Industrial Hygiene Survey Report
National Egg Products Company
Social Circle, Georgia 30279

Survey Conducted by:
Mark Boeniger, M.S., C.I.H.
John Decker, M.S., C.I.H.
John Palassis, M.S., C.I.H.

Survey Conducted October 24 - 26, 1995
and March 26 - 28, 1996
Report Completed December, 1996

Report Written by:
Mark Boeniger

Industrial Hygiene Section
Industrywide Studies Branch
Division of Surveillance, Hazard Evaluations
and Field Studies

PURPOSE OF SURVEY:	To characterize the extent of employee exposure to egg protein and chlorine compounds as part of a comprehensive evaluation of egg protein allergic sensitization and immunomodulation.
EMPLOYER REPRESENTATIVES CONTACTED:	Burtice Bright, Director of Human Resources and Safety Dan Vance, Technical Director Johnny Jacobs, General Manager Telephone: 770-464-2652
EMPLOYEE REPRESENTATIVES CONTACTED:	Johnny Crowley, Union Representative Ronald May, Area Representative Glass, Molders, Plastics and Pottery Allied Workers Union, AFL-CIO-CLC
STANDARD INDUSTRIAL CLASSIFICATION OF PLANT:	2017

Abstract

Previous NIOSH investigations of reported asthma among egg processing workers have confirmed that egg protein can cause allergic sensitization. The purpose of the present comprehensive study was to further characterize egg protein exposure and the effects on the immune system of egg-processing workers. The primary hypothesis was that the prevalence of egg-specific allergy with supporting immunological tests would be higher in the exposed plant than in the unexposed referent plant. The secondary hypothesis was that egg allergy would be associated with signs and symptoms compatible with work-related asthma and/or other allergic disorders.

This report presents only the results of the environmental exposure survey. The magnitude of aerosolized egg protein exposure was characterized in each department. Two types of laboratory analysis were performed on the air samples to determine both total non-specific protein, and specific egg proteins using a immunoassay. Size selective aerosol protein sampling was performed to establish the mass fraction of respirable-size particles in the air. As potential irritants that could potentiate the respiratory sensitization and response to airborne antigens, airborne chlorine compounds were measured using a novel approach.

Exposures to egg proteins were highest in the transfer (washing) and egg breaking departments, and the greatest number of employees were located there. There was good agreement between the air monitoring results of total non-specific protein and epitope-specific egg proteins. Chlorine gas was rarely detected, and its presence was limited primarily to the pasteurization department. Chloramine may have been present in most areas of the plant, but its identity could not be unequivocally confirmed with the current analytical method. Chloramine compounds are regarded to be quite irritating to the mucous membranes, and if present, and could be a contributory factor in respiratory sensitization.

Recommendations include reducing both cutaneous and respiratory exposure to egg protein by improving the skin protection program and through engineering changes.

ACKNOWLEDGMENTS

Field sampling support was provided by Mr. John Decker, Atlanta Regional Office, NIOSH and by Mr. John Palassis, Education and Information Division, NIOSH. Ms. Amy Beasley Spencer, Engineering Control & Technology Branch, Division of Surveillance, Hazard Evaluations and Field Studies provided the engineering assessment and design recommendations used in this report. Dr. Martin Petersen provided statistical review of the manuscript. The interest and involvement of the management and employees at the National Egg Products Company is also greately appreciated, for which without this study would not have been possible.

DISCLAIMER

Mention of company or product name does not constitute endorsement by the National Institute for Occupational Safety and Health.

INTRODUCTION

The National Egg Products Company (NEPCO) is an egg processing plant located in Social Circle, Georgia, and is owned by Hudson Foods, Inc. During October, 1994 a Health Hazard Evaluation (HHE) request by the management of NEPCO was received by the NIOSH Hazard Evaluation and Technical Assistance Branch (HETAB). Cases of employees with respiratory problems and asthma-like symptoms, possibly due to egg protein, were reported. An initial site visit was conducted during November 14 and 15, 1994. A NIOSH HETAB team met with company and union representatives and gathered information regarding the production process and employees' health concerns. A NIOSH team including representatives of the Industrywide Studies Branch (IWSB) and the Division of Physical Science and Engineering met with NEPCO company and union representatives on February 28, 1995 to discuss plans for an intensive investigation of egg protein-induced allergies and develop concepts for engineering controls. NIOSH responded to the initial HHE request by having IWSB researchers conduct the study due to the large scope of the project and since IWSB was involved in an on-going project to investigate immunological effects among workers. The main exposure survey was conducted during October 24-26, 1995.

There have been several other evaluations of NEPCO in the past. The Occupational Safety and Health Administration (OSHA) has visited twice, and the Georgia Technologic Research Institute performed an evaluation. However, little or no environmental sampling was performed during those evaluations to characterize the magnitude and differences in exposures within the various departments. In 1981, Clayton Environmental performed air sampling for possible airborne contaminants and found low concentrations of total hydrocarbons and total aerosols, but did not detect gaseous chlorine and ammonia nor mists of sodium hydroxide, potassium hydroxide or phosphoric acid. NIOSH has investigated four egg-processing plants previously through the HHE program due to concerns about egg protein sensitization, but the current investigation is the largest to date. The purpose of this report is to present the results of the environmental survey that was performed by NIOSH investigators. The results of the clinical and immunological study will be presented separately in a different report.

BACKGROUND

It is possible to experimentally sensitize animals to proteins through ingestion, inhalation or through the sub-cutaneous route. Egg protein is comprised of several specific proteins, each with a unique molecular weight and structural configuration. The primary specific proteins and percent contribution for each are: ovalbumin (54%), conalbumin (13%), ovomucoid (11%), and lysozyme (G1 globulin) (3.5%).[1] The respective molecular weights of these proteins are 45,000, 80,000, 28,000 and 14, 300. There are two distinct parts to the edible portion of an egg: the yellow or yolk, and the white or albumin. About 12 percent of the egg is protein, with roughly 41% in the albumin and 59% in the yolk.[1]

During egg processing the egg contents are separated into the yellow fraction and white fraction, are pasteurized by heating to 60°C, de-watered by reverse osmosis, spray dried to an end-moisture content temperature of between 80-90°C, and the final product bagged in 50 lb. packages or shipped as liquid product if not dried. During the heating processes, structural conformational changes in the proteins may occur, especially with lysozyme which can most easily be altered. These changes could possibly influence the extent to which individuals who are sensitized to raw egg proteins respond to processed egg proteins.

DESCRIPTION OF FACILITY AND WORKFORCE

This facility started processing eggs in 1966. Up until 1984, there were 12 Seymour egg washing and breaking machines that were operated during one shift. Impressions obtained from long-term employees who worked then were that employee exposures to egg aerosols and chlorine mists were higher in the past than they are at present. Reportedly, the concentration of sodium hypochlorite in the egg wash and in the cleaning solution for the machines and floor was reduced due to worker complaints. However, no plant records have been identified which can document these changes. Since 1985 the plant has operated (processed eggs) during two daytime shifts.

Process Description

A facility diagram is shown in Figure 1. In this figure, the arrows indicate the flow of the eggs, from receipt to finished product storage. The whole, raw eggs are received from various farms in northeast Georgia and Alabama on plastic trays stacked on pallets; approximately 3,000,000 eggs per day are delivered. The eggs are stored in a refrigerated room, and later moved to the transfer area.

In the transfer area, one or two operators load the plastic egg trays onto one of four Sonovo machines; the eggs are automatically removed from the machine via suction and placed on a conveyer leading to the egg washer. In the washer, the eggs are sprayed with a sodium hydroxide solution, passed through cleaning brushes, through another wash, and rinsed with a sodium hypochlorite-based solution called "Super Clean Shell" (Klenzade, Inc., St. Paul, MN). This alkaline wash solution has a pH of between 11-12 and a total chlorine concentration of 120-130 ppm. The U.S. Department of Agriculture (USDA) requires that the temperature of the wash solution must be 20 degrees higher than the temperature of the egg shell, with a minimum temperature of 100 degrees. At NEPCO, the wash solution is kept between 110 and 120° Fahrenheit. The sodium hypochlorite solution is replaced every 4 hours. There was an exhaust system for each washing unit.

Immediately after washing, the eggs continued on the conveyer belt to the candling station (Figure 2). At this station eggs pass over a bright light to alert an employee to cracked or otherwise unacceptable eggs. The candler employee stood alongside the

edge of the conveyor where the eggs exited from the washer. Upon seeing a defective egg, this person would manually remove the egg and crush the egg before dropping it into a bucket.

Directly after the candling station was a window equipped with a plastic curtain through which the eggs passed into the breaking room. The eggs moved rapidly around large circular horizontal conveyors and were mechanically broken into metal containers with a small hole in the bottom so the egg white could drain out. By the time the egg reached the inspector, it was mostly separated. The eggs were inspected and the unacceptable eggs were manually rejected. For the acceptable eggs, the inspector determined if the egg was properly separated; if so, the drained egg white was removed from the bottom container by gravity, and the egg yolk was removed from the upper container by a concentrated stream of air. The separated egg parts proceeded to a yolk storage tank and an egg white storage tank. If there was not proper separation, the mixed white and yolk were sent together to a whole egg storage tank.

The inspector had complete control over the speed of the machine based on the quality and separation characteristics of the eggs. The eggs were moving at a very rapid pace; one estimate suggested there were more than 250 eggs processed per minute by each inspector. As these eggs passed by the inspector, a weak stream of air blew by the eggs to the inspector, as is required by the USDA. The purpose of this air stream was so that the inspector would be able to "organoleptically examine" the egg, in effect, smelling if the egg was bad; the machine would be stopped and the unacceptable egg disposed of.

The one of the four machines that was referred to as "the big boy" is a double deck machine; it processed roughly twice as many eggs as any of the other three machines. There were two candling stations and two egg inspectors who worked at this machine.

After breaking, the shells from all machines were blown into a chute and conveyed via a paddle conveyer to the inedibles room, where they were ground and used for fertilizer. The paddle conveyer was located in the breaking room, near the floor beside the wall separating the transfer and breaking rooms.

Liquid egg products could be blended with such materials as sugar and salt, then pasteurized and sold in tanker truck quantities or dried. Yeast was added to egg whites for fermentation before drying. Eggs products were dried in one of two spray driers, one for egg whites, the other for yolks or whole eggs. In the dryers, liquid egg products were sprayed into a hot air stream. The dried egg product fell to the floor of the chamber and is transferred by a scraper conveyer to one side of the chamber and into an auger-type conveyer. The hot air passed through a baffle curtain hanging across the center of the chamber, and was exhausted from the chamber through an integral baghouse contained in the ceiling of the chamber. After spray drying, the egg product powder was conveyed to one of two packaging areas, one for yellow and one for white egg powder. There appeared to be very little egg product dust in the air, although settled dust on surfaces was apparent. It has been reported elsewhere that a typical mean particle diameter for spray-dried egg was reportedly 24 microns with a surface area of 2,500 cm^2 per cubic

centimeter of material.[1] The dried egg products were loaded into 50 pound capacity boxes lined with plastic bags. The empty bags were filled by placing them under one of two loading chutes, then secured with an elastic band. A vacuum line removed dust-laden air that was displaced from the container during filling.

