NIOSH HEALTH HAZARD EVALUATION REPORT

HETA #2005-0024-3000
United Technologies/Carrier Corporation
Indianapolis, Indiana

May 2006

DEPARTMENT OF HEALTH AND HUMAN SERVICES
Centers for Disease Control and Prevention
National Institute for Occupational Safety and Health

PREFACE

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

HETAB also provides, upon request, technical and consultative assistance to federal, state, and local agencies; labor; industry; and other groups or individuals to control occupational health hazards and to prevent related trauma and disease. Mention of company names or products does not constitute endorsement by NIOSH.

ACKNOWLEDGMENTS AND AVAILABILITY OF REPORT

This report was prepared by Loren Tapp and Lynda Ewers of HETAB, Division of Surveillance, Hazard Evaluations and Field Studies (DSHEFS). Field assistance was provided by Chandran Achutan and Gregory Burr. Analytical support was provided by DataChem Laboratories and Microbiology Specialists Incorporated. Desktop publishing was performed by Robin Smith. Editorial assistance was provided by Ellen Galloway.

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

Highlights of the NIOSH Health Hazard Evaluation

On November 11, 2004, the National Institute for Occupational Safety and Health (NIOSH) received a request from the United Steelworkers of America, Local 1999, for a Health Hazard Evaluation (HHE) at the United Technologies/Carrier Corporation, Indianapolis, Indiana. Plant workers had gastrointestinal illness, sinus problems, headaches, rashes, eye irritation, and breathing problems associated with a metal stamping and washing operation and a testing procedure called a run-test line.

What NIOSH Did

- We took bulk water and sludge samples at the 7-128 HX washer operation where problems had been reported. We also took similar samples at lines without problems.
- We took personal breathing zone (PBZ) air samples for volatile organic compounds, carbon monoxide, and aldehydes at the 7-128 run/test line.
- We checked run/test line local exhaust hoods.
- We administered questionnaires to collect information about work history, medical history, and health symptoms to workers from affected areas.
- We took stool samples of employees with active diarrhea .

What NIOSH Found

- Bulk water samples from the 7-128 HX washer operation contained large numbers of enteric (fecal) bacteria; similar machines had no evidence of enteric contamination.
- Of 20 employees working on or near the 7-128 HX washer operation, 8 reported gastrointestinal illness during the prior six months.
- Of 3 stool cultures of employees with active diarrhea, one grew a type of bacterium associated with diarrheal disease but not a type found in the water samples.
- Management found a pipe connecting the 7-128 HX water reservoir to a sewage line during the evaluation. This connector pipe was cut and capped.
- PBZ air sampling results at the 7-128 run/test line were within occupational exposure limits.
- Smoke produced during furnace testing was not well captured by the local exhaust hood.
- Most run/test employees reported work-related eye and/or nose irritation, cough, and headache during the prior 2 months.

What United Technologies Managers Can Do

- Hire an experienced cleaning contractor to disinfect the suspect washer machine, then, re-sample the 7-128 HX washer tank, sumps, and nozzles for enteric bacteria.
- Prohibit eating, drinking, chewing gum, or smoking in the plant production areas.
- Provide water-resistant protective gloves, sleeves, and aprons (vinyl or other non-latex) in addition to cloth work gloves for employees who may come in contact with contaminated rinse water until the 7-128 HX washer is found to be clean.
- Modify the run/test procedures or improve the local exhaust canopy ventilation system to better contain emissions when the furnace blower is activated.
- Encourage workers to report health concerns to the plant Medical Department.

What the United Technologies Employees Can Do

- Do not take food, beverages, or chewing gum into the production area.
- Wash your hands and face with soap and water before eating, drinking, or smoking.
- Wash rinse water-contaminated skin as soon as possible with soap and water.
- Wear water-resistant gloves, sleeves, and coveralls if you might contact the water, and change into clean clothes after the work day is finished until the 7-128 HX water system has been adequately disinfected.

What To Do For More Information:
We encourage you to read the full report. If you would like a copy, either ask your health and safety representative to make you a copy or call 1-513-841-4252 and ask for HETA Report #2005-0024-3000

Health Hazard Evaluation Report 2005-0024-3000
United Technologies/Carrier Corporation
Indianapolis, Indiana

May 2006

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SUMMARY

On November 11, 2004, the National Institute for Occupational Safety and Health (NIOSH) received a request from the United Steelworkers of America, Local 1999, for a Health Hazard Evaluation (HHE) at the United Technologies/Carrier Corporation, Indianapolis, Indiana. Plant workers were experiencing gastrointestinal illness, sinus problems, headaches, rashes, eye irritation, and breathing problems associated with a metal stamping and washing operation (7-128 HX washer) and an associated testing procedure called a run-test (7-128 run/test).

On January 12, 2005, NIOSH industrial hygienists collected bulk water and sludge samples at the suspect 7-128 HX washer, and at two similar production lines where no problems had been reported. A NIOSH medical officer interviewed workers from the affected area. Two bulk water samples from the suspect operation contained enteric bacteria in concentrations up to 10,000,000 (1.0×10^7) colony forming units/milliliter (CFU/ml). Enteric bacteria are normally found only in the intestines of animals and are an indicator of fecal contamination. *Aeromonas hydrophila*, a bacterium widely found in the aquatic environment and capable of causing gastroenteritis in healthy individuals, was also identified. The two comparison machines had no evidence of enteric contamination. After obtaining these results, plant management reported that they had disconnected and capped a drainage pipe linking the machine to a sewer line and cleaned the machine with a 1/100 dilution of sodium hypochlorite/water. Despite the repairs and cleaning, follow-up water samples taken from the contaminated machine on February 1, 2005 and March 16, 2005, by NIOSH investigators found enteric bacteria levels similar to previous samples.

During the February site visit, 20 employees working on or near the suspect operation completed a questionnaire. Eight reported gastrointestinal illness during the prior 6 months. Stool samples were collected on three employees who reported diarrhea, and one grew *Aeromonas veronii biovar sobria*, which is associated with diarrhea. The stool bacterium was the same genus but a different species than that found in the bulk water samples from the 7-128 HX washer.

