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FORT WAYNE FOUNDRY MACHINING DIVISION
FORT WAYNE, INDIANA

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SUMMARY

The National Institute for Occupational Safety and Health (NIOSH) conducted a health hazard evaluation (HHE) at the Fort Wayne Foundry Machining Division in Fort Wayne, Indiana. Employees requested the HHE because of concerns of exposure to the machining coolant (metal-working fluid, MWF), specifically the biocide Grotan®. Symptoms of skin irritation, runny nose, upper respiratory infections, shortness of breath, headaches, coughing, cuts that became easily infected, and cancer were listed by the requesters as health problems that some thought to be work-related. A NIOSH industrial hygienist and a medical officer visited the plant on March 30, 1995. They conducted a walk-through inspection of the plant and observed work practices; reviewed health and safety programs, Occupational Safety and Health Administration (OSHA) Injury and Illness logs (Form 200), material safety data sheets (MSDSs), and MWF management records; conducted confidential interviews with eight randomly-chosen machine operators; and collected a few samples. The review of the OSHA 200 logs and the interviews revealed only symptoms of skin irritation and rashes. No nitrosamines were detected in the bulk samples of the MWFs. General area (GA) air samples were analyzed for oil mist (total particulate mass) and formaldehyde, and would have been analyzed for nitrosamines if any were found in the bulk samples. The oil mist (total particulate) concentrations were 0.27 milligrams per cubic meter (mg/m^3) and 0.47 mg/m^3, well below any established occupational criteria. The formaldehyde samples were all less than 0.06 parts per million (ppm), but the last addition of Grotan® (a formaldehyde-releasing biocide) was over three weeks before the survey. On August 24, 1995, the industrial hygienist returned to collect bulk samples of the MWFs for bacterial analysis. All the bacteria identified were gram-negative rods, which all produce endotoxins, and the concentrations were in the range of 10^6 to 10^7 colony forming units (CFUs) per milliliter of MWF.

Although the sampling results do not suggest an over-exposure to formaldehyde, nitrosamines, or oil mist, the workers in this plant are exposed to a water-based MWF through dermal contact and inhalation of MWF aerosol. There is no general exposure standard for water-based MWF; and there are no standards for many of its components and contaminants, such as bacteria, endotoxins, and biocides. However, these MWFs have been associated with several dermal and respiratory health effects, and exposures to them should be reduced when possible. Since workers in this plant had poor hygiene practices and scant use of personal protective equipment, and since there was no local exhaust ventilation on any of the operations, recommendations were made to reduce dermal contact with, and inhalation exposure to the MWFs.

KEYWORDS: SIC 3363 (Aluminum Die-castings), metal-working fluid, machining coolant, Grotan®, Kathon®, formaldehyde, nitrosamines, bacteria

INTRODUCTION

The National Institute for Occupational Safety and Health (NIOSH) conducted a health hazard evaluation (HHE) at the Fort Wayne Foundry Machining Division in Fort Wayne, Indiana, on March 30, 1995. Employees requested the HHE because of concerns of exposure to the metal–working fluid (MWF), and specifically the biocide Grotan®. Skin irritation, runny nose, upper respiratory infections, shortness of breath, headaches, coughing, cuts that became easily infected, and cancer were listed by the requesters as health problems that some thought to be work-related.

BACKGROUND

The Fort Wayne Foundry Machining Division is one of the five manufacturing divisions of Fort Wayne Foundry, and it is the only one that is not a foundry operation. Approximately 25% of the automotive aluminum castings made in the foundries are machined by this Machining Division. Located in a separate plant which was constructed in 1986, it originally housed only one operation, the 4-3 line. The plant was expanded in 1990 when the 3-1 and quad-4 lines were added, in 1993 when the Cadillac and Saturn lines were added, and in 1994 when the Rochester line was added. At the time of the survey, the Rochester line was not yet operating, but in June 1995, the 4-3, 3-1, and quad-4 lines were scheduled to be shut down and the Rochester line to begin operation.

There are two central systems that supply MWF to the machining lines. The 4-3, 3-1, and quad-4 lines are all supplied by system 1, and the other lines are supplied by system 2. Each system consists of a large tank (one that holds 7,000 gallons and one that holds 11,000) under the floor from which MWF is piped to each machine. A series of troughs that run underneath the machines collect the used fluid and carry it back to the central tanks where it is filtered and used again.

The MWF is maintained completely by an outside contractor. The contractor tests the MWF in both systems every Monday and then makes the appropriate additions. Based on the pH level and the microbial count, a biocide is added approximately every two to three weeks.

Four heating, ventilating, and air-conditioning (HVAC) units and three input fans line the south wall of the plant and supply 136,000 cubic feet per minute (CFM) of air. In the north wall there are eight exhaust fans, each with a 20,000 cfm output capacity. Not all of the exhaust fans are operated daily. None of the manned operations have any local exhaust ventilation, but large fans have been place behind most of them to blow air from behind the worker toward the operation. This was done based on an outside consultant's recommendation to use fans to blow the MWF away from workers. Some of the workers use the fans while others do not.

The Machining Division was previously the responsibility of one of the five owners of the Fort Wayne Foundry. This owner reportedly had very little contact with the corporate office, but since his retirement a few months before the survey, a new connection has formed. The Machining Division's plant manager, who does not have any health and safety staff of his own, now has access

to the corporate safety engineers. These engineers are responsible for the safety and environmental issues of Fort Wayne Foundry. They also address the basic industrial hygiene issues and use a contractor to perform more detailed industrial hygiene evaluations.

