7. Data for the analysis of the PUF monitor from the classroom exposed for 3 days.

#	Compound	Search parameters		
		Purity	Fit	Reverse fit
1	2-Phenoxyethanol	468	877	508
2	1,3-Benzendiol monobenzoate	373	926	386
3	2-Methoxyethyl 1,2-benzene dicarboxylic acid	791	961	814
4	2,3-Dichlorobutyric acid	332	733	398

low rate of diffusion of these compounds from the surface into the bulk area of PUF strip.

Another sample of the PUF monitor was exposed for 45 h in a refrigerator used for the storage of chemicals. The PUF monitor was extracted with carbon disulfide and analyzed on GC-MS (See Table 3.2-8 and Figure 3.2-5). All compounds, except tris(trimethylsilyl) borate, were stored in the fridge at the time of sampling. This experiment showed that a polyurethane foam monitors can be used for the monitoring of a broad spectrum of organic compounds.

Activated carbon cloth strips (C-TEX knitted mass 1.00 g) was exposed on the roof of the Parker building for 119 h (5 d). Results of the GC-MS analysis are presented in Table 3.2-9 and a chromatogram in Figure 3.2-6 and they were similar to the result of outdoors air analysis from paragraph 3.2.1.

Experiment with a short term exposure of the ACC monitors had been carried out on the one of Air Canada flights from Montreal to Vancouver for approximately 5 h. Results of the GC-MS analysis are presented in Table 3.2-10 and a chromatogram in Figure 3.2-7 and they showed a relatively good similarity to the type of compounds found in gasoline vapors (Table3.2-3).

Results of these and a number of similar analysis carried out at different industrial sites and homes (See Appendix B) showed that activated carbon is more effective for the absorption of hydrocarbons than polyurethane foam. Polyurethane foam seems to absorb high molecular weight compounds, phthalate esters, and pesticides.

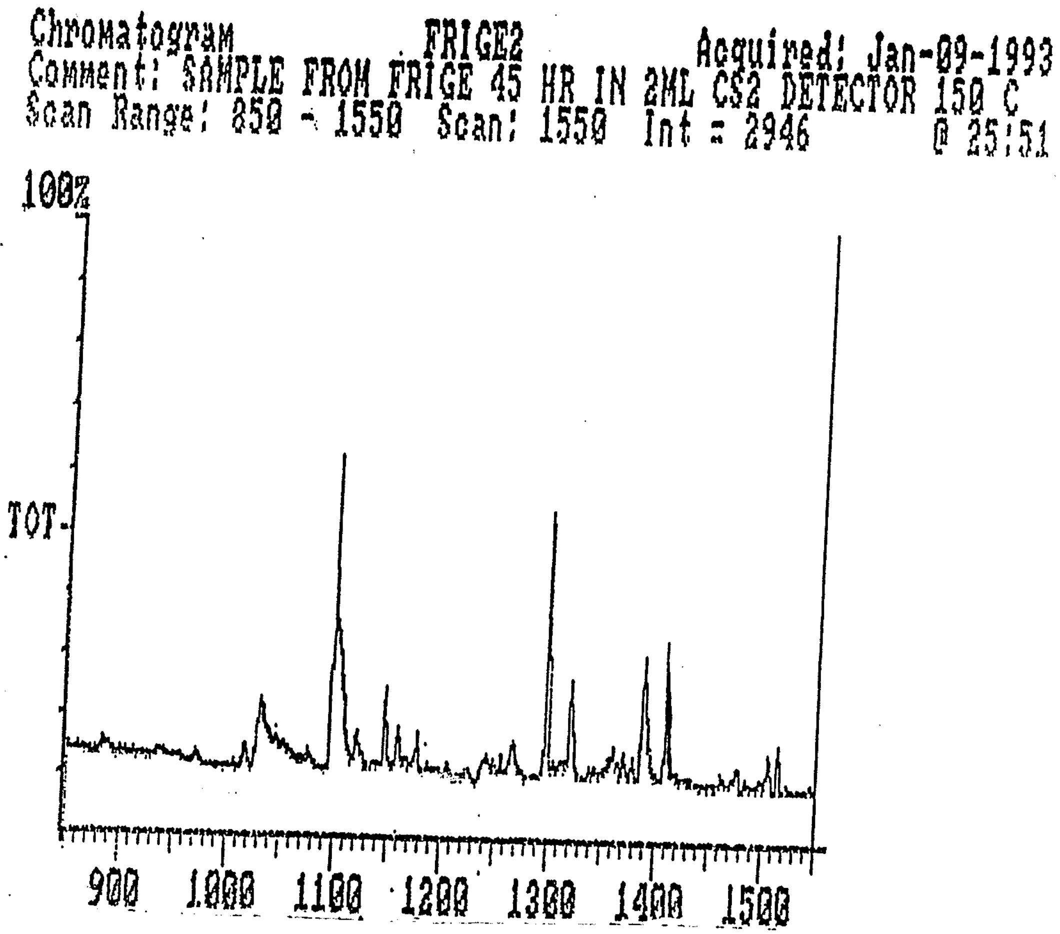


Figure 3.2-5. Chromatogram of the carbon disulfide extract from the PUF monitor exposed in the refrigerator for a storage of chemicals for 45 h. Total ion current from the mass spectrometer system (Varian 3400 - Finnigan 800).

TABLE 3.2-8. Data of the air analysis by PUF from the refrigerator used for the storage of the chemicals.

Retention time (sec)	Compound	Fit
1408	3-Methyl tridecane	942
1386	Isodecyloctyl ester of 1,2-Benzenedicarboxylic acid	903
1322	Trimethylsilyl borate	889
1300	Heptyl ester of nitric acid	911
1100	1,3,5-Trimethylsiloxy benzene	948

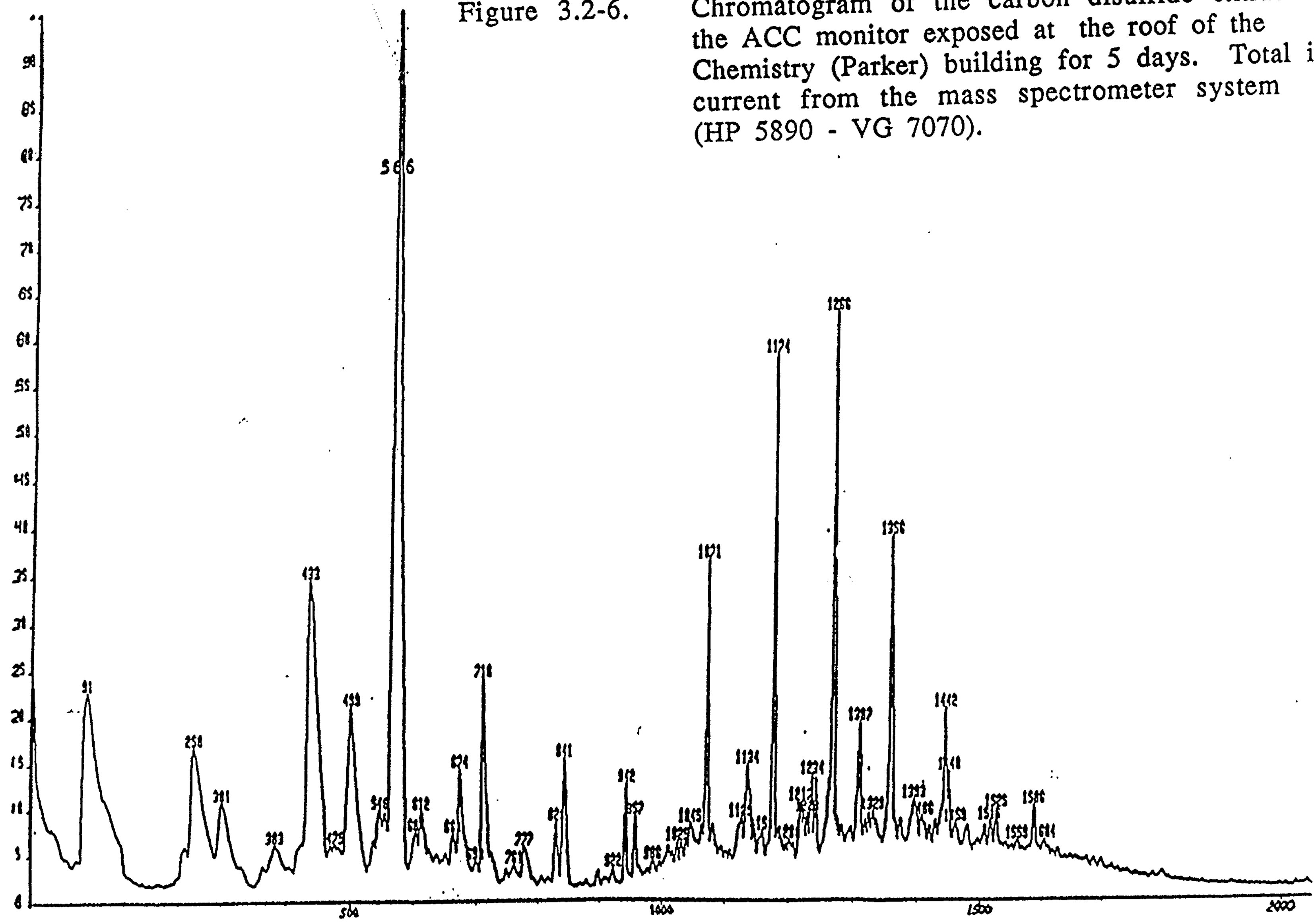


Figure 3.2-6. Chromatogram of the carbon disulfide extract from the ACC monitor exposed at the roof of the Chemistry (Parker) building for 5 days. Total ion current from the mass spectrometer system (HP 5890 - VG 7070).

TABLE 3.2-9. Results of the air monitoring at the roof of the Chemistry (Parker) building with ACC sampler.

#	COMPOUNDS	Retention time	Fit
1	2,2,3,4-Tetramethylpentane	1	878
2	Toluene	91	924
3	2,3-Dimethylbenzene	258	944
4	1,2 Dimethylbenzene	301	908
5	Octamethylcyclotetrasiloxane	433	870
6	1,2,4-Trimethylbenzene	499	912
7	d-Limonene	573	948
8	2-Butyl-1-octanol	674	880
9	Decamethyl cyclopentasiloxane	710	796
10	Naphthalene	841	916
11	Tetradecane	1071	938
12	2,6,10,15-Tetramethylheptadecane	1134	944
13	Hexadecane	1174	899
14	2,6,10-Trimcthyldodecane	1234	926
15	Nondecanol	1240	870
16	Hexadecane	1266	891
17	Dicosane	1307	933
18	Heptadecane	1356	952
19	1-Nondecene	1393	882
20	Docosane	1442	865
21	1,2-Benzenedicarboxylic acid, butyl octyl ester	1586	840

