NIOSH HEALTH HAZARD EVALUATION REPORT:

HETA #2002-0257-2916
Bil-Mar Foods, Inc.
Storm Lake, Iowa

October, 2003

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

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 Bradley King and Elena Page of HETAB, Division of Surveillance, Hazard Evaluations and Field Studies (DSHEFS). Statistical analysis was performed by Charles Mueller of HETAB, DSHEFS. Field assistance was provided by Erin Snyder, Angela Warren, Julia Maldonado, Chad Dowell, Manny Rodriguez of HETAB, DSHEFS; Walter Alarcon of Surveillance Branch, DSHEFS; James Taylor, David Spainhour, Diana Freeland, and Susan Englehart of Field Studies Branch (FSB), Division of Respiratory Disease Studies (DRDS). Analytical support was provided by Don Dollberg, Katherine Gomez, Mark Millson, and Larry Jaycox of the Chemical Exposure and Monitoring Branch (CEMB) of the Division of Applied Research and Technology (DART) and DataChem Laboratories. Desktop publishing was performed by Robin Smith. Review and preparation for printing were performed by Penny Arthur.

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Highlights of the NIOSH Health Hazard Evaluation

Evaluation of Chloramine and Endotoxin Exposures at a Turkey Processing Plant

NIOSH received a request for a health hazard evaluation (HHE) at Bil-Mar Foods in Storm Lake, Iowa. This request noted that employees in the evisceration department were experiencing symptoms such as eye and respiratory irritation. NIOSH investigators performed an evaluation to assess the possible causes of such symptoms.

What NIOSH Did

- We tested the air for chlorine, chlorine-related compounds called chloramines, and for endotoxins, a bacterial component.
- We asked employees to perform breathing tests to record any changes over the work shift.
- We asked workers about eye and respiratory symptoms they had at work.

What NIOSH Found

- Chlorine was not detected in any areas.
- Levels of the chlorine-related compounds were higher in the evisceration line than in the dark meat area.
- More people in evisceration reported respiratory and eye irritation symptoms than in dark meat.
- Those that reported these symptoms had higher exposure to some chlorine-related compound than those workers who did not report the symptoms.
- Endotoxin levels were higher in evisceration than in dark meat, but were not significantly related to employee symptoms.

What Bil-Mar Foods Managers Can Do

- Further assess the ability of the ventilation system to exhaust and dilute air contaminants.
- Continue collaborating with NIOSH to further explore possible engineering controls that can be used at this facility.
- Monitor reported health problems.

What the Bil-Mar Foods Employees Can Do

- Tell health personnel at work if you have health problems that may be associated with the work environment.

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 # 2002-0257-2916

Health Hazard Evaluation Report 2002-0257-2916
Bil-Mar Foods, Inc.
Storm Lake, Iowa
October, 2003

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SUMMARY

On May 16, 2002, the National Institute for Occupational Safety and Health (NIOSH) received a request for a health hazard evaluation (HHE) at Bil-Mar Foods in Storm Lake, Iowa, from the Occupational Safety and Health Bureau of the Iowa Division of Labor. This request for technical assistance noted that employees in the evisceration department were experiencing symptoms such as eye and respiratory irritation.

On June 26-27, 2002, NIOSH medical and industrial hygiene representatives visited the facility. On June 26th, an opening conference was held and attended by NIOSH investigators, representatives of Bil Mar Foods, and employee representatives. After the opening conference, a walk-through survey of the facility was conducted to observe operational procedures and work practices. Following the walk-through, air flow patterns were evaluated in the evisceration department. On June 26th and 27th, employees on the first shift in the evisceration and dark meat departments were administered questionnaires regarding medical, job, and personal history, and work-related symptoms. Air samples and readings for chlorine, ammonia, carbon dioxide, temperature, and relative humidity were taken in the same departments during the first shift on the 27th. No chlorine or ammonia was detected at any station.

On June 2-6, 2003, NIOSH investigators returned to the facility. Personal breathing zone (PBZ) and area air samples were collected for chloramines and endotoxins in the evisceration and dark meat areas of the facility during the 6 a.m. to 2 p.m shift on each of these five days. Dräger® tubes were used to sample for chlorine, and carbon dioxide, temperature, and relative humidity were measured throughout the week. Every individual who wore sampling equipment was also asked to perform spirometry immediately prior to, and directly after, their work shift as part of the medical monitoring aspect of the evaluation. Additionally, they were questioned about mucous membrane and respiratory symptoms experienced during that shift.

The concentrations of chloramine compounds (trichloramine and soluble chlorine [monochloramine, dichloramine, hypochlorite, and hypochlorous acid]) were significantly higher in the evisceration area than the dark meat area. Additionally, upper respiratory irritation symptoms, such as stuffy or itchy nose, frequent sneezing, and cough, and burning or stinging eyes, were found to be significantly more prevalent in the evisceration line workers than in the dark meat workers. The levels of soluble chlorine compounds measured by PBZ samples were significantly higher for those employees who reported these symptoms compared to those employees who did not. In addition, the levels of trichloramine were significantly higher in employees who reported burning or stinging eyes. Mean PBZ concentrations of trichloramine and soluble chlorine were higher in workers with significant cross-shift declines in lung function. The levels of endotoxin in the pinning room were found to be much higher than in any other area of the evisceration or dark meat areas. Endotoxin levels were significantly higher in the evisceration area than the dark meat area, although they were not significantly related to reported employee symptoms.

Results of this evaluation suggest a health hazard may exist from exposure to soluble chlorine compounds and trichloramine. Recommendations include further assessment and potential modification of the facility's ventilation system in order to maximize its ability to dilute and exhaust such airborne contaminants. Further collaboration between Bil-Mar Foods and NIOSH is planned for such an assessment. An exposure evaluation by NIOSH is also recommended after any ventilation recommendations are implemented.

Keywords: SIC 2015 (Poultry Slaughtering and Processing). Chloramine, chlorine, ammonia, endotoxin, sodium hypochlorite, superchlorination, eye irritation, respiratory irritation, ventilation.

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INTRODUCTION

In May 2002, the National Institute for Occupational Safety and Health (NIOSH) received a health hazard evaluation (HHE) request from the Occupational Safety and Health Bureau of the Iowa Division of Labor after they received a complaint from an employee of Bil-Mar Foods, Inc., in Storm Lake, Iowa. This request for technical assistance noted that employees in the evisceration department were experiencing symptoms such as eye and respiratory irritation, and that the Occupational Safety and Health Bureau had not been able to determine the cause.

An initial site visit was conducted by a NIOSH team on June 26-27, 2002. An opening conference was held with management and employee representatives, and a walk-through inspection of the facility was performed where measurements for chlorine and ammonia in the air were taken. On June 26th and 27th, employees on the first shift in the evisceration and dark meat departments were administered questionnaires regarding medical, job, and personal history, and work-related symptoms. An interim letter describing the initial site visit and preliminary findings was mailed to Bil-Mar Foods representatives on October 28, 2002.

On June 2-6, 2003, a return site visit was conducted by NIOSH investigators. Area air and personal breathing zone (PBZ) samples were collected for trichloramine, soluble chlorine, and endotoxins, as well as additional air samples for chlorine, in both the evisceration and dark meat areas of the facility. Pulmonary function tests were performed both pre- and post-shift by workers who had worn sampling equipment. Employees were also questioned about respiratory symptoms experienced during the work shift.