Each night during third shift, a sanitation process referred to as cleaning in place (CIP) took place. This was a full 8-hour job, requiring the employees to sanitize the egg breaking machines, pipes and all associated equipment. CIP entailed flushing the equipment with water and injecting a sodium hypochlorite solution, pumping that back out, flushing with city water, followed by injecting a phosphoric acid-based commercial sanitizing product. CIP was performed also in the pasteurization tanks and plumbing during the day shifts as needed. The egg dryers were cleaned about once a month. The chamber was cooled, and an operator dry swept the chamber walls, ceiling, and baffle curtain. The operator wore a disposable dust mask and coveralls.

The company currently employs about 95 employees in production. The majority work the first shift, whereas the third shift is devoted only to sanitization and equipment maintenance.

Process Ventilation

The USDA required that the egg white packaging room must be under slightly negative pressure. The chemical storage room and the inedibles room were also under a slight negative pressure. The USDA also required that the breaking room be under positive pressure at all times. This positive pressure resulted in quite a draft from the breaking room to the transfer room, especially through the "window" where the eggs entered the breaking room. The air flows in the transfer and breaking rooms are shown in Figure 3. According to plant management, this draft from the breaking room to the transfer room is helpful in preventing flies from entering the breaking room from the transfer room. The flies were reportedly sometimes a problem since the eggs from the farms enter the transfer room unwashed. The "window" to the breaking room was extended approximately two feet down under the egg conveyor; the opening was approximately two feet wide. There was a great amount of air passing under the conveyer and up through the steaming eggs. The management saw no real need for this opening under the egg conveyer. In the transfer room, there were four return (exhaust) vents, and an exhaust fan blowing into another room. The return vents were located near the candling stations.

On top of each washer, the manufacturer created an opening for an exhaust duct; the manufacturer did not suggest specifications for the exhaust - each facility "designed" its own system. The washer exhaust system consisted of plastic pipe and flexible duct that ran from each washer into a central duct. This central duct was noted to be dripping water in several locations from the condensing water. Examination of the washer ventilation with smoke tubes revealed that there was removal of contaminants up to approximately 3 inches from the end of the washer housing, but little or no removal of contaminated air near the candling operators.

The USDA required that the air supply to the breaking room be highly filtered. The air passed through filters in the air handling unit, and then through high efficiency particulate air (HEPA) filters. The HEPA filters were located in the supply air registers in the room. There were 14 supply registers in the breaking room, supplying from 20 to 40 percent fresh air. The remainder of the air supply was recycled air from the breaking room. There was only one return (exhaust) air register, and it was located near the entrance to the breaking room.

METHODS USED IN THIS SURVEY

Total Non-Specific Protein Exposure

Total non-specific protein exposure characterization was performed on randomly chosen workers who agreed to voluntarily participate. All air samples were collected on 37-mm closed-face cassettes with polyethylene-supported Teflon® filters (SKC Catalog # 225-17-04) and personal air sampling pumps were attached to the individual employees on their belts. The percentage of samples collected in each department was inversely proportional to the number of employees in each department. Thus, daily sampling included from 40% of the workers in the transfer department, which was the largest, to virtually everyone in each of the other smaller departments. Sampling was repeated over three consecutive days. Only first shift employees were monitored. Approximately 60% of the employees participating in the medical evaluation study had air sampling conducted on them at least once. Sample air flow rates were 2 Lpm, and all samples were essentially for the full shift. Flow rates were checked before and after each day and the average of the two measurements used to calculate total air volume.

Total non-specific protein analyses were performed at the University of Cincinnati Allergy Laboratory. Shortly after sample collection each day, air filter cassettes were stored intact at -20°C until processed for analysis in the laboratory. At the time of analysis, the cassettes were opened and the filter was removed from the plastic backing pad and cellulosic support pad. The protein was eluted from the filters after placing the filter into a screw-cap glass test tube (Pyrex) and covering it with 2 mL of T-PBS (0.01 M sodium phosphate, 0.15 M NaCl, pH 7.4, containing 0.05% Tween 20). Tubes were vortexed 1 minute and stored at 4°C overnight. They were again vortexed 1 minute, and the eluates were removed and aliquoted. Aliquots that were not used immediately were stored frozen at -80°C. The BCA Protein Assay (Pierce Chemical Company, ILL.) was used for estimation of total protein in air samples. The test is based on the use of bicinchoninic acid for monitoring cuprous ion produced in the reaction of protein with Cu^{2+}. This assay is a convenient alternative for the Lowry procedure that employs relatively unstable reagents. Filtrates were analyzed following the manufacturers instructions.

Standard protein solutions were prepared in-house by precise weighing and dilutions of 2.00 mg/mL solutions of lyophilized, desiccated powder of ovalbumin (90% pure crystallized albumin, ICN). When total protein levels were low (0 - 200 μg) a modified enhanced BCA test procedure was used.

Specific Egg Proteins

All air samples for specific egg proteins were analyzed by the University of Cincinnati Allergy Laboratory. Analysis was performed on the eluates from the extraction described above for total non-specific protein analysis. Standard reference material was obtained from commercial sources for ovalbumin, ovomucoid and lysozyme. Rabbit antisera was prepared through intramuscular injection of the purified proteins. All three egg proteins were assayed by indirect competitive inhibition ELISA, with the use of an IgG isotype-specific assay for rabbit antibody bound to antigen-coated plates.

Ovalbumin was also quantitated by a two-site ELISA test. The ELISA reagent for the assay was a species-specific mouse monoclonal anti-rabbit IgG. In the absence of other contradictory indicators, results of low levels of ovalbumin (0-100 μg/mL) were obtained from the two-site assay procedure.

Respirable and Total Proteins

Size selective air sampling for respirable protein aerosol was conducted in addition to sampling for total protein aerosol. To perform respirable sampling, 10-mm nylon cyclones with a 50% aerodynamic cut-off of 3.5 microns were used at a flow rate of 1.7 Lpm and compared to close face cassette samplers at the same flow rate. Previous evaluations conducted by NIOSH in egg processing plants also performed similar comparisons. It is currently not clear if it is biologically important where in the respiratory tract deposition might occur, however, it is plausible to believe that fine aerosols that are in the <3.5 μm range and that reach the tracheal-bronchial regions are more likely to provoke an asthmatic reaction in a sensitized person.

Chlorine Species

Currently there are no specific analytical approaches for distinguishing between simple chlorine species such as chlorine gas, hypochlorous acid, chloride ion, and chloramines. Alternatively, approaches have been taken to collect these species on selective sampling media. A novel approach to sampling and distinguishing between the possible chlorine species was attempted during this survey and is described below.

Sampling for chlorine species consisted of a three-stage filter arrangement in two cassettes joined in series. The first cassette followed NIOSH Method 6011 for chlorine.[2] A Teflon® prefilter selectively removed non-volatile chloride salts from

the air steam. The second filter, consisting of a silver membrane filter, reacts quantitatively with chlorine gas. Any hypochlorous acid aerosol collected on the teflon filter should decompose to chlorine gas. Analysis was performed using ion chromatography. Limited experimentation at NIOSH laboratories indicates that trichloramine is minimally collected by the silver membrane filter.

The first cassette was followed by a second cassette containing two quartz filters treated with sodium carbonate, diarsenic trioxide and glycerol.[3] It is known that the filters will capture chloramines, but probably will also effectively capture chlorine gas, if present.[3] The ion chromatography technique used for analysis is not specific for chloramines. Rather, it was hypothesized that the first cassette would remove most of the chlorine gas, leaving primarily chloramines in the air stream that enters the second cassette.

Questionnaire Survey

A questionnaire survey was conducted at NEPCO and the referent plant to assess the prevalence of symptoms and possible confounding variables. The questionnaire was distributed only to the participants in the medical study (the medical study only included workers who worked the first and second shift at each company). Only the questions concerning skin conditions are mentioned in this report as they relate to the hygienic conditions and work practices at the plant. Five questions addressed skin conditions. These questions were modified from a questionnaire used in a collaborative dermatitis surveillance program conducted by NIOSH and the Washington State Department of Labor and Industry to screen for work-related dermatological conditions.

The questions asked were: 1) during the past 12 months, have you had dermatitis, eczema, or any other red, inflamed skin rash on your hands? 2) during the past 12 months, on about how many days altogether did you have dermatitis, eczema, or some other red, inflamed skin rash on your hands?, 3) during the past 12 months, did this skin rash get better, worse, or stay about the same during the time you were away from your job?, 4) do you believe that the skin rashes or skin conditions that you have had in the past 12 months on your hands were caused or worsened by exposure to any chemicals, substances, or other conditions while you were at work?, and 5) during the past 12 months, did you miss at least one full day of work because of your skin condition? These questions were not specifically worded to identify persons that had physical damage to their skin, such as from minor cuts and abrasions, but these conditions can also cause discomfort and constitute a compromised skin barrier to external agents.

EVALUATION CRITERIA

Proteins

There are no occupational exposure standards or recommendations specific for egg protein aerosols. Exposure to egg protein may lead to sensitization. Allergic reactions may develop in sensitized individuals subsequently exposed to egg protein.[4,5,6,7] Sensitized individuals may react to allergens at low concentrations, and the extent of response may be dose related. In lieu of a specific exposure criteria for egg proteins, criteria for other proteinaceous compounds with sensitizing properties were sought. Subtilisins, a protolytic enzyme of Bacillus subtilis is a sensitizing protein. The American Conference of Governmental Industrial Hygienists (ACGIH) recommends a ceiling limit of 0.06 $\mu g/m^3$ for proteolytic enzymes of Bacillus subtilis that is intended to prevent sensitization.[8]

Four previous studies conducted by NIOSH at egg processing facilities reported total non-specific protein as well as ovalbumin, ovomucoid and lysozyme. A summary of the personal sampling results are shown in Table 1 for purposes of comparison to the results from the present study. It should be noted that some of the procedures used to collect and analyze the protein samples in the earlier studies were different from the methods used in the most recent study. In studies A through D, total protein analysis was performed on glass-fiber filters (1.6 μm pore size) and used the Micro-Kjeldahl method (EPA Method 351.2).[9] This is a reliable analysis, provided that the egg protein aerosol is collected and extracted efficiently from the filters. The total protein results for facility D are not reliable since the recovery of spiked protein samples from glass fiber filters was only 28% - 40% of the target amount. The extraction procedure was unlike the procedure performed in any of the other studies, and could have led to an underestimation of total protein. The total protein procedure used for the NEPCO survey used the BCA protein assay with extraction off the same teflon filter as was used to determine egg-specific proteins. The BCA method is considered reliable in reporting total protein concentrations. Extraction recovery of egg protein from Teflon and glass-fiber filters is presently being evaluated under contract with the University of Cincinnati Allergy Laboratory.

In all the previous studies and in the current study, specific egg proteins were collected on Teflon filters and eluted and analyzed according the RAST inhibition method by Swanson, et al.[10] The eluent used in the original published method contained glycerol which is added as a preservative but glycerol was reportedly not used in the earlier analyses since the samples were analyzed soon after receipt. The specific protein results reported for facility D were also obtained by elution without glycerol and are considered reliable.

