



Evaluation of *Mycobacterium tuberculosis* (TB) Transmission from Asian Elephants to Zoo Employees

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Disclaimer

The Health Hazard Evaluation Program investigates possible health hazards in the workplace under the authority of the Occupational Safety and Health Act of 1970 [29 USC 669a(6)]. The Health Hazard Evaluation Program also provides, upon request, technical assistance to federal, state, and local agencies to investigate occupational health hazards and to prevent occupational disease or injury. Regulations guiding the Program can be found in Title 42, Code of Federal Regulations, Part 85; Requests for Health Hazard Evaluations [42 CFR Part 85].

Availability of Report

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Introduction

Request

The National Institute for Occupational Safety and Health (NIOSH) received a request for a Health Hazard Evaluation from the chief administrative officer of a zoo and aquarium. The request concerned transmission of *Mycobacterium tuberculosis* (TB) to zoo employees who were working with and around Asian elephants.

Background

Tuberculosis (TB) is a disease that can affect people and animals and is caused by *Mycobacterium tuberculosis* bacteria that is generally found in the lungs but can attack any part of the body. Transmission can occur through inhalation of TB bacteria and infection occurs when the bacteria begin to grow. Latent TB infection (LTBI) means that a person has been infected with TB bacteria but is not showing disease symptoms and cannot spread the bacteria to others. In some cases, LTBI can progress to TB disease. People with TB disease can spread TB bacteria to others. Symptoms of TB disease may include a bad cough that last 3 weeks or longer, pain in the chest, coughing up blood or sputum, weakness or fatigue, weight loss, no appetite, fever, chills, or sweating at night. TB disease is treated with multiple antibiotics for 6 months or longer. People with LTBI are treated with one or two antibiotics for a shorter period (3–4 months) to decrease the likelihood of developing TB disease in the future.

Multiple epidemiologic investigations have documented elephant-to-human transmission of TB. Elephants have a very large lung capacity (tidal volume) relative to humans and can exhale large amounts of TB bacteria into the air of enclosed spaces (e.g., barns). In a zoo environment, TB bacteria from elephants with TB disease can be further spread during aerosol-generating procedures such as an elephant trunk wash (a diagnostic procedure used to identify elephants with TB) or potentially through cleaning (e.g., power washing) of contaminated areas. People working in close proximity in an enclosed space to an elephant with TB disease or performing aerosol-generating procedures (such as during an elephant trunk wash or power washing contaminated areas) can breathe in the bacteria and become infected themselves. This risk can persist in indoor spaces for a period even after the elephants are no longer present.

Workplace

The 29-acre zoological park was operated by a municipal corporation overseeing parks and recreation services. The zoo's two female Asian elephants were housed in the elephant barn, which was an approximately 3,875 square foot, two-story building with elephant housing on the lower level and employee workspace and animal food storage on the upper level. Adjacent to the elephant barn was a large yard where the elephants were released daily for exercise. The elephant barn and yard are referred to as the "elephant area" for the purpose of this report. At the time of the site visit, approximately 40 employees comprised of elephant keepers, veterinary staff, and facilities and operations staff worked in the barn. Before this outbreak, volunteers worked in the elephant area, but once TB was identified, no volunteers were allowed in the barn and this policy continues to be implemented to limit the number of people potentially exposed to TB.

Elephant barn employees participated in annual TB screening conducted offsite at an occupational health provider recommended by the zoo or their primary care provider with either a tuberculin skin test (TST) or blood test (interferon-gamma release assay [IGRA]). In September 2019, eight of twelve zoo employees who worked primarily in the elephant area tested positive for TB infection using IGRA tests; these employees were evaluated for TB and all received a diagnosis of LTBI and were started on LTBI treatment. All employees diagnosed with LTBI had tested negative by TST in 2018. In light of these newly diagnosed infections in employees, both elephants were tested and found to be reactive on the serologic multiantigen print immunoassay (MAPIA) test. Additionally, *Mycobacterium tuberculosis* DNA was detected by quantitative polymerase chain reaction (qPCR) performed on trunk wash samples obtained in September 2019. In November 2019, TB trunk wash cultures isolated *M. tuberculosis* from specimens collected from both animals, indicating that both elephants had infectious TB disease. One of the elephants had a long history of being MAPIA-reactive, but the other elephant was newly positive. Both elephants were considered geriatric. For these reasons, the zoo administration believed that the elephants were the probable source of infection for the eight elephant barn employees diagnosed with LTBI in September 2019.