At the time of the survey, there was no union at the plant. However, on March 31, 1995, the employees voted to unionize.

EVALUATION CRITERIA

As a guide to the evaluation of the hazards posed by workplace exposures, NIOSH field staff employ evaluation criteria for the assessment of a number of chemical and physical agents. The primary sources of environmental evaluation criteria for the workplace are the following: (1) NIOSH Criteria Documents and Recommended Exposure Limits (RELs), (2) the Occupational Safety and Health Administration (OSHA) Permissible Exposure Limits (PELs), and (3) the American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Values (TLVs).[1,2,3] The objective of these criteria is to establish levels of exposure to which the vast majority of workers may be exposed without experiencing adverse health effects.

Full-shift and shorter duration criteria are available depending on the specific physiologic properties of the agent. Full-shift limits for chemical agents are based on the time-weighted average (TWA) airborne concentration of a substance that workers may be repeatedly exposed to during an 8 or 10 hour work day, up to 40 hours a week for a working lifetime, without adverse health effects. Some substances have short-term exposure limits (STELs) or ceiling limits (CLs) which are intended to supplement the full-shift criteria where there are recognized irritative or toxic effects from brief exposures to high airborne concentrations. STELs are based on 15 minute TWA concentrations, whereas CL concentrations should not be exceeded even momentarily.

Occupational health criteria are established based on the available scientific information provided by industrial experience, animal or human experimental data, or epidemiologic studies. Differences between the NIOSH RELs, OSHA PELs, and ACGIH TLVs may exist because of different philosophies and interpretations of technical information. It should be noted that RELs and TLVs are guidelines, whereas PELs are standards which are legally enforceable. OSHA 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. The ACGIH is not a government agency; it is a professional organization whose members are industrial hygienists or other professionals in related disciplines and are employed in the public or academic sector. The TLVs are developed by consensus agreement of the ACGIH TLV committee and are published annually. The documentation supporting the TLVs (and proposed changes) is periodically reviewed and updated if believed necessary by the committee.

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 effects due to individual susceptibility, a pre-existing medical condition, previous exposures, 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) 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.

Metal-Working Fluids

Metal-working fluids (MWFs) are used for lubrication, cooling, and removal of metal chips during machining operations. There are four major types of MWFs: straight oils, water soluble oils, semi-synthetic, and synthetic. Thus, criteria for evaluating the potential health hazard from exposure to MWFs would vary depending on which type is being used. Straight oils are evaluated as an oil mist exposure and consideration must be given to potential contaminants contained in the oils. The other three types are water-based MWFs and several evaluations might be necessary, including total particulate (both size-selective gravimetric analysis and particle count), nitrosamines, ethanolamines, formaldehyde, specific biocides, volatile and non-volatile organic compounds, metals, endotoxins, and microbial contamination. The evaluation criteria for each of these evaluated during this investigation are described below.

N-nitrosamines

Nitrosamines are compounds characterized by the -N--N=O functional group. They result from the combination of primary, secondary, or tertiary amines with nitrite. These reactions can occur in the laboratory; in various food, household, or industrial products; in industrial processes; and in vivo. Because of the variety of amines and reaction conditions possible, there are hundreds of nitrosamines; and because of the large number of exposure sources, including formation in vivo, there is a complicated matrix of total nitrosamine exposure. Occupational exogenous exposures have been observed in rubber industries, leather tanning industries, metal-working industries, chemical industries, mining, pesticide production, detergent production, and fish factories.

Most nitrosamines are suspected to be human carcinogens, but direct causal associations have not yet been proven. There is circumstantial evidence that nitrosamines could cause cancer in humans. In 1956, Magee and Barnes demonstrated the carcinogenic potential of nitrosodimethylamine (NDMA) in rats.[4] Since then, nitrosamines have been studied

extensively in laboratory animals. Approximately 90% of the 300 tested nitrosamines have shown carcinogenic effects in bioassays and laboratory animals. The animals that have been studied include mammals, birds, fish, and amphibia. Of the approximately 40 animal species tested, none has been resistant. The tumor sites depend on the specific nitrosamine, the species tested, and the route of administration. Nitrosamine affects have been demonstrated in the bladder, bronchi, central nervous system, earduct, esophagus, eyelid, duodenum, forestomach, glandular stomach, hematopoietic system, intestine, jaw, kidney, larynx, nasal cavity, oral cavity, ovary, liver, mammary glands, pancreas, pelvis, peripheral nervous system, pharynx, respiratory tract, skin, testes, trachea, uterus, and vagina.[5] Dose-response studies with rats have shown "no effect levels" corresponding to dietary concentrations of 1 parts per million (ppm) NDMA, 1 ppm NDEA, and 1 ppm NPYR.[5] These n-nitrosamines and others appear to be very potent carcinogens.

All of the biochemical, pathological, and experimental data provides little evidence that humans might be resistant to the carcinogenic potential of nitrosamines.[6] Human tissues from the trachea, bronchus (lung), esophagus, colon, pancreatic duct, bladder, and buccal mucosa have been shown to metabolize nitrosamines into DNA-binding compounds.[6] Human liver tissue appears to metabolize nitrosamines with a similar activity to rodent liver tissue, and rodents have similar acute symptoms of liver necrosis and cirrhosis similar to those that have been observed in humans.[6] A few human DNA adduct studies have revealed higher levels of nitrosamine-related DNA adducts in cancer cases than in controls.[7,8] Studies in experimental animals have shown similar DNA adduct formation to those detected in the human studies.[9-11]

Only one nitrosamine, nitrosodimethylamine, is regulated in the United States. Both OSHA and NIOSH regulate NDMA as an occupational carcinogen, recommending that its exposure be reduced to the lowest feasible concentration. There are no established numerical exposure limits in this country.

