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MASTER

NEW INSTRUMENTS FOR PLANT AREA AND PERSONNEL MONITORING

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ABSTRACT

Advances in portable monitoring instruments and simple luminescence techniques for analyzing PNAs are reported. A small, derivative ultra-violet absorption spectrometer is suitable for multipollutant real-time monitoring of several mono- and bicyclic aromatic vapors. A non-compound selective fluorescence spill spotter and lightpipe luminoscope are active instruments for measuring general surface and skin contamination, respectively. A small, passive, integrating, filter paper exposure device that responds to PNA vapors such a pyrene, is a very promising and recent development. Synchronous luminescence and room temperture phosphorescence are two attractive and simple to use analytical methodologies for the rapid assaying of major PNA compounds. Their potential for analyzing the cyclohexane extract of particulate matter, or incorporation into a device for the continuous monitoring of select PNAs in aerosols in near-real-time, are discussed.

1. INTRODUCTION

In 1978, a paper was published by the authors entitled "A New Generation of Monitors for Polynuclear Aromatic Hydrocarbons (PNAs) from Synthetic Fuel Production" [1]. Coal gasification was one of the technologies being considered. An object of this paper is to summarize the advances in portable monitoring instruments that have occurred in the interim period.

This work was, and still is, a response to a lack of suitable tools for making industrial hygiene measurements on certain of the pollutants produced in synfuel technologies. The greatest practical need is for measurement of PNAs.

Exposure of workers to this important class of compounds can occur principally through the exposure pathways of inhalation of

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vapors and particulate matter, and the soiling of the skin by direct contact with dirty objects or condensation of fine droplets.

To evaluate such exposures in the workplace, the industrial hygienist has available to him only two methods that are used on a routine basis:

1. Benzene [2] or cyclohexane solubles [3] within airborne particulate matter.

2. Observation of gross fluorescence from UV irradiation of the skin.

These two methods are crude and non-PNA specific. Our efforts to expand this capability include instruments and devices that are portable, easy and safe to operate, and provide more quantitative information on exposures to specific PNAs. Application to each of the principal exposure pathways is addressed.

Only the basic operating principles of each type of instrument will be given. References are included for those interested in the details. Emphasis is placed instead on operational data taken in the field. The intention is to highlight for the reader the capabilities, advantages and drawbacks of each technique and the type of information being extracted from samples of oil and tar.

2. INSTRUMENTS AND TECHNIQUES

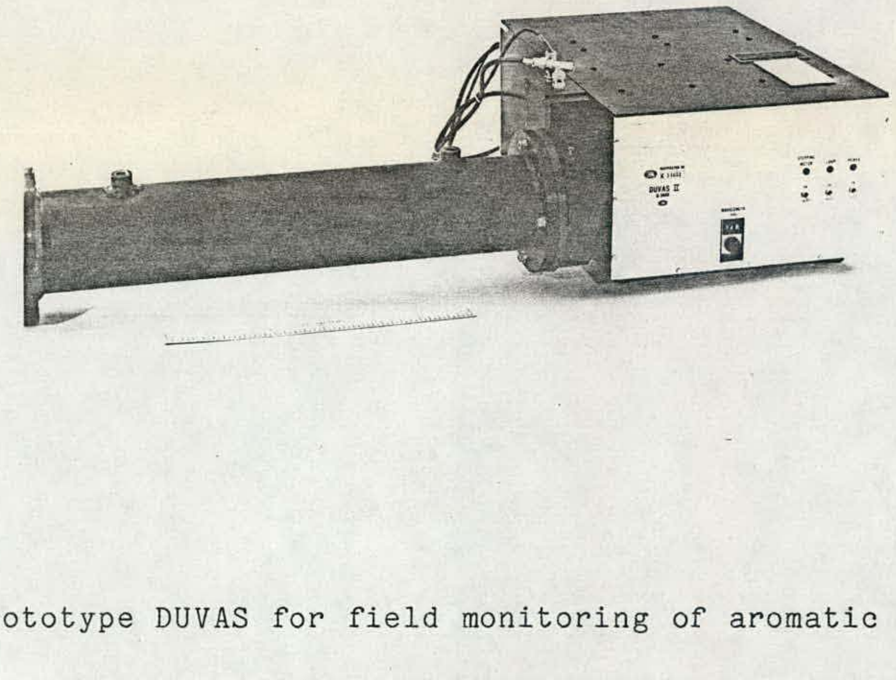

Fig.1. Prototype DUVAS for field monitoring of aromatic vapors.

2 R to [illegible]

2.1 Vapors

DUVAS. A second-derivative ultra-violet absorption spectrometer [4][5][6], with the acronym DUVAS, has been designed for the real-time monitoring of a number of aromatic vapors. Now in an advanced stage of development, its form and size are shown in Fig. 1.

The basic advantage compared to direct, or zero-derivative, absorption measurements is enhanced compound selectivity. Sharp spectral features are enhanced at the expense of broad peaks that become reduced in intensity. For example, naphthalene possesses sharp absorption bands in the ultra-violet region and it can readily be monitored at concentrations of only a few ppb in mixtures of other organic vapors.

The instrument has been used both as a leak detector and an area monitor. Compounds that have been detected in oil and tar vapors include benzene, phenol, p-cresol, naphthalene, methylnaphthalenes, and indan.

Passive integrating PNA vapor monitor. Presently under development is a small passive device that can easily be worn on the

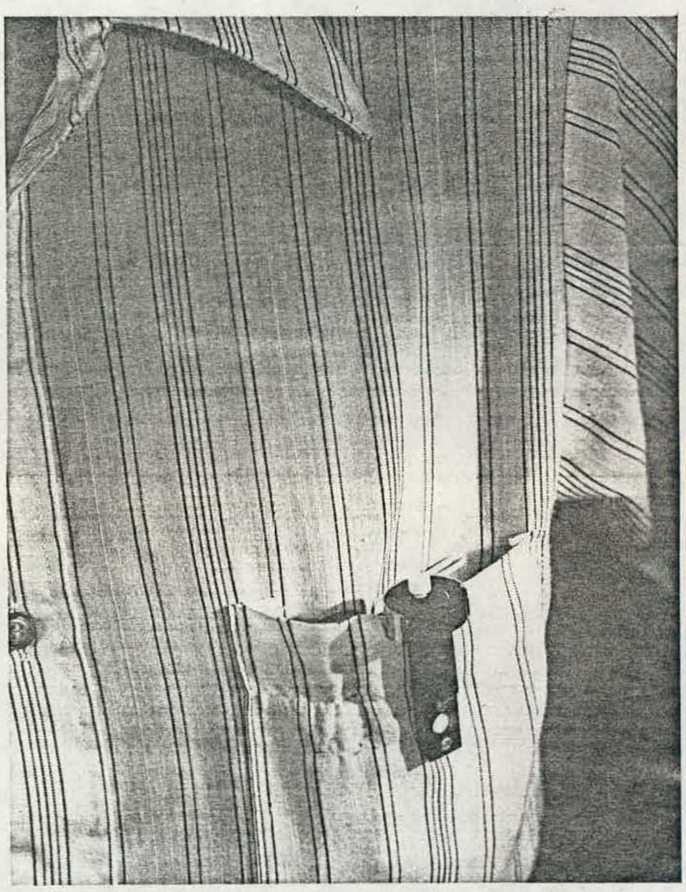

Fig. 2. Pocket meter formeasuring exposure to PNA vapors such as pyrene.

pocket as a personnel exposure meter (Fig. 2.). It is simply a holder for a disk of filter paper that adsorbs PNA vapors from the air. Active charcoal is placed behind the filter paper to act as a sink for all PNA vapors, and to produce a concentration gradient for drawing these vapors through the filter paper [7].