Chlorine and Chlorine Compounds

Chlorine gas is a potent irritant of the eyes, mucous membranes, and skin, and inhalation exposure causes pulmonary irritation.[11] Mild mucous membrane irritation may occur at 0.2 to 16 ppm: eye irritation may occur at 7 to 8 ppm, throat irritation may occur at 15 ppm, and cough at 30 ppm.[12] Other studies have shown that some individuals develop symptoms of eye irritation, headache, and cough at concentrations as low as 1 to 2 ppm.[13] The NIOSH Recommended Exposure Limit (REL), ACGIH Threshold Limit Value (TLV), and Occupational Safety and Health Administration Permissible Exposure Level (PEL) for chlorine are all 0.5 ppm time-weighted average (1.5 mg/m^3), 1 ppm short-term exposure level (2.9 mg/m^3).[2,14,15]

Free chlorine in water exists primarily as hypochlorous acid (HOCl) or hypochlorite ion, which are very potent bactericides. HOCl can react with ammonia, urea or amines, and such compounds as the degradation products of organic nitrogenous matter, to form three chloramine compounds: mono-, di- and tri-chloramine. The species of chloramine and concentrations of each are affected by the concentrations of chlorine as well as the pH and temperature.[16] Alkaline pH retards the formation of trichloramines and favors formation of the mono- and dichloramines. The trichloramine, unlike the mono- or di-chloramine, has a low solubility in water and readily volatilizes upon agitation.[17] Trichloramine is very irritating to the mucous membranes of the eyes, nose, throat and respiratory tract.[18] Because chloramines are very unstable and no satisfactory specific method has been found to sample chloramines in air, no exposure criteria presently exist.

Chloride compounds comprise a diverse number of metal salts coupled with chlorine. Most common chloride compounds, such as sodium chloride (common table salt), are essentially innocuous unless the chloride is combined from a toxic metal.

RESULTS

Total Non-Specific Protein

Fifty-five personal sampling results were used in the analysis of total non-specific protein. The results are shown in Table 2. These data are also depicted in a bar graph showing the arithmetic means and geometric means of the results for each department (Figure 4). Exposure measurement data are typically log-normally distributed, thus there is a bias towards having more data at the lower concentrations and fewer data at higher concentrations. Thus, it is usually preferred to express exposure concentration data using the geometric mean since it is probably a more descriptive indicator of the predominant data. When the geometric mean is much lower than the arithmetic mean, this indicates that the bias of the median towards the lower concentrations is especially true. However,

for health effects studies such as this one, where a linear cumulative exposure response model may be applicable to the health effect, using arithmetic exposure data may be more useful.[19]

At this plant, the highest average concentrations exist in the transfer department (arithmetic mean = 644 $\mu g/m^3$) and breaking departments (arith. mean = 255 $\mu g/m^3$). High concentrations were also found in the white packing room (arith. mean = 426 $\mu g/m^3$), but only one person was exposed per shift in this job. All other departments/jobs appeared to have appreciably lower exposure potentials (arith. mean range 91 to 9 $\mu g/m^3$).

The concentration data for each department were statistically analyzed for similarities using a parametric multiple range test (95%Scheffe confidence intervals). This analysis, plus the graphical distribution of data, allowed for combining the small numbers of samples in pasteurization, drying, yellow packing and sanitation which increased the sample size.

A visual check of the distribution of the data from the two largest departments (i.e., transfer and breaking) and use of the Shapiro-Wilkes W statistic for checking normality indicated that the data were neither normally- or log-normally distributed (in the latter case the median is less than the average). Again, however, when there is a large sample of exposure data available, it is usually found to fit a log-normal distribution and consequently log transformation of this data was performed.

The log-transformed data are depicted in a box and whisker plot in Figure 5 which graphically shows the distribution of the data and how they compare wihin each department. The highest concentrations are shown to be in the transfer and breaking rooms.

A one-way analysis of variance of the four groups of data indicated highly statistically significant differences among the groups. A parametric multiple range test using 95% Scheffe confidence intervals indicated that the transfer, breaking and white packing exposure data were not statistically significantly different from each other but that the combined pasteurization, drying, sanitation and yellow packing data were dissimilar to these other departments. It was therefore considered for comparison purposes statistically valid to consider the exposures in transfer, breaking and white packing to be different from the other departments.

Total non-specific protein levels in the white packing room were statistically similar to transfer and breaking departments, but allergenically may be different due to prior heat processing. Furthermore, although exposure in the white packing room appears similar to transfer and breaking, because of the small sample size (n = 3) confidence in this assumption is low.

Specific Egg Proteins

The results of the analyses for three specific egg proteins (ovalbumin, ovomucoid and lysozyme) are presented in Tables 3 through 5. The arithmetic mean results of these individual proteins along with their sum, referred to as total specific protein, are depicted in Figure 6. The relative concentrations of each of these proteins are shown. If these measures of specific protein are compared to the total non-specific measurement data in Figure 4, a relative concentration difference in Department 5 (white egg packaging) is suggested, possibly attributable to heat alteration of the protein which could change its conformation and the ability of the isotype-specific immunoassay to detect this altered protein. Furthermore, lysozyme, while found at low concentrations even in the transfer and egg breaking departments, appears to be conspicuously low or absent in Department 5. The small number of samples in this and in the yellow-packing department prevent more definitive conclusions regarding the likelihood of protein alteration.

The sum of the three specific egg proteins was related to the total non-specific protein analysis by linear regression analysis after normal log transformation of the data. The results are graphically depicted in Figure 7. The correlation coefficient was 0.88, indicating a moderately strong association between the two measures of protein. The model according to the analysis of variance is highly significant ($p < 0.0001$). The equation for the fitted model is LN3PROT = 0.61 + 0.922*LNTOTPROT. It might be concluded from this that using either type of chemical analysis should produce comparable results.

Respirable and Total Protein

The results in Table 6 present side-by-side stationary sampling for total protein and respirable protein. These samples were collected in three areas of the plant. Referring to the total non-specific protein results, the aerosol concentration for respirable protein is generally less than the total aerosol sample. However, in three of the eleven pairs this is not true. Similar findings were obtained in the previous studies of egg processing plants, and this may suggest that there is rather wide sampling imprecision of air sampling in general.

Overall, the average concentration of respirable non-specific protein (RNSP) and total non-specific protein (TNSP) in the paired data set is 322 and 607 $\mu g/m^3$, respectively. Because the respirable sampler is selective in collecting only the smaller aerosol ($<3.5\ \mu m$), it is expected that the respirable sample result will be less than the total aerosol result. The mean difference between RNSP-TNSP was -284.5 (std. dev. =330). It is perhaps worth noting that the two concentration measures are less dissimilar in the wet departments (transfer and breaking area means were 440 and 768 for respirable and total aerosol, respectively) than in the white packing department where dried egg protein is present (10 and 179, respectively) suggesting that the airborne aerosol size is smaller in the wet

processing areas than is the particle size of the dried egg. Since the differences of RNSP-TNSP were normally distributed, a matched-paired t-test was performed on the nontransformed data. The RNSP-TNSP difference between the two matched data sets were significantly less than zero ($p = 0.009$, 1-tailed test).

If the predominant specific protein (ovalbumin) is analyzed instead of the total non-specific protein, slightly different results appear between the matched pairs of respirable ovalbumin (ROA) and total ovalbumin (TOA), and the statistical outcome is nonsignificant ($p = 0.25$, 1-tailed test), in contrast to the non-specific protein results. The mean difference between ROA-TOA was -94 (std. dev. = 440). The paired sampling data for ovalbumin do not appear statistically different between data sets because the mean difference is closer to zero and the variation in the data is larger. The implication of this outcome may be that the specific protein analyses are less precise (more variability in response) but there is insufficient evidence of this at this time.

Referent Plant Samples

Total non-specific protein and three specific egg proteins were sampled in the referent plant in Social Circle. These were collected in various locations inside the plant and outdoors. The results are reported in Table 7. It was not expected to find egg-specific proteins in this environment, but low levels of non-specific protein could be present. Low levels of non-specific protein were found in the referent plant (ND - 41 $\mu g/m^3$) but only a trace of ovomucoid was detected in one of the egg-specific protein samples.

Quality Control Samples

For quality control purposes, field blank and laboratory blank samples were analyzed for non-specific (total) protein and three specific egg proteins in the same manner as were the field samples. These samples are expected to contain low or non-detectable amounts of analyte. The results of these analyses are provided also in Table 7. None of the field blanks from the referent plant or laboratory blanks contained specific egg proteins but trace amounts of nonspecific protein were detected in two of five samples. The field blank samples taken at NEPCO all resulted in having non-detectable quantities of total non-specific protein or ovalbumin and ovomucoid egg proteins. There were trace amounts of lysozyme protein on some of the blank samples taken at NEPCO. This lysozyme background was not detected on the blank samples taken at the referent plant or in the laboratory blanks. Due to the non-detectable, very low level, and inconsistent nature of positive blank samples, none of the reported data were blank corrected.

Chlorine Species

Chlorine sampling was performed during the egg protein exposure survey but problems with sample media contamination (as received from the manufacturer) precluded analysis of chlorine. The analysis of chloramines was completed but are not reported since it was decided to reconduct the survey for chlorine species. A second attempt to conduct this sampling was undertaken during March 26-28, 1996.

The results of sampling for chlorine compounds are shown in Table 8. The data rows are shaded in those cases where samples were collected in the same locations on consecutive days. Results are reported for the combination sampler, providing individual results for "chloride, chlorine, and chloramine". Again, it is cautioned that these chemical identifications are used loosely as the sampling and analytical approach has not yet been fully validated.

As shown in table 8, trace amounts of chloride were detected in most samples (range <4 - 35 $\mu g/m^3$). However, chlorine gas was only detected twice in the transfer and breaking rooms (7.8 and 12.5 $\mu g/m^3$). Chlorine gas was detected on two of three days in the pasteurization department (range <4 - 54 $\mu g/m^3$). The CIP sanitizing process includes the use of a sodium hypochlorite solution, but it is recycled and not drained onto the floor of the pasteurization room. However, it may be possible for chlorine to vent into the room when alkaline hypochlorite solution is used, if free chlorine gas is generated while in use.

Overall, the low incidence of detection of chlorine in this facility parallels the results gathered in other egg processing facilities surveyed by NIOSH, which might seem unlikely given the ubiquitous presence of chlorinated water and the high concentrations used in these facilities. It is likely that the alkaline nature of the wash hypochlorite solutions prevents decompostion to free chlorine. Nevertheless, the concentrations measured in the air were well below the exposure limit criteria.

Interestingly, a chlorine compound, tentatively identified as chloramine, was detected in low concentrations in most areas (Table 8). The highest average concentration was in the transfer room (11 $\mu g/m^3$) followed by the breaking room (9 $\mu g/m^3$). This compound was detected on the last sampling media in the sampling train. The results suggest that the prior sampling stages may not collect all chlorine compounds present.

However, the quality control results are somewhat ambiguous in that two of seven field media "blanks" contained detectable analyte. None of the five laboratory blanks contained analyte. Furthermore, in the first attempt to sample chlorine compounds in October 1995, none of the seven field blanks contained detectable analyte. Because the predominant blank sample results contained no detectable

analyte, no further attention was given to the few detectable results. Thus, the reported survey results were not blank corrected and the reported values should be valid.

Another concern is that many of the results were close to the limit of analytical detection, probably making these results less reliable. Additional laboratory research is still needed to confirm the likely identity of this chlorine compound and the performance reliability of the sampling method.

Questionnaire Results

Questionnaires were administered to and completed by 42 (of 55 eligible) workers at NEPCO and 33 workers at the referent plant. Employees experiencing a rash numbered 4 at NEPCO and 3 at the referent plant. None of the responses to the questions at either company were remarkably different except for the fourth question which asked about to what the worker attributed the dermatitis. While only one of the three workers at the referent plant attributed their condition to workplace chemicals or conditions, all four workers at NEPCO did. The causes of these skin conditions were associated primarily with disinfecting cleaners and soap. None of the conditions were severe enough to result in taking at least one full day of lost work because of the skin condition.

