Education and Practice

# Hypersensitivity pneumonitis with *Mycobacterium avium* complex among spa workers

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Background: The New Mexico Department of Health (NMDOH) investigated the cause of two cases of hypersensitivity pneumonitis (HP) in spa maintenance workers with laboratory confirmed *Mycobacterium avium* complex (MAC). The investigation occurred in tandem with worker protection and swimming pool regulatory investigations by the New Mexico Environment Department at the spa where the workers were employed.

Objectives: The investigation was conducted in order to identify unreported cases, exposure source(s), and to prevent further worker exposure.

Methods: NMDOH surveyed 57 spa employees about symptoms and exposures, categorized jobs according to self-reported exposure to water, and computed odds ratios for symptom reporting by exposure category. Environmental isolates from spa water and filter swabs were cultured and compared to patient isolates by the Environmental and Applied Microbiology Team, Centers for Disease Control and Prevention (CDC).

Results: Workers with the highest exposure reported more HP-like symptoms (OR=9.6), as did intermediate exposure workers (OR=6.5), compared to workers with no aerosolized water exposure. Two of 13 environmental isolates were closely related to one of the patient isolates.

Conclusions: Workers were likely exposed during spray cleaning of cartridge filters in a poorly ventilated work space. Recommendations include inhibiting organism growth in spa systems, assuring the use of respiratory protection, and adequately ventilating work spaces where filters and equipment are cleaned.

**Keywords:** *Mycobacterium avium* complex, Hypersensitivity pneumonitis, Spa, Maintenance worker, Hot tub, Pulsed-field gel electrophoresis, Respiratory, Biofilm, Water aerosols

## Introduction

Two cases of *Mycobacterium avium* complex (MAC) were confirmed in spa workers by the New Mexico Department of Health (NMDOH) between May and August, 2009. The symptoms, exposures, and presence of MAC in the two workers were indicative of hot tub lung, a hypersensitivity pneumonitis (HP) — like granulomatous lung disease associated with non-tuberculous mycobacteria (NTM). HP can occur from exposure to hot water aerosols from hot tubs and spas,[1] therapy pools,[2] showers,[3] and indoor swimming pools.[4] Person-to-person transmission of MAC does not occur.[5] MAC, a type of NTM, consists of two or more mycobacterial species, *M. avium* and *M. intracellulare*.

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MAC is ubiquitous; it can be found in water, soil, food, and it concentrates in biofilms. The addition of nutrients to water (phosphorous in the laboratory) decreases the culturability of slow-growing MAC from biofilms, but increases the growth of more competitive, heterotrophic bacteria.[6] It is the hydrophobic nature of the *M. avium and M. intracellulare*, and high mycolic acid content of the cell walls that makes MAC highly resistant to disinfectants, such as chlorine and ozone,[7] used in pools and spas as well as to ultraviolet disinfection methods.[8] Hydrogen peroxide can stimulate the growth of biofilms which harbor *M. avium* by inducing an oxidative stress response.[9] The organism persists at temperatures as high as 42°C,[10] which exceeds the upper temperature limit on spas set by the New Mexico Environment Department. Laboratory simulations demonstrate that *M. intracellulare* concentrates in aerosols in nature, indicating a pathway for human exposure.[11]

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Primarily, hot tub lung has been described in association with home spas but direct immersion in spa water is not required for the disease to develop. Two of four cases described in a case series of hot tub lung were associated with tub maintenance.[1] Even though most of the cases found in the literature are associated with home spa use, occupational cases at public recreational water facilities, such as pools and spas, have been noted. In Denver, two outbreaks of pool-related granulomatous lung disease occurred, affecting 33 lifeguard employees.[4] HP secondary to MAC was also reported in bodyscrubber workers in South Korea who showed improvement of their symptoms and radiographic abnormalities once they stopped working in the public bath.[12] There are few cases reported in the literature where hot tub lung occurred in association with outdoor spas.[13] The length of time between initial exposure to NTM in aerosols and onset of disease varies widely from an acute onset of less than 48 hours[1] to a chronic progression of the disease.[14] Because the temporal association between exposure and disease onset varies, it is often recommended that patients with atypical pneumonia that is not easily explained be questioned about hot tub exposure.[15]

### *Objectives*

The purpose of the investigation was to identify additional cases, to determine the source or sources of exposure, and to prevent further exposures with modified work practices or environmental controls. In addition, we sought to characterize patient and environmental isolates of MAC.