BACKGROUND

Facility Operations

Bil-Mar Foods, a division of Sara Lee Inc., employs approximately 600 workers at the Storm Lake, Iowa, turkey processing facility. Approximately half of these employees speak Spanish as their primary language with the majority of others speaking English and a small minority speaking Laotian. Of the three eight-hour shifts per day, two are used for turkey processing (10 p.m.- 6 a.m. and 6 a.m.- 2 p.m.) while the third is used for cleaning the facility (2 p.m. to 10 p.m.). Approximately 17,000 turkeys are processed on each shift.

Turkeys are initially unloaded by hand and hung by their feet on a shackle conveyor, after which they are electrically stunned and killed by a mechanical throat slitter. An employee in this area will manually slit throats if the machine fails. The turkeys then pass through a "bleed-out" room into a hot-water scald tank. The temperature of the water in these tanks is 138 to 140 degrees Fahrenheit (°F), which allows for easier removal of the feathers due to the opening of the pores in the turkey's skin. Following the scald tank, the turkeys are mechanically de-feathered in the picking room. After the picking room, an employee in the pinning room inspects the birds for any remaining feathers, and removes them as necessary. Additionally, hock cutters remove the legs and feet from the body of the turkeys, then the bodies are re-hung on the evisceration line.

Activities which employees perform in the evisceration line area include removal of the turkeys' entrails, head, neck, and lungs, as well as trimming off defective parts of the birds. U.S. Department of Agriculture (USDA) inspection of the birds for visible contamination also occurs on the evisceration line. Substantial amounts of super-chlorinated water (through the addition of sodium hypochlorite) are used at a number of stations on the evisceration line for disinfection of the birds. These stations include a bird-scrubber located at the start of the line, reprocessing stations where birds with potential fecal contamination are sent, and the high-pressure inside/outside bird wash. An open trough running throughout the evisceration line area catches the used super-chlorinated water along with discarded or dropped turkey parts. At the end of the evisceration line, the turkeys are split into hind (dark meat) and front (white meat) halves, which are then dropped into tanks of super-chlorinated water, and chilled to temperatures of 32 to 36°F through ammonia refrigeration.

Following a period of up to three hours in the chill tanks, the white and dark meat portions of the turkeys are sent to separate white meat and dark meat departments for further processing and packaging for shipment. Little, if any, super-chlorinated water is used in these processing and packaging departments.

Irritative Symptoms in the Poultry Processing Industry

There have been numerous reports of eye and upper respiratory tract irritation among poultry processing workers and USDA inspectors during processing steps involving the use of super-chlorinated water, and this is considered to be a widespread problem in this industry.[1,2,3,4] Reported symptoms generally are intermittent in nature, vary in severity, and may be accompanied by reports of a "chlorine-like" odor. Whether sodium hypochlorite or chlorine is used as the source of super-chlorination does not appear to account for any differences in the reporting of irritation.

Investigations to identify the cause of irritation and determine appropriate remedial action have been conducted by the USDA, NIOSH, and others at several different poultry processing plants. Efforts to identify obvious contaminants such as chlorine or ammonia in air as the cause of irritation have generally been inconclusive. Chloramines, specifically trichloramine (NCl_3), have been suspected as a primary cause of the reported symptoms because of the interaction between the chlorinated water and the nitrogenous material from the turkeys.[1]

The lack of an acceptable air monitoring technique for chloramines has been a primary obstacle to obtaining conclusive verification of chloramines as a cause of irritation. Additionally, targeting control measures has been difficult due to the lack of an air monitoring technique to evaluate the efficacy of modifications.

In 1998, researchers at the *Institut National de Recherche et de Sécurité* (INRS) in France developed a sampling and analytic method for assessing workers' exposure to chloramines in a facility that processes green salads in water containing hypochlorite.[5] The concern in this facility was for the formation of chloramines from the interaction of the hypochlorite in the water with the nitrogen compounds in the sap proteins released when cutting the vegetables. Acute eye and upper respiratory irritation were reported among the workers at the facility, and were thought to be caused by exposure to chloramines.[5]

In March 2000, NIOSH investigators conducted an HHE at a poultry processing facility in Hinton, Virginia, where employees had reported eye, nose, and throat irritation.[6] In addition to investigating chlorine and ammonia exposures, the evaluation also included a chloramine exposure evaluation using the INRS method. NIOSH investigators partnered with INRS, which had agreed to supply samplers for the chloramine exposure evaluation, as well as services for sample analysis. In addition to finding inadequate ventilation in the facility, as well as poor control of chlorine levels in the water used in the facility, NIOSH investigators concluded that chloramines may, indeed, be the cause of the irritation reported.

Because of continuing reports of such irritation among poultry plant workers, further requests for HHEs in such facilities, and the absence of other known potential irritants at the Bil-Mar Foods facility, NIOSH investigators identified the need to further develop a laboratory method for the analysis of chloramines.

METHODS

Industrial Hygiene

On the initial site visit in June 2002, area air samples were collected for screening purposes using two direct reading methods. The first method involved the use of a bellows pump and colorimetric detector tubes (Dräger®, Inc., Pittsburgh, PA) for chlorine and ammonia. Samples were taken at various stations throughout the evisceration line and the dark meat area. Efforts were made to sample near stations where the use of the super-chlorinated wash occurred and in areas where symptoms were reported more frequently. The detector tubes have a standard deviation of ±10-15% and a measuring range of 0.3 to 5 parts per million (ppm) for chlorine, and 2 to 30 ppm for ammonia. The second screening method involved the use of a Dräger Chip Measurement System (CMS®). This method uses a hand-held analyzer for measurement and evaluation, and a gas- or vapor-specific chip which is inserted into the analyzer. Each chip contains ten measurement channels, each containing a substance-specific reagent. The reaction between the reagent and the airborne gas is measured and the concentration is calculated and shown on the digital readout of the analyzer. Side-by-side measurements for chlorine were taken using the CMS® at the same time and locations as measurements with the detector tubes. The accuracy of this device is approximately ± 10 % of the measured value over the measurement range (e.g., ±0.02 ppm at 0.2 ppm); the measuring range for chlorine is 0.2 to 10 ppm.

Carbon dioxide, relative humidity, and temperature were measured at the same locations and times as chlorine. These measurements were taken with a TSI Inc. Q-Trak™ Indoor Air Quality (IAQ) Monitor model 8551. The Q-Trak™ monitors carbon dioxide using non-dispersive infrared detection technology, has an accuracy of ±3% of reading, and a range of 0 to 6000 ppm.

A Rosco Fog Machine 1600 was used following the 6 a.m. - 2 p.m. shift prior to the start of the cleaning crew shift on June 26th. Fog was generated and released through the evisceration room to observe air flow patterns and to monitor for areas of stagnant air.

On the second site visit in June 2003, area air samples were collected for chlorine, carbon dioxide, relative humidity, and temperature at various stations throughout the evisceration line and the dark meat area (for comparison purposes) using methods similar to those used during the initial site visit. Due to high readings, colorimetric detector tubes were used to sample for carbon dioxide, not only to verify the readings of the Q-Trak™, but also to provide a higher range than what the Q-Trak™ offered. The detector tubes have a standard deviation of ±10-15% and a measuring range of 1000 to 60,000 ppm for CO_2.