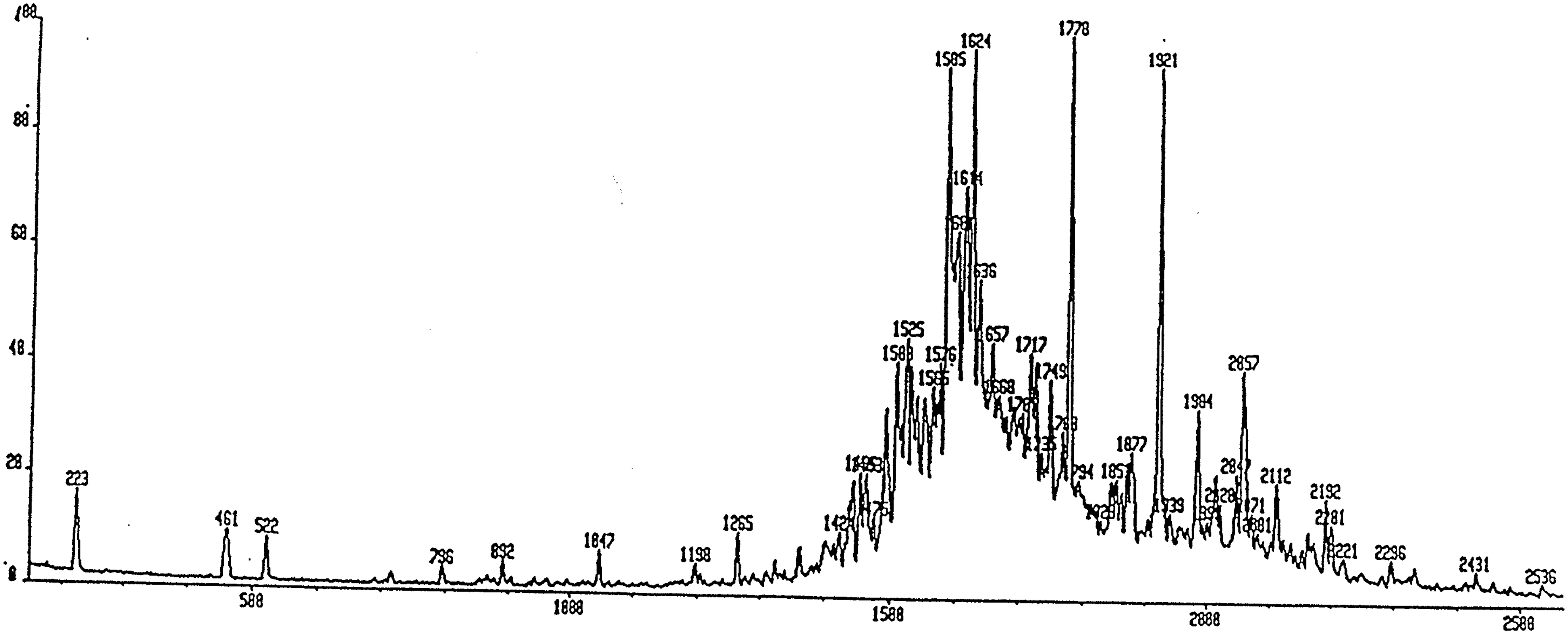


Figure 3.2-7. Chromatogram of the carbon disulfide extract from the ACC monitor exposed during the Air Canada flight 111 for 5 h. Total ion current from the mass spectrometer system (HP 5890 - VG 7070).

Table 3.2-10. Volatile organic compounds found in the indoor air of Air Canada flight #111, monitored with ACC sampler for 5 h.

#	Retention time (sec)	Compound	Fit
1.	GC*	Benzene	--
2.	223	Toluene	926
3.	461	p-Xylene	950
4.	522	o-Xylene	920
5.	896	d-Limonene	940
6.	1047	2,5,6-Trimethyldecane	918
7.	1198	5-Methyl-2-(1-methylethyl)cyclohexanone	822
8.	1265	4,7-Dimethylundecane	958
9.	1585	3,6-Dimethylundecane	951
10.	1614	6-Methyltridecane	938
11.	1624	2,7,10-Trimethyldodecane	952
12.	1636	6-Methyltridecane	929
13.	1778	2,6,11-Trimethyldodecane	954
14.	1921	Hexadecane	979
15.	1984	2,6,10,15-Tetramethylheptadecane	897
16.	2057	Heptadecane	973

* - compounds were determined by gas chromatograph with a flame ionization detector

3.3 Profile monitoring with polyurethane foam as a monitor.

Three polyurethane foam (PUF) strips were exposed indoors in the different rooms of an office in a downtown Winnipeg building for seven days. GC - MS analysis of the carbon disulfide extracts showed the presence of the same composition of organic compounds in each of the three rooms with only the relative concentrations being different (see Table 3.3-1 and Figure 3.3-1).

From the data contained in Table 3.3-1 we can assume that phthalate esters originated from the plastics used in the ventilation system and possibly from floor polish and carpet (67, 68). Phenol-type compounds can also be emitted from plastics or can be fragments of pesticide residues (69, 70).

We did not obtain full quantitative data, but from the ratios between the peaks for each experiment it is obvious that different rooms were contaminated to different degrees by different compounds (see Table 3.3-1 and Figure 3.3-1). From the data in Table 3.3-1 one can see, for example that peak #4 (methoxyethyl ester of benzendicarboxylic acid) for room #3 (main peak) is almost three times larger than the same compound in room #2 and peak #2 (2,3-dihydro-1,1,3-trimethyl-3-phenyl-1-indene) is the main compound for room #2 and about twice as much as the same compound in room #3.

Compounds #5, 6 and 7, dimethylethyl phenol, 2,2-diethyl biphenyl and diethylphthalate, have similar quantitative values in each room.

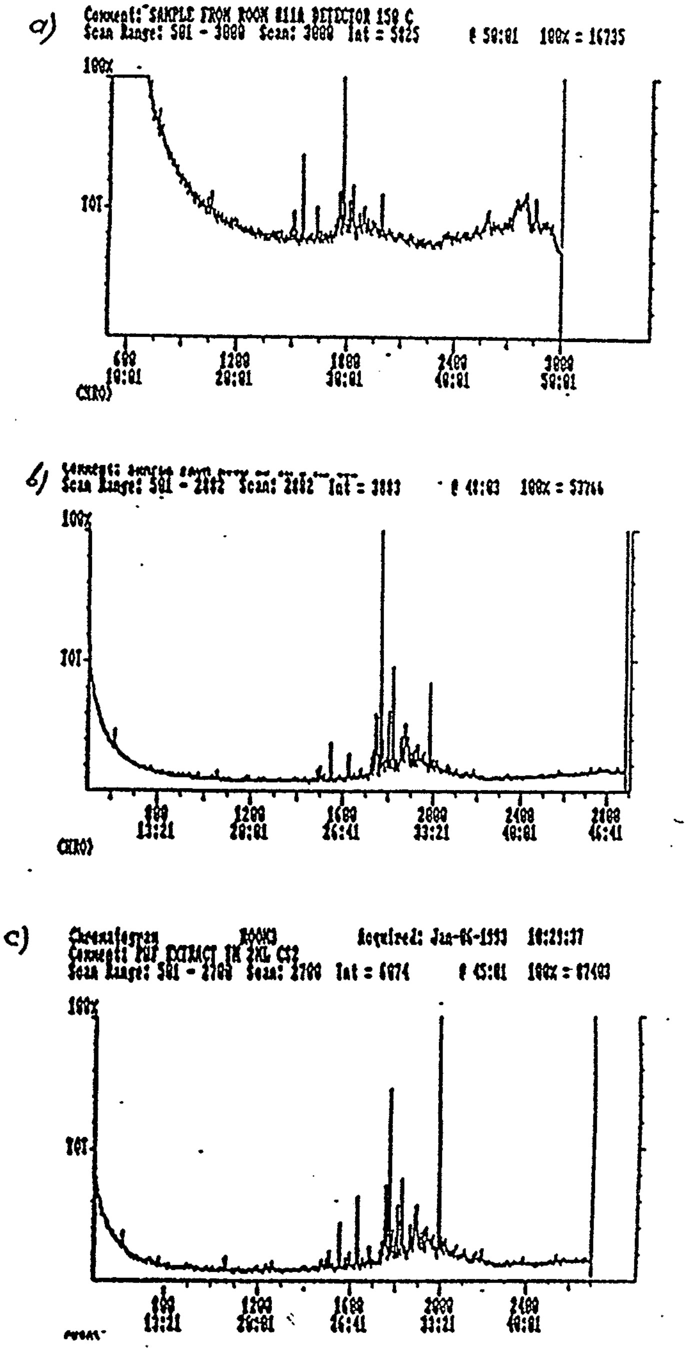


Figure 3.3-1. Chromatogram of the carbon disulfide extract from the PUF monitors exposed in the different classrooms for 5 days a) room 11a, b) room 2, c) room 3. Total ion current from the mass spectrometer system (Varian 3400 - Finnigan 800).

TABLE 3.3-1. Data of GC-MS analysis of indoor air from the offices monitored by PUF strip.

Peak #	Compound	Room #	Peak height (cm)	Fit
1	2,6-Bis(1,1-dimethylethyl)-4-methylphenol	2	1.4	961
		3	1.7	
		11a	1.5	
2	2,3-Dihydro-1,1,3-trimethyl-3-phenyl-1-indene	2	9.5	883
		3	6.4	
		11a	2.8	
3	1-Methoxy-3-(2-phenylmethyl)-benzene	2	4.0	978
		3	3.0	
		11a	0.8	
4	2-Methoxyethyl ester 1,2-benzenedicarboxylic acid	2	3.3	922
		3	9.1	
		11a	0.7	
5	Dimethylethylphenol	2	1.1	903
		3	1.1	
		11a	1.2	
6	2,2-Diethyl biphenyl	2	0.7	938
		3	0.6	
		11a	0.7	
7	Diethylphthalate	2	0.4	910
		3	0.4	
		11a	0.4	

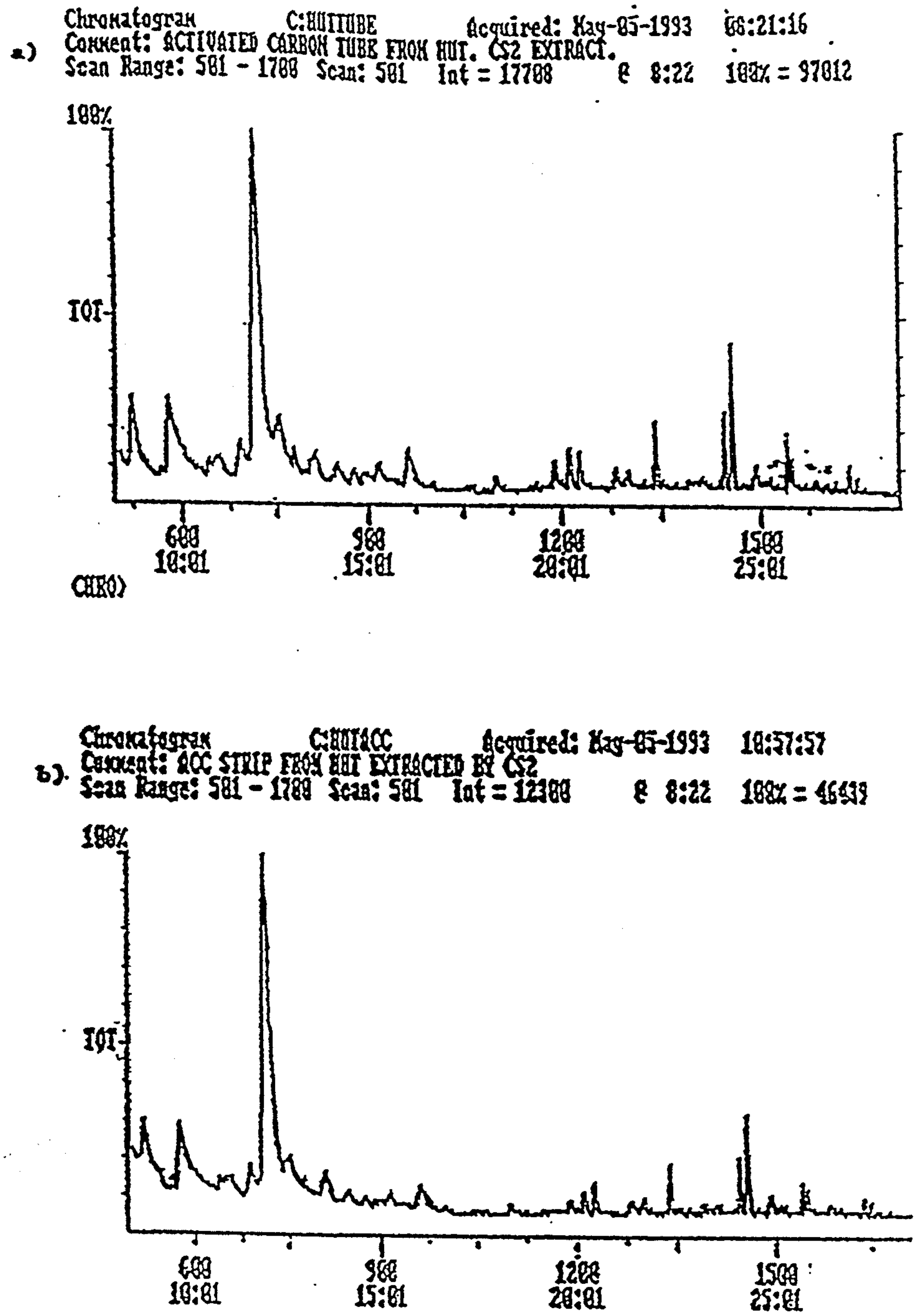
3.4. Quantitative analysis of the air with activated carbon cloth monitors.

