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I. SUMMARY

On July 20, 1987, the National Institute for Occupational Safety and Health (NIOSH) received a request from the United Steelworkers of America, Local 7687, to evaluate exposures to paint solvents at the BMY Corporation in York, Pennsylvania. Employees were reported to be experiencing dryness of the nose and throat, headaches, and sleeplessness, plus menstrual cycle problems among several female employees.

On September 15, 1987, an initial evaluation was conducted and samples were collected for qualitative analysis of airborne solvents in the touch-up paint department. A follow up environmental evaluation of the facility was conducted on October 27, 1987, which included collection of air samples for 13 organic solvents as identified during the initial visit. All exposures were below the NIOSH Recommended Exposure Limits (RELs), the Occupational Safety and Health Administration Permissible Exposure Limits (PELs), and the American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Values (TLVs). Of the solvents detected, the ranges of exposures in milligrams per cubic meter of air (mg/m^3) and the highest percentage of the PEL or TLV are listed as follows: toluene 0.8-47.0, 13%; xylene 0.6-21.1, 5%; cumene non-detectable-0.4, 0.01%; 1,1,1-trichloroethane 0.2-92.1, 5%; p-dioxane non-detectable-1.7, 47%; n-hexane non-detectable-4.0, 2%; n-butyl acetate 0.7-52.0, 9%; methyl ethyl ketone 3.0-169.9, 29%; methyl isobutyl ketone 0.6-30.4, 15%; methyl isoamyl ketone 0.4-10.8, 5%; and methyl amyl ketone 0.6-29.8, 13%. Since exposure to these solvent vapors has an additive effect, the combined exposure was calculated and was within the ACGIH TLV for mixtures.

A questionnaire designed to ascertain possible health effects was completed by 72 employees. Five employees submitted pre- and post-shift urine samples for analysis of solvent metabolites as well as a post-shift blood sample for determination of serum toluene. On August 24, 1988, an additional follow-up survey was conducted after an inspector reported a recurrence of symptoms (suggestive of an acute asthma) upon re-entering the processing area after a two week absence. During this survey air samples were collected for hexamethylene diisocyanate (HDI), 2-dimethylaminoethanol, ethylenediamine, diethylenetriamine, and triethylenetetramine. All air samples were below the limit of detection of the sampling-analytical method. In addition, blood samples were drawn from 20 employees and tested for immunoglobulin G (IgG) and immunoglobulin E (IgE) antibodies to HDI using the radio allergo-sorbent test (RAST) and enzyme linked immunosorbent assay (ELISA), respectively. Three of the employees demonstrated low levels of specific IgG antibodies to HDI suggesting a past exposure to HDI. No specific IgE antibodies to the HDI were detected.

Based upon the data collected during this HHE, the NIOSH investigators concluded that the affected workers are exposed to at least 13 different painting solvents. Although below their respective RELs and TLVs, the combined solvent exposures may be contributing to the employees' reported headaches, eye irritation, and sore throats. Although HDI was not detected in the air during the NIOSH visit, it is an ingredient in some of the paints representing a potential exposure to employees in the area. Recommendations to reduce the potential for health effects are provided in Section VIII.

KEYWORDS: SIC 3795 (tank and tank components) solvents, paint, spray painting, isocyanates, HDI, amines, RAST, ELISA.

II. INTRODUCTION

On July 20, 1987, NIOSH received a request from the United Steelworkers of America, Local 7687, to evaluate exposures to paint solvents at BMY Corporation in York, Pennsylvania. The request concerned employees' exposures to paint solvents during the touch-up painting of military vehicles in the Final Processing (touch-up painting) and Small Parts Painting Departments. Employees in these departments reported dryness of the nose and throat, headaches, and sleeplessness, as well as menstrual cycle problems among several female employees.

NIOSH investigators conducted an initial walk-through survey on September 15, 1987, in the Final Processing Department and the Small Parts Department. This initial survey involved gathering information about the process, the workforce, the occupational health and safety programs, and reviewing company medical records. Bulk air samples were collected for qualitative analyses of volatile organic compounds to provide an indication of potential contaminants released during the painting. In addition to these analyses, a list of paint ingredients was collected (Table 1) to identify other potential airborne contaminants. On October 6, 1987, a letter was sent to the company summarizing the NIOSH site visit.

A follow-up industrial hygiene and medical survey was conducted on October 27, 1987, to further investigate worker complaints and to assess solvent exposures. The environmental monitoring consisted of collecting personal breathing zone environmental air samples from three tapers (non-processors) and 12 processors for exposures to 13 solvents. Nearly all the employees present in the Final Processing and Small Parts Departments during the day shift were included in the environmental monitoring. Area air samples for solvents were collected in two locations in the Final Processing building. A questionnaire designed to ascertain possible health effects was completed by 72 employees. Five employees submitted pre- and post-shift urine samples for analysis of solvent metabolites as well as a post-shift blood sample for determination of serum toluene.

On January 22, 1988, the results of the blood and urine tests for exposures to toluene, xylene, 1,1,1-trichloroethane, and ketones were sent to the participants.

On June 17, 1988, the company informed the NIOSH investigators that an inspector who returned to the Final Process Area after two weeks off work had developed difficulty breathing, chest tightness, shortness of breath, and wheezing. Since these symptoms may have represented a sensitization to either an isocyanate or to an amine compound that may be present in the paints, the NIOSH investigators conducted a follow-up survey on August 24, 1988, to monitor for HDI, 2-dimethylaminoethanol,

ethylenediamine, diethylenetriamine, and triethylenetetramine in the Final Process area. Nine area samples were collected for HDI, 6 for 2-dimethylaminoethanol, and 5 for ethylenediamine, diethylenetriamine, and triethylenetetramine. In addition, blood samples were drawn from 20 employees and tested for immunoglobulin G (IgG) and immunoglobulin E (IgE) antibodies to HDI using the radio allergo sorbent test (RAST) and enzyme linked immunosorbent assay (ELISA), respectively.

On December 21, 1988, a letter was sent to the company on the status of the antibody testing for evaluation of exposures to isocyanate paints.