PBZ and area air samples were collected for trichloramines and soluble chlorine using the newly developed method in the evisceration line area and the dark meat area. The NIOSH approach incorporated the INRS samplers. These samplers are a combination of an absorption tube (analyzed for soluble chlorine, the combination of chlorine compounds such as monochloramine, dichloramine, hypochlorite, and free chlorine) and a treated filter cassette (analyzed for trichloramine). Samplers were constructed from a tube containing silica gel coated with sulphamic acid and a 37-millimeter (mm) polystyrene cassette containing two quartz fiber filter pads in series soaked in sodium carbonate and diarsenic trioxide. NIOSH researchers modified the INRS method by using an ion selective electrode to analyze both the sample tube and the filters rather than an ion selective electrode technique for the tube and ion chromatography for the filter. Analysis involved a simple extraction followed by inductively coupled plasma atomic emission spectroscopy (ICP-AES) for both tube and filter. During sampling, air was pulled through the silica gel-containing tube prior to passing through the filter-containing cassette. The soluble chlorine compounds (monochloramine, dichloramine, hypochlorous acid, and hypochlorite) were collected on the silica gel-containing tubes, while the trichloramine passes through the filter and is collected on the sorbent tube. The trichloramine was then trapped separately by the filters as it chemically reacted with them. The air samples were collected using calibrated SKC Hi-Flow sampling pumps at a flow rate of one liter per minute (L/m). The sampling pumps were pre- and post-calibrated using a primary standard to verify the flow rate. Samplers were shipped overnight to the NIOSH laboratory after daily sampling. Upon receipt, the samples were immediately desorbed and stored in the dark in the refrigerator until analysis.

During analysis of the tubes, extraction was performed by placing the impregnated silica gel from the tube into a 20 milliliter (mL) vial. Ten mL of a 1 g/L sulfamic acid solution was added to each vial and allowed to sit for one hour with occasional agitation. The sample extracts were decanted into another vial and refrigerated until analysis. Samples were analyzed for chloride using an ICP-AES method at a wavelength of 134.724 nm. An instrumental LOD was determined to be 0.7 micrograms (µg)/sample.

During analysis of the filters, each filter was removed from the cassette, placed in a 20 mL sample vial, and 10 mL of deionized water was added. The filters were sonicated for one hour and allowed to sit an additional 30 minutes for the solution to cool. Sample filters were refrigerated and then filtered through a 0.45 Teflon filter prior to analysis on the ICP-AES at a wavelength of 134.724 nanometers (nm). An instrumental limit of detection (LOD) for trichloramine was determined to be 0.6 µg/sample with a limit of quantitation (LOQ) of 1.9 µg/sample.

PBZ and area air samples were collected for endotoxins using pre-weighed, 5 micron (µm) pore-size filters in 2-piece 37 mm polyvinyl chloride (PVC) cassettes. The samples were collected using calibrated SKC Hi-Flow sampling pumps at a flow rate of 2 L/m. The sampling pumps were pre- and post-calibrated using a primary standard to verify the flow rate. Samples were shipped to the NIOSH contract laboratory for analysis. Gravimetric analysis for total dust was performed according to NIOSH Manual of Analytic Methods (NMAM) Method 0500 (4th ed.). For analysis of endotoxins, a 10 mL extraction solution using pyrogen-free water was obtained from the filter. The solution was centrifuged and vortexed appropriately. The sample extractions were analyzed with Kinetic-QCL instrumentation using the LAL assay. The LOD was determined to be 0.005 endotoxin units (EU)/sample with an LOQ of 0.05 EU/sample.

Medical

Overview

Workers engaged in poultry processing are conceivably exposed to chorine and chloramine compounds by inhalation if adequate engineering controls are not in place. The goal of this HHE was to determine if employees in the evisceration area of the plant, where work tasks expose them to substantial amounts of chlorinated water, have more upper and/or lower respiratory symptoms than workers whose work tasks involve significantly less chlorinated water.

Because we determined that evisceration workers in this plant were more likely to experience a variety of respiratory symptoms, but we did not detect any chlorine in the air of the plant, a follow-up evaluation was carried out that included extensive sampling for chloramines and endotoxin, as well as a medical evaluation including spirometry to measure lung function. The objective of the follow-up visit was to determine if exposure to chloramines and/or endotoxin was associated with upper and/or lower respiratory symptoms and/or declines in lung function among workers at Bil-Mar.

Selection of participants

During the initial site visit in June 2002, workers on the day shift of the evisceration and dark meat departments were administered a questionnaire. The evisceration workers were chosen because of the extensive use of super-chlorinated water in their department and because the concerns originated there. The dark meat workers were chosen as a comparison group because of the limited use of super-chlorinated water in that department.

Screening Questionnaire

The questionnaire was administered by NIOSH personnel in either Spanish or English. It consisted of questions concerning demographics (age, gender, job title, years worked, work department), personal history of allergies, eczema, asthma, and smoking, upper and lower respiratory symptoms at work in the last four weeks (not related to cold or seasonal allergies), and whether those symptoms remained the same, got worse, or got better on days off work. Upper respiratory symptoms included burning or stinging eyes, watery eyes, itchy or runny nose, stuffy nose, frequent sneezing, and sore throat. Lower respiratory symptoms included wheezing, shortness of breath, and chest tightness. Cough was also included on the questionnaire and can be either an upper or lower respiratory symptom.

Selection of Participants for Follow-up

Workers who met the case definition for work-related asthma symptoms on the initial screening questionnaire and a comparison group of workers who reported no work-related respiratory symptoms were asked to participate in the follow-up evaluation in June 2003. A subject was considered to have asthma symptoms if they reported wheezing, or any two of the following three symptoms: cough, shortness of breath, and chest tightness. Atopy was defined as having a history of hay fever or other allergies (not including allergies to medications), eczema, or asthma. Symptoms were considered work-related if they were present at work, and improved or disappeared on days away from work. Cigarette smokers were classified as current, former, or never smokers. Informed consent was obtained.

Spirometry

Pre- and post-shift spirometry was performed on each participant. Spirometry refers to the measurements of exhaled air volume and flow rates from individuals who are coached by trained technicians using either volume-based or flow-based measuring equipment. The important measurements include forced vital capacity (FVC) or the greatest volume of air exhaled from a maximal inspiration to a complete exhalation; the forced expiratory volume in one second (FEV_1) or the volume of air exhaled in the first second of a FVC maneuver; and the ratio between these two values: FEV_1/FVC. These measurements were made using a dry rolling-seal spirometer (volume-based system) interfaced to a dedicated computer. All procedures conformed to standard guidelines.[7] At least three maximal expiratory maneuvers or FVC maneuvers were performed at each session. The selection and interpretation of results also conformed to standard guidelines.[8] Predicted values were determined from published reference equations.[9]

Follow-up Questionnaire

A brief follow-up questionnaire was administered the end of the shift to determine if upper or lower respiratory symptoms noted above were present during the shift. Symptoms related to cold or seasonal allergies were not included.

Statistical Analysis

Crude associations between work area and work-related symptoms were evaluated using 2x2 contingency tables and the Chi square test. To adjust these analyses for smoking status, logistic regression models were constructed. Odds ratios (OR) were reported as a measure of association. We also calculated 95% confidence intervals (CI). If the 95% CI excluded one, then the OR was considered statistically significant.

