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Reducing Solvent Exposures of Auto Body Workers

An Educational and Motivational Study Incorporating
Personal Protective Equipment to Reduce Solvent Exposure

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SIGNIFICANT FINDINGS

1) This study identified no measurable effect of the motivational intervention program. One painter demonstrated reduced exposure levels after the intervention; however, the variability of the data precluded a definitive conclusion about any contributory effect of the intervention. Any solvent exposure reduction which may have been present in this subject sample was overshadowed by the uncertainty in exhaled breath measurements due to presumed leakage.

2) Respirator leakage was identified as a major confounding factor in exhaled breath sampling utilizing the dual sorbent half face respirator collection system.

3) Respirator leakage was nonuniform and displays high intersubject and intrasubject variability. This nonuniform response combined with insufficient information about the leakage effect over a wide range of exposure conditions precluded the possibility of any adjustment of the expired breath measurements.

4) The dual sorbent collection system still may be a valid means for sampling of organic solvents in exhaled breath if tests are conducted in a noncontaminated atmosphere.

ABSTRACT

Auto body repair shops use large quantities of organic solvents in settings which commonly have inadequate engineered protective systems. Employees are therefore at risk for potential solvent-related health problems, such as neurologic disease. Personal protective equipment probably provides the best means of individual protection in this environment, but in general such equipment is underutilized by most workers in this industry. Since the use of personal protective equipment is highly dependent upon the individual worker's degree of motivation, an educational program which incorporates exposure information derived from the individual worker's personal situation might provide a better basis to motivate use of personal protective equipment.

Unlike air sampling, the measurement of many solvents in exhaled breath or body fluids can assess an individual's exposure to those solvents by skin as well as inhalation routes. Breath sampling is relatively noninvasive and is sometimes more acceptable to individuals than is collection of blood or urine. However, exhaled breath measurements can be logistically difficult to perform, and most available techniques do not allow rapid quantification of solvent levels in breath. A breath sampling device which provides individual exposure information in a relatively rapid and reliable manner and which can actually be readily deployed in the worksite could be a valuable component of an educational program which emphasizes individual rather than generic information.

The objectives of the study were to demonstrate that: 1) the use of personal protective equipment can effectively reduce personal exposures to organic solvents in the auto body repair industry; 2) an exhaled breath sampling device, which uses a dual sorbent cartridge collection system on a modified half face air purifying respirator and which can be worn by a worker while performing nonexposure work activities, can be used in the field to assess an individual's solvent exposures and to provide reliable exposure information within 24 hours of measurement; and 3) the results of personal breath sampling for exhaled solvents can be an effective component of an educational program to motivate individual workers to use skin and respiratory personal protective equipment.

The study involved eleven painters and assistant painters in five auto body repair shops. The level of exhaled toluene was sampled in each participating worker's breath prior to work shifts on Monday, Tuesday, Wednesday, and Thursday of the week prior to the institution of a new educational program encouraging use of personal protective equipment. Airborne toluene was monitored throughout each work shift using personal charcoal passive dosimeters and also during the breath sampling session using charcoal tubes and a personal sampling pump. During the subsequent week, participants were given their individual breath and air sampling results as part of an educational program which focused on the health effects of paints and solvents and on the proper use of gloves and respirators. Appropriate gloves and respirators were provided, along with replacement supplies. Qualitative respirator fit testing was performed. Breath and air sampling were repeated using identical protocols after 2 weeks and again after 6 weeks.

This study identified no measurable effect of the motivational intervention program. One painter demonstrated reduced exposure levels after the intervention; however, the variability of the data precluded a definitive conclusion about any contributory effect of the intervention. Any solvent exposure reduction which may have been present in this subject sample was overshadowed by the uncertainty in exhaled breath measurements due to presumed leakage. Respirator leakage was identified as a major confounding factor in exhaled breath sampling utilizing the dual sorbent half face respirator collection system. Respirator leakage was nonuniform and displays high intersubject and intrasubject variability. This nonuniform response combined with insufficient information about the leakage effect over a wide range of exposure conditions precluded the possibility of any adjustment of the expired breath measurements. The dual sorbent collection system still may be a valid means for sampling of organic solvents in exhaled breath if tests are conducted in a noncontaminated atmosphere.

INTRODUCTION

The importance of evaluating worker exposure to organic solvents is underscored by a recent National Institute of Occupational Safety and Health (NIOSH) report[1] indicating that approximately 9.8 million workers are currently exposed through work practices. These organic solvents, which are commonly used in paints, glues, printing inks, degreasers/cleaners and other applications, represented a total production of 49 million tons in 1984.[1]

Industry evaluations and research efforts conducted by graduate students at the University of Washington have highlighted the auto body repair industry as a work place with widespread worker exposure to organic solvents. Automobile respray work sites have multiple solvent exposures, and high intermittent peak solvent air concentrations.[2] Characteristically, these industries employ five to ten employees, and the work is divided between metal straightening and spray painting with the most significant solvent exposure experienced by the painters and painters' helpers.[3] Industrial hygiene surveys have found that proper engineering controls are often absent or inappropriately used and that a large proportion of workers do not understand the selection, use, and maintenance of personal protective equipment.[3,4,5] Additionally, due to the limited numbers of employees at a given work place, these operations are routinely excluded from federal and state work place evaluations and do not have the financial resources or knowledge to conduct their own industrial hygiene programs.

Auto body shop industrial hygiene surveys have reported ambient air levels of commonly used organic solvents that are typically below those suggested by the American Conference of Governmental Industrial Hygienists (ACGIH), based on 8 hour time-weighted averages (TWA).[3,4] Worker exposure, however, is significantly affected by extensive dermal contact and by intermittent peak air exposures which grossly exceed the concentration component of the ACGIH short-term exposure limits (STEL).

There is widespread evidence that some of the commonly used solvents in paint formulations may produce adverse neurological response related to both acute and chronic exposures. With rare exception (isocyanates) workers in the auto body repair industry are generally unaware of the health hazards associated with their occupational exposure.

Given the ubiquitous observation of poor industrial hygiene conditions in auto body repair shops and the general lack of sufficient capital resources for engineered protective devices, the most feasible way to adequately protect the workers from exposure to organic solvents may be through the proper use of personal protective equipment. This project, which involved employees from Seattle area auto body repair facilities, addressed the following question:

> **Is it possible to motivate workers to reduce individual exposure levels to organic solvents through education and counseling which highlights measured personal body burdens and exposure levels, the health effects of chronic solvent exposure, and the proper selection, use, and maintenance of personal protective equipment?**

BACKGROUND

A. Auto Body Repair Shop Environment

In a recent literature review of health hazards associated with small businesses, Tuskes and Key [5] cited the results of their investigations which included health and safety evaluations of 131 auto body repair shops in the Houston, Texas area. The authors' summary provided a picture of characteristic conditions within the auto body repair industry which highlighted spray painting activities as one of the key industrial hygiene problem areas. They found that spray painters were poorly trained pertaining to the use, maintenance, and limitations of personal respiratory protective equipment. Forty-four percent of the surveyed shops provided dust respirators to spray painters, while 13 % provided no respiratory protection at all. Additionally, a large number of workers (78%) had received no training regarding the use of respirators, and most shops utilized improper storage (64%) or performed no routine cleaning of respiratory equipment (63%). With regard to ventilation for limiting solvent exposure, 29 % of the shops had a spray booth, 50% had a designated spray area, and 21% allowed painting with no designated area. Although a sizeable number of shops had spray booths , 29% had no ventilation in the booth, and in 32 % the measured ventilation was inadequate for the given exposure conditions. In their concluding remarks the authors noted that because most auto body shop owners had grown up in the business they tended to accept a high level of personal risk. This attitude, of course, would directly affect the behavior of the employees regarding solvents exposure and the the use of personal protective equipment.

Jayjock and Levin[4] investigated what they considered to be a typical East coast auto body shop characterized as a small (2-4 man) " bump and paint" operation. Over the course of a year they sampled for common paint solvents (i.e. toluene) in air and found peak solvent exposure levels of 123-2224 mg/m3. The highest observed toluene air concentrations, obtained during specific painting events, exceeded the concentration factor of the ACGIH TLV-STEL (560 mg/m3) by nearly five times. Similar to Tuskes and Key, the authors concluded that shop ventilation conditions were often inadequate; in this case a spray booth was in use but measurements of flow indicated extremely variable rates. In particular during the winter months painting was often conducted without using the booth exhaust system in order to conserve shop heat, and these conditions generated the highest observed exposure conditions. These levels were excessive enough to have produced visible signs of intoxication in one of the workers within 5-10 minutes of a specific paint event. The authors concluded that 1) the auto body repair shop workers were typically overexposed to airborne contaminants (solvents, dust) due to ineffective ventilation and the failure to utilize personal protective equipment, 2) the workers had little training or awareness of the potential health hazards in their work place, and 3) ambient air solvent levels frequently exceeded the recommended ACGIH TLV-STEL concentration levels with full shift exposures occasionally exceeding the ACGIH TLV-TWA. With these observations, they recommended that selective short-term use of personal protective equipment, during high exposure operations, could effectively reduce worker exposure to airborne contaminants.

Recent graduate theses by students from the University of Washington (O'Donnell[3], Millies[6], and Kirkpatrick [7]) have provided additional insight into worker solvent exposure levels through area and process measurements of ambient air, combined with biological monitoring of the exposed workers. These efforts, which evaluated auto body repair facilities in the Seattle, Washington area, also provided descriptions of the characteristic industrial hygiene conditions.

O'Donnell[3] investigated twenty- five Seattle area auto body repair shops to evaluate workers' solvent exposures and industrial hygiene conditions. The surveys included measurements of ambient air and breathing zone concentrations of solvents during specific work tasks, assessment of the shop ventilation systems, and observations of worker use of personal protective equipment. The work task exposure level evaluation identified painters and painters' helpers as the high exposure population. When comparing the mixture /TLV ratios (summation of individual solvent concentrations divided by their respective ACGIH TLVs), painters' helpers and painters had median mixture ratios of 0.19 and 0.26, respectively, compared to body repair workers with values of 0.04 . Analytical results of area and personal samples indicated that the three major organic solvent components present were acetone, toluene , and xylene. Toluene values for 8-hour TWA ambient air samples for painters and helpers ranged from .33 - 204 mg/m3. During specific painting events toluene air concentrations reached values as high as 3000 mg/m3, however the event durations were never long enough that exposures exceeded the ACGIH-STEL criteria (560 mg/m3 for 15 minutes). Although toluene levels typically did not exceed the ACGIH-TWA (375 mg/m3) , solvent mixture levels occasionally reached 50 % of the solvent mixture TLV. O'Donnell observed that engineering controls (i.e. adequate ventilation systems) to reduce worker exposure levels were generally absent or inadequate. Although a large number of shops (70%) had ventilated spray booths, the measured velocities were typically well below the recommended levels suitable for worker protection. Due to the large number of paint jobs possible at a given time, most paint operations were carried out in the shop area where general room ventilation was the only means of contaminant removal. Similar to the findings of Tuskes and Key, O'Donnell observed that workers often used inappropriate respiratory protection (e.g.dust mask for solvent vapors), did not use any protection, or maintained the respirators improperly (e.g changed cartridges only when solvent vapors could be smelled). Also although there was significant dermal solvent exposure during the painting preparatory stage and cleaning of equipment, gloves were rarely used.

Another project conducted by Millies[6] examined the feasibility of using a breath sampling system for measuring solvent exposures among workers in the auto body repair industry. This study examined the ambient air levels and exhaled breath values of toluene in 12 painters, assistant painters , and helpers. Expired breath levels of toluene were evaluated via the dual sorbent breath sampling system developed by Morgan, et al [8]. The measured post-exposure (16 hours) expired toluene breath levels were 0.4 - 2.4 mg/m^3 which were associated with previous work shift ambient air levels of 14-220 mg/m^3 (8 hour TWA) . These breath concentrations were higher than expected based on previous laboratory studies evaluating controlled toluene inhalation exposures and expired breath solvent concentrations (17-20 hours post exposure).[9,10] Millies suggested that work practices with extensive dermal solvent contact (i.e. wiping down cars with rags, cleaning equipment and cleaning exposed skin) may explain the noted increase in expired breath measurements. Industrial hygiene conditions noted in this survey were considered typical of auto body repair shops. Major paint areas were improperly ventilated, and personal respiratory protective equipment was either insufficient, inappropriate, or completely lacking. In addition none of the study participants wore protective gloves as part of their standard work practice.

In a further evaluation of solvent exposed workers within the auto body repair industry, Kirkpatrick[7] conducted an industrial hygiene survey of five auto body repair shops in the greater Seattle area. This study evaluated the exposure levels of eleven painters and painters' helpers to organic solvents, using expired breath sampling and ambient air monitoring. Measurements of pre-shift breath levels (Monday baseline and 16 hours post exposure on successive work days) were conducted to determine possible solvent buildup and to examine the relationship between breath solvent concentrations and the previous days' exposures. Pre-exposure Monday morning baseline breath samples of study participants demonstrated significantly higher values than had been found in subjects of previous studies without chronic solvent exposure. Kirkpatrick suggested that, if no weekend exposure to organic solvents had occurred, the measured breath levels represented a prolonged washout period and possible chronically elevated body burden levels. More important in evaluating the actual worker exposure level was the relationship between ambient air values and expired breath levels. Based on the controlled laboratory inhalation studies (toluene) of Litzinger[9] and Phillips[10], expired breath levels of .34 - .60 mg/m^3 would be expected for ambient air values of 75-170 mg/m^3 (8-hour TWA) . The Kirkpatrick study found pre-shift expired breath levels of .02 - 4.36 mg/m^3 in association with ambient air levels (8-hour TWA) of .31 - 116 mg/m^3. In evaluating the industrial hygiene conditions, Kirkpatrick described extensive dermal contact with solvents and noted the following: " subjects did not wear gloves while working with solvents, cars were wiped down with solvent soaked rags, and most workers cleaned their hands in solvent". This extensive dermal contact was suggested as the most significant reason for the nearly eight-fold increase in expired breath levels when compared to predicted levels.

B. Adverse Health Effects

Systemic health effects of organic solvent exposure are most commonly manifested as disturbances of central nervous system (CNS), and to a lesser degree, peripheral nervous system functions. Organic solvents such as carbon disulfide, n-hexane,and methyl-n-butyl ketone are well documented to have peripheral neurotoxic properties, and carbon disulfide is additionally capable of producing severe toxic encephalopathy[11,12]. Acute extreme high level exposures to virtually any organic solvent can produce transient disorientation, euphoria, and confusion; this acute condition can progress to unconsciousness, paralysis, convulsion, and death due to respiratory or cardiovascular failure.[13] Workers exposed to organic solvents at the lower levels which are typically encountered in the work place may also report a wide range of subchronic, nonspecific symptoms including fatigue, irritability, memory and concentration difficulties, dizziness, and headaches. Since the early 1970's a number of studies have examined the prevalence of neurologic symptoms and decrements in neuropsychological test performances among workers with chronic mixed solvent exposures. In a recent review of this literature, Baker, et al[14] concluded , " The accumulated evidence supports the occurrence of a syndrome of toxic encephalopathy caused by excessive exposure to organic solvents in such trades as painting and boat building. This syndrome is characterized by memory disturbances, impaired psychomotor function, impaired verbal abilities, and disturbances of mood." In severe cases the behavioral effects have been observed to persist years after removal from solvent exposure.

Elofsson, et al[15] conducted a cross-sectional epidemiological survey of 80 car and industrial painters and 160 unexposed electronics plant workers to determine the possible health effects resulting from chronic low level exposure to mixed organic solvents. The researchers made an attempt to evaluate actual exposure conditions through worker questionnaires and by constructing a typical workshop environment which simulated solvent exposure conditions. Toluene was the most commonly detected solvent with measured exposure levels of 93 mg/m3 (auto body painters) which were well below the Swedish TLV of 300 mg/m3. The authors evaluated the study population utilizing psychiatric, psychological, neurophysiological, neuroradiological, and ophthalmological methods. In order to account for potential confounding factors, the researchers attempted to control for the effects of age and intellectual ability when comparing the results of nervous systems parameters in the case and referent study groups. Characteristically the exposed workers reported significantly ($p<.05$) more neurasthenic symptoms (i.e. irritability, learning problems, loss of short and long term memory, headaches) than the reference group. Psychological assessments also showed statistically significant ($p<.05$) exposure-associated, relative decrements in memory, manual dexterity, perceptual speed and reaction time. Differences were also found in neurophysiological tests with the exposed population on average having slower nerve conduction velocities, lower nerve action potentials, and higher vibratory perception thresholds. While the authors noted that the presence of lead exposure was a possible confounder in assessing nervous system effects, they concluded that chronic solvent exposure was probably the influential factor in the observed nervous system deficits.

In another cross-sectional epidemiological study Husman[16] evaluated 102 male car painters from 27 car repair garages to evaluate symptomatology as an early expression of the effect of low level exposure to organic solvents. The exposed population was age matched through the age of 55, which was the mandatory retirement age of the reference group (train engineers). Analysis of questionnaire data indicated no observable differences in alcohol consumption, use of medicines, or smoking habits; and limited military test data (33 pairs evaluated) indicated that intellectual abilities were similar. The researchers measured 1-hour ambient air solvent concentrations in six randomly selected car repair facilities and found personal breathing zone solvent levels ranging from 4 to 212% of the 1974 Finnish TLVs (~1974 ACGIH TLV s) . Toluene had the highest average values with mean 1 hour levels of 113 mg/m^3 (8-hour TLV-TWA 750 mg/m3. Symptoms of fatigue and disturbances in memory and vigilance occurred statistically ($P<.05$) more often in the solvent exposed workers than in the reference population. These effects were more obvious in workers with longer time periods of exposure history. Symptoms which occurred during the work shift, such as "prenarcotic" effects (nausea, drunken feeling, dizziness, and absentmindedness), also occurred more often in the exposed population.

Recently Gregersen et al[17] completed a retrospective evaluation of 21 painters (3 car painters and 18 house painters) who had been diagnosed as having chronic toxic encephalopathy following prolonged exposure to organic solvents. Symptoms associated with the condition included headaches, dizziness, fatigue; learning, memory and concentration difficulties, and emotional instability. The authors reported that " a common feature of the worker case histories was recurrent episodes of cerebral intoxication with a gradual decreasing tendency to remission, leading to a syndrome presented clinically as irreversible intellectual impairment, at times so severe as to be occupationally disabling". The painters included in this study had rarely used the appropriate solvent respirators, and in most cases the only ventilation used was natural. Follow-up social evaluations of the affected workers discovered that those who were able to find new employment were often younger, less intellectually impaired, and had experienced a shorter exposure history. The remainder of affected workers became disability pensioners.

In addition to these potential neurologic effects, solvent-exposed workers such as painters are also at risk for other adverse health outcomes including respiratory sensitization (due to isocyanates)[18], contact dermatitis[19], and hepatic[20] or renal [21] damage due to organic solvent exposure.

