PATHOGENS IN CONDENSER COOLING SYSTEMS: A HEALTH CONCERN

BY

JEROME S. FIELDS
SENIOR ENVIRONMENTAL SPECIALIST
NUCLEAR DEPARTMENT

PENNSYLVANIA POWER & LIGHT CO.
2 NORTH 9TH STREET
ALLENTOWN, PA 18101

JANUARY, 1982

PREFACE

Preliminary data and procedures reviewing the Pennsylvania Power & Light Company pathogen study were presented at an Edison Electric Institute Biologist Workshop held in Tampa, Florida, on April 21-23, 1981.

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SUMMARY

The Pennsylvania Power and Light Co. is concerned that personnel working in and around condenser cooling systems may face health hazards from pathogens such as free-living amebas (*Naegleria fowleri* and *Acanthameba sp.*) and Legionnaires Bacteria (*Legionella pneumophila*). Water and air samples were analyzed to determine if these organisms existed. Procedures were developed to assure that workers were knowledgeable about the health effects of pathogens as well as the proper use of safety equipment.

INTRODUCTION

The Pennsylvania Power & Light Co. (PP&L) is an electric utility, located in eastern Pennsylvania, with a capacity of about 22 billion kilowatt hours per year. Many environmental and safety approvals, regulations, permits and licenses are required in order to operate its six major generating stations. Certain occupational safety regulations such as the wearing of safety shoes, hard hats, eye and ear protection, are readily accepted by employees because of obvious job-related hazards. However, when it comes to protecting workers from pathogenic micro-organisms which cannot be seen and where it is generally felt that the chance of infection is slight, the problem becomes considerably more difficult. This situation is further complicated because there are no established guidelines for such protection let alone any government agency that accepts regulatory responsibility.

On two occasions PP&L was notified about the potential health hazards to station workers from the pathogenic free-living amebas *Naegleria fowleri* (*N. fowleri*) and *Acanthameba sp.* in condenser cooling systems. The first notification occurred at a Pennsylvania Electric Association meeting in March 1979, when the Pennsylvania Department of Environmental Resources (DER) discussed the Pennsylvania Electric Company's program to determine if pathogenic organisms existed in their generating station condenser cooling water. The Pennsylvania DER recommended, however, that other utilities wait for the results of this study to see if a problem existed in Pa. The second notification came in March, 1980, when the U. S.

Nuclear Regulatory Commission (NRC) announced the possibility of occupational health hazards associated with recirculating cooling systems (1). In particular, the notice discussed a survey conducted at the Northern States Power Company's Prairie Island Nuclear Generating Station where N. fowleri were found in thirty six of thirty nine samples of the condenser cooling water (2).

To date there have been no documented cases of industrial illness or death from free-living amebas; but, considerable data exists on swimmers dying after being infected by these pathogens. In some of these instances it has been documented that victims swam in thermally enriched waters from industrial effluents (3). Infection by these amebas occurs through the nasal mucosa and then into the central nervous system producing a disease called Primary Amoebic Meningencephalitis (PAM), (4).

Pathogenic free-living amebas are present in nature throughout the world. They are difficult to eradicate by use of biocides, heat, cold or drying, since they readily encyst protecting themselves under adverse conditions. Naegleria fowleri grow well at temperatures as high as 44 C (5) and Acanthameba sp. at temperatures between 30 and 33 C. It is thought that human infection from N. fowleri is acquired from water, while Acanthameba sp. infection may be contracted from either water or air.

Another biohazard associated with condenser cooling systems is Legionnaires Disease caused by Legionella pneumophila (L. pneumophila) a bacteria. Unlike the amebic infections there have been documented cases

of Legionnaires Disease infections. Two outbreaks occurred in 1973 in which workers were infected with this bacteria even though the cause of the infection was not identified until 1979 (6). Blood sera obtained and stored since 1973 were tested in 1979 using direct immunofluorescence on antigens of four serogroups. The first incident occurred while ten previously healthy men were steam cleaning a steam turbine condenser of a Virginia Electric Power Co. plant located on the James River in Virginia. After spending several hours in the condenser without respirators, all became ill with fever, chills, headaches, muscle pain and nausea. The second incident occurred in the Oakland County Health Department Building, Pontiac, Michigan where approximately 100 people were affected after entering the building. Their symptoms were similar to the power company workers. In both instances, the strain of Legionnaires bacteria was not lethal (6).

A program for collection of both water and air samples at generating stations was established during the months of August, September and October 1980. Samples were collected from six PP&L power generating stations and a steam heating plant. Water, air and soil or sludge were sampled for free-living amebas and Legionnaires bacteria. Since these organisms may be found anywhere in nature, it was important to determine what concentrations have adverse health effects to workers.