III. BACKGROUND

BMY Corporation manufactures military tanks and other tracked vehicles. After the vehicles are assembled and spray-painted by 7 paint tunnel workers, they are sent to the Final Processing (touch-up painting) building. In this department the painting deficiencies on the vehicles are corrected and the original painting is modified. Approximately 47 processors touch-up and perform quality checks to assure that all vehicles meet contract specifications. The non-processor group consisted of tapers (who applied tape to areas of the parts that are not to be painted) and inspectors. While their jobs were not primarily painting, they work in close proximity to the paints. Processors mainly use brushes and small cans of paint to perform the touch-up painting but occasionally use spray gun applicators for brief periods of time. However, the processors in the Small Parts Department did spray painting for most of their work shift. Once completed, the vehicles are checked by one of four government inspectors.

The paints used for interior and exterior camouflage include epoxy and polyurethane. The polyurethane paints are single component paints with hexamethylene diisocyanate (HDI) concentrations of less than 0.15%. Some of the epoxy paints contain diethylenetriamine, and a few may contain 2-dimethylaminoethanol or other amines. Most of the paint ingredients reported by the paint manufacturers are listed in Table 1. To clean the paint brushes and to remove paint from the skin, the processors frequently use 1,1,1-trichloroethane.

The vehicles may have several doors and open panels. All the vehicles have small enclosed areas which are difficult to work in. Two of the smallest spaces within the vehicles are the driver's compartment and beneath the floor. The crawl space under the floor is less than three feet high and may require up to an hour to paint by hand. Half-face respirators with organic vapor cartridges are available to the painters but only a few workers wear them. These respirators provide adequate protection for exposure to solvents during brush painting, but are not adequate for spray painting.

The two rooms where Final Processing is performed are each approximately 42 feet wide by 180 feet long by 20 feet high. Each room has ceiling fans which exhaust 12,900 cubic feet of air per minute. There are also four supply air intake ducts per room that provide 12,500 cubic feet per minute. At each end of the rooms are overhead doors for the vehicles to enter. These doors are open in warm weather but closed for most of the winter. During the NIOSH evaluation the doors were closed in the morning and open in the afternoon.

In the Small Parts Department, three employees (tapers) place masking tape on vehicle parts in preparation for spray painting. These parts are suspended from hooks and move on a conveyor system. Approximately 23 processors spray paint the parts as the conveyor moves the part in front of a spray booth. Only epoxy paints are used in this area. The spray painters wear half-face respirators with organic vapor and prefilter cartridges.

IV. METHODS

A. Environmental

1. Area Bulk Air Samples

Bulk air samples were collected on four standard charcoal tubes for organic solvents plus one Ambersorb XE-347 tube for ketones, at a flow rate of one liter per minute (lpm). The samples were desorbed with carbon disulfide and qualitatively analyzed by gas-chromatography/mass spectrometry (GC-MS).

2. Organic Solvents

The organic solvent vapors were collected on standard (100/50 mg) charcoal tubes at a flow rate of 0.2 lpm. The samples were desorbed with carbon disulfide and analyzed by gas chromatography according to NIOSH Methods 1501, 1003, 1500, 1450, and 1602.[1]

3. Ketones

The ketone vapors, (methyl ethyl ketone, methyl isobutyl ketone, methyl amyl ketone, and methyl isoamyl ketone) were collected on Ambersorb XE-347, 160/80 milligram tubes, at a flow rate of 0.2 lpm. The samples were desorbed with carbon disulfide and analyzed by gas chromatography according to NIOSH Method 2500.[1]

4. Isocyanates

Hexamethylene diisocyanate was collected in midget Greenburg-Smith impingers containing 10 ml of the absorbing solution, 1-(2-methoxyphenyl) piperazine in toluene, at a flow rate of 1.0 lpm. Toluene

was periodically added to the impingers during sampling to compensate for evaporation loss. The samples were analyzed by high performance liquid chromatography according to the British Health and Safety Executive, Methods for the Determination of Hazardous Substances, Method 25.[2]

5. Amines

Ethylenediamine, diethylenetriamine, and triethylenetetramine were collected by drawing 0.1 lpm of air through sampling tubes containing XAD-2 resin coated with 10% 1-naphthylisothiocyanate. Samples were analyzed by desorbing with dimethylformamide and quantitating the amine derivative by high performance liquid chromatography using ultraviolet detection according to OSHA Method 60.[3]

6. 2-Dimethylaminoethanol

2-Dimethylaminoethanol was collected on silica gel tubes (300/150 mg) at a flow rate of 0.2 lpm, and analyzed by gas chromatography according to NIOSH Method 2007.[1]

B. Medical

On September 15, 1988, NIOSH investigators distributed a questionnaire to all employees in the processing area who were available on the day of the survey and agreed to participate in the investigation. The questionnaire was designed to ascertain the prevalence of upper respiratory tract, skin, general health, and neurobehavioral symptoms among the workers over the previous 30 days.

Since no unexposed reference group was available, we classified the workers into two groups: processors and non-processors (including tapers and inspectors). This classification was based on initial information that suggested that processors have a higher potential exposure to paints and solvents. Although the non-processors worked in areas where painting was done and occasionally performed painting operations, their overall exposure to paints and paint solvents was thought to be lower than the processors, whose primary job was painting.

Five processors randomly selected to have personal environmental air monitoring done agreed to submit pre- and post-shift urine samples for measurement of urine ketones, hippuric acid (metabolite of toluene), methyl hippuric acid (metabolite of xylene), and trichloroacetic acid (metabolite of 1,1,1-trichloroethane). In addition, a post-shift blood sample for serum toluene was obtained on the same five workers.

On August 24, 1988, NIOSH obtained blood samples from the inspector who reported the asthma-like symptoms. In addition, the management and union representatives identified 19 other employees from the processing area who were available on the day of the survey and willing to submit a blood specimen for determination of the plasma immunoglobulins (total IgE, and specific IgG and IgE) to both HDI and diphenylmethane diisocyanate (MDI). Since some reports indicate an immunologic cross-reaction between

MDI and HDI, levels of IgG and IgE to both compounds were tested. The intent of the serologic survey was to determine whether or not subtle immunologic changes were present in any of the workers exposed to the paints. Thus, the presence or absence of symptoms was not a criterion for participation.

