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JOHNSON CONTROLS
GREENFIELD, OHIO

NIOSH INVESTIGATORS:
KEVIN HANLEY, MSPH, CIH
DOUGLAS TROUT, MD
SUE BURT, MPH
ROBERT MOURADIAN, PhD

SUMMARY

In 1990, the National Institute for Occupational Safety and Health (NIOSH) received a request for a health hazard evaluation (HHE) at the Johnson Controls automobile seat production facility in Greenfield, Ohio. The HHE request, submitted by the United Auto Workers, concerned reports of halovision among plant employees exposed to amine catalysts used in polyurethane foam production at this plant. Halovision is believed to be a temporary visual disturbance that may represent a safety hazard for employees who work near machinery or drive home immediately after work.

During the initial survey in July 1990, management and employee representatives confirmed that halovision had been an intermittent problem, especially in hot weather and in areas near the foam "crushers" (devices used to compress the foam soon after it leaves the mold). Air samples, using a variety of methods, were collected to measure airborne amines and develop worker exposure categories. In October 1990, a questionnaire was completed by over 100 first shift employees to evaluate halovision and other visual disturbances among workers.

Due to analytical problems, attempts to *quantitatively* measure air levels of amines in the plant were not successful. However, organic amines that have previously been associated with halovision were qualitatively detected near the foam crushers and in the warehouse/packing area. The results from the employee questionnaire indicated that, overall, at least 75% of the workers responding had experienced halovision or other visual disturbances while working in this facility. These visual disturbances occurred more frequently during the summer. The questionnaire results did demonstrate a trend of increasing reports of visual effects with increasing exposure to amines (as estimated by the qualitative air samples and an industrial hygiene assessment of the manufacturing process and job tasks). Furthermore, the low exposure category also had over 50% of the respondents reporting visual disturbances. The foam manufacturing process also uses polyurethane resins that contain diisocyanates. The employee questionnaire revealed that in excess of 30% of the respondents reported experiencing respiratory symptoms often associated with isocyanate exposure.

Although amines were not quantitatively detected in most of the air samples, large numbers of workers at this facility reported visual symptoms. Recommendations to reduce the potential for exposure and subsequent health effects include improved exhaust ventilation, medical surveillance, and implementation of administrative controls that would rotate workers through the high symptom jobs. In particular, amine exposures should be reduced (if possible) during the last few hours of a shift before a worker would drive home. The continued use of personal protective equipment such as goggles may also reduce eye exposure to airborne amines.

Keywords: SIC 2531 (Seats: Automobile), polyurethane foam, organic amines, diethanol amine, triethylene diamine, DABCO, bis(2-dimethylaminoethyl) ether, NIAX A99, triethyl urea, halovision, visual disturbance, diisocyanates, TDI, asthma.

INTRODUCTION

In May 1990, the United Auto Workers (UAW) submitted a health hazard evaluation (HHE) request asking the National Institute for Occupational Safety and Health (NIOSH) to assess amine exposures and to evaluate the occurrence of halovision at Johnson Controls, a foam automobile seat production facility in Greenfield, Ohio. In response to this request, NIOSH representatives conducted an initial site visit in July 1990. Follow-up surveys to this facility were conducted in October 1990 and November 1992, during which air samples were collected in an attempt to assess amine exposures among the workers, questionnaires were distributed, and workers were interviewed.

BACKGROUND

This Johnson Controls facility produces foam seats for automobiles and light trucks. Although many formulations are used (according to individual specifications from each automotive company), the basic manufacturing process involves mixing polymeric isocyanate and glycol-based urethane resins with amine-based catalysts. The majority of the foam seat molding lines in this plant produce a high-resilient foam seat, using a foam that requires organic amine catalysts for the polymerization reaction. In 1990, there was one heat-cured mold line that does not use amines; this line was scheduled to be phased out.

The car seat production process consists of assembly conveyor lines containing many molds connected in sequence that form a carousel. Workers spray a release agent inside of the metal mold and insert wire springs/cloth mats prior to the automatic dispensing of polyurethane foam resin and catalyst into the mold. As the closed mold travels around the carousel, the liquid foam chemicals react and cure into a solid foam seat; the mold lid opens and the seat is manually removed at the "pop-out" station. The finished seat is trimmed with power scissors and conveyed through a foam crusher that releases unreacted catalyst contained in pores of the foam. Following inspection, the seats are hung on open conveyors and transferred to an adjacent warehouse, where they are packed in large shipping bins. Since the foam seats continue to cure while suspended on the conveyors, the large number of seats travelling through the manufacturing plant and warehouse theoretically contribute to the ambient level of amines.