On March 16-17, 2005, personal breathing zone air samples for volatile organic compounds, carbon monoxide, and aldehydes were collected at the 7-128 run/test line. Although results were within occupational exposure limits, some of the compounds identified could be respiratory irritants. In addition, the smoke produced during furnace testing was not entirely captured by the local exhaust hood when the furnace blower was engaged. Over two thirds of the 7-128 run/test employees surveyed reported work-related eye and/or nose irritation, cough, and headache in the 2 months prior to the NIOSH survey.

NIOSH investigators determined that a health hazard existed in the 7-128 HX metal stamping and washing operation due to fecal contamination of the rinse water. Employees working in this area reported a high prevalence of gastrointestinal symptoms, including diarrhea. Employees at the 7-128 run/test line reported eye and upper respiratory irritation, which was likely related to the smoke produced during furnace testing. Recommendations were to hire an experienced cleaning contractor to disinfect the 7-128 HX stamping and washer machines, modify the run/test procedures, educate employees on improved hygiene and personal protective equipment (PPE) use, and improve the ventilation at the 7-128 run/test line.

Keywords: metalworking, bacterial contamination, gastrointestinal symptoms, enteric bacteria, *Aeromonas*, ventilation
NAICS: 333415 Furnaces, warm air (i.e., forced air), manufacturing

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INTRODUCTION

On November 11, 2004, the National Institute for Occupational Safety and Health (NIOSH) received a request from the United Steel Workers of America, Local 1999, for a Health Hazard Evaluation (HHE) at the United Technologies/Carrier Corporation, Indianapolis, Indiana. According to the request, employee concerns involved two areas of the plant. The first was the Department 7-128 line where light commercial and residential furnaces are manufactured, and the second was the 7-128 run/test line where furnaces are tested. Health effects (respiratory problems, nausea, diarrhea, headaches) were suspected to be related to a metal heat-exchanger stamping and washer machine (7-128 HX), which began operation in 2002.

We made four site visits to the Carrier Corporation between January 12, 2005, and March 17, 2005. Two interim reports were sent to management and employee representatives (January 28, 2005, and February 25, 2005) alerting them to our preliminary findings regarding the 7-128 HX washer machine and to provide recommendations for worker protection near the machine. Final results and recommendations for the 7-128 washer and 7-128 run/test areas are presented in this report.

BACKGROUND

The Indianapolis Carrier operation employs about 1900 workers in the production of residential and industrial furnaces. Work shifts are 10 hours per day (6:00 a.m. – 4:30 p.m. or 5:00 p.m. – 3:30 a.m.), 4 days per week; however, there is frequent opportunity for overtime work on Fridays, Saturdays, and some Sundays. About 8,000 furnaces are produced daily, with peak production reaching 10,000 units per day.

7-128 HX Washer

Rolls of oil-coated, aluminized steel arrive at the Carrier plant to be manufactured into furnace heat exchangers. A water-based lubricating fluid (IRMCO Fluid 090-G15) is sprayed on the steel that is then cut, trimmed, and deep-draw pressed, and the stamped parts are conveyed through an enclosed water-spray washing process to remove the mill oil and draw-fluid chemicals. The parts are blown dry, folded, and crimped around the edges to form finished heat exchangers, which are hung on hooks and moved by an elevated conveyer through the plant for inspections and assembly into furnaces.

The 7-128 HX stainless steel parts washer can hold 150 heat exchangers. Waste water is recycled through 25-micron particle filters and re-circulated into a 1050 gallon reservoir water tank. Eight to ten employees per shift work at or near the 7-128 HX washer machine. According to management, the 7-128 HX washer machine and water holding tanks are drained and cleaned once a week to remove oily sludge. Local exhaust ventilation is present above the washer, and a dike surrounds the machine to contain water leaks. A sump pump in the corner of the dike returns leaked water to the wash-water reservoir for reuse in the washer machine. The 7-128 HX washer was designed to use hot water (140ºF) but its heater ruptured about a year prior to the NIOSH site visit and had not been repaired. According to workers, unpleasant odors and sludge accumulation had been associated with the 7-128 HX washer machine for a year or more prior to the HHE request. No odors in similar washer machines within the plant had been reported.

In 2004, management employed a contractor to investigate the odor problem. Two Summa canisters collected area air samples, which were analyzed by gas chromatography with mass spectrometry detection. According to the contractor's report, none of the 59 detectable organic compounds warranted health concerns.[1] Five bulk samples of water from the 7-128 HX washer were determined to contain *Acinetobacter* species and *Bacillus* species, which were elevated above the laboratory's guideline concentration of 100,000 ($1x10^5$) colony forming units per milliliters of fluid

(CFU/ml).[2] The bacteriological report stated that these types of bacteria are widespread.

According to management, additives such as chlorine, biocides, and oxygenating compounds had been introduced into the 7-128 HX washer water in an attempt to minimize odors and reduce sludge accumulation on several occasions prior to the initiation of this HHE. An ozone generator had been installed in the washer's water tank and was operational before the time of our third visit.

7-128 Run/Test Line

The final step in producing a furnace is a quality control check of the assembled unit in the run-test area. The 7-128 production line, which includes the HX stamping/washing operation of concern, feeds two run-test areas, designated "A" and "B", each consisting of 10 test stations. A total of 10 workers per shift (20 per 24 hours) were employed in the 7-128 A and B run/test areas. Every station contained a canopy hood under which the furnaces were connected to electrical power and natural gas for testing. A computer controlled most steps of the testing, such as running the blower fan and filling the heat exchangers with gas, but workers were required to manually wave a flame around the exterior of the exchanger to visually check for gas leaks. The type, brand, and size of furnaces tested at a station differed throughout the day. According to employees, heat exchangers often had a residue that produced black smoke not fully captured by the canopy hood.