## Methods

The investigation of the spa establishment where the cases worked was coordinated between NMDOH staff in the New Mexico Occupational Health Surveillance Program (NMOHSP), who conducted the epidemiologic investigation, chart review, site assessment, and environmental sampling; and regulatory inspections by compliance authorities from the New Mexico Environment Department's (NMED) Occupational Health and Safety Bureau (NMOHSB — state OSHA) and Swimming Pool Program. The Centers for Disease Control and Prevention (CDC) Environmental Microbiology Laboratory and the CDC National Institute for Occupational Safety and Health Division of Respiratory Disease Surveillance (NIOSH DRDS) were consulted regarding the appropriate water sampling methods, development of the employee questionnaire, and the assessment for possible exposure pathways at the worksite.

The exposure assessment focused primarily on work processes at the spa, although worker surveys included questions about home exposure, recent travel, and secondary employment. Clients of the establishment were not considered for inclusion because no cases of community-acquired MAC disease were reported to NMDOH, as required by law, in this geographic area during the time period of the investigation, other than the two spa workers. Confirmed cases were those employees who had tested positive for *M. avium* from February 2009 to February 2010, while probable cases were those who had respiratory symptoms indicative of HP within the same time period.

### *Data collection and analysis*

A list of employees was obtained from the employer and interviews were conducted in person or over the telephone by NMDOH staff between 18 February and 18 March 2010. Interviews were conducted with 78% (56) of the employees plus one former employee. Assistance was sought from NIOSH for questionnaire development and was based on a survey of employees for HP symptoms in relation to metal-working fluids. Questions were asked about length of employment, outside employment, pre-existing respiratory conditions, other health conditions, recent travel, use of recreational water, water sources and the health of family members in the home, respiratory symptoms that occurred between February 2009 and 2010 and other chemical, physical and biological exposures on the job.

Employee exposures were classified according to job tasks as described by the employees during their interviews. Job titles of those interviewed were reported as: administration (1), bath house cleaning (6), facilities manager (1), guest services (24), human resources (1), laundry (4), lodging (4), maintenance (5), projects (1), security/guest services (1), therapy (1), and tub maintenance (8). Job tasks were grouped into categories according to their potential exposure level. Three exposure categories emerged: (1) *tub cleaners* were workers with the highest level of aerosol water exposure; they clean and maintain tubs, clean pumps, filters, and check water chemistry; (2) *tub workers* were non-maintenance workers who had less exposure to water aerosols and whose job tasks involved checking water temperature, cleaning the spa surroundings between clients, covering tubs at closing, and adding shock treatment when needed; and (3) *non-exposed workers* were employees who had no contact with tubs during their performance of job duties. After grouping, there were 13 tub cleaners, 23 tub workers, and 21 non-exposed employees.

Employees were asked if they had experienced symptoms associated with HP such as dry cough, cough with phlegm, wheezing, shortness-of-breath, fever, chills, aches, tiredness, and weight loss. They were also asked about temporal aspects of the symptoms and if their symptoms improved when they were away from work.

Odds ratios were calculated to determine if workers with the most exposure (tub cleaners) and intermediate exposure (tub workers) were significantly more likely to experience respiratory symptoms than those employees without exposure (non-exposed workers). Significance was assessed at the 95% confidence level and exact levels reported. Index cases were then removed from the analysis. Median and range of symptoms and odds ratios were reported for exposed employee categories compared to non-exposed employees. Data were analyzed using STATA v9 (STATA, College Station, TX, USA).

