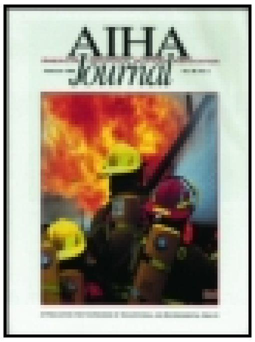

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APPLIED STUDIES

Field Evaluation of a Portable Photoionization Detector for Assessing Exposure to Solvent Mixtures

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To evaluate a portable photoionization detector for assessing personal exposure to solvent mixtures, a set of 26 side-by-side, time-weighted average (TWA) personal breathing zone samples were collected during various construction painting tasks by two different sampling methods: (1) standard charcoal sorbent tubes analyzed by gas chromatography (CST/GC), and (2) a direct-reading photoionization detector coupled with an extended datalogger (PID). The TWA concentrations of the hydrocarbons detected by CST/GC analysis were summed for comparison with the TWA concentration obtained from the direct-reading PID. Based on linear regression between the log TWA concentrations of the two sampling methods, the data were highly correlated ($r^2 = 0.95$). Since the solvents had effects that may be considered additive, threshold limit values (TLVs®) for mixtures were developed using American Conference of Governmental Industrial Hygienists formulas to evaluate solvent exposure. The logs of the TLV mixture data from the sampling methods were highly correlated ($r^2 = 0.94$). Based on the linear regression analyses, the response of the portable PID was highly correlated to the CST/GC results for hydrocarbon mixtures encountered during various painting tasks. Due to the short duration of tasks, highly fluctuating exposures, and complexity of the mixtures, the PID may provide the most cost-effective, detailed exposure assessment for solvent mixtures.

Keywords: construction painters, exposure assessment, gas chromatography, photoionization detector, solvent mixtures

Exposure assessment is an essential element for managing occupational hazards. Its specific applications range from use in epidemiological research to the formulation and evaluation of regulatory policies and programs.(1) Furthermore, exposure assessment is important for controlling and mitigating individual workplace exposures to protect the health of the worker. The preferred method of characterizing organic solvent exposure involves quantitative exposure intensity estimates that are obtained from personal breathing zone sampling.(2) Time-weighted average (TWA) personal sampling with chromatographic analysis is the most common technique for quantifying specific compounds.(3) Although integrated sampling methods provide a measure of exposure, data is lacking regarding exposure to highly fluctuating chemical concentrations.

Highly fluctuating chemical exposures are commonly found in occupational settings with repetitive tasks;(4) additionally, in settings where environmental conditions themselves are highly variable, such as in the construction industry, exposure variability is often even greater.(5) Since the majority of occupational exposure limits for organic solvents have been set to prevent adverse neurologic or neurobehavioral effects resulting from relatively prolonged exposures, few incorporate ceiling exposures. Jensen et al.,(4) in a study of short-term exposures to toluene in rotogravure printing, suggested that the current occupational exposure limits may not be protective if workers are exposed to high, short-duration

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peak concentrations even if the TWA exposures do not exceed applicable standards.

Direct-reading photoionization detectors (PIDs) have been used widely as screening instruments for hydrocarbons but have received limited use in the assessment of personal employee exposures.(6) Recently, PIDs and datalogging devices have been manufactured that are lighter and more compact, therefore suited for personal air monitoring.(7) The PID, by ionizing molecules of hydrocarbons in an airstream, provides instantaneous concentrations as a function of time that can be utilized to associate events and exposures. The real-time data obtained from the PID, when datalogged and appropriately analyzed, assists with the formation of more effective recommendations to control exposure to hydrocarbons.(8)

The PID operates by using high-energy ultraviolet (UV) light to excite the molecules, resulting in a temporary loss of an electron and the formation of a positively charged ion. The ions formed in air are driven in one direction by a bias electrode and accumulated at a collecting electrode; the ion current generated is amplified, then translated to a meter reading.(6) Most direct-reading portable PIDs display readings in parts per million (ppm) air concentration and the reading is related to the actual air concentration by calibration in a known atmosphere.