The 10 canopy hoods in each line were connected via one duct to an exhaust fan located near the ceiling. According to management, the hoods had been balanced about a year prior to our visit, but workers reported that the canopy hoods at the east end of the line, furthest from the fan, appeared to pull less air resulting in more irritating smoke escaping during furnace testing.

METHODS

Industrial Hygiene

During site visits 1 and 2 (January 12-13, 2005) sampling focused on a comparison of the 7-128 HX metal stamping and washing operation with similar operations in lines where workers had not reported symptoms. Comparison machines selected were the 7-127 HX washer and 7-128 batch washer. All three used the same aluminized steel pre-coated with mill oil to produce heat exchangers but differed with regard to chemical additives used in, or physical configurations of, the machines (Table 1). Three samples were collected for microbial analysis from the water in each of the machines. If a solid, oily sludge accumulated in the machine, one or more samples of sludge also were collected for microbial analysis. All samples were sent at ambient temperature via overnight mail to a contract microbiology laboratory.

The primary isolation media to recover molds, yeasts, and bacteria in the samples collected on January 13, 2005, was inhibitory mold agar (containing the antibiotics chloramphenicol and gentamicin), malt yeast extract agar, and buffered-charcoal yeast extract agar. Other isolation media were employed secondarily to complete identification of prominent microbial colonies and to screen for two genera found in industrial settings and thought to be potentially harmful to humans, *Legionella* species and *Mycobacterium* species. Samples were screened for enteric Gram-negative rods by inoculation onto tryptic soy agar, 5% sheep blood agar, and a Maconkey agar plate at various dilutions and were incubated at 35ºC for 24-48 hours. Colonies that grew on Maconkey agar and were Gram-negative, oxidative-negative, and fermentative were considered enteric bacteria. Samples were divided, and one section was tested for *Legionella* species using buffered charcoal yeast extraction (BCYE) selective agar. The other section was treated with potassium chloride solution before plating on BCYE selective agar. Plates were incubated at 35ºC for 10 days. *Aeromonas hydrophila* samples were identified from triple sugar iron slant cultures

and were confirmed with a bioMérieux API 20E® system.

During site visit 3 (February 1-2, 2005), four samples were collected from the 7-128 HX washer machine; no further sampling was performed on the two comparison machines that were included on the first site visit. An unused sample of the IRMCO Fluid 090-G15, which is added to the 7-128 HX washer machine, and a sample from the water line that feeds into the 7-128 HX washer machine were collected. Shipping procedures and microbial analysis followed the same procedures as on site visit 2.

Site visit 4 (March 16-17, 2005) focused on the two 7-128 run/test lines. To assess the effectiveness of the overhead canopy exhaust hoods, we sampled for volatile organic compounds (VOCs), carbon monoxide (CO), and carbon dioxide in the A and B lines. VOCs were initially evaluated using four area thermal desorption (TD) tubes placed near the two lines and following the screening method recommended in NIOSH Manual of Analytic Methods (NMAM) Method 2549.[3] The screening results were used to select specific VOCs to quantify from five full-shift, personal breathing zone (PBZ) charcoal tubes samples collected from workers. The following analytical methods were used: NIOSH Method 1501 for aromatic hydrocarbons (toluene), and NIOSH Method 1552 for terpenes (alpha-pinene, beta-pinene, and limonene). Five PBZ air samples for aliphatic aldehydes, which are a class of VOC known to irritate eyes, were collected on cartridges containing silica gel coated with acidified 2,4-dinitrophenylhydrazine (DNPH). These were analyzed for aliphatic aldehydes by high performance liquid chromatography according to NIOSH Method 2018. Direct-reading CO monitors (Q-Trak Plus Model 8554) were used to collect full-shift samples in the PBZ of four workers in the A and B lines. Smoke tubes provided visual information regarding air flow in the area of the canopy hoods. Face velocity measurements of hoods at the ends of the A and B lines were collected using a TSI Velocicalc Plus Model 8360 hot wire anemometer. In addition to the air sampling on the run/test lines, three bulk samples of water and sludge were collected from the 7-128 HX washer.

Medical

During site visit 1, two NIOSH investigators confidentially interviewed first-shift employees working on or near the 7-128 HX washer and in the corresponding run/test areas. During site visit 3, NIOSH investigators administered questionnaires to employees who worked with or near the 7-128 HX washer to collect information on their work history, medical history, and gastrointestinal symptoms. After participants filled in demographic and work history questions, NIOSH investigators asked participants individually about their medical history and symptoms. Participants with diarrhea (defined as three or more loose, watery stools per day) on the day of this evaluation were given a container to collect a stool specimen for analysis. Stool specimens were transferred to proper transporting vials and shipped to a NIOSH contract laboratory for culturing and identification of pathogenic bacteria including *Salmonella species* (*spp.*), *Campylobacter spp.*, *Shigella spp.*, and *Aeromonas spp*. The samples were not examined for parasitic organisms, blood, white blood cells, chemicals, or other substances. Employees who had seen a physician for persistent loose stools in the year prior to the NIOSH evaluation were asked to release their medical records to the medical officer for review. During site visit 4, we administered questionnaires as previously described to employees who worked the run/test areas of the 7-128 HX A and B lines to collect information on their work history, medical history, and gastrointestinal and respiratory symptoms.

EVALUATION CRITERIA

As a guide to the evaluation of the hazards posed by workplace exposures, NIOSH field staff employs environmental evaluation criteria for the assessment of a number of chemical and physical agents. These criteria are intended to suggest levels of exposure to which most

workers may be exposed up to 10 hours per day, 40 hours per week for a working lifetime without experiencing adverse health effects. It is, however, important to note that not all workers will be protected from adverse health effects even though their exposures are maintained below these levels. A small percentage may experience adverse health effects because of individual susceptibility, a pre-existing medical condition, and/or a hypersensitivity (allergy). In addition, some hazardous substances may act in combination with other workplace exposures, the general environment, or with medications or personal habits of the worker to produce health effects even if the occupational exposures are controlled at the level set by the criterion. These combined effects are often not considered in the evaluation criteria. Also, some substances are absorbed by direct contact with the skin and mucous membranes, and may increase the overall exposure. Finally, evaluation criteria may change over the years as new information on the toxic effects of an agent become available.