The industrial hygiene exposure measures (PBZ endotoxin, trichloramine, and soluble chlorine concentrations) were not normally distributed, and were log-transformed for data analysis. Values for sampling results that were below the minimum detectable concentration were estimated by dividing the MDC by two.[10] Concentrations of endotoxin, trichloramine, and soluble chlorine for the two work areas were compared using the t test. In addition, t-tests were used to determine whether PBZ exposures levels differed for those with and without respiratory symptoms, as well as those with and without meaningful declines in FEV_1 ($\geq$ 10%). Geometric means were used to report exposure concentrations. P-values of <0.05 were considered statistically significant.

The t-test was used to evaluate whether subjects with and without asthma symptoms had differing mean changes in cross-shift FEV1. Multivariable linear regression models were used to examine this relationship while adjusting for smoking status.

SAS software Version 8 (SAS Institute, Cary, North Carolina) was used for statistical analysis.

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 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 thus potentially increases 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),[11] (2) the American Conference of Governmental Industrial Hygienists' (ACGIH®) Threshold Limit Values (TLVs®),[12] and (3) the U.S. Department of Labor, Occupational Safety and Health Administration (OSHA) Permissible Exposure Limits (PELs).[13] Employers are encouraged to follow the OSHA limits, the NIOSH RELs, the ACGIH TLVs, or whichever are 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.

Ammonia

Ammonia is a severe irritant of the eyes, respiratory tract and skin. It may cause coughing, burning, and tearing of the eyes; runny nose; chest pain; and at higher concentrations, which have ranged from 2500 to 6500 ppm, cessation of respiration; and death. Symptoms may be delayed in onset. Exposure of the eyes to high gas concentrations may produce temporary blindness and severe eye damage. Exposure of the skin to high concentrations of the gas may cause burning and blistering. Repeated exposure to ammonia gas may cause chronic irritation of the eyes and upper respiratory tract[14,15] but may result in tolerance to the effects of exposure. The NIOSH REL for ammonia is 25 ppm for a 10-hour TWA. The NIOSH short-term exposure limit (STEL) for ammonia is 35 ppm. ACGIH has set limits of 25 ppm as an 8-hour TWA and a STEL of 35 ppm. The OSHA PEL for ammonia is 50 ppm for an 8-hour TWA.

Carbon Dioxide

Carbon dioxide is a normal constituent of exhaled breath and, if monitored, can be used as a screening technique to evaluate whether adequate quantities of outside air are being introduced into an occupied space. ASHRAE's most recently published ventilation standard, ASHRAE 62-1989, Ventilation for Acceptable Indoor Air Quality, recommends outdoor air supply rates of 20 cubic feet per minute per person (cfm/person) for office spaces, and 15 cfm/person for reception areas, classrooms, libraries, auditoriums, and corridors.[16] Maintaining the recommended ASHRAE outdoor air supply rates when the outdoor air is of good quality, and there are no significant indoor emission sources, should provide for acceptable indoor air quality.

Indoor CO_2 concentrations are normally higher than the generally constant ambient CO_2 concentration (range 300-350 parts per million [ppm]). When indoor CO_2 concentrations exceed 800 ppm in areas where the only known source is exhaled breath, inadequate ventilation is suspected.[17] Elevated CO_2 concentrations suggest that other indoor contaminants may also be increased. It is important to note that CO_2 is not an effective indicator of ventilation adequacy if the ventilated area is not occupied at its usual level.

Endotoxins

Endotoxins, which are lipopolysaccharide compounds from the outer cell wall of gram-negative bacteria (GNB), are released when the bacteria die.[18,19] GNB are ubiquitous in the environment. Endotoxins have a wide range of biological activities involving inflammatory, hemodynamic, and immunological responses. Of most importance to occupational exposures are the activities of endotoxin in the lung.[20]

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).[21,22] 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.[23,24,25] Chronic health effects that have been associated with airborne endotoxin exposures include chronic bronchitis, bronchial hyperreactivity, chronic airways obstruction, hypersensitivity pneumonitis, and emphysema.[22] A permanent decrease in pulmonary function, along with respiratory symptoms, has been reported in epidemiological studies.[21]

Endotoxin levels are known to be high in the live hanging and catching areas of poultry plants, where organic dust levels are elevated.[26] Endotoxin exposure has not been investigated in the areas where processing and packaging are done. These areas are not typically dusty. However, a recent evaluation in a french fry processing plant documented high levels of endotoxin in the air in areas where wastewater was collected in a drainage system in the floor.[27]

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 of analyzing endotoxins, the Limulus amebocyte lysate (LAL) assay, is a comparative bioassay.[28] 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.[28]

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. 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, the RLV action level has been exceeded.[28] The proposed maximum RLV rises to 30 times the background level in an environment where no symptoms are reported.[28] When exposures exceed the RLV action level or maximum RLV, 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.

Chlorine

Chlorine is a greenish-yellow gas with a characteristic irritating odor. Exposure to chlorine gas can cause severe irritation of the eyes and respiratory tract, resulting in tearing, runny nose, sneezing, coughing, choking, and chest pain.[14,29] Breathing difficulty, with a delayed onset, can also occur. Severe exposure can result in edema and can be fatal. Mucous membrane and eye irritation has been reported to occur at concentrations as low as 0.2-2 ppm.[14] The NIOSH REL for chlorine is 0.5 ppm as a ceiling limit. The ACGIH TLV for chlorine is 0.5 ppm; ACGIH has established a STEL for chlorine of 1 ppm. The OSHA PEL for chlorine is 1 ppm as a ceiling limit.

Chloramines

Chloramines are formed by the reaction between chlorine disinfectants and nitrogenous compounds such as ammonia, amines, or organic nitrogen-containing material. The species and concentrations of chloramine are influenced by the concentration of residual chlorine, ammonia (or other nitrogen sources), pH, and temperature.[4] In general, the lower the pH and the greater the chlorine:ammonia ratio the higher the likelihood of producing chloramines.

Soluble chlorine

The term soluble chlorine has been used in this report to designate a combination of chlorine compounds thought to be collected using the silica-gel containing tube portion of the sampler used. These chlorine compounds include monochloramine, dichloramine, hypochlorous acid, and hypochlorite. No occupational exposure criteria have been developed for soluble chlorine or for its specific possible constituents.

Trichloramine

Trichloramine, or nitrogen trichloride (NCl_3), is a brownish-yellow gas, has a pungent chlorine odor (sometimes described as rotting grapefruit or geraniums) and is a strong irritant and lacrimator.[4,30] NCl_3 has low solubility, aerates easily, and decomposes rapidly in sunlight. Eye and respiratory tract irritation appear to be the primary effects of exposure, although asthma has been documented in lifeguards and swimming instructors.[31] The irritant characteristics of NCl_3 seem to be similar to that of chlorine.[32] Occupational exposure criteria for NCl_3 have not been established.