While virtually all elements and chemical compounds can be ionized, they differ in the amount of energy required. The amount of energy required to displace an electron is called the ionization potential (IP) and is measured in electron volts (eV). Every chemical compound has its own IP; the lower the IP, the less energy is required to displace an electron. When the energy of the UV lamp is greater than the IP of the chemical compound, ionization occurs by displacement of electrons. A PID will respond to any chemical compound with an IP less than the energy of the UV lamp present in the device. The most common PID UV lamp energies are 9.5, 10.2, 10.6, and 11.8 eV.

The use of a PID to evaluate occupational exposure to organic solvent mixtures has been limited because of the nonspecificity of the response.(3) The degree of the response is based on the chemical structure of the constituents such as functional groups and the types and number of bonds. Although manufacturers of PID instruments supply "response factors" or "correction factors" that provide an indication of the expected response for specific ionizable compounds, there is little published work on the application of such factors when numerous compounds are present in an environment. Using response factors for a specific PID along with known vapor concentrations, Diaz(9) was able to show a linear relationship between total hydrocarbon concentration (known atmosphere) and PID response over a range of 0 to 500 ppm for gasoline, jet fuel, and crude oil. This is one of the few investigations, albeit based on area rather than personal sampling, that has attempted to correlate PID response to total hydrocarbon concentration for complex mixtures.

As part of an ongoing investigation to characterize exposures to organic vapors in construction painting, the suitability of using a portable PID coupled with an extended datalogger for assessing exposure to hydrocarbon mixtures was investigated. This research was predicated on the hypothesis that a portable PID response to complex hydrocarbon mixtures would be highly correlated to gas chromatography results obtained from an adjacent sample collected on a charcoal sorbent tube by a personal air sampling pump with analysis by gas chromatography (CST/GC).

There is a recognized need to gain additional information regarding construction painters' exposures to organic solvents. The heterogeneity of the solvents used along with the variability of painters' work practices has made the systematic collection of industrial hygiene data very difficult. Traditional evaluation of painters' TWA exposures to specific organic vapors is time consuming and expensive, and simpler, more cost-effective methods are needed. An additional objective of this study was to evaluate the suitability of using PID data along with information from material safety data sheets (MSDSs) to assess possible overexposures based on the American Conference of Governmental Industrial Hygienists (ACGIH) threshold limit values (TLVs®) for mixtures. Such a technique, if validated, has the potential to be widely adopted for conducting exposure assessments that are required to protect the health of construction painters.

METHODS AND MATERIALS

Any construction painter working at a job site in Colorado was eligible for inclusion in the study. All subjects who agreed to participate were given consent forms and a questionnaire so that information could be gained regarding occupational solvent exposure. A total of 26 side-by-side sample sets were collected during various construction painting tasks that involved solvent-based products. TWA personal breathing zone samples were collected on opposite sides of the workers' lapels by the two sampling methods. The "standard method" (CST/GC) involved the collection of air contaminants on coconut shell charcoal sorbent tubes using personal air sampling pumps with analysis by a laboratory gas chromatograph equipped with a flame ionization detector (FID). The test method employed a direct-reading PID coupled with an extended datalogger to continuously record PID responses.

Personal Air Sampling: CST\GC

Solvent vapors were collected on standard coconut shell charcoal sorbent tubes (SKC Inc., Philadelphia, Pa., 100/50 mg, Lot 120) using Gilian 5 Personal Air Samplers (Gilian Instrument Corp., W. Caldwell, N.J.) calibrated at flow rates between 10 and 100 mL/min. The charcoal sorbent tubes were sampled and analyzed following Occupational Safety and Health Administration Method #07 for organic vapors,(11) which involved the detection and quantification of specific compounds that were found to be present in the majority of solvent-based architectural coatings used in the residential construction industry in Colorado. The following hydrocarbons were included in the hydrocarbon scan: acetone; n-butyl acetate; ethyl alcohol; ethyl benzene; n-heptane; isobutyl acetate; methyl n-amyl ketone; methyl ethyl ketone; methyl isobutyl ketone; isobutyl alcohol; isopropyl alcohol; toluene; xylene; 2-butoxyethanol; n-propyl acetate; mineral spirits; Stoddard solvent; and VM & P naphtha. The physical characteristics of the hydrocarbons of interest are listed in Table I, including the molecular weight (MW), vapor pressure (VP), TLV, PID correction factor (PID CF), and the ionization potential (IP). The PID CFs are based on calibration to an isobutylene/air mixture.