A comparison between the active monitoring by SKC carbon tubes with a known volume of the air sampled and the passive monitoring with ACC strips was used to obtain quantitative coefficients of the sampling rates for different volatile compounds.

Indoor air was pulled through the SKC tubes by an electrical pump. The flow rate was 87.5 L/h, calibrated with a soap bubble flowmeter. O-Hydroxyacetophenone was used as an internal standard. Retention times and calibration constants for benzene, toluene, trimethylbenzene, and benzophenone were determined by injecting these compounds into the gas chromatograph. Other compounds were determined by comparison of the peak ratios from the mass spectra to the ratios from the chromatograph considering the response factor for a flame ionization detector and an assumption that the peak area of GC-MS based on total ion current was directly related to the concentration of the compound. The response factors of a flame ionization detector to these compounds were taken from Dietz (66).

Analysis was carried out in two different rooms in a school where students and teachers had experienced discomfort. Results of the air analysis from these rooms are shown in the Table 3.4-1 and the chromatograms are shown in Figure 3.4-1.

Similar passive and active analysis and passive air analysis by 3M Organic Vapor Monitor was carried out in a local printing company (See Table 3.4-2). GC traces of the extract from ACC, SKC and 3M monitors are shown in the Figure 3.4-2.



```
Chromatogram        C:HUTTUBE          Acquired: May-05-1993   06:21:16
Comment: ACTIVATED CARBON TUBE FROM HUT. CS2 EXTRACT.
Scan Range: 501 - 1700  Scan: 501   Int = 17700      @ 8:22   100% = 97012
```

```
Chromatogram        C:HUTACC           Acquired: May-05-1993   10:57:57
Comment: ACC STRIP FROM HUT EXTRACTED BY CS2
Scan Range: 501 - 1700  Scan: 501   Int = 12300      @ 8:22   100% = 46639
```

Figure 3.4-1. Chromatogram of the carbon disulfide extract from the SKC carbon tube (a), and ACC monitor (b), exposed in the room HUT at a school. Total ion current from the mass spectrometer system (Finnigan 800 - Varian 3400).

Table 3.4-1. Calculated sampling rate for the ACC C-TEX knitted (0.4 g of ACC) obtained from the experiment in the classrooms. Calculated by comparison with active monitoring.

#	Compound	K(L/ h)
1.	Benzene	44.00
2.	Toluene	44.60
3.	2,6,7- Trimethyldecane	44.80
4.	1,5-Dimethylcyclooctadecane	46.56
5.	4-Trimethyl-1-methanolcyclohexene	41.35
6.	1-Chlorooctadecane	47.29
7.	3-Methylbutyl hydroxylamine	40.82
8.	Didecyl ester decandioic acid	52.95

Both the activated carbon tube and activated carbon cloth extracts showed similar results (See Figure 3.4-2). From the data obtained by active monitoring, and the data of the concentrations for the extracts of the activated carbon cloth, exposed for the same time length and at the same places, it was possible to derive the sampling rate constants for each of the compounds for the ACC C-TEX knitted. Concentrations of the volatile organic compounds in the air were calculated as described in Section 3.1.

These results showed that the active carbon cloth trapped various volatile organic compounds with almost equal efficiency (*i.e.* approximately within a factor of 2 compare to SKC active monitor (See Table 3.4-2)). This allows for semiquantitative analysis of VOC by passive monitoring without prior calibration.

Obviously, more experimental calibration in various environments would be required to improve upon the quantitative nature of the analysis. Dependence of the sampling rate on air velocity and humidity has to be determined. Also, it is useful to compare the sampling rates obtained for low molecular weight compounds to the sampling rates of high molecular weight compounds to obtain a possible mechanism of adsorption.

Comparison of the sampling rates for the ACC monitor (see Table 3.4-2) with the data for a 3M Organic Vapor Monitor (24) show that the sampling rate for the ACC monitor calculated for the equal masses of sorbent is about 10 times greater than the sampling rate for the 3M Organic Vapor Monitor. Thus, in contrast to 3M Organic Vapor Monitor where a parallel blank extraction is required because of residual cluster peaks (see Figure 3.4-2) due to plasticizers in the

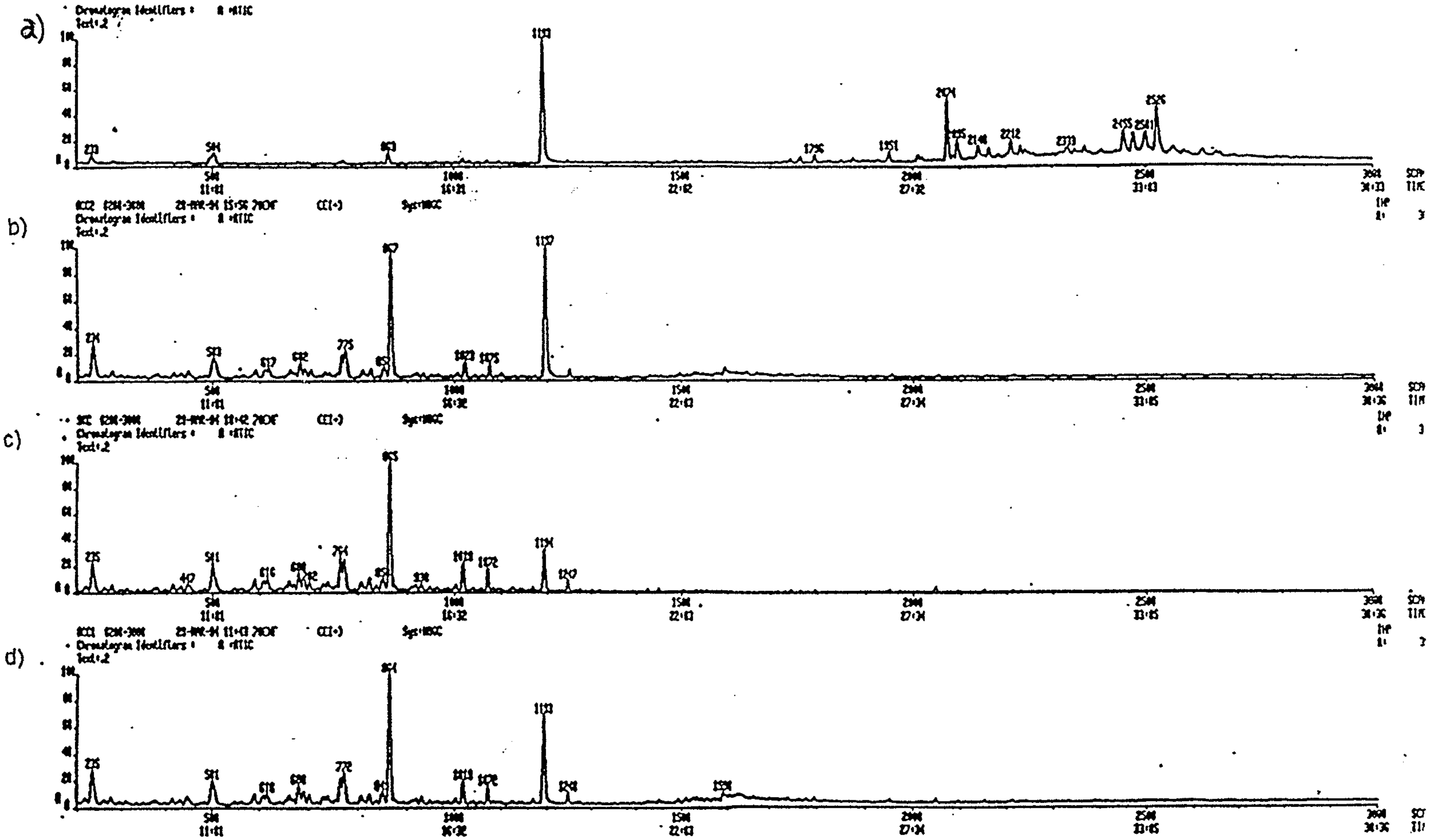


Figure 3.4-2. GC traces of indoor air monitoring from the printing company monitored with:
a) 3M Organic Vapor Monitor
b) and d) ACC Monitor
c) SKC Carbon Tube Monitor
Total ion current from the mass spectrometer system (VG 7070 - HP 5890).

Table 3.4-2. Results of Benzene and Toluene Uptake on ACC C-Tex Knitted and 3M Organic Vapor Monitor from the Indoor Air Monitoring at CCL Label. Exposure time = 24 hr.

Compound	SKC carbon tubeǂ		ACC monitor*			3M monitor (0.2g of carbon)		
	Amount Absorbed μ mol	Concentration μ mole/m^3	Amount Absorbed μ mol	Calculated Concentration*** μ mole/m^3	Calculated Sampling rate L/hr	Amount Absorbed n mol	Calculated Concentration μ mol/ m^3***	Calculated Sampling Rate L/hr
1. Benzene	1.33	0.63	0.67	0.60	44.3	34.30	0.67	2.25
2. Toluene	5.82	2.77	2.96	2.50	44.5	135.30	3.00	2.03
3. Trimethyloctane	0.14	0.068	0.058		35.6	2.82		1.73
4. Trimethylbenzene	0.14	0.066	0.062		39.1			
5. D-Limonene	0.59	0.28	0.34		50.6	4.68		2.21
6. Methyltridecane	0.08	0.039	0.042		44.9			
7. Trimethyldodecane	0.05	0.46	0.069		62.5			
8. Benzophenone	0.11	0.054	0.086		66.4	2.10		1.61

ǂ Flow rate 87.8 L/min for 24 hr.

* Contains 0.4 g ACC C-TEX knitted.

** Calculated with a sampling rate obtained from the experiment with air flow control.

*** Calculated as listed in organic vapor monitor analysis guide, 3-M.

Quantitative analysis for compounds 1 & 2 by GG FID calibration; compounds 3 to 8 by peak height and corrected by a response factor (W.A. Deatz, Response factors for gas chromatographic analysis. J. Gas Chrom. 2, 68 (1967)).

plastic sample holder and possible contamination in the production process, the ACC samplers require no blank.

Since both benzene and toluene were found in indoor air experiments and they were analyzed in the experiments carried out in the environmental chamber, one can compare the sampling rates calculated from all experiments (Table 3.4.-3). It is obvious that despite the different air velocities, the sampling rates for benzene differ by less than 10%, which is acceptable for environmental analysis. Results for toluene are similar.

Table 3.4-3. Sampling rate of ACC (for 0.4 g C-TEX knitted) and 3M monitors for benzene and toluene.

