HETA 99-0091-2846
McCain Foods, Inc.
Plover, Wisconsin

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PREFACE

The Hazard Evaluations 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 employer or authorized representative of employees, to determine whether any substance normally found in the place of employment has potentially toxic effects in such concentrations as used or found.

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 Lynda M. Ewers and Loren C. Tapp of HETAB, Division of Surveillance, Hazard Evaluations and Field Studies (DSHEFS). Field assistance was provided by Ellen Blythe, Michael Box, and Patricia McGraw of NIOSH. Analytical support was provided by Mike Whittner of the Health Effects Laboratory Division of NIOSH, Kimberly Kirkland of PathCon® Laboratories, and DataChem Laboratories. Desktop publishing was performed by Ellen Blythe and David Butler. Review and preparation for printing were performed by Penny Arthur.

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Highlights of the NIOSH Health Hazard Evaluation

Endotoxin exposures during potato processing

NIOSH investigators responded to a confidential employee request for a health hazard evaluation (HHE) at the Plover plant of McCain Foods, Inc. There were concerns about health problems due to chlorine gas, carbon monoxide gas, and other unknown substances.

What NIOSH Did

- We tested the air for chlorine gas and carbon monoxide when workers were cleaning the floors and in areas where workers thought there were health problems.
- We measured dust levels in air.
- We tested the air for parts of bacteria called endotoxins.
- We interviewed workers about their health problems.
- We conducted a questionnaire survey among processing and packaging workers.

What NIOSH Found

- Dust levels were low in all areas of the plant.
- No chlorine gas or carbon monoxide was found.
- High levels of endotoxins were found in the production area of the plant but not in the packaging areas.
- More respiratory health problems were reported by workers in the production areas than those in the packaging areas.

What the McCain Foods Managers Can Do

- Engineer the gutter system so that the time water spends in the system is reduced and steam is not released into the work areas.
- Clean and maintain the gutter system more often.
- Improve ventilation in processing areas where endotoxin exposures are possible.
- Be careful when reducing water usage not to increase potato dust levels.
- Be very careful when using recycled water so that workers are not exposed to it.
- Monitor reported health problems.
- Send workers with respiratory problems to a doctor knowledgeable in occupational medicine.
- If recommended by an occupational medicine physician, reassign workers with respiratory problems to areas where exposures are lower.

What the McCain Foods Employees Can Do

- Notify your supervisor if the gutter system becomes clogged or has a strong odor.
- Maintain good work cleanliness and safety practices.
- Tell health unit personnel if you have health problems, especially respiratory problems.

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

Health Hazard Evaluation Report 99-0091-2846
McCain Foods, Inc.
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SUMMARY

On January 29, 1999, the National Institute for Occupational Safety and Health (NIOSH) received a confidential employee request for a Health Hazard Evaluation (HHE) at the Plover, Wisconsin, facility of McCain Foods, Inc., a plant which produces frozen potato products. The requesters expressed concern regarding possible health effects, especially respiratory problems, which they believed were associated with exposures to carbon monoxide (CO), chlorine gas (Cl_2), and unknown chemicals. On March 30, 1999, a preliminary NIOSH investigation focused on the potential for Cl_2, and CO exposures. Screening tests for the presence of both chemicals in air were negative. However, informal worker interviews suggested that health problems might be widespread.

During a July 25-26, 1999, site visit, NIOSH researchers investigated whether the health effects were related to bioaerosols, such as bacteria, fungi, or their products (especially endotoxins, which are components of the coats of Gram-negative bacteria). A questionnaire survey of workers was conducted to determine the frequency of respiratory and other health symptoms and full-shift, personal breathing zone (PBZ) samples were collected to estimate time-weighted average (TWA) concentrations of airborne particulates and endotoxin. Data was categorized by whether it was collected in the potato processing areas or in the packaging areas of the plant.

The questionnaire survey of 115 of 185 workers found the prevalence of chest tightness was more than 2.5 times greater in the processing workers than the packaging workers (39% versus 14%, prevalence rate [PR] = 2.8, 95% confidence interval [CI]: 1.36-5.75). Processing employees also had twice the prevalence of shortness of breath (43% versus 18%, PR = 2.4, 95% CI: 1.29-4.63), twice the prevalence of pneumonia or chest flu episodes (48% versus 25%, PR = 2.0, 95% CI: 1.16-3.33) , and one and one-half times the prevalence of eye, nose, or throat irritation (55% versus 33%, PR = 1.7, 95% CI: 1.07-2.57) compared to packaging employees. These findings remained statistically significant after controlling for the confounding factors of age and cigarette smoking.

Airborne endotoxin concentrations in the processing area greatly exceeded those in the packaging area. PBZ endotoxin concentrations in the processing area of the plant averaged 168 endotoxin units per cubic meter (EU/m^3), but those in the packaging area were less than the lower limit of detection (0.018 EU/m^3). A likely source of

bacteria, and, therefore, endotoxins, is a wastewater gutter system located throughout the processing area of the plant.

The higher rates of respiratory symptoms in production employees and the higher levels of endotoxin in the production area compared to packaging are consistent with an association between those symptoms and endotoxin exposures at the Plover facility. However, a causal association cannot conclusively be established because of the cross-sectional nature of the study. Our results are consistent with those reported in published studies of other potato processing plants, some of which demonstrated high endotoxin levels associated with health effects. Exposures to endotoxins should be reduced to the extent feasible by instituting engineering controls designed to prevent aerosolization of wastewater from the gutter system. Maintenance and cleaning procedures on the gutter system should be improved, thereby reducing the potential for bacterial growth in the wastewater. Workers' health should be monitored, and workers with endotoxin-related health problems should be offered reassignment to areas where endotoxin exposures are lower.