The primary sources of environmental evaluation criteria for the workplace are: (1) NIOSH Recommended Exposure Limits (RELs),[4] (2) the American Conference of Governmental Industrial Hygienists' (ACGIH®) Threshold Limit Values (TLVs®),[5] and (3) the U.S. Department of Labor, Occupational Safety and Health Administration (OSHA) Permissible Exposure Limits (PELs).[6] Employers are encouraged to follow the OSHA limits, the NIOSH RELs, the ACGIH TLVs, or whichever are the more protective criteria.

OSHA requires an employer to furnish employees a place of employment that is free from recognized hazards that are causing or are likely to cause death or serious physical harm [Occupational Safety and Health Act of 1970, Public Law 91–596, sec. 5(a)(1)]. Thus, employers should understand that not all hazardous chemicals have specific OSHA exposure limits such as PELs and short-term exposure limits (STELs). An employer is still required by OSHA to protect their employees from hazards, even in the absence of a specific OSHA PEL.

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

Diarrhea

Diarrhea has many causes, including intestinal diseases (e.g., ulcerative colitis), reactions to medication or certain foods (e.g., milk in lactose-intolerant individuals), and infectious microbes, i.e., viruses, parasites, and bacteria. In the U.S. and other developed countries, viruses are the most common cause of infectious diarrhea; parasitic and bacterial causes are infrequent. Most cases of diarrhea are self-limiting and resolve within a few days; however, persistent diarrhea needs to be medically evaluated.

Enteric Bacteria

The human gastrointestinal tract is normally home to a wide variety of microbial organisms that live together in balance. These organisms include enteric bacteria, such as *Enterobacter*, *Citrobacter*, and *Klebsiella* species. While some enteric bacteria are more aggressive (virulent) and have been associated with diseases, many are normally found in human and animal intestinal tracts and do not usually cause illness in humans. However, these bacteria are an indication of fecal contamination. The NIOSH contract laboratory (Microbiology Specialists Inc. Houston, Texas) considers a total enteric count on blood agar greater than or equal to 10,000,000 (1.0×10^7) colony-forming units/milliliter of sample (CFU/ml sample) to be suggestive of sewage contamination.[7,8] No occupational exposure criteria exist for enteric bacteria in either air or water.

Aeromonas Bacteria

Aeromonas bacteria are commonly found in fresh water or brackish (slightly salty) water and are not normally found in the human intestinal system. [8] If *Aeromonas* gains entry to the human digestive tract, the ability of these organisms to cause illness is dependent on the specific species and strain. *Aeromonas (A.) caviae, A. hydrophila,* and *A. veronii biovar sobria* are associated with diarrheal diseases, while other *Aeromonas* species are not known to cause diarrhea. Usually the diarrhea is self-limiting and resolves without treatment; however, sometimes the diarrhea may be severe or persistent and require antibiotic treatment.

Skin contact with water containing *A. hydrophila* is unlikely to cause a skin infection; however, if the skin is not intact (i.e., has been cut, scraped, punctured, or injured somehow) a soft tissue infection may result. This is more commonly seen in persons with poorly functioning immune systems (immuno-compromised); in these individuals, the skin infection may progress to a severe infection. *Aeromonas* soft tissue infections can also develop after exposure to soil, in association with crush injuries, and as a complication of burns.

Volatile Organic Compounds (VOCs)

Volatile organic compounds describe a large class of chemicals that contain carbon and have a sufficiently high vapor pressure to allow some of the compound to exist in the gaseous state at room temperature. These compounds are emitted in varying concentrations from numerous sources including, but not limited to, carpeting, fabrics, adhesives, solvents, paints, cleaners, waxes, cigarettes, and combustion sources. No occupational exposure criteria exist for VOCs as a group. Typically, NIOSH investigators use qualitative air sampling and analytical methods to screen for a wide variety of VOCs and then use other methods to quantify specific VOCs that are identified and have known health effects and occupational exposure limits. In this study, the only detected VOC that has an occupational exposure criterion is formaldehyde. The NIOSH REL for formaldehyde is 0.016 parts per million (ppm) for an 8-hour TWA exposure; the OSHA PEL is 0.75 ppm for an 8-hour TWA exposure.[9]

Carbon Monoxide (CO)

CO is a colorless, odorless, tasteless gas produced by incomplete burning of carbon-containing materials (e.g., natural gas). The initial symptoms of CO poisoning may include headache, dizziness, drowsiness, and nausea. These initial symptoms may advance to vomiting, loss of consciousness, and collapse if prolonged or high exposures are encountered. Coma or death may occur if high exposures continue.

The NIOSH REL for CO is 35 ppm for an 8-hour TWA exposure, with a ceiling limit of 200 ppm. The ACGIH recommends an 8-hour TWA TLV of 25 ppm, with a ceiling level of 400 ppm. The OSHA PEL for CO is 50 ppm for an 8-hour TWA exposure.

RESULTS

Industrial Hygiene

7-128 HX Washer

Results from the first day of sampling revealed striking differences in the concentrations of bacteria among the three machines (see Table 2). The 7-128 HX washer, in contrast to the other two machines sampled (the 7-128 batch and 7-127 HX), contained much higher concentrations of total bacteria and was contaminated with enteric bacteria (associated with fecal contamination). Specific enteric bacteria identified in the 7-128 HX washer machine were *Citrobacter koseri*, *Enterobacter agglomerans* (morphotypes 1 and 2), and *Citrobacter youngae* (Table 2). One non-enteric, pathogenic bacteria was identified, *Aeromonas hydrophila*. None of these was detected in the two comparison machines. Neither *Legionella* nor *Mycobacterium* species were found in any of the machines. Several genera of fungi were also

found in the 7-128 HX washer machine, including *Candida sp., Cryptococcus laurentii,* and *Fusarium*. No fungi were found in the other machines.

