HETA 95-0331 & 95-0334-2626
Boston Harbor Tunnel Project
Winthrop, Massachusetts

David C. Sylvain, M.S., CIH

PREFACE

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ACKNOWLEDGMENTS AND AVAILABILITY OF REPORT

This report was prepared by David C. Sylvain, M.S., CIH, of the Hazard Evaluations and Technical Assistance Branch, Division of Surveillance, Hazard Evaluations and Field Studies (DSHEFS). Field assistance was provided by Mary E. Brown, D.V.M., M.P.H.. Analytical support was provided by Miriam K. Lonon, Ph.D. Desktop publishing by Pat Lovell.

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SUMMARY

On July 19, 1995, the National Institute for Occupational Safety and Health (NIOSH) received a request from the Centers for Disease Control and Prevention (CDC), National Center for Infectious Diseases (NCID) for assistance in investigating reports of increased respiratory illness among Boston Harbor Tunnel workers. During the following week, NIOSH received Health Hazard Evaluation (HHE) requests from the Occupational Safety and Health Administration (OSHA), the Massachusetts Water Resources Authority (MWRA), two contractors, and four labor organizations to investigate the incidence of respiratory problems among tunnel construction workers at this project. Because NIOSH was assisting NCID in an investigation of the problem described in the HHE requests, action was deferred on these requests until NCID completed its investigation.

From July 21 through August 7, 1995, NIOSH assisted NCID investigators. Epidemic Intelligence Service (EIS) Officers from NCID and NIOSH reviewed medical records, and developed a medical questionnaire for evaluating the nature and extent of respiratory illness among tunnel workers. Investigators from NCID and NIOSH met with representatives of Boston City Department of Health and Hospitals, contractor management, MWRA, and the unions. Investigators conducted a walk-through inspection of the tunnels on July 25 and 26, 1995.

Environmental information was collected to characterize the tunnels, tunnel ventilation systems, and microbiological reservoirs. Information describing the tunnels (size, construction, location, etc.), and work areas (locations within the tunnel, materials used, pollutant sources, etc.) was included. Bulk and swab samples were obtained from selected locations within the tunnels to evaluate the nature and extent of microbial growth.

Analysis of bulk samples for total colony count and identification of bacteria and fungi revealed reservoirs of microbiological contamination; however, nothing in the samples appears to have been related to infectious illness or allergic-type responses among tunnel workers. Elevated concentrations of bacteria in bulk samples collected in both tunnels indicates that conditions were favorable for growth of Gram-negative, as well as the Gram-positive bacteria.

The medical investigation was limited by incomplete medical records, and poor response to questionnaires. Only 132 (33%) of the 400 workers who received a Boston Department of Health and Hospitals' questionnaire responded; and only 78 (39%) of an estimated 200 Inter-Island and Outfall Tunnel workers returned the NCID/NIOSH questionnaire.

The tunnel workers' respiratory illnesses appeared to represent a spectrum of clinical disease, and had no identifiable common source or etiology. Diagnoses from medical records included other respiratory illnesses such as tracheobronchitis, sinusitis, otitis, and asthma in addition to pneumonia..

The tunnel workers' respiratory illnesses appeared to represent a spectrum of clinical disease which had no identifiable common source or etiology. A reliable estimate of the incidence of respiratory illness among tunnel workers could not be determined; therefore, it is not known if the incidence of illness among these workers was greater than would have been expected among the general population.

No workplace health hazard was associated with respiratory illness among tunnel workers. Reservoirs of bacterial and fungal growth were identified; however, nothing in the samples appears to have been related to reports of infectious illness, or allergic-type responses.

Keywords: SIC 1622 (Bridge, Tunnel, and Elevated Highway Construction), bronchitis, flu, microbiological contamination, pneumonia, respiratory illness.

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INTRODUCTION

On July 19, 1995, the National Institute for Occupational Safety and Health (NIOSH) received a request from the Centers for Disease Control and Prevention (CDC), National Center for Infectious Diseases (NCID) for assistance in investigating reports of increased respiratory illness among Boston Harbor Tunnel workers. During the following week, NIOSH received Health Hazard Evaluation (HHE) requests from the Occupational Safety and Health Administration (OSHA), the Massachusetts Water Resources Authority (MWRA), two contractors, and four labor organizations to investigate the incidence of respiratory problems among tunnel construction workers at this project. Because NIOSH was assisting NCID in an investigation of the problem described in the HHE requests, action was deferred on these requests until NCID completed its investigation.

From July 21 through August 7, 1995, NIOSH assisted in the NCID investigation. NIOSH investigators met with representatives of Boston City Department of Health and Hospitals, contractor management, MWRA, and the unions. Investigators from NCID and NIOSH conducted a walk-through inspection of the tunnels on July 25 and 26, 1995.