Room temperature phosphorescence [8][9] is the analytical technique used to identify and quantify select PNA vapors such as phenanthrene, fluoranthene and pyrene. The filter paper is pretreated with different heavy-atom salts for enhancement of the phosphorescence from select PNAs [10]. The luminescence spectra can also be recorded synchronously [11] for additional compound selectivity.

The technique is quite simple and easy to use. The holder shown in Fig. 2 fits directly into a phosphorescence spectrometer. The PNAs attached to the heavy-atom impregnated paper can then be analyzed directly.

For obtaining a reproducible sampling rate that is diffusion controlled, an appropriate honeycomb insert could be fitted in front of the filter paper. The passive sampling device marketed by Dupont [12] seems to be appropriate for this purpose.

2.2 Surface Contamination

Spill spotter. Designed as a replacement for the hand-held black lamp, the spotter is a portable, ultra-violet irradiation

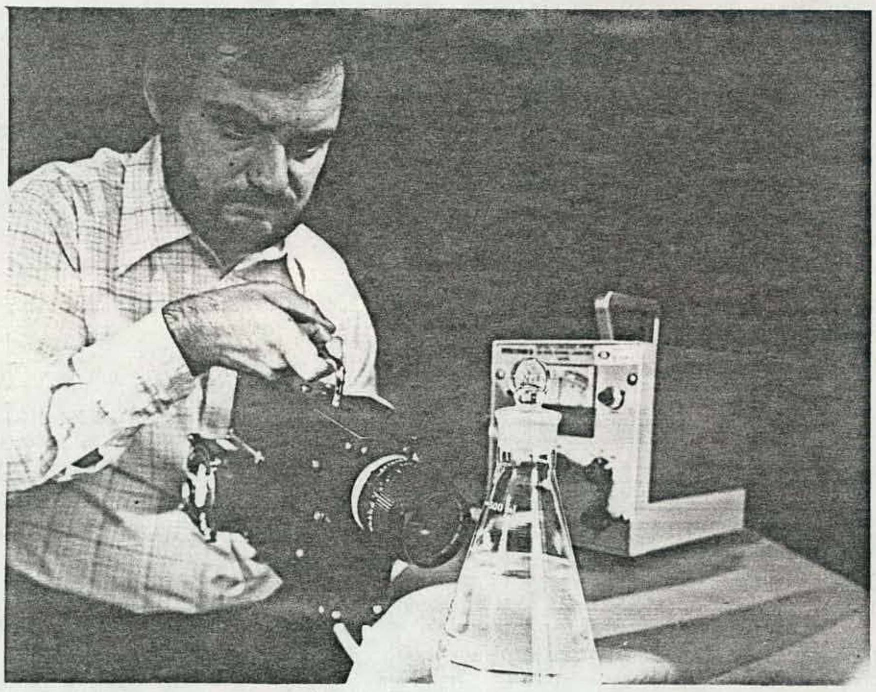

Fig.3. Fluorescence spill spotter for general surface contamination.

source and fluorescence detector (Fig. 3) for oil and tar spills. The collimated beam of illuminating light is modulated at 1 KHz. The returning, modulated fluorescent light is detected, demodulated and filtered. This permits discrimination against background illumination from other sources such as fluorescent room lights, or sunlight. Unlike the hand-held black lamp where weakly fluorescing sources of contamination have to be observed in the dark, the spill spotter can be operated under virtually any lighting conditions.

The fluorescence spotter is another instrument in an advanced stage of development and its developer was the recipient of a recent IR-100 award [14]. Although its suitability for work-area surface monitoring, and its attributes of high sensitivity and remote detection capability have already been demonstrated in coal conversion plants [15], there is one serious limitation. Limited spectral discrimination is inadequate for detection of specific PNA compounds. The light for the excitation and the fluorescence are each selected by choice of broadband optical filters. While the filter selection is appropriate to the class of compounds being monitored, the measurement is essentially one of the gross fluorescence intensity over a fairly wide spectral range. Little specific spectral information is forthcoming.

Lightpipe Luminoscope. As with the spill spotter, the lightpipe luminoscope [16-18] is an ultra-violet source of illumination, and a collector and detector of the resultant fluorescence (Fig. 4). It suffers from the same drawback as the spill spotter namely a lack of PNA compound selectivity. Its purpose and

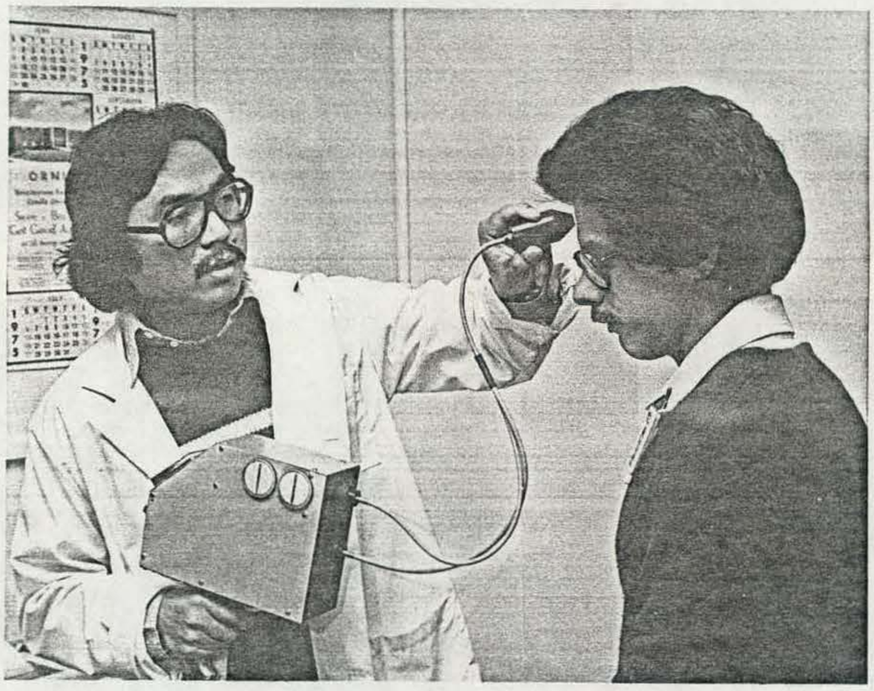

Fig.4. Fiber-optics lightpipe luminoscope for monitoring fluorescent skin contamination.

mechanics of operation are, however, substantially different from those of the spill spotter. The primary function of the lightpipe luminoscope is to detect and measure small amounts of fluorescent contamination on the skin.

