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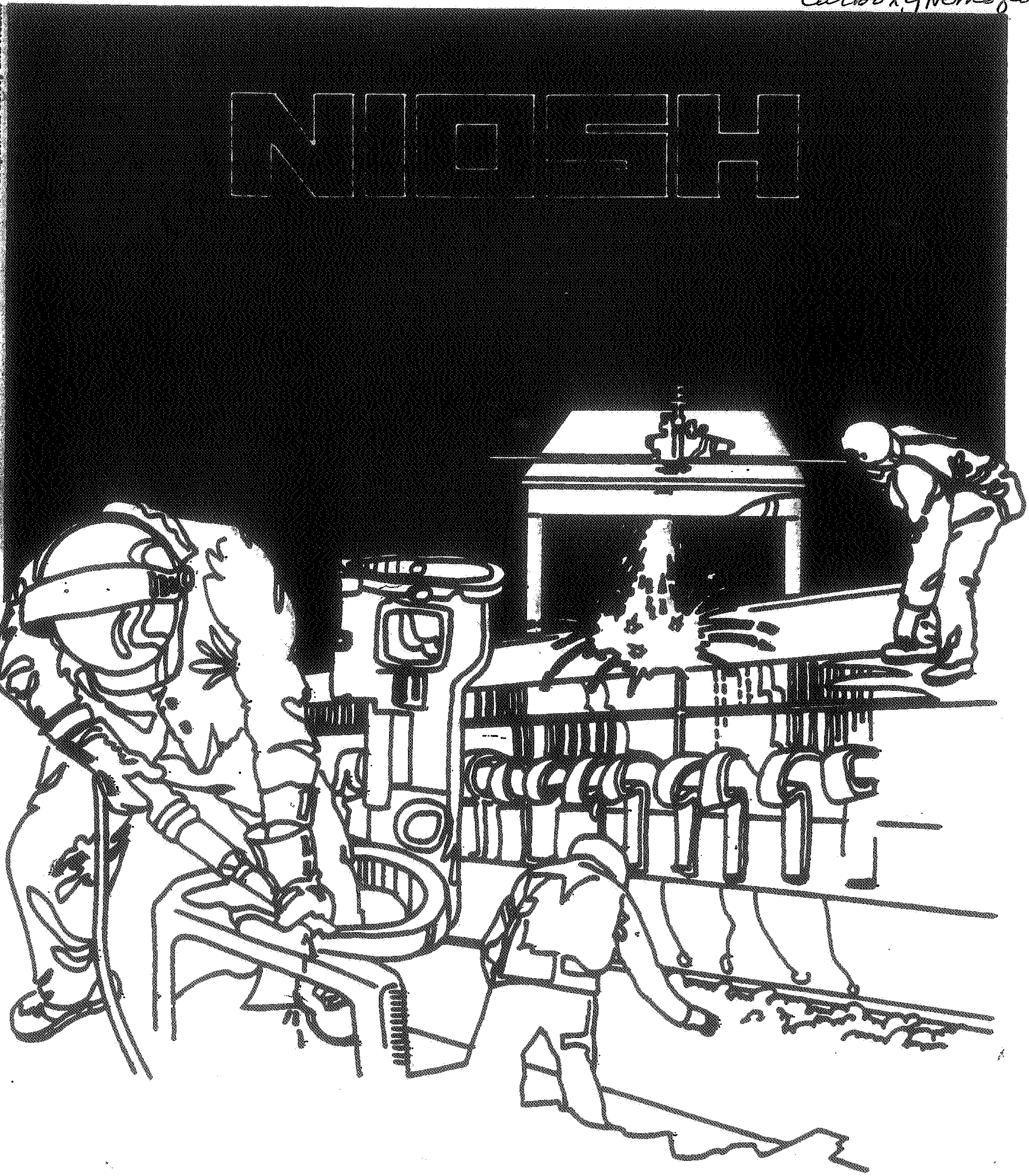
Carboxy Hemoglobin

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES • Public Health Service
Centers for Disease Control • National Institute for Occupational Safety and Health



Health Hazard Evaluation Report

HETA 84-458-1733
HETA 84-489-1733
SCHLEGEL, INCORPORATED
ROCHESTER, NEW YORK

PREFACE

The Hazard Evaluations and Technical Assistance Branch of NIOSH conducts field investigations of possible health hazards in the workplace. These investigations are conducted under the authority of Section 20(a)(6) of the Occupational Safety and Health Act of 1970, 29 U.S.C. 669(a)(6) which authorizes the Secretary of Health and Human Services, following a written request from any employer or authorized representative of employees, to determine whether any substance normally found in the place of employment has potentially toxic effects in such concentrations as used or found.

The Hazard Evaluations and Technical Assistance Branch also provides, upon request, medical, nursing, and industrial hygiene technical and consultative assistance (TA) to Federal, state, and local agencies; labor; industry and other groups or individuals to control occupational health hazards and to prevent related trauma and disease.

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I. SUMMARY

In July 1984, the National Institute for Occupational Safety and Health (NIOSH) received a request for an evaluation of exposure to substances used in manufacturing urethane foam seals and synthetic bristle brushes at Schlegel Corporation, Rochester, New York.

On November 27-30, 1984, NIOSH investigators conducted an environmental and medical survey. In the Polyurethane Department, air samples were collected for toluene diisocyanate (TDI), methylene chloride, carbon monoxide, 1-bromo-3-chloropropane, and polyurethane catalysts [bis (2-dimethylaminoethyl) ether, triethylene diamine, diethanolamine, and propylene oxide]. In the Spiral Wind Department (assembly of teflon, rayon, and dacron bristle brushes) air samples were collected for total dust and toluene.

Forty-three employees from the Polyurethane Department, three employees from the Spiral Wind Department, and sixteen employees from other departments were interviewed by the medical officer. Pulmonary function tests (PFTs) were offered to all these employees before their shifts on Monday, November 27, and following their shifts on Thursday, November 30. Carboxyhemoglobin (COHb) blood levels were drawn on 29 employees before their shifts on Monday, November 27, and following their shifts on Wednesday, November 29.

In the Polyurethane Department twenty personal breathing-zone (PBZ) air samples for TDI ranged from 1 to 30 ug/m^3 with a mean of 13 ug/m^3. The NIOSH recommended exposure limit (REL) for TDI is 40 ug/m^3. Twenty PBZ air samples for methylene chloride ranged from 11 to 180 mg/m^3 with a mean of 46 mg/m^3. The NIOSH REL for methylene chloride (MC) was 260 mg/m^3, based on carboxyhemoglobin formation. However, recent animal studies have shown methylene chloride to be carcinogenic; thus, exposure should be reduced as low as possible. Carbon monoxide (CO) levels in the Polyurethane Department were less than 5 mg/m^3. The NIOSH REL for CO is 40 mg/m^3. Six PBZ air samples for bromochloropropane were below the limit of detection (<1 mg/m^3). Air and wipe samples for polyurethane catalysts were below the limits of detection.