Since halovision was the primary health effect of interest to the requesters, this HHE focused on attempting to quantitatively measure employee exposures to amines. Likewise, the questionnaire administered to the workers focused on evaluating the prevalence of visual disturbances, although several questions related to respiratory symptoms were also included. Air samples were not collected for isocyanates because of the recognized difficulties in the analytical method available to measure polymeric isocyanates at the time of these field surveys.

EVALUATION CRITERIA

To assess the hazards posed by workplace exposures, NIOSH investigators use a variety of environmental evaluation criteria. These criteria publish exposure levels to which most workers may be exposed for a working lifetime without experiencing adverse health effects. However, because of wide variation in individual susceptibility, some workers may experience occupational illness even if exposures are maintained below these limits. The evaluation criteria do not take into account individual hypersensitivity, pre-existing medical conditions, or possible interactions with other workplace agents, medications being taken by the worker, or environmental conditions.

The primary sources of evaluation criteria for the workplace are: NIOSH Criteria Documents and Recommended Exposure Limits (RELs),[1] the Occupational Safety and Health Administration (OSHA) Permissible Exposure Limits (PELs),[2] and the American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Values (TLVs).[3] These occupational health criteria are established based on the available scientific information provided by industrial experience, animal or human experimental data, or epidemiologic studies. It should be noted that RELs and TLVs are guidelines, whereas PELs are standards which are legally enforceable. The Occupational Safety and Health Administration PELs are required to take into account the technical and economical feasibility of controlling exposures in various industries where the agents are present. The NIOSH RELs are primarily based upon the prevention of occupational disease without assessing the economic feasibility of the affected industries and as such tend to be conservative. A Court of Appeals decision vacated the OSHA 1989 Air Contaminants Standard in *AFL-CIO v OSHA*, 965F.2d 962 (11th cir., 1992); and OSHA is now enforcing the previous standards (listed as Transitional Limits in 29 CFR 1910.1000, Table Z-1-A) originally promulgated in 1971.[2] However, some states which have OSHA-approved State Plans continue to enforce the more protective ("final rule") limits promulgated in 1989. The National Institute for Occupational Safety and Health encourages employers to use the 1989 limits or the RELs, whichever are lower.

Evaluation criteria for chemical substances are usually based on the average personal breathing zone (PBZ) exposure to the airborne substance over an entire 8- to 10-hour workday, expressed as a time-weighted average (TWA). Personal exposures are usually expressed in parts per million (ppm), milligrams per cubic meter (mg/m^3), or micrograms per cubic meter ($\mu g/m^3$). To supplement the TWA where there are recognized adverse effects from short-term exposures, some substances have a short-term exposure limit (STEL) for 15-minute periods; or a ceiling limit, which is not to be exceeded at any time. Additionally, some chemicals have a "skin" notation to indicate that the substance may be appreciably absorbed through direct contact (or vapor contact) of the material with the skin and mucous membranes.

It is important to note that not all workers will be protected from adverse health effects if their exposures are maintained below these occupational health exposure criteria. A small percentage may experience adverse health effects because of individual susceptibility, a pre-existing medical condition, previous exposures, and/or a hypersensitivity (allergy). In addition, some hazardous substances may act in combination with other workplace exposures, or with medications or personal habits of the worker (such as smoking, etc.) to produce health effects even if the occupational exposures are controlled to the limit set by the evaluation criterion. These combined effects are often not considered by the chemical specific evaluation criteria. Furthermore, many substances are appreciably absorbed by direct contact with the skin and thus potentially increase the overall exposure and biologic response beyond that expected from inhalation alone. Finally, evaluation criteria may change over time as new information on the toxic effects of an agent become available. Because of these reasons, it is prudent for an employer to maintain worker exposures well below established occupational health criteria.

Halovision

Visual disturbances, such as blurred or foggy vision and appearance of rings around lights (halovision), have been noted as an adverse effect of exposure to certain amines. The problem has primarily been associated with binders used in foundries and was the subject of a recent NIOSH Alert, "*Request For Assistance in Preventing Vision Disturbances and Acute Physical Distress Due to Dimethylethylamine (DMEA) Exposure*"[4] (enclosed). In addition to their use in foundry binders, amines that have been associated with halovision are also used as catalysts in the production of polyurethane foams. Although amine-induced visual disturbances are believed to be temporary and have no known permanent effects, they may present a significant safety hazard for affected workers who must drive home, operate fork lifts and other heavy equipment, or are present near operating machinery. While halovision is known to be caused by various amines, and is noted on the Material Safety Data Sheets (MSDSs) for many of the commercial products, there is little information available on the dose-response relationship or on the no-effect level. Tertiary and ditertiary amines such as triethylamine (TEA), dimethylethylamine (DMEA), and triethylene diamine (DABCO) are widely used as catalysts in the production of foams and other polymers.[5] Although use of these compounds is probably increasing, there is relatively little information available concerning the potential health effects of occupational exposures.