V. EVALUATION CRITERIA

A. Environmental Evaluation 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. 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 (TLVs), and 3) the U.S. Department of Labor (OSHA) occupational health standards. Often, the NIOSH recommendations and ACGIH TLVs are lower than the corresponding OSHA standards. Both NIOSH recommendations and ACGIH TLVs 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 standards, 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 ACGIH has established guidelines for exposures to mixtures of hazardous substances which result in adverse effects to the exposed workers.[4] For substances with additive effects the sum of the following fractions should not exceed unity.

$$C1/T1 + C2/T2 + C3/T3 + ... Cn/Tn = \leq 1$$

C = atmospheric concentration T = corresponding TLV

If the sum of the fraction exceeds one, then the TLV of the mixture should be considered as being exceeded.

B. Solvents Exposures and Neurological Effects

In a study of 80 car and industrial spray painters in Sweden, Eloffson, et al found a statistically significant increase in neurasthenic symptoms (abnormal fatigue, concentration difficulties, memory impairment, general irritability and alcohol intolerance) as compared to unexposed controls.[5] These workers were exposed to approximately 20 different solvents, although the estimated aggregate exposure remained at relatively low levels. The exposed group also exhibited a decreased performance on tests of simple reaction time, manual dexterity and perceptional speed and memory. Other studies, such as that by Gregersen, showed similar results and demonstrated a correlation between neurotoxic signs and exposures.[6] Using the same questionnaire as that used in this study, Fidler, et al.[7] demonstrated a significant correlation between the amount of solvents/paints used and a variety of neurobehavioral symptoms among a group of construction painters. A study by Mallov, implicated methyl-n-butyl ketone with the development of peripheral neuropathy (disturbance of nerve function) in a group of spray painters.[8] A workshop convened by the World Health Organization classified neurological effects of solvent exposure into three types, ranging from mild central nervous system symptoms to severe chronic toxic encepalopathy (dementia).[9]

The occupational health literature also contains reports of workplace environments with exposures to a mixture of organic solvents at low concentrations that have resulted in employee health problems. Frequently reported symptoms include headaches, sleeplessness, and disturbances of the menstrual cycle.[10]

C. Specific Substances Common in Paints

Table 2 presents the evaluation criteria for the substances sampled during this investigation.

1. Toluene

Occupational exposures to toluene are normally through inhalation of toluene vapors and skin absorption of toluene liquid. The predominant effect from exposure to toluene is depression of the central nervous system. Exposures to 754 mg/m^3 of toluene for eight hours has produced mild fatigue, weakness, confusion, watery eyes, and a tingling sensation of the skin. At higher concentrations, effects

include nervousness, muscle fatigue, insomnia, and irritation to the eyes. Workers exposed to less than 754 mg/m^3 have complained of headaches, lassitude, and nausea. Toluene abuse by deliberately inhaling pure toluene vapors or toluene-based paints for their euphoric properties has induced progressive damage to the central nervous system structure and function that appears after 1 to 20 years of repeated exposure. Repeated or prolonged skin contact with liquid toluene has a defatting action, causing drying, fissuring, and dermatitis.[11-13]

Toluene exposure may be measured in several ways. Personal breathing zone air sampling may be done to assess environmental levels or it can be estimated through the use of urine and blood tests. Toluene measured directly in the blood can serve as a guide to environmental exposure. This is usually measured at the end of a shift.

Urine hippuric acid is another test used to measure toluene exposure. However, other substances, most notably certain food preservatives, can cause hippuric acid to be found in the urine. Hippuric acid can be checked before and after the work shift. The difference between a pre- and post- shift value represents an estimate of the total workday exposure to toluene. The amount of hippuric acid found in the urine can also be influenced by an individual's kidney function.

2. Xylene

As with toluene, exposure may occur through breathing vapors and through direct skin contact. Xylene vapor may cause irritation of the eyes, nose, and throat. Repeated or prolonged skin contact with xylene may cause drying and defatting of the skin which may lead to dermatitis. Liquid xylene is irritating to the eyes and mucous membranes, and aspiration of a few milliliters may cause chemical pneumonitis, pulmonary edema, and hemorrhage. Repeated eye exposure to high concentrations of a xylene vapor may cause reversible eye damage. Acute exposure to xylene vapor many cause central nervous system depression and minor reversible effects upon the liver and kidneys. At high concentrations xylene vapor may cause dizziness, staggering, drowsiness, and unconsciousness. Workers exposed to concentrations above 869 mg/m^3 complained of loss of appetite, nausea, vomiting, and abdominal pain. Brief exposure of humans to 869 mg/m^3 has caused irritation of the eyes, nose, and throat.[11-13]

Xylene exposure may be measured by air sampling or by blood and urine testing. Methylhippuric acid is the breakdown product of xylene and can be measured in the urine. Unlike hippuric acid, methylhippuric acid does not appear in the urine as a result of exposure to other chemicals or food products. The interpretation of methylhippuric acid results is similar to that for hippuric acid results.