During site visit 2, water samples collected from the 7-128 HX washer machine still contained unspecified enteric bacteria, and *Aeromonas hydrophila* was found in the sludge. No bacterial colonies grew in the unused IRMCO Fluid or the tap water supplying the 7-128 HX washer machine.

Site visit 3 was conducted after a second cleaning of the water tank and removal of a drain pipe connected to a sewage line. High concentrations of enteric bacteria remained in the water and in sludge collected from the water tank. While the types of bacteria identified (*Klebsiella oxytoca*, *Citrobacter frecundii*, and *Citrobacter diversus*) were different than had been previously detected, they are also types often associated with fecal contamination.

7-128 Run/Test Lines

Most of the VOCs detected near the run/test lines have no occupational exposure criteria. Several types of terpenes were found, including the following: alpha-pinene concentrations ranged from 2.1 micrograms per cubic meter ($\mu g/m^3$) to 5.53 $\mu g/m^3$, beta-pinene concentrations ranged from non-detectable to 2.1 $\mu g/m^3$, and limonene concentrations ranged from 2.4 $\mu g/m^3$ to 4.6 $\mu g/m^3$. These terpenes are compounds produced by many plant species and often are introduced into the work environment as components of industrial cleaning products.

Aldehydes detected included formaldehyde, acetaldehyde, propanal, butanal, iso-valeraldehyde, valeraldehyde, and acrolein. Of these, only formaldehyde was in a high enough concentration to be quantifiable, but the concentration (0.003 ppm) was below the NIOSH REL of 0.016 ppm.

Carbon monoxide concentrations, both peak (1-minute interval) concentrations and TWA, were below the NIOSH REL and OSHA PEL (Table 3).

As shown in Table 4, the average face velocities on the canopy exhaust hoods along the A and B run/test lines ranged from 57 to 83 feet per minute (fpm). These are within the range of 50 to 500 feet per minute recommended for substances not considered highly hazardous (i.e., TLVs greater than 10 ppm).[10]

Medical

Interviews

During site visit 1, confidential interviews were conducted with 11 of 19 employees working first shift on or near the 7-128 HX washer (8 of 9) and employees in the run/test areas (3 of 10). Three of the 11 were female, the average age was 41 years (range: 27 – 60 years), the average number of years working at Carrier was 12.4 years (range: 2 – 39 years), and the average number of years at their current job was 2.3 years (range: 0.3 – 5 years).

Table 5 describes the occurrence of persistent symptoms experienced at work in the 2 months prior to the survey among 7-128 HX employees. Among the eight washer employees, eye, nose, and throat irritation; nasal congestion; headache; cough; and diarrhea were the most prevalent symptoms. Among the three run/test employees, eye irritation, nasal congestion, headache, and cough were most prevalent. Other symptoms reported include loss of appetite, bitter taste in mouth, hoarse voice, upset stomach, dizziness, nosebleeds, and nasal sores.

Seven of the 11 interviewees felt that their symptoms were related to their work environment because the symptoms improved or went away completely when off of work. Five reported seeing a doctor due to the symptoms; three reported their symptoms to the company medical unit. All 11 employees knew other workers with similar symptoms.

Three of eleven had a history of sinusitis and/or seasonal allergy. One had taken an antibiotic for an intestinal infection in the past few months. Three employees reported smoking currently; no workers reported hobbies with exposures to solvents, fumes, or chemicals.

Interviewed employees stated that hearing protection, safety glasses, and leather gloves were required personal protective equipment (PPE). Protective sleeves and aprons were available if needed.

Many interviewees reported a foul odor in their work environment that they described as resembling that from moldy laundry, dirty feet, or sewage. This odor was reported to be worse when turning on the machines after a weekend or day off. Many employees reported that they did not have any symptoms or problems before the 7-128 HX line was installed in 2002. Soon after the new line was put in, problems and odors began. Some employees reported that when the water heater stopped working, their symptoms continued to be about the same; others felt symptoms were worse. Many employees felt that the machine was not cleaned and maintained properly.

Survey Results of 7-128 HX Washer Area Employees

On site visit 3, NIOSH investigators invited all employees who worked with or near the 7-128 HX metal stamping and washer operation to fill out a questionnaire. Fourteen of 15 employees on first shift and 6 of 9 employees on second shift participated, including four operators and one operator lead on a machine adjacent to 7-128 HX; three operators, two operator leads, and three cell hangers on the 7-128 HX washer machine; three maintenance workers; three forklift drivers; and one inspector. Of the 20 participants, five were female, the average age of employees was 44.5 years (range: 23 – 66 years); the average time at their current job was 2.8 years (range: 1.5 – 10 years); and the average time spent in the 7-128 HX machining area was 7 hours (range: 0 – 10 hours).

Five (25%) of 20 participating employees handled rinsed, newly-formed heat exchanger parts at least 4 hours per day; eight (40%) handled them less than 4 hours a day, and 7 (35%) did not handle these parts. Nine had no contact with rinse water from the 7-128 HX washer machine; nine had less than 4 hours of contact, and two had over 4 hours of contact. Five employees neither handled rinsed heat exchanger parts nor had contact with the rinse water from the machine.

Twelve (60%) employees always wore gloves on the job, two usually did, one sometimes, one rarely, and four stated that the question did not apply. Fourteen (70%) typically wore leather gloves; one wore latex, one cotton. The average number of times employees washed their hands a day was 7.5 (range: 3-20). Nineteen washed their hands with soap and water. Thirteen always washed their hands before they ate, six usually did, one sometimes. Twelve (60%) employees regularly ate at the 7-128 HX break table. Twelve (60%) reported currently smoking cigarettes. Among the twelve smokers, one always washed hands before smoking, three usually did, six sometimes, and two rarely.

Table 6 describes the prevalence and frequency of symptoms in the 6 months prior to the survey among 7-128 HX washer machine employees. Nausea or upset stomach was reported most commonly, followed by diarrhea and abdominal pain or cramping. Fifty percent of employees reporting nausea/upset stomach also reported that these symptoms improved away from work. In contrast, none of those with diarrheal symptoms reported improvement away from work.