A Hewlett-Packard 5890 (Hewlett-Packard, Avondale, Pa.) GC-FID was equipped with a 25-m capillary column (Rustek MTX-502.2, Restek Corp., Bellefonte, Pa.) using helium as a carrier gas operated at a flow rate of 9.5 mL/min. The detector and injector temperatures were maintained at 250°C and 225°C, respectively; oven temperature was ramped at 5°C per minute up to 140°C after remaining at an initial temperature of 40°C for 6 min. Calibration curves were constructed for the 18 solvents in carbon disulfide.

The coconut shell charcoal tube samples were agitated for 30 min with 2 mL of carbon disulfide to desorb the hydrocarbons.

TABLE I. Selected Characteristics of Hydrocarbons of Interest

Chemical	Vapor Pressure[A] (mm/Hg)	Molecular Weight[A]	TLV (ppm)-TWA/STEL[B]	PID CF[C]	IP[A] (eV)
Acetone	180	58.1	500/750	1.1	9.69
2-Butoxyethanol	0.8	118.2	25 S[D]	4.4 L[E]	10.00
n-Butyl acetate	10	116.2	150/200	2.6	10.00
Ethanol	44	46.1	1000	12	9.51
Ethyl benzene	7	106.2	100/125	0.52	8.76
n-Heptane	40	100.2	400/500	2.6	9.90
Isobutyl acetate	13	116.2	150	5.2 L[E]	9.97
Isobutyl alcohol	9	74.1	50	9.3 L[E]	10.12
Isopropyl alcohol	33	60.1	400/500	6	10.10
Methanol	96	32.1	200/250 S[D]	NA[F]	10.84
Methyl n-amyl ketone	3	114.2	50	—	9.33
Methyl ethyl ketone	78	72.1	200/300	0.86	9.54
Methyl isobutyl ketone	16	100.16	50/75	1.2	9.30
Mineral spirits	—	140	100[G]	0.82 L[E]	—
n-Propyl acetate	25	102.2	200/250	3.5	10.04
Stoddard solvent (pet. distillates)	—	97	100	1.4 L[E]	—
Toluene	21	92.1	50 S[D]	0.5	8.82
V.M.&P. naphtha	—	87–114	300	—	—
Xylene	9	106.2	100/150	0.5	8.44

[A] Source: Ref. 18.
[B] Source: Ref. 14.
[C] Source: Ref. 19.
[D] "S" notation indicates a chemical with a skin designation according to the 1998 ACGIH TLV.
[E] "L" indicates a response factor estimated from laboratory data conducted for this study; all other response factors supplied by manufacturer.
[F] Not applicable.
[G] Based on the 1998 TLV for Stoddard solvent.

The front and back sections of the charcoal sorbent tubes were analyzed separately to detect breakthrough. Five microliter injections of the samples and standards were introduced into the GC-FID using the "solvent flush" technique. Desorption efficiencies were estimated for all 18 solvents on coconut shell charcoal using a modified method described by Supelco.(12) Field blanks were collected for each sampling day and all sample results were blank corrected.