Epidemic Intelligence Service (EIS) Officers from NCID and NIOSH reviewed medical records, and developed a medical questionnaire to evaluate the nature and extent of respiratory illness among tunnel workers; however, only 39% of an estimated 200 workers who attended a July 23, 1995, Tunnel Workers' union meeting responded to the questionnaire. Repeated attempts by the EIS Officers to meet with the Operating Engineers Local 4, and the International Brotherhood of Electrical Workers Local 103 (which represented 30% and 12% of the tunnel workforce, respectively), were unsuccessful; therefore, workers in these unions could not be contacted for distribution of the questionnaire. On August 7, 1995, NCID representatives concluded their investigation with a presentation of observations and recommendations at a meeting/teleconference held at the offices of Boston City Health and Hospitals.

On August 9, 1995, NIOSH initiated an investigation of the HHE requests following NCID's determination that respiratory illness among tunnel workers represented a range of clinical disease with no identifiable common etiology. On August 24, 1995, NIOSH investigators held an opening conference which was attended by representatives from management, MWRA, and union representatives.

BACKGROUND

The Boston Harbor Tunnel Project involves the construction of two tunnels for transporting sewage effluent to and from a new sewage treatment plant located on Deer Island, in Winthrop, Massachusetts. The Inter-Island Tunnel, which will connect Nut Island with the sewage treatment facility, is approximately 240 feet below sea level, 17 feet in diameter, and will be five miles long when completed. The Outfall Tunnel originates at Deer Island, and will transport treated effluent for nine miles beneath Massachusetts Bay, where it will be discharged into the bay through a system of diffusers. The Outfall Tunnel is reported to be the longest single-entry tunnel ever constructed.

Inter-Island Tunnel

A total of approximately 150 people worked in the Inter-Island Tunnel at the time of this investigation. The majority of the workforce was located at either end of the tunnel, i.e., at the heading, or at the Deer Island shaft. Of the 30 to 40 workers on each of the three shifts, there were approximately 20 tunnel workers (miners), 2-3 electricians, and 8 operating engineers. Ten to 12 tunnel workers were located at the tunnel boring machine (TBM), with the remainder working in support of the boring operation. The engineers operated equipment throughout the tunnel, which included the diesel-powered locomotives ("loci") and cars that transported equipment and personnel between the shaft and the heading; and excavated rock ("muck") from the TBM at the heading.

Mechanical ventilation brought air into the tunnel through the Long Island shaft, which is located approximately midway along the length of the

tunnel. The supply duct was split into the main line, which supplied ventilation to the heading; and a shorter, secondary line which supplied air between Long Island and the heading. The flow from these lines forced air to flow through the tunnel toward Deer Island, where it exited via the Deer Island shaft. Each of the supply ducts ("baglines") was equipped with several fans to maintain flow along the length of the collapsible rubber duct. The main bagline was 42 inches in diameter, and the secondary bagline had a diameter of 36 inches. The baglines had been extended along the length of the tunnel as the tunnel was bored. It was reported that additional ventilation was to be provided through a third shaft when the tunnel reached Nut Island.

Town water was piped to the heading where it was used in the wet scrubber, and for dust suppression at the face. Air was drawn through the wet scrubber to remove dust generated by the TBM. When the TBM was operating, water was reportedly supplied continuously to the scrubber and was not recirculated. (The scrubber drained into the invert.) Air from the scrubber was exhausted into the tunnel in the direction of the Deer Island shaft.

Outfall Tunnel

Of the approximately 150 employees who worked in the Outfall Tunnel on all shifts, 80 to 90 were tunnel workers (miners), 50 to 60 operating engineers, and approximately 6 are electricians. The majority of workers were located at the shaft, heading, and grouting operations. Grouting occured at two rail switches known as the Colorado and California switches. As in the Inter-Island Tunnel, personnel and equipment were transported through the tunnel on a diesel-powered train; however, unlike the Inter-Island Tunnel, muck was removed by a conveyer.

The Outfall Tunnel is approximately 330 feet below sea level. The tunnel is lined with precast concrete sections which were assembled at the heading to form rings approximately 24 feet in diameter, and 5 feet long. Sanded grout (a mixture of sand, cement, and water) was pumped into the space between the rings and the tunnel wall. Sanded grout was batched on the surface, and was pumped to the tunnel where it was transported in agitator cars to the California switch, approximately 3000 feet from the heading. Neat cement (containing no sand), was dry-batched at the Colorado switch, and was pumped behind the concrete lining to control the flow of water into the tunnel.