Der Ausschuβ für Gefahrstoffe (AGS) in Germany has strict regulations for occupational exposures to nitrosamines. In general industry, the total exposure to all nitrosamines present may not exceed 1 microgram per cubic meter ($\mu g/m^3$). In certain industries, such as rubber vulcanization, exposures to all nitrosamines present may not exceed 2.5 $\mu g/m^3$. In addition to these regulations, eight nitrosamines are regulated individually--nitrosodimethylamine, nitrosomorpholine, nitrosopiperidine, phenyl-ethylnitrosamine, phenyl-methylnitrosamine, di-N-butylnitrosamine, di-iso-propylnitrosamine, diethylnitrosamine.

Formaldehyde

Formaldehyde is a colorless gas with a strong odor. Exposure can occur through inhalation and skin absorption. The acute effects associated with formaldehyde are irritation of the eyes and respiratory tract and sensitization of the skin. The first symptoms associated with formaldehyde exposure, at concentrations ranging from 0.1 to

5 ppm, are burning of the eyes, tearing, and general irritation of the upper respiratory tract. There is variation among individuals, in terms of their tolerance and susceptibility to acute exposures of the compound.[12]

In two separate studies, formaldehyde has induced a rare form of nasal cancer in rodents. Formaldehyde exposure has been identified as a possible causative factor in cancer of the upper respiratory tract in a proportionate mortality study of workers in the garment industry.[13] NIOSH has identified formaldehyde as a suspected human carcinogen and recommends that exposures be reduced to the lowest feasible concentration. The OSHA PEL is 0.75 ppm as an 8-hour TWA and 2 ppm as a STEL.[14] ACGIH has designated formaldehyde to be a suspected human carcinogen and therefore, recommends that worker exposure by all routes should be carefully controlled to levels "as low as reasonably achievable" below the TLV.[3] ACGIH has set a ceiling limit of 0.3 ppm.

NIOSH testimony to the U.S. Department of Labor on May 5, 1986, stated the following: "Since NIOSH is not aware of any data that describe a safe exposure concentration to a carcinogen NIOSH recommends that occupational exposure to formaldehyde be controlled to the lowest feasible concentration; 0.1 ppm in air by collection of an air sample for any 15-minute period as described in NIOSH analytical method 3500 which is the lowest reliably quantifiable concentration at the present time." NIOSH also lists a PEL for formaldehyde of 0.016 ppm for up to a 10-hour TWA exposure (again using NIOSH analytical method 3500 and indicating that this is the lowest reliably quantifiable concentration at the present time). Researchers should be aware that formaldehyde levels can currently be measured below 0.016 ppm. It may be appropriate to refrain from using numerical limits and instead state that concentrations should be the lowest feasible (in some situations, this may be limited by the ambient background concentration).

Oil Mist

The evaluation criteria for oil mists are primarily based on studies conducted with petroleum-based, white mineral oil with no additives.[15,16] Mineral oils, as well as other lubricating or cutting oils, can contain a complex mixture of aromatic, naphthenic, and straight- or branched-chain paraffinic hydrocarbons. The composition of a given oil depends upon the way in which the oil was processed, and the degree to which it was processed. Many mineral oils in use today vary in composition and can contain various additives and impurities.

Inhalation of mineral oil mist in high concentrations may cause pulmonary effects, although few cases have been reported. A single case of lipoid pneumonitis suspected to have been caused by exposure to very high concentrations of oil mist was reported in 1950; this occurred in a cash register serviceman who had heavy exposure over 17 years of employment.[17] Early epidemiological studies linked cancers of the skin and scrotum with exposure to mineral oils.[18] These effects have been attributed to contaminants such as polycyclic aromatic hydrocarbons (PAHs) and/or additives with carcinogenic

properties. The International Agency for Research on Cancer (IARC) determined that there is sufficient evidence for carcinogenicity to humans, based on epidemiologic studies of uncharacterized mineral oils containing additives and impurities; there is inadequate evidence for carcinogenicity to humans for highly refined oils.[19] Prolonged exposure to mineral oil mist may also cause dermatitis. Persons with pre-existing skin disorders may be more susceptible to these effects.

Environmental evaluation criteria for mineral oil mist have been established by ACGIH and OSHA at 5 milligrams per cubic meter (mg/m^3) of air as an 8-hour TWA. This concentration was selected to minimize respiratory irritation and pulmonary effects. The NIOSH REL for oil mist is also 5 mg/m^3, with a STEL of 10 mg/m^3. However, since the role of additives and oil fume from partial heat-decomposition have yet to be completely evaluated experimentally, NIOSH suggests that these criteria may not be applicable to all forms of oil mists.[15]

Water-soluble MWFs cannot be analyzed using the oil mist sampling method. Thus, a total mass measurement is made, knowing that the water soluble oil portion of the sample collected must be less than the total mass. This measurement is the same one that is used for particulates not otherwise classified (PNOC). However, this measurement is also not a good choice for water-based MWFs since these MWFs do have a biologic effect. At this time, there is no generic occupational exposure standard or guideline for MWFs.