The PP&L generating stations utilize either once-through or recirculating cooling systems (natural draft cooling towers) to dissipate excess heat given off during the production of electricity. Water above 30 C is an

ideal breeding medium for these pathogens (3). During station operation or maintenance outages, workers can come into contact with heated water or vapor. Prior to determining if these pathogens were present, PP&L decided that personnel working in and near the condenser cooling system would be required to wear protective equipment and to follow good hygiene practices.

In parallel with the pathogen sampling program, chlorine data were collected at both the Martins Creek Units 1 & 2 (once-through) and 3 & 4 (recirculating) condenser circulating water systems. The purpose of this study was to determine if a free available chlorine level of 2.0 mg/l could be maintained in the system while still meeting the present National Pollution Discharge Elimination System Permit discharge limits (0.5 mg/l maximum and 0.2 mg/l average). It was suggested, based on chlorination at the Prairie Island Nuclear Station, that by maintaining a free residual of 2 mg/l the free-living amebas could be controlled (2).

PROCEDURES

A task force from several PP&L departments was organized to determine if a health problem existed from pathogenic micro-organisms. A literature search was conducted to provide background information on *N. fowleri*, *Acanthameba sp.* and *L. pneumophila*. This review included data on the effects to swimmers from free-living amebas such as PAM (7), as well as Legionnaires Disease (6). In addition, various sampling methods and procedures were considered for detection of these pathogens their concentrations, as well as the parameters necessary for their life support. To obtain more data, over sixty utilities were contacted by a computer system call "Notepad", and asked the following question; "Have pathogenic organisms been found in your plant condenser cooling systems and if so, what action was taken?" From information obtained a list of specialists was compiled and telephone conversations or meetings were held to determine if and what type of survey should be undertaken. Also discussed were the precautionary safety procedures to minimize worker exposure to the pathogenic micro-organisms.

Dr. Richard J. Duma, M.D., Ph.D., Chairman, Division of Infectious Diseases, Medical College of Virginia, Virginia Commonwealth University was selected to perform a pathogen survey for PP&L. The objective of the survey was to determine if any of these pathogens were present at PP&L's generating stations, and if so, to recommend appropriate biocide

treatment. The services also included interim guidelines for worker safety. Water samples were collected in August, September and October 1980 from the condenser cooling systems prior to and after thermal enrichment. During this same period, soil and sludge samples were collected where possible from the condensers when plants were down for an outage or from cooling tower basins. Air samples were taken in the vicinity of the condenser or inside cooling towers.

At the Medical College of Virginia Infectious Diseases Laboratory, the samples were tested to determine the presence of both types of pathogens. Attempts were made to isolate N. fowleri and Acanthanameba sp. on various agars at temperatures up to 44 C and 30 C respectively. After about two weeks of growth the pathogenic free-living amebas were injected intranasally (N. fowleri) or intra-cerebrally (Acanthameba sp.) into mice. The presence of free-living ameba pathogens was confirmed if death occurred within ten days. A portion of each sample was filtered and imprinted onto glass slides and stained with specific fluorescein labeled anti-sera for L. pneumophila. The slides were then examined under a fluorescent microscope for the presence of labeled bacteria (8).

Air samples for free-living amebas and L. pneumophila were collected using two different sample systems. In August and September, an Anderson Air Sampler (two-tier) was used but because of clogging and humidity problems, it was replaced in October by an MSI Model 3100, liquid impingement air sampler. Air samples were then processed in the laboratory as if water samples (8).

During the sampling and isolation periods, pathogenic control strategies were reviewed. Chlorine was selected since most of the generating stations have chlorination systems which are used to remove algae and other organisms from the condenser cooling systems. A test was devised where a 12.5% sodium hypochlorite solution was introduced into the cooling water. At the Martins Creek SES Units 1 & 2 (once-through) and Units 3 & 4 (recirculating). At Units 1 & 2, sodium hypochlorite was pumped into one condenser half immediately before the condenser inlet water box. This solution entered the pipe at a 42" elbow immediately before the condenser. The circulating water flow inside the pipe was turbulent and the sodium hypochlorite mixed with the circulating water. The range of feed rates varied between 0.44 and 0.83 gpm with free available chlorine levels of 1.80 and 2.2 mg/l in the condenser. By chlorinating one condenser half at a time, discharged chlorine residual was minimized by dilution. At Units 3 & 4 recirculating system, sodium hypochlorite was pumped at a rate of 4.8 gpm and produced a free available chlorine level of 2.8 mg/l (9).