Eight (40%) participants reported having gastrointestinal illness episode(s) with at least three of the following symptoms during the 6 months prior to the evaluation: nausea; abdominal cramping; three or more loose, watery stools per day; and/or fever/chills. Five (25%) reported recent “abnormal” stools; three of the five reported having diarrhea on the day of the evaluation, but none had family members with diarrheal illnesses. Two of these five workers had seen a physician, but no stool samples had been collected. One worker with prior diarrhea had seen a physician for persistent diarrhea months before our evaluation; the physician had taken a stool specimen and given the worker an antibiotic, after which the worker’s symptoms resolved.

No relationship between gastrointestinal symptoms and the amount of time workers were in contact with the 7-128 HX rinsed heat exchanger parts or rinse water, or type of work tasks or work area, could be found. The number of times employees washed their hands during a work shift, whether they ate at the 7-128 HX break table, or if they always washed their hands before eating or smoking did not appear to influence gastrointestinal symptoms reported. Statistical analysis could not be performed due to the small number of employees.

Stool Analysis

Three (15%) participating washer employees reported active diarrhea on the day of the questionnaire, and each submitted a stool sample. One employee's stool sample grew *Aeromonas veronii biovar sobria*; the other two samples did not grow any pathogenic bacteria. Letters were sent to the three employees and their private physicians on February 18, 2005, explaining their individual test results.

Medical Record Review

Four of five surveyed employees who had seen a medical provider for gastrointestinal symptoms agreed to release their medical records for review. For all four, the records documented episodes of diarrheal illness within the past 3 years, but only one record mentioned obtaining stool for bacterial culture and examination for parasites. This record did not contain results of these stool tests, but documented that an antibiotic had been prescribed. Of the four employee records, two documented episodes of diarrheal illness in February and March 2005, one documented a diarrheal episode in July 2004, and one documented recurrent bouts of abdominal symptoms with diarrhea between 2002 and 2004.

Survey Results of 7-128 Run/Test Line Employees

On March 16, 2005, the NIOSH medical officer administered questionnaires to 7-128 HX Line A second shift run/test workers (Line B was not operating during second shift). Four of the five employees participated. On March 17, 2005, ten employees from first shift 7-128 run/test (Lines A and B) were asked to participate in the questionnaires; eight participated.

Of the 12 run/test workers who participated in the questionnaires, eight were female. The average employee age was 41 years (range: 24-56); the average number of years working at UT Carrier was 8 (range: 1-19); and the average number of years working as run/test operator was 4 years (range: 0.5-12). Eight interviewees worked on Line A and four on Line B. Five were current smokers; none reported hobbies that included exposure to solvents, glues, or other chemicals.

Table 7 describes the prevalence of symptoms during work in the 2 months prior to the survey among 7-128 run/test employees (N=12). The most commonly reported symptom was eye irritation (12 of 12 employees), followed by nasal irritation (10), headache (10), nasal congestion (9), cough (8), and throat irritation (7).

Eleven of 12 run/test employees reported symptoms that would resolve completely or improve when away from work, such as over weekends or vacations. Four reported three or more of the following symptoms in the 2 months prior to the survey during work: shortness of breath, chest tightness, cough, and/or wheeze; two of the four were current smokers. In addition, two employees reported nasal sores and one reported nosebleeds in the 2 months prior to the survey. Nine of the 12 reported seeking medical care for symptoms; two reported their symptoms to the plant medical unit. All interviewed workers reported concerns about poor ventilation and too much smoke in their work areas. Four reported experiencing more smoke after the new lines A and B were built (approximately 2-3 years before this site visit).

DISCUSSION

7-128 HX Washer

This HHE determined a probable cause for diarrheal symptoms among 7-128 HX area workers by finding enteric bacteria, some potentially pathogenic, in the wash water of the 7-128 HX washer machine. After receiving our interim report of January 28, 2005, management attempted to remedy problems with the 7-128 HX washer, assuming that the initial contamination by enteric bacteria was associated with a drainage pipe between the machine and a sewer line. On January 31, 2005, the company severed and capped the line, which management said had a faulty back-flow valve, and subsequently cleaned the machine with a chlorine solution. We advised the use of chlorine (sodium hypochlorite) mixed with clean water in a 1 to 100 dilution (e.g., 1 liter of 5.25% to 6% household bleach to 100 liters of clean water) to reach a concentration of 525 to 600 milligrams per liter (mg/L) of available chlorine. However, water and sludge sampling on March 16-17, 2005, indicated the continued presence of bacteria associated with fecal contamination. Furthermore, workers reported that, after a short improvement coinciding with the capping and cleaning, odors returned especially after weekends or when regular maintenance of the 7-128 washer was delayed due to heavy production schedules.

It is possible that the initial source of contamination was severed when the sewer line was capped, but the bacteria were not totally eliminated despite machine cleaning. Microorganisms often form biofilms, colonies of bacteria within a protective polysaccharide matrix. *Klebsiella* and *Citrobacter* (genera found in the machine on our final sampling) are known to create complex biofilms that are resistant to sanitation procedures.[11] Effective methods to disinfect surfaces once a biofilm has developed are not well established. One study reported in the scientific literature suggested that mechanical cleaning is better than chemical disinfection, another study suggested that disinfectant foams were effective, and another suggested sanitizing at intervals of less than 12 hours.[12, 13, 14]

Possible routes of exposure between the machine and workers were evident. For example, we observed employees working on the 7-128 HX washer machine without gloves and drinking and/or eating food on tables near the machine. Employees working in this area reported a high prevalence of gastrointestinal symptoms, including diarrhea, and one symptomatic employee was found to have *Aeromonas* bacteria growing in a stool culture. Another employee had been treated for a bacterial gastrointestinal infection.