Sodium Hypochlorite

Sodium hypochlorite is a greenish-yellow liquid with a moderate chlorine odor that is commonly used as a general purpose germicidal agent, disinfectant, and bleach. Household bleach is a 5.25% solution of sodium hypochlorite and water. The pH of a 5% aqueous solution of sodium hypochlorite is approximately 10-11; a 15% solution has a pH of 11.2.[32]

Sodium hypochlorite can generate harmful gases such as chlorine or chloramine if mixed with acids, acidic salts, ammonia, or ammonia-containing products. Sodium hypochlorite is an oxidizing agent and can produce a number of reactions, depending on what other chemicals are mixed with it. There have been a number of cases of severe illness from inhalation of toxic vapors in both residential and commercial settings, resulting from intentional or inadvertent mixing of bleach with incompatible cleaning or disinfecting agents.[33,34,35]

Airborne exposure to sodium hypochlorite is likely to be in the form of an aerosol, or mist. NIOSH, OSHA, or ACGIH occupational exposure criteria have not been established for sodium hypochlorite. The American Industrial Hygiene Association has established a Workplace Environmental Exposure Limit (WEEL) guide for sodium hypochlorite of 2 milligrams per cubic meter (mg/m^3), however an air sampling method for sodium hypochlorite was not referenced.[32]

RESULTS

Results from the sampling in the evisceration line area on June 27, 2002, are summarized in Table 1. Chlorine was not detected at any sampling station by either sampling method used. Sampling locations included those which use or are near large quantities of the super-chlorinated wash such as the 1st Bird Brush Wash, the Inside/Outside Wash, and the Chillers. Elevated levels of CO_2 were, however, found in two areas: the 1st Bird Brush Wash and the Vent Gun/Fecal Vac. The levels recorded during these short term, or 'spot' samples, measured above 5000 ppm, and were almost certainly due to the carts of dry ice located nearby. Most likely, 8-hour TWA exposures at these two locations would be below the PEL of 5000 ppm due to the fact that these carts of dry ice are routinely brought into and out of the area, so that constant exposure to the source of carbon dioxide is unlikely.

Similar results were obtained for samples taken in the dark meat area. These results are summarized in Table 2. Again, chlorine was not detected at any sampling station by either sampling method used. CO_2 monitoring at the thigh skin remover and the hot dog meat station revealed levels above the 5000 ppm level:.

Direct-reading Dräger tubes were used in various locations of the facility to measure ammonia levels in the air. Five samples were drawn in and around areas such as the engine room (from where the chemical is pumped), the trimmer area outside the door of the engine room, and the chillers. Ammonia was not detected in any sample.

The concentration of chlorine in the wash water was reported to be 20 ppm as recorded in company records for that day. This concentration is equal to the level required by the U.S. Department of Agriculture for spray water on evisceration lines and in salvage and reprocessing areas of poultry processing facilities.

Fog release showed that the airflow in the evisceration line was in a direction consistent with the design of the ventilation system, flowing from the main supply vent toward the return vents to be exhausted. However, many of the cooling fans positioned above stations along the line caused a great deal of turbulence in the airflow, many times blowing the air in a direction opposite to which it was intended. The effect was air re-circulated from other areas of the line, including areas which had heavy use of the super-chlorinated water sprays.

During the initial site visit, in June 2002, questionnaires were administered to 109 of 115 (95%) eligible employees (68 out of 69 [98%] in evisceration and 41 out of 46 [89%] in dark meat). The participation rate for evisceration was slightly higher than dark meat because four workers in dark meat only spoke Laotian and a translator was not available. Workers in both departments were similar in age, tenure, and history of atopy. Evisceration workers were significantly more likely to be current or former smokers, however. These results are summarized in Table 3.

The prevalence of work-related wheezing, coughing, sneezing, and watery eyes was significantly higher among evisceration workers (See Table 4). Work-related sore throat, burning or stinging eyes, and asthma symptoms were also more frequently reported by evisceration workers, but this was not statistically significant. There was no significant difference between departments in prevalence of shortness of breath, chest tightness, itchy runny nose, and stuffy nose. Multivariate analysis was conducted to control for the potential effects of smoking status (never, former, current smoker), but did not meaningfully alter the relationships seen above, with the exception of burning or stinging eyes, the prevalence of which became statistically significantly higher in evisceration workers after controlling for smoking. These results are also in Table 4.

Forty-seven persons were selected to participate in the second survey in June 2003, 23 of whom met our screening questionnaire definition of occupational asthma and 24 of whom reported no work-related respiratory symptoms. At the time of the second survey, seven of these persons were no longer employed, three were not present at the time of the survey, two had changed shifts, and one refused to participate. The remaining 34 employees participated fully in the environmental sampling and the medical evaluation, including the pre and post-shift spirometry and the questionnaire. Sixteen worked in dark meat and 18 in evisceration.

During the second survey, carbon dioxide, temperature and relative humidity were measured at various locations in the evisceration area and the dark meat area during the week of the site visit. These results are summarized in Table 5. Most notably, CO_2 levels were elevated in both the evisceration and dark meat areas. On the first three days, readings of at least 6000 ppm were recorded using the TSI Inc. Q-Trak™. 6000 ppm is the highest level that can be measured by the Q-Trak™. A measurement of 1750 ppm was also recorded in the cafeteria on one of these days. The results returned from two Q-Traks™ and Dräger tubes for CO_2 on June 5 all revealed levels of CO_2 approximately half or below those measured on previous days. As seen on the initial site visit, large containers of dry ice used to maintain the freshness of the processed turkey parts were present in the processing areas of the facility on these first few days and are most likely the source of the CO_2. It was reported by an employee that these large containers of dry ice are used approximately three of five days during a typical week.

No chlorine was detected at any location tested using Dräger tubes.

Results from the sampling for trichloramines, soluble chlorine, and endotoxins performed in the dark meat area are summarized in Tables 6 and 7, according to the type of sample taken (i.e., area air sample or PBZ sample). Tables 8 and 9 summarize sampling results from the evisceration line area, also according to type of sample taken. Sampling for trichloramines and soluble chlorine revealed considerably higher levels in the evisceration line area versus the dark meat area. Table 10 compares the full shift PBZ air sampling results. The mean TWA concentration of trichloramine was significantly higher in the evisceration department than in the dark meat department (5.07 vs. 1.20 $\mu g/m^3$, $p<0.01$), as was the mean TWA concentration of soluble chlorine (63.45 vs. 9.38 $\mu g/m^3$, $p<0.01$).

The pinning room had endotoxin levels considerably higher than all other areas monitored. The two area air samples taken in this room measured concentrations of 398 and 278 EU/m^3. The endotoxin concentrations in these two samples were at least one order of magnitude higher than in the majority of area samples. The endotoxin concentrations in the two PBZ samples taken on employees in this room were also considerably higher than those taken in the remainder of the evisceration area and in the dark meat area. These results were 85 and 82 EU/m^3, taken on June 3 and 5, respectively. Therefore, ACGIH's proposed RLV action level was exceeded in that the levels in the pinning room were greater than 10 times higher than the background level in the dark meat area (when health effects were reported) and ACGIH's proposed maximum RLV was exceeded in that the levels in the pinning room were greater than 30 times higher than background level (when no symptoms are reported.) Overall, endotoxin concentrations were significantly higher in the evisceration department (1.08 vs. 0.11 EU/m^3, p<0.01), also shown in Table 10.

Workers who reported either wheezing, or two of the following three symptoms: chest tightness, shortness of breath, or cough on the day they were surveyed were considered to have current symptoms of asthma. Forty-four percent of workers with current asthma symptoms were current or former smokers, compared to 20% of those without current asthma symptoms (p=0.20). The mean change in cross-shift FEV$_1$ in those with current asthma symptoms was -4.83 %, compared to -0.89 % in those without current asthma symptoms (p=0.01). Controlling for smoking, the mean changes were -4.55% and -0.99%, respectively (p=0.02). In addition, workers who reported current asthma symptoms had higher geometric mean exposure to soluble chlorine than those without current asthma symptoms (47.76 µg/m^3 vs. 18.75 µg/m^3, p=0.04) (Table 11). Geometric mean concentrations of endotoxin and trichloramine did not differ significantly between those with and without current asthma symptoms (0.30 EU/m^3 vs. 0.40 EU/m^3, and 2.85 µg/m^3 vs. 2.48 µg/m^3, respectively).