RESULTS

Naegleria fowleri were positively identified in the condenser inlet sample location for Martins Creek Unit 3, in October 1980. The concentration exceeded 10,000 organisms/liter. The water temperature in the inlet was 32 C. No *N. fowleri* were detected in Martins Creek Units 1, 2 or 4. Some growth in Chang's liquid in the laboratory suggested that extremely small concentrations of either *N. fowleri* or non-pathogenic *Naegleria* may have been present in samples collected at the Walnut Steam Heating Plant in the ash settling basin, Martins Creek Unit 1 at the condenser outlet, Martin Creek Unit 3 in the cooling tower basin and Brunner Island in the discharge. *N. fowleri* were not found in any of the air samples. Also, *Acanthameba sp.* were not found in either water or air samples (8).

Legionella pneumophila were found in all condenser cooling systems sampled, with the exception of the Susquehanna SES Unit 1. This system was undergoing pre-operational testing. The concentration of *L. pneumophila* in condenser cooling system water was between 1×10^5 and 1×10^6 organisms per liter. These organisms were isolated in condenser inlets and outlets, cooling tower basins and discharge canals in each month sampled. These concentrations were similar to those found in nature (8). Because of air sampling problems, these bacteria were only identified in the October air samples. In October, using an MSI air sampler, 1.65 bacteria/liter of air were identified in the Holtwood SES

Unit 17 condenser intake screen house. No *L. pneumophila* were identified in air samples at the other stations (8). Unlike the injection of the free-living amebas into mice to confirm pathogenicity, *L. pneumophila* were not injected into animals since we were interested only in determining their presence.

DISCUSSION

Since there was no information coming from other Pennsylvania studies by March 1980, the PP&L Corporate Management Committee realized the urgency of this project and provided their full support for a survey. From March and through August 1980 procedures were established for a pathogenic survey. Since pathogenic free-living amebas and Legionnaires bacteria are thermophilic, a program needed to be established by late summer. The pathogens would be at peak concentrations at this time of year since river water temperatures would be highest. The drought of 1980 in the northeastern Unites States resulted in even higher than usual river temperatures. This was confirmed by comparing Susquehanna River temperature data collected in the vicinity of the Susquehanna SES from August through October in 1979 and 1980 (10, 11). In theory, the number of organisms per liter of water in the September and October samples should be less because of decreasing river temperatures. This trend did occur for both the concentrations of pathogenic free-living amebas and *L. pneumophila* (8).

Beginning July 1980, safety memos were provided to workers discussing potential health related problems from these pathogens. Those people working in or in the vicinity of the condenser cooling systems were required to wear safety equipment and follow good health habits. This

included, wearing a Wilson 1200 Series Respirator equipped with a R-12 filter or equivalent, chemical goggles and Best Co. #728 Nitrile gloves (neoprene coated) or equivalent. The goggles and gloves could be cleaned and reused. Rain suits and rubber boots were optional. Workers were also required to refrain from eating or smoking when near suspect areas.

Discussions were held with PP&L management and union representatives on the health effects of the pathogens and the proper safety procedures. There were complaints by some of the workers about fogging of the goggles and difficulty in working in confined areas when wearing all the safety equipment. In one instance an employee, while working in a condenser, fell into a four foot diameter discharge pipe injuring his legs and buttocks. It was uncertain if wearing the equipment caused this accident. Even though some workers complained that there was a greater chance of falling from wearing fogged up goggles than being infected by these organisms, PP&L required the use of safety equipment since the consequences from being infected could cause serious health problems.

Even with the safety memos placed on bulletin boards at the stations there were complaints from personnel about poor communications from the Pathogenic Task Force. Also, there were communication problems within the stations. One incident occurred where an employee working in the Martins Creek coal yard contracted Legionnaires Disease in November of 1980. He was a 60 year old male not in the best of health, fitting the description of a typical person who contracts Legionnaires Disease. Although it was uncertain how or where he contracted this disease, Martins Creek SES was

the only PP&L generating station at that time was not chlorinating its cooling water since there was no slime buildup in the condensers. Also, PP&L did not find out about this infected employee until he came back to work in early 1981. To avoid problems like this in the future, and to provide guidance in occupational health matters, an Industrial Hygienist was hired in April 1981 to coordinate occupational health activities.

A second employee, a construction helper, in October 1981 working in the condenser cooling system at the Montour Steam Electric Station contracted Legionnaires Disease. Unlike the other worker who contracted this disease, he was younger and in good health prior to this incident. It was first reported that this worker was following PP&L safety requirements; however, after further investigation it was found that he had not been wearing a respirator.

Chlorination practices have been modified for control of pathogen concentrations at the generating stations for worker protection. Previously chlorine was used only to prevent condenser slime. Because of future regulatory requirements for the minimization of chlorine in surface water discharges, additional discussions may be necessary with various agencies to review alternate solutions for control of pathogens in condenser cooling waters. These alternates may include low temperatures (below 20 C), high temperatures (55 - 65 C), iodine and drying (12).

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