Keywords: SIC 2037 (Frozen Fruits, Fruit Juices, and Vegetables), endotoxin, chlorine, carbon monoxide, potatoes, respiratory symptoms

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INTRODUCTION

On January 29, 1999, the National Institute for Occupational Safety and Health (NIOSH) received a confidential employee request for a Health Hazard Evaluation (HHE) at the Plover, Wisconsin, facility of McCain Foods, Inc. The requesters expressed concern regarding possible health effects, especially respiratory problems, which they believed may be associated with exposures to carbon monoxide (CO), chlorine gas (Cl_2), and unknown chemicals.

Two site visits were conducted by NIOSH investigators. Opening conferences were held with management and employee representatives on each occasion. On March 30, 1999, a preliminary investigation focused on the potential for Cl_2 and CO exposures, and a limited number of worker interviews were conducted. During the July 25-26, 1999, site visit, researchers collected data to investigate whether workers' health effects were related to bioaerosol exposures, such as bacteria, fungi, or their products. In addition, personal breathing zone (PBZ) concentrations of airborne particulates were estimated, and a health questionnaire survey was administrated to all available workers on two shifts.

BACKGROUND

Production of potato products at the Plover plant occurs throughout most of the year. To achieve this year-round schedule, spoilage of the autumn-harvested potatoes is reduced by applying a carbamate herbicide (Clean Crop Sprout Nip 7A, Platte Chemical Co., Fremont, Nebraska) and by storing the potatoes in climate-controlled bunkers. On a typical day, about three million pounds of potatoes are transported from the bunkers to the plant. At the loading dock, located in an isolated building, potatoes are rolled out the rear of inclined semi-trailers onto a conveyor for preliminary sorting. They enter the main processing building through a water-transport pipe. After skin removal in the blanching/peeling/scrubbing machines, the potatoes are transported to a trim room for manual "specking," i.e., trimming black spots. Further sorting occurs before they enter cutting machines of various types, depending upon the desired product. Two main lines (Plover 1 and 2 areas) slice the potatoes into french fries, which are partially fried before freezing and packaging. Packaging occurs within the same building as processing, but in a separate area. About two million pounds of potato products per day are distributed to commercial outlets and grocery stores by an independent company.

Central to the manufacturing process is the water-transport system, which moves potatoes into the building and between some processing steps. About two and one-half million gallons of chlorinated water per day are needed in this system. Water is recycled in some machines, notably the blanching machine, which requires heated water (140-160°F). Wastewater generated during the water transport is captured in a gutter system covered by an open metal grid, which extends throughout the Plover 1 and 2 areas (but not the packaging area). The gutter system includes pumping stations to force water to a treatment facility.

Throughout the day, floors and machinery are sprayed with water containing various disinfection products (e.g., Ultra Foam and Ultra Foam B, both chlorinated liquid detergents; Can D Dairy Hi Foam, a phosphoric acid foam wetting agent; Q-K, a quaternary ammonium disinfectant and sanitizer; Kelly Foam, a neutral detergent; and ALAS-478 acid anionic cleaner, all products of Chaska Chemical Company, Inc., Savage, Minnesota). The resulting wastewater is flushed into the gutters. According to management, potato processing is halted at intervals ranging between 10 and 24 hours while the gutters and blanching machines are flushed, a process requiring about one hour. On the first Saturday of each month, or over a holiday period, production is halted for a 24-hour period while the entire plant is disinfected by washing machinery and floors with the above-mentioned products.

The Plover plant operates 24-hours a day, 7 days a week, and employs approximately 850 people; 180-200 employees work in the Plover 1 and 2

processing areas and about 200 work in the packaging area. There are four 12-hour shifts; shifts A and C alternate working 6 a.m. - 6 p.m., and shifts B and D alternate working 6 p.m. - 6 a.m. Each shift works a total of seven 12-hour shifts over 14 days. The primary manual tasks performed in Plover 1 and 2 processing areas are: (1) specking, performed by "grade one" workers (8-10 per shift), (2) cleaning both floors and machinery performed by "clean up" employees (12 per shift), and (3) machinery operation performed by "operators" (at least 2 per shift).

McCain Foods, Inc. has acquired and operates several potato processing plants throughout the United States, of which the Plover facility is the largest. Since the Plover facility's acquisition in 1997, a general policy to standardize processes among McCain plants has resulted in phased modifications to the physical plant and operations. For example, prior to the NIOSH site visits, walls had been removed throughout the factory, machines had been vented to the outside, and plans to remove the gutter system were under discussion.

METHODS

Medical

During NIOSH's initial site visit, 12 employees working in the Plover 1 or 2 processing areas were chosen systematically to be interviewed from the areas having the greatest number of employees reporting health concerns and symptoms. Nine of the twelve had a history of shortness of breath at work, six had tightness in the chest, four had cough, four had sore throat, four had eye irritation, and one had wheeze. Four had a history of symptom worsening after 4-6 hours at work, and improving 2-3 hours out of work. Two reported an increase in symptoms when they worked around the gutters. Based on this information, we designed a questionnaire survey to be administered at the second site visit.

NIOSH investigators conducted the questionnaire survey at the McCain Foods work site on July 25-26, 1999. All employees working in the Plover 1 and 2 processing areas and packaging areas during the NIOSH site visit were invited to participate. Employees working in the packaging department were chosen as the comparison group because of their minimal exposure to the processing areas of the plant. The purpose of the questionnaire was to determine the prevalence of symptoms among participating employees and to address the question of whether reported symptoms were related to workplace exposures. The questionnaire included questions about symptoms and illnesses and their potential relationship to work exposure, demographic factors (age, gender, etc.), medical and work history, and non-occupational exposures which could affect the health symptoms being experienced.