The studies that have been published in this area were summarized by Albrecht and Stephenson in a 1988 review article which described a wide range of health effects that have been reported following either occupational or experimental exposures to specific tertiary amines.[6] Exposure to tertiary amines has been associated with a number of visual disturbances, including inability to focus and halovision. These result from edema (swelling) of the cornea (the clear, front part of the eye). In addition, a number of systemic effects have been reported, including tachycardia (rapid heart beat) and a transient drop in blood pressure.

As part of a NIOSH HHE, Stephenson measured DMEA levels in an aluminum foundry and attempted to correlate air concentrations with reports of visual disturbances, headache, nausea, and stomach pain.[4] A NIOSH Alert on DMEA, based in part on this evaluation, suggested that visual disturbances could be avoided by limiting 8-hour TWA exposures to 2 ppm, and 15 minute peak exposures to concentrations of about 10 ppm.[4]

The NIOSH Alert was followed by a publication from Ashland Chemical that, based on a study of foundries, suggested re-evaluation of the current exposure limits.[7] In the Ashland study, air monitoring data from 42 foundries were pooled to estimate average and peak exposure levels to DMEA and TEA in various job categories. Information on the incidence of visual disturbances was obtained through an "informal survey." Although the study suffers from poor documentation of health effects and a failure to correlate environmental measurements with specific effects, the authors did conclude that visual disturbances could occur at exposure levels of 3 to 10 ppm.[7]

In addition to the two studies of foundry workers, visual disturbances have also been reported in the production of polyurethane foams. Initially, this was believed to be caused by exposure to isocyanates, but it now appears that the problem is actually caused by amine catalysts. In 1986, Potts reported an unusual keratopathy (corneal disorder) that occurred in two employees of a polyurethane production facility.[8] Similar effects were produced in the eyes of several cats and one monkey following exposure to TEA. Animals exposed to isocyanates also experienced damage to the eye. However, the appearance of the lesions was distinctly different from that produced by TEA and did not resemble that seen in the exposed workers.

Following another report of visual disturbances among foam production workers, Akesson followed 19 employees for a total of 11 weeks.[9] He reported that halovision occurred 47 times. A four-day industrial hygiene survey conducted at the same site recorded average TEA levels of 3.5 ppm in jobs where halovision was reported and concentrations of 1.2 ppm in other areas. Although there was little information on exposure patterns, the authors suggested that visual disturbances were more likely caused by short peaks of high concentration than by sustained exposure at lower levels.

Isocyanates

Because of the highly unsaturated nature of the isocyanate functional group, the diisocyanates readily react with compounds containing active hydrogen atoms to form urethanes. The chemical reactivity of diisocyanates, and their unique ability to cross-link, makes them ideal for polymer (polyurethane) formation. Hence, they are widely used in surface coatings, polyurethane foams, adhesives, resins, elastomers, binders, sealants, etc. Diisocyanates are usually referred to by an abbreviation; e.g., TDI for 2,4- and 2,6-toluene diisocyanate, HDI for 1,6-hexamethylene diisocyanate, MDI for 4,4'-diphenylmethane diisocyanate, NDI for 1,5-naphthalene diisocyanate, etc. Commercial-grade TDI is an 80:20 mixture of the 2,4- and 2,6- isomers of TDI, respectively.

Exposure to the diisocyanates is irritating to the skin, mucous membranes, eyes, and respiratory tract. High concentrations may result in chemical bronchitis (inflammation of airways of the lungs), chest tightness, nocturnal dyspnea (difficult breathing at night), pulmonary edema (fluid accumulation in the lungs), and death.[10,11]

Diisocyanates also are known dermal and respiratory sensitizers.[11-13] Sensitization refers to an allergic reaction which becomes established as a result of repeated exposure over a period of days to months. Sensitization may develop depending on the type and route of exposure, the exposure concentration, and individual susceptibility. After becoming sensitized to diisocyanates, subsequent exposure (even to concentrations below occupational health criteria) could produce an allergic reaction. Respiratory sensitization from exposure to diisocyanates results in the typical symptoms of asthma. Estimates of the prevalence of diisocyanate-induced asthma in exposed worker populations vary considerably; from 5% to 10% in diisocyanate production facilities,[14,15] to 25% in polyurethane production plants,[14,16] and 30% in polyurethane seat cover operations.[17] Dermal sensitization can result in such symptoms as rash, itching, hives, and swelling of the extremities.[10,13]

Although no epidemiologic data exist which link TDI exposure to elevated cancer rates in exposed workers, NIOSH has concluded based on animal and *in vitro* studies, that sufficient evidence exists to classify TDI as a potential occupational carcinogen.[18] Hence, NIOSH recommends that occupational exposures to TDI be reduced to the lowest feasible concentration.