### *Site assessment*

The spa had several tubs, some with accompanying cold-plunge tubs. Showers accompanied some of the tubs, but shower stalls were also provided in the locker rooms. Two of the tubs were communal, while the rest were private. At the time of the assessment, two of the hot tubs were constructed of wood. Disinfection in all tubs was achieved through a combination of hydrogen peroxide, ozone, ultraviolet light, and silver/copper ion generation.

An informal walk-through was conducted by NMDOH to observe work processes that might contribute to worker exposure. Processes observed included spa tub operation, water testing, and spa filter cleaning. Spa tub cleaning was not observed, but the process was described by current and former workers during interviews.

At approximately the same time as the NMDOH investigation, the NMOHSB conducted a compliance inspection for worker health and safety and the Swimming Pool Program conducted inspections of each tub for violations related to injury prevention and sanitation. Spa sanitation inspections took 2 weeks during which some tubs were closed by the Swimming Pool Program.

### *Sample collection and laboratory methods*

Water samples and swabs were obtained from 91% of the functioning tubs (one tub was drained at the time of sample collection), as well as swabs from non-operational filter cartridges (3), shower heads (4), and non-recreational, decorative water sources (2). A minimum of one water sample per sampled tub and swabs of biofilms from water surface/tub interfaces, shower heads, and filters were collected for microbial assessment. Water samples were collected by NMDOH epidemiologists in 1-l water sample bottles with sodium thiosulfate added (1 ml at 10%) by plunging the bottle downward, 12–18 inches below the water surface of each spa. Bottles were filled at that depth with a forward- sweeping motion when brought to the surface and then capped with a small amount of head space. Bottles were then sealed with parafilm, bagged and labeled for chain-of-custody. A total of 27 swab and 14 water samples were collected and held under refrigeration over the weekend. Samples were delivered under cold-shipping to the CDC Environmental Microbiology Laboratory where they were analyzed for MAC.

High-pressure liquid chromatography and PCR-restriction fragment length polymorphism of isolates were performed to obtain group level identifications. The 16s rRNA gene sequenced and GenBank BLAST searches and Ribosomal Database Project's SeqMatch were used to identify *M. avium* from environmental samples and to confirm the patient isolates. Molecular typing of both patient isolates and 13 environmental isolates was performed by pulsed-field gel electrophoresis (PFGE). Isolates were considered genetically related if their patterns were more than 90% similar.

## Results

### *Patient interviews and clinical history*

One patient, employed as a spa maintenance worker at the establishment since 2007, sought medical treatment in August 2009 with signs and symptoms of cough, hemoptysis, and dyspnea that began in February 2009. He had a 10 mm tuberculin test and a chest X-ray that showed diffuse interstitial prominence. His sputum culture grew NTM, specifically *M. avium*-intracellulare in the laboratory. His symptoms worsened and he was hospitalized in September 2009. A high-resolution CT scan at that time showed 'scattered areas of ground-glass infiltration within all lobes with no evidence of cavitation', confirming pulmonary disease. He was prescribed antibiotics (rifampin, ethambutol, and clarithromycin) and was seen at the New Mexico Department of Health clinic in November for refills of the prescriptions. In December 2009, he saw a pulmonologist who suspected that his symptoms were linked to the workplace and encouraged him to report this condition to his employer after which he was reassigned to the laundry, thereby removing him from exposure to spa water. Sputum cultures obtained during February 2010 were negative and this patient recovered.

The other patient, also a tub maintenance spa worker since 2006, was seen in May 2009 at the local public health office with worsening cough and respiratory symptoms. A sputum culture in June 2009 grew MAC; he was hospitalized in early July, during which time he was placed on azithromycin, rifampin, and ethambutol. An ordered bronchoscopy with biopsy was not performed and his medications were not obtained because the patient could not afford them. The employee was still symptomatic and was reassigned to the laundry at the time of interview in February 2010. He was only working part-time due to continuing symptoms; however, he has since recovered.

Neither case had a prior history of lung problems. During the tuberculosis workup, both had a positive purified protein derivative, but had received bacille Calmette–Guerin (vaccine for tuberculosis) in their native Mexico. Both were married, but no other household members reported symptoms. Neither case had a history of prior work or hobbies that typically could have led to exposure to MAC.