Microbial Contamination

Microorganisms (including fungi and bacteria) are normal inhabitants of the environment. The saprophytic varieties (those utilizing non-living organic matter as a food source) inhabit soil, vegetation, water, or any reservoir that can provide an ample supply of a nutrient substrate. Under the appropriate conditions (optimum temperature, pH, and with sufficient moisture and available nutrients) saprophytic microorganism populations can be amplified; water-based MWFs provide an ideal environment for microbial amplification.

Both bacteria and fungi have been identified in MWFs, and biocide addition is the most common method for controlling the growth. Three major groups of organisms have been noted in MWFs: obligative anaerobic sulfate reducers, specifically *Desulfovibrio desulfuricans*; aerobic bacteria, especially *Pseudomonas* species and coliforms; and imperfect fungi, including members of the genus *Fusarium*, *Cephalosporium*, and *Candida*.[20] Bacterial concentrations are recommended to be maintained at or below 10^5 colony forming units per milliliter (CFU/ml), but concentrations of 10^6 to 10^8 CFU/ml are more commonly maintained, and concentrations as high as 10^9 CFU/ml have been documented.

Some individuals manifest increased immunologic responses to bacteria, fungi, or their metabolites encountered in the environment. These responses and the subsequent

expression of allergic disease is based, partly, on a genetic predisposition. Allergic respiratory diseases resulting from exposures to microbial agents have been documented in agricultural, biotechnology, machining, office, and home environments.[21-29] Acceptable levels of airborne microorganisms or bioaerosols have not been established, primarily because allergic reactions can occur even with relatively low air concentrations of allergens, and individuals differ with respect to immunogenic susceptibilities.

Although some pathogenic organisms have been identified in oil emulsion MWFs in the past,[30,31] most pathogens do not persist well in MWFs.[32-35] As mentioned above, the most common bacterial species identified are *Pseudomonas* species,[20,36-38] and one study has demonstrated a humoral antibody response to *Pseudomonas pseudoalcaligenes* in workers exposed to MWFs that were contaminated primarily with that species.[39] Another study recently demonstrated serum antibody precipitins to bacteria isolated from a MWF in workers who were diagnosed with hypersensitivity pneumonitis (HP) and exposed to the MWF.[40]

HP, also called extrinsic allergic alveolitits, is a spectrum of granulomatous, interstitial lung diseases which occur because of repeated inhalation and sensitization to a wide variety of microbial agents (bacteria, fungi, amoebae), animal proteins, and low-molecular weight chemical antigens.[41] It is marked by a pneumonitis which is reversible if exposure to the antigen is stopped; continued exposure can lead to a chronic interstitial fibrosis or scarring of the lungs. Only limited data are available on the epidemiology of HP. The type of exposure (e.g., antigen concentration, particle size, and antigen solubility) as well as individual susceptibility and individual risk factors all play a role in determining if an individual will develop HP. The time of onset of HP after initial exposure to an antigen may range from a period of weeks to years.

In general, HP is marked by nonspecific symptoms. Acute HP begins in the first 12 hours after exposure with cough, dyspnea (shortness of breath), chest tightness, fevers, chills, malaise, and myalgias (muscle aches). The symptoms of the subacute and chronic forms of HP include cough, dyspnea, possible wheezing, loss of appetite, and weight loss. The diagnosis should be considered in anyone with recurrent pneumonias or recurrent respiratory symptoms. Making a definite diagnosis of HP can be very difficult and demands a high level of suspicion from the physician. It is important to emphasize that no single aspect of the patient's history, symptoms, physical findings, or laboratory tests is diagnostic of HP.

EVALUATION METHODS

Environmental Evaluation

N-nitrosamines

Three bulk samples of the metal-working fluid were collected for nitrosamine analysis. Four general area (GA) air samples were also collected, and if nitrosamines were detected in the bulk samples, the GA samples would be analyzed. These GA air samples were collected using Gillian® high-flow pumps at a flow rate of 1.0 liter per minute (l/min), and analyzed in a NIOSH laboratory using a capillary column gas chromatograph and a high resolution mass spectrometer (MS) in the selected-ion-monitoring (SIM) mode.

Formaldehyde

GA air samples were collected on XAD-2® sorbent tubes using Gillian® low-flow pumps at a flow rate of 100 milliliters per minute (ml/min) in accordance with NIOSH Analytical Method 2541. The analysis of the sample media also was in accordance with method 2541, but with modifications. The desorption process was one hour with sonication in 1.0 milliliter (ml) of toluene containing 0.2 microliters per milliliter (µl/ml) DMF as an internal standard. The gas chromatograph was a Hewlett-Packard model 5890A equipped with a flame-ionization detector. The column was a 15 meter by 0.32 millimeter fused silica capillary column, coated internally with 0.5 micrometers of DB-1301. The oven was at 70°C for 1 minute, up to 110°C for 2 minutes at a rate of 6°C per minute, then up to 270°C for 2.34 minutes at a rate of 40°C per minute. Media standards were used in this analysis.

Oil Mist

GA air samples were collected on polyvinyl chloride filters using Gillian® high-flow pumps at a flow rate of 2 l/min. Since the metal-working fluid is water-based, an analysis to measure only the oil mist was not possible. Instead, a modification of NIOSH Analytical Method 0500 was used to analyze for total particulate weight.