EVALUATION METHODS

Industrial Hygiene Assessment

To evaluate potential amine exposures at this facility, the foam production process was reviewed with facility engineers, MSDSs were obtained for each of the agents used in foam production, and bulk samples of unused catalysts were analyzed by gas chromatography and mass spectroscopy (GC/MS). Based on the literature reviewed and on information obtained from the MSDSs and GC/MS analyses, a decision was made to measure worker exposures to airborne levels of diethanolamine, triethylene diamine, bis(2-dimethylaminoethyl) ether, and triethylurea.

Although amines are generally difficult to measure in air, earlier reports indicate that some investigators have had success using solid sorbent collection followed by analysis with either gas or liquid chromatography. In other cases, impinger sampling using a weak hydrochloric acid solution has been shown to be more reliable. For the initial evaluation conducted in the summer of 1990, a sampling strategy that used solid sorbents (allowing full-shift PBZ sampling) was selected. Unfortunately, analysis of samples collected on the solid sorbents (XAD resins and activated charcoal) did not provide any useful data due to poor amine collection by these sorbents. Therefore, a second visit was performed in October 1990, which involved area air sampling using a variety of wet collection methods and impingers. In November 1992, an additional follow-up survey was conducted to collect short-term PBZ and full-shift area samples, in an effort to develop and confirm job title groupings into high and low exposure categories. Table 1 summarizes all of the sampling methods used in this survey in an attempt to sample airborne amines.

Medical

During the October 1990 site visit, a self-administered questionnaire was distributed to all 119 first shift workers. The questionnaire included questions on demographics, job titles and duties, and medical information concerning visual changes and respiratory symptoms.

The frequency of vision disturbances and asthma reported on the questionnaires was calculated for each job title and exposure category developed for both amines and isocyanates. A case of asthma was defined as a positive response to questions regarding: (1) wheezing or whistling breathing; or (2) chest tightness <u>and</u> either shortness of breath or difficult breathing. A "change in vision" was defined as a positive response to any of the questions regarding blurred vision, hazy vision, or halovision.

During the November 1992 site visit, NIOSH staff interviewed eight employees during and after the plant walk-through, and reviewed plant occupational injury and illness logs (OSHA 200 logs) and the infirmary log of injury reports.

RESULTS AND DISCUSSION

Industrial Hygiene

Four bulk liquid samples of unused catalysts were obtained during the initial NIOSH site survey and were qualitatively analyzed using GC/MS. The GC/MS analyses did not identify simple aliphatic amines but did identify other organic amines to be present in these catalysts including diethanol amine, triethylene diamine (DABCO), bis(2-dimethylaminoethyl) ether (NIAX A99), and triethyl urea.

During the on-site surveys of this HHE, a total of 61 air samples (32 impinger samples, 24 silica gel sorbent tube samples, and 5 activated charcoal tube samples) were collected and analyzed using six different analytical methods. Full-shift and half-shift area samples were collected near mold opening areas, trimming stations, and foam crushers for manufacturing lines #1, 3, 4, and 6 as well as in the packing area of the warehouse. For comparison, a few samples were also obtained from the heat cured line that did not use amine catalysts. In addition, seven short-term personal breathing zone (PBZ) samples were collected on line 1, 3, and 4 operators who removed foam seats out of molds, trimmed seats with power scissors, and checked seats immediately following the foam crushers. As summarized in Table 1, none of the air sampling methods used in this evaluation were effective in quantifying the amount of amines present in the workplace. The only method that produced limited success was an impinger method using sulfuric acid for collection that was analyzed via GC and a nitrogen phosphorous detector (NPD). Triethylene diamine, bis(2-dimethylaminoethyl) ether, and triethyl urea were detected in many of these samples. However, this method did suffer from sample instability during storage and poor recovery which affected the ability to quantitate the samples.