Three persons had significant cross-shift declines ($\geq$ 10%) in their FEV$_1$.[36] Two of these persons were not able to meet reproducibility criteria on their pre-shift spirometry; one had normal results and one (a smoker) showed borderline restriction. Both, however, were able to meet criteria on their post-shift spirometry. Including these two individuals, the geometric mean TWA trichloramine concentration in persons with a significant cross-shift decline in their FEV$_1$ was 21.74 µg/m^3 compared to 2.09 µg/m^3 in those without a significant cross-shift declines in their FEV$_1$ (p=0.04). Geometric mean TWA endotoxin did not differ significantly between those who experienced a significant cross-shift decline in FEV$_1$ and those who did not (0.36 and 0.38 EU/m^3, respectively; p=0.9). Geometric mean TWA soluble chlorine compounds concentration was 70.5 µg/m^3 in those with a significant cross-shift decline in FEV$_1$ compared to 21.86 µg/m^3 in those without (p=0.10).

Mean TWA soluble chlorine concentrations were significantly higher in persons who reported burning or stinging eyes, itchy or stuffy nose, cough, asthma symptoms, and frequent sneezing, as compared to those who did not report such symptoms, as shown in Table 11. Mean TWA soluble chlorine concentrations were also higher in persons who reported watery eyes and sore throat, but not significantly so. Mean TWA trichloramine concentrations were significantly higher in persons who reported burning or stinging eyes, but not other symptoms. There were no significant associations between any symptom and mean endotoxin concentration. The relationship between asthma symptoms and exposure was also examined while controlling for smoking status and findings did not change meaningfully.

DISCUSSION AND CONCLUSIONS

Respiratory, especially upper respiratory, symptoms are common among poultry workers, who usually relate their symptoms to chlorine exposure because of symptom correlation with odor. However, numerous evaluations of chlorine levels, including ours, have failed to document chlorine concentrations that could account for these symptoms. It has been postulated that trichloramine, produced by the reaction of nitrogenous materials from the poultry and the chlorinated water used to disinfect the birds, may be responsible for these symptoms. In our study, trichloramine did not appear to be the predominant chlorine compound produced. This corresponds, however, to the results reported by INRS in their study of chloramine exposure in a green salad processing plant.[5] Their reported results showed that, unlike swimming pools where chloramine exposure is mainly composed of trichloramine, between 30 and 70% of the amount of chlorine species in the atmosphere of the facility were chlorine species trapped on the silica gel tube (i.e., the soluble chlorine) rather than trichloramine. It was suggested that the majority of the soluble chlorine trapped on the tube could be composed of mono- and dichloramine. One reason given for this was the fact that aerosolization of the chlorinated water was much more intense in the facility, as compared to a swimming pool environment, which would lead to a proportionally higher emission of mono-and dichloramine.[5] This reasoning may help explain the higher quantities of soluble chlorine measured at the Bil-Mar facility, where aerosolization can easily occur due to the number of spray washes used throughout the evisceration area.

Despite the small number of participants in this study, statistically significantly positive associations were demonstrated between soluble chlorine concentrations and burning or stinging eyes, itchy or stuffy nose, cough, and frequent sneezing. In addition, trichloramine concentrations were positively associated with burning or stinging eyes.

Reported symptoms of asthma on the day of the survey corresponded to a statistically significantly greater decline in FEV_1 and to higher concentrations of soluble chlorine. However, the magnitude of the differences in the FEV_1 was small and may not reflect any clinical impairment of breathing. In addition, persons with cross-shift declines in FEV_1 of $\geq$ 10% had higher PBZ concentrations of soluble chlorine and trichloramine.

It is expected that trichloramine and soluble chlorine compounds would cause similar health effects. In this evaluation, soluble chlorine compounds predominated, and therefore more symptoms were associated with exposure to them. Soluble chlorine has been related to irritative symptoms in green salad processors, where it is generated in larger quantities than trichloramine.[5] In swimming pools, trichloramine predominates and has been related to irritative symptoms in lifeguards and swimming pool instructors.[37] In addition, trichloramine has been reported to cause asthma.[31]

As stated previously, the endotoxin exposures were recorded to be highest in the pinning room of the evisceration line area. The pinning room is an enclosed room adjoining the defeathering room with an open doorway between them. After the majority of feathers have been mechanically plucked from the turkeys, workers in the pinning room manually remove any remaining feathers. This may lead to the potential for increased levels of organic dust of which endotoxin can be a contaminant. Also running closely by the pinning room is a large trough in the floor carrying substantial amounts of wastewater leading out of the plant. The combination of these conditions may be the cause of the higher endotoxin levels exceeding ACGIH's proposed RLVs for endotoxin exposure. We did not find an association between endotoxin levels and either reported symptoms or changes in lung function, however.

Limitations of this study include intermittent and unpredictable nature of the symptoms, which restricted our ability to perform spirometry and environmental sampling on days when symptoms occurred. Reasons for the intermittence may include fluctuations in chlorine concentration in the water and in the amount of nitrogenous material from the turkeys. An additional limitation was the comparatively high minimum quantifiable concentration (MQC) values for the soluble chlorine samplers as compared to the MDC value for soluble chlorine and the MQC and MDC for trichloramine. Although the instrumental LOQ was much lower, the method LOQ (upon which the MQC is based) was estimated from the first recovery study performed by the NIOSH laboratory during method development. The estimate was based on a desorption efficiency less than the NIOSH acceptable limit of 75% for media spikes of 55 µg/sample. Since that time, further recovery studies have taken place and have seen a reduction in the method LOQ. While some data points do fall between the MQC and the MDC, the statistical analysis lends significant support to the observed trend of higher levels in the evisceration line compared to the dark meat area, suggesting this did not have an important impact on our findings.

Recommendations

1. Proper ventilation is likely a component of the solution to reduce contaminant levels in the work area. The proper use of components such as overhead fans (observed on the initial visit to distribute the air in a manner counter to the ventilation system) and drip pans collecting condensate water (positioned directly under the exhaust fans, potentially inhibiting their ability to exhaust workplace air) is important in maintaining adequate dilution ventilation. Collaboration between Bil Mar and NIOSH ventilation engineers is planned in order to identify optimum ventilation solutions.

2. Perform frequent testing in the chiller tanks to ensure that chorine levels remain constant between 20 and 50 ppm, and decrease the levels of the chlorine in the chiller tank water should they surpass 50 ppm.

3. Consider covering/enclosing the chiller tanks and placing them under slight negative pressure via an exhaust system to minimize the contact that employees have with any chlorine by-products rising from the interaction of the chlorinated water in the tanks and organic matter from the turkeys.