Spiral Wind workers were exposed to airborne total dust concentrations ranging from less than 0.1 mg/m^3 to 0.3 mg/m^3. The ACGIH Threshold Limit Value for nuisance dust is 10 mg/m^3. The gluing operator was exposed to toluene levels of 22 mg/m^3 on November 27, and 13 mg/m^3 on November 28. The NIOSH REL for toluene is 375 mg/m^3.

Polyurethane department workers were not more likely than other workers to report respiratory symptoms. Two polyurethane department workers who had never smoked had no hobbies or former jobs involving respiratory hazards, had an obstructive PFT pattern ($FEV_1/FVC < 0.7$).

Six (66%) of the nine non-smoking methylene chloride-exposed employees had post-shift COHb levels above the upper limit of normal (2%) for non-smokers. The mean shift changes in COHb levels were 0 for the group of workers not exposed to methylene chloride and +0.81 for the polyurethane and urethane experimental lab workers ($P<0.05$). Findings were similar for non-smokers versus smokers, when they were analyzed separately.

On the basis of the data collected in this evaluation, a hazard may exist from methylene chloride exposure in the polyurethane department at the Schlegel Corporation. Though no exposures above recommended limits were found for toluene diisocyanate, an obstructive pulmonary function pattern in two non-smokers is consistent with but not conclusive evidence of known effects of TDI exposure. No overexposures to contaminants were found in the Spiral Wind department of the Schlegel Corporation. However, this study was conducted when the workforce in that department had been reduced from twenty-one to three, and when only one work station was open. Recommendations for reducing TDI exposures and for medical surveillance and worker education are presented in Section VIII of this report.

KEYWORDS: SIC 282 (Plastic Materials and Synthetic Resins, Synthetic Rubber, Synthetic and other Man-Made Fibers, except Glass) polyurethane, toluene diisocyanate, TDI, methylene chloride, pulmonary sensitization, carboxyhemoglobin.

II. INTRODUCTION

In July 1984, the National Institute for Occupational Safety and Health (NIOSH) received a request for a health hazard evaluation at Schlegel Corporation in Rochester, New York. The request was submitted by employees who were concerned about exposure to materials used in manufacturing urethane foam seals and synthetic (fluorocarbon fiber) bristle brushes.

During November 27-30, 1984, NIOSH investigators conducted an environmental and medical survey of both processes. Results of environmental sampling were distributed to company and employee representatives on April 24, 1985.

III. BACKGROUND

Polyurethane Department

The Polyurethane Department is about 17 years old. TDI and polypropylene glycol are pumped automatically through closed systems to pressurized tanks where they are mixed. Methylene chloride (MC) is used several times per shift for cleaning the foam heads (point where the liquid urethane mixture is dispersed) to the gasket molds. Each of the foam heads are locally exhausted by a variety of hood systems.

Spiral Wind Department

The Spiral Wind Department is about 15 years old and normally employs 16 workers over two shifts. Brushes for use in IBM® duplicating machines are assembled using either Teflon®, Dacron®, or Rayon® fibers. The fibers are fastened to cardboard tubes to which rubber caps are attached. The parts are washed with a small paint brush dipped in toluene to clean up the trail of glue. After gluing, the brush fibers are trimmed in enclosed rotary shearing machines.

Medical Department

The medical unit is operated by a nurse. Ordinary pre-placement physical examinations include a brief exam, a vision test, a urinalysis, and an audiogram. For the polyurethane department, each worker also receives a pulmonary function test, and a complete blood count. Pulmonary function tests are also done yearly on polyurethane workers; they may be repeated after six months if problems are suspected. The PFTs have been conducted by a contract unit for the past two years. One problem is that this unit may take several months to report the data back to the company. A posterior-anterior and lateral chest radiograph is done every other year on polyurethane workers, as well as a complete blood count. Pre- and post-shift pulmonary function testing is not done. Referrals for pulmonary problems are made first to the contract unit; they may also be referred to a pulmonary specialist. At least two workers have been transferred from the polyurethane area in the past year because of decreased respiratory functions, respiratory symptoms, and possible sensitivity to TDI.

IV. METHODS

A. Environmental

On November 27-28, 1984, NIOSH investigators collected 90 air samples to evaluate worker exposure to toluene diisocyanate (TDI), total reactive isocyanates, methylene chloride, 1-bromo-3-chloropropane, bis (2-dimethylaminoethyl) ether, triethylene diamine, diethanolamine, and propylene oxide in the Polyurethane Department. Toluene, and airborne dust were sampled in the Spiral Wind Deparment. Both personal breathing-zone and area air samples were collected by battery powered pumps and a variety of sampling media. The sampling and analytical methods used for these contaminants are summarized in Table I.

Seven surface wipe samples were collected for polyurethane catalysts using gauze patches wetted with methanol (Table I). Ventilation measurements of local exhaust systems were collected using a Sierra Model 441®.

B. Medical

Questionnaire-interviews were done for all employees on all three shifts from the Spiral Wind and Polyurethane Departments who wished to participate. Three employees were interviewed from Spiral Wind, and forty-three from the Polyurethane Department. To provide additional information which could be used in control comparisons, sixteen employees from other departments were also interviewed.

Employees filled out the first part of the questionnaire by themselves, with NIOSH interviewers present to answer questions and to go over the questionnaires briefly at the end to resolve discrepancies or ambiguities. This first part included questions on race, sex, history of respiratory or chest disease, other relevant medical history, respiratory symptoms and perceived associations with activities at home or at work, neurological and gastrointestinal symptoms, smoking history, and use of alcohol.

The second part of the questionnaire was filled out by a NIOSH interviewer who questioned each employee separately. This part of the questionnaire included questions regarding perceived exposures, if any, to methylene chloride, bromochloropropane, and TDI (used in the Polyurethane Department) and to toluene and rubber-based glue (used in the Spiral Wind Department). It also asked for an occupational history concerning jobs and possible exposures at Schlegel, a history of other jobs where there might have been exposure to solvents and other respiratory irritants or sensitizers, and questions on possible exposures to hazards during work on hobbies.

Everyone who was interviewed was also offered a pre- and post-shift pulmonary function test. Pre-shift pulmonary function tests were performed before each shift began on Monday, November 27. Post-shift pulmonary function tests were performed after each shift ended on Thursday, November 30.

One-second forced expiratory volume (FEV) and forced vital capacity (FVC) were measured with an Ohio Medical Model 822 dry rolling seal spirometer attached to a Spirotech 200 B dedicated computer. Equipment and test procedures conformed to the American Thoracic Society's criteria for screening spirometry.[1] Predicted values for FEV and FVC were calculated using the equation of Knudson;[2] these values were multiplied by 0.85 to obtain the predicted values for blacks.[3]

Fifty-three employees, thirty-seven from Polyurethane, two from Spiral Wind, and fourteen from other departments, had both pre- and post-shift pulmonary function tests; five from Polyurethane, one from Spiral Wind, and three from other departments had only pre-shift tests and did not return for the post-shift test.

Seventeen employees from the Polyurethane Department, three from Spiral Wind, and nine from other departments also had blood drawn for carboxyhemoglobin (COHb) measurements before work on Monday and after work on Wednesday.

Statistical Analysis

Questionnaire responses were analyzed by unpaired t-tests or the Wilcoxon rank-sum test for continuous data and chi-square analysis or Fisher's exact test for categorical data. Changes over shift in pulmonary function tests were also analyzed by unpaired t-tests.