Job titles were organized into high and low "relative" exposure categories for both amines and isocyanates. (The relative exposure categories were based on estimations of exposure potential developed by an assessment of the manufacturing process, workers' proximity to exposure sources, and job tasks.) Job titles that were placed into the high amine exposure group include the checkers, operators, cold foamer, and general plant relief (GPR) unless they worked *only on line 2*, the heat-cured line. Twenty-six workers were placed in the low amine exposure category, and 79 were placed in the high amine exposure category. Potential exposure to amines and isocyanates were found to follow similar patterns, with the exception of line 2 workers that were excluded out of the high amine category. (Job titles estimated to be exposed to low levels of amines were also estimated to be exposed to low levels of isocyanates; and *all* checkers, operators, cold foamers, and GPR workers were included in the high isocyanate exposure group for both the heat-cured and amine-cured manufacturing lines.)

Although the heat-cured line (line 2) did not use amine catalysts, these workers could be exposed from the ambient levels within this manufacturing plant. In order to evaluate if a difference in reported symptoms existed for line 2 workers, the dichotomous amine exposure classification was modified. A three group exposure classification was developed by moving the heat-cured (line 2) workers into a separate low category while maintaining the other relative exposure groups. Workers previously listed in the low category that worked with amine-cured foam were reassigned to a *moderate* exposure category; the high exposure group was unaffected. The questionnaire results for vision changes were evaluated using both of these exposure classifications. The asthma questionnaire results were only analyzed using the dichotomous (high versus low) exposure categories.

Medical

The questionnaire (administered in 1990) was returned by 108 (91%) of 119 workers. Not all of the respondents completed all the questions, leading to differences in denominators for many of the questions. Descriptive statistics of the workforce are presented in Table 2. Three (3%) of 102 workers reported being diagnosed by a doctor as having asthma, while 33 (34%) of 97 met our symptom-based definition of asthma. Overall, 77% of the employees completing the questionnaire reported experiencing a change in vision, with 73% specifically noting halovision. Although visual disturbances were reported as occurring in all seasons, 75% of the respondents reported having visual disturbances during the summer. Fifty-nine (57%) of 103 respondents reported that they have had difficulty driving home from work because of impaired vision, while 42 (43%) of 98 reported that they have had difficulty working at their job because of impaired vision. The number of workers from each job title, along with the percentage of workers reporting respiratory and visual effects, are presented in Table 3.

The interviews performed in 1992 indicated that vision changes due to exposures at the plant continued to be a substantial concern among a large number of employees. One of the eight interviewed employees reported difficulty breathing and shortness of breath occurring as a result of exposure at work; the others did not report any respiratory symptoms. Management representatives stated that two persons who had become sensitized to isocyanates currently work in an area of the plant with minimal exposure to isocyanates. Review of plant records revealed that three persons were currently on medical leave from work due to potential occupationally related respiratory symptoms. Review of the infirmary records did not reveal any injuries or accidents suspected to be related to visual disturbances among employees.

Job titles that were organized into high and low exposure categories to amines and isocyanates are presented in Table 4. The percentages of workers in each of the exposure categories reporting asthma and visual effects are presented in Table 5. No association between increased reports of asthmatic symptoms and exposure categories for isocyanates was apparent. (Thirty-two percent of respondents reported symptoms for the low group versus 35% for the high exposure category.) However, the total percent of workers (34%) at this facility that reported these respiratory symptoms is cause for concern. The true prevalence of asthma among employees at this plant is difficult to determine from the data, as is the potential for occupational exposure as a causative factor. The symptom-based definition of asthma, [a positive response to questions regarding: (1) wheezing or whistling breathing; or (2) chest tightness <u>and</u> either shortness of breath or difficult breathing], detected 33 cases of asthma, as compared to three persons who reported having been diagnosed by a doctor as having asthma.

A pattern of increased reports of symptoms with the high amine exposure category was noticed for vision changes and halovision, but not for eye irritation. The percentage of workers who reported halovision were 48% and 94%, respectively, for the low and high amine exposure categories. A similar pattern for these exposure groups existed for vision changes. As shown in Table 7, when line 2 workers were separated into their own (low) exposure category, this pattern of increased reports of vision changes with increasing amine exposure category also existed (37% for low vs. 77% for moderate vs. 96% for high).

CONCLUSIONS

Although the air monitoring was unable to quantitatively measure organic amines at this plant, a large number of workers reported experiencing visual disturbances while at work. These visual disturbances were reported to occur to the greatest extent during the summer and were reported with increased frequency among workers with the highest estimated amine exposure. Considering that the literature has reported visual changes following exposure to these amines, it is likely that the vision changes reported at this Johnson Controls plant are related to workplace amine exposure. Although no resulting incidents or injuries have been documented, visual disturbances pose a potential safety hazard, both at work and while driving home from work.

An association between reported asthma and isocyanate exposure category was not apparent, but the prevalence of reported respiratory symptoms is of concern for both the high and low exposure categories.