C. Motivational, Counseling and Education Efforts to Reduce Worker Exposure

In an attempt to measure the effectiveness of counseling and education to reduce worker exposure, Hopkins et al[22] evaluated three plants making fiberglass reinforced styrene plastic products. The researchers developed a training program to teach workers the appropriate work behavior to reduce work exposures, and a behavior maintenance program was developed to encourage the selected work practices . Examples of the selected work behavior included: 1) keeping styrene off skin, 2) keeping breathing zone outside a minimum distance from the work, and 3) working only in properly ventilated areas. In addition to work practice changes the workers were encouraged to use improved housekeeping techniques (i.e., floor areas covered with disposable material, all spray booth filters in place). The workers were provided training sessions utilizing videotapes demonstrating both good housekeeping and work practice and then were monitored over a period of time (mean time 112 ± 16 days). The workers were evaluated for compliance by observers and were tested on their knowledge of the defined behavior/housekeeping parameters. Workers were praised for good work practice and were rewarded with limited financial rewards for passing tests on behavior/housekeeping variables and for maintaining certain work practices (i.e. keeping styrene off the skin). If employee behavior or work conditions failed to meet the prescribed criteria , the employee was counseled again on the reasons for specific behaviors and aided in correcting housekeeping problems . The study found that in all three participating plants worker exposure to styrene was significantly lowered over the course of the study. Mean ambient air levels were reduced from 145 to 89 mg/m^3 (Plant 1), 217 to 60 mg/m^3 (Plant 2), and 140 to 21 mg/m^3 (Plant 3). The authors concluded that the best protection for workers in all industries is likely to require a combination of engineering controls and proper behavioral controls.

In another counseling and motivation program Bentley[23] investigated the exposure of sawmill workers to sapstain solutions containing chlorinated phenols (pentachlorophenol - PCP, tetrachlorophenol - TCP). The worker exposure levels were monitored via biomonitoring (urine), labeled skin exposures (sapstain solution including fluorescent dye) , and ambient air and surface wipe samples. Exposed employees were placed in front of a long wave length UV light source, and contaminated areas of the skin or clothing were made visible with the fluorescent tagged sapstain solution. The employees were then counseled regarding the use of proper personal protective equipment (gloves, barrier creams, aprons) and appropriate work practices to reduce exposure (i.e., no eating on the job, washing work clothes daily, washing contaminated skin immediately). Information was also provided regarding exposure to sapstain solution and the potential health effects. Despite the fact that ambient air levels and surface sample concentrations of both PCP and TCP did not decline over the course of the study, urinary analysis indicated a significant ($P<.05$) reduction in worker body burden levels. With the exception of one worker exhibiting an increase in urinary PCP, the remaining workers had decreases in urinary levels of 5-40% (TCP) and 0.5-19% (PCP). These results support the concept that workers, when provided with information regarding personal exposure levels, potential health effects due to contaminant exposure, and training in the use of the proper protective equipment, can be motivated to change work behavior thereby reducing personal exposure.

D. Biological Monitoring of Solvent Exposed Workers

The importance of biological monitoring in the assessment of exposure to organic solvents has been recognized by the American Conference of Governmental Industrial Hygienists in their establishment of the biological exposure indices (BEI)[24]. At the current time the ACGIH has established BEI's for eleven different organic solvents with the suggested methods of biological monitoring being blood, urine and/or exhaled air [25]. As stated in the background material for the establishment of the BEI's, the primary and significant usefulness of biomonitoring techniques lies in the ability to more fully assess the true biological burden of potentially toxic materials.

It has been recognized in previous studies [6,7,26,27] that ambient air monitoring will often provide a very incomplete picture of the true body burden due to such factors as dermal exposure, biological solvent accumulation, and physiologic variables (e.g pulmonary ventilation rates). The potential of the dermal exposure route has also been emphasized by studies specifically evaluating rates of skin absorption of common organic solvents. Dutkiewicz and Tyras[28] found that very short exposure to pure liquid toluene (minutes) or prolonged contact to a toluene-water solution (1 hour) could produce a body absorption equivalent to inhalation of 111 mg/m^3 toluene over an eight hour period. Aitio et al [29] also demonstrated that solvents such as TCE, toluene, or 1,1,1, trichloroethane are absorbed by the skin to such an extent that blood samples, collected immediately after the exposure has ceased, may provide erroneous information regarding estimations of actual work shift solvent exposures.

Previously cited studies[6,7] of Seattle area auto body spray painters have demonstrated the feasibility of monitoring worker exposures to organic solvents utilizing expired breath collected with a modified respirator sampling system developed by Morgan et al [8]. Field and laboratory testing of this system has demonstrated that reliable solvent concentration measurements may be obtained even at the low levels that are commonly seen in expired breath samples. This sampling device offers many advantages over other forms of exposure monitoring, among which are the opportunity for accurate integration of complex exposure patterns(dermal and inhalation) and relative noninvasiveness compared to the collection of blood or urine samples.

METHODS

A. Subject Selection

Participants in this study were recruited by telephone solicitation and personal visitation of Seattle, Washington area auto body repair shops. Based on sampling logistics and analytical time constraints, it was decided that a minimum of two auto body painters per shop would be needed as subjects . Auto body repair shops meeting these criteria were selected based on information supplied by the Contacts Influential Business directory [30] and suggestions from personnel of the Field Research and Consultation Group (Department of Environmental Health, University of Washington). Sixteen individual auto body repair shops were contacted, and of these six agreed to review the proposed study. Initially the owners or managers of the interested repair facilities were presented with a summary of the proposed study (Appendix A) , and permission was requested to meet the individual auto body painters. The painters were provided with a description of the study (Appendix A) and, if interested in participating, were also given a personal consent form (Appendix A). Based on this selection process, eleven individual painters from five different repair facilities agreed to participation in this study. One painter was excluded after initial sampling due to incomplete participation. The remaining ten subjects completed the nine week sampling period, except for one subject who terminated his employment before completing the last sampling session.

B. Study Design

The study consisted of a three phase sampling protocol designed to evaluate the effect of a motivational intervention program on the reduction of organic solvent exposure in the participating auto body painters. A detailed description of the sampling protocol follows and is displayed graphically in Figure 1.

Phase 1 (Sample Week 1 - Pre-intervention and Intervention)

Baseline measurement period with subjects maintaining normal work practices followed by an end-of-week intervention session.

1) *Pre-shift breath sampling (Monday-Thursday)*

Breath sampling was performed as described in Methods - Section C. The Monday morning sample reflects the body burden following a period of non-exposure to organic solvents on the previous week-end. Individual measurements conducted on Tuesday through Thursday were taken before any new solvent exposure and each was presumed to primarily reflect to the previous day's solvent exposure. All subjects were fit tested in the sampling respirator, with attached cartridge, prior to the Monday morning sample. The preliminary qualitative fit testing mode utilized both positive and negative pressure procedures suggested by NIOSH[31], which were supplemented by a second procedure incorporating an odorous chemical (isoamyl acetate). To assure a similar respirator fit during all testing periods, each subject was assigned a specific respirator for the entire study, and respirator strap measurements were both recorded and maintained after the baseline fit testing.

2) *Pre-shift ambient air sampling (Monday-Thursday)*

Breathing zone samples were collected with a personal sampling pump and charcoal tubes daily, Monday through Thursday, during the breath sampling procedure to document toluene concentration in the test atmosphere. This information was needed to assess the potential of respirator leakage and its influence on the observed breath values.

3) *Work-shift ambient air sampling (Monday-Thursday)*

Passive charcoal dosimeter badge samples were collected to provide measurements of average personal breathing zone solvent exposures during the full work shift.

4) *Intervention period(Friday Week 1)*

At the conclusion of the first sampling week, the painters were presented with individual breath sample measurements, data on the health effects of organic solvent exposure, and information on the proper use, selection, and maintenance of personal protective equipment. The time period allotted for the presentation (described below) was 15-20 minutes. Depending on the level of interest expressed by the subjects this discussion occasionally required 45 minutes to 1 hour.

a) Individual breath sample measurements - These data were presented with reference to the average toluene expired breath levels observed in previous Seattle area auto body repair surveys and to expected breath concentration levels resulting from a controlled 8-hour inhalation exposure at the TLV of 375 mg/m3.

b) Data on the health effects of organic solvent exposure - The primary emphasis was central nervous system deficits resulting from chronic solvent exposure over a working lifetime. Other potential health effects addressed were dermatitis, liver and kidney disorders, and respiratory dysfunction due to isocyanate exposure.

c) Information on the proper use, selection, and maintenance of personal protective equipment - This portion of the presentation highlighted the following areas:

1) Development of a knowledge base regarding the solvent hazards associated with their work place. Potential sources that were suggested included material data safety sheets, paint product information labels, and consultation with local health and safety agencies.

2) Selection, use, and maintenance of respiratory protection - The areas of emphasis were selection of the proper respiratory protection (dual organic vapor cartridge half face respirator w/ paint pre-filter vs. disposable dust mask), usage time for respiratory protection (high solvent exposure activities such as painting or using wax/grease removers), and respiratory equipment maintenance (organic vapor cartridge replacement schedule, storage of equipment). It was also suggested that isocyanate based paint products should be used in a spray booth with supplied air respiratory protection.

3) Glove selection and use - Information on glove selection emphasized the mode of potential dermal contact. NBR-Nitrile gloves were recommended for liquid solvent exposure contact, and disposable latex gloves were suggested for potential paint over-spray contact.

At the conclusion of this presentation the subjects were supplied and fit tested in new half face dual organic vapor cartridge respiratory protection and provided with gloves to reduce dermal solvent exposure. Additional respirator supplies and gloves were supplied to all participants throughout the course of the study. Replacement organic vapor cartridges and paint pre-filters were provided to allow changing on a bi-weekly and weekly basis respectively.

Phase 2 (Sample Week 4 or 5-) First follow-up measurement period

1) *Pre-shift breath sampling (Monday-Thursday)*
2) *Pre-shift ambient air sampling (Monday-Thursday)*
3) *Work-shift ambient air sampling (Monday-Thursday)*
4) *Presentation and discussion of breath sample results(Friday)*

Phase 3 (Sample Week 9) - Second follow-up measurement period

1) *Pre-shift breath sampling (Monday-Thursday)*
2) *Pre-shift ambient air sampling (Monday-Thursday)*
3) *Work-shift ambient air sampling (Monday-Thursday)*
4) *Presentation and discussion of breath sample results(Friday)*

Toluene was chosen as the marker or reference solvent for this study based on a review of manufacturer's paint product labels and material data safety sheets. Previous research of the auto body repair shop work environment [4,7] has also shown that toluene is one of the most common organic solvents based on ambient air measurements.

C. Breath Sampling

1. General Information

Expired breath samples were collected with a modified respirator sampling system developed by Morgan et al [8]. This sampling device consists of a cartridge collection system containing charcoal cloth sorbent layers and molecular sieve (Figure 2), which is attached to a standard half face air purifying respirator with a modified exhalation port . The system design is based on 1) adsorption of organic vapors on charcoal cloth with subsequent analysis via standard gas chromatographic methods and 2) determination of expired breath volume, utilizing the relationship between collected breath moisture (weight gain on molecular sieve) and the nearly constant water vapor content in expired breath in most individuals of 0.034 grams per liter.

2. Breath Sampling Respirator

The sampling respirators used for collection of breath samples were American Optical (A/O) Model 5500 half face air purifying respirators with a modified exhalation port, designed to receive the breath sampling cartridge. The modification of the respirator was limited to placement of a Wilson brand inhalation port cartridge holder (Model R675) with an attached exhalation valve to the standard A/O respirator exhalation port. This cartridge receptacle was then cemented in place with a silicone sealant. To filter the ambient air during the breath sampling process, the inhalation ports were fitted with organic vapor cartridges and paint pre-filters(A/O Models R51A and R49A).

3. Charcoal Cloth and Molecular Sieve Preparation

Preparation of the charcoal cloth used as the sorbent layers consisted of using a machined stainless steel punch to cut 7.5 cm diameter circles from supplied sheet goods (Charcoal Cloth,Ltd., Berkshire, England) . These circular sections, which were designed to fit the upper section of the sampling cartridge, were then placed in open mesh stainless steel baskets and activated in a high temperature vacuum oven by baking off organic solvent contaminants in an inert atmosphere. The temperature was controlled in the VWR Model 1410 vacuum oven at 210 ^{o} C for a period of twelve hours. Establishment of an inert atmosphere was maintained by continuously flowing N_2 gas through the oven at a rate of 29 milliliters per minute; a constant measure of flow was obtained via a Dwyer rotameter (0-1.0 SCFH model) at a setting of 0.125 SCFH. After activation the charcoal cloth samples were placed in capped glass jars and stored in a solvent free atmosphere within a laboratory desiccator. The stainless steel mesh support screens used in the sampling cartridge were also prepared in a similar fashion.

The molecular sieve (Davison Chemical Grade 564 molecular sieve) used for breath moisture collection was prepared for sampling by dehydrating the sieve, heating it in the vacuum oven at temperature of 210 ^{o}C for a minimum period of twelve hours. Air flow was maintained through the oven at a constant rate of 17 liters per minute to remove any evolved water vapor.

4. Collection of Breath Samples

Approximately twelve hours prior to the collection of breath samples from the subjects, the sample cartridges were prepared in the following manner:

a. Pre-weighing of the molecular sieve in storage jars on Sartorius Model 2842 Electronic Analytical Balance, to a precision of .0001 grams.

b. Transfer of pre-weighed sieve to lower portion of sampling cartridge with paper funnel. This adsorbent was secured in place with stainless steel mesh screens and a teflon o-ring.

c. Two sections of charcoal cloth were placed on the permanently affixed mesh screen bottom of the upper portion of the sampling cartridge. This section formed the back-up set of the two charcoal cloth pairs. The lower cloth section was overlain by a retaining teflon o-ring, stainless steel mesh support screen, the second charcoal cloth pair (front section of the charcoal cloth pairs), and a stainless steel support screen, all of which were held firmly in place by a final teflon o-ring. (Figure 2)

All of the cartridge loading procedures were done while wearing latex disposable gloves to avoid contamination of the collection media. After completion of the cartridge loading process, the samples were stored in sealed plastic bags for transfer to the individual auto body repair work sites.

Breath sampling of the participating painters was performed at the work site before the beginning of the work shift. This sampling time frame represented a period of 12-16 hours of elapsed time since the previous day's solvent exposure. Based on solvent excretion kinetics studies this time has been suggested as the optimal time for assessing biological body burden[32], since samples which are collected at the end of a work shift are characteristically reflective of the most recent exposure. Prior to the initiation of the actual breath sampling process, the subjects wore the sampling respirator without the collection cartridge for a period of approximately 5 minutes. This pre-sample period is intended to warm the respirator to reduce breath moisture condensation, and to eliminate recent solvent contamination of the physiologic dead air space. After the warming phase the cartridge was inserted into the sampling respirator and worn by the painter for a timed period of 20-25 minutes. The subjects were instructed to avoid any work processes with active solvent generation, such as painting or the use of wax and grease removers. Work tasks which were generally completed during the sampling process included taping and masking of intended paint areas, sanding, and buffing of previously completed paint jobs.

Following collection of the breath sample, the sample cartridges were stored in sealed plastic bags for transfer to the analytical laboratory. The charcoal cloth sorbent sets (back,front) were placed into labeled 4 dram glass vials with teflon lined lids, and the molecular sieve was returned to the original storage jars. Storage jars containing the molecular sieve were then re-weighed on the electronic analytical balance. The measured weight gains were used to determine the expired breath volume based on previous observations of a relatively constant water vapor content of 0.034 grams per liter of exhaled breath[33].

D. Ambient Air Measurements

1. Work Shift Time Weighted Average Personal Breathing Zone Sampling

The subjects' daily exposures to solvents were monitored by using passive charcoal organic vapor dosimeter badges (SKC 530-11). These badges were attached to the shirt or paint overall collar and remained there throughout the entire work shift , including any time off for breaks or lunch. At the end of the work shift the painters were instructed to remove and cap the badge, place it in a provided sealed plastic bag, and record the time of removal on a supplied time sheet. The Monday through Wednesday samples were used as a correlative measure of personal solvent exposure to the succeeding pre-shift breath measurement. Additional samples, which were collected on Thursday and were not correlated to breath sampling results, were intended to provide additional ambient air solvent concentration data useful in assessing the weekly exposure variability.

2. Pre-Shift Personal Breathing Zone Sampling

In order to assess the ambient air concentration of toluene that occurred during the breath sampling procedure, charcoal tube samples were taken with a personal sampling pump. These samples were taken simultaneously with the breath sample for a measured time period of 20-25 minutes. All samples were collected using SKC 600 milligram charcoal tubes utilizing a Gillian Model HFS 113A high flow personal sampling pump. The flow rate of the sample pumps was set at 2 liters per minute and verified daily, before and after sampling, with a calibrated rotameter (Brooks Instrument Company -Model #1355CA1C1AAA). Samples were not included in the data analysis if the observed flow rate varied by more than 5% or if the pump failed .

The potential for respirator leakage influencing the expired solvent breath levels was further characterized by consecutive sampling (breath and charcoal tube) of two volunteer subjects (D1 and E2) in the following manner:

1) Collection of an initial pair of expired breath and breathing zone samples while the subject was in a very low solvent concentration atmosphere (parked car outside of repair shop). This sampling occurred before the painter had entered the work environment to reduce any potential for fresh solvent inhalation.

2) Collection of a second sampling set in the normal manner in the usual work place sampling area (i.e. similar to all other samples collected for that subject).

3) To investigate the effect of respirator leakage in a high solvent exposure atmosphere, a variation of the above scenario was performed. In this case, the initial samples (breath and charcoal tube) were collected in the normal work area and were followed by a second sample set collected while the painter worked in the paint mixing room.

E. Data Analysis and Presentation Techniques

1) Data Presentation

The primary method of assessing the effect of the motivational intervention in reducing solvent exposure in the subject painters was by evaluation of the expired breath solvent levels that occurred over the course of the study. These measurements are presented in the following two formats:

a) Comparison of the weekly mean values for expired breath and weekly mean previous work days solvent exposure levels, and

b) Comparison of the weekly average breath to badge concentration ratio versus pre-shift ambient air concentration (charcoal tube). This breath to badge ratio accounts for the variance in daily and weekly solvent inhalation exposure levels . Support for this normalization technique is based on occupational and controlled solvent exposure studies[34,35] which have demonstrated a linear relationship between prior work shift solvent air exposure concentrations and the following day pre-shift expired breath measurements. These observations suggest that for a given increase or decrease in the prior work shift inhalation exposure levels a directly related change should be observed in the following day's pre-shift expired breath solvent concentrations. By using this ratio information to account for subject solvent exposure concentration variability, an increase in the use of personal protective equipment (positive effect of the motivational intervention) should be reflected by a downward trend in breath to badge ratio in the post-intervention measurement periods (Weeks 4 and 9).

2) Definition of Sample Triad Sets

The minimum amount of daily information required for the evaluation of the intervention program was collectively referred to as a sample triad. This combination was composed of the following three parameters:

a) Previous work shift ambient air solvent concentration (Previous day's badge sample)
b) Pre-shift ambient air solvent concentration (Pre-shift charcoal tube sample)*
c) Pre-shift expired breath solvent concentration (Pre-shift expired breath sample)*

* These samples were collected simultaneously

Figure 3 graphically depicts the inter-relationship of these three sample parameters. Although prior work shift dermal exposure potentially affects the measured expired breath levels, no evaluation was made of this factor due to the complexity of sampling and quantifying dermal solvent exposure.