3. Cumene

Cumene vapor is very irritating to the eyes and mucous membranes. It is a depressant to the central nervous system and has a potential narcotic effect. Contact with the skin causes erythema and irritation.[11]

4. 1,1,1-Trichloroethane

Like many other solvents, 1,1,1-trichloroethane is also irritating to the eyes, mucous membranes, and skin; as well as being a central nervous system depressant. In addition, 1,1,1-trichloroethane can cause proarrhythmic activity which sensitizes the heart to epinephrine-induced arrhythmias. This sometimes will cause a cardiac arrest particularly when massively inhaled.[11] Urine trichloroacetic acid can be measured to assess exposure to this agent. Prolonged or repeated skin contact may result in drying and cracking due to defatting action.[11]

5. p-Dioxane

p-Dioxane is an irritant of the eyes, mucous membranes, and skin; on prolonged exposure it is toxic to the brain, liver and kidneys. The onset of p-dioxane poisoning is marked by drowsiness, headache, nausea, vomiting, and irritation of the eyes and respiratory tract. Prolonged or repeated skin contact may result in drying and cracking due to defatting action.[11]

6. n-Hexane

Normal hexane is a mild upper respiratory irritant and causes central nervous system depression. Symptoms such as dizziness have been observed when concentrations exceeded 3524 mg/m^3 but not when below 1762 mg/m^3. Until recently, chronic effects from hexane and similar hydrocarbons had rarely been reported. However, in 1967, seventeen cases of polyneuritis were reported among workers exposed to n-hexane at concentrations of 1762-3524 mg/m^3. Other studies have reported n-hexane neuropathy among furniture workers and among workers exposed to n-hexane used as a solvent in plastic cements. n-Hexane has produced sensory-motor or motor peripheral neuropathy in workers who chronically inhaled workplace concentrations of approximately 211 to 846 mg/m^3 and in individuals who abusively inhaled the compound. 2,5-Hexanedione, a metabolic product of n-hexane, possesses a greater neurotoxic potential than the parent compound and is believed to be responsible for producing peripheral neuropathy in humans. Inhalation exposure to methyl ethyl ketone in combination with n-hexane for 15 weeks potentiated the neurotoxicity of n-hexane in male rats when compared with exposures to n-hexane alone for the same period.[11,12]

7. Ketones

Ketone refers to a class of chemical substances that include the carbonyl group (C=O). Common examples of ketones used in painting are methyl ethyl ketone, methyl isobutyl ketone, and methyl iso-amyl ketone. All ketones are moderate irritants of mucous membranes. High exposures to ketones result in central nervous system depression and prenarcotic symptoms, which may progress to narcosis.[14] Chronic exposure may produce a toxic sensory-motor peripheral neuropathy. Symptoms include loss of tactile sense and sensitivity to pain and temperature. Motor involvement is revealed by muscle weakness and diminished or lost deep tendon reflexes.[14] Skin contact must be avoided because of rapid defatting action, often leading to dermatitis.[11]

8. Diethylenetriamine

Diethylenetriamine vapors may cause eye irritation, including lacrimation, conjunctivitis, and corneal edema (swelling of the anterior portion of the eye), and halo vision (perception of halos and lights around objects). Inhalation can lead to irritation of the nose and throat as well as lung effects, manifested as dyspnea and cough.[15] Diethylenetriamine is a known skin sensitizer and may contribute to bronchial asthma in exposed workers.[16]

9. Isocyanates

The diisocyanates and polyisocyanates may be considered together, since they have similar toxicologic properties. Exposure to isocyanates can cause skin and mucous membrane irritation, nausea, vomiting and abdominal pain.[17,18] In high concentrations, isocyanates have a primary irritant effect on the respiratory tract. They can also act as respiratory sensitizers, producing asthma-like symptoms in sensitized individuals, even at very low concentrations.

Asthmatic attacks may occur immediately after exposure or at an interval of hours after cessation of exposure, presenting as nocturnal cough and breathlessness. Exposure to isocyanates may also result in chronic impairment of pulmonary function.[19] Isocyanate exposure during accidental spills is a major cause of sensitization, and there is evidence that massive exposures may produce effects on the central nervous system.[19]

In one reported case, a 35-year-old male developed a cough and chest tightness after he spray painted his car with a polyurethane paint containing prepolymerized HDI. A year later he again sprayed his car with the same paint and developed a cough and considerable chest tightness that persisted for two weeks. A month later he was in a room adjacent to a spraying operation with the same paint. Within 15 minutes he developed a cough, tight chest and chills. The symptoms progressed into a serious asthmatic reaction, for which he was admitted to an intensive care unit at a hospital. Three months later the patient's serum was analyzed with the radioallergosorbent test (RAST) and found to

have developed IgE antibodies to the MDI. Other studies have implicated IgG antibodies in the pathogenesis of asthma and alveolitis.[20,24] The levels of specific IgG in these affected workers were considerably higher than those found in this study.

IgG antibodies to HDI have been prospectively studied in a population of 150 employees by Grammer et al.[23] They evaluated workers in a factory that spray painted truck cabs and found that 21% of the workers demonstrated evidence of IgG antibodies to HDI, despite environmental levels of isocyanate that were well below the OSHA standard, and, in some cases, nondetectable. No evidence of immunological disease was found in any of the workers with a positive IgG antibody to HDI. The authors concluded that low levels of specific IgG to an isocyanate are simply a marker of exposure to the compound.

VI. RESULTS

A. Environmental Survey

1. Area Airborne Bulk Samples

The major compounds detected on the bulk air samples during the touch-up painting were 1,1,1-trichloroethane, toluene, n-butyl acetate, xylenes, p-dioxane, n-hexane, cumene, methyl ethyl ketone, methyl isobutyl ketone, methyl isoamyl ketone, methyl amyl ketone and several unidentified compounds. This is in agreement with the information on the volatile components of the paints, supplied by the paint manufacturers.

2. Organic Solvents (non-ketones)

Thirty-two personal breathing zone samples for seven non-ketone organic solvents were collected from three tapers and 12 processors (Table 3). Toluene exposures ranged from 0.8 to 47.0 mg/m^3. 1,1,1-Trichloroethane exposures ranged from 1.3 to 92.1 mg/m^3. n-Butyl acetate exposures ranged from 0.7 to 52.0 mg/m^3. Xylene exposures ranged from 0.6 to 21.1 mg/m^3, Cumene exposures ranged from non-detectable to 0.4 mg/m^3, p-dioxane exposures ranged from non-detectable to 1.7 mg/m^3, and n-hexane exposures ranged from non-detectable to 4.0. All samples were less than 14 percent of the TLV.