At one time, an area of skin of approximately 1 cm^2 is illuminated and monitored under a stethescopic head pressed against the skin. The transmission of light is through a flexible, bifurcated fiber-optics light-guide. Because the measurement is conducted in the dark enclosure of the stethoscopic cap, there are no inferences from other light sources. Hence, there is no need for modulation of the light beam, as is the case for the spill spotter. This factor permits a considerable reduction in the complexity of the instrumentation.

To minimize the effects of direct toxicity of near ultraviolet light on the skin, as well as possible phototoxifying effects of ultra-violet light on the PNA compounds [19], the light intensity of the excitation is reduced to a low level. The results to be shown are for an intensity 1/100th that of direct sunlight in the wavelength region of 320-400 nm.

2.3 Airborne Particulate Matter

Much of the monitoring of PNA bearing materials in the workplace has been conducted on airborne particulate matter, usually in the form known as coal tar pitch volatiles. The gravimetrically measured benzene or cyclohexane soluble fraction of total particulate matter [2][3] is a supposed index of the potential health hazard to particles in the respirable size range. The recommended standard for cyclohexane extracts is 0.1 mg/m^3 of air [3]. This limit is based upon the smallest weight of material that can be reliably extracted and weighed, given the limitations of currently available sampling pumps. The method has the serious deficiency of being non-compound specific.

In a review of the analytical methods for measurement of coal tar pitch exposures, Schulte et. al. [20] stated that it was desirable to find a new analytical method. This was principally because the benzene solubles method is non-specific, analyzing for all compounds soluble in benzene. Cyclohexane is now considered a more desirable solvent because of the toxicity of benzene. These authors also felt that a method specific for certain compounds or classes of compounds was needed.

New real-time PNA particulate monitor. A system for area monitoring of select PNA compounds in airborne particles is still in the preliminary stages of development. This new approach to monitoring is in partial response to Schulte et. al.[20], who pointed out the need for a more compound specific method. The problem is a difficult one to solve but because of its importance, our limited efforts to date will be reported.

A rough prototype is under construction that uses the following components. Air is pumped through a fiberglass filter to extract particulate matter. Several options are available for the extraction of PNAs from the particles. In one method a stream of hot nitrogen gas will be directed at the filter to evaporate the PNA compounds in the outer layers of the particles. The PNA vapors are subsequently condensed downstream on a tape of filter paper treated with heavy-atoms to solicit phosphorescence at room temperature in the following and final step of the analysis. The unit is designed to operate automatically under microprocessor control. The compounds capable of being analyzed are similar to those monitored by the passive filter paper device described in section 2.1.

Luminescence analysis of cyclohexane extract. One of our future projects will be to apply fairly simple methods of luminescence spectroscopy to the cyclohexane extract of particulate matter. The object is to gain specific information on one or more PNA compounds.

Several real-life samples of complex PNAs in ultra-violet transparent solvents have already been analyzed successfully. Two luminescence techniques are used; synchronous fluorescence (SF) of solutions at room temperature [21][22], and the already mentioned room temperature phosphorescence (RTP) from solutions spotted on filter paper treated with a heavy-atom [10][11].

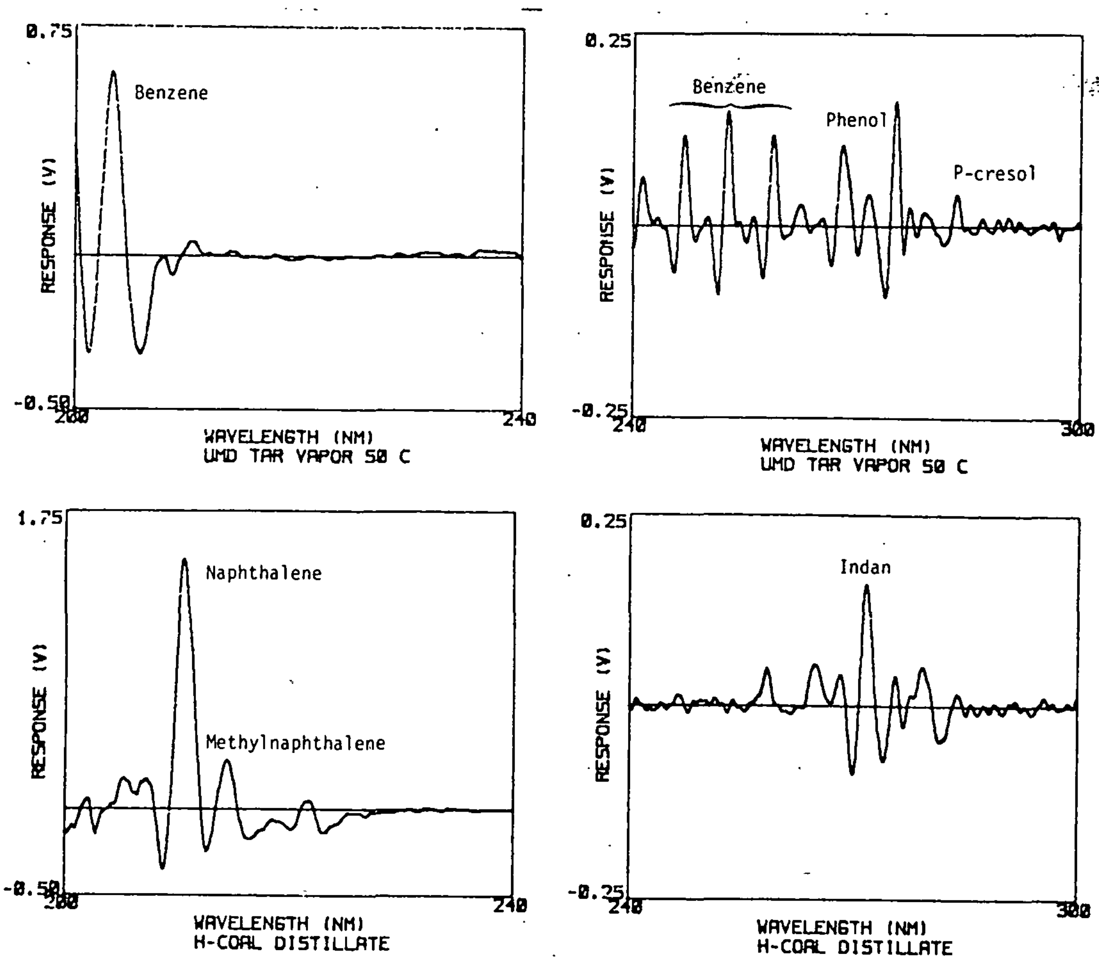

Fig.5. Spectral fingerprints of aromatic compounds in oil and tar vapors.