DISCUSSION

It should be recalled that the physical structure of several egg proteins is known to be altered by the pasteurization and drying processes and may be allergenically different than the raw egg protein. There is some evidence of this found in the environmental sample results. The relative difference found in Department 5 between the concentration of total non-specific protein and in the concentration of egg-specific protein using a epitope-specific immunoassay suggest that protein conformational transformations may have occurred. Thus the final egg product may be allergenically different than the raw egg proteins, at least in respect to some egg proteins. It may be possible for someone to be sensitized to proteins in the finished egg product that are not the same as in the raw egg, and vise-versa. In this research study, worker participants were tested for sensitivity to both raw and processed egg proteins. Although there was generally a good correlation between total non-specific and specific egg protein, and the simpler total protein determination would suffice for most exposure assessment purposes, for this research study it was of particular importance to measure airborne concentrations of specific egg proteins as well.

Furthermore, the respirable-selective versus total aerosol sampling performed in the wet versus dry products areas suggests that the aerosol size in the wet areas might be smaller than in the packing room, making the particles more likely to reach the lower regions of the respiratory system. The larger mean spray-dried

particle size of 24 μm reported elsewhere would support the suggestion that dried egg protein is less respirable.[1] It is reasonable to expect that potential allergens, like egg protein particles that are too large to reach the bronchi and lower lung, will be less likely to result in an asthmatic episode.

Due to the lack of past exposure data, it was not possible during this environmental survey to determine if current exposure concentrations are different than past concentrations, especially prior to 1984, which is when substantial process design changes occurred. Personal accounts indicate that exposures were higher before those changes occurred. Ventilation design and capacity may have changed but this could not be documented. Chlorinated wash solution products may have also changed which could have affected the air concentrations of these chemicals. Although current concentrations of chlorine gas, and possible chloramine, appear to be low, accounts by employees suggest higher air concentrations in the past. There is literature that suggest the combination of irritation and allergen exposure may potentiate sensitization.[20,21,22] Specific to egg proteins, it has been shown that the co-administration to mice of ovalbumin mixed with diesel exhaust particulates, by either the intraperitoneal or intranasal routes, results in increased production of IgE antibody specific to the protein allergen.[23,24] In addition, exposure to guinea pigs to high concentration of sulfur dioxide followed by sensitization with ovalbumin was shown to result in both elevated levels of specific IgE antibody and increased airway responses following inhalation challenge with the protein.[25] Such evidence supports the need to continue to maintain low exposures to irritating compounds.

Presently there is an incomplete understanding of the events leading to egg protein allergy and the magnitude of exposure necessary for this to occur. Apparently there are important biological differences within individuals that are related to their susceptibility to become sensitized. From this environmental data alone, it cannot be concluded that current exposures will lead to future cases of egg protein allergy. However, the protein air concentrations documented in this facility are comparable to earlier studies where egg-related asthma was found. The concentrations of airborne egg protein are up to 10,000 times greater than airborne concentrations of ragweed allergen at the peak of the ragweed pollinating season and 50-300 times higher than that found for protein aerosols inducing asthma in other occupational settings.[26] In ragweed pollen, the predominant antigenic protein accounts for only 0.2% of the total solids and a high daily exposure to this protein may amount to only 40 nanograms.[27]

Current airborne egg protein concentrations at this facility have been thoroughly documented in each department. Understanding the magnitude of exposure for each job is important to know in regards to the relative magnitude of risk of sensitization and response, once sensitized. Only the exposure potential of the first shift employees in the production process were evaluated, since no apparent differences exist between the first shift workers and the second shift. The

sanitation workers working the third shift are unique to operating only on that shift but their exposure to egg protein appears to be less than for transfer and breaking department workers, according to the monitoring results.

The possibility of a cutaneous route of exposure to egg proteins should not be discounted. For healthy intact skin, the large molecular size of egg proteins would prevent these proteins from passively diffusing through the stratum corneum. However, damaged skin is much less effective as a barrier to external exposure and egg proteins could readily come in contact with the deeper epidermis and its vital immune capacity. Using the guinea pig, intradermal injection of low concentrations of ovalbumin has been shown to be much more able to induce subsequent respiratory response to aerosolized egg protein than two other well known allergens-trimellitic anhydride and dust mite antigen.[28] Local sensitization might well progress to systemic sensitization that could result in respiratory asthma.[29]

The potential for having compromised skin barrier function is considerable at NEPCO. First, constant wearing of occlusive gloves or immersion in liquids damages the skin because of the wetness. Some of the gloves that had been worn were checked and a few contained holes that could allow the egg protein to enter underneath the glove and to be in constant contact with the skin. The average lifetime of glove wear reported by the workers is about two weeks. Secondly, physical damage to the skin can occur from contact with the egg shells. One candler employee was observed not wearing any gloves, which are optional in the transfer room. This person repeatedly crushed eggs in the hand before dropping them into a bucket. This could easily cause small cuts and abrasions in hands that were frequently wet and in fact the employee's hands showed considerable damage. This employee's condition reportedly had been progressing in severity for some time. One source of information at NEPCO recalled gloves first being introduced for widespread use in the early 1970s. Given that the plant started operating in the mid-1960s, gloves may not have always been as readily available or worn as often as at present. Several employees complained that the gloves provided were only ordered in sizes 8 and 9 and usually only one size was ever present at any one time. Finally, another compromising factor that can damage the skin is the use of hypochlorite sanitizing solutions to disinfect the eggs and dilute phosphoric acid solution for sanitizing the hands in the transfer and breaking rooms, respectively.[30,31,32,33] Hypochlorite sensitivity of the delayed type as well as immediate type reactions are known to occur among sensitized individuals.[33]

GENERAL RECOMMENDATIONS

The highest concentrations of airborne egg protein liquid aerosols occur in the transfer and breaking rooms, while the highest concentration of egg protein powder exists in the egg packaging room. There is clear evidence that egg protein can sensitize humans, but it is far less clear if there is a threshold of exposure below

which there is little risk. There appears to be great interpersonal differences in the ability to become sensitized to potential allergens. However, as with most biologically active compounds, there is increasing likelihood of effect with increasing dose. The engineering control recommendations provided below, including the use of general dilution ventilation and improved local exhaust ventilation, could be used to reduce these airborne concentrations. Additional modifications in the equipment design provided by the equipment manufacturer may be necessary to further reduce airborne exposures to egg proteins.

Air sampling to ascertain airborne concentrations of egg protein could be performed periodically to confirm that engineering controls that are in place are working and that modifications in the equipment and control ventilation are performing as intended. As a result of the comparison between the two methods that were used in this study to determine airborne proteins, choosing a total non-specific protein assay, such as the micro-Kjeldahl or BCA protein assay is recommended.

Several employees have experienced dermatological problems on their hands at this facility. These problems may be caused or aggravated by the disinfecting chemicals, frequent wet conditions, or by the gloves. Some gloves contain additives that are capable of causing sensitization and rubber latex proteins are also a potential cause of allergy. Several types of gloves should be available that are hypoallergenic in respect to both the glove additives as well as low in free rubber proteins if made of natural rubber latex. By wearing gloves in the breaking room, it should be possible to keep the use of disinfecting solutions on the hands to a minimum. If gloves are to be used over an extended period of time, a means of drying the insides between use should be investigated. Decreasing exposures and conditions that are damaging to the skin, and recognizing and treating dermatitis early is important in preventing more serious skin-related problems and possibly in decreasing systemic sensitization to egg proteins. Finally, employees should be provided information in the personal aspects of healthy skin maintenance.

For a mixed gender population, several size gloves, especially including smaller sizes to accommodate female workers, should be always available to encourage glove use and enhance employee productivity. Separate glove liners are available that are intended to absorb perspiration underneath a gloved hand. These may be replaced when wet and laundered for reuse.

Specific Engineering Control Recommendations

In November 1994, a NIOSH engineer took some preliminary aerosol measurements using a GCA Real-time Aerosol Monitor (RAM). These measurements were taken to prioritize potential sources of exposure to egg containing dusts and mists. The highest measurements of aerosol concentrations were in the transfer and egg-breaking areas. Since the highest potential airborne exposures are in the transfer and breaking rooms, the recommendations below for engineering controls are

limited to these areas. These concepts for improved controls were developed on-site during the walk-through evaluation. These ideas were discussed with the facility's technical director to determine process compatibility and compliance with USDA regulations.

Transfer Room

Visible aerosol escaped from the egg washer near the exit. The amount of aerosol is probably related to the temperature of the wash water. This mist may be an important source of exposure to egg protein since broken eggs inevitably enter the washer and the wash water. To reduce misting, it is desirable to lower the temperature of the wash water to the lowest degree while still maintaining the cleaning capacity and meeting the USDA requirement. The average temperature of the incoming egg shells should be re-calculated and the temperature of the wash water altered according to USDA regulations (egg shell temperature plus 20 degrees). Since the eggs are stored in a cooler before entering the transfer room, perhaps the operators could use the "first in, first out" rule, thereby allowing the eggs to cool before entering the transfer room. Another possibility is to do a quick temperature check of the eggs before entering the transfer room for the washing process; this would ensure the eggs are below a certain temperature before washing. Either of these procedures should lower the overall minimum temperature for the wash water (based on egg shell temperature) as required by the USDA. The built-in thermometers should be calibrated regularly to ensure accurate temperature readings. A tight temperature range in the wash solution should be maintained.

It is possible that NIOSH researchers or others could take aerosol measurements with the RAM inside the egg washer exhaust duct while varying the temperature of the wash water. With increasing wash water temperature, there will theoretically be increased aerosol formation. This would show the significance of reducing egg wash water temperature with respect to aerosol formation.

The ventilation system for the egg washer should be redesigned, with consultation from a ventilation engineer, to provide an in-draft sufficient to capture the escaping mist. The exhaust flow rate should be increased. The housing of the machine where the egg exits, after the washing process, could be extended. This extended housing would allow for ventilation closer to the candlers to assist with aerosol removal nearer to the candlers.

A large amount of air enters the transfer room from the breaking room via the windows; this air is likely contaminated with protein mists. There was a large air flow from the portion of the window below the conveyor, causing air to flow up through the wet, sometimes broken eggs, up to the candler. The window opening should be closed below the conveyor; although this will not change the net amount of air entering the transfer room from these windows, it would limit the airflow through the wet eggs. Since the total amount of flow would remain unchanged, the

facility should consider the installation of exhaust hoods directly above the transfer room windows to capture the air entering the transfer room from the breaking room.

In the facility, there appeared to be the impression that the more negative the air pressure is in the transfer room, the better (since this will pull air from the breaking room, ensuring positive pressure). The USDA regulations state only that the breaking room must be under positive air pressure, not excessively positive air pressure. This simply means that there must be more air volume coming into the room than is exhausted. It appears that currently, there is a lack of supply air in the transfer room. The air entering the transfer room from the breaking room could be exhausted through a hood over the window in the transfer room. The USDA's regulation for positive pressure in the breaking room would still be met. An air balance should be performed by a heating, ventilation and air conditioning (HVAC) engineer.