3. Ketones

Seventeen personal breathing zone samples for methyl ethyl ketone, methyl isobutyl ketone, methyl isoamyl ketone, methyl amyl ketone were collected from the employees (Table 4). All exposure levels were within the NIOSH RELs. The exposures ranged from 3.0 to 169.9 mg/m^3 for methyl ethyl ketone, 0.6 to 30.4 mg/m^3 for methyl isobutyl ketone, 0.4 to 10.8 mg/m^3 for methyl isoamyl ketone, and 0.6 to 29.8 mg/m^3 for methyl amyl ketone. All samples were less than 30 percent of the TLV.

4. Threshold Limit Values for Mixtures

Since the solvent vapors from the paints are a mixture, the combined exposure was calculated in Table 5 as described earlier. On the day that the NIOSH investigators sampled for solvents, the calculated additive effect was less than unity, and therefore, within the ACGIH TLV for mixtures. In general, the processors had a higher additive solvent exposure than the tapers. This is most likely due to the processors' close proximity to the paints.

5. Hexamethylene diisocyanate

Paints containing less than 0.15% hexamethylene diisocyanate were being applied during the sampling. Nine area air samples were collected for hexamethylene diisocyanate in the touch-up painting areas. Sampling equipment was placed on tables, near paint cans, and on vehicles. All samples were non-detectable at a limit of detection of 0.42 micrograms per cubic meter of air (ug/m^3).

6. Amines

One of the paints in use during the sampling contained an unknown concentration of diethylenetriamine. Five area air samples were collected for ethylenediamine, diethylenetriamine, and triethylenetetramine in locations with potentially high exposures. All five samples were non-detectable at a limit of detection of 417 ug/m^3 for ethylenediamine and 17 ug/m^3 for diethylenetriamine and triethylenetetramine.

7. 2-Dimethylaminoethanol

None of the paints used during the sampling were reported to contain 2-dimethylaminoethanol. However, 2-dimethylaminoethanol is frequently used in paints and can result in asthma-like symptoms in some employees. Six area samples were collected for 2-dimethylaminoethanol in locations of potentially high exposure. All samples were below the limit of detection of 208 ug/m^3.

B. <u>Medical (Questionnaire)</u>

1. Participation

Forty-nine (70%) of 70 workers identified by the personnel roster as processors agreed to participate in the study. Twenty-three other individuals whose job category included tapers, inspectors, and a few paint tunnel workers (who wear supplied air respirators) also participated. All of the 23 individuals in the non-processor categories who responded are exposed to the paints and solvents in the course of their work activities. Since only 3 of the non-processors (tapers) were present in the Processing and Small Parts Departments on the day of the survey, exposures of the remaining 20 non-processors were not assessed during this evaluation.

2. Demographics (Table 6)

The 49 processors had a mean age of 36 years (range: 28 to 61 years). Forty (82%) of the workers were male. The average time working as processors was 5.4 years (range: less than 1 year to 13 years). Twenty (41%) of the current workers were smokers. The average smoker had a 14.6 pack/year history of cigarette use. There were no significant differences between processors or non-processors with respect to age, duration of employment, or smoking status.

3. Work Habits (Table 6)

Although very little spray painting in the Processing Department was observed during the survey, twenty-four processors (49%) reported spraying polyurethane paint for an average of 20 hrs/week. Forty-one (84%) reported that their jobs included brushing polyurethane paint for an average of 21 hours per week (hrs/wk). Twenty-seven (55%) workers sprayed epoxy paint an average of 17 hrs/week. Forty-six (94%) brushed epoxy paint an average of 25 hrs/week. Processors performed a significantly greater amount of brushing the paints than non-processors. Spray painting operations were not significantly different between the two groups.

4. Symptoms

Among the processors, headache was the most common symptom at work cited during the past 30 days, with 73% reporting this symptom (Table 7). Other symptoms reported include sore throat (61%), excess fatigue (55%), dizziness/lightheadedness (49%), watery eyes (33%), and shortness of breath (30%). Twenty-nine percent complained of coughing spells and twenty-six percent complained of skin rashes or irritation, with the same number reporting sinus pain (Table 7).

The prevalence of symptoms was compared between the different painting operations (spraying vs brushing; polyurethane vs epoxy). Workers who identified themselves as spraying epoxy paint had an increased frequency of headaches as compared with those workers who did not use epoxy paints (23/36 vs 4/13; Relative Risk = 1.44; 95% Confidence Interval = 1.01, 2.05). No other statistically significant differences in symptom prevalence were found between either users or non-users of the two paints used or between persons performing and not performing spraying or brushing operations. Stratification of the results by gender revealed no significant differences between exposure groups.

5. Neurobehavioral Symptoms

Reported symptoms were grouped into categories of memory effects, gastrointestinal symptoms, alcohol related symptoms, neurasthenic symptoms, cognitive symptoms, skin problems, chest symptoms, peripheral nervous system dysfunction, and headaches. Symptoms were scored on a 0-4 point scale with higher scores reflecting greater severity. Scores were adjusted for gender by analysis of covariance.

Results of the analysis revealed no statistical differences in mean score for any of the individual categories when processors and non-processors were compared (Table 8). However, for all 9 symptom groups non-processors had a greater prevalence ($p = 0.004$, 2-tailed sign test). Table 8 contains the results of the analysis. It should be noted that the mean scores for both groups is relatively low (< 2, in all cases).

A mean symptom score of greater than 2 for an individual reflects a mean of at least "a little" for each symptom in the symptom complex. When the number of individuals in each group with a symptom score greater than 2 were compared, the non-processor group had a significantly higher prevalence of peripheral nervous system symptoms (Table 9). There were no other statistically significant differences.

6. Biological Monitoring Results

No workers had detectable amounts of urine ketones, trichloroacetic acid, or methyl hippuric acid. For urine hippuric acid, the mean pre-shift concentration was 1.1 grams per liter (g/l) (range 0 - 2.2) and the mean post-shift value was 1.2 g/l (range 0.1 - 2.5 g/l). None of the workers had toluene in post-shift blood.

7. Menstrual Dysfunction

Five (55%) of the female processors complained of menstrual dysfunction, while one (33%) of the female non-processors had this complaint, though this difference was not statistically significant (Relative Risk = 1.7; 95% Confidence Interval = 0.3, 9.2). The complex physiology of the menstrual cycle and the small number of women participating in the study prevent a more thorough examination of this concern and do not allow a definitive conclusion about an association between solvent exposure and menstrual irregularities.