The ventilation system was designed to provide approximately 60,000 cubic feet of air per minute (cfm). The system included a chiller for removing moisture from intake air, and a bagline that extends to the heading. Air was discharged at the heading, and flowed through the tunnel to the Deer Island shaft. Town water was used for dust suppression at the TBM. An air cleaning system, equipped with bag filters, was used to remove airborne dust generated during tunnel boring. The air from this system discharged at the TBM trailing gear.

METHODS

Medical Evaluation

NCID and NIOSH investigators defined a case as the occurrence of an infiltrate on a chest radiograph, with one of the following: fever, cough, wheezing, or difficulty breathing. It was suspected that those persons who had been diagnosed with pneumonia would have received the most thorough evaluation and would, therefore, be most likely to have an etiologic diagnosis.

NCID and NIOSH investigators examined all available medical records of tunnel workers who reported respiratory symptoms of dry or productive cough, fever, wheezing, or difficulty breathing from June 1, 1994, through July 15, 1995, on questionnaires administered in June 1995 by the Boston Department of Health and Hospitals, and by the NCID/NIOSH investigation team on July 23, 1995. A detailed description of medical evaluation methods during this investigation is presented in the EPI-Aid Trip Report which has been included in Appendix A.

Environmental Evaluation

Information was collected to characterize the tunnels, with emphasis on the ventilation systems,

microbiological reservoirs, and other conditions which could contribute to respiratory illness among tunnel workers. Descriptive information for the tunnels (size, construction, location, etc.), and work areas (location within the tunnel, materials used, pollutant sources, etc.) were included. Swab and bulk samples (liquid and solid) were obtained from selected locations within the tunnels to evaluate microbiological contamination. The samples were packed in a cooler within an hour after exiting the tunnel, and were shipped overnight to a laboratory where they were analyzed for total count and speciation of fungi and bacteria. Bacteria were identified using the Microlog Microbial Identification System (Biolog, Hayward, California). The purpose of the environmental evaluation was to ascertain whether microbiological contamination might be associated with the incidence of respiratory illness fitting the case description.

EVALUATION CRITERIA

Microbial Contaminants

Microorganisms (including fungi and bacteria) are normal inhabitants of the environment. The saprophytic varieties (those utilizing nonliving organic matter as a food source) inhabit soil, vegetation, water, or any reservoir that can provide an ample supply of a nutrient substrate. Under the appropriate conditions (optimum temperature, pH, and with sufficient moisture and available nutrients) saprophytic microorganism populations can be amplified. Through various mechanisms, these organisms can then be disseminated as individual cells or in association with soil/dust or water particles. In the outdoor environment, the levels of microbial aerosols will vary according to the geographic location, climatic conditions, and surrounding activity.

Some individuals manifest increased immunologic responses to antigenic agents encountered in the environment. These responses and the subsequent expression of allergic disease are based, partly, on a genetic predisposition.[1] Allergic diseases typically associated with exposures in indoor environments include allergic rhinitis (nasal allergy), allergic asthma, allergic bronchopulmonary aspergillosis (ABPA), and extrinsic allergic alveolitis (hypersensitivity pneumonitis).[2] Allergic respiratory diseases resulting from exposures to microbial agents have been documented in agricultural, biotechnology, office, and home environments.[3,4,5,6,7,8,9,10]

Individual symptomatology varies with the disease. Allergic rhinitis is characterized by paroxysms of sneezing; itching of the nose, eyes, palate, or pharynx; nasal stuffiness with partial or total airflow obstruction; and rhinorrhea (runny nose) with postnasal drainage. Allergic asthma is characterized by episodic or prolonged wheezing and shortness of breath in response to bronchial (airways) narrowing. Allergic bronchopulmonary aspergillosis is characterized by cough, lassitude, low-grade fever, and wheezing.[2,11] Heavy exposures to airborne microorganisms can cause an acute form of extrinsic allergic alveolitis which is characterized by chills, fever, malaise, cough, and dyspnea (shortness of breath) appearing four to eight hours after exposure. In the chronic form, thought to be induced by continuous low-level exposure, onset occurs without chills, fever, or malaise and is characterized by progressive shortness of breath with weight loss.[12]

Acceptable levels of airborne microorganisms have not been established, primarily because allergic reactions can occur even with relatively low air concentrations of allergens, and individuals differ with respect to immunogenic susceptibilities. The current strategy for on-site evaluation of environmental microbial contamination involves an inspection to identify sources (reservoirs) of microbial growth and potential routes of dissemination. In those locations where contamination is visibly evident or suspected, bulk samples may be collected to identify the predominant species (fungi, bacteria, and thermoactinomycetes). In limited situations, air samples may be collected to document the presence of a suspected microbial contaminant. Air sample results can be evaluated epidemiologically by comparing those from the "complaint areas" to those from noncomplaint areas, or by relating exposure to immunologic findings.