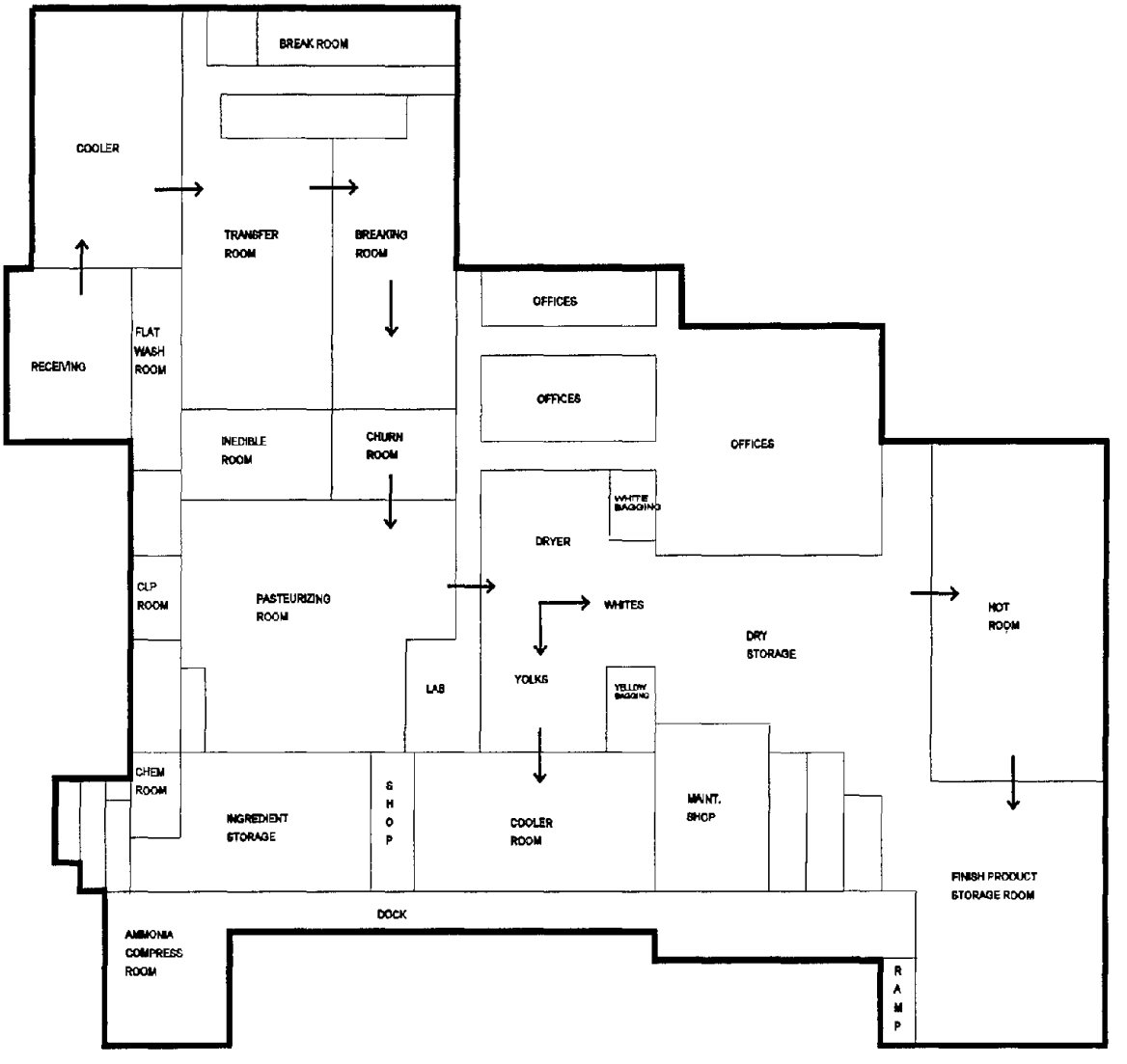
In November 1994, it was estimated that there is approximately 800 cfm of air coming into the transfer room from the breaking room through each window. The facility's technical director noted that the amount of exhaust in the transfer room was necessary to remove the heat and humidity. The rate of exhaust can remain the same, however, there should be more fresh supply air introduced into the transfer room. This air should be introduced near the candlers. One source of air supply should be "air showers" installed directly over the candlers, not more than 2 feet above their heads. These air showers should be of a velocity of approximately 50 cfm/ft^2, with the register resembling pegboard so as to evenly distribute the air. There can be other supply registers located elsewhere to maintain adequate room pressure.

Breaking Room

As was the case in the transfer room, low velocity air showers should be incorporated over the stationary workers in the breaking room. As was noted by the initial NIOSH walk-through in November 1994, the high velocity compressed air used to remove and transport the shells apparently causes the atomization of some egg material and induces an airflow down the egg ejector chute. The chute could serve nicely as an exhaust hood by the connection to an exhaust duct at a rate of about 150 to 200 cfm. In addition, covers should be kept in place on the shell conveyor.

For the person who sits at the breaking machine and "sniffs" the bad eggs, automatic sensors might be installed to detect hydrogen sulfide that would eliminate the need and exposure created by the air jet. It would need to be determined if the response time is quick enough to alert the operator of a bad egg.

Figure 1
Facility Layout for Egg Processing Plant
NEPCO, Social Circle, Georgia



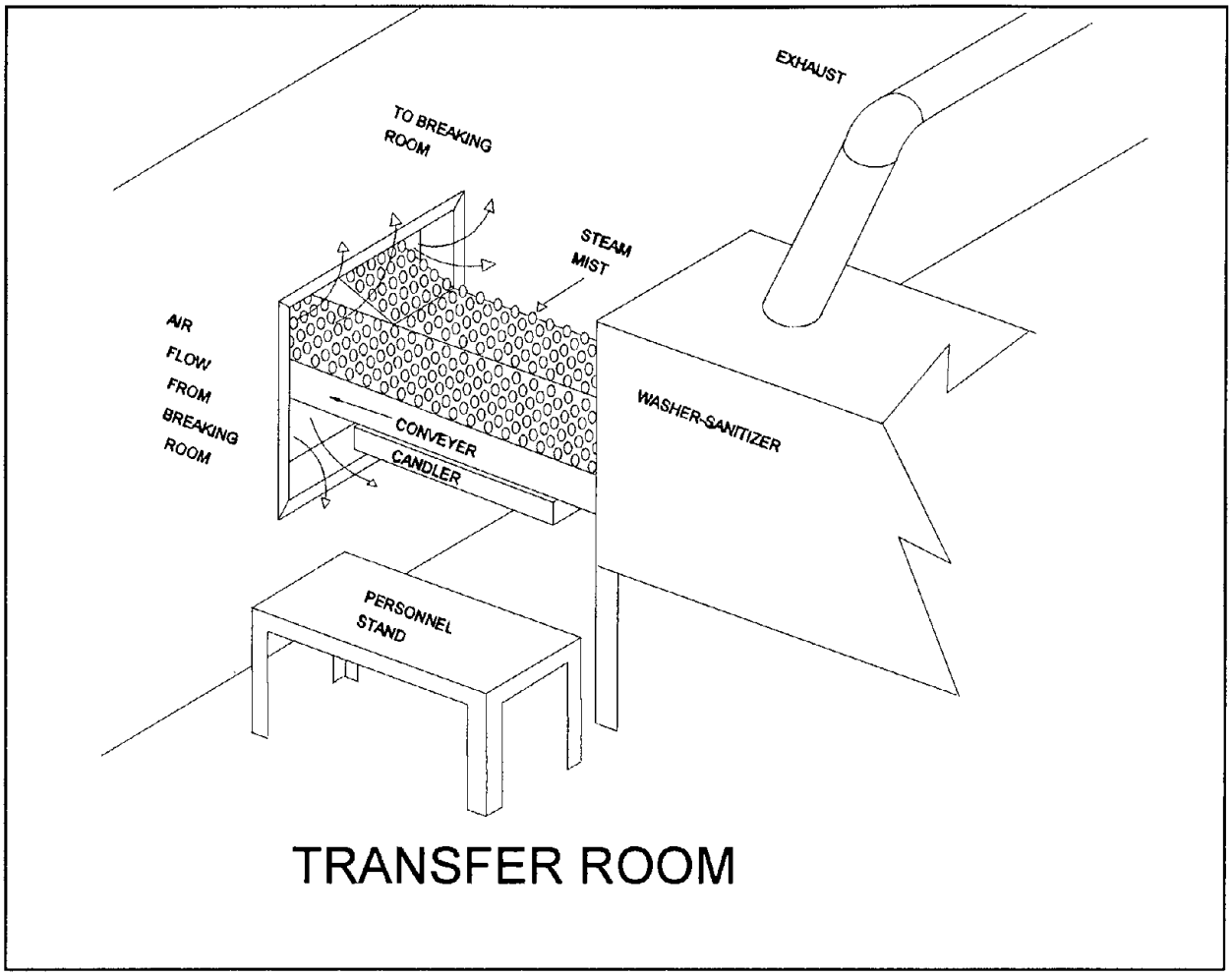


Figure 2: NEPCO Transfer room diagram

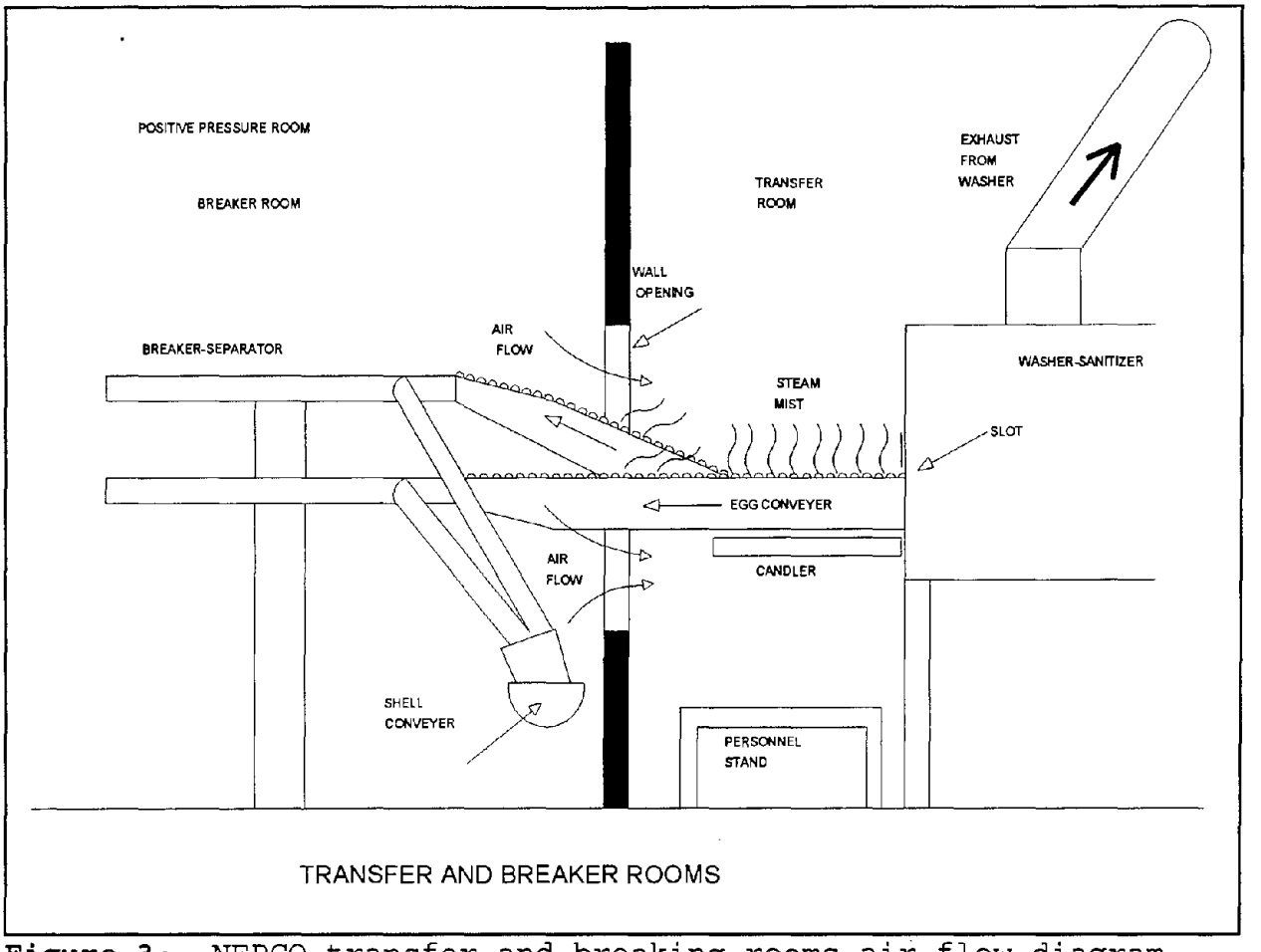
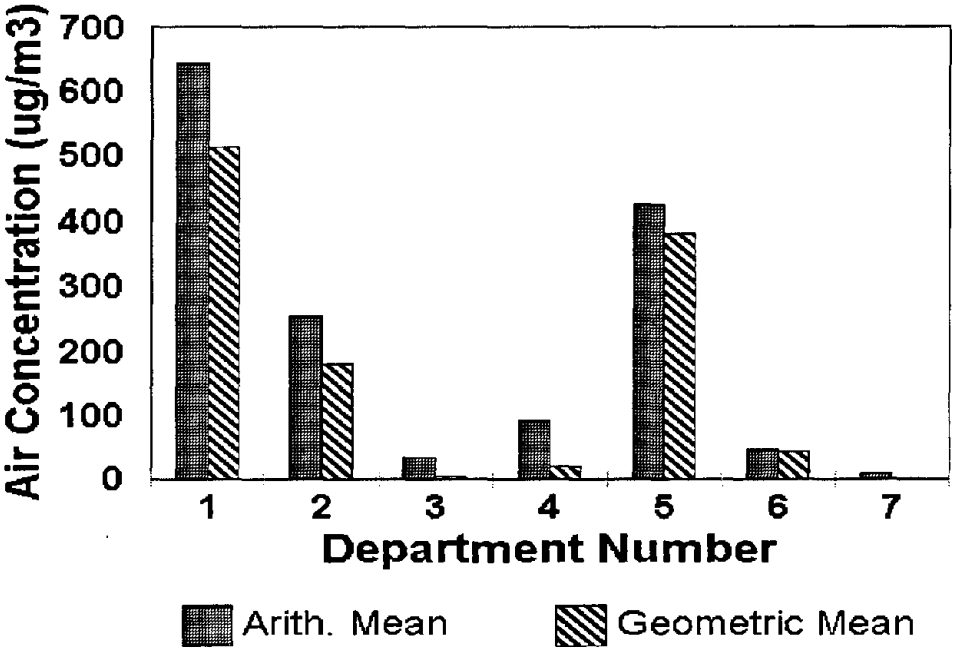