### *Employee interviews*

Demographics and the occupational characteristics of workers interviewed were as follows: 29 females and 28 males; ages ranged from 21 to 65 years with a mean age of 37 years. Three workers declined to report their age. The length of employment ranged from less than 1–23 years (mean: 4.7 years). Employees worked an average of 33 hours per week ranging from 12 to 55 hours. Twenty employees reported working at other jobs in addition to the spa, but a Chi-square test for independence demonstrated no association between symptoms and outside employment (data not shown).

Efforts were made to interview all employees with tub exposure; all but one employee in the intermediate (tub worker) exposure category were interviewed and all tub cleaners who were employed at the time of the investigation were interviewed (see the section on 'Data collection and analysis' for a description of exposure categories).

Thirty-five of the employees interviewed denied having any of the symptoms listed. Among employees who had symptoms, the average number reported was 2; the maximum was 8. Self-reported symptoms by job exposure category are listed in Table 1.

One identified former employee was interviewed and reported experiencing symptoms during the same 2009 timeframe as the two index cases. This employee, who was the tub maintenance supervisor at that time, also sought medical care for his symptoms, but had not been tested for MAC; his tuberculin test was negative. He was not symptomatic at the time of interview in March 2010.

The odds ratio of a tub worker having any respiratory symptoms compared to a non-exposed worker was 6.5 (95% CI: 1.3–42.3). The odds ratio of a tub cleaner having any respiratory symptoms compared to a non-exposed worker was 9.6 (95% CI: 1.5–72.7). The mean number of symptoms reported by the 13 tub cleaners was 2.3; the 23 tub workers had a mean of 1.3 symptoms per worker; and the 21 non-exposed workers had a mean of 0.3 symptoms per worker (Table 2). When index cases were excluded from the analysis, the odds of tub cleaners having symptoms compared to non-exposed workers was 7.2 (95% CI: 1.0–57.5) and for tub workers was 6.5 (1.3–42.3) (Table 3).

### *Site assessment*

The 'filter deck', a small (approximately $2.5 \times 3.7$ m), enclosed shed towards the rear of the facility became the focus of the investigation. Cylindrical filters measuring approximately $25 \times 61$ cm, were soaked and cleaned in the filter deck after removal from the circulation system. Several filters were observed soaking in a large rectangular vat of water with trisodium phosphate. After soaking, filters were sprayed with an acid-based filter cartridge cleaner (brands vary depending on availability), and then were sprayed with water using a hose fitted with a pressure nozzle in order to dislodge remaining debris. This process created a high volume of aerosolized water within the shed. The worker performing this task was observed wearing a half-mask respirator at the time of our visit. Workers can spend 2–3 hours daily in the shed performing this task. It was later revealed in interviews that the filter shed had previously been open to the air, but had been enclosed within the last year. Spa cleaning was not observed, but the process of cleaning was described by current and former workers during interviews as follows: spa surfaces were power-washed, then scrubbed with brushes; skimmers were also scrubbed with scrubber pads and then all surfaces were hosed, then water was removed by vacuum pump. This task was performed for 2–5 hours per day depending on bather load at the spa.

**Table 1 Self-reported symptoms by job exposure category**

| | Tub cleaner (*N*=13) | Tub worker (*N*=23) | Non-exposed (*N*=21) |
|---|---|---|---|
| Dry cough | 1 | 9 | 2 |
| Cough with phlegm | 6 | 5 | 2 |
| Wheeze | 4 | 3 | 2 |
| Tiredness | 4 | 4 | 0 |
| Chills | 3 | 1 | 0 |
| Shortness-of-breath | 4 | 1 | 0 |
| Weight loss | 3 | 2 | 0 |
| Chest tightness | 3 | 1 | 0 |
| Fever | 4 | 3 | 0 |
| Muscle aches | 2 | 1 | 0 |

**Table 2 Mean number of symptoms and odds ratios by job exposure category — all employees**

| Exposure category | Percent (*N*) | Mean symptoms/worker | Odds ratio* (OR) | 95% confidence interval |
|---|---|---|---|---|
| Tub cleaner | 22.8 (13) | 2.31 | 9.6 | 1.5–72.7 |
| Tub worker | 40.4 (23) | 1.26 | 6.5 | 1.3–42.3 |
| Non-exposed | 36.8 (21) | 0.29 | … | … |

Note: *For any respiratory symptoms, by exposure category, compared with unexposed individuals.