The PNA solutions require little or no fractionation prior to luminescence analysis. Avoidance of fractionation considerably enhances the attractiveness of SF and RTP techniques for rapid screening analysis of a small number of the major PNA compounds.

3. RESULTS

3.1 Aromatic Vapors

DUVAS. A variety of coal conversion and shale oil products have been examined in the laboratory for the aromatic vapors that they emit. The spectra recorded by the DUVAS in the wavelength range of 200-300 nm are gratifyingly simple for the purposes of compound identification and quantitation.

Characteristic signatures are obtained from different kinds of products. Examples are shown in Figure 5. Tar from a low-Btu coal gasifier at the University of Minnesota - Duluth (UMD) contains entrained benzene and phenol. The spectral fingerprints of these two compounds are dominant. A heavy distillate produced by an H-Coal liquefaction plant gives a different signature. The most prominent peaks from the vapors are caused by naphthalene and indan.

The DUVAS is demonstrably useful for detecting the vapors of

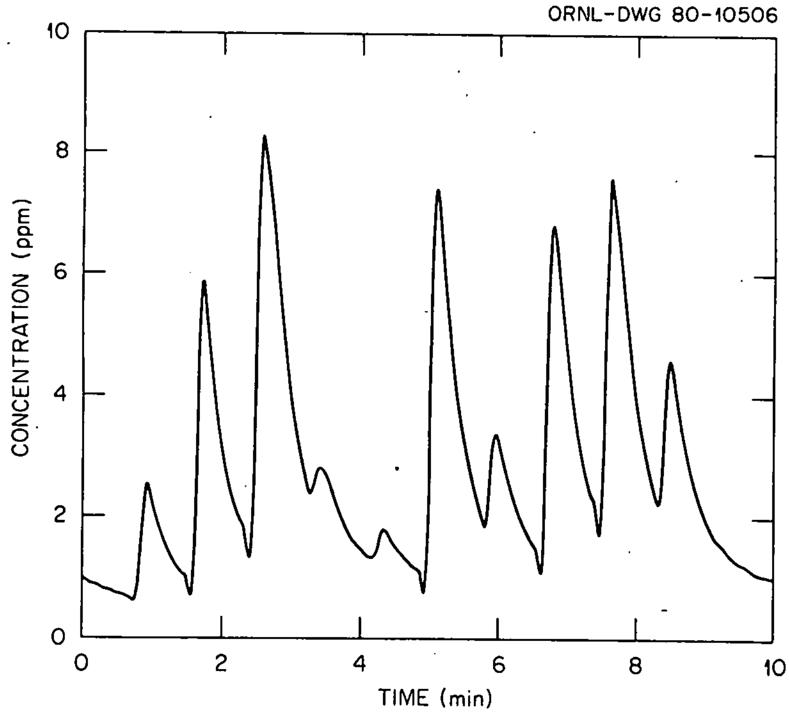

Fig.6. Benzene fugitive emissions with each opening of the knife valves of the UMD gasifier.

certain volatile, mono- and bicyclic aromatic compounds. The device can be used to assess vapor concentrations in different parts of a plant, either as a survey instrument, an area monitor, or as a leak detector. In the latter capacity, the DUVAS was able to monitor (Figure 6) the tarry fumes leaking from a series of knife valves through which coal was being injected into the reactor of a low-Btu coal gasifier[6]. The instrument was operated in the dwell mode at the wavelength corresponding to the main peak of benzene. The tarry fumes, as indicated by the concentration of benzene vapor, rise and fall in synchronization with the opening and closing of the valves.

Filter paper monitor. This device has been subjected to only very preliminary testing, but the results have been most encouraging. It was found that exposure of filter paper to the vapors of pyrene crystals in a closed vessel for between 1 and 10 hours produces a characteristic RTP signal. Furthermore, the intensity of the RTP increases linearly with the time of exposure. There exists, therefore, the potential for quantifying exposures to specific PNA vapors in units of equilibrium vapor concentration x hours.

This monitoring device was field tested at a coal conversion pilot plant. Several devices were located in various parts of the plant in the open atmosphere. Some locations were obviously more dirty than others. One area where spillage had occurred produced the strong response shown in Figure 7. The PNA compound responsible for this RTP signal is pyrene.

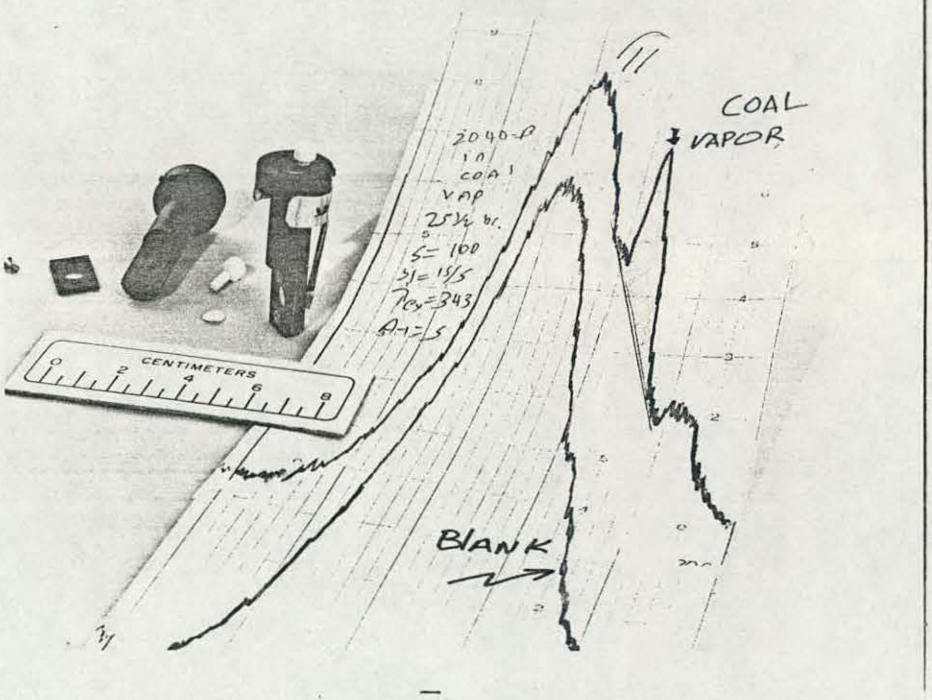

Fig.7. Detection by RTP of pyrene collected by a passive filter monitor at a coal conversion pilot plant.

Preliminary indications are that the single filter paper monitors can be used as collection devices to evaluate potential exposures to condensing PNA vapors or fine droplets. The devices can be used either as area or personnel monitors. The analysis by RTP is also very sensitive. Previous studies [10] established that the lower limits of sensitivity for a large number of PNA compounds were in the sub-nanogram region.