3) Calculation of 8-Hour TWA Equivalent Work Shift Exposures

To account for variability in the length of the subjects' work shift or nonstandard work periods (< or > 8 hours per day), all of the work-shift ambient air sample toluene concentrations measured with the passive dosimeter badges were converted to 8-hour TWA equivalent values. Conversion of the badge toluene concentration data was made in the following manner:

$$\underline{\text{8 Hour TWA Equivalent}} = \text{Measured Toluene Concentration(ug/m3)} * \frac{\text{Length of exposure(hours)}}{\text{8 Hours}}$$

F. Laboratory Analysis

1. Gas Chromatograph Description and Experimental Settings

Analyses of all breath and ambient air samples were accomplished with a Shimadzu GC Mini-2 gas chromatograph utilizing a flame ionization detector (FID) and capillary column . Parameters of the capillary column (J&W Model DB-5) include length (30 meters), film thickness (0.25 microns), and inside diameter (0.32 millimeters). Due to the large number of individual contaminants in both the ambient air and breath samples, a temperature program was employed to insure elution of all compounds prior to the beginning of the next analysis. Quantification of the organic solvent concentrations contained in the ambient air and breath samples was accomplished using peak area response, which was recorded with a Hewlett Packard Model 3396-A electronic integrator. The following provides a list of operational parameters for both the gas chromatograph and the electronic integrator:

Shimadzu G.C. Mini 2 Gas Chromatograph

a) Injector/detector temperature - 170^{o}C
b) Capillary Column Temperature (Temperature programmed)
  1) Initial temperature phase - 70^{o}C for 6 minutes to allow elution of toluene.
  2) Final temperature phase - Ramp at 20^{o}C per minute to final temperature of 140^{o}C and hold for two minutes.
  3) Cool down column to original temperature (70^{o}C) prior to next analysis.
c) Attenuation - 1 / Range - 1 (Combination for highest sensitivity)

d) Coarse gain - Set to produce a zero response (base line) integrator value of approximately 13.0 when the chromatograph was at operational temperature and the FID lit.
e) Gas flows for the FID (Air and H_2), make up gas (N_2) and bypass flow were measured with a Gillian Gilabrator Primary Flow Calibrator . The capillary column carrier gas (He_2) flow was determined using the relationship of the retention time, in minutes, of an unretained compound (CH_4) and the column volume of 2.413 milliliters. All flows were measured with the GC at operational temperatures, and both the bypass and column flows were determined after the FID was lit.

1) Column Carrier Gas (Pre-pure Helium) - 1.39 ml/min.
2) Air (Breathing Quality) - - 269 ml/min
3) Hydrogen - - 46.5 ml/min.
4) Nitrogen- - 53.7 ml/min.
5) Bypass split - - 126.3 ml/min.
6) Split ratio - - 91 : 1 (Bypass to column)

Hewlett Packard Model 3396-A Electronic Integrator

a) Zero setting = 20, 13.0*
b) Att^2=1
c) Cht Sp= 1.0 cm/min.
d) Area Rej = 0
e) Threshold = 1
f) Peak Width = 0.04

* This value is dependent on the initial coarse gain setting of the Shimadzu GC Mini 2 at the suggested analytical temperatures with the FID lit.

2. Toluene Calibration Standards

Based on air and breath levels established in previous industrial hygiene surveys of auto body repair shops[4,6,7], a set of calibration standards was developed by serial dilution to produce a concentration range of 0.85-1700 nanograms toluene per microliter (ng/ul) of standard. These calibrants were prepared with CS_2 as the diluent, which contained an internal standard (2,2,4-trimethylpentane) in a known concentration of 691.8 ng/ul. The gas chromatograph response through this concentration range was linear , and all solvents used in the standard preparation were glass distilled spectrophotometric grade. Breath concentrations were based on a calibration curve that related area and mass ratios between toluene and the internal standard; for ambient air samples, toluene concentrations were determined by the area response of the toluene peak versus microliter of injection volume. For all samples the level of quantification was the value of the lowest standard calibrant or 0.85 ng/ul.

3. Sample Preparation and Analysis

Breath samples were prepared for analysis by pipetting 10 milliliters of the internal standard spiked CS_2 solution into the 4 (~15 ml) dram vials containing the charcoal cloth pairs; for analytical consistency this volume of desorbing solution was supplied with a Optifix (Model 101.08-38) pipetting dispenser. To assure complete contact of the charcoal cloth with the desorbing solution a stainless steel spatula was employed to remove air trapped on the cloth surface. After a minimum desorption time of two hours, aliquots were transferred with disposable pasteur pipets to a 1/2 dram(~2 ml) septa top (teflon lined) vial for analysis.
The ambient air charcoal collection media (tube and dosimeter badges) were transferred to a 1 1/2 dram (~6 ml) glass vial capped with teflon lined lids . Three milliliter aliquots of the desorbing solution containing the internal standard were added with the dispensing pipet to each sample. These solutions were allowed to desorb for a minimum of two hours prior to analysis. As with the breath samples, after desorption, a small aliquot was transferred to 1/2 dram (~ 2 m l) septa top (teflon lined) vial for analysis. For the charcoal tube samples, front and back sections were analyzed independently.

All injections of the standard calibrants, breath, and ambient air samples were made with a Hamilton 5 ul syringe (Models # 95N/95RN). With all sample types, breath or ambient air, at least one sample was evaluated daily with three repeated gas chromatographic analyses.

G. Quality Control

Constancy of the gas chromatograph instrument response and analytical conditions were checked on a daily basis before the beginning sample analysis by evaluating the chromatographic response of a standard calibrant . The observed variance of the standard, checked relative to the original area count response for that calibrant, was typically less than ±10%.

To evaluate the background levels of toluene during sample preparation and prior to collection, sample blanks were used daily for each sampling media. These blanks, which were identical to actual sample media, were treated in similar manner except that breath or ambient air was not actively sampled. For the passive charcoal dosimeter badge, the reproducibility of the sampling procedure was evaluated by taking paired samples with a dual sampling badge holder. Any toluene mass collected with blank samples was subtracted from the appropriate media when final concentrations were determined.

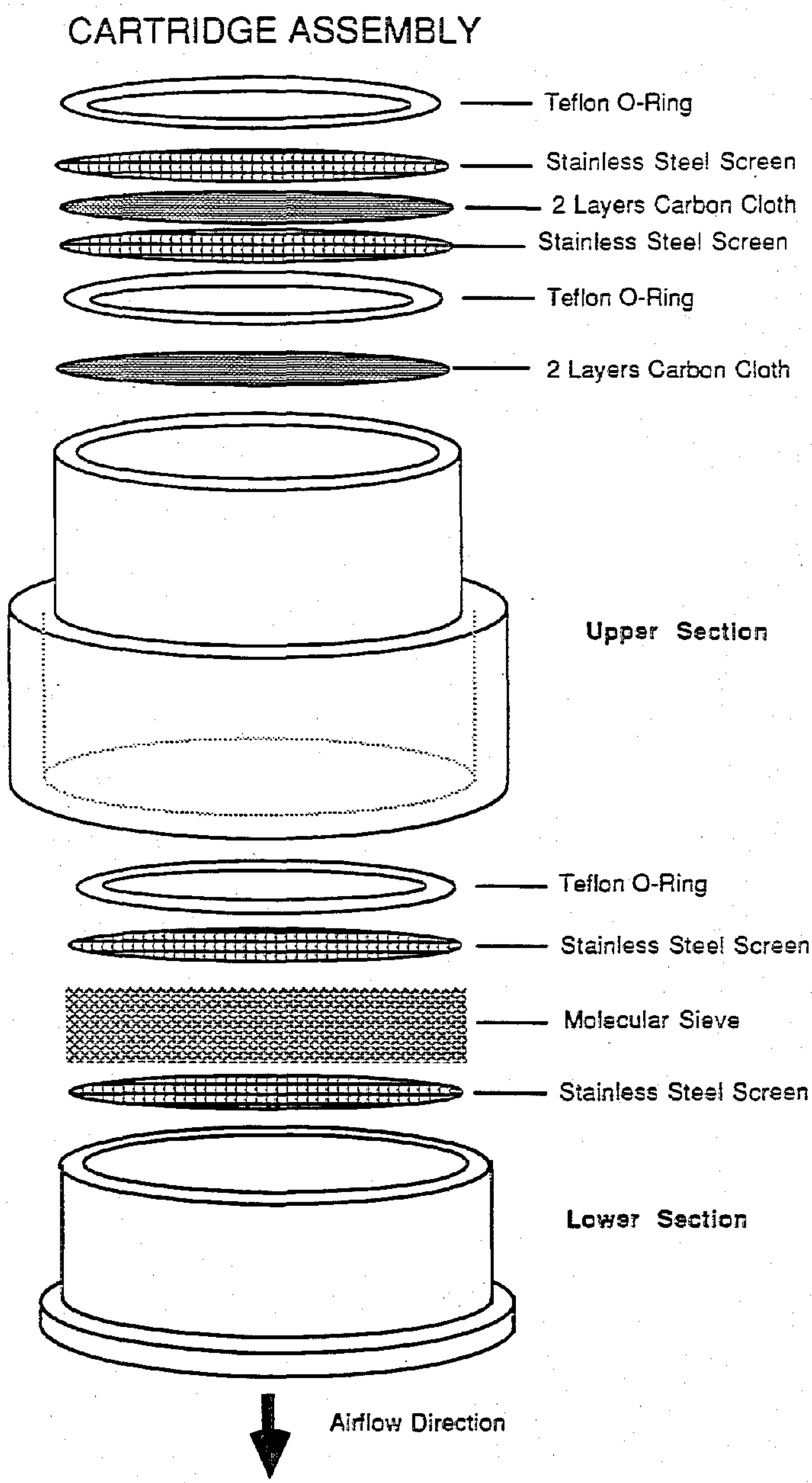
Desorption efficiency was determined for five charcoal tubes and badges. A measured volume, approximately 1 microliter, was applied in liquid form to the front section of the charcoal tube, while the badge media was exposed by application of a similar amount of toluene to a filter paper before capping the badge. All spiked samples were allowed to stand for 20 hours and were then treated in an identical fashion to the ambient air samples.

	Monday	Tuesday	Wednesday	Thursday	Friday
Wk 1	Pre-shift breath Pre-shift air Work shift air	Pre-shift breath Pre-shift air Work shift air	Pre-shift breath Pre-shift air Work shift air	Pre-shift breath Pre-shift air Work shift air	<u>PRESENTATION OF</u> Breath sample results Health effects education Information on selection, maintenance, use of PPE
Wk 4 or 5	Pre-shift breath Pre-shift air Work shift air	Pre-shift breath Pre-shift air Work shift air	Pre-shift breath Pre-shift air Work shift air	Pre-shift breath Pre-shift air Work shift air	<u>PRESENTATION OF</u> Breath sample results
Wk 9	Pre-shift breath Pre-shift air Work shift air	Pre-shift breath Pre-shift air Work shift air	Pre-shift breath Pre-shift air Work shift air	Pre-shift breath Pre-shift air Work shift air	<u>PRESENTATION OF</u> Breath sample results

Figure 1

Study Design Sampling Protocol Template

Note: Arrows demonstrate correlative relationship between prior work shift ambient air and the following days' pre-shift expired breath solvent concentrations.



<u>Figure 2</u>

Schematic of Dual Sorbent Sampling Cartridge

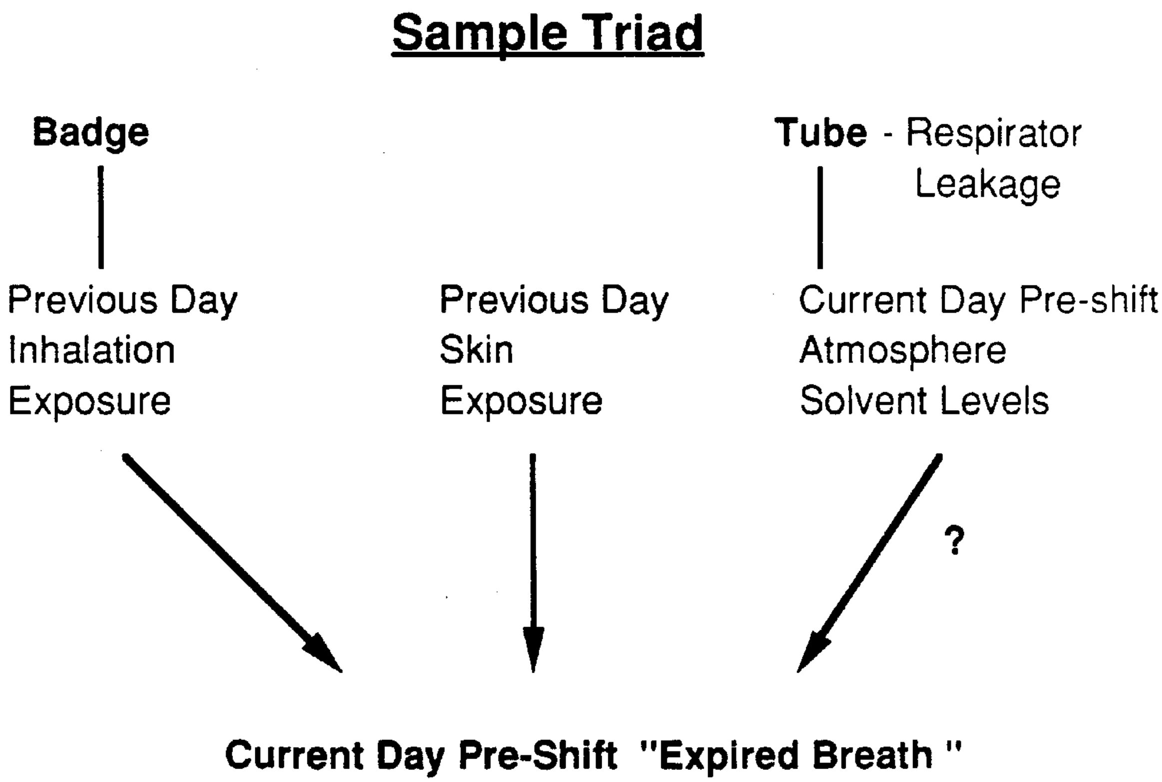


Figure 3

Relationship of Sample Triad Members (Work Shift Ambient Air-Badge, Pre-Shift Ambient Air-Tube, and Pre-Shift Expired Breath)

RESULTS

Individual daily measurements of the toluene concentration in expired breath, and personal breathing zone samples collected during both the work shift (passive dosimeter badge) and breath sampling procedures (charcoal tube) are provided in Appendix B. Data for the subject painters were alphabetically coded to identify auto body repair shops and numerically indexed for both specific painters within a given repair facility and the time sequence of sampling dates (e.g. D1-12 = Shop D, Painter 1, 12th Sample Day).

A. Ambient Air Samples

1. Work Shift Ambient Air Breathing Zone Samples (Charcoal Dosimeter Badge Samples)

Based on the complete dosimeter badge sample set (N=102) given in Appendix B , the average observed toluene concentration for all painters during the entire study period was 40491 ± 23669 ug/m3 or approximately 10 % of the ACGIH 8-Hour TWA TLV of 375,000 ug/m3. This mean ambient air toluene work shift exposure level is somewhat lower than toluene air levels measured in auto body repair shops by O'Donnell (55000 ± 41000) ug/m3) and Kirkpatrick (54000 ± 36000), however when the amount of variance is considered, all measurements represent similar solvent exposure levels. Individual toluene work shift exposure levels ranged from 6900 to 105,000 ug/m3 (0.1 to 30 % of the ACGIH TWA-TLV).

Table 1 presents a summary of the weekly average work shift toluene exposure levels based on the results of daily (Monday - Thursday) work-shift ambient air samples collected, from all painters, during completion of the nine week study protocol. The painter with the highest observed average weekly ambient air exposure was C1 (79000 ug/m3) while the the painter with the lowest measured toluene exposure level was E1 (11000 ug/m3). Figure 4 presents the mean ambient air solvent exposure for each painter which occurred throughout all three sample periods.

2. Pre-Shift Ambient Air Breathing Zone Samples (Charcoal Tube Samples)

A total of 108 charcoal tube breathing zone samples were collected during the breath sampling procedure from participants in the five auto body repair shops. As displayed in Figure 5, 90% of the observed toluene concentration values were less than approximately 12,000 ug/m3 (12 mg/m3 or 3.1 PPM). The mean value of all pre-shift toluene air levels was 6737 ± 17569 ug/m3, while the average values for samples greater than 12,000 ug/m3 was 43974 ± 39491 ug/m3 . The average concentration values of the low ambient air data set (< 12000 ug/m3) of 2514 ± 2164 were very low in comparison to toluene paint event levels (225,000 ug/m3) but were nearly six times higher than the average Monday morning baseline breath samples observed in this study (384 ug/m3).

In order to investigate the relationship of expired breath samples to pre-shift breathing zone measurements (charcoal tubes) and previous work shift ambient air exposure (charcoal badges), data collected throughout the overall study period were evaluated utilizing simple and multiple linear regression. For this analysis 69 sample triad sets (previous work shift ambient air exposure, pre-shift expired breath, pre-shift breathing zone sample) were available.

The results of simple linear regression modeling are presented in Figures 6 and 7 . Correlation coefficients between expired breath and pre-shift breathing zone (charcoal tube) measurements were $r = 0.48$ ($p<.0001$) for all samples, and $r = 0.72$ ($p<.0001$) for the sample population set minus two apparent sample outliers (low expired breath for high tube values). Analysis of the expired breath and previous work days inhalation exposure (charcoal badge) relationship suggested a minimal correlation ($r = 0.14$, $p<.21$) . Multiple linear regression was used to simultaneously examine the effects of solvent contamination during pre-shift sampling (tube) and the previous day's exposure (badge) on the pre-shift breath measurement. The two outlying triads were excluded from the multiple regression model because they appeared to represent variant patterns of the tube-badge-breath association compared to other values, and because even after logarithmic or square root data transformations, the attempted regression models did not fit the data as well as did the model that excluded these two triads and used untransformed data. In the latter model, the partial correlation coefficient between badge and breath measurements was 0.28. Conversely the partial correlation coefficient for the tube versus breath relationship was 0.74.

Further evaluation of the relationship between expired breath measurements and the ambient air levels of solvent present in the test atmosphere (charcoal tube) is given in Table 2. In consecutive samples which compared very low to low exposure environments (car to work place) the expired breath measurements increased by a factor of 1.5 to 2 while the toluene air levels increased by a factor of 7 -70. Another sample set was collected to compare a low to a relatively higher solvent exposure setting (work place to paint room). In this case the breath toluene concentration level increased by a factor of 7 for ambient air values that differed by a factor of nearly 400. Figure 8 represents a data plot of the consecutive sample data sets for the two participating painters (D1 and E2). This presentation graphically displays the variation in the observed expired breath samples in relation to toluene levels in the atmosphere during breath sampling. Calculated slope factors for the breath and charcoal tube sample pairs for D1 are .03 and .08 while corresponding values for subject E2 were .08, .61 and .008 .

The information supplied by the statistical analysis of the sample triad population set and the descriptive analysis of consecutive subject sampling both support the conclusion that respirator leakage resulted in contamination of breath samples. (See Discussion - Analysis of Pre-Shift Ambient Air Data). Additional evidence of respirator leakage influencing expired breath sample measurements is also provided in Monday morning (Week 1) baseline breath samples. Painter D1 displayed a baseline toluene breath level of 962 ug/m3 which is very high compared to the mean Monday morning value for all painters of 384 ug/m3 and to the succeeding D1 Monday morning samples which averaged 313 ug/m3 . Exhalation blow-by (leakage around the nose area of the respirator face piece) was observed by the subject after initiation of the sampling process. Additionally Painter C2 had a Monday morning expired breath toluene level of 6523 ug/m3 . This subject spent a large part of the breath sample time in the paint mixing room where the pre-shift ambient air toluene concentration (charcoal tube) exceeded 80,000 ug/m3 . Both subjects indicated that there had been no solvent exposure on the previous week-end. It should be noted that these subjects were refit in the sampling respirator prior to collection of subsequent samples in Week 1.