Bacterial Endotoxin

A bacterial endotoxin is a lipopolysaccharide compound from the outer cell wall of Gram-negative bacteria, which occur abundantly in organic dusts.[13] It has been shown that the biological properties of endotoxin vary depending upon the bacterial species from which they are derived, as well as upon the state of the growth cycle of the bacteria.[14] 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.[15] The primary target cell for endotoxin-induced damage by inhalation is the pulmonary macrophage. Human macrophages in particular have been shown to be extremely sensitive to the effects of endotoxin in vitro.[16] Endotoxin, either soluble or associated with particulate matter, will activate the macrophage, causing the cell to produce a host of mediators.[15]

Clinically, little is known about the response to inhaled endotoxins. Exposure of previously unexposed persons to airborne endotoxin can result in acute fever, dyspnea, coughing, and small reductions in forced expiratory volume in one second (FEV_1), although some investigators have not been able to demonstrate acute changes in FEV_1.[15] The effects of repeated exposure to aerosols of endotoxins in humans are not known. Some animal studies have demonstrated a chronic inflammatory response characterized by goblet cell hyperplasia and increased mucous production. This suggests that repeated exposure may cause a syndrome similar, if not identical, to chronic bronchitis.[15]

Occupational exposure criteria have not been established for bacterial endotoxin by either OSHA, NIOSH, or ACGIH. However, Jacobs has reported that a sufficient toxicological data base is believed to exist for establishing an occupational limit for endotoxin based on acute changes in pulmonary function.[15] Eight-hour (8-hr) TWA concentrations have been suggested for over-shift decline in FEV_1 (100 - 200 nanograms of bacterial endotoxin per cubic meter of air [ng/m^3]), for chest tightness (300 - 500 ng/m^3), and for fever (500 - 1,000 ng/m^3).[14]

An 8-hr TWA threshold for airborne endotoxin of 10 ng/m^3 has also been suggested based on a decline in FEV_1 for individuals sensitized to cotton dust.[17] The exposure system for the study from which this recommendation was made consisted of a commercial carding machine in a cardroom, an exposure room, and connecting duct work. Airborne dust concentrations were determined in the exposure room using four vertical elutriators.[17] The vertical elutriator has traditionally been the instrument of choice for cotton dust sampling because it will not collect cotton fly lint fibers and dust particles with an aerodynamic mass medial diameter larger than 15 µm.[18]

RESULTS

Medical

The medical investigation was limited by the low questionnaire response rate, and by incomplete medical records. Only 132 (33%) of the 400 workers who received a Boston Department of Health and Hospitals questionnaire responded; and only 78 (39%) of an estimated 200 Inter-Island and Outfall tunnel workers returned the NCID/NIOSH questionnaire. The NCID/NIOSH questionnaire was distributed at a July 23, 1995, union meeting called by the Tunnel Workers' Union, Local 88, to discuss health concerns. The distribution of questionnaires at this meeting may have introduced a reporting bias into the case finding, since workers who had experienced respiratory illness may have been overrepresented at the meeting.

The tunnel workers' respiratory illnesses appeared to represent a spectrum of clinical disease, and had no identifiable common source or etiology. Diagnoses from medical records included other respiratory illnesses such as tracheobronchitis, sinusitis, otitis, and asthma in addition to pneumonia. Most patients had been treated empirically with antibiotics. A detailed description of medical evaluation results is presented in the EPI-Aid Trip Report (see Appendix A).

Environmental

Inter-Island Tunnel

On July 24, 1995, NIOSH investigators accompanied representatives of NCID, and various State agencies on an evaluation of the tunnel. The evaluation consisted of a train ride to the heading, with periodic stops to observe conditions in the tunnel.

Saline water permeated the unlined tunnel wall in many areas, and rained into the tunnel. Sheets of "panning" were fastened to the top and sides of the tunnel to divert the water to the bottom of the tunnel (the "invert") where the water flowed continuously to pumps to remove it from the tunnel. Although panning helped to create a drier environment, workers had to wear rubber boots and full rain gear. The depth of invert water ranged from approximately 6 inches to more than 12 inches.

Air velocity measurements taken within the tunnel indicated a flow of 250 to 300 feet per minute (fpm) at station 50 (5000 feet from Deer Island). The air temperature was approximately 58°F, and the relative humidity was 85%. The air velocity between the TBM trailing gear and the loci was generally less than 50 fpm. The TBM was not operating during this visit.