To learn more about the workplace, go to [Section A in the Supporting Technical Information](#)

Our Approach

In November 2019, a NIOSH team and member of the Centers for Disease Control and Prevention's Division of Tuberculosis Elimination visited the zoo. We completed the following activities during our evaluation:

- Toured the elephant area (including the elephant barn and yard) and observed workplace practices, including personal protective equipment (PPE) use when working with elephants and in the elephant area.
- Assessed the elephant barn ventilation system.
- Conducted voluntary, confidential interviews with 19 employees, including elephant keepers, veterinary staff, and facilities and operations staff.
- Reviewed the TB exposure control plan for employees including the respiratory protection program, fit testing plan, and draft employee TB surveillance protocol.
- Met with county and state health department representatives.

To learn more about our methods, go to [Section B in the Supporting Technical Information](#)

Our Key Findings

Employees who primarily worked in the elephant area and had contact with the elephants were more likely to test positive for TB infection.

- Employee survey results found that employees whose primary worksite was the elephant area and reported having direct contact with elephants were more likely to have a positive TB IGRA blood test compared with employees who worked in the elephant area, but it was not their primary worksite or they did not have direct contact with elephants.
- Tasks associated with a positive IGRA result included preparing elephant food, performing elephant trunk washes, sweeping stalls, cleaning the barn, disinfecting the elephant barn on weekends, and bathing the elephants.

At the time of the health hazard evaluation, the zoo had a respiratory protection program and employee TB surveillance program; however, upon review both could be improved.

- The respiratory protection program was written for the entire zoo and not specific to the elephant area and keepers. It did not specifically address TB exposure control.
- The type of respiratory protection fit test (qualitative vs. quantitative) and responsible party for conducting fit testing was not explicitly stated.
- The employee TB surveillance program did not include baseline or preemployment TB testing or specify the type of test to use such as the IGRA test.
- Some of the essential elephant area employees did not participate in the employee TB surveillance program.
- A comprehensive, confidential record keeping system to track the respiratory protection program and TB surveillance program was not in place; employee occupational health records were not available for review.
- There was no occupational health coordinator identified. Adequate staff training is an important component of a respirator protection program; however, employees demonstrated gaps in knowledge about proper PPE use during observation of daily activities.

One ventilation system serviced both the elephant housing area and office space in the elephant barn, allowing air from the elephant housing area to enter employee workspaces.

- A single air handling unit serviced both the elephant housing area and office space in the elephant barn.
A single ventilation system was problematic because TB spreads via airborne particles, called droplet nuclei, that could travel between the two areas through the ventilation system.
- Exhaust air from the elephant barn was discharged through louvers on the west side of the building above the employee parking lot adjacent to the barn.
This configuration is not ideal because of the potential for employees parking in the area to be exposed.

Employees needed more information on TB risk and prevention.

- Employee survey results revealed inconsistent training frequency and knowledge level among employees on TB risk factors (e.g., high-risk activities, transmission), testing, and prevention (e.g., PPE use).
- While observing work practices, we noted employees touching or readjusting their N95 respirators. We were told that some employees who ostensibly passed their fit test wore N95 respirators with facial hair that might impair the protective seal.

To learn more about our results, go to [Section B in the Supporting Technical Information](#)

Our Recommendations

The Occupational Safety and Health Act requires employers to provide a safe workplace.