Microbial Bulk Samples

Samples of MWF were collected in 50 milliliter (ml) polypropylene beakers. From each beaker, three dipslide samples were collected using Biosan Laboratories, Inc. SaniCheck BF® slides. They were submersed in the MWF for two to three seconds and put back into their vials, and shipped overnight to a contract laboratory, where they were incubated and colony forming units (CFUs) were counted. Also from each beaker sample of MWF, three sets of serial dilutions were performed and streaked onto trypticase soy agar (TSA) plates. A bulk sample was collected from three of the four sample locations. The plates and bulk samples were also shipped overnight to the contract laboratory. The plates were

incubated and CFUs were counted, and one of each triplicate set was used to speciate the bacteria. The bulk samples were serially diluted, streaked onto TSA plates, incubated, counted, and speciated.

Medical Evaluation

Confidential interviews were conducted with eight randomly-chosen machine operators. Inquiries were made about any possible symptoms being experienced, exposure to MWFs, operations/activities that resulted in the greatest exposure to MWFs, and use of personal protective equipment. The OSHA 200 Injury and Illness logs were also reviewed.

RESULTS AND OBSERVATIONS

Environmental

On the day of the survey the production was less than normal. Only two lines were operating continuously; the 4-3 line and the Cadillac line operated intermittently; and the 3-1 line was not operating at all.

During the survey, NIOSH investigators met with the contractor that was hired in 1991 to be solely responsible for all aspects of the MWF. The contractor tests the coolant in both systems every Monday and then makes the appropriate additions. Based on the pH level and the microbial count, a biocide is added approximately every two to three weeks. The coolant is a water soluble MWF that consists mainly of hydrotreated light and heavy naphthenic petroleum distillates. It has a petroleum sulfonate base and a paraffin extreme pressure (EP) component. The pH of the MWF is maintained at about 8. The primary biocide added to this MWF is Kathon® 886 MW, but Grotan® is also used. Kathon® is reported to possibly cause nose, throat, and lung irritation, as well as skin irritation and allergic contact dermatitis. Grotan® is also reported as a skin irritant, and it is a formaldehyde-releaser, which can result in mucous membrane irritation and allergic reactions of both the skin and respiratory system. From September 10, 1993, to March 14, 1995, biocide was added 34 times. Twenty-one of the times Kathon® was added and 13 of the times Grotan® was added. During the month of the survey (March 1995), Grotan® was added on March 7, and Kathon® was added on March 14. Only the contractor personnel, not the plant employees, are permitted to make any additions to the MWF. However, a few employees reported that they believed that plant maintenance personnel were making additions to the MWF.

GA air samples for nitrosamines and formaldehyde were collected at the quad–4, Cadillac, and Saturn lines, and GA air samples for oil mist were collected at the Cadillac and Saturn lines.

The formaldehyde samples were all less than 0.06 ppm (minimum quantifiable concentration was 0.05 ppm and minimum detectable concentration was 0.02 ppm). This is not surprising

since the last addition of Grotan® occurred over three weeks before the survey. The fact that is was still detectable suggests that the concentrations might be higher when the Grotan® is first added.

The oil mist samples had total particulate weights of 0.27 mg/m^3 and 0.47 mg/m^3 for the Cadillac operation 40 and Saturn operation 20, respectively. Since oil is only part of the water-based MWF, the oil mist air concentration must be less than the total particulate weight. These concentrations may not be representative of normal exposures since not all of the lines were operating on the day of the site visit.

Nitrosamines were not detected in the MWF and therefore the air samples were not analyzed.

Microbial bulk samples were collected from one location off of one central system (Henry 1) and from three locations off of the other central system (Henry 2). On line 3-1 (location 1), a 50 milliliter (ml) MWF sample was collected; and from that sample, three dipslide samples were collected and three sets of serial dilutions were performed and streaked onto trypticase soy agar (TSA) plates. At the central tank for the Henry 2 system (location 2), a 50 milliliter (ml) MWF sample was collected; and from that sample, three dipslide samples were collected, three sets of serial dilutions were performed and streaked onto TSA plates, and a bulk sample was collected. This was repeated for a 50 ml sample collected from one of the machines served by Henry 2 (location 3). Also, a bulk sample of MWF was collected from a stagnant pool in a pan on one of the machines served by the same system (location 4). The results are displayed in Table 1. The total bacterial counts from the dipslide samples did not differ much from the total counts from the plates streaked in the field or from the bulk samples. The speciation results did differ between the samples plated in the field and the bulk samples. At locations 2 and 3, the species identified on the plates streaked in the field were *Acinetobacter johnsonii*, *Enterobacter cloacae*, and *Shewanella putrefaciens*; yet, the bulk samples only contained *Comamonas terrigena* from location 2 and contained *Comamonas terrigena* and *Shewanella putrefaciens* from location 3. The bulk sample from location 4 also contained *Comamonas terrigena* and *Shewanella putrefaciens*. These differences imply that simply collecting a bulk sample for species identification is not accurate, and that the bulk sample can evolve into an ecosystem containing different microbes than are actually present in the MWF.

Workers were observed eating, drinking, and smoking at their work stations. Smoking is permitted throughout the plant. Personal protective equipment (PPE) is provided by the floor supervisor on request. Workers were provided with gloves and aprons, but use was not mandatory. Many employees were observed to be wearing clothing that was soaked through with MWF, most commonly on the forearms, the front side from the stomach down the pant legs, and the lower pant legs into the boots. Workers do not change clothes when they become wet, nor do they change before leaving the plant. Safety boots, eye protection, and hearing protection were required, but the hearing protection use was not enforced. There had not been any personal noise level monitoring conducted in the plant, but a few occasionally performed processes had been measured above 85 decibels on an A-weighted scale (dB(A))

and the use of hearing protection was based on those measurements. In 1989 audiometric testing was performed on the employees, but there is not a formal hearing conservation program at this plant.