3.2 Surface Contamination

Spill spotter. The spill spotter has been field tested at a number of coal conversion facilities. One of these was a low-Btu coal gasifier at the University of Minnesota at Duluth (UMD). Measurements were taken on obviously contaminated and also on apparently uncontaminated surfaces. The objective was to determine the sensitivity of the spotter for detecting low-level buildup of tar condensation as well as obvious contamination caused by spills and leaks. A few of these measurements are listed in Table 1.

TABLE 1. CONTAMINATION AROUND THE ELECTROSTATIC PRECIPITATOR

	Apparent Contamination ($\mu g/cm^2$)	
1. Drain pipe from electrostatic precipitator (ESP)	2.3	Pipe is visibly contaminated
2. Same as 1, but after application of $MeCl_2$ cleaner	>11.7	Pipe is visibly contaminated
3. Another area on drain pipe	0.0	
4. Same as 3, but after application of $MeCl_2$ cleaner	0.9	Not visibly contaminated, but apparently some condensation on it
5. Electrostatic Precipitator body (aluminum sheet)	1.2	Not visibly contaminated
6. Same as 5, but after application of $MeCl_2$ cleaner	5.8	Not visibly contaminated

The contamination levels are given in units of apparent micrograms of UMD tar per cm^2 of surface area. The point calibration standard was a disk of optical cement loaded with 10 ppm by weight of UMD tar. The amount of quenching associated with these measurements is unknown; this is usually the norm. Hence the ability to quantify surface contamination is generally not very good. The instrument, however, is ideal for the qualitative spotting of contamination.

In general, measurements were taken on and around the ESP before and after the application of a commercially available methylene chloride based paint stripper. Such a stripper is used in clean-up operations.

Solvation of the surface contamination reduces quenching and enhances the fluorescent intensity. Even contamination too small to be seen with the naked eye becomes readily detectable with the spotter. The spotter will have obvious uses in defining the boundaries of a spill and in judging the effectiveness of a cleanup operation.

TABLE 2.—AREA AND EQUIPMENT MEASUREMENTS AT AN OPERATING COAL LIQUEFACTION PILOT PLANT

Entry	Location	Contamination (μg/cm)	Comments
1	LR floor	1.3-4.4	Dried spots-not transferable
2	LR chair	2.9	Dried spots-not transferable
3	LR table	1.3	Dried spots-not transferable
4	LR wall	1.3-5.4	Dried spots-not transferable
5	LR carpet	3.8	Dried spots-not transferable
6	MS floor-spot	1.0-83	Wet contamination-some visible, some not
7	MS wrench #1	1.3-6.0	Wet contamination-some visible, some not
8	MS wrench #2	2.7-1100	Wet contamination-some visible, some not
9	MS wrench #1	3.2-13	Wrench #1 after cleaning in solvent
10	MS wrench #2	3.5-51	Wrench #2 after cleaning in solvent
11	CR trousers (work clothes)	8.3	Inside pants pocket. Difference between visually clean and soiled areas
12	CR trousers	1.3	Outside of work trousers near back pocket
13	CR trousers	3.2	Spot on same trousers
14	CR shirt	3.2	Only cont. area was inside cuff. Brand new, worn first time.
15	CR boots	3.2-8.3	Difference between heel and clean (raised) portion of insole. Much dried stuff on boots not detectible w/o solvent. Did not use solvents here.
16	CR helmet #1	222-1100	Cont. with light oil
17	CR helmet #2	2.5-46	Fl. visible in beam
18	CR helmet #3	3.2	Fl. visible in beam
19	CR helmet #4	3.5	Fl. visible in beam

MS - Machine Shop LR - Lunch Room CR - Clothes change room

Another important use of the spill spotter is for the monitoring of oil and tar that is being tracked into "clean" areas of a plant, such as the outer change room or lunch room. The results of preliminary tests that have been conducted in a coal liquefaction pilot plant [15] are listed in Table 2.

The apparent contamination, in $\mu g/cm^2$, in the workplace has been obtained by reference to an experimentally measured calibration curve. Known amounts of the heavy distillate from the process have been applied to weakly fluorescent filter paper and measured with the spill spotter.

Referring to Table 2 entries 1-5, all of the contamination detected in the lunchroom is weakly fluorescing dried material that is not easily transferable to the skin. A greater hazard is presented by still wet and easily transferable contamination on the floor of the machine shop (entry 6), and on tools (entries 7-10) just brought in from an in-plant repair job. It is also noteworthy that passing these tools once through the solvent normally used to clean them(entries 9-10) did not completely remove the contamination. These results show how difficult it is to keep any area in a coal conversion facility in a condition of pristine cleanliness.

The clothing of personnel coming off shift has also been examined for contamination (entries 11-19). The most contaminated areas of the coveralls are the pockets (entries 11-12) and the shirt cuffs (entry 14), which indicates transfer of this material from contaminated hands or objects placed in the pockets. The employee's work boots appear to be contaminated, but most of this material is dried and not strongly fluorescent. All of the helmets examined have been contaminated (entries 16-19); this contamination, however, is confined to distinct, visible spots and smears. No general buildup of PNA contamination due to aerosol condensation on the helmets has been detected. These kinds of data are potentially useful for assessing the relative importance of the condensation of tarry droplets route of personnel exposure vs. the direct skin contact with contaminated objects.

Lightpipe luminoscope. Heavy contamination of the skin is seen directly with the eyes as dark spots or smears and can be washed off. The luminoscope is needed only for detecting and measuring invisibly small amounts of contamination, or residuals left after washing. The ability of the luminoscope to measure trace amounts of tar [16] is evidenced by the data in Figure 8. The lower limit of detection is 10^{-7} g/cm^2 which corresponds to a dilution factor of 10,000 for an initial application of 10^{-3} g/cm^2 of the raw tar. Amounts of tar less than 10^{-5} g/cm^2 are invisible to the naked eye. These data have been obtained with filter paper rather than skin as the substrate. Experiments have commenced recently with the skin of hairless mice.