COMPOUND	SAMPLING RATE (L/h)			
	ACC monitor			
	Indoor 1†	Indoor 2††	Standardized*	3M monitor†
Benzene	44.0	42.5	47.0	2.2
Toluene	44.6	39.7	44.7	2.0

† - exposure time 24 h, 56 x 56 mm monitor (0.4 g ACC)

†† - exposure time 5 d, 100 x 60 mm sampler(0.98 g ACC), Values have been normalized to 0.4 g ACC.

*- experiment was carried in environmental chamber

3.5 Application of passive monitors for water analysis.

The monitoring of the organic contamination in the Red River were carried out twice. In the first test an ACC strip was submerged in the river for five days. The monitor was attached by a string to an anchor.

For analysis the strip was pressed in a syringe to remove the excess water and then extracted with carbon disulfide in the same way as for air analysis (See Chapter 2).

GC-MS analysis of the extract showed the presence of the several compounds at very low concentration levels as shown in Table 3.5-1 and Figure 3.5-1a. The presence of trichlorobenzene was also confirmed by using isotopic ratio, which gave a characteristic peak intensities ratio for chlorinated compounds. Because of the low concentrations we could only identify these compounds using the VG 7070 - HP 5890 gas chromatograph - mass spectrometer system. Only compounds identified with a fit better than 800 are shown in Table 3.5-1.

In the second experiment, the ACC sample was submerged in the river for two weeks; however, the concentrations of organic compounds were still at the same low levels (Figure 3.5-1b). It could be due to the low concentration of organic compounds in the river, but most probably the applied method has a low detection limits. In addition to the compounds, identified, several other compounds were detected (See Table 3.5-2), but again the search identification parameters were not perfect. This seems to indicate that the water had to be removed completely prior to solvent extraction, which can

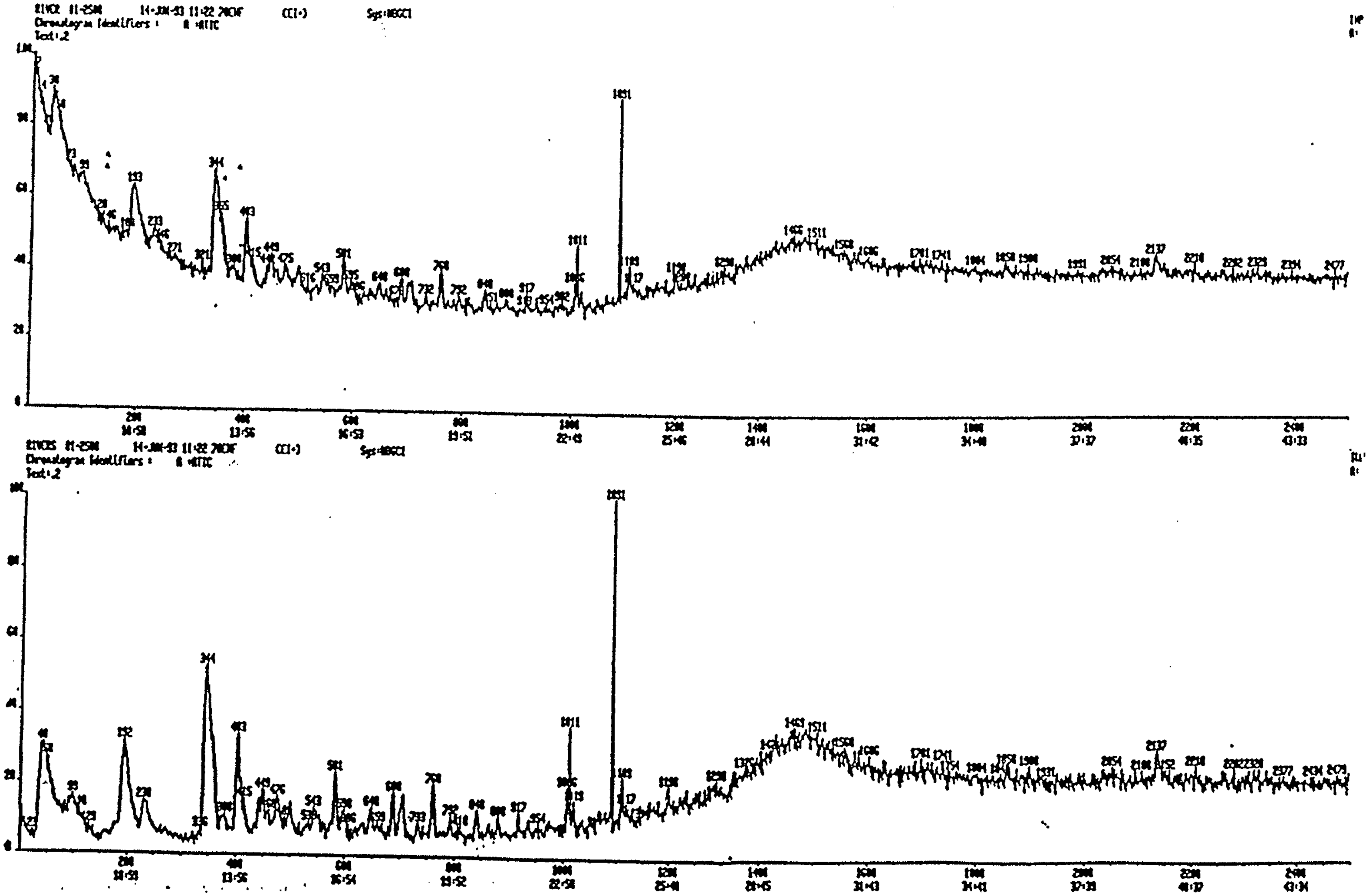


Figure 3.5-1 Chromatogram of the carbon disulfide extract from the ACC monitor exposed in the Red River;

a) for 5 days

b) for 2 weeks

Total ion current from the mass spectrometer system (VG 7070 - HP 5890).

TABLE 3.5-1. Results of the monitoring of organic pollutants in the Red River by ACC sampler exposed for five days.

#	COMPOUND	SCAN	Fit
1	Benzene	23	910
2	Toluene	38	815
3	*o*-Xylene	193	908
4	*p*-Xylene	233	950
5	1,3,5-Trimethylbenzene	403	915
7	Cyclopentasiloxane, decamethyl	581	937
8	1,2,3-Trichlorobenzene	688	835

TABLE 3.5-2. Several additional organic pollutants found in the Red River by ACC sampler exposed for two weeks.

#	COMPOUND	SCAN	FIT
1	Methyl ester of carbonochloridodithioic acid	760	832
2	1,3-Propanediol, 2-amino-2-hydroxymethyl or amphetamine	840	890
3	n-Methyl-methanamine or methylsilane	1011	846
4	n-Methyl-methanamine or methylsilane	1091	920
5	α-3,4-Trimethyl benzeneethaneamine	1109	870

be achieved by centrifugation, or by treatment of the ACC or PUF monitors with a water miscible solvent.

It is obvious that further work is required to develop the method of water analysis by passive monitors without a membrane.

CHAPTER IV
CONCLUSIONS

4.1 Conclusions

From the present study, the following conclusions can be drawn:

1. The results of the analysis showed that activated carbon is more effective for the absorption of hydrocarbons than polyurethane foam. Polyurethane foam seemed to better absorb high molecular weight compounds, phthalate esters and pesticides.

2. Passive sampling with ACC strips allows monitoring of the same organic pollutants as with active sampling by pulling air through SKC carbon tubes. Passive monitoring, however, is a substantially less expensive process compared with active sampling. The results of the present work show that the active carbon cloth traps various volatile organic compounds with almost equal efficiency (approximately within a factor of 2) as SKC carbon tube monitors and that the sampling rates were not affected by differences in concentration of the contaminant in air and air movement in indoor environment.

3. Comparison of the sampling rates for the ACC monitor with 3M organic vapor monitor showed that the sampling rate for the ACC monitor is about 20 times greater than the sampling rate for the 3M Organic Vapor Monitor or 10 times greater if calculated for the same mass of activated carbon.

Thus, in contrast, to both 3M and SKC passive samplers, where a parallel blank extraction is required because of residual cluster peaks due to plasticizers in the plastic sample holder and possible contamination in the production process, the ACC samplers require no blank.

4. This type of passive sampler can allow quantitative analysis for VOC to be possible by passive monitoring without the need of calibration of the sampling rate variations due to membrane permeability.

5. The calibration data seems to suggest that the sampling rate for the volatile organic compounds are similar, even suggesting the possibility that all molecules will sorb to the surface of the ACC monitor with equal efficiency. This can allow the use of the ACC monitor without calibration.

6. The comparison of the sampling rates for benzene and toluene obtained from the experiments conducted in indoor air and in the environmental chamber showed that the sampling rate probably does not depend on air velocity (at least at the velocities used) because a fan had been used for air distribution inside the environmental chamber.

7. PUF or ACC samplers can be employed for profile monitoring to determine a source of the contamination.

8. High density polyethylene Ziploc™ bags employed for the shipment of the monitors do not contaminate the monitors.

9. In water, the activated carbon cloth showed a very low adsorption rate probably due to the fact that the wet ACC does not permit the carbon disulfide to be an effective extractant of the absorbed organics. A new method of drying the ACC monitor before the extraction must be employed in future investigations.

4.2 Suggestions for future work

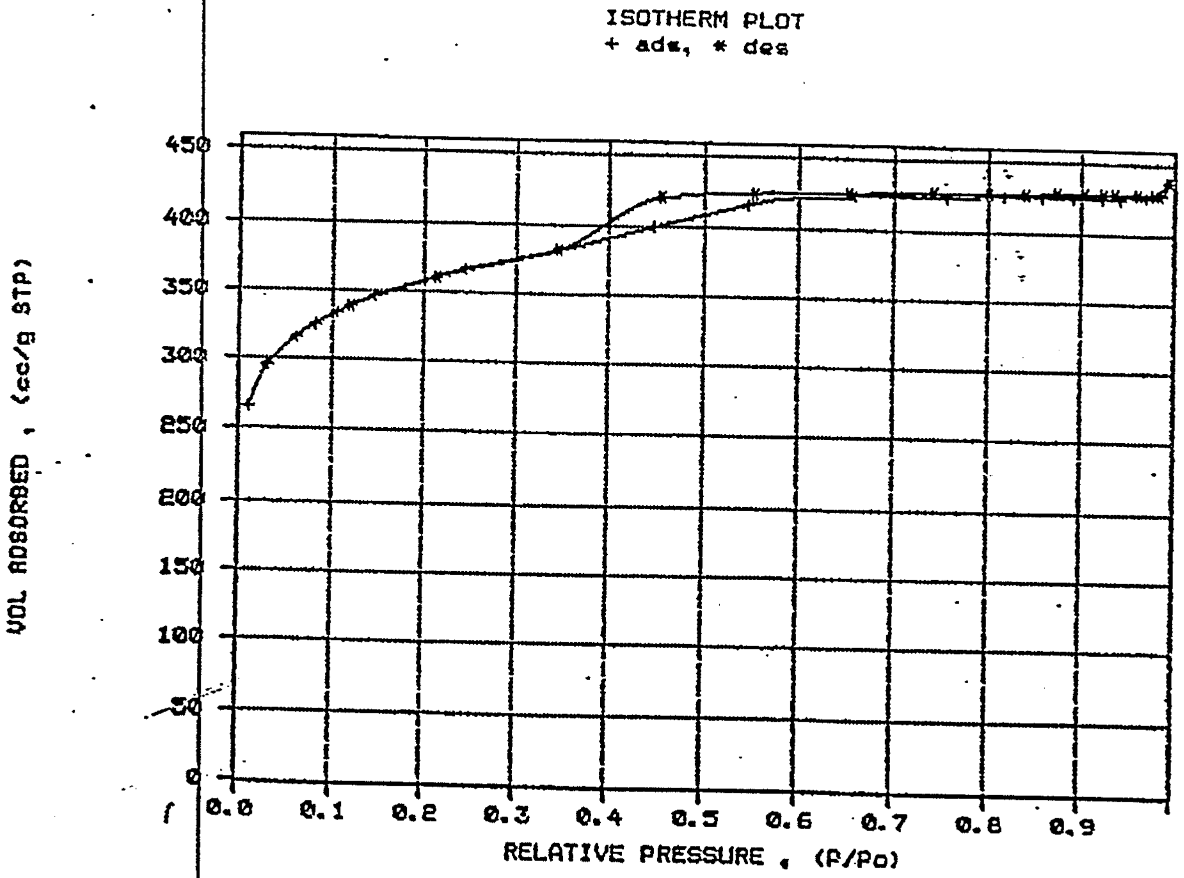
1. More experimental calibration in various environments and with different volatile organic compounds would be required to improve upon the quantitative nature of the analysis with ACC monitor. Determination of the sampling rate for high molecular weight compounds in indoor air has to be done.
2. Dependence of the sampling rate on humidity and possible air velocity should be investigated.
3. Calibration of the passive PUF monitors can be provided by a comparison with results of the active sampling with polyurethane foam plugs.
4. Possibility of applications of passive monitors without a membrane for water and soil analysis should be investigated.