During the first site visit, company injury/illness records were reviewed for the time period between July 1998 and July 1999. The Occupational Safety and Health Administration (OSHA) Log and Summary of Occupational Injuries and Illnesses Form 200 (OSHA 200 log) was reviewed for the years 1996 through July 1999.

A statistical analysis was done to assess the relationship between reported symptoms and illnesses and occupational exposure to potato processing. Employees who reported spending at least 50% of their total work-time in the processing areas were defined as "exposed" workers; those with less than 50% of their work-time in processing were defined as "unexposed." The magnitude of a difference was assessed by the prevalence ratio (PR); a 95% confidence interval which excluded the number 1 was considered to indicate a statistically significant finding. The PR represents the prevalence of the symptom in the exposed group relative to the prevalence in the unexposed group. A PR of 1 means that no association between the symptom/illness and exposure has been found. A PR greater than 1 means an association has been found. For example, a PR of 2 would mean that a person in the exposed group is 2 times more likely to have reported the symptom than a person in the unexposed group. We considered the following list of non-occupational factors to see if they had an effect on the prevalence ratios: age, cigarette smoking,

farming, exposure to birds, welding, glues, wood working, and isocyanates.

Industrial Hygiene

Area air samples were collected for screening purposes using a bellows pump and associated colorimetric detector tubes (Dräger,® Inc.) for Cl_2 and CO. Specific processes and areas of the plant identified by the requesters as the possible source of these gases were sampled. Detector tubes have an accuracy of +/- 25-30% and a measuring range of 0.3-5 parts per million (ppm) for Cl_2 and 5-150 ppm for CO.

Twenty-three full-shift personal breathing zone (PBZ) samples and eight area air samples were collected for analysis of total airborne particulates and endotoxin; endotoxin is a component in cell walls of Gram-negative bacteria (GNB). All workers on the day and night shifts (B and D crews) were eligible to volunteer and participate in the study. Endotoxin samples collected from the processing side of the plant were considered to be from the "exposed" side, and background samples were collected from the packaging side. Area samples were distributed throughout the packaging and processing work zones. The samples were collected on tared 5.0 micrometer (μm) pore size, 37 millimeter (mm) polyvinyl chloride filters using a calibrated flowrate of 2 liters per minute (Lpm). Samples were weighed using NIOSH method 0500[1], which has a limit of detection of 0.02 milligrams (mg). The filters were subsequently analyzed for endotoxin content using the Kinetic-QCL Limulus Amebocyte Lysate (LAL) assay kit (BioWhittaker, Walkerville, Maryland) according to the manufacturer's recommended procedures. For these analyses, 10 endotoxin units (EU) are equivalent to 1 nanogram of endotoxin. The limit of detection (LOD) for the endotoxin analyses was 0.5 EU per sample, which results in a minimum detectable concentration (MDC) of 0.018 endotoxin units per cubic meter (EU/m^3) based on a sample volume of 28 m^3, the minimum volume of the PBZ air samples. Results of endotoxin air monitoring and PBZ particulate levels were compared to relevant evaluation criteria if available and between the processing and packaging areas of the plant. Statistical analysis was performed using SAS® software.[2]

In addition to air sampling for endotoxins, bulk wastewater samples from the gutters running throughout the plant were analyzed for endotoxin and cultured for aerobic bacteria and fungi. All bulk samples were chilled and sent to the laboratory within 24 hours of collection. Fungi were grown on malt extract agar (MEA) and bacteria were grown on R2A agar. The MEA and R2A plates were incubated at room temperature (23±3°Celsius) for 7 days and 4-7 days, respectively. The number and characteristics of all fungi and the three most predominant bacteria were recorded. Fungi were identified to the genus level by direct microscopic observation. Bacteria were identified to the genus level by standard Gram-staining techniques and biochemical tests (i.e., catalase, oxidase, oxidation, and fermentation of glucose). Specific human pathogenic bacteria that require a selective medium and elevated incubation temperatures, such as *Legionella*, are not detectable using these tests.

EVALUATION CRITERIA

As a guide to the evaluation of the hazards posed by workplace exposures, NIOSH field staff employ 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 preexisting 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 thus potentially increase the overall exposure. Finally, evaluation criteria may change over the years as new information on the toxic effects of an agent become available.

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

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. Table 1 presents the relevant evaluation criteria for the substances investigated by NIOSH at the Plover facility. However, inhalable particulate criteria are applicable only to substances for which there is no evidence of specific toxic effects; the criteria may not be appropriate at this plant, where bioaerosols could reasonably be expected to result from the processing of potatoes. Workers may display various responses to bioaerosols ranging from relatively low levels of irritation to serious or fatal effects. Occupational exposure limits for microorganisms or their products have not been established by OSHA or NIOSH. Microorganisms and associated exposures are reviewed below.

Microorganisms

Acceptable levels of airborne microorganisms 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. The current strategy for on-site evaluation of environmental microbial contamination involves an inspection to qualitatively identify sources (reservoirs) of microbial growth and potential routes of dissemination. Air samples for microorganisms, endotoxins, or other microbial components can be collected to document the presence of suspected microbial contaminants.