On September 13, 1995, the NIOSH industrial hygienist conducted a walk-through inspection of the entire tunnel, from the heading to the tail shaft. The bagline was inspected in response to reports that it became distended with water; and that holes had to be cut in the line to release the water so that the loci and train could pass beneath. During the walk-through, small punctures were made at several locations where it appeared that the bagline might contain water; however, all but the two locations identified in Table 1 were dry. No areas were observed which appeared to be grossly distended.

During the September visit, water and swab samples were collected from locations which appeared to be favorable for microbiological growth. As shown in Table 1, bacteria were more prevalent in the samples than were fungi; and Gram-positive bacteria (probably soil bacteria) predominated in most samples. However, water obtained from the secondary bagline (sample #10) contained extensive concentrations of two Gram-negative species, as well as Cladosporium (fungus); and yeasts were found in high concentrations in the main bagline. The scrubber, which was not operating at this time, contained approximately eight inches of water. No sludge or residue was observed in the sump.

Outfall Tunnel

On July 26, 1995, NIOSH and NCID investigators were transported to the heading. The visit was conducted in the same manner as the earlier visit to the Inter-Island Tunnel. The train stopped at switches and other locations so that investigators could observe conditions in the tunnel.

During this visit, a representative from the Massachusetts Attorney General's Office obtained one 4-hour air sample which was analyzed for endotoxin and total particulate. The sample was obtained using a personal sampling pump, which the Attorney General's representative wore throughout the tunnel visit. Analysis of the sample determined the air concentration of endotoxin in the Outfall Tunnel to be 0.35 ng/m^3; and total particulate, 0.88 milligrams per cubic meter of air (mg/m^3).

On September 12, 1995, bulk samples were obtained from the Turbofilter and a bagline valve (Table 2). Sample #1 consisted of dust obtained from the bag filters used to capture dust generated by the TBM (Turbofilter). Sample #2 consisted of a very small piece of solid material that blew out of the bagline valve when the valve was opened. The bagline was dry at the valve, and at rings 4074 and 7359 where punctures were made in the bagline in an attempt to obtain water samples. With the exception of locations where there were ladders, or other means to reach the bagline, the bagline was not accessible for sampling.

DISCUSSION

Analysis of bulk samples for total colony count and identification of bacteria and fungi revealed microbiological contamination; however, nothing in the samples appears to have been related to infectious illness or allergic-type responses among tunnel workers. The mere presence of

microbiological contamination is not sufficient to establish an association between the contamination, and health complaints which *may* have involved responses to airborne allergens. Air sampling data, supported by a positive skin test to specific bacteria or fungi identified during air sampling, would be needed to establish such an association. Unfortunately, immunologic data could not be obtained for the tunnel workers.

Elevated concentrations of bacteria in bulk samples collected in both tunnels indicate that conditions were favorable for growth of Gram-negative bacteria, as well as the Gram-positive bacteria that predominated in most samples. Despite the absence of air sampling data, elevated bacterial counts in bulk samples obtained from the scrubber sump and baglines in the Inter-Island Tunnel; and the Turbofilter in the Outfall Tunnel, indicated the need for effective preventive maintenance to eliminate these sources of potential exposure. Although fungi appeared to present a lesser risk in the tunnels, the presence of a high concentration of yeast in the Inter-Island Tunnel bagline should be noted. The significance of the high colony count in sample #2 (Outfall Tunnel, bagline valve) is not clear, due to the very small sample size.

The retrospective review of medical records was limited by incomplete laboratory diagnostic testing of the pneumonia cases, which did not enable investigators to determine a specific etiology for respiratory illness among tunnel workers. It was not possible to distinguish between the incidence of communicable illness in the community, workplace bronchitis, and other upper respiratory symptoms. The limited nature of information that could be extracted from medical records was exacerbated by the poor response of workers to repeated attempts by investigators to administer a medical questionnaire.

CONCLUSIONS

The tunnel workers' respiratory illnesses appear to represent a spectrum of clinical disease which had no identifiable common source or etiology. A reliable estimate of the incidence of respiratory illness among tunnel workers could not be determined; therefore, it is not known if the incidence of illness among these workers was greater than would have been expected among the general population.

No workplace health hazard was identified which appeared to be associated with respiratory illness among tunnel workers. Reservoirs of bacterial and fungal growth were identified; however, nothing in the samples appeared to be related to the reports of infectious illness, or allergic-type responses.

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Table 1. Inter-Island Tunnel, Bulk Samples.