RECOMMENDATIONS

1. All visual disturbances and respiratory symptoms thought to be work-related should be reported to the appropriate supervisors. Maintain a log of these reports so that trends over time and potential high-exposure jobs (i.e., frequent reports of symptoms) may be identified. Plant accident and injury reports should be monitored to determine whether impaired vision is a contributing factor.

2. Regarding potential exposure to amines present in this workplace:

    a. For those workers experiencing halovision, an ophthalmologic evaluation should be considered to objectively evaluate the visual symptoms.

    b. Recommendations made in the NIOSH Alert[4] should be considered to minimize exposure to amines. Engineering controls should be the first line of prevention, with personal protective equipment such as eye goggles possibly serving as an interim measure. (Eye goggles can diminish vision and contribute to a safety hazard, as well as creating discomfort and increased risk for dermatitis.)

    c. Local exhaust ventilation at the foam crushers should be improved. A more effective crusher enclosure (immediately followed by a longer staging conveyor) equipped with side-mounted slot exhaust ventilation should remove air contaminants more efficiently than the observed canopy style local exhaust ventilation. Local exhaust ventilation should also be considered for other work stations that result in frequent reports of visual disturbances, including but not limited to, trimming stations and inspection locations.

    d. Installing additional ceiling exhausts (dilution ventilation) near chain conveyors transporting curing foam seats may reduce the ambient amine concentrations within the plant. Consider installing false ceilings below chain conveyors in areas of the plant and warehouse where large numbers of curing foam seats are conveyed.

e. Consider implementing administrative work scheduling to rotate workers out of jobs with frequent reports of symptoms near the end of their workshift.

3. Regarding potential exposure to isocyanates present in this workplace:

a. When it is not possible to eliminate a diisocyanate from a production process without altering the integrity of the desired product, strategies for reducing diisocyanate exposure should focus on the use of engineering controls. Personal protective equipment should only be used when engineering controls are not feasible, in the interim when engineering controls are being installed or repaired, or when engineering controls have not sufficiently reduced diisocyanate exposures. Whenever there is the potential for significant exposure to diisocyanates, including concentrations below the NIOSH REL, NIOSH recommends that the employer provide the worker with supplied-air respiratory protection.[10]

b. All workers potentially exposed to diisocyanates should be entered into both preplacement and periodic medical surveillance programs.[10] The preplacement evaluations should consist of detailed medical and work histories with emphasis on pre-existing respiratory and/or allergic conditions, a physical examination that centers on the respiratory tract, a baseline pulmonary function test that measures FEV_1 and FVC, and a judgement on the worker's ability to wear a supplied-air respirator. Annual examinations should be provided which update the medical and work histories, and measure the worker's FEV_1 and FVC.

REFERENCES

1. NIOSH [1992]. Recommendations for occupational safety and health: compendium of policy documents and statements. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 92-100.

2. Code of Federal Regulations [1989]. 29 CFR 1910.1000. Washington, DC: U.S. Government Printing Office, Federal Register.

3. ACGIH [1994]. 1994-1995 threshold limit values for chemical substances and physical agents and biological exposure indices. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

4. NIOSH [1987]. NIOSH Alert: request for assistance in preventing vision disturbances and acute physical distress due to dimethylethylamine (DMEA) exposures. U.S. Department of Health and Human Services, U.S. Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, NIOSH Publication No. 88-103.

5. Grayson M, ed. [1978]. Kirk-Othmer Encyclopedia of Chemical Technology. Third Edition, John Wiley and Sons, New York, NY.

6. Albrecht WN, Stephenson RL [1988]. Health hazards of tertiary amine catalysts. Scand J Work Environ Health 14:209-219.

7. Warren DW, Selchan DF [1988]. An industrial hygiene appraisal of triethylamine and dimethylethylamine exposure limits in the foundry industry. Am Ind Hyg Assoc J 49(12):630-634.

8. Potts AM, Rouse EF, Eiferman RA, Au PC [1986]. An unusual type of keratopathy in polyurethane workers and its reproduction in experimental animals. American Journal of Industrial Medicine 9:203-213.

9. Akesson B, Bengtsson M, Floren I [1986]. Visual disturbances after industrial triethylamine exposures. Int Arch Occup Environ Health 57:297-302.

10. NIOSH [1978]. Criteria for a recommended standard: Occupational exposure to diisocyanates. Cincinnati, OH: U.S. Department of Health, Education, and Welfare, Public Health Service, Center for Disease Control, National Institute for Occupational Safety and Health, DHEW (NIOSH) Publication No. 78-215.