Endotoxins, lipopolysaccharide compounds from the outer cell wall of GNB, are released from the bacteria when they die.[6,7] GNB are ubiquitous in the environment. In experimental studies, human volunteers exposed via inhalation to high levels of endotoxins experience airway and alveolar inflammation as well as chest tightness, fever, and malaise and have an acute reduction in lung function, as measured by the forced expiratory volume in one second (FEV_1).[8,9] Airborne endotoxin exposures between 45 and 400 EU/m^3 have been associated with acute airflow obstruction, mucous membrane irritation, chest tightness, cough, shortness of breath, fever, and wheezing.[7,10,11,12] Chronic health effects that have been associated with airborne endotoxin exposures include chronic bronchitis, bronchial hyperreactivity, chronic airways obstruction, hypersensitivity pneumonitis, and emphysema.[9] A permanent decrease in pulmonary function, along with respiratory symptoms, has been reported in several cross-sectional epidemiological studies.[8]

While a causal role for endotoxins in human health effects has become more generally accepted in recent years, a dose-response relationship has not been established. One reason for the lack of relationship is that the most commonly used method for analyzing endotoxins, the LAL assay, is a comparative bioassay.[8] In other words, changes in the LAL test procedures themselves can erroneously appear as changes in the measured endotoxin activity levels. Until problems with the LAL test are resolved, it is not possible to compare endotoxin samples collected at different times or analyzed by different laboratories. For these reasons, ACGIH has proposed that relative limit values (RLVs), rather than the more usual TLVs, be used as a reference for endotoxin.[8]

RLVs require that samples be collected from an area considered to represent background levels of endotoxin and be analyzed at the same time as the samples of interest. The RLV is expressed in terms of a comparison between the exposed and background areas.[8] ACGIH proposes that, if there are health effects consistent with endotoxin exposure, and if the endotoxin exposures exceed 10 times the simultaneously determined background levels, then the RLV action level has been exceeded. When exposures exceed the RLV action level, remedial actions to control endotoxin levels are recommended. It is important to note that the nature of the relationship between the RLV and health effects has not been elucidated at the time of writing this report. Consequently, our recommendations are only based on whether the RLV action level has been exceeded or not, not on the magnitude of the endotoxin level.

RESULTS

Medical

The 163 OSHA 200 log entries for the years 1996 through July 1999 included entries for musculoskeletal injuries, eye injuries, burn injuries, and one case of heat exhaustion. No cases of respiratory illness were recorded. Review of company injury records revealed five reports of chest pain, six of dizziness or lightheadedness, and three of respiratory symptoms, including one asthma exacerbation.

The McCain's facility health unit is staffed by an occupational health nurse Monday through Friday during first shift. All employees undergo a baseline health assessment, which includes a medical history and an audiogram, followed by yearly audiograms. Those employees who are part of the Hazmat Team (e.g., first responder, boiler and refrigeration workers, and team leaders) also have an annual medical assessment, which includes respiratory fit test, OSHA respiratory questionnaire, pulmonary function testing, electrocardiogram, chest x-ray, blood tests, vision testing, and physical exam performed by a contracted offsite medical clinic.

Of the 188 employees working in the processing and packaging areas during our site visit, 115 (61%) completed a questionnaire survey. Of the 115 participants, 113 could be categorized as "exposed" or "unexposed" based on questionnaire responses ("exposed" defined as working at least 50% of the time in processing areas; "unexposed" defined as working less than 50% of the time in processing areas.) Fifty-six (50%) of the 113 were considered exposed and included 46 processing, 4 lab quality assurance (QA), 3 packaging, 1 salaried, and 2 "other" employees. Fifty-seven (50%) of the 113 employees were considered "unexposed" and included 49 packaging, 4 processing, 1 lab QA, and 3 "other" personnel. The participating employees represented workers from two of the four rotating shifts. The number and percentages of self-reported symptoms and illnesses are given in Table 2. The most commonly reported symptoms among all participants included: sinus problems, 56%; persistent cough, 50%; irritation of eyes, nose, or throat, 44%; and unusual tiredness or fatigue, 42%. A symptom was defined as being work-related if the respondent answered "yes" to the question: "Do you think it [the symptom] is related to work?" The percentages of work-related symptoms in those with the symptoms were greatest for irritation of eyes, nose, or throat, 81%; unusual shortness of breath,

70%; unusual tiredness or fatigue, 68%; ache all over, 66%; and tightness in chest, 66%.

The prevalence of reported symptoms by exposure category are given in Table 3. Among the statistically significant findings, chest tightness was 2.8 times more prevalent in the exposed group than in the unexposed. Exposed employees also had 2.5 times the prevalence of shortness of breath, 2 times the prevalence of pneumonia or chest flu episodes, 1.7 times the prevalence of eye, nose or throat irritation, and 1.5 times the prevalence of persistent cough. Although not shown in Table 3, the prevalence of *work-related* shortness of breath (36%) and *work-related* chest tightness (34%) in the exposed workers were more than double those in the unexposed workers (18% and 11%, respectively); for work-related shortness of breath, PR = 2.2 (95% CI: 1.00-4.78) for chest tightness, PR = 2.6 (95% CI = 1.10-6.17). After considering non-occupational factors, we found no meaningful effect; therefore, it was considered unnecessary to adjust the prevalence ratios for these factors.

Among the different job titles, grade I spec employees (also known as "trimmers"), operators, and clean-up employees had the highest prevalences of most symptoms, particularly respiratory symptoms, as shown in Table 4. These jobs are located in the processing areas. The highest prevalence of respiratory symptoms reported to be work-related were among clean-up and grade I spec employees. The prevalence of symptoms by area are shown in Table 5. Employees working in the Plover 2 processing area had the highest prevalence of most symptoms.

Industrial Hygiene

Table 6 presents the locations and results of the Cl_2 and CO monitoring. Chlorine was not detected in the screening samples collected at any location; the LOD was 0.3 ppm. Sampling for CO was generally negative; a slight atypical color on one sample may have been due to interfering compounds in that location. If the color was due to the presence of CO, the concentration indicated was less than 5 ppm CO, well below the occupational exposure limit.