Personal Air Sampling: Direct-Reading PID

A Rae Systems (Sunnyvale, Calif., model name "Professional PID") direct-reading PID was used to measure ionizable compounds as a surrogate for total hydrocarbon exposure. The Rae Systems PID was selected because of the size and portability, datalogging capabilities, and ease of use. The instrument was equipped with a new 10.6-eV lamp; the lens was cleaned after approximately 10 days of field use, depending on the concentrations of hydrocarbons encountered. The output from the PID was recorded on a DataRAE datalogging system (RAE Systems). Air was removed at a flow rate of 500 mL/min from the breathing zone through a Teflon™-lined 20 mm internal diameter tube and delivered to the PID and datalogger attached to the worker's belt. The data were recorded and stored at 3-second intervals as the average of three, 1-sec readings. The datalogger was downloaded to a personal computer, where the data were subsequently analyzed. The PID was pre- and postcalibrated using a 1-L Tedlar bag (SKC, Inc.) containing a certified 101 ppm isobutylene/air mixture (Scott Specialty Gases, Longmont, Colo.). Temperature and relative humidity measurements were taken close to the workers during the times personal sampling was conducted.

Data Analysis of Solvent Exposure

For each charcoal tube sample, a total hydrocarbon variable was calculated by summing the TWA concentrations of any of the 18 solvents detected during the GC analysis. The PID instantaneous readings from the datalogger were averaged to provide a total hydrocarbon variable in isobutylene equivalent parts-per-million concentration to compare with the CST/GC result.

The statistical methods used in the analyses required that the distributions of data be approximately normal. However, the frequency distributions of both PID averages and CST/GC data were highly skewed, and tests of normality indicated the data were nonnormal. Logarithmic transformations were found to be most suitable to stabilize the variances. Based on the Pearson correlation between the normal scores of the residuals and the residuals, the assumption of normality was not rejected for the log transformed data. Since the assumptions of normality, linearity, and homogeneity were tested and satisfied, parametric analyses were appropriate. Linear regression analyses were performed with log PID as the dependent variable and log CST/GC as the independent variable. Relative humidity and temperature were tested in all models; however, they were not found to be statistically significant factors.

To address the additive effects of the mixture components a measure termed the "hygienic effect," which is defined as the ratio between the actual concentration of the compound (C) and its American Conference of Governmental Industrial Hygienists (ACGIH) TLV, was calculated for each component of each sample.(13) The hygienic effect is equivalent to the ACGIH TLV mixture calculation listed in Appendix B of the ACGIH 1998 TLV booklet. A total hygienic effect was calculated by incorporating the TWA solvent concentrations from the CST/GC sampling results into the ACGIH mixture formula that assumes additive effects.(14) If the sum of the solvent ratios exceeded unity then the worker exposure was determined to have exceeded the TLV-TWA of the mixture. The equation for calculating the TLV of mixtures is

$$C_1/T_1 + C_2/T_2 + C_3/T_3 + \cdots = 1 \tag{1}$$

where C_1 = indicates the observed atmospheric concentration and T_1 = the corresponding TLV.

Since the concentrations of specific components of the mixture were unknown for the PID data, the TLV-TWA for the mixture was calculated from the percentage composition data obtained from applicable MSDSs. Using the ACGIH formula that assumes the atmospheric composition is similar to that of the original liquid material, a TLV for the mixture was estimated using the percentage composition from the MSDS:(14)

TLV of mixture

$$= \frac{1}{f_a/TLV_a + f_b/TLV_b + f_c/TLV_c + \cdots + f_n/TLV_n} \quad \textbf{(2)}$$

where f_a = percentage composition by weight of the mixture and TLV_a = corresponding TLV of the constituent in mg/m³.

The PID TWA solvent exposure in isobutylene equivalent parts per million was divided by the calculated TLV-TWA of that mixture (Equation 2) to provide a measure that was based on unity, thus directly comparable with the CST/GC data. In the Results section this ratio is termed the "PID mix equation," whereas the TLV of the mixture computed from the CST/GC data (Equation 1) is referred to as the "GC mix equation."