Figure 3: NEPCO transfer and breaking rooms air flow diagram

Figure 4

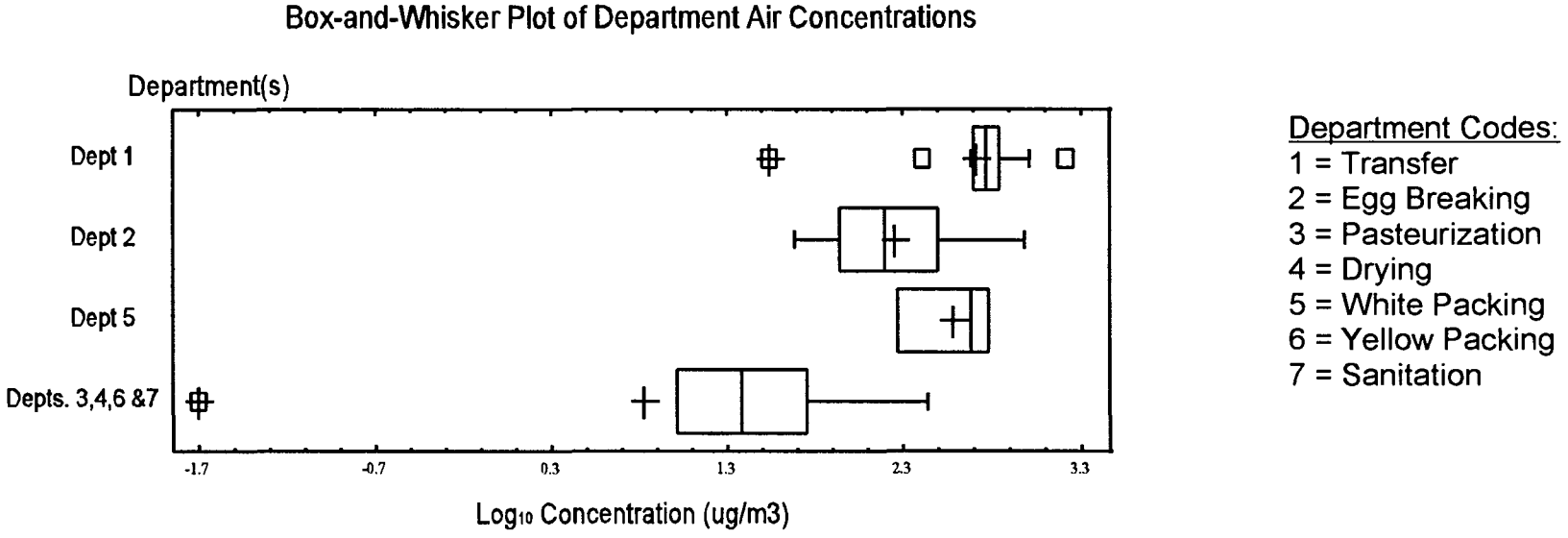
Total Non-Specific Protein in Each Department
NEPCO, Social Circle, Georgia
October 24 -26, 1995



Department Codes:

1 = Transfer
2 = Egg Breaking
3 = Pasteurization
4 = Drying
5 = White Packing
6 = Yellow Packing
7 = Sanitation

Figure 5
Total Non-Specific Protein Air Concentrations
NEPCO, Social Circle, Georgia
October 24 -26, 1995



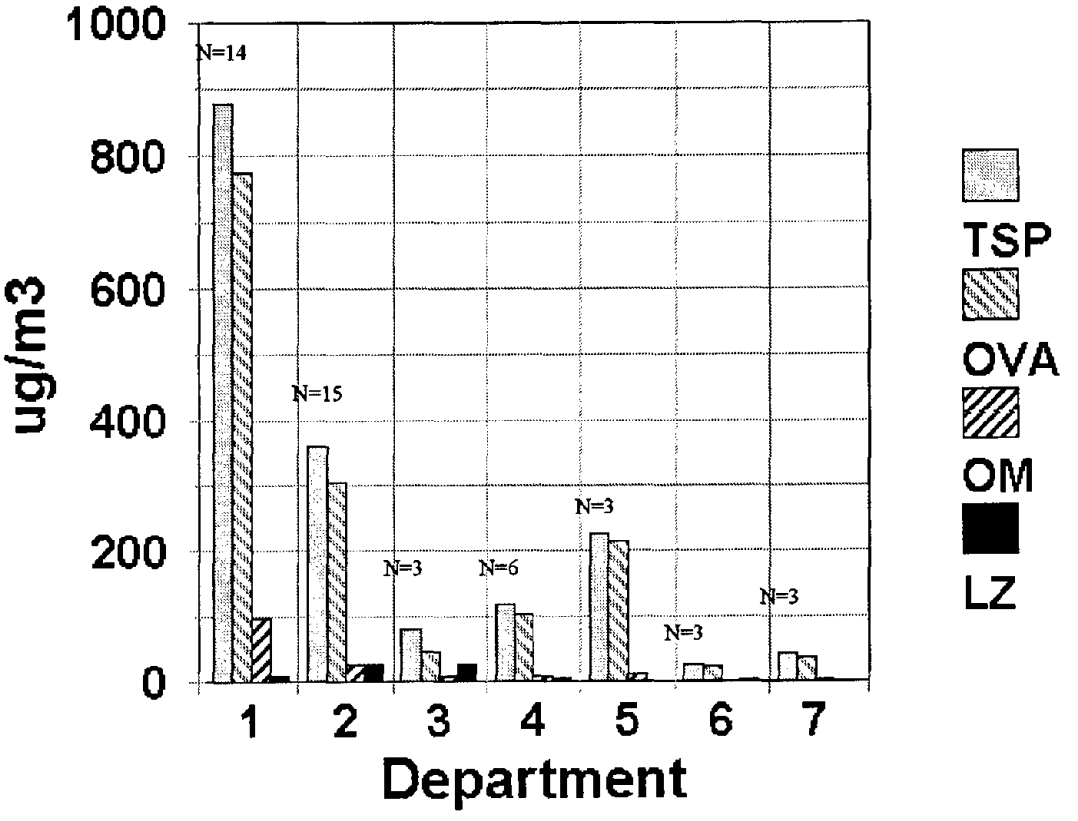
Department Codes:
1 = Transfer
2 = Egg Breaking
3 = Pasteurization
4 = Drying
5 = White Packing
6 = Yellow Packing
7 = Sanitation

The box plot divides the data into four areas of equal frequency (quartiles). A box encloses the middle 50 percent of the data. The median is drawn as a vertical line inside the box. The mean is indicated by a +. Horizontal lines extend from each end of the box to the smallest or largest data point or within 1.5 interquartile ranges from the first or third quartile. Individual points, data values that fall beyond the whiskers but within 3 interquartile ranges (suspect outliers) are shown. For far outside points (outliers) -- those data points more than 3 interquartile ranges below the lower quartile or above the upper quartile -- a special character is used (a point with a + through it).