Based on these observations of suspected respirator leakage, the following discussion of expired breath measurements used in evaluation of the motivational intervention must be reviewed cautiously .

B. Expired Breath Samples and the Effect of Motivational Intervention

Data analyses of the expired breath solvent levels and associated ambient air measurements (charcoal tube and badge) used to evaluate the effect of motivational intervention in reducing solvent exposure were based on subject groupings as follows.

<u>Full Participation Group</u> - Group A (A1,A2,B1,C1,D1)
(Minimum of two pairs of sample triad sets for each of the weekly sample periods)

<u>Incomplete Participation Group</u> - Group B (B2,B3,C2,E1,E2)
(Less than two pairs of sample triad sets for any one of the weekly sample periods)

This subject arrangement was necessary based on worker employment termination, sample contamination (solvent exposure prior to breath sampling or paint spray on badge) and incomplete prior work shift solvent exposure information (missing badge data due to failure of the subject to place dosimeter badge in the provided sealed container at the end of work shift or worker absenteeism).

Figures 9A-18A provide a mean weekly comparison of the subjects' measured levels of toluene in the expired breath and prior work shift solvent exposure levels for each week. In a complimentary graphical analysis, Figures 9B-18B present individual summary measurements of the breath to badge ratio as compared to the atmospheric levels of toluene(charcoal tube) observed during the breath sampling procedure. With these plots a positive effect (decreased solvent exposure) of the motivational intervention would be indicated by a combination of the following two observations: 1) Decreasing mean weekly expired breath levels relative to average work shift solvent exposure levels (badge), and 2) Decreasing breath to badge ratios relative to mean pre-shift ambient air levels (charcoal tube).

Based on these data only one painter (B1) demonstrated a possible positive effect of the motivational intervention process. Both the expired breath toluene levels and breath/badge ratio for B1 decreased by 26% and 13% (Wk 1 vs. Wk 9) respectively while work shift exposure(badge) remained nearly constant and average pre-shift ambient air levels(tube) increased dramatically (93%). For all other painters decreases in the expired breath levels or breath to badge ratios in the post intervention period were accompanied by parallel changes in either the badge or tube concentration toluene concentration levels .

Figures 19 and 20 are summary plots of the mean weekly breath to badge ratio levels which occurred throughout the entire study. There was no consistent pattern in the post-intervention phase that would suggest a uniform response in the solvent exposure reduction (e.g. decreasing ratio levels) in the subjects. For the painters in Group A , Subjects A1, A2, and B1 demonstrate an apparent decrease of solvent exposure, D1 displayed elevated ratio levels, and for C1 no apparent change was observed. Although the data for Group B painters is incomplete, the following apparent changes were observed. Subjects B2 and B3 had decreased solvent exposure levels, Subjects C2 and E1 demonstrated increased ratio levels, and Subject E2 displayed no relative change.

Table 1

Summary of the Weekly and Study Work Shift Ambient Air Levels of Toluene

Subject #	Work-shift Ambient Air Concentration of Toluene (ug/m3) Week 1 (Mean/SD)	Work-shift Ambient Air Concentration of Toluene (ug/m3) Week 4 (Mean/SD)	Work-shift Ambient Air Concentration of Toluene (ug/m3) Week 9 (Mean/SD)	Work-shift Ambient Air Concentration of Toluene (ug/m3) All Weeks (Mean/SD)
A1	42344 ± 13267	51219 ± 21193	47576 ± 13333	46667 ± 14491
A2	46692 ± 10875	56720 ± 18897	37586 ± 7299	46115 ± 13633
B1	52214 ± 38314	41734 ± 12220	37454 ± 21693	43801 ± 24725
B2	24682 ± 3476	31752 ± 26909	47740 ± 15981	33098 ± 18417
B3	43861 ± 34487	11467 ± 3780	69928 ± 44508	45538 ± 38674
C1	73709 ± 38231	51072 ± 7772	78927 ± 19942	67903 ± 26135
C2	54236 ± 19475	28110 ± 5081	45751 ± 25326	41650 ± 20090
D1	30549 ± 10721	31064 ± 8262	13571 ± 7742	26106 ± 11481
E1	23154 ± 2325	11205 ± 2625	-------------	18033 ± 6767
E2	24060 ± 4015	26022 ± 6936	23025 ± 12800	24397 ± 8286

Note: These measurements include data collected throughout each sample week (Monday-Thursday). Subject E1 terminated his employment and withdrew from the study after the second sample period. The second sample period for subject E2 was Week 5 ; subjects C1 and C2 were sampled during a split week format of Weeks 9 and 10.

Table 2

Summary of Consecutive Expired Breath and Pre-Shift Ambient Air (Charcoal Tube) Samples

Sample #	Sample Pair Ordering	Sample Date	Br Conc Tol (ug/m3)	High Breath ÷ Low Breath	Tb Conc Tol (ug/m3)	High Tube ÷ Low Tube	Loc of Sample
D1-11	2nd	3/22/89	472	1.57	5203	69	W
D1-11a	1st	3/22/89	300		75		C
D1-12	2nd	3/23/89	374	1.54	1727	17	W
D1-12a	1st	3/23/89	243		104		C
E2-10	2nd	5/9/89	329	1.46	1428	28	W
E2-10a	1st	5/9/89	225		51		C
E2-11	2nd	5/10/89	416	2.17	430	7	W
E2-11a	1st	5/10/89	192		66		C
E2-12	1st	5/11/89	362		814		W
E2-12a	2nd	5/11/89	2668	7.37	302908	372	P

Sample Location	Relative Solvent Air Levels
C=Car	Very low
W=Wksite	Low to moderate
P=Paint Rm	High

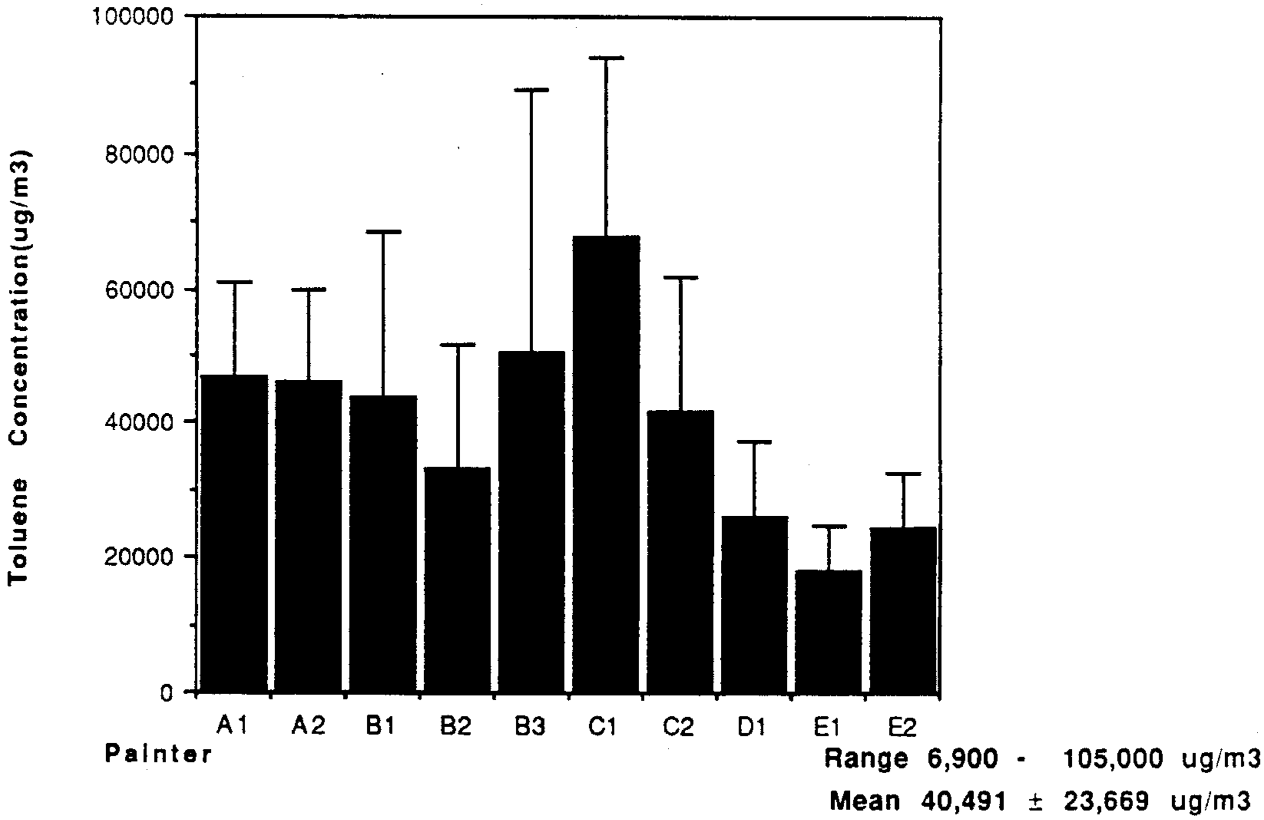


Figure 4

Mean Work Shift Ambient Air Exposure Levels of Toluene (Sample Weeks 1, 4, and 9 Included)
(Error Bars = + 1 SD)

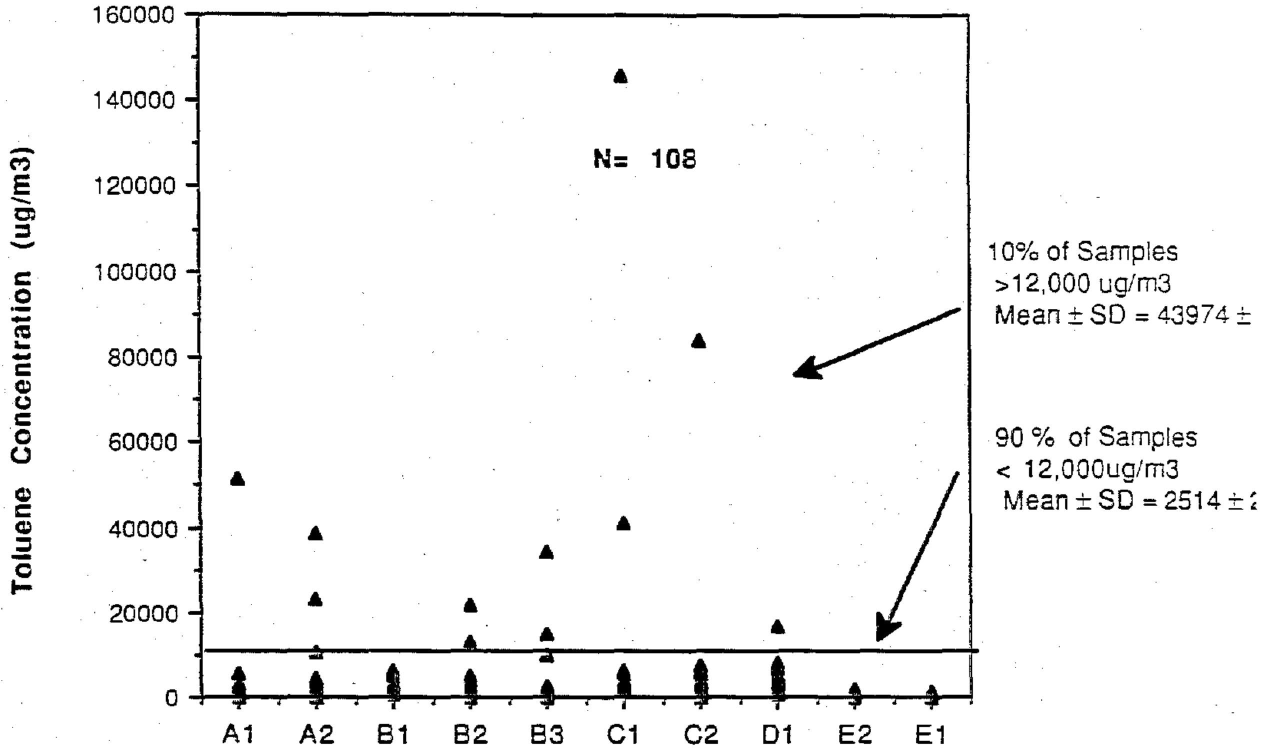


Figure 5

Pre-Shift Ambient Air Levels (Charcoal Tube) of Toluene

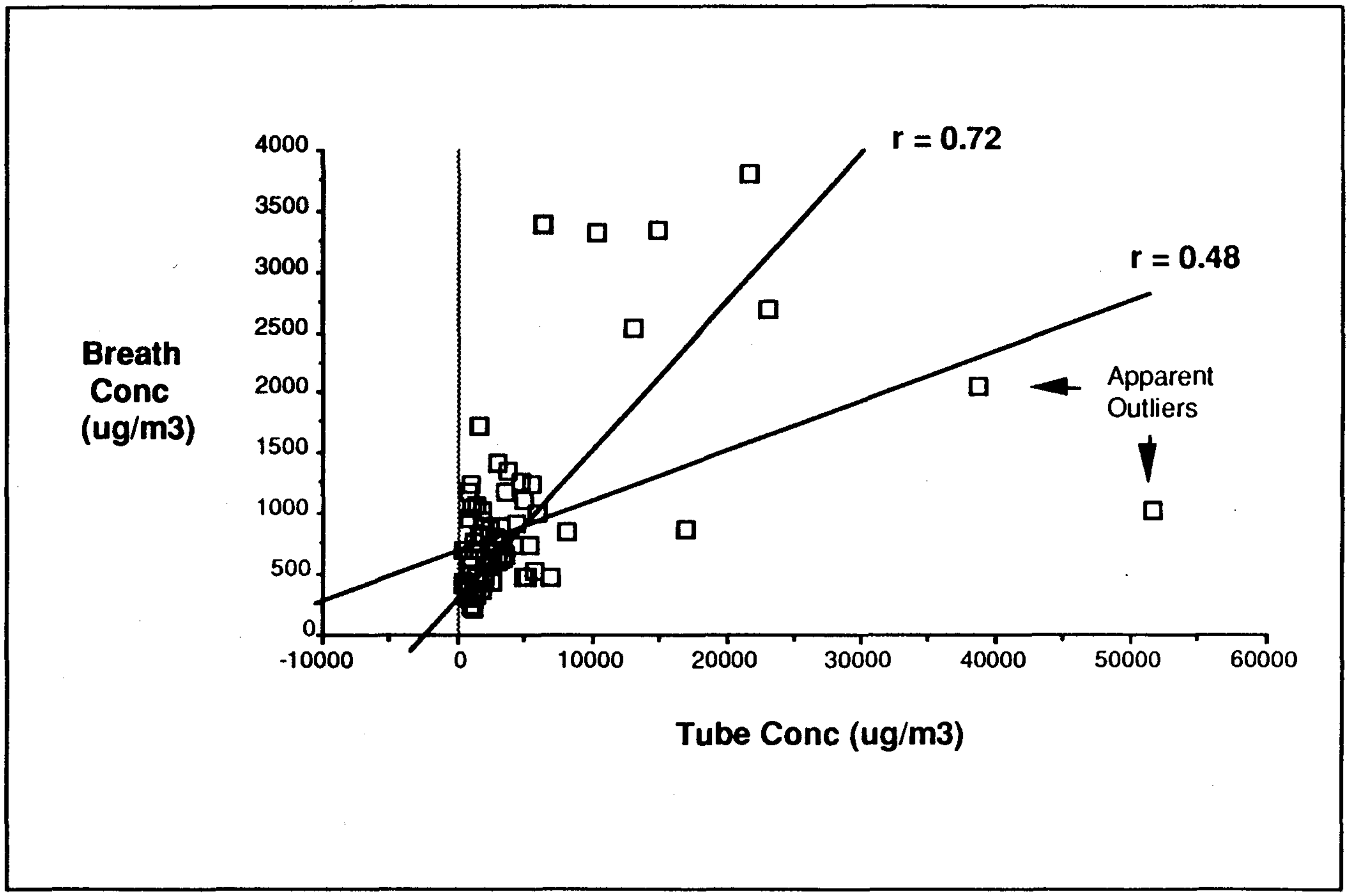


Figure 6

Linear Regression Modeling of Pre-Shift Expired Breath vs. Pre-Shift Ambient Air (Charcoal Tube)

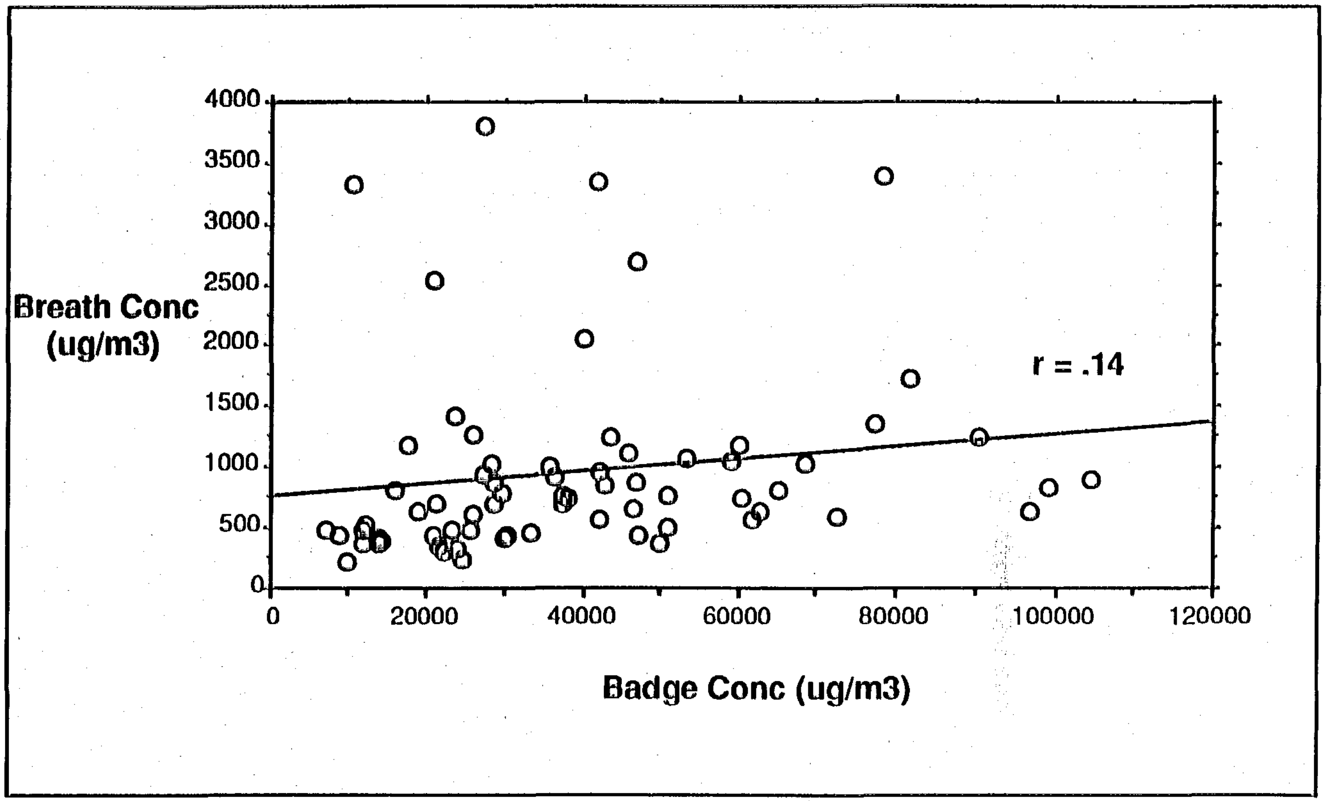


Figure 7

Linear Regression Modeling of Pre-Shift Expired Breath vs. Prior Work Shift Ambient air (Charcoal Badge)