Linear regression was used to evaluate the effectiveness of manufacturer-supplied correction factors for PID responses to specific organic vapors. The CST/GC TWA solvent concentrations were adjusted before logarithmic transformation by the applicable CFs to calculate a predicted PID TWA solvent concentration:

Predicted PID concentration

$$= \frac{1}{CF} \times \text{CST/GC TWA of constituent.} \quad \textbf{(3)}$$

For example, if the CST/GC results indicate that an employee was exposed to 35 ppm of acetone and 10 ppm mineral spirits over a particular task, the predicted PID response for acetone and mineral spirits can be calculated based on applicable CFs for the MiniRae PID (see Table I). The overall predicted PID response is simply the sum of the individual predicted responses for each air contaminant. The calculations for the simple acetone/mineral spirits mixture would be:

Predicted PID concentration (acetone)

$$= \frac{1}{1.1} \times 35 = 32 \text{ ppm}$$

Predicted PID concentration (mineral spirits)

$$= \frac{1}{0.82} \times 10 = 12 \text{ ppm}$$

Overall PID predicted concentration

$$= 32 \text{ ppm} + 12 \text{ ppm} = 44 \text{ ppm.}$$

To compare the effectiveness of using CFs to obtain a more accurate assessment of total hydrocarbon exposures using a PID, the PID result was compared with the CF-predicted PID result with linear regression analysis.

RESULTS

A summary of the sampling results from both methods is presented in Table II. The maximum TWA concentration based on the PID data was 686 ppm, whereas the maximum obtained through charcoal tube sampling (GC TWA) was 1386 ppm. Overall, the PID method underestimated TWA organic vapor exposure when compared with the CST/GC method by approximately 12%. Due to the variability in solvent concentrations among the different work tasks, the geometric standard deviations of the data were large. The PID coupled with the extended datalogger was limited to storing 3-sec average values that were less than 1010 ppm; therefore, this was the highest ceiling value recorded for any sample. The variability in the data also was reflected in the maximum 15-min TWAs, as the PID short-term exposure limit (STEL) values listed in Table II range from 4 to 1009 ppm.

TABLE II. Air Sampling Results of Mixtures Obtained from Two Methods of Evaluating Personal Exposure to Total Volatile

Sample Duration (min)	PID STEL[A] (ppm)	PID[B] Ceiling (ppm)	PID TWA[C] (ppm)	PID Mix Equation[D]	GC TWA[E] (ppm)	GC Mix Equation[F]
157	6	84	3	0.03	2	0.02
273	33	631	18	0.17	35	0.37
127	139	905	85	0.92	77	0.79
165	265	897	46	0.46	57	0.73
106	362	1010	149	1.49	231	1.98
56	272	978	200	2	249	3.22
78	302	1010	217	2.17	269	2.73
50	332	1010	263	2.63	315	2.79
64	327	1010	250	2.5	336	4.20
42	836	969	585	4.43	1386	15.66
176	459	1010	184	1.56	129	1.29
148	567	1010	366	3.1	303	3.03
9	138	865	138	1.17	238	8.01
106	419	1010	325	2.75	243	2.43
85	84	306	56	0.47	38	0.38
106	75	309	57	0.47	51	0.51
182	1009	1009	686	6.4	1008	11.48
193	102	864	39	0.37	36	0.38
100	128	1009	69	0.69	55	0.62
61	122	1010	52	0.44	58	0.59
173	434	1009	245	2.5	151	1.98
327	92	250	35	0.3	70	0.73
188	4	278	3	0.02	5	0.06
324	21	503	4	0.04	5	0.05
416	12	326	6	0.05	7	0.09
69	27	599	14	0.11	24	0.35

[A] PID STEL = highest 15 min TWA obtained from the PID.
[B] PID Ceiling = highest 3-sec average concentration obtained from the PID.
[C] PID TWA = the TWA concentration obtained for the length of the work task from PID.
[D] PID Mix Equation = ACGIH mixture calculation formula using percentage composition data from the MSDS.
[E] GC TWA = the TWA concentration obtained for the length of the work task from GC.
[F] GC Mix Equation = ACGIH mixture calculation formula using component concentrations obtained from GC.