8. RAST and ELISA Results

Three workers demonstrated low levels of IgG antibodies to the HDI. The serum of one individual showed an equivocally positive level of IgG antibodies to MDI, although no IgG antibodies to HDI were present. It is not clear whether this represents a reaction of cross-reactivity or was merely a false positive laboratory test. No workers demonstrated IgE antibodies to the either of the isocyanates tested. Since the antibody levels were extremely low, no attempt was made to relate symptoms to antibody titer.

VII. CONCLUSIONS AND DISCUSSION

The symptoms described by the individuals completing the questionnaire are compatible with the known effects of many of the solvents used in the processing area at BMY. Although the measured exposures to the individual solvents are within OSHA standards, as well as NIOSH RELs and ACGIH TLVs, the solvents can have an additive or synergistic effect on the central nervous system and other organs that may cause symptoms that are disproportionate to the measured airborne concentration of the individual solvents.

It is possible that some of the individuals who responded to the questionnaire may have a true allergic reaction to some of the chemicals in either of the paints. Classical allergic reactions such as skin rash and asthma have been ascribed to the isocyanates and amines. However, non-immunological mechanisms for isocyanate associated asthma have also been described.

This study did not attempt to address the issue of true prevalence of serologic markers of isocyanate exposure in the painting area. The selection of participants in this study was not random and thus caution must exercised in extrapolating these results to estimate the true proportion of individuals in the workforce with these subtle immunological changes.

There is no current evidence in the medical literature that specific IgG antibodies to an isocyanate, at the levels detected in this survey, have any clinical significance. There is also no evidence to support the use of these tests as a screening tool, since immunological tests can only supplement and not replace an appropriate clinical evaluation of individuals with a suspected work related illness.

In almost all cases, there were similar prevalences of irritative symptoms in both processors and non-processors. It is unlikely that group medical screening or further industrial hygiene monitoring will isolate a single agent that is responsible for the multiple symptoms.

Of major concern in the interpretation of the questionnaire results is the ability to distinguish between the exposure levels in the two study groups (processors and non-processors). During the environmental survey, the processors had a greater exposure to the paints than the non-processors. However, many non-processors indicated on the questionnaire that they also performed painting. Overall, the group of non-processors most likely experiences less exposure to paints than the processors, though for some individuals, this may not be true. Obviously, the potential for misclassification error exists regarding exposure to the various chemicals. Such misclassification would obscure any exposure-related health effects among this population.

Even though individual solvent vapors were not present in excess of exposure criteria, it would be advisable to further reduce exposure where possible in order to minimize the potential for health effects that may be due to additive or synergistic effects of the mixtures.

VIII. RECOMMENDATIONS

In view of the findings of the investigation, the following recommendations are made to further reduce the potential for health effects, thereby creating a safer and healthier work environment for the employees.

1. Where possible, substitute the paints that contain HDI with paints that are free of all isocyanates.

2. A respiratory protection program needs to be implemented for the painters. The details of this program can be found in the enclosed NIOSH publication, Guide to Industrial Respiratory Protection, DHHS (NIOSH) publication number 87-116. The half-face respirators issued to the processors will reduce their exposure to the solvents. However, they will not protect the employees from airborne isocyanates. NIOSH's position on controlling respiratory exposures to isocyanate-containing paints is that the lack of warning properties of isocyanates eliminates NIOSH approval for air-purifying respirators. The problem of sensitization of persons exposed to very low concentrations of isocyanates dictates use of the best available respiratory protection. NIOSH recommends that positive pressure supplied air respirators be used for respiratory protection against isocyanate-containing paints.[21]

3. A constant supply of fresh air to the interior of the vehicles will reduce isocyanate and solvent exposures. In our letter of October 6, 1987, to the company, we recommended that portable ventilation be used to provide fresh air into the vehicles by using a large hose or flexible duct work attached to a fan. Since that time the company has purchased portable fans that can be mounted on the top manhole entrance of the vehicle to provide fresh air into the vehicle. In addition to this, more general ventilation in the paint processing area will further dilute solvent vapor concentrations.

4. During touch-up painting, gloves impervious to the paints and solvents will help to prevent skin contact thereby avoiding a possible dermal route of exposure and skin problems.

5. Employees should be prohibited from eating, drinking, or smoking in the Final Processing and the Small Parts areas.

6. Pulmonary function testing can be useful in the diagnosis of work related occupational respiratory disease. Baseline pulmonary function testing should be conducted before any exposure occurs and preferably after a minimum of 3 days away from work (such as after a 3 day weekend) Appropriate testing would include the measurement of FEV1, FVC, and the FEV1/FVC ratio, and should be conducted in accordance with American Thoracic Society Recommendations.[22]

7. Pre and post shift pulmonary function tests, serial peak flow measurements, and determination of specific IgG and IgE antibodies to the isocyanates can also be useful tools in the evaluation of individuals suspected of having occupational asthma due to isocyanates.

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XI. DISTRIBUTION AND AVAILABILITY OF REPORT

Copies of this report are temporarily available upon request from NIOSH, Hazard Evaluations and Technical Assistance Branch, 4676 Columbia Parkway, Cincinnati, Ohio 45226. After 90 days, the report will be available through the National Technical Information Service (NTIS), 5285 Port Royal, Springfield, Virginia 22161. Information regarding its availability through NTIS can be obtained from NIOSH Publications Office at the Cincinnati address. Copies of this report have been sent to:

1. BMY Corporation
2. United Steel Workers of America, Pittsburgh, Pennsylvania
3. United Steel Workers of America, Local Union 7687, District 7, York, Pennsylvania
4. DCASMA, Reading, Pennsylvania
5. NIOSH, Boston Region
6. OSHA, Region 3

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 1
Chemicals Contained in the Paints used at BMY Corporation
BMY Corporation
York, Pennsylvania
HHE 87-367, September 15, 1987