Table 7 lists the taxa of bacteria cultured from the wastewater moving through the gutter system, including samples from the pump pit, distribution area, blancher, 2 peelers, sp3 area, and the main sump leading to the wastewater treatment facility. Many of the taxa are commonly found in soil or vegetable matter, which would be expected at a potato processing plant. Counts of the colony forming units of bacteria and fungi ranged from 8.1 x 10^6 to greater than 3.0 x 10^7, and from less than 10 to 3.2 x 10^4, respectively.

Table 8 displays the PBZ-TWA concentrations of total particulates and endotoxin, and Table 9 displays these results for the area samples. Total particulate concentrations were low. A t-test of the log transformed PBZ-TWA particulate concentrations indicated that PBZ-TWA concentrations from processing area employees were significantly higher than those for employees in the packaging area, with geometric means (GMs) of 0.221 mg/m^3 [geometric standard deviation (GSD) = 1.66] and 0.096 mg/m^3 (GSD = 1.88), respectively. PBZ endotoxin concentrations for processing workers averaged 168 EU/m^3, while concentrations for packaging employees were all less than 0.018 EU/m^3, the lower limit of detection for the endotoxin method. In other words, the ratio of endotoxin concentrations in the processing area to those in the packaging area greatly exceeded the RLV action level of 10 times background proposed by the ACGIH.

DISCUSSION

In our initial site visit at McCain Foods, Inc., the primary consideration was the potential for health effects due to chemical exposure, especially Cl_2 and CO. However, no detectable exposures to those substances were identified, even during specific tasks that employees identified as causing symptoms. The possibility of occupational exposure to bioaerosols as a cause of work-related symptoms then was considered. It is difficult to rigorously establish causality in any industry such as potato processing,

where there is a complex mixture of exposures to chemicals and biological agents. Nevertheless, in this case several lines of evidence led us to conclude that the health symptoms experienced by many of the workers are caused by bioaerosol exposures, especially endotoxins, resulting from the growth of microorganisms within the gutter system.

First, conditions observed within the Plover plant, particularly the gutter system, appeared ideal for the growth of microbes and their subsequent aerosolization. Transport water is chlorinated, but the soil, starches, proteins, etc., released from the potatoes during processing produce a very high organic load, which would reduce the effectiveness of chlorination in inhibiting microbial growth. Hot water was recirculated within some of the machines, possibly concentrating potato nutrients prior to the water's release to the gutters. Heated water was added to the wastewater stream, increasing the water temperature. In the pumping pits, the wastewater was highly agitated, producing aerosols. Throughout most of their length, the gutters and pumping pits were only covered with an open metal grid, which readily allows the escape of the aerosols into the work areas.

Second, reported health effects were more common among employees in the processing area, which contains the gutter system. Personal and area air sampling data revealed significantly higher endotoxin levels in the processing areas of the plant compared to the packaging area. Although seasonal health effects data were not collected, higher microbial activity levels during the late spring and summer, when temperatures are higher and the last of that year's potato crop is being processed, could possibly aggravate symptoms in some affected process workers. During the summer (which was when the NIOSH bioaerosol sampling occurred) more decomposing potatoes are brought in from the storage bins, and higher levels of bacteria may exist in the potato transport water.

Third, prevalences of respiratory symptoms (up to 60%) reported by the potato processing employees at the Plover facility are too high to be fully explained by an allergic mechanism. Approximately one of every six individuals in the U.S. is reported to have allergies,[13] with about 30% of the population having atopy, or the predisposition to becoming allergic.[14] It is well known that individuals exposed to airborne organic dust containing fungal, bacterial, plant or animal antigens can develop hypersensitivity illnesses, including hypersensitivity pneumonitis (HP), allergic rhinitis, and allergic asthma to airborne organic materials.[15,16,17,18] The high prevalence rate of some symptoms among the Plover workers, however, implies something more than an allergic etiology, and could be explained by the wide range of biological endotoxin activity including inflammatory, hemodynamic, and immunological responses.

Finally, studies of other potato processing plants support our hypothesis that bioaerosols, particularly endotoxins, are a cause of health effects at the Plover facility. These studies found that 16-46% of process workers reported work-related respiratory symptoms, particularly shortness of breath and chest tightness.[19,20,21] More recent studies of workers exposed to various types of organic dust have focused on the possibility of endotoxin exposures as causal agents for health effects. For instance, a U.S. study in cotton textile workers clearly established that endotoxin, but not dust, exposure levels were related to worker respiratory symptoms.[10] A study of the potato processing industry in the Netherlands found that workers exposed to high endotoxin levels had lower measured lung function at baseline and underwent a greater loss in average FEV_1 over a work shift than the low endotoxin exposure group. Also, those workers with work-related respiratory symptoms had a threefold larger cross-shift decrease in lung function (forced vital capacity [FVC] and FEV_1) than asymptomatic workers.[22] Several researchers have attempted to distinguish the health effects of dust exposure, endotoxin exposure, and potato antigen exposure in dust. While process workers in one study were found to have specific antibodies for potato antigens, prevalence of these antibodies was not correlated with reported respiratory symptoms, i.e., antibodies were formed, but were not associated with reported symptoms.[16] A study conducted in a potato processing plant in Poland found that airborne endotoxin levels peaked dramatically after a blanching process, and the

authors postulated that the process of steaming potatoes may enhance the biological activity of endotoxin by changing its physical structure. Almost 50% of the Polish workers in this study reported work-related respiratory symptoms, and employee FVC and FEV_1 decreased significantly over the work shift.[18] Another study found that bacterial and endotoxin levels are higher in warmer and more humid environments, and exposure appeared to be strongly related to process water temperatures.[23]