APPENDIX A

SURFACE AREA AND PORE STRUCTURE ANALYSIS OF C-TEX KNITTED AND ACC-10 ACTIVATED CARBON CLOTH

```
                    SURFACE AREA AND PORE STRUCTURE ANALYSIS
ASAP 2000 V2.02

SAMPLE DIRECTORY/NUMBER: DATA1   /252
SAMPLE ID:                     C-TEX KNITTED             START 14:30:01 01/27/94
SUBMITTER: UNIVERSITY OF MANITOBA                        COMPL 17:17:10 01/27/94
OPERATOR: BW                                             REPRT 17:17:11 01/27/94
UNIT NUMBER: 1                                           SAMPLE WT:     0.0890 g
ANALYSIS GAS:  Nitrogen                                  FREE SPACE:  34.8970 cc
                                                         EQUIL INTRVL:      5 sec
```



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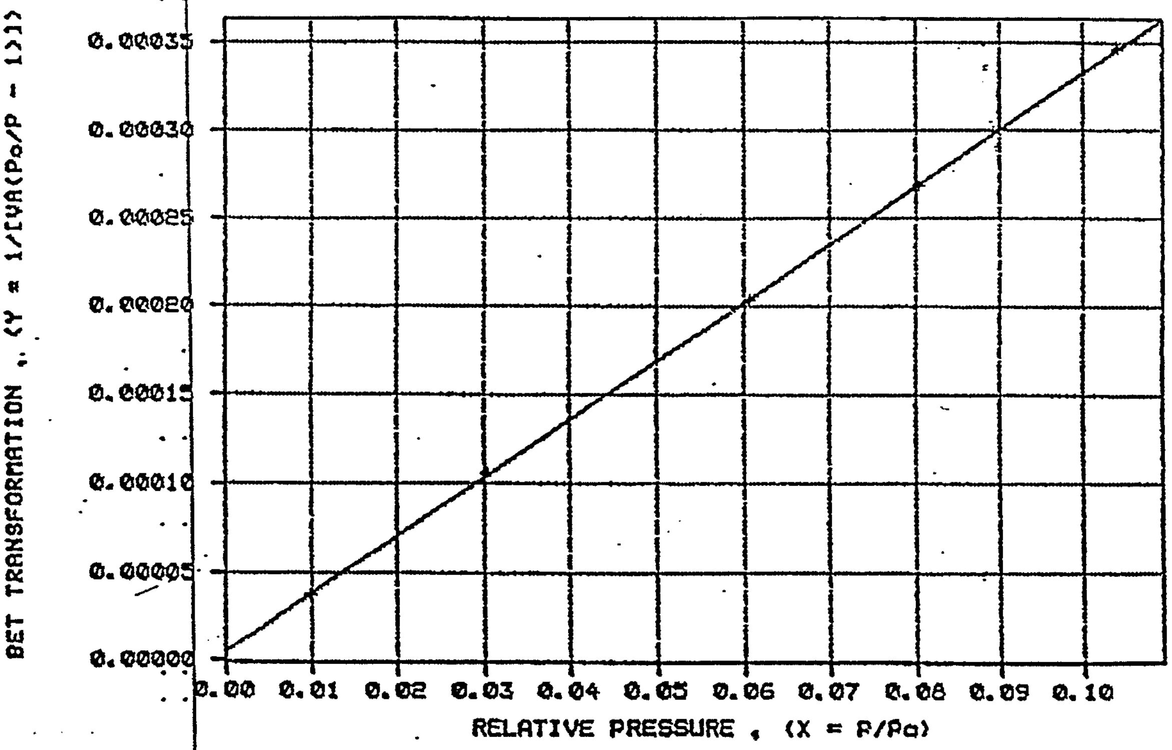
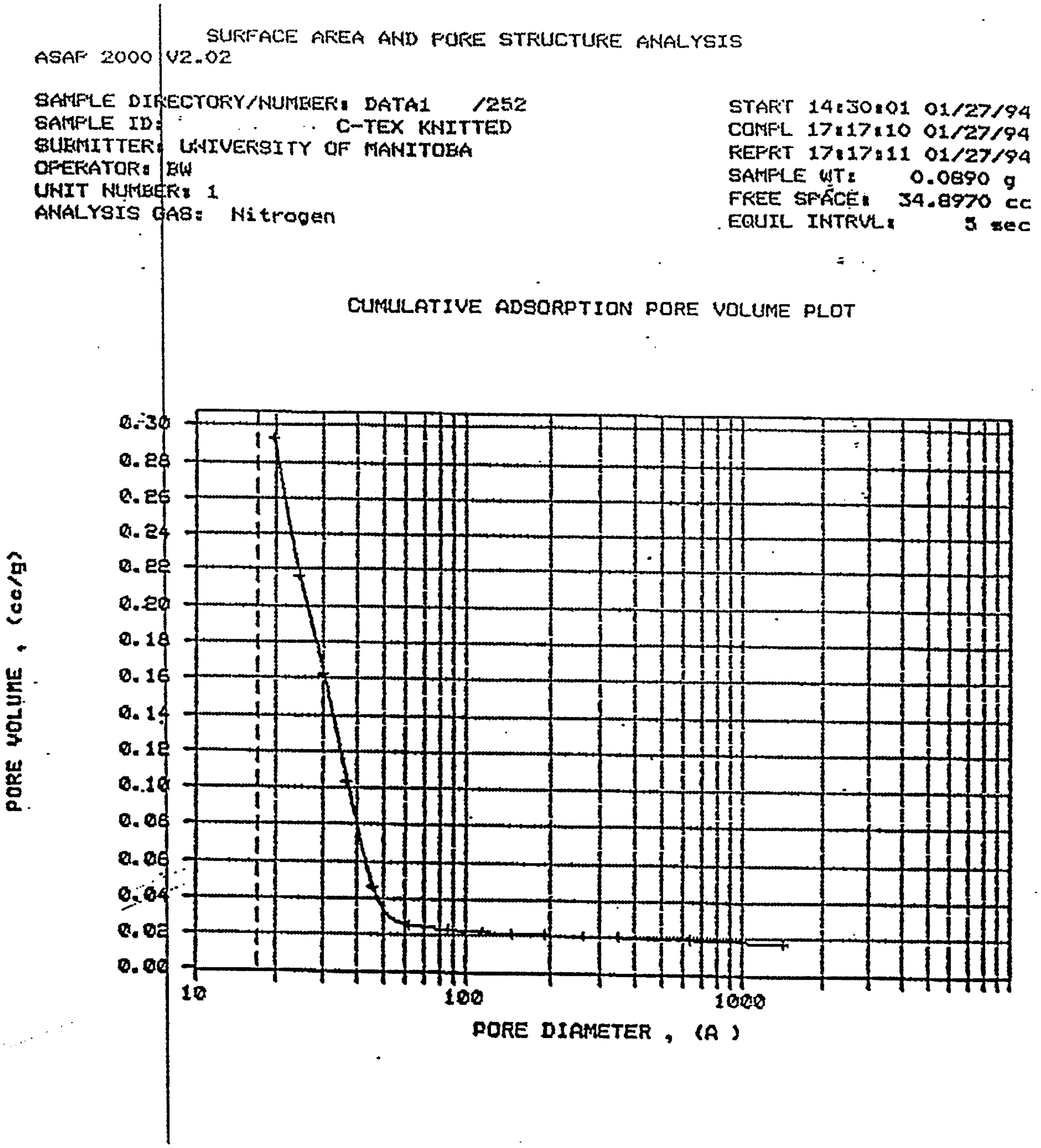
                  SURFACE AREA AND PORE STRUCTURE ANALYSIS
ASAP 2000 V2.02

SAMPLE DIRECTORY/NUMBER: DATA1   /252                    START 14:30:01 01/27/94
SAMPLE ID:                    C-TEX KNITTED              COMPL 17:17:10 01/27/94
SUBMITTER: UNIVERSITY OF MANITOBA                        REPRT 17:17:11 01/27/94
OPERATOR: BW                                             SAMPLE WT:     0.0890 g
UNIT NUMBER: 1                                           FREE SPACE:  34.8970 cc
ANALYSIS GAS:  Nitrogen                                  EQUIL INTRVL:      5 sec
```

BET PLOT





```
                 SURFACE AREA AND PORE STRUCTURE ANALYSIS
ASAP 2000 V2.02

SAMPLE DIRECTORY/NUMBER: DATA1    /252          START 14:30:01 01/27/94
SAMPLE ID:               C-TEX KNITTED          COMPL 17:17:10 01/27/94
SUBMITTER: UNIVERSITY OF MANITOBA               REPRT 17:17:11 01/27/94
OPERATOR: BW                                    SAMPLE WT:     0.0890 g
UNIT NUMBER: 1                                  FREE SPACE:   34.8970 cc
ANALYSIS GAS:  Nitrogen                         EQUIL INTRVL:       5 sec
```

CUMULATIVE ADSORPTION PORE VOLUME PLOT

```
                 SURFACE AREA AND PORE STRUCTURE ANALYSIS
ASAP 2000 V2.02

SAMPLE DIRECTORY/NUMBER: DATA1   /252              START 14:30:01 01/27/94
SAMPLE ID:                 C-TEX KNITTED           COMPL 17:17:10 01/27/94
SUBMITTER: UNIVERSITY OF MANITOBA                  REPRT 17:17:11 01/27/94
OPERATOR: BW                                       SAMPLE WT:     0.0890 g
UNIT NUMBER: 1                                     FREE SPACE:  34.8970 cc
ANALYSIS GAS:  Nitrogen                            EQUIL INTRVL:      5 sec

                           SUMMARY REPORT


                              AREA

BET SURFACE AREA:                                       1324.2638   sq. m/g

SINGLE POINT SURFACE AREA AT P/Po 0.1039:               1303.2832   sq. m/g

BJH CUMULATIVE ADSORPTION SURFACE AREA OF PORES
 BETWEEN      17.0000 AND   3000.0000 A  DIAMETER:      376.4162   sq. m/g

BJH CUMULATIVE DESORPTION SURFACE AREA OF PORES
 BETWEEN      17.0000 AND   3000.0000 A  DIAMETER:      471.4824   sq. m/g


                             VOLUME

SINGLE POINT TOTAL PORE VOLUME OF PORES LESS THAN
   1420.4635 A  DIAMETER AT P/Po 0.9862:                   0.662413 cc/g