Heavy distillates from coal liquefaction processes (H-Coal) are currently being painted on the skin of athymic nude mice in 2 $\mu\ell/cm^2$ aliquots. Attesting once again to the high sensitivity of the method, the limit of detection corresponds to dilution factors of up to 100,000. Standard response versus concentration curves are being measured with the objective of eventually being

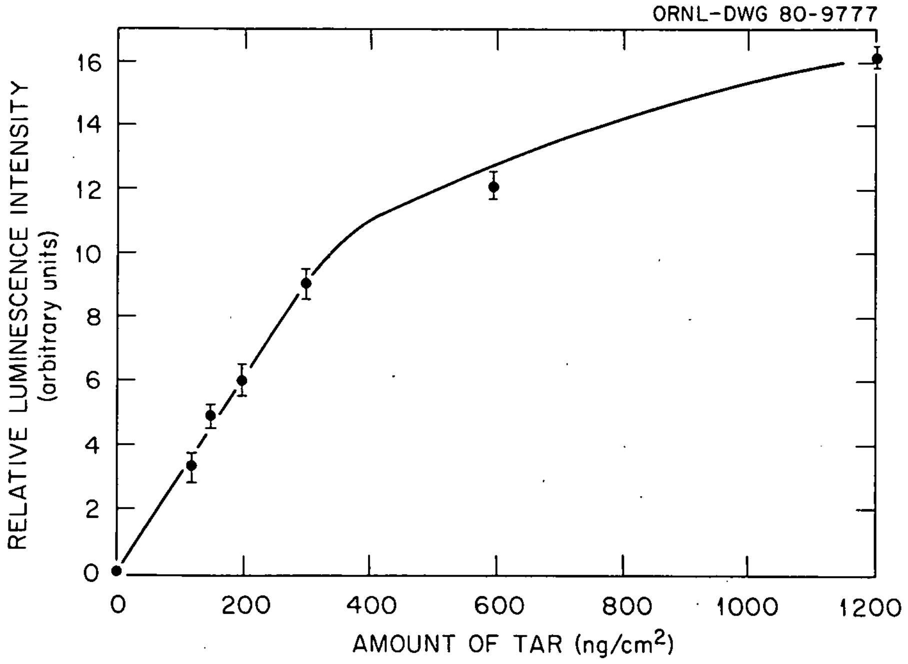

Fig.8. Fluorescent intensity of ESP tar from the UMD gasifier measured with the lightpipe luminoscope.

able to quantify actual workplace exposures.

A very limited number of measurements have been made on a few workers at the UMD low-Btu gasifier and reported [18]. The fluorescence measurements, however, could only be interpreted qualitatively at that time. Variations of the natural fluorescence from different regions of skin on the hands and forearms were noted, and two cases of fluorescent contamination were detected.

Analysis by SF and RTP techniques. Two examples will be given of the application of SF and RTP techniques to the rapid screening analysis of real-life samples. The first example [23] involves an interlaboratory examination of combined XAD-2 extracts from air-borne particulates. These were collected by Source Assessment Sampling Systems (SASS) as part of a study [23] to verify the efficacy of the analytical scheme outlined in the Industrial Environmental Research Laboratory - Research Triangle Park Procedures Manual: Level 1 Environmental Assessment [24].

Within the SASS sample, thirteen PNA components were identified and measured (Table 3) in fairly rapid screening procedures commensurate with the ± 300% requirement of accuracy at the EPA Level 1 for environmental analysis [24]. These data have been reduced to a relative decade scale in Table 4. This enables the data to be compared to low resolution mass spectroscopy data obtained by another laboratory for Level 1 analysis. At this low level of accuracy, the degree of matching is good.

TABLE 3. CONCENTRATIONS OF PNA COMPOUNDS IN THE SASS SAMPLE EXTRACT AS MEASURED BY SYNCHRONOUS FLUORESCENCE (SF) AND ROOM TEMPERATURE PHOSPHORESCENCE (RTP)

Compound	Concentration (M)*	
	SF	RTP
Anthracene	7.7×10^{-6}	---
Phenanthrene	$<2 \times 10^{-7}$	8×10^{-6}
Fluorene	1.2×10^{-7}	1.5×10^{-7}
Dibenzothiophene	$<4 \times 10^{-7}$	3×10^{-7}
1,2,5,6-Dibenzanthracene	$<5 \times 10^{-7}$	1×10^{-7}
2,3-Benzofluorene	3.3×10^{-7}	3×10^{-7}
Fluoranthene	1.9×10^{-6}	1.6×10^{-6}
Chrysene	3.2×10^{-6}	3.6×10^{-6}
Pyrene	3.0×10^{-6}	2.3×10^{-6}
Tetracene	1.9×10^{-8}	---
Benzo[e]pyrene	$<6 \times 10^{-6}$	4×10^{-7}
Benzo[a]pyrene	6.0×10^{-7}	$<10^{-6}$
Perylene	1.0×10^{-8}	---

*Measurements taken with a 1000-fold diluted solution.

TABLE 4. RELATIVE CONCENTRATIONS ON A DECADE SCALE OF PNA COMPOUNDS IN THE SASS SAMPLE

Compound	Synchronous Luminescence*	Low Resolution Mass Spectroscopy (Arthur D. Little, Inc.)
Anthracene/ Phenanthrene	100	100
Pyrene	100	100
Benzofluoranthrene	---	---
Fluoranthene	100	100
Chrysene, Benzanthracene	100	100
Benzopyrenes	100	10
1,2,3,6-Dibenzanthracene	10	---
2,3-Benzofluorene	10	10
Dibenzothiophene	10	10
Fluorene	10	10
Tetracene	1	---
Perylene	1	---

Concentration extrapolated to the original sample.

* $> 1 \times 10^{-3}$ M = 100

$< 1 \times 10^{-3}$ but $> 1 \times 10^{-4}$ M = 10

$< 1 \times 10^{-4}$ M = 1

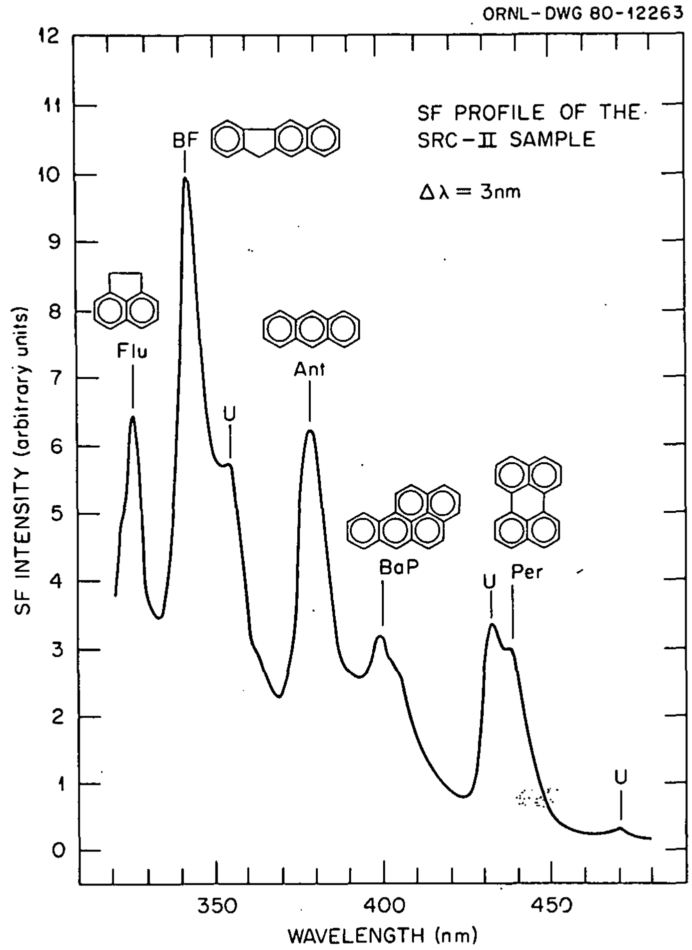

Fig.9. Characterization of fluoranthene in the SASS sample by RTP.