The regression analysis (Table III, Equation 1) of the log of the total hydrocarbon result from the PID by the log of the CST/GC result provided evidence that the measures were highly correlated ($r^2 = 0.95$). A plot of residuals versus CST/GC values provided no evidence of a lack of fit. Temperature and humidity were dropped from the final models because they were not statistically significant. The log PID total hydrocarbon results versus the log CST/GC results are plotted in Figure 1. Additionally, Figure 1 shows the wide range over which the relationship between results of the two sampling methods was linear.

The regression analysis of TLV-TWA mixture calculations between the two sampling methods evaluated the capability of the PID for assessing compliance to a calculated TLV for a mixture

TABLE III. Summary of Final Linear Regression Models for the Relationship of Log CST/GC Results to Log PID Results with (1) Uncorrected Data (ppm), (2) Data Expressed in Terms of the TLV of Mixtures, and (3) Data Corrected by Response Factors (ppm)

Final Regression Equation		r^2	p-value
(1)	log PID (ppm) = 0.04 + 0.95 log CST/GC (ppm)	0.95	$<$0.001
(2)	log PID TLV (mix equation) = 0.07 + 1.02 log CST/GC TLV (mix equation)	0.94	$<$0.001
(3)	log PID results (ppm) = −0.08 + 0.99 log CF-predicted PID results (ppm)	0.94	$<$0.001

based on the MSDS percentage composition data. For all 26 samples, each sampling method reached the same conclusion using unity to evaluate compliance with the TLV-TWA of the mixture. The regression analysis (Table III, Equation 2) of the mixture calculation variable between the sampling methods provided a high degree of correlation ($r^2 = 0.94$). The PID TLV-TWA mixture calculation versus the CST/GC mixture TLV-TWA result is plotted in Figure 2.

The third regression analysis (Table III, Equation 3) was performed to evaluate the effectiveness of the PID manufacturer-supplied CFs for sampling solvent mixtures. The TWA solvent concentrations obtained from the CST/GC method were adjusted by the appropriate CFs) to calculate a CF predicted PID response. The CF predicted PID response was compared to the actual PID response by linear regression analysis. Although a high correlation was found between the two measures ($r^2 = 0.94$), the adjustment did not improve the overall correlation for total solvent exposure.

DISCUSSION

The data provided evidence that the portable PID can be a valuable instrument for assessing personal exposure to solvent mixtures. Although the PID data underestimated exposure, the high correlation with the CST/GC sampling results indicated that the PID response was representative of the TWA total hydrocarbon exposure. The results provided evidence of a linear relationship between total hydrocarbon measurements obtained using charcoal sorbent tubes and both corrected and uncorrected TWA responses obtained with a PID. Similar findings were reported by Diaz,(9) who showed that PID responses, after response factors were applied, were linearly correlated with total hydrocarbon concentrations for gasoline, jet fuel, and crude oil.

According to the data obtained in the present investigation, and using the regression equation of total hydrocarbon exposure, at a true concentration of 1000 ppm the PID result would be 23% less, at 100 ppm 14% less, and at 10 ppm 3% less. It is well known that at very high concentrations, such as over 2000 ppm, the PID response is nonlinear;(6) however, Maslansky and Maslansky(6) pointed out that even at hydrocarbon concentrations exceeding 400 to 500 ppm, the PID response may drop off. Additionally, in the current study, the datalogging software was limited to recording 3-sec averages under 1010 ppm, and this may have resulted in a systematic error. Fortunately, this error was likely minimal, as plots of the raw data indicated that the time the PID concentrations exceeded 1010 ppm were relatively short (Figure 3).

Another possible explanation for the lower than expected PID response could have been attributed to the presence of compounds with ionization potentials greater than 10.6 eV in the sampled atmospheres. For example, methanol was present in some of the mixtures and with an ionization potential of 10.84 eV would not have made an appreciable contribution to the PID response, yet is easily ionized by the FID and would add to the overall total hydrocarbon concentration obtained from the CST/GC. At high total organic vapor concentrations this effect may have been aggravated, as there would likely be a much greater number of molecules present in the detection chamber that would not be ionizable, thus interfering with the ionization of other compounds. Additionally, the PID used in the study had a very small ionization chamber, and it has been suggested that chamber size is related