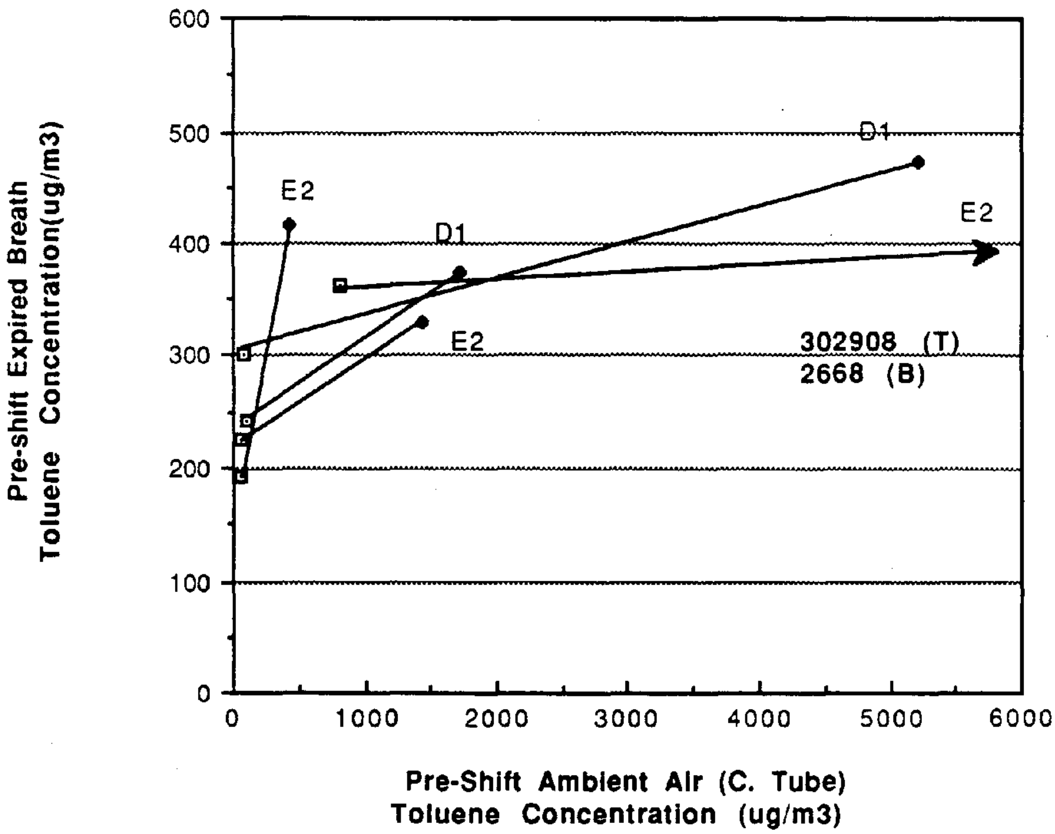


Figure 8

Results of Consecutive Expired Breath and Pre-Shift Ambient Air (Charcoal Tube) Sampling.
(Painters D1 and E2)

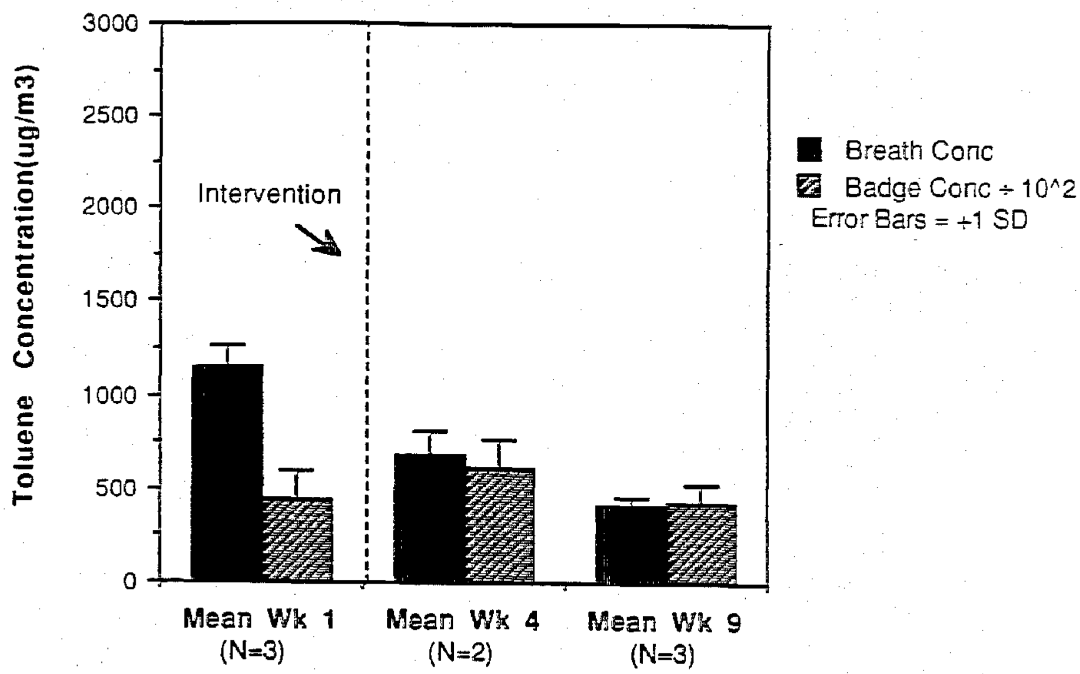


Figure 9A Mean Expired Breath and Work Shift Ambient Air Toluene Levels(Badge) Subject A1

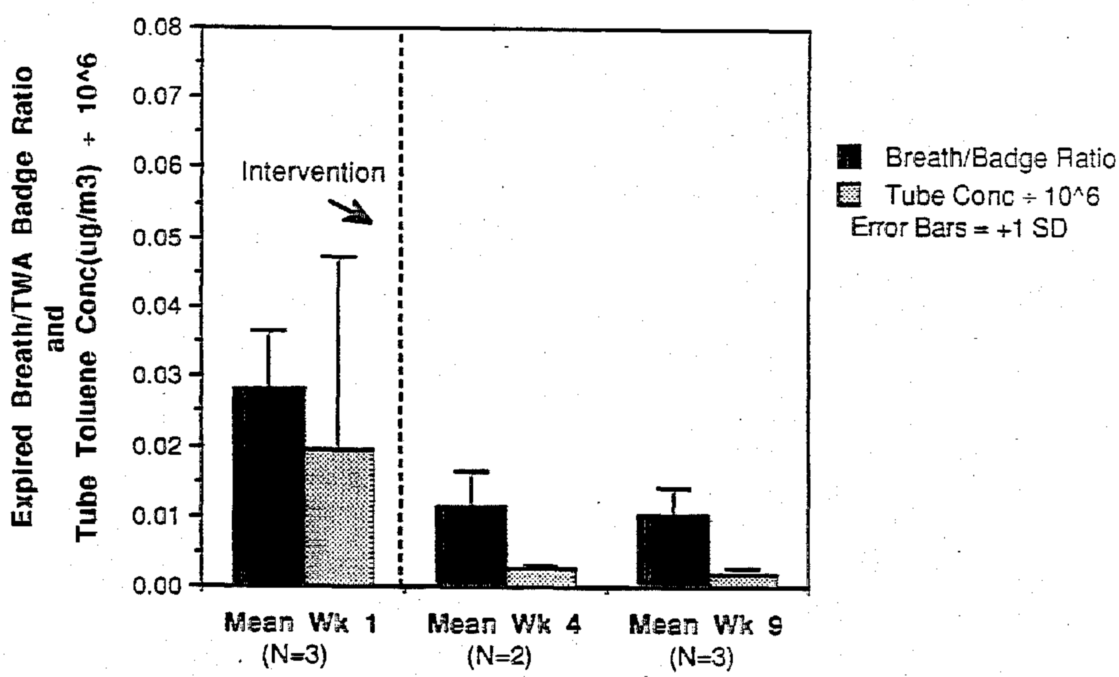


Figure 9B Mean Breath to Badge Ratio and Pre-Shift Ambient Air Toluene Levels(Tube) Subject A1

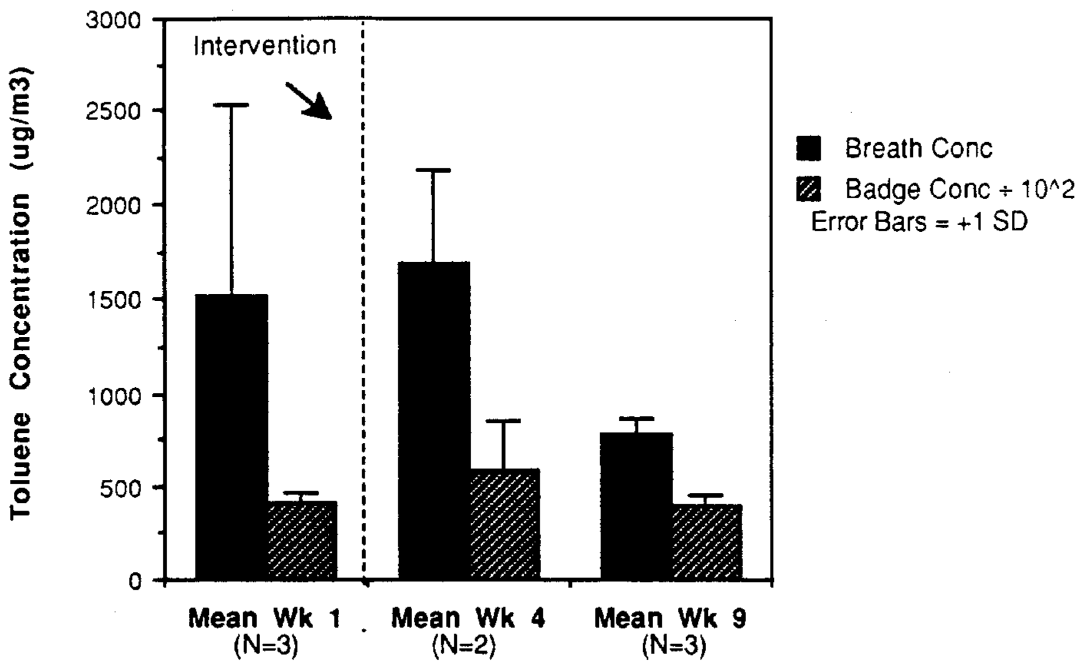


Figure 10A Mean Expired Breath and Work Shift Ambient Air Toluene Levels(Badge) Subject A2

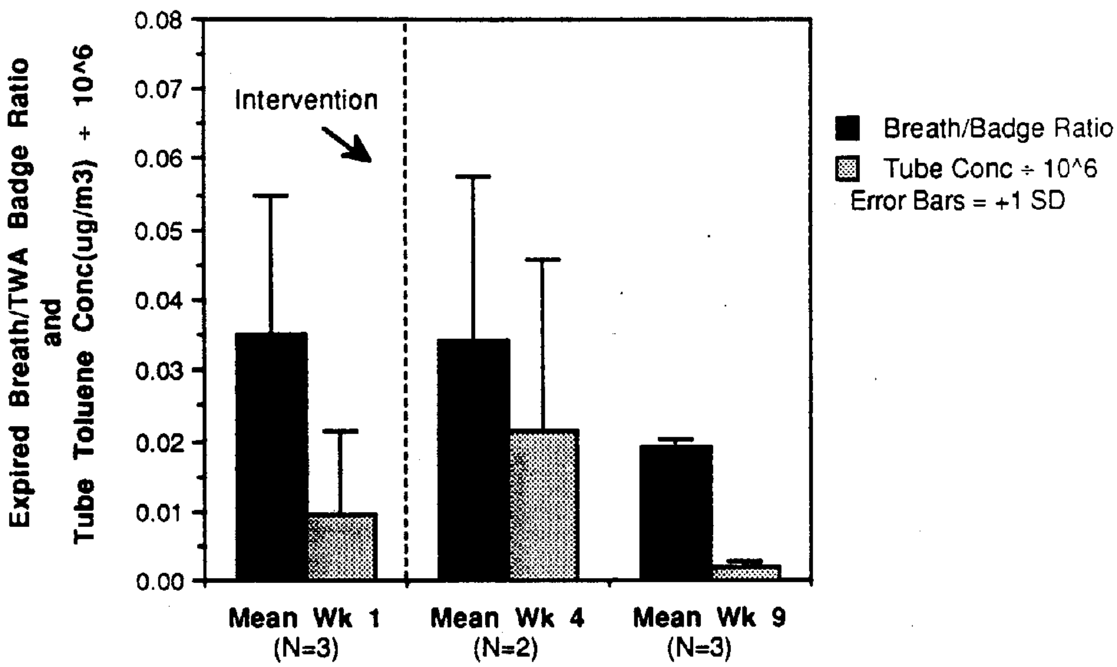


Figure 10B Mean Breath to Badge Ratio and Pre-Shift Ambient Air Toluene Levels(Tube) Subject A2

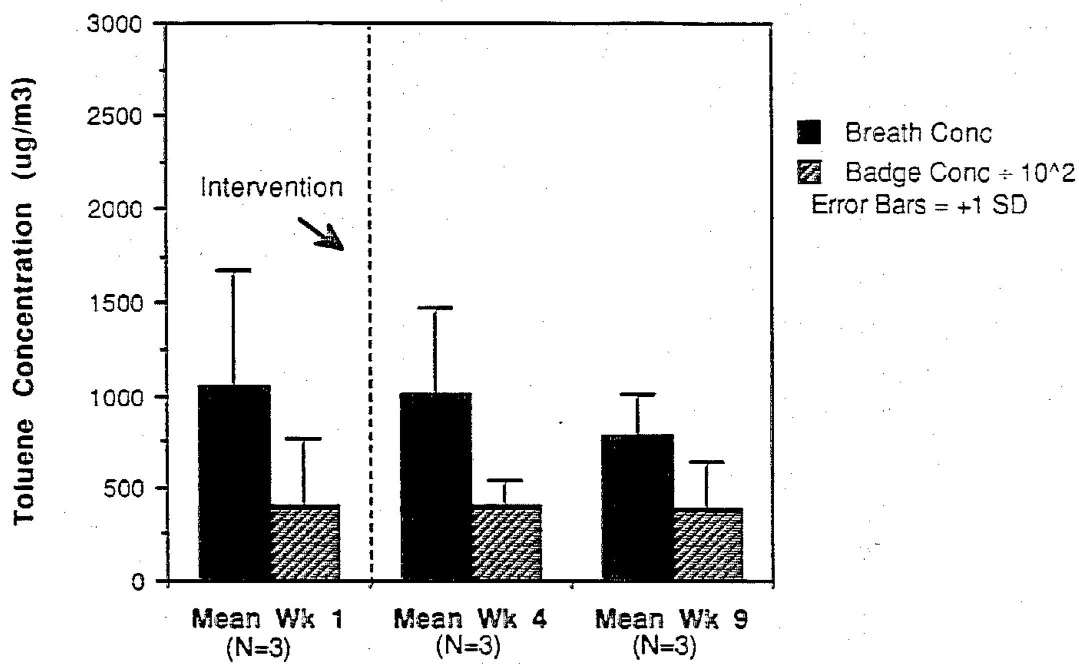


Figure 11A Mean Expired Breath and Work Shift Ambient Air Toluene Levels(Badge) Subject B1

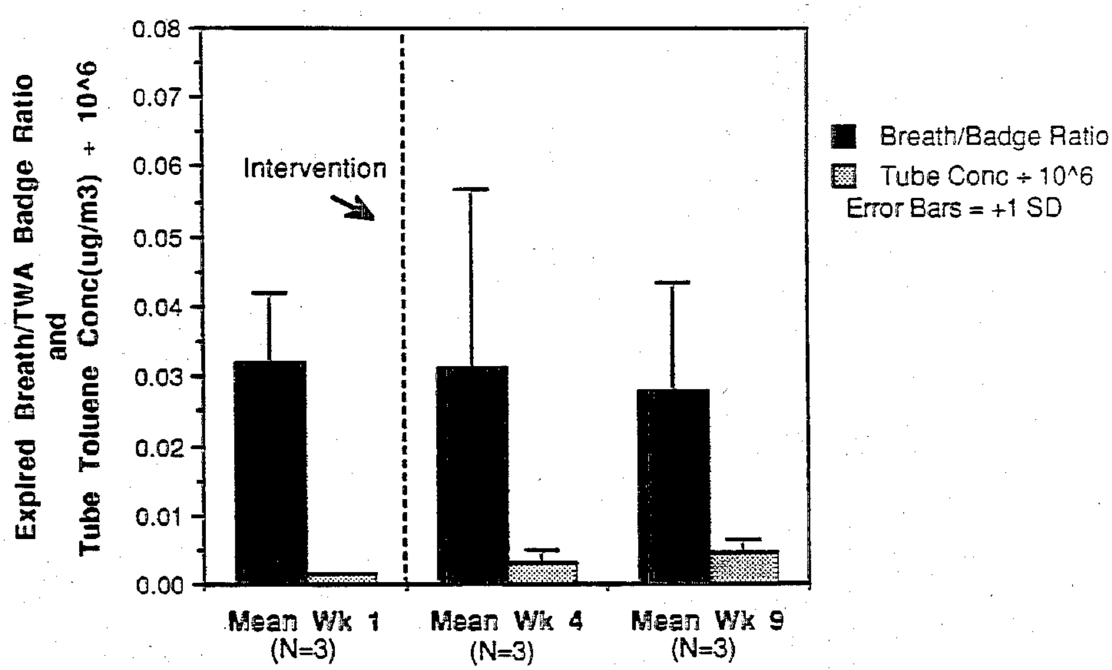


Figure 11B Mean Breath to Badge Ratio and Pre-Shift Ambient Air Toluene Levels(Tube) Subject B1