BJH CUMULATIVE ADSORPTION PORE VOLUME OF PORES
 BETWEEN      17.0000 AND   3000.0000 A  DIAMETER:         0.293392 cc/g

BJH CUMULATIVE DESORPTION PORE VOLUME OF PORES
 BETWEEN      17.0000 AND   3000.0000 A  DIAMETER:         0.319249 cc/g


                            PORE SIZE

AVERAGE PORE DIAMETER (4V/A BY BET):                     20.0085   A

BJH ADSORPTION AVERAGE PORE DIAMETER (4V/A):             31.1774   A

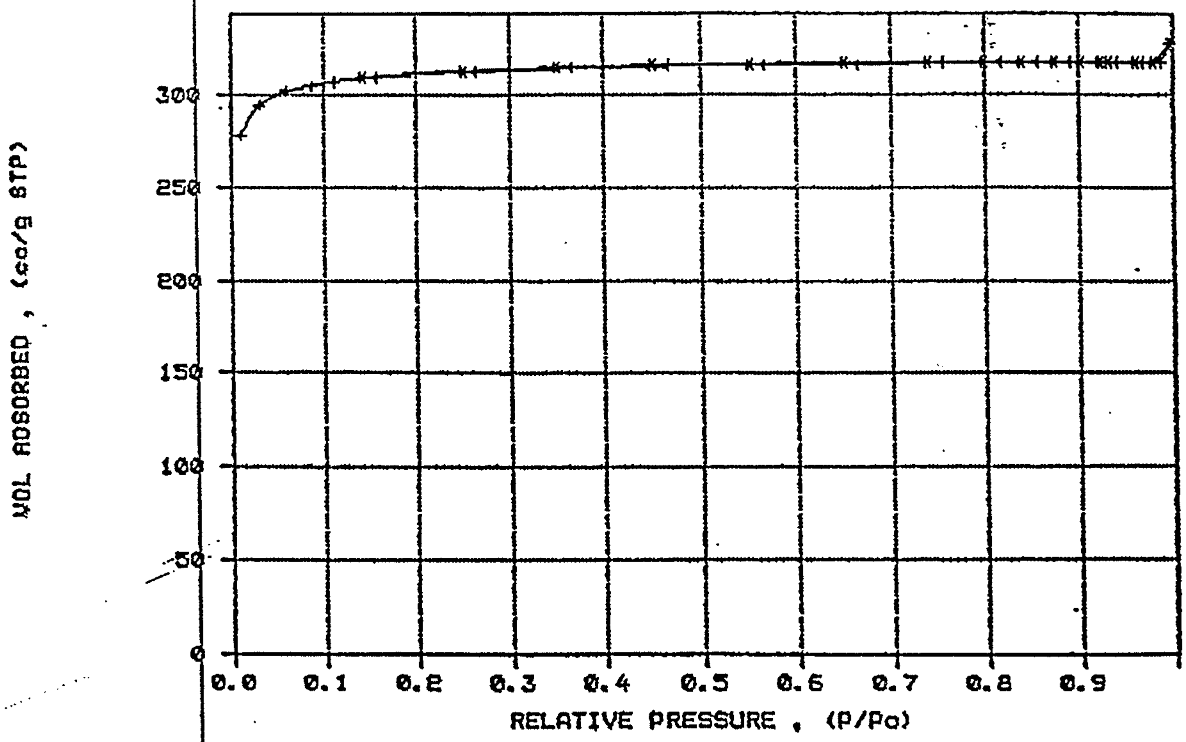
BJH DESORPTION AVERAGE PORE DIAMETER (4V/A):             27.0847   A
```

de gas at 50°C for 48h.

```
                SURFACE AREA AND PORE STRUCTURE ANALYSIS
ASAP 2000 V2.02

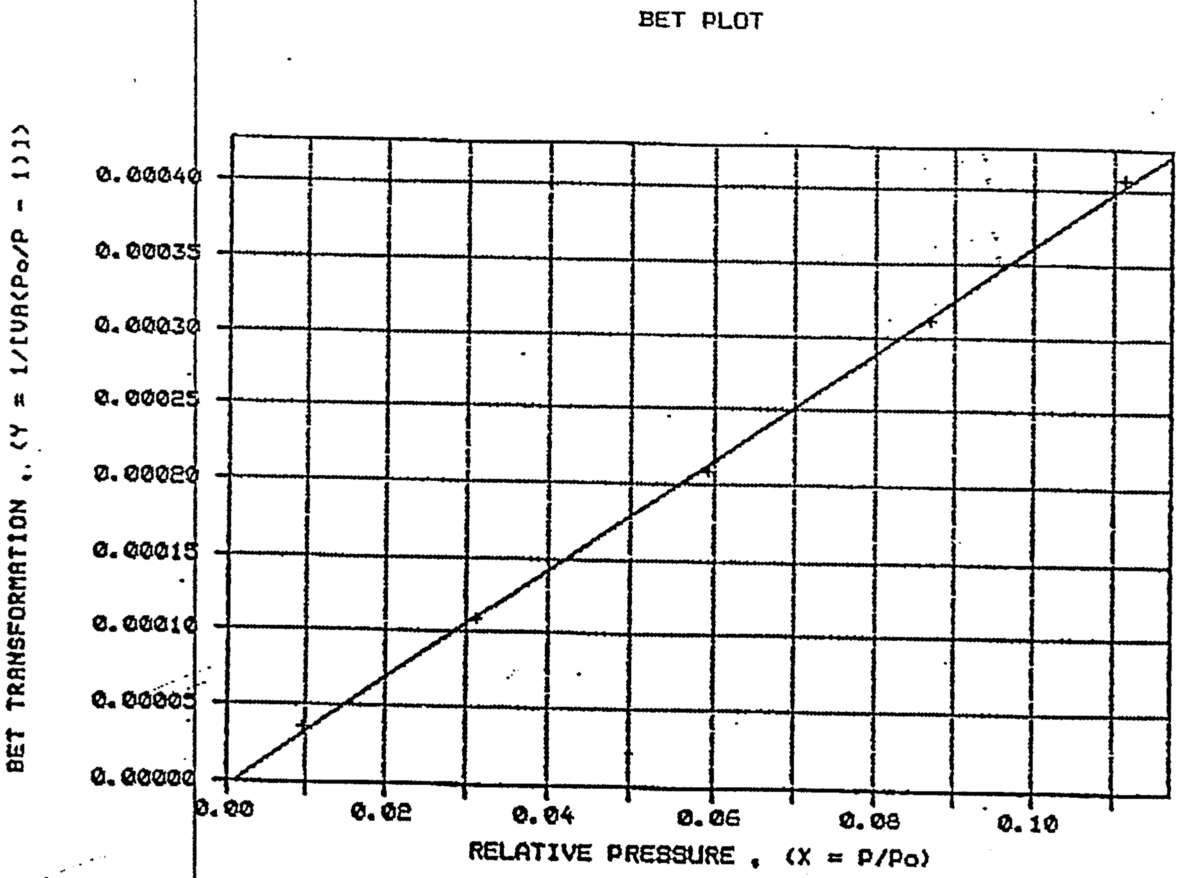
SAMPLE DIRECTORY/NUMBER: DATA1   /253              START 08:42:15 01/28/94
SAMPLE ID: ACC-10                                  COMPL 11:12:50 01/28/94
SUBMITTER: UNIVERSITY OF MANITOBA                  REPRT 11:12:51 01/28/94
OPERATOR: BW                                       SAMPLE WT:     0.0940 g
UNIT NUMBER: 1                                     FREE SPACE:  34.5179 cc
ANALYSIS GAS:  Nitrogen                            EQUIL INTRVL:      5 sec
```

ISOTHERM PLOT
+ ads, * des



```
                SURFACE AREA AND PORE STRUCTURE ANALYSIS
ASAP 2000 V2.02

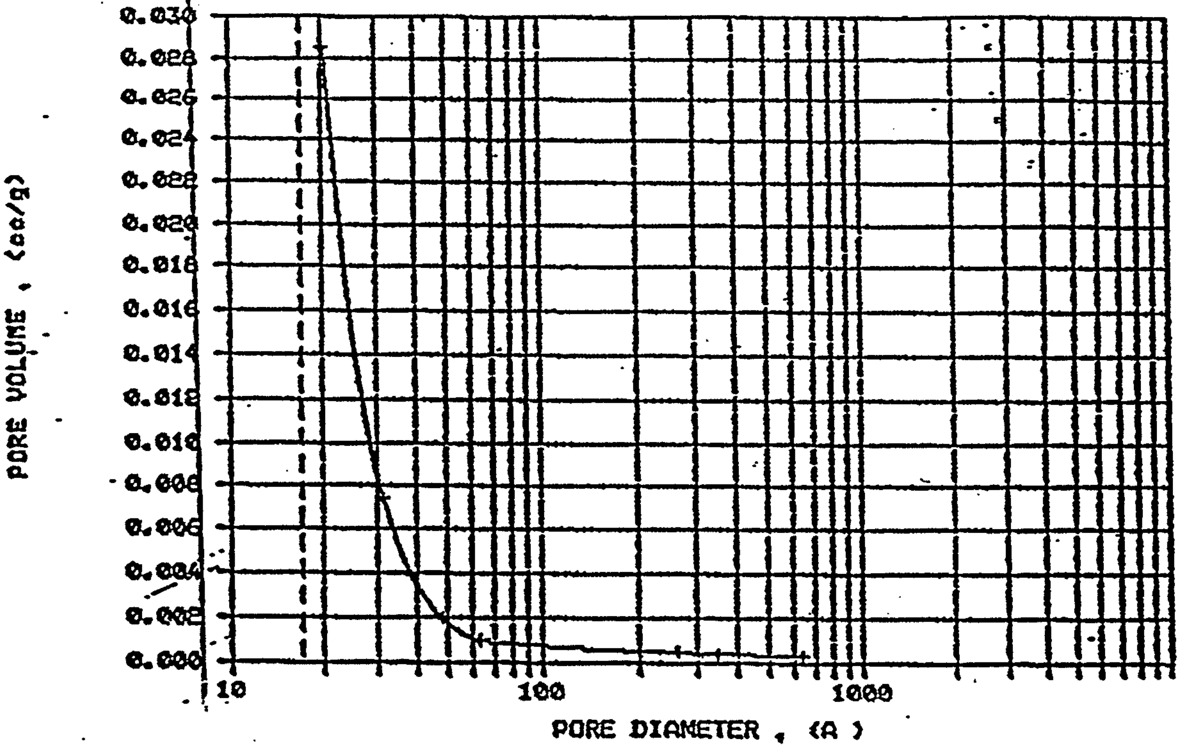
SAMPLE DIRECTORY/NUMBER: DATA1    /253
SAMPLE ID: ACC-10                                START 08:42:15 01/28/94
SUBMITTER: UNIVERSITY OF MANITOBA                COMPL 11:12:50 01/28/94
OPERATOR: BW                                     REPRT 11:12:51 01/28/94
UNIT NUMBER: 1                                   SAMPLE WT:    0.0940 g
ANALYSIS GAS:  Nitrogen                          FREE SPACE:  34.5179 cc
                                                 EQUIL INTRVL:       5 sec
```



```
                    SURFACE AREA AND PORE-STRUCTURE ANALYSIS
ASAP 2000 V2.02

SAMPLE DIRECTORY/NUMBER: DATA1    /253              START 08:42:15 01/28/94
SAMPLE ID: ACC-10                                   COMPL 11:12:50 01/28/94
SUBMITTER: UNIVERSITY OF MANITOBA                   REPRT 11:12:51 01/28/94
OPERATOR: BW                                        SAMPLE WT:    0.0940 g
UNIT NUMBER: 1                                      FREE SPACE:  34.5179 cc
ANALYSIS GAS:  Nitrogen                             EQUIL INTRVL:      5 sec
```

CUMULATIVE ADSORPTION PORE VOLUME PLOT