### *Compliance inspections*

A total of 10 violations were cited during the NMOHSB inspection as follows: (1) failure to perform an assessment of the hazards to determine appropriate personal protection equipment against chemical exposures in employees performing maintenance; (2) failure to provide training on the type of personal protection equipment to use when performing hazardous tasks. The employer failed to (3) establish a respiratory protection program, (4) provide medical evaluations prior to respiratory protection use, (5) provide fit tests for employees required to wear half mask (N-95) respirators, (6) provide sanitary respirators, and (7) properly store and protect respirators from contamination, dust, excessive moisture, and hazardous chemicals when not in use. Employees who were required to wear respirators were (8) not provided with annual respirator training and (9) the employer did not consult with employees to ensure the proper use of respirators. Finally, (10) employees required to work with hazardous liquid and dry chemicals were not provided with information or training prior to initial use.

During the Swimming Pool Program inspections, it was noted that the operators were collecting water samples for chemistry testing at the plumbing ports inside the equipment rooms. Flow rates were not monitored for four of the spa tubs, water chemistry logs were not being completed for some tubs, and water testing was not conducted every 2 hours as required by permit conditions. Additionally, the cartridge filters were being commingled and rotated from one spa tub to another at random. The establishment was notified by the Swimming Pool Program to discontinue the practice of collecting water samples for routine testing at the plumbing ports inside the equipment rooms and to discontinue the practice of randomly commingling and rotating filter cartridges from one spa tub to another. The establishment was also advised to hire an outside consultant in order to conduct remediation and periodic sampling for MAC.

### *Laboratory assessment*

All water samples had a substantial burden of rapid and slow-growing mycobacteria, >800 CFU/ml (typically measured in drinking water as CFU/100 ml). Small buff or pale yellow colonies with raised centers and transparent irregular edges grew slowly and appeared after 2 weeks of incubation as determined by examination with a dissecting microscope. These were considered suspect isolates and acid-fast stained. Acid-fast suspect colonies were isolated from 37 of 41 samples tested.

High-pressure liquid chromatography testing and polymerase restriction analysis identified the two patient isolates and the 13 environmental isolates as *M. avium* complex, while 16S rRNA sequencing identified the isolates as *M. avium*. PFGE of the tested isolates revealed diverse band patterns. Two environmental isolates were closely related to one of the patient isolates, 2010-07-42, with either one band difference (2010-07-07) (swab from a cartridge), or two band differences (2010-07-37) (swab from a cold-plunge tub). These were designated Group A (Fig. 1), and were closely related by the Tenover criteria.[16] The second patient isolate, 2010-07-44, did not appear to be closely related to any of the other tested environmental isolates. Considering the tremendous quantity of *M. avium* recovered from the samples, the presence of a source related to the second patient's isolate could not be ruled out.

## Discussion

The two confirmed cases of HP with MAC and one probable case described in this report were most likely caused by occupational exposure to aerosolized *M. avium* while performing routine cleaning and maintenance of spa filters and tubs. This conclusion is based on PFGE analysis of environmental samples matching biological specimens of one of the two cases and the finding of a lack of evidence of other exposure sources. No other confirmed cases were found through epidemiological investigation. However, workers who had contact with spas had significantly more respiratory symptoms than did workers without spa contact. Other potential exposure sources were assessed through the employee questionnaire which took into account outside employment, recent travel, use of recreational waters, and water sources in the home. Employees were also asked about other health conditions that might contribute to respiratory effects.