The Hazard Communication Program was inadequate. The Material Safety Data Sheets (MSDSs) are updated routinely and kept in three accessible locations throughout the plant. Nevertheless, some employees were not aware of where to find them and did not know how to read them. The plant manager reported that an outside contractor performed hazard communication training at one time in the past, but that new employees have not been trained. The corporate safety engineers conduct the hazard communication programs for the four other manufacturing divisions of Fort Wayne Foundry and plans were underway for them to start the program in the Machining Division. There also used to be a joint employee-management health and safety committee, but it was disbanded by a reported lack of interest. This committee was reformed a few months before the survey, but was put on hold until after the vote whether or not to unionize.

Medical

The eight interviewed employees had worked at this facility for times ranging from a few months to five years. All reported experiencing skin rashes. Five of the eight had visible skin irritation on the day of the survey. The skin problems occurred on exposed areas such as the hands, arms, and face, and also in areas where clothing had been saturated with MWF, such as the groin area, legs, and feet. The workers reported that the rashes resolved over weekends and vacations. No other symptoms were reported by the interviewed employees. The OSHA 200 logs for 1994 and the first months of 1995 revealed mainly sprains/strains and contusions, and one incidence of a hand rash.

Table 1. Bacteria Sampling Results from Bulk Samples of Metal-working Fluid. August 24, 1995. HETA 95-0153.

Location	Dipslides (triplicate samples)	Plates Streaked in Field (triplicate samples)		Bulk Samples
	CFU/ml	species from first of the triplicate samples (CFU/ml)	CFU/ml	species and count (CFU/ml)
Location 1 Line 3-1 (Henry 1)	1×10^7 1×10^7 1×10^6 average 7×10^6	*Pseudomonas diminuta* (2.1×10^5)	2.1×10^5 1.92×10^6 1.1×10^6 average 1.1×10^6	not collected
Location 2 Central Tank (Henry 2)	$>1 \times 10^7$ 1×10^6 1×10^6 average $>4 \times 10^6$	*Acinetobacter johnsonii* (3.5×10^6) *Enterobacter cloacae* (3.0×10^5) *Shewanella putrefaciens* (1.2×10^5)	3.9×10^6 6.1×10^6 8.2×10^6 average 6.1×10^6	*Comamonas terrigena* (9.8×10^5)
Location 3 Rochester 4-3 Line operation 10 (Henry 2)	$>1 \times 10^7$ $>1 \times 10^7$ $>1 \times 10^7$ average $>1 \times 10^7$	*Acinetobacter johnsonii* (1.7×10^7) *Enterobacter cloacae* (5.0×10^5) *Shewanella putrefaciens* (2.5×10^5)	1.8×10^7 3.3×10^7 6.2×10^6 average 1.9×10^7	*Comamonas terrigena* (9.8×10^7) *Shewanella putrefaciens* (1.1×10^6)
Location 4 Rochester Line stagnant coolant by north washer (Henry 2)	not collected	not collected	not collected	*Comamonas terrigena* (3.1×10^7) *Shewanella putrefaciens* (3.0×10^6) Thermophilic *Actinomyces* and *Legionella Pneumophila* were not detected

CFU/ml - colony forming units per milliliter

DISCUSSION

Microbial Contamination and Endotoxins

All of the bacterial species identified have been documented previously in MWFs, and all are gram-negative species which produce endotoxins. *Pseudomonas* and *Acinetobacter* are both opportunistic pathogens – microbes that can infect immunocompromised humans. The more probable health hazards from the contaminated MWFs are potential sensitization to the microbes and exposure to endotoxins. The issue of sensitization was addressed in the evaluation criteria section of this report. The health hazards associated with endotoxin will be discussed below.

Endotoxins are lipopolysaccharides (LPS) that are part of the outer membrane of all gram-negative bacteria (GNB). The LPS consists of a lipid (lipid A) that is embedded in the outer cell membrane and a polysaccharide that protrudes out into the environment. The polysaccharide is composed of a core oligosaccharide, which is connected to the lipid A, and a longer O-specific chain, which projects from the core. This O-specific chain is the most variable segment and it evokes a specific antibody response. The core segment contains unusual sugars, heptose and Kdo – the latter of which is found in all endotoxins, but occurs nowhere else in nature. The lipid A component is the least variable and is responsible for the ill effects of endotoxin exposure.[42-44]

GNB, and therefore endotoxins, are ubiquitous in nature. Endotoxins are released when the bacterial cell is lysed (broken down) or when it is multiplying.[43,44] They are found in water, soil, and living organisms. Endotoxins have been found in various agricultural materials, such as grains, silage, hays, straws, animal bedding, composted wood chips, stored timber, tobacco, bulk cottons, mushrooms, manure, compost, and spawn. They have been found in swine confinement units, poultry confinement and processing facilities, and in horse and dairy cow barns. Also, endotoxins have been quantified in cotton, wool, and flax processing; in machining operations where water-based metal-working fluids are used; in waste disposal, sewage, and sewage composting operations; in animal feed production; in potato processing; in biotechnology processes, and in industrial and non-industrial environments associated with cooling towers, humidifiers, air-conditioners, and other water-associated processes.[44-47]

Health effects from exposure to endotoxins have been documented in human case studies, human experimental studies, and animal studies. The more common effects associated with endotoxin exposure include: fever, malaise, subjective chest tightness, increased respiratory and pulse rate, airway irritation, acute bronchoconstriction, chronic bronchitis, cough, dyspnea (shortness of breath), wheezing, changes in white blood cell counts (mostly an increase in neutrophils), and decreased pulmonary function (although some studies did not document any decrements in pulmonary function).[42-46,48-52] Many ill effects have been associated with endotoxin exposure, specifically respiratory changes and fever.