Figure 6

Arithmetic Mean Air Concentrations of Four Protein Measures

Total Specific Protein = TSP; Ovalbumin = OVA; Ovomucoid = OM; Lysozyme = LZ



Department Codes:

1 = Transfer

2 = Egg Breaking

3 = Pasteurization

4 = Drying

5 = White Packing

6 = Yellow Packing

7 = Sanitation

Regression of Sum of Three Specific Egg Proteins and Total Non-Specific Protein Air Sampling Results (µg/m^3)

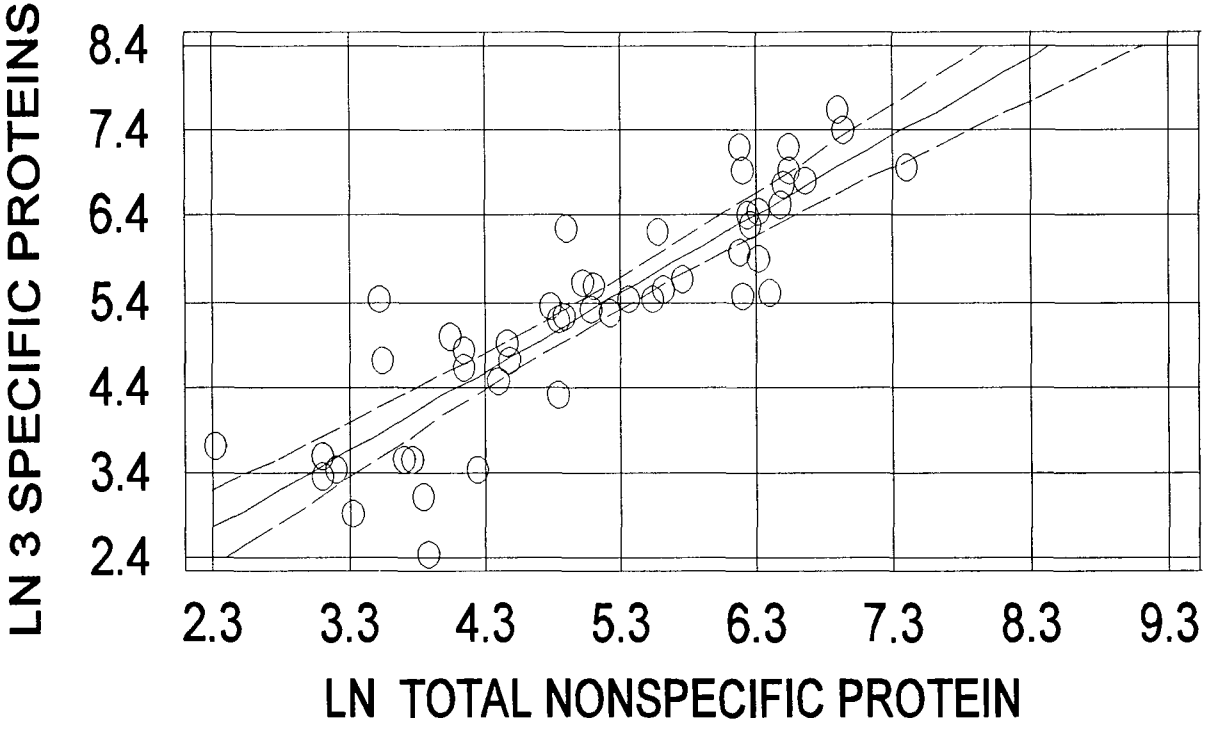


Table 1
Egg Protein Concentrations Obtained at Other Egg Processing Facilities
Personal Monitoring Results

Facility/Location	Total Protein			Ovalbumin	
	Number of Samples	Average ($\mu g/m^3$)	Standard Deviation	Number of Samples	Average ($\mu g/m^3$)
Facility A - 3/87 [34]					
Transfer Rm.	5	580	174	1	107
Breaking Rm.	3	167	11	1	7
Dryer	1	390	--	1	132
Packaging	2	1615	--	1	140
Facility B - 3/87 [35]					
Transfer Rm.	7	404	62	2	150
Breaking Rm.	3	267	106	1	420
Yellow Dryer	2	545	--	2	555
White Dryer	1	10000	--	1	9800
Blend Packaging	3	57000	63720	2	34500
Facility C - 3/87 [36]					
Transfer Rm	6	665	291	2	119
Breaking Rm	4	710	168	1	360
Facility D - 8/93 [37]					
Transfer Rm.	7	38	28	6	1022
Breaking Rm.	5	339	261	6	2518

See text for interpretation of results.

Table 2
Personal Non-Specific Protein Sampling Results ($\mu g/m^3$)
NEPCO, Social Circle, Georgia
October 24 -26, 1995

Job/Department:	Transfer	Breaking	Pasteurization	Dryer	White Pack.	Yellow Pack.	Sanitation	Flat Wash
	34.4	48.9	[0.02]	[0.02]	184.5	22.1	[0.02]	66.4
	263.2	63.1	[0.02]	24.6	489.9	46.4	12.8	583.1
	480.6	82.1	[0.02]	40.8	603.8	68.8	15.1	
	496.2	87.9	10.2	86.4				
	514.0	131.2	22.0	119.2				
	519.8	134.6	27.7	275.9				
	551.4	150.0	42.6					
	647.8	161.1	56.5					
	671.7	162.8	126.9					
	686.3	210.9						
	696.9	254.1						
	780.5	317.9						
	1043.0	483.4						
	1634.0	551.8						
		982.5						
Arith. Mean	644.3	254.8	31.8	91.2	426.1	45.8	9.3	
Geo. Mean	513.3	180.3	2.9	19.6	379.3	41.3	1.6	
GSD	2.4	2.3	44.7	32.4				

Values in brackets [ ] are below the limit of detection (LOD) of 0.02 μg/sample, and the value of LOD/2 was used to calculate the summary statistics.

Table 3

Ovalbumin Personal Air Sampling Results ($\mu g/m^3$)
NEPCO, Social Circle, Georgia
October 24 -26, 1995

Job/Department:	Transfer	Breaking	Pasteurization	Dryer	White Pack.	Yellow Pack.	Sanitation	Flat Wash
	66.7	11.1	14.8	20.1	193.1	18.6	15.4	36.2
	448.9	82.1	31.5	22.5	205.3	20.8	25.2	1249.5
	499.8	84.1	32.5	44.8	241.5	28.1	77.0	
	533.0	98.6	36.6	129.7				
	541.0	116.4	37.6	198.2				
	598.0	166.6	46.8	198.6				
	736.5	184.8	56.4					
	777.1	187.3	72.5					
	790.3	197.2	94.1					
	918.8	222.0						
	936.2	223.4						
	1193.6	262.5						
	1310.8	306.5						
	1490.1	371.9						
		2085.3						
Arith. Mean	774.3	306.7	47.0	102.3	213.3	22.5	39.2	
Geo. Mean	648.8	170.9	41.6	68.5	212.3	22.2	31.0	
GSD	2.1	3.0	1.7	2.9	1.1	1.2	2.3	

Values in brackets [ ] are below the limit of detection (LOD) of 0.2 μg/sample, and the value of LOD/2 was used to calculate the summary statistics.

Table 4
Ovomucoid Personal Air Sampling Results ($\mu g/m^3$)
NEPCO, Social Circle, Georgia
October 24 -26, 1995

Job/Department:	Transfer	Breaking	Pasteurization	Dryer	White Pack.	Yellow Pack.	Sanitation	Flat Wash
	3.4	[0.1]	[0.1]	[0.1]	1.1	[0.1]	[0.1]	[0.1]
	43.0	0.2	0.2	0.3	2.2	[0.1]	[0.1]	45.8
	43.7	0.3	0.7	1.1	32.7	3.9	7.6	
	51.0	0.5	1.6	2.0				
	64.7	5.8	3.1	12.2				
	71.1	9.0	3.2	35.0				
	73.8	18.7	6.1					
	91.6	20.5	8.4					
	91.9	30.3	50.8					
	93.6	35.5						
	104.3	42.3						
	139.3	49.4						
	176.1	51.1						
	305.0	56.1						
		66.0						
Arithmatic Mean	96.6	25.7	8.2	8.4	12.0	1.3	2.5	23
Geometric Mean	70.0	7.9	2.0	1.7	4.3	0.3	0.4	
GSD	2.7	9.3	6.0	9.1				

Values in brackets [ ] are below the limit of detection (LOD) of 0.2 μg/sample, and the value of LOD/2 was used to calculate the summary statistics.

Table 5
Lysozyme Personal Air Sampling Results ($\mu g/m^3$)
NEPCO, Social Circle, Georgia
October 24 -26, 1995

Job/Department:	Transfer	Breaking	Pasteurization	Dryer	White Pack.	Yellow Pack.	Sanitation	Flat Wash
	[0.1]	[0.1]	[0.1]	[0.1]	[0.1]	[0.1]	0.5	1.0
	[0.1]	[0.1]	[0.1]	4.8	0.4	[0.1]	1.0	37.5
	0.6	0.1	[0.1]	6.1	0.7	10.4	1.5	
	0.9	0.5	[0.1]	8.9				
	1.8	0.8	1.2	10.0				
	2.1	1.0	1.6	17.5				
	2.1	1.1	2.6					
	2.8	1.2	35.0					
	3.6	1.4	189.9					
	5.2	2.6						
	6.0	4.5						
	10.2	10.7						
	36.0	21.3						
	41.0	28.7						
		321.4						
Arith. Mean	8.0	26.4	25.6	7.9	0.4	3.5	1.0	
Geo. Mean	2.4	1.9	1.1	4.1	0.3	0.5	0.9	
GSD	6.1	10.0	15.8	6.3	2.5	15.8	1.6	

Values in brackets [ ] are below the limit of detection (LOD) of 0.2 μg/sample, and the value of LOD/2 was used to calculate the summary statistics.

Table 6
Paired Respirable and Total Aerosol Sampling Results
Stationary Sampling
NEPCO, Social Circle, Georgia
October 24 -26, 1995

		Respirable Aerosol						Total Aerosol					
				Air Concentrations ($\mu g/m^3$)						Air Concentrations ($\mu g/m^3$)			
Date	Location	Sample Number	Duration (Minutes)	Non-Spec. Protein	Ovalbumin	Ovomucoid	Lysozyme	Sample Number	Duration (Minutes)	Non-Spec. Protein	Ovalbumin	Ovomucoid	Lysozyme
10-24-95	Transfer, line 2	P21	455	209.8	1940.8	9.2	3.9	P27	455	784.5	1250.7	61.4	1.4
10-24-95	Transfer, line 1	P22	450	[0.02]	[0.1]	[0.1]	[0.1]	P25	450	442.3	116.4	14.0	3.0
10-24-95	White Packing	P23	363	29.3	9.8	[0.1]	[0.1]	P24	422	255.9	116.3	65.1	7.0
10-24-95	Breaking, dual feed	P20	252	524.8	510.8	2.8	6.0	P28	252	1223.4	986.6	31.6	11.8
10-25-95	White Packing	P39	565	[0.02]	30.2	47.4	0.5	P43	567	95.7	122.6	33.6	1.2
10-25-95	Transfer, line 1 (candler end)	P47	426	1003.1	724.4	125.4	0.5	P55	426	761.0	295.2	73.8	1.6
10-25-95	Transfer, line 3	P41	423	756.0	494.8	104.5	41.2	P51	483	665.9	1229.4	112.7	110.6
10-25-95	Breaking, line 1	P40	563	625.4	677.5	62.5	0.5	P42	562	598.3	329.5	81.5	4.3
10-26-95	Transfer, line 1, center	P57B	334	191.9	293.1	80.3	[0.1]	P56	334	781.4	919.3	27.6	[0.1]
10-26-95	White Packing	P61B	392	[0.02]	29.7	17.8	1.6	P69	392	184.9	182.5	29.2	[0.1]
10-26-95	Breaking, line 1	P65	352	204.8	229.1	48.6	4.5	P64B	352	883.3	427.4	96.9	1.3

Table 7
Referent Plant Samples and Blank Sample Results
Total and Specific Egg Proteins

Referent Plant								
					Air Concentrations ($\mu g/m^3$)			
Date	Type Sample[1]	Sample Number	Duration (Minutes)	Air Volume (L)	Total Protein	Ovalbumin	Ovomucoid	Lysozyme
7-26-95	ATP	LP1P	412	825.2	24.2	ND	ND	ND
7-26-95	ATP	LP2P	413	820.6	ND[2]	ND	2.7	ND
7-26-95	ATP	LP3P	432	862.5	ND	ND	ND	ND
7-26-95	ATP	LP4P	412	820.6	41.4	ND	ND	ND
7-26-95	ATP	LP5P	410	812.6	12.3	ND	ND	ND

Referent Plant	Analytical Results (μg/sample)							
7-26-95	FieldBlank	LP6P			6.0	ND	ND	ND
7-26-95	FieldBlank	LP7P			ND	ND	ND	ND
5-06-96	LabBlank	#1			ND	ND	ND	ND
5-06-96	LabBlank	#2			ND	ND	ND	ND
5-06-96	LabBlank	#3			6.0	ND	ND	ND

Egg Plant	Analytical Results (μg/sample)							
10-24-95	FieldBlank	P29			ND	ND	ND	4.2
10-24-95	FieldBlank	P30			ND	ND	ND	1.8
10-26-95	FieldBlank	P60A			ND	ND	ND	ND
10-26-95	FieldBlank	P53B			ND	ND	ND	0.6

[1] ATP = Area Total Protein

[2] ND = Not Detected. These samples were below the limit of detection for these analytes.