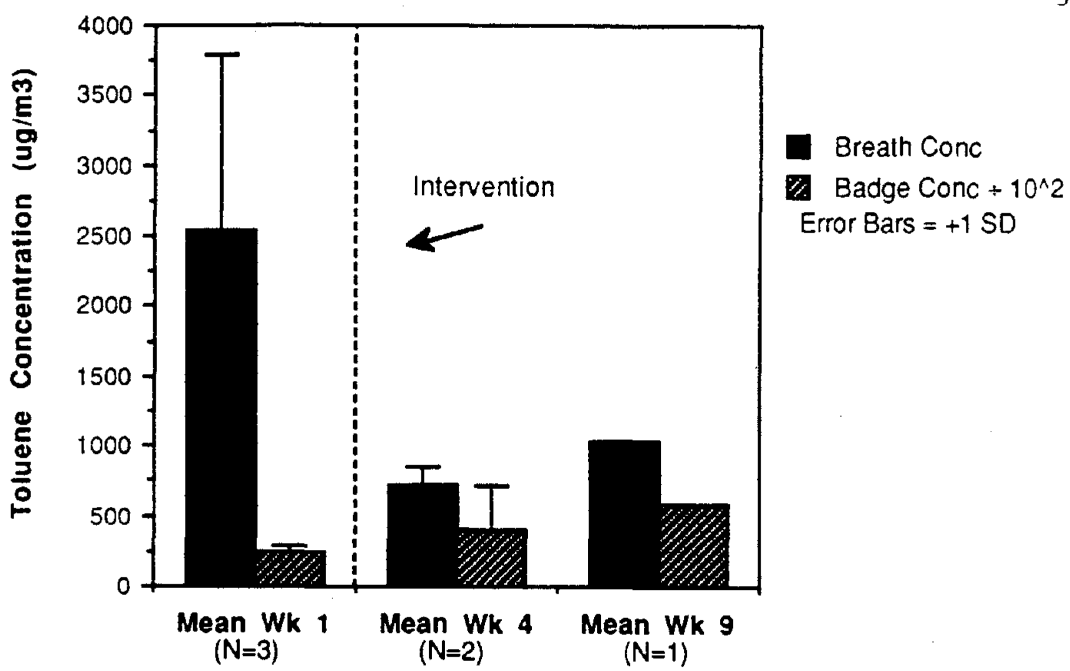


Figure 12A Mean Expired Breath and Work Shift Ambient Air Toluene Levels(Badge) Subject B2

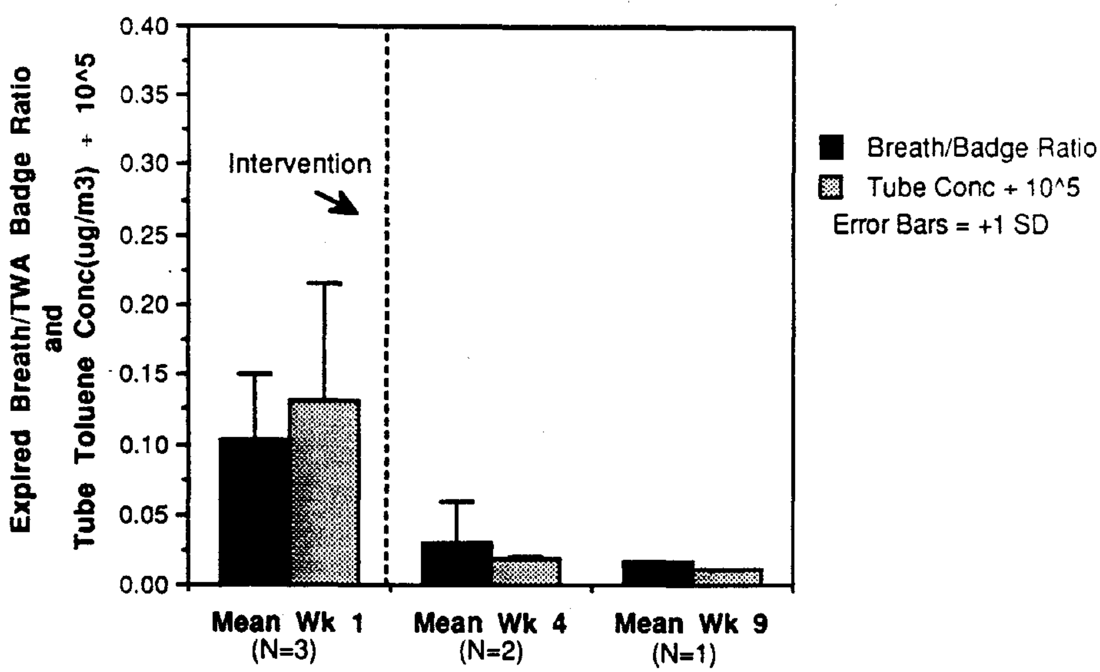


Figure 12B Mean Breath to Badge Ratio and Pre-Shift Ambient Air Toluene Levels(Tube) Subject B2

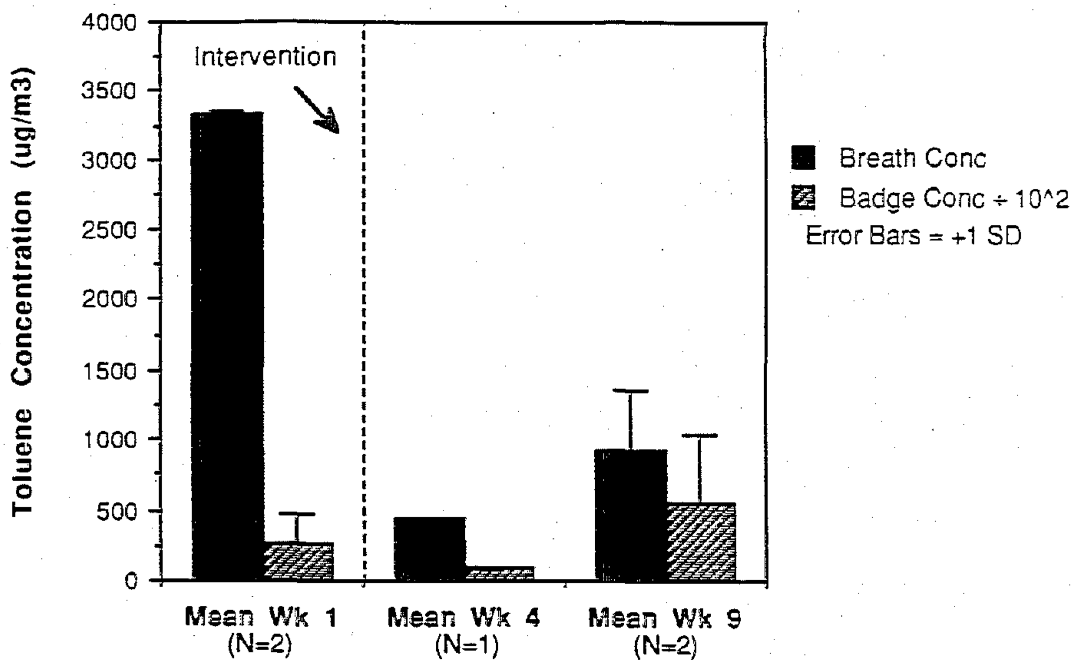


Figure 13A Mean Expired Breath and Work Shift Ambient Air Toluene Levels(Badge) Subject B3

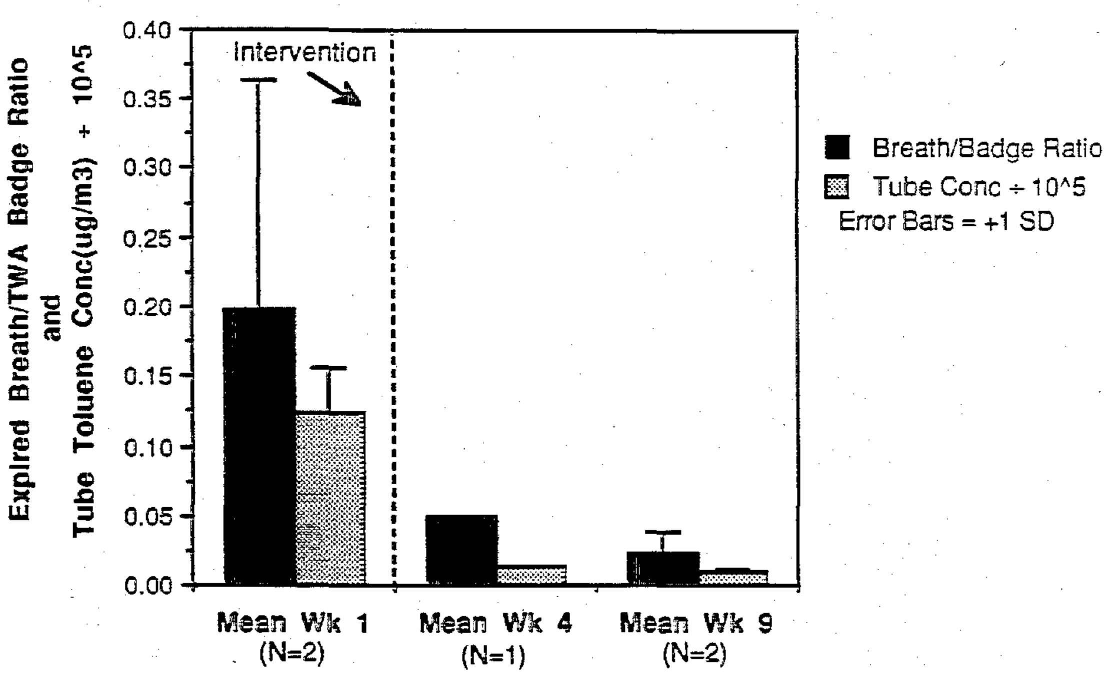


Figure 13B Mean Breath to Badge Ratio and Pre-Shift Ambient Air Toluene Levels(Tube) Subject B3

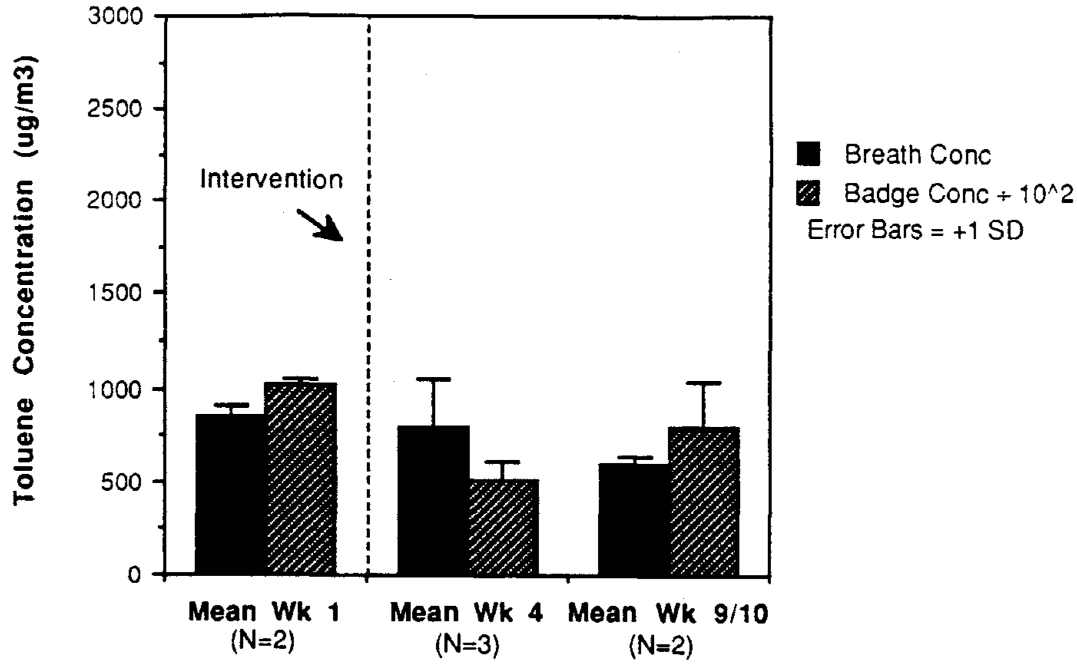


Figure 14A Mean Expired Breath and Work Shift Ambient Air Toluene Levels(Badge) Subject C1

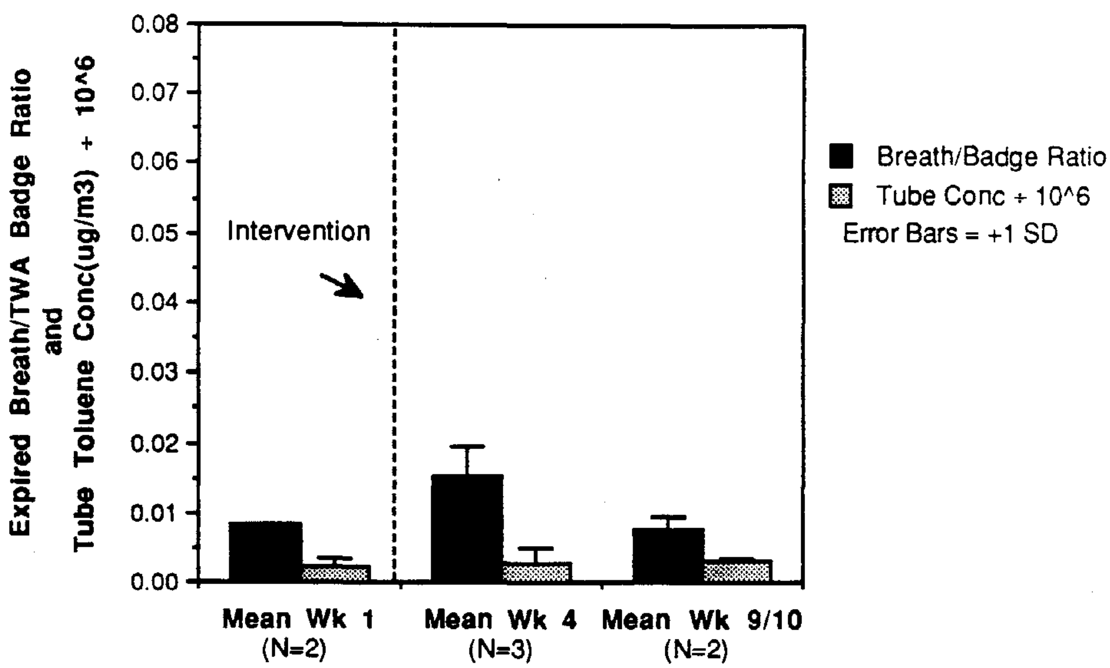


Figure 14B Mean Breath to Badge Ratio and Pre-Shift Ambient Air Toluene Levels(Tube) Subject C1

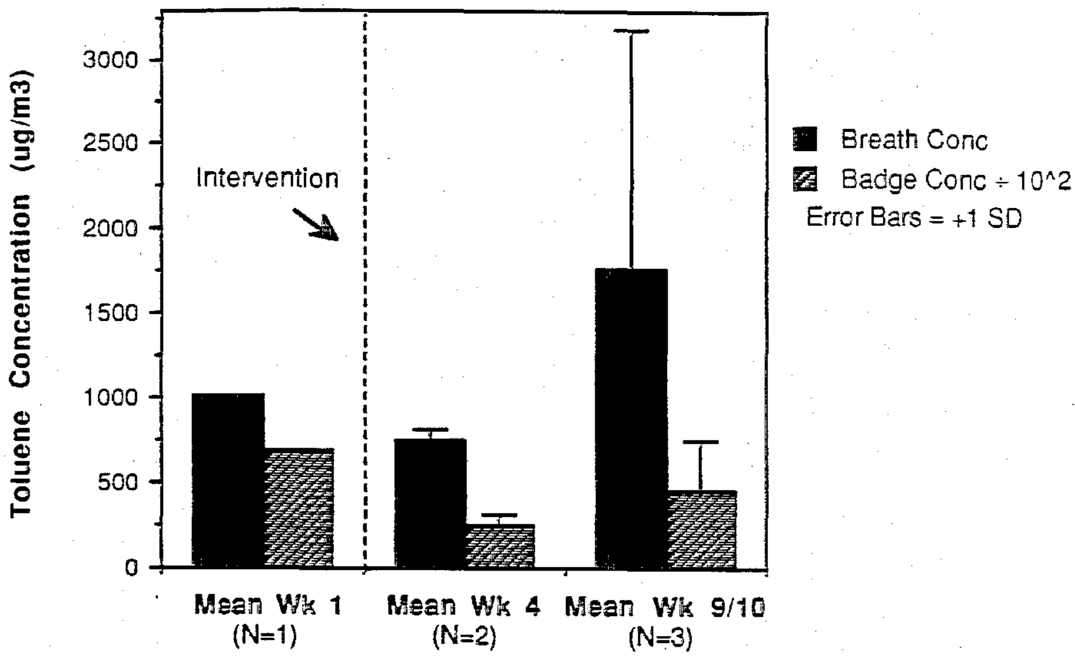


Figure 15A Mean Expired Breath and Work Shift Ambient Air Toluene Levels(Badge) Subject C2

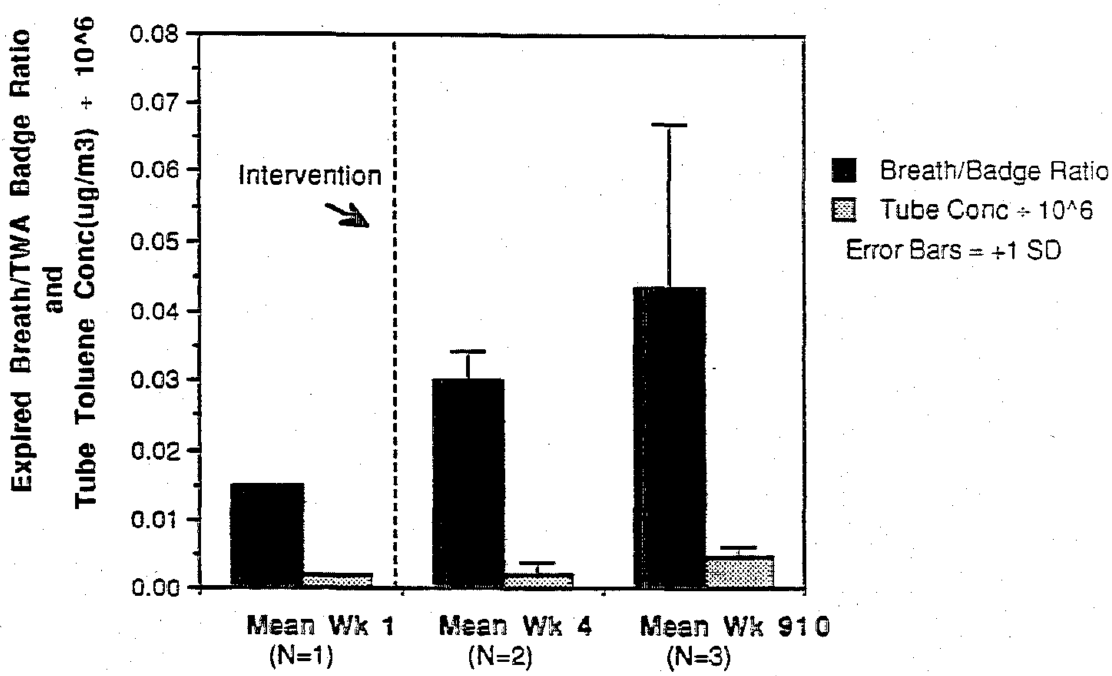


Figure 15B Mean Breath to Badge Ratio and Pre-Shift Ambient Air Toluene Levels(Tube) Subject C2