Because carboxyhemoglobin levels are a good measure of exposure to methylene chloride but not to other solvents, changes over shift in blood carboxyhemoglobin levels among workers who stated that they were exposed daily to methylene chloride, were compared by unpaired t-tests, to those who stated that they were not. The exposed group included one employee from the experimental urethane lab, and 14 from the Polyurethane Department. The non-exposed group included three from the Polyurethane Department, two from Spiral Wind, and seven of the "control group."

We had also planned to compare the twenty-one workers from Spiral Wind to the originally constituted control group. However, because there were only three workers left in Spiral Wind when our study was in process, the Spiral Wind group was not large enough to make any statistical comparisons meaningful.

V. EVALUATION CRITERIA

A. Environmental Criteria

As a guide to the evaluation of the hazards posed by workplace exposures, NIOSH field staff employ environmental evaluation criteria for assessment of a number of chemical and physical agents. These criteria are intended to suggest levels of exposure to which most workers may be exposed up to 10 hours per day, 40 hours per week for a working lifetime without experiencing adverse health effects. It is, however, important to note that not all workers will be protected from adverse health effects if their exposures are maintained below these levels. A small percentage may experience adverse health effects because of individual susceptibility, a pre-existing medical condition, and/or a hypersensitivity (allergy).

In addition, some hazardous substances may act in combination with other workplace exposures, the general environment, or with medications or personal habits of the worker to produce health effects even if the occupational exposures are controlled at the level set by the evaluation criterion. These combined effects are often not considered in the evaluation criteria. Also, some substances are absorbed by direct contact with the skin and mucous membranes, and thus potentially increase the overall exposure. Finally, evaluation criteria may change over the years as new information on the toxic effects of an agent become available.

The primary sources of environmental evaluation criteria for the workplace are: 1) NIOSH Criteria Documents and recommendations, 2) the American Conference of Governmental Industrial Hygienists' (ACGIH) Threshold Limit Values (TLV's), and 3) the U.S. Department of Labor (OSHA) occupational health standards. Often, the NIOSH recommendations and ACGIH TLV's are lower than the corresponding OSHA standards. Both NIOSH recommendations and ACGIH TLV's usually are based on more recent information than are the OSHA standards. The OSHA standards also may be required to take into account the feasibility of controlling exposures in various industries where the agents are used; the NIOSH-recommended exposure limits, by contrast, are based primarily on concerns relating to the prevention of occupational disease. In evaluating the exposure levels and the recommendations for reducing these levels found in this report, it should be noted that industry is legally required to meet those levels specified by an OSHA standard.

A time-weighted average (TWA) exposure refers to the average airborne concentration of a substance during a normal 8- to 10-hour workday. Some substances have recommended short-term exposure limits or ceiling values which are intended to supplement the TWA where there are recognized toxic effects from high short-term exposures.

The evaluation criteria and adverse health effects[4] of the substances investigated during this evaluation are summarized in Table II.

B. Toluene Diisocyanate (TDI)

1. Occupational Exposure Limits

The current U.S. Federal OSHA permissible exposure limit for TDI is 140 ug/m^3 as a "ceiling value" which shall not be exceeded any time during the work shift. The current NIOSH recommended exposure limit is 140 ug/m^3 for any 20 minute sampling period and 40 ug/m^3 for up to a 10-hour workday, 40-hour workweek.

The NIOSH recommended standard applies only to TDI monomer. The possibility that polymeric diisocyanates may induce pulmonary hypersensitivity has not been adequately studied, but investigators have speculated that the inhalation of any species having multiple unreacted isocyanate groups may impair respiratory function or give rise to sensitization.[5,6] On February 2, 1983, the United Kingdom Health and Safety Commission set a "common control limit" for workplace exposure to all isocyanates. The new exposure limit is 20 ug of isocyanate group/m^3 for an 8-hour time-weighted average, and 70 ug of isocyanate group/m^3 during any 10-minute sampling period. This requires that the analytical method be capable of measuring both the monomers and prepolymers of isocyanates.

2. Acute Effects

a) Primary Irritation

At high concentrations of TDI, all exposed individuals are susceptible to effects on the respiratory tract, resulting in a burning sensation in the nose and throat, a choking sensation, dry or productive cough, and general chest pains. These effects are often mistaken for "colds" or upper respiratory tract infection. Exposure to higher concentrations can lead to severe bronchoconstriction, mimicking an asthmatic attack. This attack may occur at the time of exposure or may be delayed. Overdose can also cause upper respiratory tract symptoms that mimic acute flu-like symptoms, with rhinitis, fever, chills and cough. It may produce a chemical pneumonitis as well.[7,8]

At lower levels TDI may produce headaches, sleeplessness, ataxia, and euphoria. Nausea, vomiting and abdominal pain may also occur. If liquid TDI is allowed to remain in contact with the skin, it may produce redness, swelling, and blistering. Contact of liquid TDI with the eyes may cause severe irritation, which may result in permanent damage if untreated. Swallowing TDI may cause burns of the mouth and stomach.[9]

b) Allergic Sensitization

TDI can produce an immunological sensitization (allergy) and very low concentrations may elicit various symptoms. Shortness of breath and cough, as well as symptoms and signs of asthma, may appear in sensitized individuals. However, typical asthmatic symptoms may not always occur: a feeling of "stuffy" head or nose, similar to that often experienced with hay fever, is often a sign of sensitization. Sensitization of individuals may occur at concentrations below 0.002 ppm but the frequency of sensitization increases following acute high level exposure as after a spill. Once a person becomes sensitized, even very low levels of exposure may cause severe asthmatic attacks. Once a person has become sensitized, it is likely he or she will have to avoid all exposure to diisocyanates, as no safe levels have been found. Four and three-tenths per cent of a population of 277 exposed workers were found to be sensitized in a recent study. Of this subgroup of workers who developed hypersensitivity to TDI, some failed to regain pre-exposure values of FEV_1 after removal from the area of exposure.[10]

c) Drop In Lung Function Over A Shift

Some TDI-exposed workers show an acute, asymptomatic drop in their pulmonary function over the workshift -- that is, drops occur when a pulmonary function test taken before work is compared to one taken after work -- at concentrations below 0.02 mg/m^3.[11]

3. Chronic Effects

a) Accelerated Loss of Lung Function

A fourth respiratory effect, which can result from chronic low level exposure, is that of a chronic, accelerated loss of lung function over years of exposure even in the absence of sensitization. Studies have been conducted both in workers exposed to TDI in production of TDI and in production of urethane foam from TDI. These investigation show that chronic exposure to low doses of TDI (less than 0.02 ppm) leads to: (1) permanent decreases in FEV_1 and FVC in sensitized workers.[12] However, permanent decreases in FEV_1 and FVC in chronically exposed workers who are not sensitized have also been found.[13,14]

In the most extensive study to date, Weill et al reported in 1981 that 8-hour TWA levels of 0.002 ppm with excursions beyond 0.02 ppm occurring only 3% of the time produced a more rapid fall in One Second Forced Expiratory Volume (FEV_1) than would be expected from a cross-sectional study of normal populations.[10] These findings were more pronounced for non-smokers as the obstructive effects of smoking may mask the effect, but the effect was also found in smokers. The different health effects observed in these groups supports the NIOSH-recommended standard of 5 ppb TDI as an 8-hour TWA.

b) Restrictive Lung Disease

A 1978 study of polyurethane workers showed changes consistent with restrictive lung disease in workers exposed daily to concentrations of TDI less than the OSHA standard of $0.14 mg/m_3$ for a period of 1-10 years.[15]

c) Carcinogenicity

No information on carcinogenicity in humans in available. A study done by the National Toxicology Program (NTP)[16] found dose-related statistically significant cancer excesses in mice and rats.