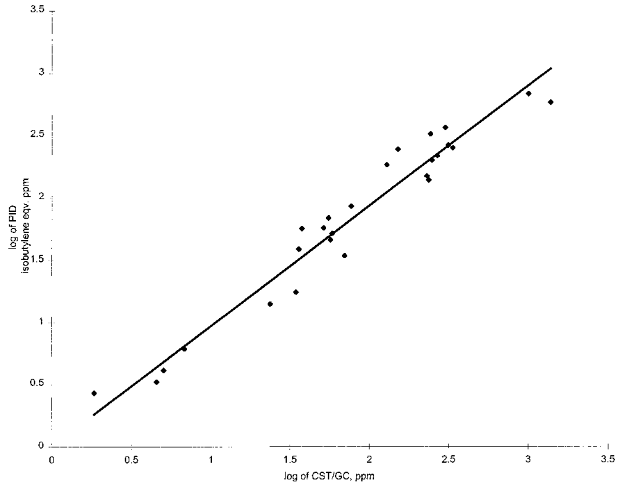

FIGURE 1. Plot of log PID and log CST/GC data of TWA hydrocarbon concentration (uncorrected)

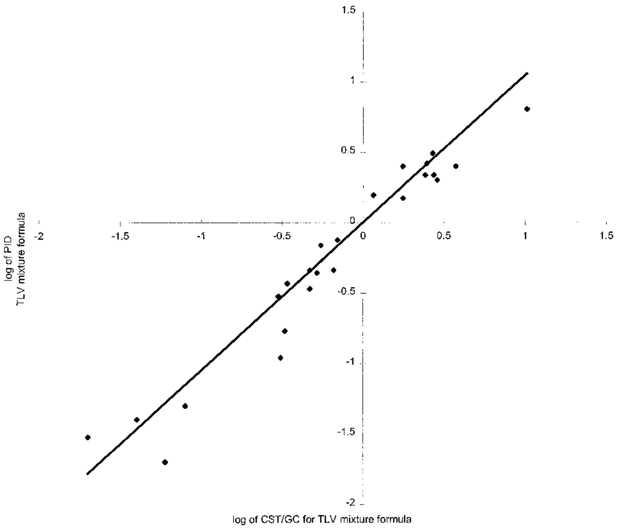

FIGURE 2. Plot of log PID and log CST/GC data of TLV mixture equation

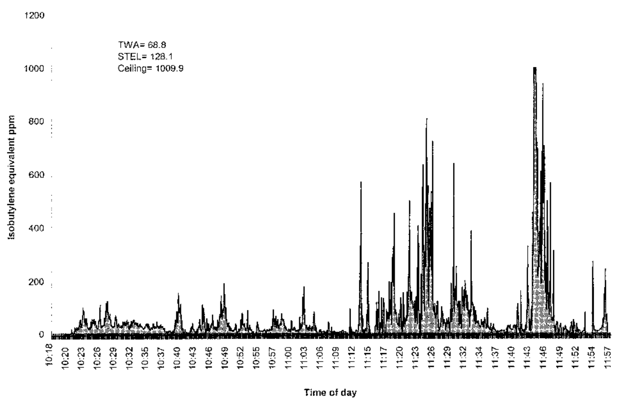

FIGURE 3. Real-time measurements from the PID in isobutylene equivalent parts-per-million concentration versus time for the task of wiping stain and reducer

to the maximum number of molecules that can be ionized as they pass through the UV light (i.e., the detector reaches saturation).(6)

Several investigators have evaluated solvent exposure using the ACGIH mixture formulas, which sum the ratios of the solvent concentrations over their respective TLV-TWAs (8-hour).(15–17) In this investigation there was very good agreement between mixture formulas computed using results from the PID versus results from CST/GC. All 10 results that exceeded 1.0 (Figure 2) exceeded that value through both methods of calculation. The PID method using MSDS percentage composition data to calculate an estimated TLV of the mixture may provide a useful screening method for assessing risk for painting. Although none of the sampling times were 8 hours in duration, these results indicate that the use of the TLV mixture calculation based on the PID monitoring results with the compositional data from MSDSs would be potentially useful in exposure assessment studies. It should be noted that calculating the TLV using MSDS compositional data uses the assumption that the air composition is similar to the liquid composition, which may not be valid since the vapor pressures of the solvents vary over a wide range.