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Table 1. Sampling Results: Evisceration Line, Initial Site Visit: June 27, 2002

Location and Time of Sample	Chlorine: Dräger Tube (ppm)	Chlorine: Dräger CMS (ppm)	Carbon Dioxide (ppm)	Temp. (°F)	Relative Humidity (%)
Conference Room	ND[a]	< 0.200	–	–	--
1st Bird Brush Wash (a.m.)	ND	< 0.200	5800	65.9	66.9
Vent Gun/Fecal Vac (a.m.)	ND	< 0.200	5650	65.1	72.0
USDA Inspectors (a.m.)	ND	< 0.200	3500	69.7	79.9
Reprocess 1 & 2 (a.m.)	ND	< 0.200	2205	69.2	79.2
Neck Breaker/Chiller (a.m.)	ND	< 0.200	2360	67.5	78.3
Salvage (a.m.)	ND	< 0.200	2795	65.6	72.9
OM (a.m.)	ND	< 0.200	2590	67.8	75.6
Trimmers (a.m.)	ND	< 0.200	2494	68.9	77.5
Trimmers (a.m.)	ND	< 0.200	2720	67.0	73.9
I/O Wash (a.m.)	ND	< 0.200	3060	65.4	69.5
Next to Chiller A (a.m.)	ND	< 0.200	2936	64.6	65.5
Next to Chiller B (a.m.)	ND	< 0.200	3330	57.1	58.7
1st Bird Brush Wash (p.m.)	ND	< 0.200	1714	71.5	79.0
Vent Gun/Fecal Vac (p.m.)	ND	< 0.200	1630	71.3	78.0
USDA Inspectors (p.m.)	ND	< 0.200	2000	74.6	79.6
Reprocess 1 & 2 (p.m.)	ND	< 0.200	3296	71.7	58.6
Salvage (p.m.)	ND	< 0.200	3094	71.0	63.7
OM (p.m.)	ND	< 0.200	2390	73.3	67.4
Trimmers (p.m.)	ND	< 0.200	2159	72.9	69.4
IO Wash (p.m.)	ND	< 0.200	2045	72.3	55.2
Next to Chiller A (p.m.)	ND	< 0.200	3082	66.1	59.9

[a] ND denotes 'non-detectable level'

Table 2. Sampling Results: Dark Meat Area, Initial Site Visit: June 27, 2002

Location and Time of Sample	Chlorine: Dräger Tube (ppm)	Chlorine: Dräger CMS (ppm)	Carbon Dioxide (ppm)	Temp. (°F)	Relative Humidity (%)
Thigh Deboning (a.m.)	ND[a]	< 0.200	3412	56.3	67.0
Thigh Skin Remover (a.m.)	ND	< 0.200	6000	49.5	67.1
Hot Dog Meat Station (a.m.)	ND	< 0.200	5048	53.2	72.2
Drum Packaging (a.m.)	ND	< 0.200	4340	49.0	67.4
Entrance to Dark Meat Area (a.m.)	ND	< 0.200	3298	52.0	75.9

[a] ND denotes 'non-detectable level'

Table 3. Demographics and Selected Characteristics by Exposure Group, Initial Site Visit: June 27, 2002

	Evisceration	Dark Meat
Participation Rate	68/69 (98%)	41/46 (89%)
Mean Age (Years)	36	39
Mean Tenure at Bil-Mar (Years)	8	7
Gender		
Male	57%	44%
Female	43%	56%
History of Atopy[a]	21%	23%
Smoking Status		
Current[b]	24%	5%
Former[b]	32%	13%
Never[b]	44%	82%

[a] Atopy is history of any of the following: hay fever or other allergies (except for allergies to medications), asthma, or eczema
[b] $p < 0.05$

Table 4. Work-Related[a] Symptoms by Department, Initial Site Visit: June 27, 2002

	Evisceration n=68	Dark Meat n=40	OR (95% CI)	Adjusted OR[c] (95% CI)
Itchy, runny nose	32 (47%)	18 (45%)	1.09 (0.50, 2.38)	1.41 (0.60, 3.42)
Watery eyes	31 (46%)	5 (13%)	5.86 (2.05, 16.79)	7.00 (2.43, 23.89)
Frequent sneezing	30 (44%)	8 (20%)	3.16 (1.27, 7.85)	4.89 (1.84, 14.29)
Cough	28 (41%)	5 (13%)	4.90 (1.71, 14.06)	6.16 (2.14, 20.96)
Burning or stinging eyes	27 (40%)	9 (23%)	2.27 (0.93, 5.51)	3.29 (1.26, 9.22)
Asthma symptoms[b]	18 (26%)	5 (13%)	2.52 (0.86, 7.43)	2.77 (0.93, 9.54)
Stuffy nose	17 (25%)	10 (25%)	1.00 (0.41, 2.46)	1.79 (0.68, 4.95)
Wheezing[#]	15 (22%)	2 (5%)	5.38 (1.16, 24.91)	5.91 (1.44, 40.38)
Sore throat	14 (21%)	4 (10%)	2.33 (0.71, 7.66)	3.15 (0.96, 12.49)
Shortness of breath	10 (15%)	9 (23%)	0.59 (0.22, 1.62)	0.69 (0.23, 2.05)
Chest tightness	10 (15%)	6 (15%)	0.98 (0.33, 2.93)	1.16 (0.35, 3.98)

[a]defined as experienced at work during the last four weeks, but improved on days away from work
[b] defined as wheezing, or any two of the following three symptoms: cough, chest tightness, and shortness of breath
[c] adjusted for smoking status

Table 5. CO_2 and Environmental Sampling Results: Evisceration, Return Site Visit: June 2-6, 2003

Date	Location	Chlorine: Drager Tube (ppm)	Carbon Dioxide (ppm)	Temperature (°F)	Relative Humidity (%)
June 2	Dark Meat - near boxing	ND[a]	6000[b]	50.7	69.2
June 2	Dark Meat - trim table	ND	6000	49.7	71.4
June 2	Evisceration - trimming	ND	6000	56.1	92.3
June 2	Evisceration - USDA inspect.	ND	6000	61.2	91.8
June 2	Cafeteria	–	1750	–	--
June 3	Dark Meat - trim table	ND	6000	53.1	58.4
June 4	Dark Meat - trim table	ND	6000	53.2	54.2
June 4	Evisceration - reprocessing	ND	6000	66.9	55.5
June 4	Evisceration - standing under supply vent	–	3000	–	--
June 5	Evisceration - gut drop	ND	2750	69.8	77.9
June 5	Evisceration - pinning room	ND	630	75.7	91.3
June 5	Evisceration - salvage	ND	2100	72.3	78.5
June 5	Dark Meat - trim table	ND	3200[c] 2800[d] 2000[e]	63.1	48.6

[a] ND denotes ‘non-detectable level’
[b] 6000 ppm Q-Trak max
[c] result from original Q-Trak™ monitor
[d] side-by-side result from second Q-Trak™ monitor
[e] side-by-side result from Dräger tube for CO_2

Table 6. Area Air Sampling Results by Dark Meat Location, Return Site Visit: June 2-6, 2003

Date	Location	EU/m^3	Soluble chlorine (tube) µg active Cl/m^3	Trichloramine (filter) µg NCl_3/m^3
June 2	hot dog grind	0.12	4.90	ND[a]
June 3	hot dog grind	0.19	10.20	ND
June 4	hot dog grind	0.31	7.13	ND
June 5	hot dog grind	0.73	6.12	ND
June 6	hot dog grind	0.18	9.57	ND
June 2	thigh table	ND	2.70	ND
June 2	thigh table	0.09	9.73	ND
June 3	thigh table	ND	lost [b]	ND
June 4	thigh table	0.13	6.76	ND
June 5	thigh table	0.45	10.20	ND
June 6	thigh table	0.18	9.57	ND
June 6	thigh table	0.15	9.83	ND
	GEOMETRIC MEAN:	**0.10**	**7.38**	**0.625**
	MDC:	0.005	1.46	1.25
	MQC:	0.05	183.33	3.96