Substance	CAS No.
toluene	108-88-3
xylene	1330-20-7
methyl acetate	79-20-9
methyl ethyl ketone	78-93-3
methyl isobutyl ketone	108-10-1
methyl isoamyl ketone	110-12-3
n-butanol	71-36-3
ethyl cellosolve	110-80-5
ethyl cellosolve acetate	111-15-9
butyl cellosolve	111-76-2
1,1,1-trichloroethane	71-55-6
cumene	98-82-8
n-butyl acetate	123-86-4
diacetone alcohol	123-42-2
diethylene triamine	111-40-0
hexamethylene diisocyanate	822-06-0
epichlorohydrin	106-89-8
4,4-isopropylidine diphenol	80-05-7
2-dimethylamino ethanol	108-01-0
amyl alcohol	71-41-0
polyamide resin	
epoxy resin	
4,4-isopropylidine diphenol epichlorohydrin resin	
titanium dioxide	
cobalt	
cobalt titanate	
chrome oxide	
trivalent chrome (water sol)	
trivalent chrome (insol)	
silica	
talc	
extender pigments	

TABLE 2

Summary of NIOSH RELs for Organic Solvents with Corresponding OSHA PELs and ACGIH TLVs

Compound	NIOSH REL mg/m^3	OSHA PEL and ACGIH TLV in mg/m^3
Toluene	375 8-hr TWA	375 TWA
	750 ceiling (10 min)	560 STEL
Xylene	434 10-hr TWA	435 TWA
	868 ceiling (10 min)	655 STEL
Cumene	None	245 TWA (skin)
1,1,1-Trichloroethane	1,910 ceiling (15 min)	1900 TWA
		2450 STEL
p-Dioxane	3.6 ceiling (30 min)	90 TWA (skin)
n-Hexane	350 8-hr TWA	180 TWA
	1800 ceiling (15 min)	
Methyl Ethyl Ketone	590 10-hr TWA	590 TWA
		885 STEL
Methyl Isobutyl Ketone	200 10-hr TWA	205 TWA
		300 STEL
Methyl Isoamyl Ketone	230 10-hr TWA	240 TWA
Methyl Amyl Ketone	465 10-hr TWA	235 TWA
		445 STEL
Hexamethylene Diisocyanate	0.035 10-hr TWA	0.035 TWA
Ethylenediamine	None	25 TWA
Diethylenetriamine	None	4 TWA

RELs = Recommended Exposure Limits skin) = Potential Exposure by the cutaneous route TLVs = Threshold Limit Values mg/m^3 = milligrams per cubic meter of air PELs = Permissible Exposure Limits 8-hr TWA = 8 hour time-weighted average STEL = Short Term Exposure Limit (ACGIH)

TABLE 3
Personal Breathing Zone Solvent Exposures in mg/m^3
BMY Corporation
York, Pennsylvania
HETA 87-367
October 27, 1987

Job Title	Sample No.	Time (minutes)	Toluene	Xylene	Cumene	1,1,1-Trichloroethane	p-Dioxane	n-Hexane	n-Butyl Acetate
Taper 1	C-3 C-6	480	1.2	0.8	ND	3.8	ND	0.1	0.9
Taper 2	C-1 C-4	480	0.9	0.7	ND	3.5	ND	0.1	0.7
Taper 3	C-5 C-2	480	0.8	0.6	ND	1.3	ND	ND	0.7
Processor 1	C-12	463	18.7	7.9	0.1	13.2	0.1	0.2	12.1
Processor 2	C-11 C-9	457	1.5	5.2	0.4	9.3	0.2	0.1	1.3
Processor 3	C-13 C-10	456	13.3	5.5	0.2	26.3	0.5	ND	7.4
Processor 4	C-7 C-8	439	6.8	3.2	0.1	0.2	0.1	0.2	3.8
Processor 5	C-19 C-20	441	2.4	1.4	ND	39.8	0.7	0.9	1.8
Processor 6	C-22 C-21	428	3.0	1.3	ND	63.5	1.3	0.8	2.0
Processor 7	C-16 C-17	251	29.6	12.7	ND	92.1	1.7	0.8	22.6

continued

TABLE 3 (cont.)
Personal Breathing Zone Solvent Exposure in mg/m^3
BMY Corporation
York, Pennsylvania
HETA 87-367
October 27, 1987

Job Title	Sample No.	Time (minutes)	Toluene	Xylene	Cumene	1,1,1-Trichloroethane	p-Dioxane	n-Hexane	n-Butyl Acetate
Processor 7	C-38 C-37	148	47.0	21.1	ND	37.8	0.7	4.0	36.7
Processor 8	C-18 C-15	456	40.0	20.0	ND	61.7	1.3	1.9	52.0
Processor 9	C-31 C-32	229	15.1	5.8	ND	30.0	0.4	0.2	4.8
Processor 9	C-36 C-35	145	11.9	5.3	ND	35.5	0.7	2.2	8.6
Processor 10	C-30 C-24	347	1.6	1.1	ND	55.1	1.0	0.6	1.4
Processor 11	C-27	410	5.4	2.4	ND	87.9	1.4	1.1	3.6
Processor 12	C-25	400	37.7	15.1	0.2	9.9	ND	0.3	23.9

Most of the participants wore two sampling trains in case the laboratory was unable to analyze all the requested solvents on one sample. Since the laboratory was able to analyze for toluene, xylene, cumene, 1,1,1-trichloroethane, p-dioxane, n-hexane, and n-butyl acetate on each sample, the average exposure from the two samples was calculated for each worker.
Exposure criteria see Table 2
The limit of detection is 0.1 mg/m^3.