Although previous studies have shown that the use of CFs may be useful in interpreting PID data obtained when multiple hydrocarbons are present,(9) this was not supported in the present study. The incorporation of the PID correction factors into the data set did not improve the correlations obtained. One possible explanation was that since so many contaminants were present in each of the samples the overall effect may have been diluted (i.e., some response factors were above 1.0 and some were less than 1.0, resulting in cancellation). Additionally, response factors are determined individually, and the assumption that individual response factors can be proportionally summed for a complex mixture may not be appropriate.

Drummond(7) also used a MiniRae PID in the assessment of benzene exposures during the task of unloading gasoline from a truck. The sampling train for the PID was similar to the one used in the present study, with the instrument and datalogger worn on the belt and a Teflon-lined tube bringing the air from the worker's breathing zone. A 150-mg charcoal tube was attached to the outlet of the PID. The benzene TWA from the charcoal tube analysis divided by the TWA from the PID for the same period was the calculated response factor for benzene. For the one sample that was obtained using this novel approach, a response factor of 0.2 was calculated. For example, from the figure provided, the maximum PID reading of 74 ppm (isobutlylene) for the gasoline mixture corresponded to 15 ppm benzene.

The approach of using information from a PID to assess exposures is similar to Drummond's. Instead of using one correction factor to modify the PID response to determine exposure to a single compound, the present authors were interested in determining total exposures to hydrocarbons. Their findings support the use of the PID to estimate total volatile organic compound concentrations even when exposure involves a complex hydrocarbon mixture. The findings also support the utility of employing PID data in conjunction with MSDS information to compute mixture TLVs to characterize potential risks. The authors agree with Drummond's(7) conclusion that even in situations in which the response factors are well established, collecting a charcoal tube sample periodically would provide a good quality assurance check that such risk assessments using PID data are correct.

From the graphs of the PID real-time data, exposures to solvents during construction painting tasks were characterized by highly fluctuating concentrations (Figure 3). Integrated air sampling may not be the most appropriate method for evaluating exposure to highly fluctuating concentrations because of lack of information regarding exposure patterns. Research by Jensen et al.(4) indicated that although average and short-term TWA exposures were well within accepted limits for toluene in rotogravure printing, peak concentrations many times above the occupational exposure limit occurred. A direct-reading instrument coupled with a data recording device could improve the evaluation of short-term and peak exposures. Solvent exposure and health risk among construction painters may be more appropriately assessed by the use of the ceiling or other excursion levels.

RECOMMENDATIONS

The results of this research support the use of a portable PID for assessing exposures to solvent mixtures. The following protocol is recommended for assessing exposure to hydrocarbon mixtures with a portable PID and datalogger. Perform a thorough review of the MSDS of the products to identify all potential contaminants and investigate the properties of the contaminants such as the IP, percentage composition, PID CFs, occupational exposure limits, and vapor pressures. For complex mixtures the PID can be calibrated to isobutylene to provide an assessment of the exposure in isobutylene-equivalent concentration. If a single contaminant or a class of compounds is present, the PID should be calibrated to the contaminant or to a major contaminant for the class of chemical. The PID may be used to perform general hydrocarbon monitoring to evaluate the TWA, short-term exposures, and peak exposures for the sampling period. The total hydrocarbon concentration measured by the PID may not be useful for characterizing the exposure related to a given contaminant and its exposure level, especially for compounds with low exposure limits or poor instrument response.

The findings of this investigation also provide support for the use of data from the PID and compositional information from MSDS to compute mixture TLVs for initial risk assessments. Overall, personal monitoring of solvent vapors using a portable datalogging PID has the potential to provide the most cost-effective method for evaluating exposure to complex hydrocarbon mixtures during construction painting.

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