11. NIOSH [1990]. Pocket guide to chemical hazards. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 90-117.

12. NIOSH [1986]. Occupational respiratory diseases. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 86-102.

13. Levy BS, Wegman DH (editors) [1988]. Occupational health: recognizing and preventing work-related diseases. Second Edition. Boston/Toronto: Little, Brown and Company.

14. Weill H [1979]. Epidemiologic and medical-legal aspects of occupational asthma. The Journal of Allergy and Clinical Immunology 64:662-664.

15. Porter CV, Higgins RL, Scheel LD [1975]. A retrospective study of clinical, physiologic, and immunologic changes in workers exposed to toluene diisocyanate. American Industrial Hygiene Association Journal 36:159-168.

16. Adams WGF [1975]. Long-term effects on the health of men engaged in the manufacture of toluene diisocyanate. British Journal of Industrial Medicine 32:72-78.

17. White WG, Sugden E, Morris MJ, Zapata E [1980]. Isocyanate-induced asthma in a car factory. Lancet i:756-760.

18. NIOSH [1989]. Current intelligence bulletin 53: toluene diisocyanate (TDI) and toluenediamine (TDA), evidence of carcinogenicity. Cincinnati, OH: U.S. Department of

Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 90-101.

AUTHORSHIP AND ACKNOWLEDGMENTS

Evaluation Conducted By:	Kevin Hanley, MSPH, CIH Industrial Hygienist Industrial Hygiene Section
	Douglas Trout, MD Medical Officer Medical Section
	Sue Burt, MPH Medical Officer Medical Section
	Robert Mouradian, CIH, PhD Industrial Hygienist Industrial Hygiene Section

Assistance provided by:

Gregory Burr, CIH
Supervisory Industrial Hygienist
Industrial Hygiene Section

Glen Hadwen, MS
Industrial Hygienist
Industrial Hygiene Section

Originating Office:

Hazard Evaluations and Technical Assistance Branch
Division of Surveillance, Hazard Evaluations and Field Studies

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2. United Auto Workers Local 1842
3. OSHA Region V

For the purpose of Informing affected workers, 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
Sampling and Analytical Methods for Amines and Other Organic Compounds
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Analytes	Collection Method	Comments
Bulk liquid samples of four amine-based catalysts	Portions of each bulk sample were diluted with ethanol and the solutions analyzed by a gas chromatograph (GC) equipped with a flame ionization detector (FID).	The four amine catalysts included triethylene diamine, diethanol amine, bis (2-dimethylamino ethyl) ether, and triethyl urea. The analysis of the bulk samples indicated the presence of triethylenediamine, diethanolamine, and triethylurea.
Aliphatic amines	Air samples were collected on silica gel and then subsequently desorbed in sulfuric acid. The samples were then made basic with the addition of potassium hydroxide and then analyzed by a GC equipped with a nitrogen phosphorus detector (NPD).	No nitrogen containing compounds were detected on any of the air samples. It is suspected that the nitrogen compounds were present in concentrations too low for identification by GC.
Organic amines: (triethylenediamine) (diethanolamine) (bis [2-dimethylamino ethyl] ether) (triethylurea)	Impingers filled with twelve milliliters of 0.5 molar sulfuric acid. After sampling, toluene and sodium hydroxide were added to the samples, mixed, then centrifuged. The top layer of toluene (containing any extracted amines) was then analyzed by a GC equipped with a NPD.	The presence of triethylenediamine, bis [2-dimethylamino ethyl] ether, and triethylurea was confirmed in some of the samples. Diethanolamine was not detected in any of the samples.
Diethanolamine	NIOSH Method No. 2007 (using silica gel sorbent tubes.) The silica gel tubes were desorbed in methanol and water and analyzed with a GC equipped with a NPD.	No response to diethanolamine was obtained under a variety of chromatographic conditions.
Diethanolamine	NIOSH Method No. 3509. Impingers filled with 2 mM of hexane sulfonic acid. The impinger samples were analyzed by ion chromatography.	No diethanolamine was detected on any of the air samples.
Organic compounds	Air samples were collected on charcoal tubes (CT) or XAD-2 sorbent tubes and then desorbed with a variety of solvents. The CT samples were desorbed in either carbon disulfide or methylene chloride. The XAD-2 tubes were desorbed with ethyl acetate. All samples were then screened with a GC equipped with a FID. Selected samples were also analyzed by GC-Atomic Emission Spectroscopy (AES).	All of these air samples had very similar components. Major compounds identified included 1,1,1 trichloroethane; siloxanes, p-dioxane, and aliphatic hydrocarbons in the C_9 to C_{12} range.