A definitive cause-effect relation cannot be established with a small, cross-sectional study such as this one at the Carrier Corporation. Interpreting results of environmental sampling taken from a changing environment, such as the rinse water storage tank, is difficult. Fluctuations in microbial concentrations can occur even on a minute-to-minute basis, and it is unrealistic to expect that the types of microbes in the 7-128 HX washer machine would remain constant during the 2 years when the workers reported persistent health problems.[15] Nor did we expect the limited number of water samples collected from the tank to be sufficient to provide a complete categorization of the organisms present in all microhabitats within the tank. The collected samples represent a snapshot of some types of organisms present and, most importantly, revealed the presence of fecal contamination. Additionally, stool cultures are known to have limitations; for example, specimen collection and handling that leaves the specimen at room temperature for prolonged periods may lead to a false-negative culture. Performing a single stool culture in symptomatic individuals suspected of bacterial diarrhea may not capture the offending organism.[16]

The fact remains that diarrhea-causing bacteria were identified in the washer operation, and employees working in the 7-128 washer area who were not protected with appropriate PPE developed diarrhea. The workers' complaints were quite specific to the 7-128 HX washer, and

the hypothesis that this machine was a unique source of problems at the plant is further supported by the lack of fecal contamination in either of the other two similar machines sampled. Fecal contamination is unexpected and undesirable in a typical industrial process and should be addressed. We concluded that 1) the presence of enteric bacteria in the machine, 2) the work location of employees who reported gastrointestinal problems, and 3) the finding of related types of bacteria in stool and washer water samples provide sufficient evidence to justify the recommendations listed below.

7-128 Run/Test Line

The face velocities of the canopy hoods were within recommended guidelines, but when using smoke tubes we observed that when the blower of the furnace was engaged (a step in the testing) the canopy exhaust hood was completely overwhelmed. Instead of being captured and removed, the smoke was pulled down through the breathing zone of the worker standing in front of the hood. Although concentrations of VOCs and CO were low, most surveyed run/test workers reported eye and upper respiratory irritation. The cause of sensory irritation is an active area of research, and the results of recent mouse bioassays have suggested that terpenes' (e.g., limonene and pinenes found in this study) oxidation reactions may generate sensory irritation at very low concentrations.[17]

CONCLUSIONS

At the time of the NIOSH evaluation, a health hazard existed in the 7-128 HX washer machining area due to fecal contamination of the rinse water. Employees working in the area a reported high prevalence of gastrointestinal symptoms, including diarrhea, and one employee with active diarrheal symptoms was shown to have a bacterial cause for the symptoms. Another had been treated by a private physician for a bacterial gastrointestinal infection.

The 7-128 run/test canopy hood exhaust ventilation systems were not effective in capturing emissions during the tests we observed. During the blower phase of furnace testing smoke escaped into the breathing zone of the employees. It is possible that low concentrations of VOCs in the breathing zone of workers could contribute to irritant symptoms reported by some workers.

RECOMMENDATIONS

What the Company Should Do

1. Use a company experienced in disinfection procedures to thoroughly clean the components of the 7-128 HX washer machine (water tank, sumps, nozzles) and the area immediately surrounding this machine (including the employee break table). Other surfaces that have come in contact with contaminated water should be cleaned with detergent and clean water. Disinfectants should be applied with care to minimize overuse and unnecessary worker exposure to chemicals.

2. Re-sample the 7-128 HX water tank, sumps, and nozzles for enteric bacteria to ensure that the disinfection has been successful or if odors persist or reappear near the 7-128 HX washer machine. If necessary, disinfect the 7-128 HX washer and sample the machine for enteric bacteria again.

3. Permanently prohibit eating, drinking, chewing gum, or smoking in the production areas of the plant, including the employee break table located near the 7-128 HX stamping and washer machine.

4. Provide water resistant protective gloves, protective sleeves, and aprons (vinyl or other non-latex) in addition to cloth work gloves for employees who may come in contact with the contaminated 7-128 HX rinse water. This should continue until the 7-128 HX water has been successfully disinfected.

5. Modify the run/testing procedures or improve the local exhaust canopy ventilation

system to better contain emissions when the furnace blower is activated during the testing.

6. Strengthen the existing Health and Safety Committee, ensuring open communication between management and employees. The Committee should meet regularly, consist of management and union representatives appropriately supported with resources, and deal with health and safety issues promptly. Disseminate health and safety information, including the conclusions and recommendations of this report, to all workers to prevent work-related illnesses and injuries.

6. Encourage workers to report health concerns to the plant Medical Department. The Medical Department should develop an ongoing surveillance system to periodically review health logs to identify trends in work-related illnesses and injuries. Such a system should be coordinated with the industrial hygiene and other health and safety staff.

7. Instruct workers with work-related health concerns to be evaluated by a physician knowledgeable in occupational illnesses and injuries.

What the Employees Should Do

1. Do not take food, beverages, chewing gum, or cigarettes into the 7-128 HX machine area.

2. Wash your hands and face with soap and water before eating, drinking, or smoking.

3. Wash rinse water-contaminated skin as soon as possible with soap and clean water.

4. Until the 7-128 HX washer water system has been adequately disinfected:

a. Wear water-resistant gloves under the work gloves provided.

b. Wear water-resistant sleeves if rinse water may contact forearms.

c. Wear water-resistant coveralls that can protect clothing from splashing.

d. Change into clean clothes after the work day is finished. Place dirty work clothes in a plastic bag to carry them home and wash them in your regular laundry in hot water. Until the clothes are laundered, persons who handle these clothes should wash their hands after handling them.

e. Shower, wash your hair, and change into clean clothes as soon after work as possible.

5. Contact your supervisor, the company health department, or a management/labor health and safety committee member if unusual odors are noticed near the 7-128 HX washer machine.