Limit of detection: Non-Specific Protein, 0.02μg/sample; Ovalbumin, 0.1μg/sample; Ovomucoid 0.1μg/sample; Lysozyme, 0.1μg/sample

Table 8
Air Sampling Results for Chlorine Compounds
NEPCO, Social Circle, Georgia
March 26 - 28, 1996

Date	Location	Analytical Results		
		Chloride Conc. ($\mu g/m^3$)	Chlorine[1] Conc. ($\mu g/m^3$)	Chloramine[1] Conc. ($\mu g/m^3$)
3-26-96	Breaker Rm., Over Wash Sinks, Ctr. Rm.	<4	<4	11.3
3-27-96	Breaker Rm., Over Wash Sinks, Ctr. Rm.	<4	<4	5.6
3-28-96	Breaker Rm., Over Wash Sinks, Ctr. Rm.	5.3	<4	7.5
3-26-96	Breaker Rm., Line 1 Oper. Stn.	<4	12.5	9.5
3-27-96	Breaker Rm., Line 1 Oper. Stn.	35.2	<4	<4
3-28-96	Breaker Rm., Line 1 Oper. Stn.	9.8	<4	5.5
3-26-96	Breaker Rm., Line 4, Over Conveyor	7.3	<4	11.8
3-27-96	Breaker Rm., Line 4, Over Conveyor	8.0	<4	9.6
3-28-96	Breaker Rm., Line 4, Over Conveyor	7.5	<4	3.7
3-26-96	Dryer Rm., Center	<4	<4	7.8
3-27-96	Dryer Rm., Center	4.3	<4	<4
3-28-96	Dryer Rm., Center	<4	5.0	<4
3-26-96	Pasteurization Rm., Control Panels	<4	53.8	15.9
3-27-96	Pasteurization Rm., Control Panels	7.1	6.5	<4
3-28-96	Pasteurization Rm., Control Panels	4.3	<4	<4
3-26-96	Transfer Rm., Line 2, Center	13.8	<4	15.5
3-27-96	Transfer Rm., Line 2, Center	9.8	<4	<4
3-28-96	Transfer Rm., Line 2, Center	17.8	<8	23.7
3-28-96	Transfer Rm., Line 2, Center	13.0	<4	32.5
3-26-96	Transfer Rm., Line 3, Center	13.1	7.8	17.6
3-27-96	Transfer Rm., Line 3, Center	14.4	<4	7.6
3-27-96	Transfer Rm., Line 3, Center	15.2	<8	<8
3-28-96	Transfer Rm., Line 3, Center	11.9	<4	<4
3-27-96	Transfer Rm., Line 4, Candler	8.3	<4	<4
3-28-96	Transfer Rm., Line 4, Candler	8.0	<4	18.6
3-26-96	Transfer Rm.,Line 1, Center	21.7	<4	<4
3-26-96	Transfer Rm.,Line 1, Wall Opening	16.0	<4	17.3
3-27-96	Transfer Rm.,Line 1, Wall Opening	29.2	<4	3.9
3-28-96	Transfer Rm.,Line 1, Wall Opening	31.6	<4	<4
3-27-96	White Packaging	21.5	<4	5.9
3-28-96	White Packaging	14.1	<4	<4

[1] The exact identification of these compounds cannot be confirmed due to limitations of the the sampling and analytical methods used.

References

1. Stadelman, W.J., and Cotterill, O.J.: Egg Science and Technology, 2nd Ed., AVI Publishing Company, Inc., Westport, Conn., 1977.

2. NIOSH Manual of Analytical Methods, Fourth Ed., Method dated August 15, 1994. DHHS(NIOSH) Publication 94-114.

3. Hery, M., Hecht, G., Gerber, J.M., et al.: Exposure to Chloramines in the Atmosphere of Indoor Swimming Pools. Ann. Occup. Hyg. 39(4):427-39, 1995.

4. Edwards, J.H., McConnochie, K. and Davies, B.H.: Skin-test Reactivity to Egg Protein - Exposure by Inhalation Compared with Ingestion. Clinical Allergy 15:147-150, 1985.

5. Carmona, J.G., Picon, S., Sotillos, M. and Gaston, P.: Occupational Asthma in the Confectionary Industry Caused by Sensitivity to Egg. Allergy 47:190-191, 1992.

6. Smith, A.S., Bernstein, D.I., London, M.A., Gallagher, J., et. al.: Evaluation of Occupational Asthma from Airborne Egg Protein Exposure in Multiple Settings. Chest 98:398-404, 1990.

7. Bernstein, D.I., Smith, A.I., Moller, D.R., et al.: Clinical and Immunologic Studies Among Egg-Processing Workers with Occupational Asthma. J. Allergy Clin. Immunol. 80:791-797, 1987.

8. ACGIH. Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Limit Indices for 1995-1996. Cincinnati, Ohio. American Conference of Governmental Industrial Hygienists, 1996.

9. Official Methods of Analysis. Fourteenth Edition. Method 33.051, 33.052, AOAC, Arlington, Virginia, 1984.

10. Swanson, M.C., Agarwal, M.K., Reed, C.E.: An Immunochemical Approach to Indoor Aeroallergen Quantitation with a New Volumetric Air Sampler: Studies with Mite, Roach, Cat, Mouse, and Guinea Pig Antigens. J. Allergy Clin. Immunol. 76:732-38, 1980.

11. Hathaway, G.J., Proctor, N.H., Hughes, J.P., Fischman, M.L.: Proctor and Hughes' Chemical Hazards in the Workplace. 3rd Ed. New York, NY: Van Nostrand Reinhold, pp 152-154, 1991.

12. Committee on Medical and Biological Effects of Environmental Pollutants, National Research Council: Chlorine and Hydrogen Chloride. Washington, DC: National Academy of Sciences, pp 116-123, 1976.

13. Hazard Evaluation and Technical Assistance Report: Columbia Farms Poultry Plant, Columbia, SC. NIOSH Report No. 87-110, 1988.

14. National Institute for Occupational Safety and Health: NIOSH Recommendations for Occupational Safety and Health. DHHS (NIOSH) Pub. No. 92-100. NIOSH , Cincinnati, OH (1992).

15. Code of Federal Regulations: Occupational Safety & Health Administration, Air Contaminants; Final Rule (to be codified Federal Regulations. OSHA 29 CFR 1910) U.S. Government Printing Office, Office of Federal Register, Washington, D.C. (Wednesday, June 30, 1993).

16. Sanderson, W.T., Weber, A., Echt, A.: Case Reports: Epidemic Eye and Upper Respiratory Irritation In Poultry Processing Plants. Appl. Occup. Environ. Hyg. 10(1):43-49, 1995.

17. Williams, D.: Elimination of Nitrogen Trichloride. J. Amer. Water Works Assoc. 41:248-254, 1949.

18. White, G.: The Handbook of Chlorination, 2nd Ed. Van Nostrand-Reinhold Company, New York, 1986.

19. Seixas, N.S. Robins, T.G. and Moulton, L.H.: The Use of Geometric and Arithmetic Mean Exposures in Occupational Epidemiology. Am. J. Indust. Med. 14:465-77, 1988.

20. Andersen, K.E, Hamann,K.: How Sensitizing Is Chlorocresol? Allergy Tests in Guinea Pigs Versus the Clinical Experience. Contact Dermatitis 11:11-20, 1984.

21. Soto-Aguilar, M.C., Salvaggio, J.E.: Immunologic Aspects of Occupational Asthma. Seminars in Respiratory Medicine. 12:185-195,1991

22. Biagini, R.E., Moorman, W.J., Lewis, T.R. and Bernstein,I.L.: Ozone Enhancement of Platinum Asthma in a Primate Model. American Review of Respiratory Disease,134:719-725, 1986

23. Muranaka, M., Suzuki, S., Koizumi, K., et al.: Adjuvant Activity of Diesel-Exhaust Particulates for the Production of IgE antibody in Mice. J. Allergy Clin. Immunol. 77:616, 1986.

24. Takafuji, S., Suzuki, S., Aoizumi, K., et al: Diesel-Exhaust Particulate Inoculated by the Intranasal Route have an Adjuvant Activity for IgE Production in Mice. J. Allergy Clin. Immunol. 79:639, 1987.

25. Riedel, F. Kramer, M., Scherbenbugen, C. and Rieger, C.H.L.: Effects of SO_2 Exposure on Allergic Sensitization in the Guinea Pig. J. Allergy Clin. Immunol. 82:527, 1988.

26. Halverson, P.C., Swanson, M.C. and Reed, C.E.: Occupational Asthma in Egg Crackers is Associated with Extraordinarily High Airborne Egg Allergen Concentrations. (abstract) J. Allergy Clin. Immunol. 81, Pt.2:321, 1988.

27. King, T.P., Norman, P.S. and Connell, J.T.: Isolation and Characterization of Allergens from Ragweed Pollen: II. Biochemistry 3:458, 1964.

28. Arakawa, H., Lotvall, J., Morikawa, A.: Airway Responses Following Intradermal Sensitization to Different Types of Allergens: Ovalbumin, Trimellitic Anhydride and Dermatophagoides farinae. Int. Arch. Allergy Immunol. 108:274-280, 1995.

29. Kimber, I.: The Role of the Skin in the Development of Chemical Respiratory Hypersensitivity. Toxicology Letters 86:89-92, 1996.

30. Racioppi, F., Daskaleros, P.A. Besbelli, N. et al.: Household Bleaches Based on Sodium Hypochlorite: Review of Acute Toxicology and Poison Control Center Experience. Food and Chemical Toxicology, 32: 845-861, 1994.

31. Hostynek, J.J., Wilhelm, K-P., Cua, A.B., Maibach, H.I.: Irritation Factors of Sodium Hypochlorite Solutions in Human Skin. Contact Dermatitis, 23:316-324, 1990.

32. Hess, J.A., Molinari, J.A., Gleason, M.J., Radecki, C.: Epidermal Toxicity of Disinfectants. American Journal of Dentistry, 4:51-56, 1991.

33. Hostynek, J.J., Patrick, E., Younger, B. and Maibach, H.I.: Hypochlorite Sensitivity in Man. Contact Dermatitis. 20:32-37, 1989.

34. NIOSH, Health Hazard Evaluation Report of Siouxpreme Egg Products, Inc. Sioux Center, Iowa, 1987. HETA Report No. 86-446-1918. Hazard Evaluation and Technical Assistance Branch, Cincinnati, Ohio.

35. NIOSH, Health Hazard Evaluation Report of Ballas Egg Products Corporation, Zanesville, Ohio, 1987. HETA Report No. 86-461-1920. Hazard Evaluation and Technical Assistance Branch, Cincinnati, Ohio.

36. NIOSH, Health Hazard Evaluation Report of Estherville Foods, Estherville, Iowa, 1987. HETA Report No. 86-447-1919. Hazard Evaluation and Technical Assistance Branch, Cincinnati, Ohio.

37. NIOSH, Health Hazard Evaluation Report of Brown Produce Company, Farina, Illinois, 1992. HETA Report No.92-0354. Hazard Evaluation and Technical Assistance Branch, Cincinnati, Ohio.