TABLE 4
Personal Exposures to Ketones in mg/m^3
BMY Corporation, York, Pennsylvania, HETA 87-367
October 27, 1987

Job Title	Sample No.	Time (minutes)	Methyl Ethyl Ketone	Methyl Isobutyl Ketone	Methyl Isoamyl Ketone	Methyl Amyl Ketone
Taper 1	A-1	480	4.8	4.3	1.7	4.5
Taper 2	A-2	480	3.3	2.5	1.4	2.0
Taper 3	A-3	480	3.0	2.5	2.2	3.3
Processor 1	A-8	463	52.9	19.4	0.9	20.5
Processor 2	A-6	457	3.9	1.1	2.6	13.0
Processor 3	A-5	456	39.2	3.1	0.4	3.5
Processor 4	A-4	439	9.0	1.4	0.7	1.3
Processor 5	A-12	441	6.2	0.8	6.1	0.8
Processor 6	A-14	428	8.6	0.6	2.2	0.6
Processor 7	A-13	251	100.0	9.4	6.0	8.9
Processor 7	A-10	148	169.9	30.4	10.8	29.7
Processor 8	A-7	456	55.2	18.8	7.5	23.7
Processor 9	A-17	229	25.2	5.0	8.2	2.7
Processor 9	A-9	145	41.2	9.3	5.8	12.0
Processor 10	A-15	347	4.9	0.7	3.7	0.7
Processor 11	A-16	410	17.5	0.6	5.0	0.7
Processor 12	A-19	400	66.0	27.2	0.8	29.8

Exposure criteria see Table 2

Table 5
Additive Effects Calculation for an 8-Hour TWA
Exposure to Paint Solvents, BMY Corporation, York, Pennsylvania
HHE 87-367, October 27, 1987

Job Title	Additive Effects Value
Taper 1	.064
Taper 2	.039
Taper 3	.036
Processor 1	.355
Processor 2	.100
Processor 3	.136
Processor 4	.062
Processor 5	.054
Processor 6	.084
Processor 7	.538
Processor 8	.486
Processor 9	.243
Processor 10	.052
Processor 11	.125
Processor 12	.330

The ACGIH has established guidelines for exposures to mixtures of hazardous substances which result in adverse effect to the exposed workers. For substances with additive effects the sum of the following fractions should not exceed one.

$$C1/T1 + C2/T2 + C3/T3 + ... Cn/Tn = \leq 1$$

C = atmospheric concentration T = corresponding threshold limit value
If the sum of the fraction exceeds one, then the threshold limit of the mixture should be considered as being exceeded.[4]
TWA = time-weighted average

TABLE 6
DEMOGRAPHICS/WORK PRACTICES
BMY Corporation
York, Pennsylvania
HHE 87-367
October 27, 1987

	Processors	Non-Processors	p value
Number	49	23	
Age (mean)	36	36	.89**
Years Employment (mean)	5.4 years	3.6 years	.07**
Smokers	20 (41%)	7 (30%)	.36*
Brush Epoxy	46 (94%)	8 (35%)	.000*
Brushing Epoxy (mean hours/week)	25	3	.002**
Spray Epoxy	27 (55%)	9 (39%)	.20*
Spraying Epoxy (mean hours/week)	17	27	.18**
Brush Polyurethane	41 (84%)	8 (35%)	.000*
Brushing Polyurethane (mean hours/week)	21	3	.005**
Spray Polyurethane	24 (49%)	8 (35%)	.25*
Spraying Polyurethane (mean hours/week)	20	30	.18**

* - chi-square
** - pooled t-test

TABLE 7
Symptoms during past month at work: Processors vs non-processors
BMY Corporation
York, Pennsylvania
HHE 87-367
October 27, 1987

Symptom	# and (%) among 49 Processors	# and % among 23 Non-Processors	p value
Headache	36 (73%)	14 (61%)	.42
Sore Throat	30 (61%)	17 (74%)	.43
Excess Fatigue	27 (55%)	11 (48%)	.74
Dizziness/Lightheaded	24 (49%)	10 (43%)	.85
Watery Eyes	16 (33%)	10 (43%)	.53
Shortness of breath	15 (30%)	8 (34%)	.93
Coughing Spells	14 (29%)	11 (48%)	.18
Skin rash/Irritation	13 (26%)	8 (35%)	.65
Sinus pain	13 (26%)	10 (44%)	.24
Nausea	11 (22%)	7 (30%)	.66
Females only:			
Menstrual disorders	5 (55%)	1 (33%)	.50

TABLE 8
Mean Symptom Scores Adjusted for Gender:
BMY Corporation
York, Pennsylvania
HHE 87-367
October 27, 1987

	Processors	Non-Processors	p value
Number	49	23	
Memory [a]	1.2	1.7	.15
G.I. [b]	0.7	0.8	.58
Alcohol-related [c]	1.4	1.5	.56
Neurasthenia [d]	1.6	1.8	.46
Cognitive [e]	1.1	1.5	.17
Skin [f]	1.3	1.6	.31
Chest [g]	0.9	1.3	.12
Peripheral Nervous System [h]	0.5	0.9	.09
Headache [i]	1.6	1.9	.59

* reflects a mean of at least " a little " for each symptom in the symptom complex

** Fisher's exact

Neurobehavioral Questionnaire: Symptom Groupings

a. Trouble remembering, relatives notice not remembering things, have to make notes.

b. Loss of appetite, weight loss, diarrhea, indigestion, nausea, cramps, and constipation.

c. Trouble driving home, decreased tolerance to alcohol, "high" from chemicals.

d. Tired, weak, depressed, irritable, dizzy, trouble sleeping, trouble falling asleep.

e. Trouble concentrating, confused

f. Short of breath, cough, chest pain, heart palpitations, increased perspiration

g. Decreased arm strength, decreased leg strength, numb fingers, numb toes, incoordination.

TABLE 9
Mean Symptoms Scores Greater Than 2 *
BMY Corporation
York, Pennsylvania
HHE 87-367
October 27, 1987

Symptom	Processors	Non-Processors	p value
Memory	18 (37%)	9 (43%)	.62
Gastrointestinal	6 (12%)	1 (4%)	.29
Alcohol Symptoms	16 (33%)	6 (27%)	.57
Neurasthenic Symptoms	18 (37%)	9 (39%)	.84
Cognitive Symptoms	18 (37%)	9 (39%)	.84
Skin	16 (33%)	10 (43%)	.37
Chest	6 (12%)	6 (23%)	.14
Peripheral Nervous System	1 (2%)	5 (21%)	.01**
Headache	37 (76%)	13 (57%)	.10