6. Report health concerns to the Medical Department.

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Table 1
Comparison of Washer Machines Tested for Microbial Contamination
United Technologies/Carrier Corporation
HHE 2005-0024-3000

Machine	IRMCO 090G15 Fluid Used	Magna Spray 3410 Washer Soap Used	Water heated (to 140ºF)
7-128 HX Washer* (spray/blow-off process)	Yes	No	No
7-128 Batch Washer (batch process)	Yes	Yes	Yes
7-127 HX Washer (spray/blow-off process)	No	Yes	Yes

*Suspect machine

Table 2.
Enteric Bacteria Collected from Water and Sludge in Washer Machines
United Technologies/Carrier Corporation
HHE 2005-0024-3000

Machine (process)	Sample Types	Concentration(colony forming units/ milliliter) Sample Date 1/13/05	Concentration (colony forming units/ milliliter) Sample Date 2/1/05	Concentration(colony forming units/milliliter) Sample Date 3/17/05
7-128 HX (Spray/ blow-off)	Tank water	10,000,000 unspecified enteric bacteria	70,000,000 unspecified enteric bacteria	10,000,000 Klebsiella oxytoca 5,000 Citrobacter freundii
	Tank water	1,200,000 unspecified enteric bacteria	-	-
	Tank water from nozzles	5,000,000 Citrobacter koseri 3,000,000 Enterobacter agglomerans 1 3,000,000 Enterobacter agglomerans 2	-	-
	Sludge collected in water tank	14,000,000 unspecified enteric bacteria 5,700,000 Aeromonas hydrophila 2,900,000 Citrobacter youngae	50,000,000 Aeromonas hydrophila	250,000,000 Klebsiella oxytoca 83,000,000 Citrobacter diversus
	Sludge collected from storage can	7,500,000 unspecified enteric bacteria 2,300,000 Citrobacter youngae	-	6,900,000 Klebsiella oxytoca 3,500,000 Citrobacter freundii
	IRMCO Fluid	-	Not Detected	-
	Tap water supply	-	Not Detected	-
7-128 Batch	First tank water	Not Detected	-	-
	First tank water	Not Detected	-	-
	Second tank water	Not Detected	-	-
7-127 HX (Spray/ blow-off)	Tank water	Not Detected	-	-
	Tank water	Not Detected	-	-
	Tank water	Not Detected	-	-

Dash (-) indicates that a sample was not collected on this date

Table 3
Carbon Monoxide Concentrations at Assembly Lines A and B
United Technologies/Carrier Corporation
HHE 2005-0024-3000
March 15-16, 2005

Location	Sampling Duration (minutes)	Peak (ppm)	TWA (ppm)
Line A, East End	9 hours, 29 min	21	5
Line A, West End	9 hours, 14 min	15	4
Line B, East End	8 hours, 53 min	8	3
Line B, West End	8 hours 51 min	22	4
NIOSH Recommended Exposure Limit		200 C‡	35
OSHA Permissible Exposure Limit			50
‡ Ceiling limit, not to be exceeded			

Table 4
Face Velocity on Canopy Hoods at Assembly Lines A and B
United Technologies/Carrier Corporation
HHE 2005-0024-3000
March 15-16, 2005

7-128 run/test line	Average Air Flow (feet per minute)
A Duct #11	70
A Duct #20	57
B Duct #1	67
B Duct #10	83

Table 5
Symptom Prevalence among 7-128 HX Line Washer Machine and Run/Test Employees
United Technologies/Carrier Corporation
HHE 2005-0024-3000
January 12, 2005

Persistent Symptom During Work in Prior 2 Months:	All employees (N=11)	Washer employees (N=8)	Run/test employees (N=3)
Eye irritation	11	8	3
Nasal irritation	10	8	2
Nasal congestion	10	7	3
Headache	10	7	3
Cough	10	7	3
Throat irritation	8	6	2
Cough with phlegm	7	5	2
Diarrhea	5	5	0
Nausea or vomiting	4	2	2
Rash	4	4	0
Abdominal pain/cramping	3	3	0
Chest tightness	3	3	0
Shortness of breath	2	2	0
Wheeze	2	1	1

Table 6
Symptom Prevalence, Frequency, and Work-relatedness among 7-128 HX Washer Machine Employees (N=20)
United Technologies/Carrier Corporation
HHE 2005-0024-3000
February 1-2, 2005

Symptoms in past 6 months	Number of workers with symptom	Frequency of symptom:				Symptom improves away from work
		Not in past 4 weeks	1-3 times in past 4 weeks	1-3 times a week	Daily or almost daily	
Nausea or upset stomach	18*	3	7	6	1	9
Diarrhea**	12	4	4	1	3	0
Abdominal pain, cramping	9	3	4	1	1	1
Vomiting	3	2	1	0	0	0
Blood in stool	1	0	1	0	0	0

* One participant with symptom of nausea/upset stomach did not respond to frequency question.

** Diarrhea defined as three or more loose, watery stools in one day

Table 7 Symptom Prevalence among 7-128 Run/Test Employees United Technologies/Carrier Corporation HHE 2005-0024-3000 March 16-17, 2005	
Symptom during work in the 2 months prior to survey	Number of interviewed workers reporting symptom (N=12)
Eye irritation	12
Headache	10
Nasal irritation	10
Nasal congestion	9
Cough	8
Throat irritation	7
Shortness of breath	4
Cough with phlegm	4
Diarrhea	3
Chest tightness	3
Wheeze	3
Rash	2
Abdominal pain	1
Nausea or vomiting	1

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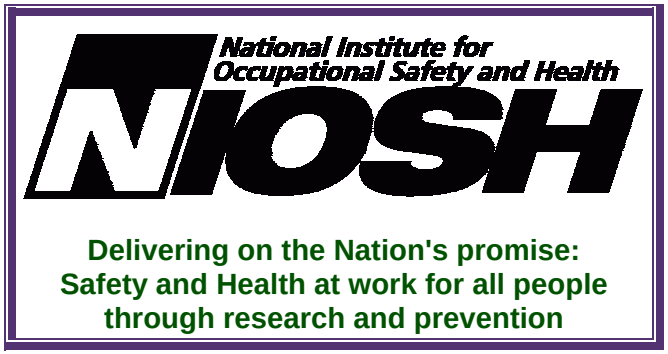

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