Although our results indicate that the high endotoxin levels in the processing areas of the Plover facility are associated with the increased prevalence of work-related respiratory symptoms, certain study limitations must be noted. These limitations include sampling only two of the four shifts working at the facility, the potential for mis-categorizing exposure groups, and sampling exposures over a very short time span, which may not give an accurate picture of the average work exposures. In addition, "transfer bias" may be occurring. A transfer bias occurs when those workers who enter a job and develop health problems remove themselves from the job they feel is causing their problems; those workers who remain tend to have fewer health effects and symptoms. When studying worker populations, the influence of the transfer bias may weaken the associations found between exposure and symptoms and lead to an underestimation of exposure-effect relationships. A recent study found a transfer bias when evaluating potato processing workers five years after an initial survey; workers who had been employed > 5 years had fewer respiratory symptoms, higher lung function, and less atopy than those employed < 5 years.[24]

CONCLUSIONS

Although it is not possible to establish a definitive causal link between the reported health effects and endotoxin exposures, this link is plausible based both on NIOSH findings at the Plover plant and the scientific literature. Potato processing employees reported significantly more respiratory symptoms than packaging employees. Average endotoxin concentrations in the processing area were significantly higher than those in the packaging area and greatly exceeded the ACGIH-proposed RLV action level of 10 times background. Clearly, steps to reduce the endotoxin levels in the processing area of this plant are warranted and can likely be achieved by modifications to the gutter system.

RECOMMENDATIONS

- Engineering modifications to the present gutter system should be instituted to reduce the time that wastewater remains within the gutters and to reduce escape of aerosolized water or steam into the work environment. An experienced engineering firm should be consulted to determine how best to accomplish this.

- Local exhaust ventilation or covering of the gutter or water-transport systems should be considered in those areas where worker exposure to the transport water or wastewater is possible, e.g., in the trim rooms, the area near the blanching machines, and the pumping pits of the gutter system.

- Cleaning and maintenance procedures should be improved for the gutter system by establishing regular, frequent, and thorough flushing.

- Care should be taken that, in the process of reducing exposure to water, excess potato dust is not generated. Potato dust might provoke other health problems, such as allergic reactions to potato antigens, unacceptable levels of nuisance dust, or even exposure to endotoxins that are present on the surface of the potatoes before they enter the plant.

- Recycled water should be considered to be highly contaminated with endotoxins, and worker exposures should be minimized.

- Employees should report health effects thought to be caused by work exposures to the plant medical facility. Those employees found to have potential work-related health effects should be referred to a physician knowledgeable in occupational medicine.

■ As part of the safety and health program, McCain Foods should monitor health problems in a systematic manner designed to identify particular job duties, work materials, machines, or areas of the plant which may be associated with particular health effects. A periodic health assessment, including respiratory symptom history, should be offered to employees working in production areas of the plant. Those with new-onset and/or work-related respiratory symptoms should be evaluated by a physician knowledgeable in occupational medicine. Individuals with occupational illnesses should be protected from exposures to agents presumed to cause or exacerbate the disease by using engineering (e.g., isolation, ventilation) and/or administrative (e.g., work and hygienic practices, housekeeping) controls primarily if feasible, and personal protective equipment (PPE) secondarily. In some cases, workers may have to be reassigned to areas where exposure is minimized or nonexistent. In such cases, the reassigned worker should retain wages, seniority, and other benefits that might otherwise be lost by such a job transfer.

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Table 1. Evaluation Criteria for Chemicals Investigated
McCain Foods, Inc.
HETA 99-0091
July 24-26, 1999

Chemical or Physical Agent	NIOSH REL	OSHA PEL	ACGIH TLV®	Symptoms Related to Excessive Exposure to this Agent
Carbon monoxide	35 ppm ceiling 200 ppm	50 ppm	25 ppm	Headache, rapid respiration rate, nausea, dizziness, chest pain
Chlorine	ceiling 0.5 ppm (15 minute)	ceiling 1 ppm	0.5 ppm 1 ppm STEL	Burning of eyes, nose & mouth; tearing of eyes; cough; choking; pain beneath sternum; nausea; vomit; headache; dizziness; loss of consciousness; fluid in lungs; pneumonia
Particulates not otherwise regulated/specified	NA[2]	15 mg/m^3 (total particulate)	10 mg/m^3 (inhalable fraction)	Irritation of eyes, skin, throat & upper respiratory system

[1] Total and inhalable particulate criteria are applicable only to substances for which there is no evidence of specific toxic effects; the criteria may not be appropriate at this plant, where bioaerosols could reasonably be expected to result from the processing of potatoes.

[2] Not applicable.

Table 2. Self-Reported Symptoms and Illnesses Reported on Questionnaire
McCain Foods, Inc.
HETA 99-0091
July 24-26, 1999

Symptom/Illness	Number (% of 113 participants) who reported symptom/illness	Number (% of participants with symptom) who reported symptom as work-related[1]
Sinus problems	64 (55.7%)	25/61 (41%)
Persistent cough	58 (50.4%)	20/57 (35.1%)
Irritation of eyes, nose, or throat	50 (43.5%)	39/48 (81.3%)
Unusual tiredness or fatigue	47 (42%)	32/47 (68.1%)
Ache all over	44 (38.6%)	27/41 (65.9%)
Chest flu or pneumonia	42 (36.5%)	NA[2]
Unusual shortness of breath	34 (30.1%)	23/33 (69.7%)
Tightness in chest	30 (26.1%)	19/29 (65.5%)
Wheezing or whistling in chest	28 (24.3%)	14/26 (53.8%)
Cough with phlegm	18 (15.7%)	NA
Fever, sweats, chills	17 (15%)	7/16 (37.5%)
Rash or skin irritation	12 (10.5%)	6/10 (60%)
Asthma diagnosed by physician	10 (8.7%)	NA
Symptoms consistent with chronic bronchitis[3]	7 (6.2%)	NA
Asthma now	6 (5.2%)	NA

[1] Answering "yes" to the following question: "Do you think it (the symptom) is related to work?"
[2] Not applicable.
[3] Symptoms consistent with chronic bronchitis were defined as a productive cough occurring more than three months out of the year for more than two consecutive years.