Table 2
Characteristics of Study Population
Johnson Controls, Greenfield, OH
HETA 90-0277

Mean Age	40 (Range 20 -- 59)
Sex	63 male; 45 female
Mean Time at Plant (years)	14 (Range 1.5 -- 33)
Mean Time at Current Job (years)	5 (Range 0.1 -- 20)

Table 3
Respiratory and Visual Effects Reported by Employees - By Job Title
Johnson Controls, Greenfield, OH
HETA 90-0277

Job Title	Total # of Employees	% with Asthma[1] (N=97)[3]	% with Change in Vision[2] (N=103)	% with Eye Irritation[4] (N=98)	% with Halovision (N=95)
Bagger	6	60 %	80 %	83 %	80 %
Checker	5	20 %	100 %	80 %	100 %
Cold Foam	2	0 %	100 %	100 %	100 %
Compounder	1	0 %	0 %	100 %	0 %
GPR[5]	6	17 %	83 %	67 %	80 %
Inserter	2	50 %	0 %	100 %	0 %
Janitor	3	0 %	67 %	0 %	67 %
Laborer	1	0 %	100 %	100 %	100 %
Mat. Handler	5	25 %	75 %	75 %	67 %
Operator	66	39 %	76 %	78 %	71 %
Inspector	5	50 %	100 %	100 %	100 %
Sandblaster	2	0 %	50 %	0 %	50 %
Wirehanger	1	0 %	100 %	100 %	0 %
Total	105	34%	77%	78 %	73%

1 Asthma was defined as a positive response to questions regarding: (1) wheezing or whistling breathing; or (2) chest tightness and either shortness of breath or difficult breathing.
2 Change of vision was defined as blurred vision, hazy vision, or halovision.
3 In determining the percentages, the denominator (N) varies in each category due to varying number of respondents providing adequate information.
4 Eye irritation was defined as itchy eyes or watery eyes.
5 General plant relief.

Table 4
Job Titles by Estimated Exposure Category-Amines and Isocyanates
Johnson Controls, Greenfield, OH
HETA 90-0277

Estimated Exposure Category-Amines and Isocyanates	Job Titles
1 (Low)[1]	Bagger, Compounder, Inserter, Janitor, Laborer, Material handler, Plant inspector, Wirehanger, Sandblaster, Line 2 workers[1]
2 (High)[2]	Checker, Operator, Cold foam, General plant relief

1 Line 2 workers were placed in the low amine exposure category regardless of job title.
2 All of the checkers, operators, cold foamers and general plant relief operators were placed in the high isocyanate category regardless of manufacturing line.

Table 5
Percentage of Employees Reporting Health Effects, By Estimated Exposure Category
Johnson Controls, Greenfield, OH
HETA 90-0277

Estimated Exposure Category	% with Asthma[1] (N=97)[2]	% with Change in Vision[3] (N=103)	% Eye Irritation[4] (N=98)	% with Halovision (N=95)
1 (Low)	32 %	55 %	70 %	48 %
2 (High)	35 %	96 %	85 %	94 %
Total	34 %	77 %	78 %	73 %

1 Asthma was defined as a positive response to questions regarding: (1) wheezing or whistling breathing; or (2) chest tightness and either shortness of breath or difficult breathing.
2 In determining the percentages, the denominator (N) varies in each category due to varying number of respondents providing adequate information.
3 Change of vision was defined as a positive response to questions concerning blurred vision, hazy vision, or halovision.
4 Eye irritation was defined as a positive response to questions concerning itchy eyes or watery eyes.

Table 6
Job Titles by Estimated Exposure Category-Amines and Isocyanates
Johnson Controls, Greenfield, OH
HETA 90-0277

Estimated Exposure Category-Amines and Isocyanates	Job Titles
1 (Low)	All workers who only worked line 2 (Heat-cured foam)
2 (Moderate)	Bagger, Compounder, Inserter, Janitor, Laborer, Material handler, Plant inspector, Wirehanger, Sandblaster (Amine-cured foam)
3 (High)	Checker, Operator, Cold foam, General plant relief (Amine-cured foam)

Table 7
Percentage of Employees Reporting Health Effects, By Estimated Exposure Category
Johnson Controls, Greenfield, OH
HETA 90-0277

Estimated Exposure Category	% with Change in Vision[1] (N=103)	% Eye Irritation[2] (N=98)	% with Halovision (N=95)
1 (Low)	37 %	68 %	25 %
2 (Moderate)	77 %	71 %	75 %
3 (High)	96 %	85 %	94 %
Total	77 %	78 %	73 %

1 Change of vision was defined as a positive response to questions concerning blurred vision, hazy vision, or halovision.
2 Eye irritation was defined as a positive response to questions concerning itchy eyes or watery eyes.