An example of the definitiveness of the characterization by RTP of a major PNA component (in this case fluoranthene) is shown in Figure 9. With the judicious selection of heavy atom and excitation wavelength, a nearly interference free RTP spectrum of fluoranthene is obtained from the SASS sample.

The other coal conversion product that has been analyzed is a Solvent Refined Coal (SRC II) heavy distillate. Our participation [25] was part of a round-robin analysis jointly organized by the National Bureau of Standards (NBS) and the Department of Energy.

The luminescence analyses were carried out on the raw coal liquid dissolved in ethanol without any prior fractionation or separation procedures. A total of ten PNA compounds were analyzed. The spectrum in Figure 10 was obtained by one rapid synchronous scan with a fixed wavelength interval (Δλ) of 3 nm between the excitation and emission wavelengths. The spectral signatures of five PNA compounds can be readily distinguished with several more due to as yet unidentified components. The values for quantitation of these five PNAs by SF analysis are listed in Table 5. Another two PNAs were measured using a different value of Δλ.

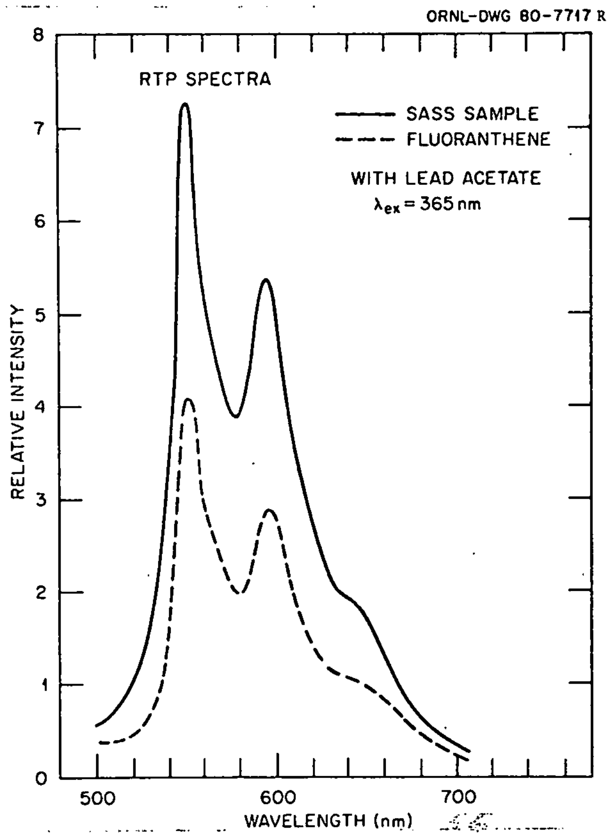

Fig.10. Synchronous fluorescence profile of the SCR II heavy-distillate (Ace = acenaphthene; BF = 2,3-benzofluorene; Ant = anthracene; BaP = benzo[a]pyrene; Per = perylene; U = unidentified species).

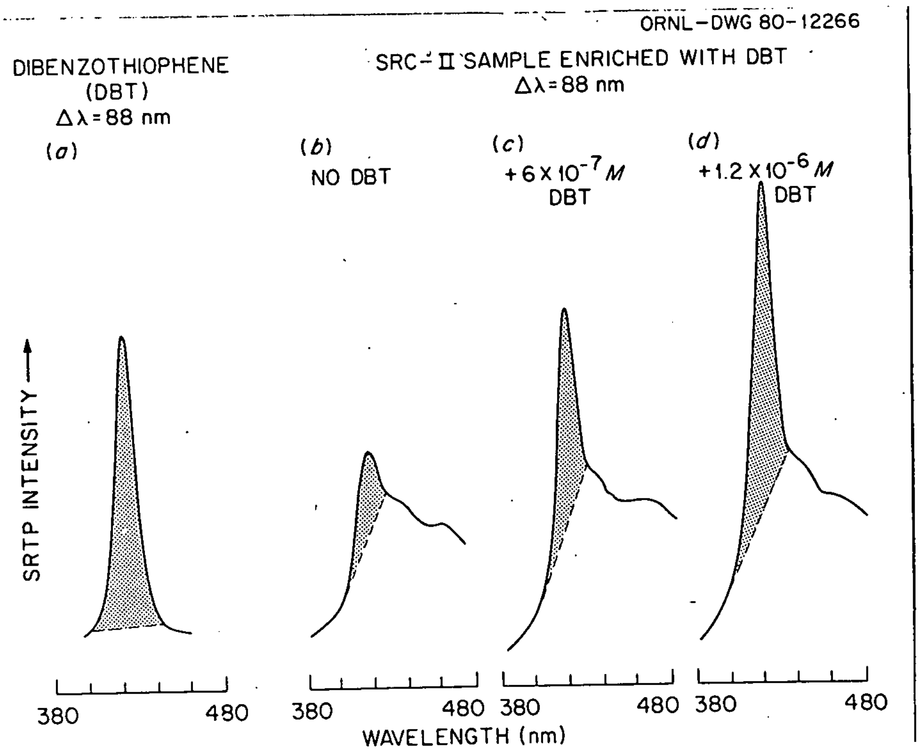

Fig.11. Synchronous RTP spectra of dibenzothiophene and DBT in the SRC II sample spiked with various amounts of DBT.

Complementary values of concentration for three additional PNAs were forthcoming by RTP analysis (Table 4). Two of these were heterocyclic PNA compounds, carbazole and dibenzothiophene (DBT). Synchronous RTP spectra of DBT are shown in Figure 11. Thallium acetate was the heavy-atom salt used to promote the phosphorescence of DBT. The quantitative determination was performed by the technique of standard addition. The results are in quite satisfactory agreement with the analytical data provided by the NBS.

TABLE 5. DETERMINATION OF PNA COMPOUNDS IN A RAW SRC II SAMPLE BY SYNCHRONOUS FLUORESCENCE AND ROOM TEMPERATURE PHOSPHORESCENCE

Compound	SF mg/g	RTP mg/g	NBS Data[a] (mg/g)
Anthracene	1.7 ± 0.2	N[b]	NA[c]
2,3-Benzofluorene	1.8 ± 0.2	1.8 ± 0.6	NA
Benzo[a]pyrene	0.129 ± 0.03	N	0.134
Benzo[e]pyrene	N	0.117 ± 0.025	0.143
Carbazole	N	3.9 ± 1.0	1.96
Dibenzothiophene	N	1.0 ± 0.3	1.02
Fluoranthene	5.2 ± 1.5	5.5 ± 1.5	3.30
Fluorene	1.5 ± 0.3	N	NA
Perylene	0.02 ± 0.006	N	0.026
Pyrene	6.0 ± 2	3.6 ± 0.6	6.0

[a] The NBS data are of a preliminary nature (LC and/or GC-MS). The accuracy of the NBS results range within 5-10%.