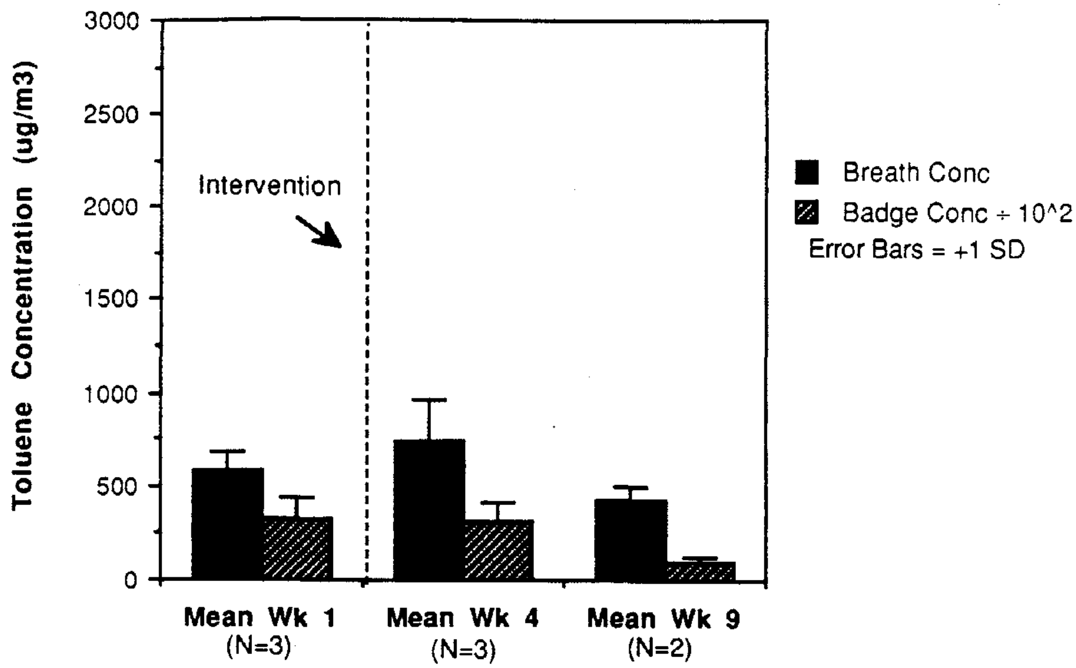


Figure 16A Mean Expired Breath and Work Shift Ambient Air Toluene Levels(Badge) Subject D1

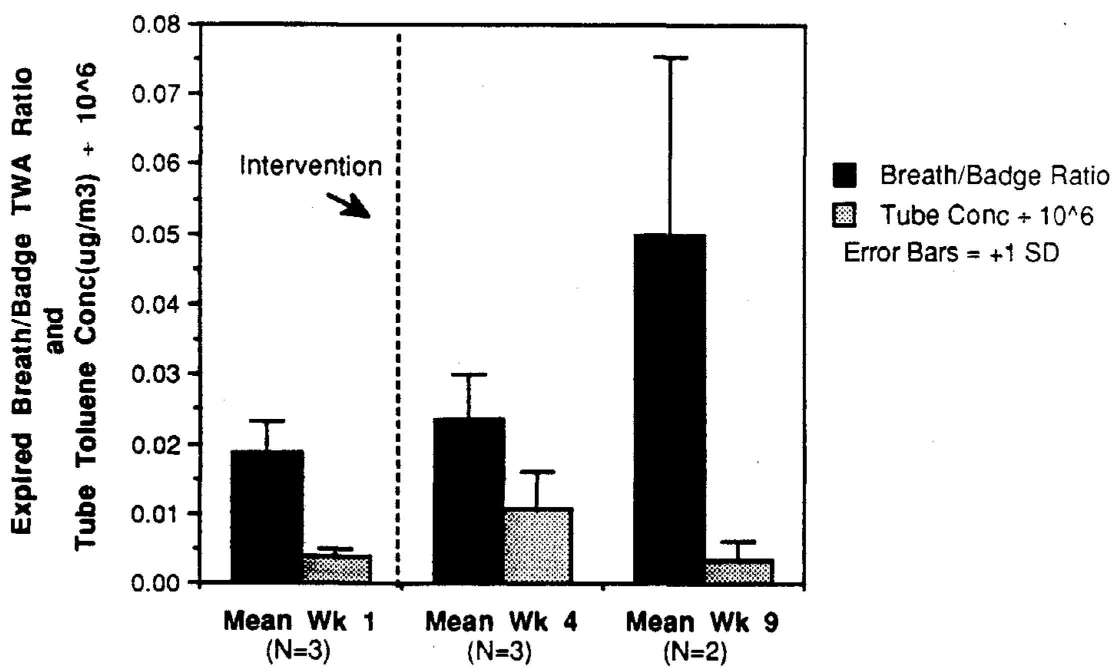


Figure 16B Mean Breath to Badge Ratio and Pre-Shift Ambient Air Toluene Levels(Tube) Subject D1

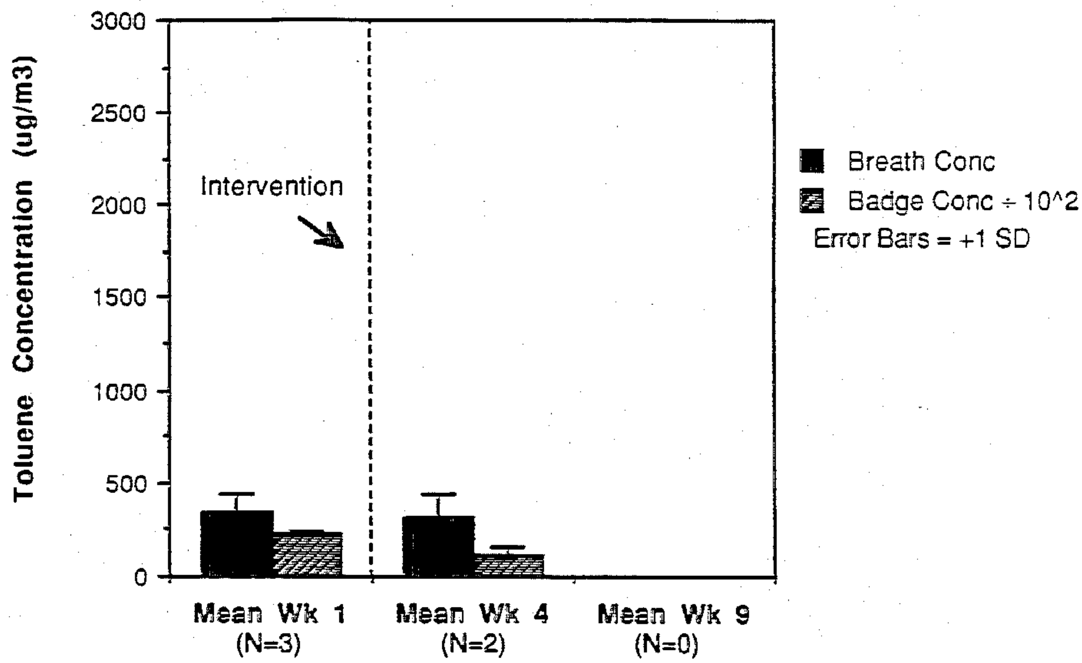


Figure 17A Mean Expired Breath and Work Shift Ambient Air Toluene Levels(Badge) Subject E1

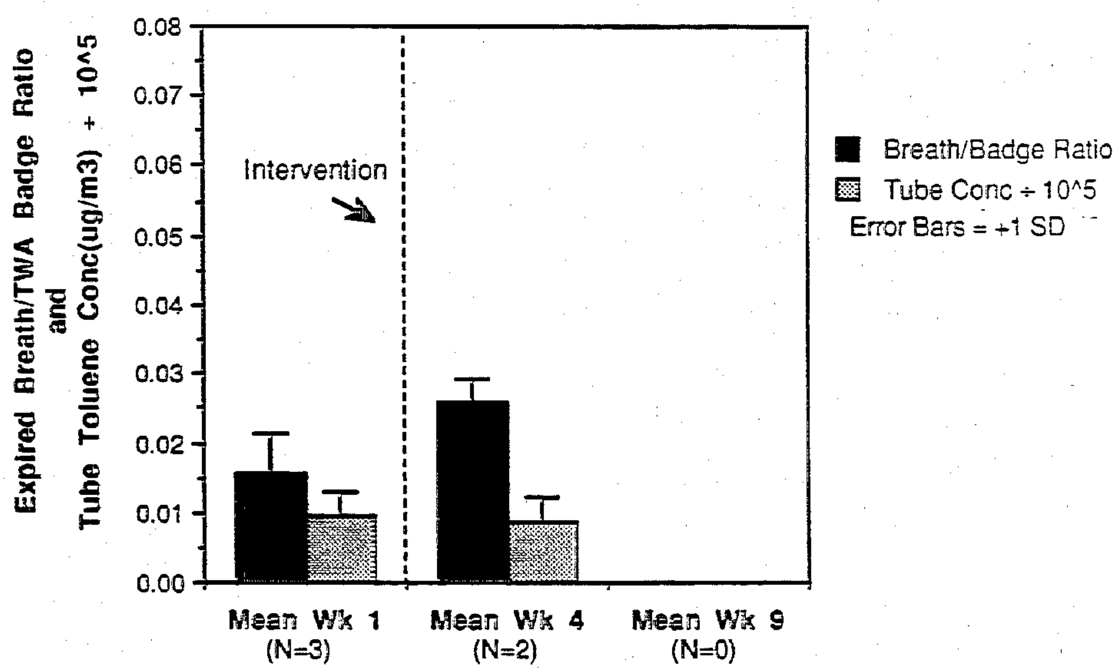


Figure 17B Mean Breath to Badge Ratio and Pre-Shift Ambient Air Toluene Levels(Tube) Subject E1

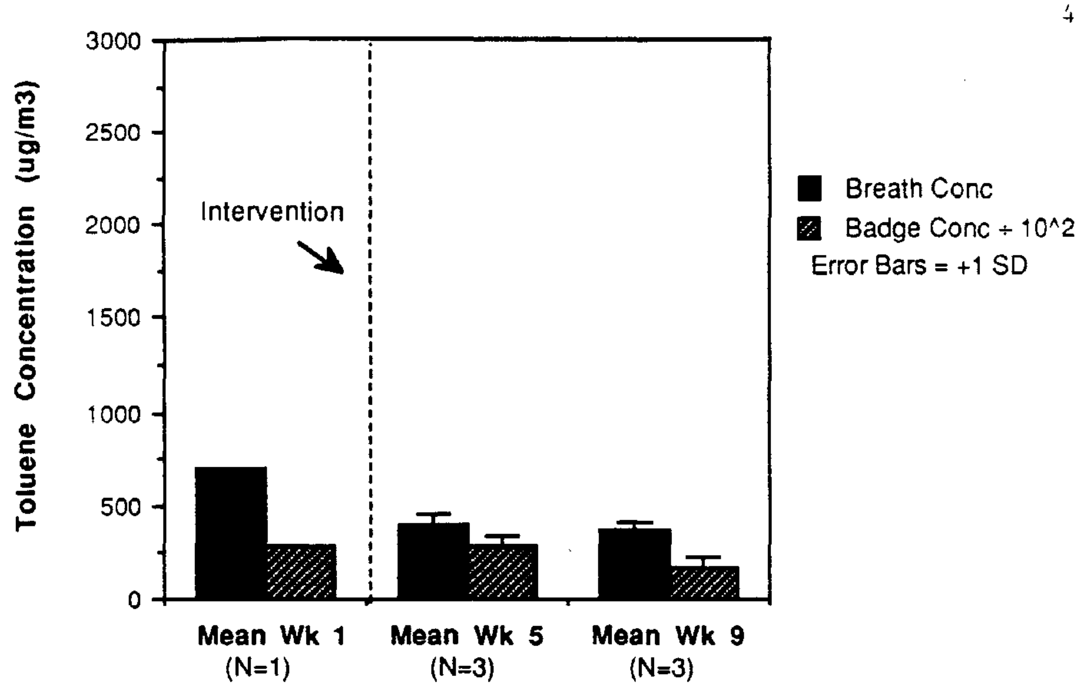


Figure 18A Mean Expired Breath and Work Shift Ambient Air Toluene Levels(Badge) Subject E2

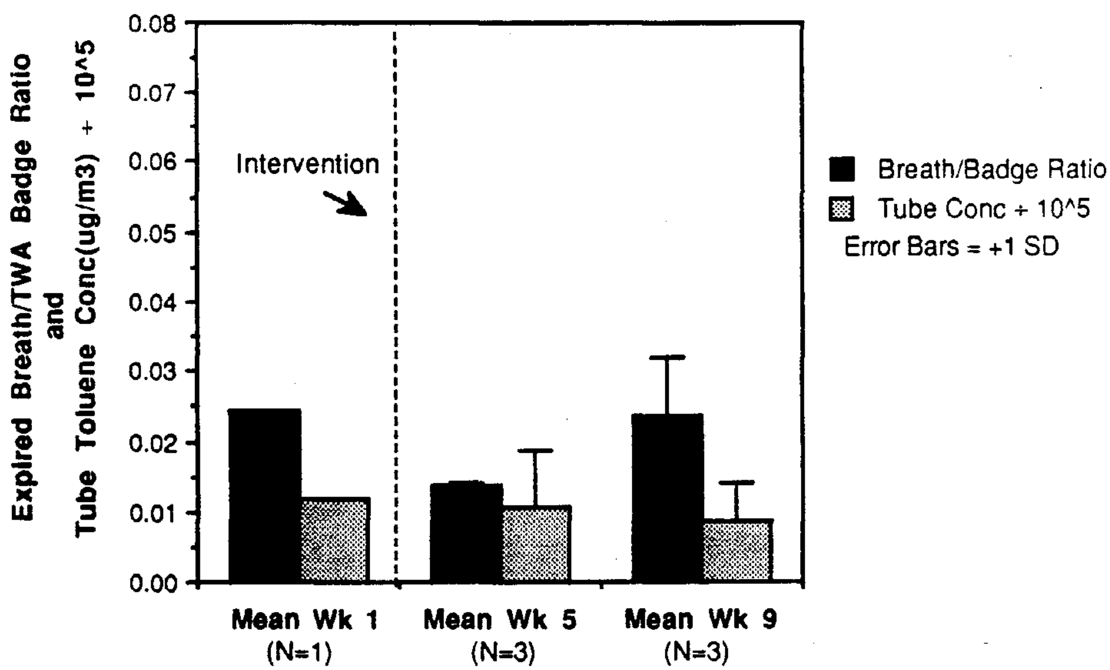
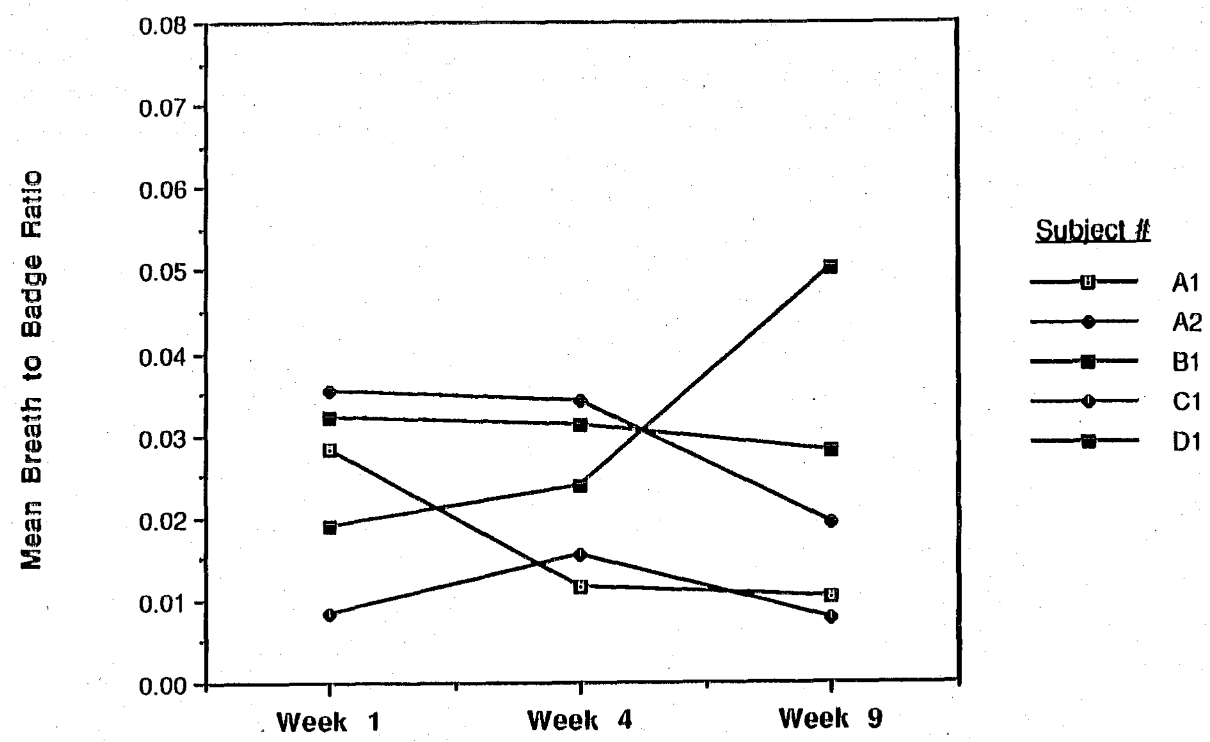


Figure 18B Mean Breath to Badge Ratio and Pre-Shift Ambient Air Toluene Levels(Tube) Subject E2



<u>Figure 19</u>

Breath to Badge Ratio Summary - Group A Painters

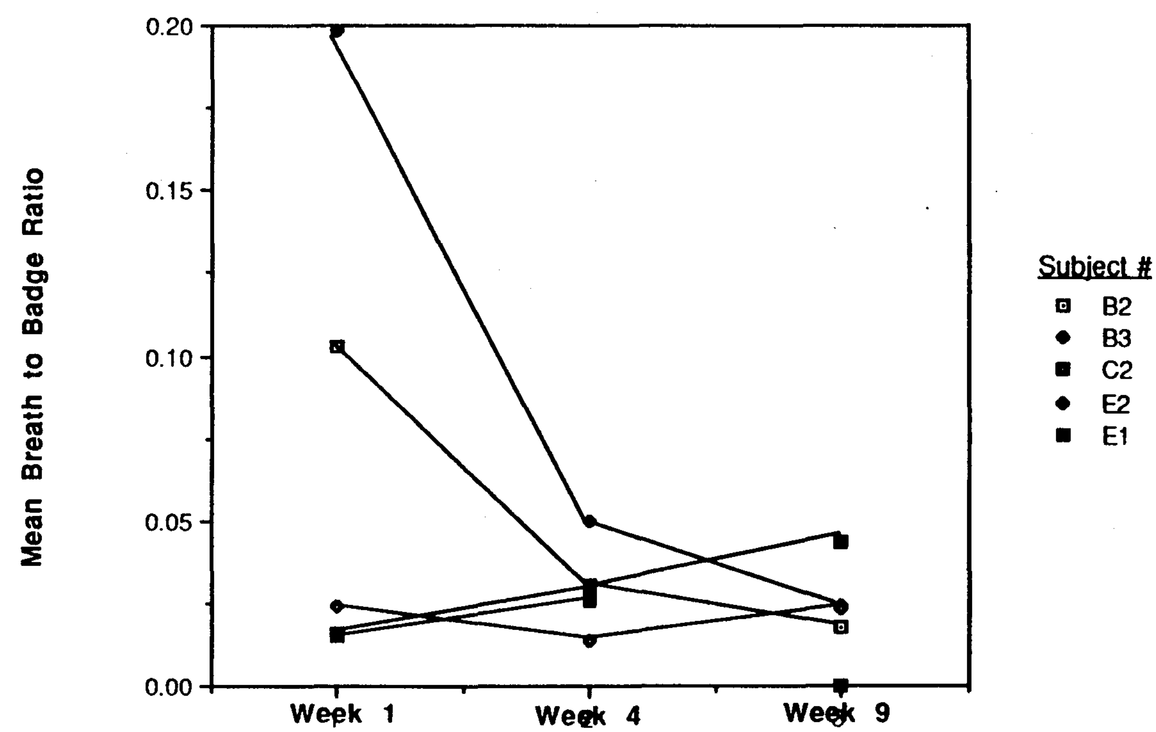


Figure 20

Breath to Badge Ratio Summary - Group B Painters

DISCUSSION

A. Solvent Exposure Variability - Time and Ambient Air Concentration Levels

The ability to assess the effects of the motivational intervention is based primarily on comparative analyses of expired breath and work shift ambient air solvent levels. To provide an equivalent comparison of these parameters over a protracted multi-week sampling period, it is necessary to account for observed work shift variations in both the exposure time period (length of work shift) and ambient air solvent concentrations. For the painters in this project the length of the work shift (solvent exposure period) averaged 9.3 ± 1.7 hours and ranged from 4-14 hours. Also, as indicated in Table 2 and Figure 4 (Results Section) considerable inter- and intra-personal differences in solvent exposure concentrations were measured during completion of the three phase sampling protocol (e.g. relative standard deviation of the mean study work shift solvent exposure levels ranged from 30% for A2 to 85% for B3).