Table 3. Reported Symptoms/Illnesses Among "Exposed" and "Unexposed" Employees[1] McCain Foods, Inc. HETA 99-0091 July 24-26, 1999

Symptom/Illness	Number of Exposed (% of 56) reporting symptom/illness	Number of Unexposed (% of 57) reporting symptom/illness	Prevalence Ratio[2] [95% Confidence Interval]
Persistent cough	34 (60.7%)	23 (40.4%)	1.5 [1.03-2.20]
Irritation of eyes, nose, or throat	31 (55.1%)	19 (33.3%)	1.7 [1.07-2.57]
Pneumonia or chest flu	27 (48.2%)	14 (24.6%)	2.0 [1.16-3.33]
Unusual shortness of breath	24 (42.9%)	10 (17.5%)	2.4 [1.29-4.63]
Tightness in chest	22 (39.3%)	8 (14.0%)	2.8 [1.36-5.75]
Sinus problems	36 (64.3%)	27 (47.4%)	1.4 [0.97-1.90]
Unusual tiredness or fatigue	25 (46.3%)	22 (39.3%)	1.2 [0.76-1.82]
Ache all over	24 (43.6%)	20 (35.1%)	1.2 [0.78-1.98]
Wheezing or whistling in chest	15 (26.8%)	13 (22.8%)	1.2 [0.62-2.24]
Cough with phlegm	12 (21.4%)	5 (8.8%)	2.4 [0.92-6.48]
Fever, sweats, chills	10 (18.5%)	6 (10.7%)	1.7 [0.68-4.43]
Rash or skin irritation	5 (9.1%)	7 (12.3%)	0.7 [0.25-2.19]
Asthma diagnosed by physician	5 (8.9%)	5 (8.8%)	1.0 [0.31-3.32]
Asthma now	4 (7.1%)	2 (3.5%)	2.0 [0.39-10.67]
Symptoms consistent with chronic bronchitis[3]	3 (5.5%)	3 (5.4%)	1.0 [0.22-4.83]

[1] "Exposed" defined as working at least 50% of the time in processing areas; "unexposed" defined as working less than 50% of the time in processing areas

[2] Exposed group compared with the unexposed group.

[3] Symptoms consistent with chronic bronchitis were defined as a productive cough occurring more than three months of the year for more than two consecutive years.

Table 4. Reported Symptoms/Illnesses by JOB
McCain Foods, Inc.
HETA 99-0091
July 24-26, 1999

Symptom	Operator (P) (20)[1]	Cleanup (P) (13)	Grade I Spec (17)	Packaging (53)	Lab QA (6)
cough	14 (70%)	8 (62%)	10 (59%)	19 (36%)	4 (67%)
wheeze	2 (10%)	3 (23%)	7 (41%)	14 (26%)	2 (33%)
chest tightness	5 (25%)	5 (38%)	9 (53%)	10 (19%)	1 (17%)
shortness of breath	7 (35%)	5 (38%)	11 (65%)	10 (19%)	1 (17%)
irritation of eyes, nose, or throat	6 (30%)	9 (69%)	13 (76%)	18 (34%)	3 (50%)
sinus symptoms	8 (40%)	9 (69%)	12 (71%)	27 (51%)	4 (67%)
pneumonia/flu	9 (45%)	4 (31%)	10 (59%)	14 (26%)	4 (67%)
fever/chills	3 (15%)	1 (8%)	4 (25%)	8 (15%)	1 (17%)
ache	5 (25%)	7 (54%)	9 (56%)	19 (36%)	2 (33%)
tired/fatigued	5 (25%)	6 (50%)	12 (71%)	22 (42%)	1 (17%)
rash	1 (5%)	0	4 (24%)	6 (11%)	0
phlegm	2 (10%)	1 (8%)	6 (35%)	7 (13%)	1 (17%)
chronic bronchitis	0	0	1 (6%)	5 (9%)	0
diagnosed asthma	3 (15%)	0	0	6 (11%)	1 (17%)
asthma now	3 (15%)	0	0	2 (4%)	1 (17%)
one or more respiratory symptom	17 (85%)	10 (77%)	15 (88%)	25 (47%)	4 (67%)
one or more work-related respiratory symptom	9 (45%)	8 (62%)	13 (76%)	21(40%)	4 (67%)

[1] Number of respondents.