4. Occupational Asthma

Approximately two percent of all cases of asthma appear to be job connected in the U.S., but the incidence of occupational asthmas varies among different industries. About 6% of research-animal handlers become sensitized to serum or dander products; from 10% to 20% of bakers develop flour-dust-related asthmas; virtually all employees in the platinum salt industry are reported to develop at least mild respiratory symptoms.

In the U.S., some 50,000 people are exposed to TDI at the workplace. Approximately 5% of these develop severe asthmatic symptoms; others may develop milder symptoms such as a stuffy nose. There are three mechanisms by which asthmatic symptoms may be produced: (1) by direct irritation; (2) by an IgE mediated reaction; that is, a reaction whereby the previously exposed person immediately produces antibodies to TDI when a subsequent exposure, even to low levels such as 0.002 ppm, occurs. These antibodies in turn cause the release of chemicals in the body that are associated with asthmatic symptoms. (3) By "direct pharmacologic mechanisms" not associated with IGE or the immune system. Several studies have shown no correlation between the presence of positive intracutaneous skin tests or special IgE antibodies against TDI in subjects with proven TDLI-induced asthma. Investigations have shown that TDI can inhibit the stimulatory action of isoproterenol and prostaglandin E_1 on lymphocyte cuclic adenosine 3'5'-monophosphate in vitro, which suggests that TDI could induce asthma by interference with pharmacolic-mediator control mechanisms. It has also been postulated that TDI may cause the direct release of histamine. This may explain the severe effects of high doses of TDI (greater than 0.5 ppm) on the respiratory tract of virtually anyone who inhales it. At lower concentrations, TDI may compromise only those individuals who have preexisting susceptibility, such as hyperreactivity of the airways, or by the direct pharmacologic mechanisms. It has been shown that many, though not all, TDI-sensitive individuals have increased bronchial reactivity to methacholine inhalation, in contrast to nonsensitive TDI workers.[17]

C. Methylene Chloride

1. General Characteristics

Methylene chloride (MC) is a volatile, aliphatic, organic solvent that is easily absorbed through the lungs (55%-70% retention of inspired concentration at rest, and 24-35% with exercise),[18] by direct skin contact,[19] and by ingestion.[20]Methylene chloride is excreted unchanged (95%) through lungs and small amounts via kidney. The metabolism of methylene chloride to carbon monoxide is felt to occur via the process of microsomal oxidative dechlorination. This occurs primarily in the liver, but these microsomes are also present in the lungs and kidneys.[21]

Methylene chloride is an irritant of the skin, eyes, and upper respiratory tract. Skin and eye burns may occur from direct contact with methylene chloride if not promptly removed. In cases of accidental poisonings in humans, notable effects have included cardiovascular effects, central nervous system depression, behavioral changes, mucous membrane irritation, pulmonary tract irritation and edema, as well as elevated carboxyhemoglobin levels.[20]

2. Carboxyhemoglobin as a Measure of Methylene Chloride Exposure

The absorption of methylene chloride which is metabolized to carbon monoxide, is most conveniently measured by assessing the carboxyhemoglobin (COHb) level in the blood. Carboxyhemoglobin is formed when the blood's oxygen carrier -- hemoglobin -- is exposed to carbon monoxide in the bloodstream. Hemoglobin binds more avidly to carbon monoxide than to oxygen, forming a molecule which is about 200 times more stable than the oxyhemoglobin (oxygen combined with hemoglobin) molecule. The most common source of personal environmental carbon monoxide is cigarette smoke. Cigarette smokers may average as much as 10% COHb in the blood (i.e., one tenth of their hemoglobin is bound to CO instead of to oxygen). Non-smokers may have as much as 1-2% carboxyhemoglobin in the blood under "normal" circumstances in an industrial society, where there are exposures from internal combustion engines, smokers, etc.

Although COHb is an imperfect measure of CO effect -- both because duration and intensity of CO exposure affect the COHb level, and because CO effects on oxidative enzyme systems are even more profound than the effects on hemoglobin -- it is nonetheless the most useful and practical biological measurement available.

The half-life of carboxyhemoglobin resulting from methylene chloride exposure is 10-12 hours; that is, after a person absorbs methylene chloride (through skin or inhalation), COHb in the blood will not be eliminated immediately, but will decrease by one-half approximately every 10-12 hours. Actually, the COHb level will continue to rise with continued exposure if the rate of absorption is greater than the rate of elimination. Also, the COHb level can continue to rise even after a person is removed from methylene chloride exposure. This most likely results from continued conversion to COHb of methylene chloride stored in body tissues.[22] Over time, the COHb content of the blood will be related to a given level of CO or of methylene chloride in inspired air. Human male subjects (non-smokers) exposed experimentally to methylene chloride for 7.5 hours daily on 5 consecutive days attained average peak COHb percentages of 2.9% at 50 ppm methylene chloride, 5.7% at 100 ppm methylene chloride, and 9.6% at 250 methylene chloride. In each case, the peaks were attained on the 5th day of exposure. Higher values would be expected if subjects exercised during exposure. Because of this change over time, symptoms of the CO effect do not precisely correlate with COHb levels in the blood. Early symptoms of CO intoxication -- headache and breathlessness with exertion -- may occur in the COHgb range from as low as 5% up to greater than 20%. At levels between 20 and 40%, more severe symptoms, such as severe headache, emotional lability, unusual fatigue, and mental confusion may occur. Above 40%, disorientation, staggering, and unconciousness may occur progressively, with death supervening in the range between 50 and 80% COHb.

The rise in COHb levels as a consequence of methylene chloride exposure may also be sufficient to stress individuals with underlying cardiac or pulmonary disease. Three myocardial infarctions, including a death following paint stripping in a basement, have been reported.[23]

The previous NIOSH Recommended Exposure Limit (REL) for methylene chloride was 75 ppm, 261 milligrams per cubic meter (mg/m^3), as a TWA for up to a 10-hour workday, 40-hour workweek with a 500 ppm (1,740 mg/m^3) peak exposure concentration as determined over any 15-minute sampling period during the workday. The REL was based on the need to prevent significant interference with the delivery of oxygen to the tissues of the body and abnormalities in functions of the central nervous system (CNS) as a result of the production of COHb by the metabolism of methylene chloride. The goal was to maintain carboxyhemoglobin levels below 5% in non-smokers. The limit of 5% COHb was originally set for the NIOSH recommended standard for carbon monoxide, based on studies of persons with subclinical or overt coronary artery disease who showed evidence of compromised cardiac function at COHb levels in excess of 5%.[24]

3. Methylene Chloride and Carbon Monoxide

The toxicities of methylene chloride and carbon monoxide (CO) are additive.[25] Because of this additive effect, provisions for calculating a reduced REL for methylene chloride in the presence of CO were included in the document, Criteria for a Recommended Standard....Occupational Exposure to Methylene Chloride published by NIOSH. When concentrations of CO exceed 9 ppm in the workplace, either the concentration of methylene chloride or the concentration of CO should be reduced. The value 9 ppm is that included in the air quality standard of the Environmental Protection Agency and was derived from data indicating that typical background concentrations of CO in environments in the United States were generally less than 10 ppm and frequently greater than 5 ppm.