[a] ND denotes 'non-detectable level'
[b] sample lost during analysis due to pump malfunction on the ICP-AES

Table 7. Personal Breathing Zone Sampling Results by Dark Meat Location, Return Site Visit: June 2-6, 2003

Date	Location	EU/m^3	Soluble chlorine (tube) µg active Cl/m^3	Trichloramine (filter) µg NCl_3/m^3
June 4	cold room packaging	0.05	5.46	ND[a]
June 2	floater	0.17	11.93	ND
June 2	floater	0.16	9.40	ND
June 5	L piece	0.26	19.23	ND
June 4	lead person	0.09	7.48	ND
June 6	packing	0.10	6.64	37.85
June 2	push carts and hangs	0.06	45.17	2.05
June 4	shipping	0.54	7.22	ND
June 2	thigh table trimmer	0.07	3.52	1.38
June 2	thigh table trimmer	0.05	9.86	ND
June 2	thigh table trimmer	0.08	10.42	ND
June 2	thigh table trimmer	0.06	10.00	ND
June 5	thigh table trimmer	0.12	8.10	ND
June 5	thigh table trimmer	0.12	7.74	ND
June 6	thigh table trimmer	0.17	10.66	47.12
June 2	unknown	0.14	7.69	ND
	GEOMETRIC MEAN:	**0.11**	**9.38**	**1.20**
	MDC:	0.005	1.46	1.25
	MQC:	0.05	183.33	3.96

[a] ND denotes 'non-detectable level'

Table 8. Area Air Sampling Results by Evisceration Location, Return Site Visit: June 2-6, 2003

Date	Location	EU/m³	Soluble chlorine (tube) µg active Cl/m³	Trichloramine (filter) µg NCl_3/m³
June 6	chillers	0.23	23.81	ND[a]
June 5	gut drop	6.77	185.86	9.35
June 6	gut drop	6.60	183.91	12.67
June 2	inside/outside wash	0.86	145.28	11.28
June 3	inside/outside wash	0.09	lost [b]	8.31
June 4	inside/outside wash	0.47	198.90	26.10
June 5	pinning room	398.08	91.32	6.74
June 6	pinning room	278.80	93.68	2.34
June 2	reprocessing	1.18	167.87	11.25
June 3	reprocessing	0.37	lost	8.78
June 6	reprocessing	21.33	81.30	ND
June 4	salvage	1.10	261.54	23.56
June 5	salvage	8.20	60	10.14
June 6	salvage	3.77	240.85	ND
June 2	trimming	0.51	170.32	5.60
June 3	trimming	0.53	lost	14.26
June 4	trimming	0.91	178.17	14.19
June 5	trimming	18.37	142.86	19.65
June 6	trimming	14.25	138.89	22.55
	GEOMETRIC MEAN:	**2.96 (1.69)**[c]	**129.49**	**7.05**
	MDC:	0.005	1.46	1.25
	MQC:	0.05	183.33	3.96

[a] ND denotes 'non-detectable level'
[b] sample lost during analysis due to pump malfunction on the ICP-AES
[c] mean of sample results including pinning room results **(** mean of sample results excluding pinning room results**)**

Table 9. Personal Breathing Zone Sampling Results by Evisceration Location , Return Site Visit: June 2-6, 2003

Date	Location	EU/m³	Soluble chlorine (tube) µg active Cl/m³	Trichloramine (filter) µg NCl_3/m³
June 4	assistant supervisor	3.59	84.39	5.27
June 3	bird wash	0.08	64.52[b]	ND[a]
June 5	condemn	23.94	77.82	10.54
June 3	cropper	0.08	70.18	156.73
June 5	cropper	17.69	116.05	14.66
June 5	floater	2.32	77.22	6.70
June 4	inspector's help	5.61	126.32	8.82
June 4	neck boxer	0.36	116.96	14.66
June 3	oil gland cutter	0.16	17.99	1.80
June 3	pinning room	84.76	38.10	3.94
June 5	pinning room	82.23	59.43	1.71
June 5	room technician	0.11	10.51	ND
June 3	tank washer	1.50	lost [c]	ND
June 3	trimming	0.10	39.53	7.43
June 3	trimming	0.07	lost	6.66
June 4	trimming	0.51	99.21	10.50
June 4	trimming	0.32	124.74	8.36
June 4	vent gun	0.61	84.57	4.19
	GEOMETRIC MEAN:	**1.08 (0.63)[d]**	**63.45**	**5.07**
	MDC:	0.005	1.46	1.25
	MQC:	0.05	183.33	3.96

[a] ND denotes 'non-detectable level'
[b] result of 2nd tube of 2 used during shift; 1st tube sample lost during analysis due to pump malfunction on the ICP-AES
[c] sample lost during analysis due to pump malfunction on the ICP-AES
mean of sample results including pinning room results (mean of sample results excluding pinning room results)

Table 10. Full-shift PBZ Concentrations for Chlorine Compounds and Endotoxin by Location Return Site Visit: June 2-6, 2003

	Evisceration (n=18)		Dark Meat (n=16)	
	Geometric Mean	**Range**	**Geometric Mean**	**Range**
Trichloramine[a]	5.07 µg/m³	ND - 156.73 µg/m³	1.20 µg/m³	ND - 47.12 µg/m³
Soluble chlorine[a]	63.45 µg/m³	10.42 - 126.32 µg/m³	9.38 µg/m³	3.52 - 45.17 µg/m³
Endotoxin[a]	1.08 EU/m³	0.07 - 84.76 EU/m³	0.11 EU/m³	0.05 - 0.54 EU/m³

[a] mean concentrations differ by location ($p<0.01$)

Table 11. Endotoxin, Trichloramine, & Soluble Chlorine Levels by Respiratory Symptoms
Return Site Visit: June 2-6, 2003

	Endotoxin (EU/m³)			Trichloramine (µg/m³)			Soluble chlorine (µg /m³)		
	n	geometric mean	p value	n	geomtric mean	p value	n	geometric mean	p value
Burning, stinging eyes									
present	12	0.50	0.58	12	5.77	**0.02**	10	56.85	**<0.01**
absent	22	0.32		22	1.66		22	16.60	
Itchy or stuffy nose									
present	11	0.55	0.47	11	4.61	0.13	9	66.23	**<0.01**
absent	23	0.31		23	1.95		23	16.50	
Cough									
present	9	1.18	0.06	9	4.08	0.31	8	58.16	< **0.01**
absent	25	0.25		25	2.18		24	18.26	
Frequent sneezing									
present	6	0.75	0.39	6	5.36	0.21	5	95.48	**<0.01**
absent	28	0.32		28	2.20		27	18.95	
Watery eyes									
present	6	0.71	0.43	6	2.69	0.94	6	36.44	0.35
absent	28	0.33		28	2.55		26	22.23	
Sore throat									
present	3	0.36	0.97	3	3.39	0.75	2	70.22	0.19
absent	31	0.38		31	2.50		30	22.73	
Asthma Symptoms[a]									
present	9	0.30	0.73	9	2.85	0.82	9	47.76	**0.04**
absent	25	0.40		25	2.48		23	18.75	

[a] Workers who reported either wheezing, or two of the following three symptoms: chest tightness, shortness of breath, or cough on the day they were surveyed were considered to have current symptoms of asthma

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