Endotoxins can stimulate the immune system. They appear to possess antitumor properties; and lipid A has been shown to reverse T-cell tolerance to polysaccharide antigens, a property being studied for the design of new antimalaria vaccines.[42] Unfortunately, the fact that endotoxins stimulate the immune system suggests that they could potentially cause allergic sensitization reactions. This area is just beginning to be researched.[42]

Currently, acceptable exposure concentrations to endotoxins have not been established. Since endotoxins are ubiquitous, exposure is also, but background levels are in the nanogram range.[42]

Formaldehyde, Grotan®, and Kathon®

Since Grotan® is a formaldehyde-releaser, the presence of formaldehyde in the MWF is certain. It was interesting that low air concentrations were detected on the day of the survey, which was over three weeks after the last addition of Grotan®; but this low concentration could be from cigarette smoke. As mentioned in the evaluation criteria section, formaldehyde is a mucous membrane irritant and a skin sensitizing agent. Allergic contact dermatitis can occur among workers exposed to formaldehyde. Exposure has also been associated to a reduction in ventilatory capacity and to hypersensitivity reactions, including asthma and laryngeal edema.[53,54] Grotan® itself is a skin sensitizing agent. Patients with allergies to formaldehyde-releasing biocides (FRB), such as Grotan®, are often also allergic to formaldehyde, but not always.[55] Although not a FRB, Kathon® has also been demonstrated to be a skin sensitizing agent.[55-57]

Dermal Health Effects Associated with MWFs

Contact with straight oil MWFs can cause oil-acne or folliculitis,[58-61] a condition caused by clogging of the skin pores as a result of chemical irritation.[58,59] Bacterial infection may arise secondarily, but it does not play a primary role in folliculitis.[59] Treatment is often easy and recurrence is prevented by the reduction of skin contact and the use of proper cleaning methods.[59]

Exposure to water-soluble MWFs most frequently causes dermatitis, or inflammation of the skin.[58-61] There are two distinct types of skin reactions – a direct reaction, irritant contact dermatitis (ICD), and an allergic reaction, allergic contact dermatitis (ACD). A direct reaction occurs at the site of contact, while an allergic reaction occurs not only locally at the point of contact but also systemically. The type of rash and the degree of irritation may vary among individuals. Some researchers believe that ICD comprises 80% of the eczematous skin reactions to MWFs, while others believe that only 50% is ICD and 50% is ACD.[60,61] In both ICD and ACD cases, it is often difficult to attribute a single causative agent to the reaction. Also, it can be difficult to distinguish between ICD and ACD, because even if an individual is sensitized to a component of the MWF, it is usually impossible to know how much the allergy was responsible for the reaction and how large a role the irritancy of the MWF played preceding, accompanying, or following the sensitization.[59]

ICD results from contact with a skin damaging chemical substance. Common primary irritants in MWFs are the overall alkalinity of the MWF, solvents, surfactants (emulsifiers or wetting agents), biocides, and microtrauma from the metallic filings and strong hand-washing detergents.[60] The potential role of microbial enzymes and metabolites in ICD cases has not yet been addressed.

ACD results from individual sensitization to a sensitizing agent, an allergen. This sensitization results in an allergic reaction, or an immune system response. The sensitization develops based on an individual's genetic predisposition, the first exposure to the allergen, and the time and amount of exposure to the allergen. Once an individual becomes sensitized, exposure to even a small amount of the allergen can result in a reaction. Since allergic reactions are specific to each individual, not every person exposed will have a reaction, and those who do might react with different symptoms and varying degrees of severity. It is postulated that ICD can lead to ACD by damaging the skin and allowing sensitizers to penetrate.[60] Common sensitizers in MWFs are metals (chrome, cobalt, nickel), rubber accelerators, corrosion inhibitors, coupling agents, emulsifiers, fragrance additives, and biocides.[60,61] As with ICD, the potential role of microbial contamination of MWFs in ACD cases has not yet been addressed.

Respiratory Health Effects Associated with MWFs

MWF exposure has been associated with a variety of respiratory health effects, including irritant bronchitis, occupational asthma, and hypersensitivity pneumonitis.[40,62] Subclinical changes in pulmonary function tests and lipoid pneumonia have also been associated with MWF exposures.[62] One study documented significant associations of cross-shift decrements in forced expiratory volume in one second (FEV_1) on Mondays and Fridays with inhalable aerosol concentrations ranging from 0.20 to 2.03 micrograms per cubic meter ($\mu g/m^3$) of straight oil, soluble oil, and synthetic MWFs;[63] but, another concluded that there were no adverse respiratory effects from exposure to soluble oil MWFs and only tenuous adverse effects from exposure to straight oil MWFs based on respiratory symptoms prevalence and lung function tests.[64]

CONCLUSIONS AND RECOMMENDATIONS

1. Dermal contact with MWFs should be reduced as much as possible by use of personal protective equipment and modification of work practices. Employees should use techniques to minimize the amount of MWF that drips, spills, or sprays onto them. Employees should wear either a face shield or goggles, a rubber full-front apron, and rubber gloves that cover the forearms. If work practices cannot eliminate the MWF from soaking the lower pant legs, socks, and shoes of workers, then the workers should also wear rubber cover boots or gators. The type of rubber protection depends on the MWF. For mineral spirits, nitrile rubber is a good choice.