[b] N = emission not detected or not resolved.

[c] NA = data not available.

4. SUMMARY

Considerable progress has been made during the last few years for improving the tools that will be available to the industrial hygienist to monitor PNAs in the forms of vapors, airborne particulates and surface contamination. Some instruments and methodologies have progressed to advanced states of maturity while others are in the developmental or conceptual stages of development.

In the category of advanced stage of development are a portable instrument (DUVAS) for measuring concentrations of select aromatic vapors in real-time and a portable fluorescence spill spotter for measuring general surface contamination. A lightpipe luminoscope for measuring skin contamintion is advanced to the stage of field testing. To add meaning to the human skin measurements, the fluorescence of coal-conversion products painted on animal skin is being measured.

A new and less well tested device is a simple, passive, integrating exposure meter for PNA vapors such as pyrene. The initial results, however, are very promising.

Two methodologies for the rapid screening of PNAs, synchronous fluorescence and room temperature phosphorescence, are well developed and understood. They will be applied to the analysis of cyclohexane extracts of airborne particulate matter, and incorporated into automated, continuous sampling devices designed to provide near-real-time monitoring of select PNAs in aerosols. Thus, practical monitoring devices for use in the workplace, addressing each of the major pathways of exposure to PNAs, are in various stages of development.

REFERENCES

1. Gammage, R.B., Vo-Dinh, T., Hawthorne, A.R., Thorngate, J.H. and Parkinson, W.W. 1978. A new generation of monitors for polynuclear aromatic hydrocarbons from synthetic fuel production. Carcinogenesis, Vol. 3: Polynuclear Aromatic Hydrocarbons, ed. by Jones, P.W. and Freudenthal, R.I., Raven Press, pp. 155-174.

2. American Conference of Government Industrial Hygienists: Threshold limits for 1967...Recommended and intended values. 1967. Cincinnati, ACGIH, p.7.

3. National Institute for Occupational Health and Safety: Criteria for a recommended standard...Occupatinal exposure to coal tar products. 1977. DHEW (NIOSH) No. 78-107.

4. Hawthorne, A.R. and Thorngate, J.H. 1978. Improving analysis from second derivative UV-absorption spectrometry. Appl. Opt., 17., pp. 724-729.

5. Hawthorne, A.R. and Thorngate, J.H. 1979. Application of second-derivative UV-absorption spectrometry to polynuclear aromatic compound analysis. Appl. Spectrosc., 33, pp. 301-305.

6. Hawthorne, A.R. 1980. DUVAS: A real-time aromatic vapor monitor for coal conversion facilities. Am. Ind. Hyg. Assoc. J., 41, (to be published in December 1980 issue).

7. Vo-Dinh, T. U. S. patent applied for.

8. Vo-Dinh, T. and Gammage, R.B. 1979. The applicability of the second-derivative method to room-temperature phosphorescence analysis. Anal. Chim. Acta, 107, pp. 261-271.

9. Vo-Dinh, T. and Winefordner, J.D. 1977. Room temperature phosphorimetry as a new spectrochemical method of analysis. Appl. Spectrosc. Rev., 13, pp. 261-294.

10. Vo-Dinh, T. and Hooyman, J.R. 1979. Selective heavy-atom perturbation for analysis of complex mixtures by room-temperature phosphorimetry. Anal. Chem., 51, pp. 1915-1921.

11. Vo-Dinh, T. and Gammage, R.B. 1978. Singlet-triplet energy difference as a parameter of selectivity in synchronous phosphorimetry. Anal. Chem., 50, pp. 2054-2058.

12. Lautenberger, W.J., Kring, E.V. and Morello, J.A. 1980. A new personnel badge for organic vapors. Am. Ind. Hyg. Assoc. J., 41, pp. 737-747.

13. Schuresko, D.D. 1980. Portable fluorometric monitor for detection of surface contamination by polynuclear aromatic compounds. Anal. Chem. 52, pp. 371-373.

14. Schuresko, D.D. 1980. Industrial Research and Development, Technical Publishing Co., Barrington, Illinois. October, p. 120.

15. Schuresko, D.D. 1981. Portable fluorometric spotter for detection of surface contamination by polynuclear aromatic compounds. To be published in Polynuclear Aromatic Hydrocarbons: Chemistry and Biological Effects, Fifth International Symposium, Battelle Press, Columbus, Ohio.

16. Gammage, R.B. and Vo-Dinh, T. 1980. Luminescence monitoring of oil or tar contamination for industrial hygiene. Nucl. Instr. and Meth., 175, pp. 236-238.

17. Vo-Dinh, T. and Gammage, R.B. 1981. The use of a fiber-optics skin contamination monitor in the workplace. To be published in Measurement and Control of Chemical Hazards in the Workplace Environment, ed. by Choudhary, G., ACS Symposium series.

18. Vo-Dinh, T. and Gammage, R.B. 1980. The lightpipe luminoscope for monitoring occupational skin contamination. Am. Ind. Hyg. Assoc. J., 41 (to be published in December 1980 issue).

19. Tanenbaum, L., Parrish, J.A., Anderson, R.R. and Fitzpatrick, T.B. 1975. Tar phototoxicity and phototherapy for psoriasis. Arch. Dermatol., 111, pp. 467-470.

20. Schulte, K.A., Larsen, D.J., Hornung, R.W. and Crable, J.V. 1975. Analytical methods used in a study of coke oven effluent. Am. Ind. Hyg. Assoc. J., 36, pp. 131-139.

21. Vo-Dinh, T. 1978. Multicomponent analysis by synchronous luminescence spectrometry. Anal. Chem., 50, pp. 396-401.

22. Vo-Dinh, T., Gammage, R.B., Hawthorne, A.R. and Thorngate, J.H. 1978. Synchronous spectroscopy for the analysis of polynuclear aromatic compounds. Environ. Sci. and Technol., 12, pp. 1297-1302.

23. Vo-Dinh, T., Gammage, R.B. and Martinez, P.R. 1981. Analysis of a workplace air particulate by synchronous luminescence and room temperature phosphorescence. Anal. Chem. (to be published in February 1981 issue).

24. Level 1 environmental assessment performance evaluation. 1977. EPA/IERL-RTP, Report No. ADL 79347-34. November 23.

25. EPA/IERL-RTP procedures manual: Level 1 environmental assessment (second edition). 1978. EPA-600/7-78-201, October.

26. Vo-Dinh, T. and Martinez, P.R. 1980. Direct analysis of a coal liquefaction product by synchronous luminescence techniques. Anal. Chim. Acta (in press).