```
                 SURFACE AREA AND PORE STRUCTURE ANALYSIS
ASAP 2000 V2.02

SAMPLE DIRECTORY/NUMBER: DATA1    /253
SAMPLE ID: ACC-10                                        START 08:42:15 01/28/94
SUBMITTER: UNIVERSITY OF MANITOBA                        COMPL 11:12:50 01/28/94
OPERATOR: BW                                             REPRT 11:12:51 01/28/94
UNIT NUMBER: 1                                           SAMPLE WT:     0.0940 g
ANALYSIS GAS:  Nitrogen                                  FREE SPACE:  34.5179 cc
                                                         EQUIL INTRVL:      5 sec
                              SUMMARY REPORT

                                   AREA

BET SURFACE AREA:
                                                          1189.7175   sq. m/g
LANGMUIR SURFACE AREA:
                                                          1351.3383   sq. m/g
SINGLE POINT SURFACE AREA AT P/Po 0.1114:                 1187.5605   sq. m/g

BJH CUMULATIVE ADSORPTION SURFACE AREA OF PORES
 BETWEEN       17.0000 AND   3000.0000 A   DIAMETER:        43.4360   sq. m/g

BJH CUMULATIVE DESORPTION SURFACE AREA OF PORES
 BETWEEN       17.0000 AND   3000.0000 A   DIAMETER:        49.8577   sq. m/g


                                  VOLUME

SINGLE POINT TOTAL PORE VOLUME OF PORES LESS THAN
   1460.6007 A  DIAMETER AT P/Po 0.9866:                    0.490168 cc/g