2. NIOSH investigators recommend that each employee have uniforms and that they be required to shower and change before leaving work. Used uniforms should not be stored in contact with clean ones or with personal clothing. Employees should also be encouraged to change clothes that have become soaked with MWFs. The uniforms should be laundered at the facility.

3. Eating, drinking, and smoking should not be allowed along the production lines. Workers should be encouraged to wash hands thoroughly before engaging in these activities.

4. Smoking should be restricted to designated smoking areas. Environmental tobacco smoke (ETS) consists of exhaled mainstream smoke from the smoker and sidestream smoke which is emitted from the smoldering tobacco. ETS consists of between 70 and 90% sidestream smoke. More than 4000 compounds have been identified in laboratory-based studies, including many known human toxins and carcinogens such as carbon monoxide, ammonia, formaldehyde, nicotine, tobacco-specific nitrosamines, benzo(a)pyrene, benzene, cadmium, nickel, and aromatic amines.[65,66] Many of these toxic constituents are more concentrated in sidestream than in mainstream smoke.[67] In studies conducted in residences and office buildings with tobacco smoking, ETS was a substantial source of many gas and particulate polycyclic aromatic compounds.[68]

   ETS has been shown to be causally associated with lung cancer and cardiovascular disease in adults, and respiratory infections, asthma, middle ear effusion, and low birth weight in children.[69-71] It is also a cause of annoying odor and sensory irritation. The U.S. Environmental Protection Agency (EPA) has classified ETS as a known human (Group A) carcinogen.[72] NIOSH considers ETS to be a potential occupational carcinogen and believes that workers should not be involuntarily exposed to tobacco smoke.[73]

   Worker exposure to ETS is most efficiently and completely controlled by simply eliminating tobacco use from the workplace. To facilitate elimination of tobacco use, employers should implement smoking cessation programs. Management and labor should work together to develop appropriate nonsmoking policies that include some or all of the following:

   - Prohibit smoking at the workplace and provide sufficient disincentives for those who do not comply.

   - Distribute information about health promotion and the harmful effects of smoking.

   - Offer smoking-cessation classes to all workers.

   - Establish incentives to encourage workers to stop smoking.

The most direct and effective method of eliminating ETS from the workplace is to prohibit smoking in the workplace. Until this measure can be achieved, employers can designate separate, enclosed areas for smoking, with separate ventilation. Air from this area should be exhausted directly outside and not recirculated within the building or mixed with the general dilution ventilation for the building. Ventilation of the smoking area should meet general ventilation standards, such as the American Society of Heating, Refrigerating, and Air-conditioning Engineers (ASHRAE) Standard 62-1989, and the smoking area should have slight negative pressure to ensure airflow into the area rather than back into the airspace of the workplace.[73]

5. Local exhaust ventilation (LEV) should be installed for each operation. This would reduce worker exposure to the MWF aerosol that contains bacteria, endotoxins, and formaldehyde. Since it is not yet clear what component or components of MWFs cause respiratory effects, exposure to aerosolized MWF should be reduced.

   The LEV could exhaust outside of the building or be re-circulated back into the building and an air-cleaning device, such as a mist collector, should be installed. Any air-cleaner must be properly and routinely maintained, especially if the air is recirculated, so that it does not become the source of a health hazard itself. (For example, a poorly maintained mist collector can become an amplification site for microbes and also aerosolize them and their metabolites.) A ventilation engineer should be consulted for proper design of the LEV and air-cleaners. The aerosol generated will vary depending on the operation, machining speed, and MWF, and thus the aerosol must be characterized before an appropriate air-cleaner can be selected.

6. NIOSH investigators recommend performing a noise level survey and then developing a hearing conservation program (HCP), if it is necessary, that is consistent with the monitoring results. The NIOSH recommended exposure limit for noise is 85 decibels, A scale-slow response (dB(A)) for 8 hours, using a 3 dB exchange rate.[74] This relationship means that a worker may only be exposed to 88 dB(A), which is 3 dB greater than the exposure limit of 85 dB(A), for half the amount of time allowed at 85 dB, or 4 hours. Conversely, a worker may be exposed to 82 dB(A), which is 3 dB less than the exposure limit of 85 dB(A), for double the amount of time allowed at 85 dB, or 16 hours. The OSHA PEL for noise is 90 dB(A) with a 5 dB exchange;[75] and the ACGIH TLV is 85 dB(A) with a 3 dB exchange.[3]

   The OSHA regulation has an action level (AL) of 85 dB(A) at which an employer must administer a continuing, effective HCP. The program must include personal monitoring, audiometric testing, employee notification of results, hearing protection, training programs, and record keeping.[75] This standard also requires that noise levels in excess of the OSHA PEL be reduced through feasible engineering and administrative controls to the extent possible.[75]

7. An effective Hazard Communication Program is essential to a healthy work environment, and information and training are a critical part of the program. If workers express concern about not understanding the hazards of their workplace, then the program is not effective. NIOSH investigators recommend that both the union and the management work together to develop more effective hazard communication training. A better understanding of potential work place hazards and open lines of communication should not only reduce worker exposures, but also worker anxieties about potential exposures that are not understood.

   The joint labor-management health and safety committee could be a useful tool for better communication of issues and concerns. This committee should have routine meetings, and communicate all proceedings to the employees.

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HEALTH HAZARD EVALUATION REPORT

HETA 95-0153-2549
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