Measurements of methylene chloride in blood (as carboxyhemoglobin) or in expired air (as carbon monoxide) can be used as a measure of the magnitude of MC exposure. Interpretation of blood COHb and expired CO measurements in smokers is difficult because cigarette smoke contains carbon monoxide which may also elevate these measurements.

The experimental literature on the effects of methylene chloride and carbon monoxide indicates that COHb is the biological indicator that best correlates with the neurobehavioral effects of both chemicals.[26] The major neurobehavioral effects attributed to methylene chloride and carbon monoxide exposure are incoordination, limb numbness and tingling, disorientation and confusion, vigilance deficits, time estimation losses, and remote memory impairment.[27,28,29,30]

4. <u>Methylene Chloride and Carcinogenesis</u>

$B6C3F_1$ mice exposed to methylene chloride in air developed cancers and adenomas of the lung, and hepatocellular carcinomas of the liver.[31] Fischer 344 rats exposed to methylene chloride in air developed fibromas and fibroadenomas of the mammary gland.[31] Sprague-Dawley rats exposed to methylene chloride in air developed cancers (sarcomas) of the salivary glands and fibromas and fibroadenomas of the mammary glands[32]

One epidemiologic study of a small worker population, suggests that methylene chloride exposure may be related to increased risk of pancreatic cancer.[33,34,35] The excess was associated with a significance level of less than 5% but greater than 1%; that is, there is less than a 5% likelihood that the excess occurred by chance, but a greater than 1% likelihood that it occurred by chance. Because 1% was the statistical criterion chosen to evaluate the risk categories before the risks were calculated, the authors could not call this a statistically significant cancer excess. However, this study had only a 35% statistical power to detect an association at this level of significance;[36]that is, at the 1% level of significance it is difficult to detect moderate increases in less common cancers such as pancreatic cancers without studying a larger group than was used in this study. This study must be considered suggestive, and larger studies are indicated.

Because methylene chloride has been shown to induce increased numbers of benign and malignant neoplasms in rats and mice, it meets the criteria provided in the OSHA Cancer Policy for classifying a substance as a potential occupational carcinogen; therefore, NIOSH recommends that methylene chloride be considered a potential human carcinogen in the workplace, and that occupational exposure to methylene chloride be controlled to the lowest feasible limit.[37]

D. Exposures to Solvents

1. Toluene

The primary acute exposure effect of toluene at high concentrations is narcosis. In concentrations of 300-600 ppm, fatigue, mental confusion, exhilaration (a "high" feeling) nausea, headache, and dizziness can result in as little as 2-3 hours. Even at lower levels, acute exposure may cause irritation of the eyes, respiratory tract, and skin. Other symptoms included headache, dizziness, fatigue, and drowsiness. With chronic lower level exposure inconsistent changes in red and white blood cells have been reported with no definite consistent effects noted. Most industrial exposures result from breathing toluene vapor since it is absorbed slowly through the skin. Frequent handwashing is important, however, since skin absorption does take place. Also, skin contact with toluene should be minimized because of its irritant and defatting properties.[38]

2. Combined Exposures

Toluene, methylene chloride, and other solvents can act additively to produce irritation, headache, nausea, fatigue, narcosis, and respiratory irritation. When an employee is exposed to two or more of these compounds, as is usually the case in the departments studied at Schlegel, their combined effect rather than that of one individual component should be considered. Equivalent total exposure from a mixture of solvent vapors can be calculated as follows:

$E_m = (C_1$ divided by $L_1 + C_2$ divided by $L_2 +$ (C_n divided by L_n))

Where:

E_m is the equivalent exposure for the mixture

C is the airborne concentration of the particular chemical

L is the exposure limit for that chemical

The concentration of the combination of chemicals is considered to be unacceptable if E_m is greater than 1.0.

E. Teflon (Polytetrafluoroethylene) and Rayon Fibers

Teflon when not heated is considered to be harmless, and a literature search has revealed no studies on the ability of teflon fibers to cause respiratory irritation or disease. If teflon is heated, a "polymer fume fever" can develop within a few hours. Symptoms included chest discomfort, coughing, aches, chills, and fever. These symptoms can be produced when cigarettes are contaminated with teflon and then smoked, as the burning of the cigarettes will produce high enough temperatures to cause teflon vapors to be inhaled.[39]

A literature search has revealed no studies on the ability of rayon fibers to cause respiratory irritation or disease.

Because no standards have been recommended for these fibers, they are classified as "nuisance dusts," a general term used for all dusts which are harmless at low levels and for dusts whose toxicities have not been well characterized.

VI. RESULTS

A. Environmental

1. Polyurethane Department

In the Polyurethane Department, twenty personal breathing-zone (PBZ) full-shift air samples for TDI (2,4-TDI and 2,6-TDI) ranged from 1 to 30 ug/m^3 with a mean of 13 ug/m^3 (Table III). Set-up workers and operators were exposed to a mean TDI concentration of 16 ug/m^3, whereas assistants had a mean exposure of 7 ug/m^3. The NIOSH recommended exposure limit for TDI is 40 ug/m^3.

Detector tube measurements for methylene chloride ranged up to 700 mg/m^3 while workers were flushing the heads in the polyurethane lines. The ACGIH recommended short term exposure limit for methylene chloride is 1,740 mg/m^3. Twenty full-shift air samples for methylene chloride ranged from 11 to 180 mg/m^3 with a mean of 46 mg/m^3. The NIOSH recommended exposure limit for methylene chloride was 260mg/m^3, based on carboxyhemoglobin formation. However, recent animal studies have shown methylene chloride to be carcinogenic, thus, exposures should be reduced to the lowest possible level.

Five detector tube measurements for carbon monoxide (CO) in the Urethane Foam Department were all less than 5 mg/m^3. The NIOSH recommended exposure limit for CO is 40 mg/m^3.

Six PBZ air samples for bromochloropropane were below the limits of detection (<1 mg/m^3). Air and wipe samples for polyurethane catalysts were below the limits of detection with the possible exception of organotin. Wipe samples of the Set-Up worker's hand and weighing flask handle had 30 to 40 ug of tin per 100 cm^2 of surface area, however, it is not known to what extent, if any, sources of metallic tin in the work area could have interfered with the sampling.

Problems were encountered with the analysis of impinger samples for total reactive isocyanates (Table IV). Even though side-by-side area sampling results from the sorbent tube method showed TDI concentrations as high as 340 ug/m^3, no reactive isocyanates (<18 ug/m^3) were detected in any of the impinger samples. Possible reason(s) for this discrepancy are currently being investigated.