Tub cleaning involves cleaning each tub filter once a week. This task was performed in the poorly ventilated filter deck by using a hose with a pressure nozzle to dislodge debris from dirty filters. Work practices and the environmental conditions had been modified during the summer of 2009, according to

**Table 3 Median number of symptoms and odds ratios by job exposure categories, excluding index cases**

| Exposure category | Percent (*N*) | Median symptoms/worker (range) | Odds ratio* (OR) | 95% confidence interval |
|---|---|---|---|---|
| Tub cleaner | 20.0 (11) | 1 (0–7) | 7.2 | 1.0–57.5 |
| Tub worker | 41.8 (23) | 0.08 (0–5) | 6.5 | 1.3–42.3 |
| Non-exposed | 38.2 (21) | 0 (0–3) | … | … |

Note: *For any respiratory symptoms, by exposure category, compared with unexposed individuals.

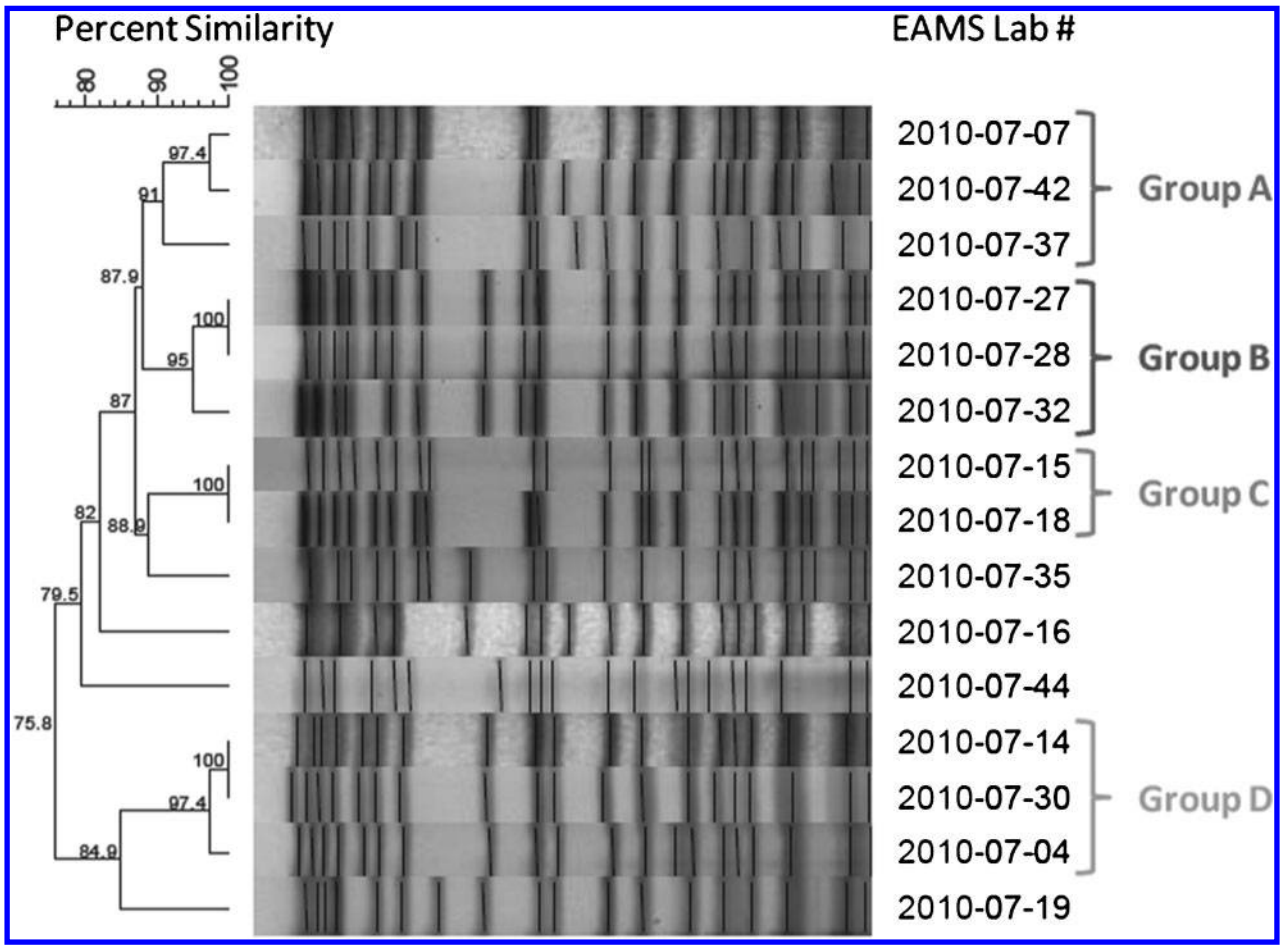


**Figure 1 PFGE dendrogram of MAC isolates. Two environmental isolates were closely related to one of the patient isolates (2010-07-42), with one band difference (2010-07-07) (swab from cartridge #3), and two band differences (2010-07-37) (swab from a cold plunge tub). These were designated Group A, and were closely related by the Tenover criteria.[16]**

several employees. Enclosure of the filter deck likely reduced ventilation, thereby increasing the exposure to aerosols containing microorganisms. Decontamination and cleaning practices did not completely eliminate NTM from tubs as demonstrated by the presence of NTM in environmental samples. Power washing of tubs with a high-pressure hose may have provided an opportunity for exposure to aerosolized microorganisms, but this process was not observed. Respirators were reportedly not worn during this unobserved process.

Currently, there are no specific guidelines for preventing the growth of MAC in hot tubs beyond standard sanitation procedures.[13] Hot tubs should be maintained according to manufacturers' recommendations, which include both frequent water changes and adequate use of disinfectants.[15] The US EPA recommends preventing growth of biofilms because MAC can sequester within them.[17] This investigation concluded that exposure of the two confirmed MAC cases occurred during the process of removing biofilms from filters and tubs, and therefore, the focus of worker protection should be on these processes. Mycobacteria have particular characteristics that can render them resistant to standard water treatment methods. The World Health Organization recommends that treatment and prevention methods for the control of *M. avium* include source water protection, coagulation, flocculation, sedimentation, filtration, disinfection, and protection of the distribution system.[18]