Sample #	Location	Type	Total Fungi (CFU/ml)[1]	Identification	Total Bacteria (CFU/ml or swab)[1]	Identification	Gram Stain
6	scrubber sump	liquid	10 10	*Penicillium* *Verticillium*	22,000 15,000 2,000	*Curtobacterium citreum* *Clavibacter michiganese* *Curtobacterium flaccumfaciens*	+ + +
7	fresh water feed, 234+ 90	liquid	nd		6,200 5,000 500	yellow Gm− rod, cat+ , ox− white Gm− rod, cat+ , ox+ *Flavobacterium gleum*	− − −
8	inside bagline, 160+ 60	swab	nd		30 30 20	*Curtobacterium citreum* *Clavibacter michiganese* *Curtobacterium flaccumfaciens*	+ + +
9	bagline drainage, 116+ 15	liquid	180 10 10 200,000	*Cladosporium* *Aspergillus niger* *Penicillium* Yeast	230,000	*Clavibacter michiganese*	+
10	bagline drainage, secondary bagline, 103+ 20	liquid	2,400 200	*Cladosporium* *Penicillium*	500,000 400,000	*Acinetobacter radioresistens* *Xanthomonas campestris*	− −

[1] Colony forming units per milliliter of liquid, or swab. The limit of sensitivity was 10 CFU/ml or swab.
nd = none detected.

Table 2. Outfall Tunnel, Bulk Samples.

Sample #	Location	Type	Total Fungi (CFU/g)[1]	Identification	Total Bacteria (CFU/g)[1]	Identification	Gram Stain
1	Turbo filter	dust	3,000 300	*Aspergillus fumigatus* *Cladosporium*	3,200,000 200,000	*Bacillus cereus* *CDC Group EO-2*	+ −
2	Bagline valve, ring 43	solid	220,000 200,000	*Cladosporium* *Fusarium*	1,500,000 80,000	yellow-green rod, cat+ , ox− *Curtobacterium flaccumfaciens*	− +

[1] Colony forming units per gram of sample.

APPENDIX A

DEPARTMENT OF HEALTH & HUMAN SERVICES

Public Health Service

Centers for Disease Control
and Prevention (CDC)
Atlanta, GA 30333

October 23, 1995

EIS Officer, EBMDB, DBMD, NCID

EPI-AID TRIP Report: Investigation of Respiratory Illness in Boston Harbor Project Inter-Island and Outfall Tunnels, Deer Island, Massachusetts (95-64-1).

Pamela Chin, Acting Director, Division of Training, EPO
Through: Director, DBMD, NCID
Acting Chief, ES, EBMDB, DBMD, NCID

BACKGROUND

From April through June 1995, local physicians reported an increase of respiratory illness among workers from the Boston Harbor Project, Deer Island tunnels. This project consists of two long, deep tunnels being bored beneath Boston Harbor to carry sewage to the Deer Island Sewage Treatment Facility for processing and disposal in the Atlantic Ocean (Fig. #1). The labor force consists of members of three union groups: tunnel workers, electricians, and engineers. The Inter-Island Tunnel will be approximately 300 feet deep, 17 feet wide, and 5 miles long, carrying sewage from the South Shore area to Deer Island. It is cool and damp since the seawater-impermeable concrete lining will not be applied to the walls until October 1995. The Outfall Tunnel, which will carry treated sewage out to sea, is now 8 miles long and 30 feet in diameter and will be 9 miles long at completion. It is a much drier tunnel, partly because it is 100 feet deeper, but also because it is sealed with a concrete ring and grout applied directly behind the tunnel boring machine. The project was initiated in 1991, with completion expected in 1998.

In June 1995, the Boston City Department of Health and Hospitals investigated reports of respiratory illness in tunnel workers by administering a questionnaire to approximately 400 Deer Island tunnel construction employees, inquiring about fever, cough, wheezing, or difficulty breathing over the previous year. A total of 132 persons from all job categories responded, and 100 of these reported that they had had a respiratory illness during the last year. Boston Department of Health and Hospitals reviewed records by telephone of those who responded that they had seen a physician.

On July 14 the Massachusetts Department of Public Health and the Boston Department of Health and Hospitals requested CDC assistance to investigate this possible increase in respiratory illness among those workers. The Emerging Bacterial and Mycotic Diseases Branch, Division of Bacterial and Mycotic Diseases (DBMD), National Center for Infectious Disease (NCID), requested National Institute for Occupational Safety and Health (NIOSH) involvement since the respiratory illness was reported to be occupationally-related. Emily M. McClure, M.D., M.P.H., and David A. Ashford, D.V.M., M.P.H., EIS Fellows, and Annie Kao, ASPH intern, traveled to Boston on July 20. They were joined on July 21 by David C. Sylvain, industrial hygienist with the Boston regional NIOSH office, and on July 22 by Mary E. Brown, D.V.M., M.P.H., EIS Fellow at NIOSH, Cincinnati. The team was joined on July 25 by Udo Buchholz, M.D., visiting NCID Fellow.