2. <u>Spiral Wind Department</u>

Spiral Wind workers were exposed to airborne total dust concentrations ranging from less than 0.1 mg/m^3 to 0.3 mg/m^3 (Table V). The ACGIH Threshold Limit Value for nuisance dust is 10 mg/m^3. The gluing operator was exposed to toluene levels of 22 mg/m^3 on November 27 and 13 mg/m^3 on November 28 (Table VI). The NIOSH recommended exposure limit for toluene is 375 mg/m^3.

3. Ventilation

Face velocities of the exhaust hoods for the TDI lines ranged from 200 to 4000 feet per minute (fpm). However, the capture velocities (measured where TDI is applied to the mold) were non detectable (<50 fpm) on Lines 2,4,5,6, and 7. Capture velocities were 50 to 100 fpm on Lines 1 and 3. The poor contaminant capture potential was due mostly to inefficient hood designs and the excessive distances of the exhaust hoods from the foam heads and mold lines. Also, a lot of cross interference (up to 500 fpm) was found to be caused by the large floor fans used for comfort ventilation in the work area.

B. MEDICAL RESULTS

1. Demographic Variables

a. Polyurethane Department

Of the 43 interviewed from the Polyurethane Department, 27 (64%) were white, 10 (24%) were black, 3 (7%) were Hispanic, 2 (5%) were Asian, and 1 did not answer the question. Thirty-two (74%) were male and eleven (26%) were female. The mean (average) age in the polyurethane department was 36 years; the median was 29 years.

b. Spiral Wind Department

Of the three interviewed from the Spiral Wind Department, two (66%) were white and one (33%) was black. All three were males. The mean age was 33; the median age was 27.

2. Personal protective equipment and practices

a. Polyurethane Department

Thirty-five (81%) of the employees in the polyurethane department stated that they never wore a dust mask; eight (19%) stated that they occasionally wore a dust mask. Thirty-nine (91%) stated that they never wore a cartridge respirator; 4 (9%) stated that they occasionally did so. Two (5%) stated that they never wore gloves; twenty-four (56%) that they occasionally did so; 15 (35%) that they usually did so, and 2 (5%) that they always did so. Twenty-five (58%) stated that they never wore protective clothing; five (12%) that they occasionally did so; 7 (16%) that they usually did so, and six (14%) that they always did so. Twenty-two (51%) stated that their work clothes were laundered at home with other laundry; twenty-one (49%) stated that their work clothes were laundered at home separately from other clothing. Seven (16%) stated that they usually washed their hands before smoking or eating at work; 36 (84%) stated that they always did.

b. Spiral Wind Department

None of the three men interviewed from the Spiral Wind department ever wore dust masks, cartridge respirators, gloves, or protective clothing at work. All three always washed their hands before smoking or eating at work. Two (67%) had their uniforms laundered at home with other laundry; one (33%) had his laundered separately.

3. Smoking history

a. Polyurethane Department

Thirty-three of the forty-three workers interviewed in the Polyurethane Department had smoked at sometimes during their lives; ten (23%) had never smoked. Thirty-three had smoked at some time in their lives, but only 25 (55%) were current smokers.

b. Spiral Wind Department

Two (67%) of the men interviewed from Spiral Wind were current smokers; one (33%) had never smoked.

4. Medical History

a. Polyurethane Department

Only one (2%) of the Polyurethane employees had a history of chest illness which had led to hospitalization; one (2%) had a history of asthma. None had a history of tuberculosis; four (9%) had a history of pneumonia; two (5%) of pleurisy; ten (23%) of bronchitis; none of emphysema; three (7%) of sinusitis; five (12%) of hay fever; four (10%) of other allergies. No one had a history of cancer; one (2%) had a history of heart disease.

b. Spiral Wind Department

None of the three workers interviewed from the Spiral Wind department had ever been hospitalized for a chest illness. None had a history of respiratory disease, allergies, cancer, or heart disease.

5. Respiratory Symptoms

a. Polyurethane Department

Eight (19%) of the forty-three interviewed stated that they had had wheezy or whistly breathing in the past month. Seven (88%) stated that the wheezing happened sometimes or most of the time at work. Four (50%) stated that on days away from work, the wheezing happened not at all, or less frequently than on workdays. Six (76%) stated that on vacation the wheezing happened not at all, or less frequently than on workdays.

Eleven of the forty-three interviewed stated that they had a cough as much as three months in the year; of these, ten (91%) stated that the cough was usually productive of mucus or phlegm. Six (13%) of the forty-three interviewed stated that they often had an itchy nose while at work; eleven (26%) stated that they often had a stuffy nose while at work; five (12%) stated that they had frequent sneezing while at work, and seven (16%) stated that they frequently had itchy, watery eyes while at work.

No significant differences were found in respiratory symptom comparisons between the control group and the polyurethane workers. However, many of the controls came from Polyband, where there are exposures to other potential respiratory irritants such as solvents.

b. Spiral Wind Department

One (33%) of the three interviewed stated that he had had wheezy or whistly breathing in the past month. He stated that this never occurred following exposure to certain materials at home, but sometimes occurred at work. On days away from work and on vacations, it happened less frequently than on workdays.

None of the three interviewed stated that they had a cough as much as three months in the year. One (33%) stated that he often had an itchy nose while at work; two (66%) stated that they often had a stuffy nose while at work; two (66%) stated that they had frequent sneezing while at work, and two (66%) stated that they frequently had itchy, watery eyes while at work.

6. Gastrointestinal and Neurological Symptoms

Seven of the forty-three Polyurethane employees reported a history of diarrhea in the past month. Six (14%) reported a history of abdominal cramps in the past month. Four (9%) reported vomiting in the past month. Nine (21%) reported a history of dizziness in the past month. Twenty-three (53%) reported a history of headache in the past month. Five (12%) reported a history of trembling hands in the past month. Seven (16%) reported a history of weakness in the hands, arms, and legs in the past month. Seven (16%) reported a history of skin rash in the past month.

All workers interviewed had a mean of two out of sixteen "yes" answers on the modified Swedish Sixteen Questionnaire designed to detect effects of chronic low level solvent exposure. Whether groups were compared by department (polyurethane, spiral wind, and "other") or by methylene chloride exposure (exposed and non-exposed), no group mean differed significantly from this mean. Some individuals had totals of as many as nine "yes" answers, but this questionnaire is designed only to compare group means only, and no conclusions can be drawn about individuals whose mean was higher than their group's mean. Because there is solvent exposure in the polyurethane department, the spiral wind department, and in polyband, from which department many of the "other" group were taken, and because the Swedish sixteen does not differentiate between the effects of various solvents, it is not surprising that no useful comparisons between these groups can be made using this instrument.

7. Pulmonary Function Test Results

a. Shift Changes

Three (7%) of the polyurethane workers tested had evidence of obstructive lung disease; one (33%) of the Spiral Wind workers had evidence of obstructive lung disease; and one (7%) of the workers from another department had evidence of obstructive lung disease. Two (66%) of the three polyurethane workers with obstructive lung disease were non-smokers; the rest were smokers.