Based on these observations, it is clear that any attempt to use the ambient air work shift measurements in a comparative analysis with expired breath data must recognize these forms of exposure variability. In this study variations in the exposure period and recognition of non-standard work shifts were adjusted for by calculation of the 8-hour TWA equivalent exposure parameter. Differences in work shift solvent exposure concentrations were accounted for in the motivational data set analyses by creation of the breath to badge ratio.

B. Analysis of Pre-Shift Ambient Air Data (Charcoal Tube)

As mentioned previously, the sampling of the ambient air during the breath sampling process was conducted to investigate the possibility of respirator leakage resulting in contaminated expired breath . The following observations support the identification of respirator leakage as a confounding factor in the evaluation of expired breath samples collected with the dual sorbent half face respirator sampling system.

1) Recognition of anomalous Monday morning (Week 1) baseline expired breath solvent in two of the subject painters

Two of the subject painters displayed unusually high Monday morning baseline breath levels. Painters C2 and D1 displayed values of 962 mg/m3 and 6523 mg/m3 respectively, this is in direct contrast with the mean Monday morning levels of 384 ug/m3 for all other painters. Respirator leakage was confirmed by observed exhalation blow-by during the breath sampling process (D1) and highly suspected for C2 due to collection of the expired breath sample in a solvent contaminated atmosphere (pre-shift ambient air level = 80,000 ug/m3).

2) Association of expired breath and pre-shift(charcoal tube) ambient air levels of solvent.

Using both simple and multiple linear regression data analysis of the sample population triad data, a strong positive relationship (r =0.72) was seen between the levels of solvent in the air during the breath sampling procedure(charcoal tube) and the measured expired breath values.

3) Results of consecutive sampling

The most convincing evidence of contaminated breath solvent levels, resulting from respirator leakage, was that obtained via consecutive expired breath sampling (Painters D1 and E2) . The average increase in the expired breath concentration due to variable concentrations of toluene in the test atmosphere (excluding the work place-paint room sample pair) was 158 ug/m3. Evaluation of the slope factors for each of the consecutive sample pairs additionally suggests that the effect of respirator leakage is non-linear and demonstrates extreme inter- and intra-personal variability. This pronounced variability in the apparent leakage factor and the limited nature of the data set precluded the development of a broadly applicable expired breath correction factor based on this information.

The ability of respiratory protection to adequately protect workers against inhalation of hazardous substances is frequently characterized with Assigned Protection Factors (APF)[31]. APF are typically determined using quantitative respirator fit testing methodology (aerosol generators, exposure chambers, and aerosol particle counters) to evaluate the leakage characteristics of submicron particulates (e.g. sodium chloride, di-octyl thalate)[36]. A n APF of 10 (typically assigned to half face respirators for protection against gases/vapors) means that 10% of the contaminant will be available for respiratory intake due to respirator face seal leakage. This value assumes installation of fresh gas/vapor sorbent cartridges in the testing respirator. Recent investigations [37], comparing quantitative (aerosol particles) vs qualitative fit testing procedures, have suggested that qualitative fit testing procedures similar to those used in this study (negative pressure/ isoamyl acetate) should correctly identify poorly fitting respirators (APF < 10) 93% to 100 % of the time. The relationship between respirator leakage and exhaled breath levels in this study is complex, and includes such factors as the ambient air solvent concentration, true respirator protection factor, blood/air partition coefficient and respiratory/mask dead space. Consequently, the data collected in this study are insufficient to determine the protection factor that was actually achieved during the breath sampling process. In order to protect the health of workers, future studies should be conducted to verify that APFs generated through aerosol fit testing are in fact appropriate for exposure to hazardous gases and vapors.

C. Assessment of the Motivational Intervention Program in Reducing Solvent Exposure

Painter B1 was the only painter with an apparent positive effect of the intervention program , however the variance of the associated data (breath, badge, and tube) and the contamination of expired expired breath samples through respirator leakage precluded a definitive indication of reduced solvent exposure (increased use of personal protective equipment). Although apparent reduced mean expired breath solvent and breath/badge ratio levels (Figures 9A-18B) were also observed in 4 additional painters (A1,A2,B2,B3) these decreases were paralleled by pronounced similar differences in the mean weekly pre-shift ambient air solvent concentrations(charcoal tube). This parallel trend relationship and documented evidence of respirator leakage, suggest that any indication of a positive motivational intervention effect in reducing solvent exposure based on these results is highly uncertain. All further discussion of the results of the intervention protocol must be viewed with this in mind.

An anomalous pattern in the mean weekly breath to badge ratio summary measurements was observed in Painters D1 and E1 which displayed a trend of increased breath to badge ratio levels versus relatively constant pre-shift ambient air solvent levels(charcoal tube). This would seem to imply that, for these painters, the motivational intervention period resulted in increased solvent exposure (negative effect of motivational intervention). For subject D1 this breath to badge trend is particularly confusing as this painter was observed to have the highest level of solvent avoidance work practices of all participants at the beginning of the study (e.g.painting with supplied air respirator in paint booth) . Additionally, based on information provided in the intervention period of this study, the subject incorporated the use of gloves as a routine work practice to reduce dermal exposure. These observations would seem to preclude a reduction in the use of personal protective equipment as the probable cause of increased breath to badge ratio through time. Although the actual factor influencing the observed ratio discrepancies is unknown, one potential explanation could be a reduced correlation between prior work shift ambient air and expired breath solvent levels at lower exposure conditions.

It is interesting to note that painters who exhibited trends of decreased breath to badge ratios in the post intervention period typically displayed the highest average weekly expired breath measurements in the Week 1 pre- intervention phase. The average expired breath toluene concentration for these painters, with a minimum of two sample triad sets, was 1916 ± 984 ug/m3 (A1, A2, B1, B2, and B3) compared to 597 ± 258 ug/m3 for painters D1, C1, and E1. This observation suggests that the effectiveness of expired breath values as a motivational tool, to reduce solvent exposure, may be limited to painters with high baseline solvent exposure or limited solvent protective work practices. Low average expired breath solvent concentrations observed in select painters, with acceptable use of personal protective equipment, may only reflect exposure to continual low background levels of solvents. This would preclude the ability to use expired breath samples as a motivational tool to further reduce solvent exposure in these subjects.

D. Future Motivational Studies Utilizing the Dual Sorbent Expired Breath Collection System.

With the recognition of the large number of potentially solvent exposed workers (~9.8 million in 1984), it is apparent that future studies using motivational intervention to reduce chemical exposure have great value. In particular the use of expired breath sampling, using the dual sorbent collection system, is particularly attractive because of the following:

1) It provides subjects with a relatively immediate feedback of their personal solvent body burden based on their daily work exposure. This is much more meaningful than merely providing an assessment of the ambient air solvent concentrations to the worker.

2) The sampling methodology is easy to perform, requiring only a limited time commitment (20-25 minutes) from the participating workers .

3) This form of biological monitoring is non-invasive compared to either blood or urine sampling. Workers often find urine sampling intrusive or suspect an invasion of privacy(drug testing) and find blood sampling uncomfortable. Additionally the sampling respirator is similar to personal protective equipment they may use in daily work practices, thus the sampling apparatus is familiar to them.

With these benefits in mind the following suggestions are offered for future motivational studies to reduce solvent exposure utilizing this sample collection system :

1) To avoid the potential of respirator leakage (contaminated breath samples) the expired breath sampling must be conducted in a atmosphere free of organic solvents. For instance, in this study the painters could have been sampled in a vehicle outside of the work place.

2) The sampling should also be conducted prior to the subject entering the work place, this will prevent physiologic solvent contamination.

3) Although subject compensation is generally viewed as a confounding factor in motivational studies, consideration should be given to monetary reimbursement of subjects or employers for lost work time in future studies. This is especially true for subjects who work on commission basis (auto body painters) where sampling time may mean lost wages. Any discussion of monetary reimbursement with subjects should stress that any monies paid are intended to compensate for lost time only, the actual reimbursement cannot be directly related to the subjects' performance or successful completion of the sampling protocol. If such compensation were provided the level of subject participation might be higher. In this study, increased subject participation might have prevented the loss of ambient air exposure data (missing dosimeter badge data).

V.CONCLUSIONS

The results of this study which attempted to evaluate a motivational intervention program designed to reduce organic solvent exposure in auto body painters are as follows:

1) No measurable effect of the motivational intervention program was observed in these auto body painters. One painter demonstrated reduced exposure levels; however, the variability of the data precluded a definitive conclusion. Any overall solvent exposure reduction which may have been present in this subject grouping was overshadowed by the uncertainty in expired breath measurements due to presumed respirator leakage.

2) Respirator leakage has been identified as a major confounding factor in expired breath sampling utilizing the dual sorbent half face respirator collection system.

3) Respirator leakage is non-uniform and displays high inter- and intra-subject variability. This non-uniform response combined with insufficient information about the leakage effect over a wide range of exposure conditions precluded the possibility of any adjustment of the expired breath measurements.

4) The dual sorbent collection system is still valid for breath sampling of organic solvent if tests are conducted in a non-contaminated atmosphere. The key advantages of this procedure are that it is a relatively simple, non-invasive sampling technique that is readily acceptable by workers.

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APPENDIX (Table 3)

Summary of Daily Pre-Shift Expired Breath, Pre-Shift Ambient Air (Charcoal Tube), and Work Shift Ambient Air (Charcoal Badge) Concentrations of Toluene

Sample #	Date Sampled	Breath Toluene Conc (ug/m3)	Badge Toluene Conc (ug/m3)	C.Tube Toluene Conc (ug/m3)
A1-1	12/12/88	307	28255	1620
A1-2	12/13/88	1028	43506	51628
A1-3	12/14/88	1245	59867	5460
A1-4	12/15/88	1173	37748	849
A1-5	1/3/89	227	50967	3130
A1-6	1/4/89	771	72537	2866
A1-7	1/5/89	589	30153	2521
A1-8	2/6/89	153	47042	184
A1-9	2/7/89	437	49954	2591
A1-10	2/8/89	382	30442	1111
A1-11	2/9/89	439	62866	1533
A2-1	12/12/88	699	46692	4333
A2-2	12/13/88	2694	36260	23073
A2-3	12/14/88	914	42121	4362
A2-4	12/15/88	953	61695	845
A2-5	1/3/89	494	40229	10822
A2-6	1/4/89	2044	77340	38489
A2-7	1/5/89	1348	52590	3847
A2-8	2/6/89	349	46805	P
A2-9	2/7/89	878	37279	2447
A2-10	2/8/89	692	37313	2519
A2-11	2/9/89	762	28946	1191
B1-1	1/9/89	407	11838	812
B1-2	1/10/89	482	27299	1414
B1-3	1/11/89	934	81584	1734
B1-4	1/12/89	1733	88134	1511
B1-5	1/30/89	257	50800	570
B1-6	1/31/89	497	23704	875
B1-7	2/1/89	1416	45720	2975
B1-8	2/2/89	1106	46714	4915
B1-9	3/6/89	466	12178	514
B1-10	3/7/89	528	65194	5652
B1-11	3/8/89	806	35783	2697
B1-12	3/9/89	1001	36662	5928

Table 3 (Cont.)

Sample #	Date Sampled	Breath Toluene Conc (ug/m3)	Badge Toluene Conc (ug/m3)	C.Tube Toluene Conc (ug/m3)
B2-1	1/9/89	587	20735	3563
B2-2	1/10/89	2537	27285	12992
B2-3	1/11/89	3793	26026	21683
B2-4	1/12/89	1266	F	4726
B2-5	1/30/89	254	15911	391
B2-6	1/31/89	810	62821	1878
B2-7	2/1/89	632	16524	2059
B2-8	2/2/89	A	A	A
B2-9	3/6/89	631	C(888658)	2717
B2-10	3/7/89	1013	F	2361
B2-11	3/8/89	995	59041	1073
B2-12	3/9/89	1052	36439	1074
B3-1	1/9/89	407	41682	2544
B3-2	1/10/89	3348	F	14677
B3-3	1/11/89	C(8573)	10515	34111
B3-4	1/12/89	3314	79385	10187
B3-5	1/30/89	328	14140	387
B3-6	1/31/89	A	A	A
B3-7	2/1/89	318	8794	1991
B3-8	2/2/89	437	F	1386
B3-9	3/6/89	536	90354	1879
B3-10	3/7/89	1240	18856	1036
B3-11	3/8/89	634	F	812
B3-12	3/9/89	1157	100557	1534
C1-1	1/23/89	C,R(8261)	70109	145610
C1-2	1/24/89	R(5112)	104571	40703
C1-3	1/25/89	892	99116	3160
C1-4	1/26/89	829	21041	1675
C1-5	2/13/89	451	41971	3540
C1-6	2/14/89	562	53093	1096
C1-7	2/15/89	1070	60496	1404
C1-8	2/16/89	748	48727	5363
C1-9	3/20/89	216	61783	1555
C1-10	3/21/89	NS	61543	NS
C1-11	3/22/89	561	95535	2361
C1-12	3/23/89	A	A	A
C1-13	3/28/89	NS	96848	NS
C1-14	3/29/89	626	NS	3353
C1-15	3/30/89	NS	F	NS
C1-16	3/31/89	668	NS	5969

Table 3 (Cont.)

Sample #	Date Sampled	Breath Toluene Conc (ug/m3)	Badge Toluene Conc (ug/m3)	C.Tube Toluene Conc (ug/m3)
C2-1	1/23/89	R(6523)	68270	83805
C2-2	1/24/89	1020	62437	1836
C2-3	1/25/89	A	A	A
C2-4	1/26/89	945	32001	1124
C2-5	2/13/89	517	33533	5668
C2-6	2/14/89	A	21327	A
C2-7	2/15/89	707	29534	510
C2-8	2/16/89	797	28043	3279
C2-9	3/20/89	M	78249	2204
C2-10	3/21/89	3382	17505	6354
C2-11	3/22/89	1177	49156	3564
C2-12	3/23/89	A	A	A
C2-13	3/27/89	2489	NS	7594
C2-13A	3/28/89	NS	38092	NS
C2-14	3/29/89	744	NS	4083
D1-1	1/23/89	R(961)	25543	4206
D1-2	1/24/89	479	25839	4909
D1-3	1/25/89	607	46596	3061
D1-4	1/26/89	666	24217	3591
D1-5	2/13/89	471	23319	2938
D1-6	2/14/89	481	42741	6959
D1-7	2/15/89	847	28514	8068
D1-8	2/16/89	883	29684	16951
D1-9	3/20/89	155	F	444
D1-10	3/21/89	134	6924	1827
D1-11	3/22/89	472	11718	5203
D1-12	3/23/89	374	22071	1727
E2-1	3/13/89	269	20725	530
E2-2	3/14/89	C(3142)	F	788
E2-3	3/15/89	1411	28517	735
E2-4	3/16/89	692	22939	1177
E2-5	4/10/89	487	33477	677
E2-6	4/11/89	454	29945	1948
E2-7	4/12/89	426	22409	403
E2-8	4/13/89	296	18256	880
E2-9	5/8/89	379	23819	302
E2-10	5/9/89	329	13680	1428
E2-11	5/10/89	416	13753	430
E2-12	5/11/89	362	40847	814

Table 3 (Cont.)

Sample #	Date Sampled	Breath Toluene Conc (ug/m3)	Badge Toluene Conc (ug/m3)	C.Tube Toluene Conc (ug/m3)
E1-1	3/13/89	239	20756	758
E1-2	3/14/89	440	24645	510
E1-3	3/15/89	250	21629	1101
E1-4	3/16/89	346	25586	1190
E1-5	4/3/89	119	9693	493
E1-6	4/4/89	229	14237	1116
E1-7	4/5/89	402	9687	614

Missing Data Code Index:

A = Worker Absenteeism
F = Subject failure to place dosimeter badge in provided sealed bag
P= Sampling pump failure
C = Contaminated sample. Solvent exposure before breath sampling or paint on dosimeter badge.
R= Respirator leakage identified during 1st sample week. Respirator refit prior to further breath testing.
M= Sampling cartridge prepared without charcoal sampling media.
NS= No sample attempted. Worker requested not to be sampled on given day .

Note : Subjects C1 and C2 samples were taken on a split week format (Weeks 9 and 10) due to worker absenteeism or request for non-participation in sampling process on certain sampling days. Additionally the second sample session for Subject E2 was Week 5, this painter had terminated his employment after the first sample session but returned to work and agreed to re-enter study.

50272-101

REPORT DOCUMENTATION PAGE	1. REPORT NO.	2.	3. PB91-188938

4. Title and Subtitle Reducing Solvent Exposures of Auto Body Workers - An Educational and Motivational Study Incorporating Personal Protective Equipment to Reduce Solvent Exposure	5. Report Date 1989/12/00
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7. Author(s) Hall, B., W. Daniell, B. Millies, M. Morgan, and S. Horstman	8. Performing Organization Rept. No.
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15. Supplementary Notes

16. Abstract (Limit: 200 words) Employees from Seattle area auto body repair facilities participated in a study to determine whether it was possible to motivate workers to reduce individual exposure levels to organic solvents through education and counseling. The program emphasized measured personal body burdens and exposure levels, the health effects of chronic solvent exposure, and the proper selection, use, and maintenance of personal protective equipment. The study consisted of a three phase sampling protocol designed to evaluate the effect of a motivational intervention program on the reduction of organic solvent exposure in the participating auto body painters. The results of the study identified no measurable effect from the motivational intervention program. Respirator leakage was identified as a major confounding factor in exhaled breath sampling utilizing the dual sorbent half face respirator collection system. Respirator leakage was nonuniform and displayed high intersubject and intrasubject variability. The dual sorbent collection system still may be a valid means for sampling of organic solvents in exhaled breath if tests are conducted in a noncontaminated atmosphere.

17. Document Analysis a. Descriptors

b. Identifiers/Open-Ended Terms NIOSH-Publication, NIOSH-Grant, Grant-Number-R03-OH-02422, End-Date-09-30-1989, Control-technology, Organic-solvents, Solvent-vapors, Painters, Occupational-exposure, Biological-monitoring

c. COSATI Field/Group

18. Availability Statement	19. Security Class (This Report)	21. No. of Pages
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