BJH CUMULATIVE ADSORPTION PORE VOLUME OF PORES
 BETWEEN       17.0000 AND   3000.0000 A   DIAMETER:        0.028584 cc/g

BJH CUMULATIVE DESORPTION PORE VOLUME OF PORES
 BETWEEN       17.0000 AND   3000.0000 A   DIAMETER:        0.031328 cc/g


                                PORE SIZE

AVERAGE PORE DIAMETER (4V/A BY LANGMUIR):                  14.5091    A

BJH ADSORPTION AVERAGE PORE DIAMETER (4V/A):               26.3232    A

BJH DESORPTION AVERAGE PORE DIAMETER (4V/A):               25.1336    A
```

degas at 50°C for 48 h

APPENDIX B

THE TYPICAL VOLATILE ORGANIC COMPOUNDS MONITORED BY ACTIVATED CARBON CLOTH AND POLYURETHANE FOAM MONITORS

LIST OF THE VOLATILE ORGANIC COMPOUNDS MONITORED WITH ACTIVATED CARBON CLOTH IN THE AIR*.

Nonaromatic hydrocarbons

1. Trimethyldecane
2. 3-Carene
3. Limonene
4. Tetradecane
5. Hexadecane
6. Docosane
7. Heptadecane
8. 1-Nondecene
9. Trimethyloctane
10. Nonane
11. Decane
12. Methylundecane
13. Dimethylundecane
14. Trimethyldodecane
15. 4,4-Dimethyl-2-pentane
16. Octadecene
17. Hexadecene
18. 17-Pentatriacontene
19. Cyclohexane
20. Cyclohexene

* - From the tables 3.2.1 - 3.2.10, Appendix D, and numerous of analysis of industrial sites and households

Aromatic hydrocarbons

1. Benzene
2. Toluene
3. Xylenes
4. Trimethylbenzenes
5. Naphthalene
6. Ethylmethylbenzenes
7. Diethylbenzenes
8. 1-Ethyl-2,4-dimethylbenzene
9. Tetramethylbenzene
10. Methyl naphthalene
11. 1,1'-Biphenyl, 2,2'-diethyl

Compounds containing halogen or sulfur

1. Trichlorobenzene
2. Chlorooctadecane
3. Tetrachlorethylene
4. Dimethylsulfide
5. Dimethyltrisulfide
6. Diclorobenzene
7. Chlorohexadecane

Amines and compounds containing nitrogen

1. Methylbutyl hydroxylamine
2. Methylpirimidine
3. 3,5-Dimethyl-1-purazole
4. 2,6-Dimethylpurazine

5. *o*-Decyl hydroxylamine

Esters and compounds containing oxygen

1. Formaldehyde
2. Didecyl ester decandioic acid
3. Butyl octyl ester of 1,2-benzenedicarboxylic acid
4. Dimethylbutylcyclohexanol
5. Dimethylhexanal
6. Furanmethanol
7. 1,2-Ethandiol diacetate
8. 5-Methyl-2-furancarboxaldehyde
9. 2-Furanmethanol, acetate
10. Caffeine
11. Nonanal
12. Butyl-2-methylpropyl-1,2-benzenecarboxylic acid
13. Butyloctanol
14. Ethyldecanol
15. Benzophenone
16. Dimetoxyethylphtalate
17. Octanol
18. Cyclohexanol

Compounds containing silicon

1. Octamethylcyclotetrasiloxane
2. 2,5-Bis((trimethylsilyl)oxy) benzaldehyde
3. Trimethylsiloxybenzene

VOLATILE ORGANIC COMPOUNDS MONITORED WITH POLYURETHANE FOAM SAMPLERS.

Hydrocarbons

1. Benzene*
2. Toluene*
3. Xylenes*
4. 1,1'-Biphenyl, 2,2'-diethyl
5. 2,3-Dihydro-1,1,3-trimethyl-3-phenyl-1-indene
6. 3-Methyltridecane

* - Can be monitored only at high concentrations or very long time of expositure (approximately one month).

Compounds containing oxygen

1. Diethylphthalate
2. Dimethylethylphenol
3. Bis(2-methoxyethyl) ester, 1,2-benzenedicarboxylic acid
4. 1-Methoxy-3-(2-phenylmethyl)-benzene
5. 2,6-Bis(1,1-dimethyl)-4-methylphenol
6. 2-Phenoxyethanol
7. 1,3-Benzenediol monobenzoate
8. 2,3-Diclorobutyric acid
9. Isodecyloctyl ester 1,2-benzenedicarboxylic acid
10. Heptyl ester of nitric acid
11. 2-Butyl-1-octanol
12. Decanol

Compounds containing silicon

1. 1,3,5-Tris(trimethylsiloxy) benzene
2. Tris(trimethylsilyl) borate

APPENDIX C

LIBRARY SEARCH PARAMETERS FOR A MASS SPECTRAL ANALYSIS

TYPES OF LIBRARY SEARCH PROGRAMS FOR THE MASS - SPECTRA.

1. Fit Search.

A fit search measures the degree to which the library spectrum is included in the unknown spectrum. A fit of 1000 indicates that all library peaks occur as peaks in the unknown and that, for those common peaks, all intensities are exactly proportional. A high fit (800-900) with a lower purity (500-600) suggests that the unknown spectrum is a mixture that includes the compound selected from the library, or that the two compounds have some major substructure in common.

2. Reverse Fit Search.

The reverse fit search measures the degree to which the unknown spectrum is included in the library spectrum. A fit or reverse fit of 800 or more implies a close resemblance between the components. A value of 600 or more implies important shared structural features.

3. Purity Search.

A purity search measures the resemblance of the currently selected data to the specified library entry. A purity of 0 indicates no peaks in common and a purity of 1000 indicates identical mass lists and exactly proportional, locally normalized peak intensities. A purity of 800 suggests that the two compounds have closely related mass spectra. A purity of 600 or more suggests that the two compounds have many fragmented ions in common.

APPENDIX D

SAMPLES OF THE INDOOR AIR MONITORING FROM INDUSTRIAL AND HOUSEHOLD SITES.

DIRECTIONS FOR USE OF PASSIVE MONITORS.

Please read this completely before opening the self sealing polybag. Call Dr. H. D. Gesser at (204) 474-9893 or in evening (204) 489-9893 if you have any questions.

1. Do not handle the material unnecessarily. Use clean well rinsed hands.
2. First prepare the site for handling the samplers.
3. Open the polybag and gently remove the sampler.
4. Attach the sampler to support by means of a safety pin, tie wire string or other mean.
5. Record the sample number, date and time starting of exposure and leave for at least a week of regular normal conditions.
6. After the appropriate time, record the date and time when the sampler is returned to the same polybag. DO NOT include the pin, tie wire or string.
7. Return polybag containing the sampler to Dr. H. D. Gesser, Department of Chemistry, University of Manitoba, Winnipeg, Manitoba, R3T 2N2.

Tear of this part and enclose in envelope provided.

Sample #____ Name of Person______________

Telephone___________ Address____________________________

____

Sampling started at Location ________________________________

hall, kitchen, office, basement, etc.

Please indicate type of floor covering (carpet, hardwood, etc.), heating system (gas, electrical, etc.) and if anyone smokes in the house.

____

____

Date______________ Time_________________

Sampling stopped:

Date______________ Time_________________

Do you have any health problem related to the indoor air quality or any reason to believe that the air in your home or office can be contaminated.

____

____

Application Form.

Yes I am interested in having my office/home tested for air pollutants.

Name___________________________

Address_________________________

Telephone # home______________
bus. ______________

The reason I have for suspecting an air problem is:

____
____
____
____
____
____
____
____
____
____

Mr. Steven Rowat
1-16 Beckwith Ave
Ottawa, Ontario
K1S 0K7

February 21, 1994

Dear Mr. Rowart

Enclosed are the results of the analysis of the monitors exposed in your apartment. Both kitchen/living room and bedroom in your apartment contain the same organic contaminants listed in the Table 1.

There are no substantial differences between concentrations of volatile organic compounds in the kitchen/living room and bedroom which will allow us to locate the source of contamination. That is probably due to good air mixing in the apartment.

Also all compounds found in your home have been detected in other homes at comparable concentrations.

Compounds 1-13 are always present in indoor air and originate from car exhaust and cooking activities. The automobile exhaust in the home can be reduced by having an outside air intake to the furnace area. I suggest that you or your landlord get professional help here to reduce the air infiltration to your apartment.

It would be helpful check the carpet for dust mite which are believed to cause allergic reactions. A radon test at your home may also be desirable because a high radon concentration is claimed by some sources cause weakness of immune system.

I hope this has been of some help to you.

Sincerely

Dr. H.D. Gesser & E. Giller

cc: CHMC

Table 1. Volatile organic compounds in the kitchen/living room and bedroom of the Mr. S. Rowart apartment.

#	Retention time (sec)	Compound	Monitor
1.	177	Benzene	ACC
2.	339	Toluene	ACC
3.	383	*p*-Xylene	ACC
4.	467	*m*-Xylene	ACC
5.	785	4,5-dimethylnonane	ACC
6.	977	Trimethylbenzene	ACC
7.	1152	2,6,10.15-Tetramethylheptadecane	ACC
8.	1314	3,5,24-Trimethyltetracontane	ACC
9.	1404	2,6,10,15-Tetramethylheptadecane	ACC
10.	1409	5-Dicyclohexyl-tridecane	ACC
11.	1463	Tritetracontane	ACC
132	1763	Tetramethylhexadecane	ACC

Ms. Kathy Munro
1609 Donald B. Munro Dr.
Carp, Ontario.
K0A 1L0

Feb. 21, 1994

Dear Ms. Kathy Munro

Enclosed are the results of the analysis of the monitors exposed in your house. Both basement and bedroom in your house contain the same organic contaminants listed in the Table 1.

Concentrations of organic contaminants relatively higher in the basement. It can be caused by differences in the air exchange or the source of contamination (possible heating system) could be in the basement.

Also all compounds found in your home have been detected in other homes at comparable concentrations.

Compounds 1 - 10,14,15 are always present in indoor air and originated from car exhaust and cooking activities. The automobile exhaust in the home can be reduced by having an outside air intake to the furnace area. I suggest that you get professional help here to reduce the air infiltration to your home.

Compounds 11,12,13 are usually emitted by all carpets and some plastics and the rate of emission slightly increases with the age of the carpet.

Also, compound containing silicon (16) had been found in other households possible originated from stain resistant coating.

It would be helpful check the carpet for dust mite which are believed to cause allergic reactions. A radon test at your home may also be desirable because a high radon concentration is claimed by some sources cause weakness of immune system.

I hope this has been of some help to you.

Sincerely

Dr. H.D. Gesser & E. Giller

cc: CHMC

Table 1. Volatile organic compounds in the bedroom and dining room of the Ms. Munro house.

#	Retention time (sec)	Compound	Monitor
1.	GC	Toluene	ACC
2.	GC	*m*-Xylene	ACC
3.	GC	*p*-Xylene	ACC
4.	684	1-methyl-5-methylethyl-cyclohexene	ACC
5.	768	Hexadecene	ACC
6.	908	6-methyl-tridecane	ACC
7.	1156	Tridecanol	ACC
8.	1268	4,5- dimethylnonane	ACC
9.	1368	Methylcyclodecane	ACC
10.	1416	Dodecylcyclohexanol	ACC
11.	1464	Ethanol, 2-phenoxy, benzoate	ACC, PUF
12.	1508	1,1'-biphenyl, 2,2'-diethyl	ACC, PUF
13.	1552	Dimethoxyethyl phthalate	ACC, PUF
14	2052	2-methyl eicosane	ACC
15	2248	3-Methyl nonadecane	ACC
16	2552	Octamethyl cyclotetrasiloxane	ACC, PUF

Ms. Judith Spence
536 Dovercourt Ave.,
Ottawa, Ontario,
K2A 0T9

Feb. 21, 1994

Dear Ms. Spence

Enclosed are the results of the analysis of the monitors exposed in your house. Both kitchen and living room in your house contain the same organic contaminants listed in the Table 1.

Concentration of the compounds 1-4 approximately 2.5-3 times higher in the kitchen than in the living room.

Compounds 1-4, 6-10 are hydrocarbons usually originate from car exhaust or cooking activities, but your home contained high concentration of the unsaturated hydrocarbons. It possible could be caused by insufficient combustion or leaks in the gas furnace or pilot light from the gas stove (if you have one). The automobile exhaust and hydrocarbons content in the home can be reduced by having an outside air intake to the furnace area. I suggest that you get professional help here to reduce the air infiltration to your home.

Compound 5 possibly originated from stain resistant coating.

It would be helpful check the carpet for dust mite which are believed to cause allergic reactions. A radon test at your home may also be desirable because a high radon concentration is claimed by some sources cause weakness of immune system.

I hope this has been of some help to you.

Sincerely

Dr. H.D. Gesser & E. Giller

cc: CHMC

Table 1. Volatile organic compounds in the kitchen and livning room of the Ms. Spence house.

#	Retention time (sec)	Compound
1.	GC	Toluene
2.	GC	*m*-Xylene
3.	GC	*p*-Xylene
4.	637	4-ethenyl-1,4-dimethylcyclohexane
5.	745	2,5-bis(trimethylsylyl) benzaldehyde
6.	967	2,6,8-trimethyldecane
7.	1009	17-pentatriacontene
8.	1035	3-octadecene
9.	1097	3-hexadecene
10.	1125	3,5,24-trimethyltetracontane

Mr. Tom Gouldsborough
343 Cordova St.
Winnipeg, Manitoba
R3N 1A5

March 25, 1994

Dear Mr. Tom Gouldsborough

Enclosed are the results of the analysis of the monitors exposed in your house. All location tested show very low concentrations of organic contaminants listed in the Table 1.

Concentrations of organic contaminants relatively higher in the basement but still two to five times lower than average contamination in the houses tested in Winnipeg. Also all compounds found in your home have been detected in other homes at comparable or even higher concentrations.

All compounds are always present in indoor air and originated from car exhaust and cooking activities.

It would be helpful check the home for fungus, mold and mite which are believed to cause allergic reactions. A radon test at your home may also be desirable because a high radon concentration is claimed by some sources cause weakness of immune system.

I hope this has been of some help to you.

Sincerely

Dr. H.D. Gesser & E. Giller

Table 1. Volatile organic compounds in the bedroom and dining room of the Mr. Tom Gouldsborough house.

#	Retention time (sec)	Compound
1	GC*	Benzene
2	GC*	Toluene
3	814	2,4,6-trimethyloctane
4	896	3,3-dimethylhexane
5	978	2,6,6-trimethyldecane
6	1055	2,7-dimethylundecane

* - compounds were determined by gas chromatograph with a flame ionization detector

Mr. and Mrs. Litz
27 Dumbarton Blvd.
Winnipeg, MB
R3P 2C7

Apr. 7, 1994

Dear Mr. & Mrs. Litz,

Enclosed are the results of the analysis of the monitors exposed in your house. Indoor air from the pool area contained the organic contaminants listed in the Table 1.

Also all compounds found in your home have been detected in other homes at comparable but usually at lower concentrations.

Compounds 1-4,6-10 are always present in indoor air and originated from car exhaust and cooking activities, as well as natural gas stoves. The concentration of these compounds in the home can be reduced by having an outside air intake to the furnace area. I suggest that you get professional help here to reduce the air infiltration to your house.

Compound 5 can be found in a furniture polishing oils and has not been known to be harmful to your health.

It would be helpful check the carpet for dust mite which are believed to cause allergic reactions. A radon test at your home may also be desirable because a high radon concentration is claimed by some sources cause weakness of immune system.

I hope this has been of some help to you.

Sincerely

Dr. H.D. Gesser & E. Giller

Table 1 Volatile organic compounds in the indoor pool area of the Mr. & Mrs. Litz house.

#	Retention time (sec)	Compound
1.	688	3-carene
2.	726	Ethyl methylbenzene
3.	778	Trimethylbenzene
4.	924	2,5,6-Trimethyldecane
5.	980	Bis-(Trimethylsilyl)oxy-benzaldehyde
6.	1054	2,6,7-Trimethyldecane
7.	1174	2,4,6-Trimethyloctane
8.	1284	2,6,8-Trimethyldecane
9.	1384	4,7-Undecane
10.	1478	Octacosane

Mr. Rick A. Gutwein
CCL Label
80 Paramount Road
Winnipeg, MB
R3X 2W3

Apr. 7, 1994

Dear Mr. Gutwein

Enclosed are the results of the analysis of the monitors exposed in the arts and accounting departments of your company. Indoor air from both departments contains the same organic contaminants are listed in the Table 1.

Also most of all compounds found in your company have been detected in other industrial sites and homes at comparable but usually at lower concentrations.

Compounds 1-12,14,15,17-20, 22,23,25 are saturated hydrocarbons and often present in indoor air and originated from car exhaust, office equipment, ink, etc.

Compound 13 can be found in a furniture polishing oils and has not been known to be harmful to your health.

Origin of the compound 16 is unknown.

Compounds 21,24,26 are commonly used as a plasticizers.

High concentration of hydrocarbons can be explained by having some problem with ventilation. I suggest that you get professional help here from Appin Associates or other engineering company.

I hope this has been of some help to you.

Sincerely

Dr. H.D. Gesser & E. Giller

Table 1. Volatile organic compounds found in the indoor air of CCL Label.

#	Retention time (sec)	Compound
1.	235	Toluene
2.	491	2,4,6- trimethyloctane
3.	589	2,3,7- trimethyloctane
4.	596	5-methylundecene
6.	616	α-pinene
7.	661	2,5-dimethyloctane
8.	680	Ethylmethylbenzene
9.	702	1,3,5-Trimethylbenzene
10.	764	Decane
11.	772	1,2,4-Trimethylbenzene
12.	882	2,6-dimethylnonane
13.	865	D-limonene
14.	1019	4,6-dimethyldodecane
15.	1066	2,7,10-trimethyldodecane
16.	1194	Ethanone ,1-(4-hydroxyphenyl)
17.	1247	6-methyltridecane
18.	1504	Indene, octahydrohexamethyl
19.	1531	3,5-octadiene, 4,5-diethyl, 3,6-dimethyl
20.	1630	4-methylundecene
21.	1744	Phenol, 2,6-bis(1,1-dimethylethyl)-4-methyl
22.	1795	2,6,11-trimethyldodecane
23.	1950	Trimethyltetracontane
24.	2047	Benzophenone
25.	2094	Trimethyltetracontane (isomer)
26.	2151	1,1'-biphenyl, 2,2'-diethyl

Mrs. Elisabet Gage
Entertainment Publication
595 Jackson Ave.
Winnipeg, MB
R3M 2J2

March 16, 1994

Dear Mrs. Gage

Enclosed are the results of the analysis of the monitors exposed in your company office. Indoor air from the office area contains the organic contaminants listed in the Table 1. Also, all compounds found in your office have been detected in other homes and industrial sites at comparable but usually at lower concentrations. All these compounds are hydrocarbons and they always present in indoor air and originated from car exhaust, cooking activities, natural gas heating systems, furniture varnish,paint, etc.

The concentration of these compounds in the home can be reduced by having an outside air intake to the furnace area. I suggest that you get professional help here to reduce the air infiltration to your house. It would be helpful check the carpet for dust mite which are believed to cause allergic reactions.

I hope this has been of some help to you.

Sincerely

Dr. H.D. Gesser & E. Giller

Table 1. Volatile organic compounds found in the office of Entertainment Publication.

#	Retention time (sec)	Compound
1.	587	*o*-xylene
2.	621	2,5,6-trimethyldecane
3.	669	2,2,3,4-tetramethylpentane
4.	675	3-octadecene
5.	683	3-hexadecene
6.	713	2,4,6-trimethyloctane
7.	735	2,5,6-trimethyldecane
8.	773	2,5,9-trimethyldecane
9.	811	2,6,8-trimethyldecane
10.	835	17-pentatriacontene
11.	863	3,5,24-trimethyltriacontane
12.	879	2,2,3,3-tetramethylhexane
13.	923	4,7-dimethylundecane
14.	1051	3-octadecene
15.	1283	2,7-dimethyloctane

Mr. Leo Sichewski
Petro Canada
P.O. Box 189
St. Norbert,
Winnipeg, MB,
R3V 1L6

Apr. 17, 1994

Dear Mr. L. Sichevski

Enclosed are the results of the analysis of the monitors exposed in the lunch room of your company. Indoor air contains following organic contaminants are listed in the Table 1.

Also most of all compounds found in your company have been detected in other industrial sites and homes at comparable concentrations.

Compounds 1, 3-9 are saturated hydrocarbons and often present in indoor air and originated from car exhaust, office equipment, ink, etc.

Compound 2 - dichlorobenzene is a solvent and it can be found in an industrial cleaners.

Compounds 10,11 are commonly used as a plasticizers.

I hope this has been of some help to you.

Sincerely

Dr. H.D. Gesser & E. Giller

Table 1. Volatile organic compounds found in the indoor air of the Petro Canada Building.

#	Retention time (sec)	Compound
1.	786	2,5,6-trimethyldecane
2.	826	1,2-dichlorobenzene
3.	848	limonene
4.	938	4,7-trimethylundecane
6.	1080	2,6,8-trimethyldecane
7.	1208	2,4,6-trimethyloctane
8.	1322	2,5-dimethylnonane
9.	1428	tetramethylhexane
10.	1545	diethylphtalate
11.	1664	1,1'-biphenil, 2,2'-diethyl

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