The objectives of the investigation were to determine the nature and etiology of the respiratory illness affecting workers; to attempt to identify a common infectious source for this illness, if any; and, based on these findings, to develop prevention strategies.

METHODS

Case Definition

We defined a case as the occurrence of one of the following in a worker on the Deer Island Tunnel Project: an infiltrate on chest radiograph, with one of the following; fever, cough, wheezing, or difficulty breathing. We suspected that those persons who had been diagnosed with pneumonia would have received the most thorough evaluation and would, therefore, be most likely to have an etiologic diagnosis.

Case Finding and Ascertainment

For case finding, we examined all available medical records of tunnel workers reporting respiratory symptoms of dry or productive cough, fever, wheezing, or difficulty breathing from June 1, 1994, through July 15, 1995, on questionnaires administered in June 1995 by the Boston Department of Health and Hospitals and by the NCID/NIOSH investigation team on July 23, 1995.

In June 1995, the Boston Department of Health and Hospitals (BDHH) had distributed a questionnaire at Deer Island asking workers where and for how long they worked in the tunnel, and whether they had respiratory symptoms during the preceding 12 months. The NCID/NIOSH investigation team obtained records for those patients found on follow-up from the BDHH questionnaire to have had a chest radiograph taken.

On July 23, the investigation team attended a meeting of the Tunnel Workers Union Local #4, where 78 of the approximately 150 union members present completed an NCID/NIOSH questionnaire that attempted to identify those who had developed any respiratory illness since April 1, 1995. The 53 persons reporting respiratory symptoms were contacted by telephone to collect

more detailed information on their illness and to identify their medical provider during their respiratory illness. These patients were also asked whether they had had a chest radiograph for their reported respiratory illness. Hospital and clinic charts were requested and reviewed by the NCID/NIOSH investigators. Data were collected on a standard form and included findings on physical examination, medical and smoking history, laboratory findings, and type of work task performed.

RESULTS

Health and Hospitals Questionnaire

Of the 132 respondents to the Health and Hospitals questionnaire, 100 reported having a respiratory illness between June 1, 1994, and May 31, 1995. In the last year, 61 of 100 ill reported trouble breathing, 97 reported cough, and 54 reported sputum production. Physicians were consulted by 70 of the 100 ill workers for these respiratory symptoms.

NCID/NIOSH questionnaire

Of the 78 respondents to the NCID/NIOSH questionnaire distributed to the Tunnel Workers Local #4 on July 23, 1995, 53 reported that they had experienced a respiratory illness since April 1, 1995. Four persons stated that they had been ill only during the previous week, 19 said that they had a respiratory illness between April 1, 1995 and July 15, 1995, and 30 said that they had been ill several times or continuously since April 1, 1995.

Of the 50 who supplied contact information, 30 said that they had seen a physician for the respiratory illness, 18 had not seen a physician, and two could not recall whether or not they had seen a physician for respiratory problems. Four of the 19 pneumonia cases were identified by responses to this questionnaire.

Boston Department of Health and Hospitals, CDC combined questionnaire results

We reviewed 62 records of those who said that they had been diagnosed with pneumonia or received a chest radiograph since June 1994, as reported from either the BDHH or CDC questionnaire. Of these 62 workers who stated they had seen a physician for respiratory complaints suggestive of pneumonia, 17 did not have a chest radiograph taken, 21 had a negative radiograph, and 19 had infiltrates diagnostic of pneumonia. Five patients' radiology reports were not readily available.

Those 17 who did not have a chest radiograph were diagnosed with bronchitis (5), sinusitis (5), otitis media (3), viral infection (3), and allergies (1). Of the 21 who had a chest radiograph without reported pneumonia, 16 were diagnosed with bronchitis, five with otitis media, five with sinusitis, three with viral upper and lower respiratory infection, one with a bacterial upper respiratory infection, one with silicosis pneumonitis, and one with asthma. Some patients had more than one diagnosis. Radiology reports were not readily available for five persons.

Eighteen persons met the case definition. Ages of patients ranged from 27 to 53 years, and all were male. One patient developed pneumonia following blunt chest trauma and was not considered a case. Of the other 18, nine worked in the Inter-Island and nine in the Outfall Tunnel. Ten patients spent most of their workday near the tunnel boring machine, two at ground level, three in the mid-shaft area and other sites, and three had no job site reported. In the 11 cases in which smoking history was known, six cases of pneumonia occurred in persons with a known history of smoking, five in persons who had never smoked.