Table 5. Reported Symptoms/Illnesses by AREA
McCain Foods, Inc.
HETA 99-0091
July 24-26, 1999

Symptom	Plover 1 (11)[1]	Plover 2 (21)	Plover 1 and 2 (25)	Packaging (51)
cough	5 (45%)	17 (81%)	11 (44%)	19 (37%)
wheeze	1 (9%)	8 (38%)	5 (20%)	14 (27%)
chest tightness	2 (18%)	11 (52%)	7 (28%)	9 (18%)
shortness of breath	4 (36%)	12 (57%)	8 (32%)	9 (18%)
irritation of eyes, nose, or throat	5 (45%)	14 (67%)	11 (44%)	16 (31%)
sinus symptoms	5 (45%)	16 (76%)	14 (56%)	25 (49%)
pneumonia/flu	4 (36%)	10 (48%)	12 (48%)	13 (26%)
ache	4 (36%)	10 (50%)	9 (36%)	18 (35%)
fever/chills	2 (18%)	5 (26%)	2 (8%)	7 (14%)
tired/fatigued	2 (20%)	13 (65%)	10 (40%)	20 (40%)
rash	1 (9%)	1 (5%)	3 (12%)	5 (10%)
phlegm	0	6 (29%)	4 (16%)	6 (12%)
chronic bronchitis	0	1 (5%)	1 (4%)	4 (8%)
diagnosed asthma	0	4 (19%)	0	5 (10%)
asthma now	0	4 (19%)	0	2 (4%)
one or more respiratory symptom	7 (64%)	19 (90%)	17 (68%)	24 (47%)
one or more work-related respiratory symptom	6 (55%)	14 (67%)	13 (52%)	20 (39%)

[1] Number of respondents

Table 6. Colorimetric Tube Sampling for Chlorine and Carbon Monoxide McCain Foods, Inc. HETA 99-0091 March 30, 1999

Chemical[1]	Area or task	Estimated Concentration
Chlorine	Area near entry of factory - cleaning foam present on floor	ND[2]
	P1 - processing, over pumping pit of gutter system	ND
	Specking room - damaged parts of potatoes manually removed	ND
	Near blanching area - over gutters filled with steaming water	ND
	During cleaning floors with foam	ND
	Near speciality P3 frier	ND
Carbon monoxide	Specking room - damage parts of potatoes manually removed	ND
	Near blanching area - over steaming gutters	ND
	In analytical laboratory with air supply from SB3 friers	Slight blue-green color - <5 ppm CO - possibly due to interfering compounds

[1] Detector tubes have an accuracy of +/- 25-30% and a measuring range of 0.3-5 parts per million (ppm) for Cl_2, and 5-150 ppm for CO.

[2] ND = non-detectable

Table 7. Bacteria Identified in Gutter Water
McCain Foods, Inc.
HETA 99-0091
July 24-26, 1999

Taxa	Gram-stain	Possible origin[1]
Aeromonas-like	negative	fresh water and sewage
Acinetobacter	negative	naturally occurring in soils
Corynebacterium- like	positive	mucous membranes and skin of mammals and other species; occasionally other sources
Curtobacterium-like	positive	plants, soil, oil brine
Enterobacteriaceae	negative	widely distributed in nature
Klebsiella-like	negative	common in soils, foodstuffs, seeds, plant roots, etc.
Pseudomonas fluorescens group	negative	common in water or soil
Streptococcus, not *pyogenes*	positive	vertebrates, especially mouth and upper respiratory tract
Unidentified rod	negative	no information
Unidentified rod	positive	no information

[1] from: Holt JG, Krieg NR, Sneath PHA, Staley JT [1994]. Bergey's Manual® of Determative Bacteriology. 9th ed. Baltimore, MD: Williams and Wilkins Co.

Table 8. Personal Breathing Zone Concentrations of Total Particulates and Endotoxin McCain Foods, Inc. HETA 99-0091 July 24-26, 1999

Area	Job Title	Sampling Time (minutes)	Particulate Concentration in Air (mg/m^3)	Endotoxin Concentration in Air[1] (EU/m^3)
Packaging	Floater	286	0.070	ND[2]
	Forklift operator	263	0.194	ND
	Forklift operator	252	0.121	ND
	Line operator	295	0.068	ND
	Line operator	275	0.073	ND
	Line operator	266	0.038	ND
	Line operator	267	0.094	ND
	Packer (hashbrowns)	336	0.075	ND
	Packer (hashbrowns)	304	0.316	ND
Processing	Blancher (P2)	330	0.159	83.9
	General cleaner	326	0.204	287
	General cleaner	360	0.304	111
	Cleaner (P1)	353	0.527	184
	Cutter operator (P1)	259	0.098	55.9
	Cutter operator (P2)	347	0.200	73.3
	Operator (peeler)	264	0.425	161
	Specialist (P1)	398	0.380	822
	Trimmer (Trim room)	267	0.115	103
	Trimmer (Trim room)	242	0.149	187
	Trimmer (Trim room)	384	0.157	54.5
	Trimmer (Trim room)	368	0.205	82.4
	Trimmer (P1)	381	0.198	51.8
	Fry operator (P1)	390	0.371	87.7

A

[1] The limit of detection (LOD) for the endotoxin analyses was 0.5 endotoxin units (EU) per sample, which results in a minimum detectable concentration (MDC) of 0.018 endotoxin units per cubic meter (EU/m^3) using a sample volume of 28 cubic meters, the minimum volume of the personal breathing zone (PBZ) air samples.

[2] ND = non-detectable

Table 9. Area Concentrations of Dust and Endotoxin
McCain Foods, Inc.
HETA 99-0091
July 24-26, 1999

Area	Location	Sampling Time (minutes)	Dust Concentration (mg/m^3)	Endotoxin Concentration[1] (EU/m^3)
Packaging	Entrance	453	0.056	ND[2]
	Rear of plant	448	0.045	ND
	Near french fry conveyers	438	0.040	ND
Processing	French fry area	442	0.197	ND
	P1- near sorting machine	511	0.222	130
	Blancher	504	0.141	180
	P2	506	0.345	205
	Trim room	498	0.104	121

[1] See Table 8
[2] ND = non-detectable

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