Ideally, observations of the entire cleaning process, including the power washing of spa tubs, would have taken place. Although MAC was isolated from filters, it was also found in tubs, including cold water plunge tubs. MAC quantification in aerosol samples should have been collected from spray generated during the cleaning process. Measurement of the circumference of aerosolization during the cleaning process could have demonstrated whether spray extended into the workers' breathing zones, thereby adding evidence for an exposure route. Additionally, these cases should have been investigated sooner. The delay in notification to the Occupational Health Surveillance Program may have resulted in a failed opportunity to confirm a third case. Sputum cultures were not obtained from other workers who had reported symptoms, so we cannot definitively establish that their symptoms were due to MAC exposure.

The NMDOH recommended that the employer comply with worker protection regulations under NMOSHB and with NMED Swimming Pool Code requirements, including the use of halogen

disinfection of water. We further recommended that the establishment have an independent industrial hygienist, assess the filter deck, and adopt ventilation recommendations. We also recommended the use of personal respiratory protection equipment, while filters are being washed and when power washing tubs to protect against aerosolized biofilms. Because the organism sequesters in biofilms, we recommended that the spa prevent the growth of biofilms in all parts of the spa circulation system and to discontinue the use of wooden tubs where biofilms may accumulate. We recommended that the spa discontinue the use of hydrogen peroxide as a disinfectant and that they use an EPA-registered tuberculocide to treat surfaces coming into contact with spa water where biofilms tend to accumulate.[19]

Recommendations for health-care providers also arose from the investigation, including the submission of biological specimens for laboratory testing for MAC in patients/workers diagnosed with atypical pneumonia who are exposed to aerosolized spa waters, and the removal of MAC positive workers from work environments where further exposure could occur. Finally, health-care providers are required to report all potentially occupational cases of MAC to the NMDOH as per New Mexico Administrative Code 7.4.3,[20] and should do so in a timely fashion so further illnesses can be prevented.

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