Five (12%) Polyurethane workers, all smokers, showed a decrease of 5% or more in FEV_1 from pre- to post-shift. One additional worker, who also showed such a decrease, had been in Spiral Wind until the week before, but had been transferred. These six workers all had scores above the norm of 80% predicted both pre-shift and post-shift, but a shift change of greater than 5% should still be noted. All of these were smokers, but there was no significant difference between the time since their last cigarette before the pre-shift and post-shift tests. Three, all polyurethane operator's assistants, reported daily exposure to TDI; one was a polyurethane part inspector who reported no direct exposure to TDI; one was a dipper in polyurethane who reported no direct exposure to TDI, one had been in Spiral Wind until the week before but had been transferred to another department.

Two (5%) workers from Polyurethane, both smokers, had a decrease in FEV_1/FVC of greater than 5%; both had pre-shift scores above the norm and post-shift scores below the norm. One smoker, a urethane operator's assistant who reported direct exposure to TDI daily, had a decrease in FEV_1/FVC of of 8%, from 72% to 64% (that is, to below the norm). Another smoker, a dipper in polyurethane who reported no direct exposure to TDI, had a decrease of 5% from 71% to 66% (again, below the norm). The first reported a morning cough which he associated with smoking; the second reported no respiratory symptoms.

It is possible that both those polyurethane workers reporting symptoms associated with work have been sensitized to TDI; sensitization is not always characterized by the wheeze more commonly associated with asthma. The former Spiral Wind worker, whose only respiratory history was an episode of bronchitis in 1980, reported frequent sneezing when on the gluer in Spiral Wind. It is possible that she was still reacting to some similar substance in the new department (textiles).

b. Obstructive Lung Disease

As mentioned previously, three (7%) of the Polyurethane workers tested had evidence of obstructive lung disease ($FEV_1/FVC < 0.7$); one (33%) of the Spiral Wind workers had evidence of obstructive lung disease; and one (7%) of the workers from another department had evidence of obstructive lung disease. Two (66%) of the polyurethane workers were non-smokers; the rest were smokers.

One of the non-smokers, who had an FEV_1/FVC of 66%, was a urethane operator's assistant who reported daily exposure to TDI, stated that he had daily wheezing associated with work. The other non-smoker, who had an FEV_1/FVC of 0.67, was a urethane set-up worker with previous experience as a urethane operator and an operator's assistant. He reported no history of respiratory disease, and no respiratory symptoms. Neither worker had smoked, had any hobbies, or former jobs, that were associated with exposures to respiratory hazards. If the evidence of obstructive lung disease is confirmed, and lung function tests taken before work at Schlegel do not show obstruction, it is possible that the obstructive pattern represents a long-term decrease in lung function that may be related to chronic exposure to TDI. These workers have been advised to have their lung function tests repeated.

The smoker from Polyurethane with evidence of obstructive lung disease is a finisher with an FEV_1/FVC of 58%. He has no daily direct exposure to TDI, with a former job as a polyurethane operator's assistant with exposure to TDI. He has a cough which occurs equally at all times of day and a stuffy nose which he attributes to dry air at work. He was exposed to cotton dust (which is usually associated with restrictive rather than obstructive lung disease) in a job from 1949 to 1951.

One (33%) of the three tested from Spiral Wind also shows evidence of obstructive lung disease. He was a Set Up person, who reported stuffy nose, frequent sneezing, and itchy, irritated eyes at work; he associates these particularly with rubber-based glue, toluene, and teflon dust.

One (7%) of the workers from other departments also showed evidence of obstructive lung disease. He is a smoker who works in the Thermatron Department, and has no exposure to respiratory hazards; nor does he have any history of exposures.

The association of smoking with obstructive lung disease has been repeatedly shown. Therefore it is impossible to say, in the cases of the two smokers with exposures to potential occupational hazards and obstructive lung disease, how much disease, if any, could be attributed to workplace exposures. It is possible that both smoking and workplace exposures may have contributed to the decrease.

8. Conclusions on Pulmonary Effects

A substantial number of polyurethane workers complain of effects which are likely to be primary irritant effects, since they are for the most part not accompanied by pulmonary function changes. Exposures to TDI and a variety of other solvents may be contributing to these effects; a combination of solvents may be more irritating than is reflected in individual exposure level recommendations. Some workers who have now been transferred have documented sensitization in the past, and a few workers in our study who are non-smokers show evidence of lung disease. This suggests that TDI levels may at some times be high enough to cause respiratory effects. The fact that many workers had been laid off just before our visit and that some workers who had been transferred because of sensitivity to TDI were not available for study may mean that this study does not accurately reflect the true prevalence of pulmonary disease in the polyurethane department.

As we were only able to interview three workers currently working in Spiral Wind, the fact that two had symptoms associated with work cannot be considered representative of this population, and conclusions about the prevalence of respiratory disease and symptoms cannot be drawn. Toluene is known to be a respiratory irritant; little work has been done to characterize the potential of rayon and teflon fibers, which the workers believe to be most irritating.

C. Carboxyhemoglobin Levels in Methylene Chloride Exposed Vs Non-Methylene Chloride Exposed Workers

Twenty-nine carboxyhemoglobin levels were drawn pre-shift on Monday and post-shift on Wednesday; two of these, one pre-shift and a different post-shift, were damaged in transit or handling and could not be used. The remaining twenty-seven were divided into methylene-chloride-exposed (15 workers) and non-methylene-chloride-exposed (12 workers). Nine (60%) of the exposed group and 6 (50%) of the unexposed group, were non-smokers.

The mean pre- and post-shift COHgb levels for MC-exposed smokers were 6.10 and 6.92%, respectively. Smokers not exposed to MC had a pre-shift mean of 5.32% and a post-shift mean of 5.52%.

The mean change in COHb level was zero in the non-exposed group and +0.81 ($p < 0.05$. Wilcoxon rank in test) in the exposed. For non-smokers only, the mean change in COHb level was -0.20 in the non-exposed group and +0.81 in the exposed group ($p < 0.05$ by the Wilcoxon 2-sample test). For smokers only, the mean change in COHb level was -0.20 in the non-exposed group and +0.82 in the exposed group ($p < 0.05$ by the Wilcoxon 2-sample test).

Six (66%) of nine MC-exposed non-smokers had carboxyhemoglobin levels which went from a pre-shift level of <2.0% to a post-shift level of >2.5%, which is above the norm for non-smokers. The highest post-shift levels, found in two of these workers, was 3.6%. Five of these workers worked in the Polyurethane Department: two were machine operators, one an operator's assistant, and one a urethane set-up person. One was a developmental engineer in the experimental urethane department. The mean number of "yes" answers on the Swedish questionnaire was 3.5 for this group. The mean pre- and post-shift COHgb levels for unexposed non-smokers were 2.0% and 1.9%, respectively.

D. Conclusions on Carboxyhemoglobin Levels

Methylene chloride exposed workers in the polyurethane department, whether smokers or non-smokers, are receiving enough methylene chloride exposure to increase their carboxyhemoglobin levels significantly in comparison to the increase experienced by non-exposed workers. Although no smokers had levels over the 12%, the upper limit of the "norm" for smokers, the majority had levels over the 5% considered "safe" by NIOSH.