Nine cases of pneumonia occurred among 303 workers in the Inter-Island Tunnel, for a 13.5 month incidence rate of 3.0 %. Nine cases occurred in 431 Outfall Tunnel workers, for an incidence rate of 2.1%. There was no clustering of cases by tunnel (InterIsland vs. Outfall) or by onset date (Fig. #2).

Laboratory Findings

Laboratory specimens were submitted for 12 patients meeting the case definition. None of the 18 pneumonia cases meeting the case definition had an etiologic agent identified. Two patients submitted sputum cultures, which were negative. One patient had negative blood cultures. Legionella antigen tests were performed in three cases and were negative. Two patients had moderately elevated titers to Mycoplasma in acute phase serum samples, but no convalescent phase sera were obtained to confirm the diagnosis. No other serologic tests were performed.

Discussion

The tunnel workers' respiratory illnesses appear to represent a spectrum of clinical disease and have no identifiable common source or etiology. Diagnoses from medical records included other respiratory illnesses such as tracheobronchitis, sinusitis, otitis, and asthma in addition to pneumonia. Most patients were treated empirically with antibiotics.

This investigation was limited by the low response rate to our questionnaires and by incomplete medical records. Of the 400 workers who received a Health and Hospitals questionnaire, only 132 (33%) responded, and only 78 (39%) of the estimated 200 InterIsland and Outfall Tunnel Workers Union members returned the NCID/NIOSH questionnaire. The July 23, 1995, meeting of the Tunnel Workers Local #4 was called to discuss health concerns on the worksite. Those attending the meeting and responding to the NCID/NIOSH questionnaire distributed there may have been those who had experienced respiratory illness, possibly introducing a reporting bias into the initial case finding. The attack rates per tunnel, therefore, cannot be interpreted with certainty.

Despite repeated attempts to meet with the engineers and electricians unions who make up approximately 30% and 12% of the tunnel workforce, respectively, we were not able to distribute the NCID/NIOSH questionnaire to these unions, probably resulting in underreporting of respiratory illness among workers in these groups. Recall of respiratory illness of all types might have been greater for those becoming ill most recently.

CONCLUSIONS AND RECOMMENDATIONS

Our retrospective review of available medical records could not determine a specific infectious etiology for the respiratory illness. Our analysis of the medical records for epidemiologic purposes was limited by the incomplete laboratory diagnostic testing of the pneumonia cases. It is important to note that diagnostic evaluations appropriate for epidemiologic or surveillance purposes may differ from those appropriate for individual medical care and treatment of illness. There was no clustering of cases in time or by tunnel. Prospective evaluation using a standard data collection protocol would be more useful for determining the exact nature of this illness and possibly identifying an etiologic agent.

We agree with the recommendation of the Boston Department of Health and Hospitals letter of August 1, 1995, that cooperation of labor, management, and government authorities is essential for the success of all phases of this surveillance effort.

We recommend that top management from the governmental agencies, contractors, and the unions participate fully in the critical components of the surveillance effort put forth by the Boston City Department of Health and Hospitals. All parties should have involvement in decisions on appropriate interventions affecting employees with respiratory symptoms in the tunnels.

Management should provide specific education and information to the employees at the tunnels regarding recognition of respiratory symptoms and the importance of early reporting of symptoms. Workers complaining of cough, fever, difficulty breathing, or wheezing should be identified as soon as possible through self-referral on the job site. They should be evaluated in a timely manner by a health care provider familiar with occupational health issues, particularly respiratory conditions, and, if possible, tunnel or mining hazards. We recommend that an occupational, medical, and smoking history be taken at this initial visit. All persons with pneumonia should be evaluated with a chest radiograph and sputum gram stain and culture (if a productive cough is present). They should have serum samples collected (both acute- and convalescent-phase) for further serologic testing. The data collection form (see addendum) used by the investigation team for chart review should be strongly considered for use for prospective surveillance and case reporting.

When this surveillance system is implemented, we will be interested in assisting all parties in the interpretation of data and development of a strategy for prevention of respiratory illness in the workers.

NIOSH has responded to requests for a Health Hazard Evaluation from Deer Island tunnel workers and is currently collecting data for environmental analysis. Should any NIOSH assays suggest that infectious agents are a hazard in the Deer Island tunnels, NCID will resume its work on this investigation.

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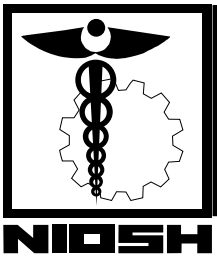

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