VII. RECOMMENDATIONS

A. Engineering

1. The local exhaust ventilation systems for each of the TDI lines should be redesigned to provide at least 100 fpm capture velocity at the TDI heads and the open portion of the foam molds.

2. Floor fans should not be used where they may interfere with local exhaust systems.

B. Medical

1. Yearly pulmonary function testing on polyurethane employees should be continued. If pulmonary function is decreasing more quickly than would be expected, even if the results are still "normal", further medical evaluation should be undertaken.

2. Nurses who staff the clinic at Schlegel should have the benefit of continuing education courses in occupational health.

3. Problem lists and work histories, including exposure histories if possible, should be included in medical charts. These could help to alert clinical staff to potential problems before they become widespread.

C. Educational

1. Workers exposed to potential respiratory and neurological hazards and irritants should be educated about their nature and the necessity to minimize exposure. Management and employees should work together to develop an educational program, which should include work design, work practices, personal protective equipment and practices, and selection of chemicals; all of these should be designed to minimize exposure. Information is available from health and safety professionals, from union health and safety offices, from management training courses, and from other sources. This information should be included as part of initial training programs and should be updated periodically.

2. Anti-smoking education should include information about possible synergistic effects with workplace exposures. It is particularly important that workers in Spiral Wind understand the dangers of smoking cigarettes near a source of Teflon fibers, or with hands contaminated by Teflon fibers.

D. Personal Protection

1. Gloves should be worn whenever possible when manually transferring solvents. Rubber gloves have a very short breakthrough time with methylene chloride and are not appropriate for use with methylene chloride. Viton® gloves are recommended for use with methylene chloride.

2. Contaminated work clothes should be laundered at the plant if at all possible. If they are laundered at home, they should be laundered separately. Smokers at home who may be handling laundry should be warned that Teflon-contaminated cigarettes can cause polymer fume fever.

3. The importance of frequent handwashing should be emphasized as an adjunct to other protective measures. The possibility of significant skin absorption of such chemicals as methylene chloride should be emphasized as a reason for handwashing. Further systemic exposure to hazardous chemicals can come from application of cosmetics in work areas, and eating and drinking in work areas; the importance of avoiding these means of additional exposure should be emphasized.

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1. Schlegel Corporation
2. Local 3T
3. NIOSH, Region II
4. OSHA, Region II

For the purpose of informing affected employees, copies of this report shall be posted by the employer in a prominent place accessible to the employees for a period of 30 calendar days.

TABLE I

Sampling and Analytical Methods

Schlegel Corporation
Rochester, New York
HETA 84-458 and 84-489
November 27-28, 1984

Contaminant	Sample Type and No. Collected	Sample Media	Flow Rate (lpm)	Analysis
TDI	20-PBZ 10-area	glass wool treated with N-p-nitrobenzyl-N-propylamine	1.0	high pressure liquid chromatography NIOSH P&CAM 326
Total Reactive Isocyanates	10-area	1-(2-methoxyphenyl) piperazine and toluene in midget impingers	1.0	high pressure liquid chromatography NIOSH Method 5505
Methylene Chloride 1-Bromo-3-Chloropropane	20-PBZ 6-PBZ	charcoal tubes	0.02	gas chromatography NIOSH Method S-329
Airborne Dust	4-PBZ 3-area	pre-weighed filters	1.5	gravimetric
Toluene	2-PBZ 2-area	charcoal tubes	0.05 0.05	gas chromatography NIOSH Method S-343
Bis (2-Dimethylaminoethyl) Ether, Triethylene Diamine, and Diethanolamine	5-area 5-surface wipes	Thermosorb A® sorbent cartridges gauze patches and methanol	1.0 -	gas chromatography with TEA
Propylene Oxide	2-area	charcoal tubes	0.05	gas chromatography NIOSH Method S-75
Tin	2-surface wipes	gauze patches and methanol	-	atomic absorption spectroscopy NIOSH Method S-183
Carbon Monoxide	5-area	Draeger® detector tubes	-	colorimetry

TABLE II

Evaluation Criteria

Schlegel Corporation
Rochester, New York
HETA 84-458 and 84-489
November 27-28, 1984

Contaminant	OSHA Permissable Exposure Limit	ACGIH Threshold Limit Value	NIOSH Recommended Standard	Principle Health Effects
TDI	140 ug/m^3, ceiling	40 ug/m^3 140 ug/m^3, 15 min. ceiling	40 ug/m^3 140 ug/m^3, 20 min. ceiling	dermatitis; irritation of eyes, nose, and throat; bronchitis; pulmonary edema; respiratory sensitization.
Diethanolamine	-	15 mg/m^3	-	irritation of skin, eyes, and respiratory tract
Triethylene Diamine	-	-	-	irritation of skin, eyes, and respiratory tract, skin and respiratory sensitization
Bis (2-Dimethylaminoethyl) Ether	-	-	-	irritation of skin, eyes, and respiratory tract
Propylene Oxide	240 mg/m^3	50 mg/m^3	-	irritation of skin, eyes, and respiratory tract
Organotin	100 ug/m^3	100 ug/m^3	100 ug/m^3	skin lesions and irritation, headaches, dizziness, vomiting, urinary retention, inhibition of oxidative phosphorylation
Nuisance Dust	15 mg/m^3	10 mg/m^3	-	reduced visibility, unpleasant deposits in eyes, ears, and nose

(Continued)

Table II

(Continued)

Contaminant	OSHA Permissable Exposure Limit	ACGIH Threshold Limit Value	NIOSH Recommended Standard	Principle Health Effects
Methylene Chloride	1740 mg/m^3	350 mg/m^3	Lowest Feasible Limit	headaches, dizziness, fatigue, increased carboxyhemoglobin
Carbon Monoxide	55 mg/m^3	55 mg/m^3	40 mg/m^3	headaches, dizziness, fatigue, increased carboxyhemoglobin
Toluene	750 mg/m^3	375 mg/m^3	375 mg/m^3	headaches, dizziness, fatigue, liver damage in high concentrations
bromochloropropane	-	-	-	headache, dizziness, fatigue

TABLE III

Personal Breathing - Zone Air Samples for
2,4-TDI, 2,6-TDI, Methylene Chloride, and
1-Bromo-3-Chloropropane

Schlegel Corporation
Rochester, New York
HETA 84-489
November 27-28, 1984

Job		Sample Period	2,4-TDI (ug/m^3)	2,6-TDI (ug/m^3)	Methylene Chloride (mg/m^3)	Bromochloropropane (mg/m^3)
set-up	11/27	805-1530	20	7	75	N.D.*
set-up		807-1530	9	4	21	N.D.
#2 operator		812-1545	10	6	38	-
#3 operator		747-1530	20	7	49	-
#4 operator		740-1530	20	8	75	-
#5 operator		755-1530	10	5	63	-
#7 operator		757-1440	5	3	31	-
#2 assistant		815-1530	2	1	12	-
#3 assistant		750-1530	7	3	38	-
#7 assistant		800-1530	2	1	20	-
set-up	11/28	730-1515	9	5	24	N.D.
set-up		810-1515	1	ND	18	N.D.
#2 operator		807-1515	10	6	33	-