Benefits of Improving Workplace Health and Safety:

- | | |
|--|--|
| ↑ Improved worker health and well-being | ↑ Enhanced image and reputation |
| ↑ Better workplace morale | ↑ Superior products, processes, and services |
| ↑ Easier employee recruiting and retention | ↑ May increase overall cost savings |

The recommendations below are based on the findings of our evaluation. For each recommendation, we list a series of actions you can take to address the issue at your workplace. The actions at the beginning of each list are preferable to the ones listed later. The list order is based on a well-accepted approach called the “hierarchy of controls.” The hierarchy of controls groups actions by their likely effectiveness in reducing or removing hazards. In most cases, the preferred approach is to eliminate hazardous materials or processes and install engineering controls to reduce exposure or shield employees. Until such controls are in place, or if they are not effective or practical, administrative measures and PPE might be needed. Read more about the hierarchy of controls at <https://www.cdc.gov/niosh/topics/hierarchy/>.



We encourage the company to use a health and safety committee to discuss our recommendations and develop an action plan. Both employee representatives and management representatives should be included on the committee. Helpful guidance can be found in “*Recommended Practices for Safety and Health Programs*” at <https://www.osha.gov/shpguidelines/index.html>.

Given the many unknowns about the TB disease process in elephants, the recommendations below are focused on ways to mitigate the risk of transmission from elephants to current and future employees, strengthen employee TB surveillance, and inform employees on risk and prevention.

Recommendation 1: Reduce potential employee exposure to *M. tuberculosis*

Why? Multiple epidemiologic investigations have documented zoonotic *Mycobacterium tuberculosis* transmission between people and elephants. TB bacteria exhaled into the air by elephants with infectious TB disease and can be further spread by aerosol-generating procedures such as during a trunk wash or cleaning (e.g., power washing) contaminated areas. People working in close proximity to an infected elephant or performing these activities can breathe in the bacteria and become infected themselves. In some cases, latent TB infection (LTBI) can progress to TB disease. People with weakened immune systems who have LTBI are at higher risk of progressing to TB disease. Symptoms of TB disease can include: a bad cough that lasts 3 weeks or longer, chest pain, coughing up blood or sputum, weakness or fatigue, weight loss, no appetite, chills, fever, or sweating at night. People with TB disease can spread TB bacteria to others. People with LTBI and TB disease need treatment with antibiotics.

In September 2019, eight zoo employees working in the elephant area were newly diagnosed with LTBI. *Mycobacterium tuberculosis* was isolated from trunk wash specimens collected in September 2019 from both animals, thus indicating infectious TB disease. At the time of the health hazard evaluation, the zoo decided the elephants would not be treated for TB because of concerns the antibiotics would be difficult to administer based on the animals' history and temperament, and the potential for antibiotic-resistant TB development. The zoo had also decided against euthanizing either animal unless their clinical condition deteriorated. As a result, the two elephants with TB disease continued to pose a risk of TB exposure for employees working in the elephant area.

How? At your workplace, we recommend these specific actions:



Cease all nonessential tasks, and remove all nonessential items, personnel, or animals from the elephant barn to minimize the risk of *M. tuberculosis* transmission to as few persons or animals as possible.



Limit the number of employees and volunteers who work in the barn when the elephants are inside or when the housing and husbandry areas are being cleaned.

- Consider dividing elephant area employees into two groups to stratify risk into two tiers to minimize the number of employees at increased risk of transmission: one group only inside when elephants are indoors or when cleaning is occurring (increased risk), and one group only inside when elephants are in the outdoor yard and no cleaning is occurring (limited risk).



Employees should limit aerosol generating activities as much as possible.

- Use alternative cleaning methods in lieu of power washing the elephant housing area and wet down bedding before sweeping to minimize dust.

- When aerosol generating activities cannot be avoided, employees should wear a fit-tested NIOSH-approved respirator (N95 or equivalent or higher level respirator), disposable coveralls such as Tyvek, and gloves.

Recommendation 2: Implement a respiratory protection program and require all employees and volunteers at risk of TB exposure to participate in the zoo's respiratory protection program.

Why? A respiratory protection program is a critical component to preventing TB transmission to current and future elephant area employees and employees working with other species that can pose a risk for zoonotic TB.

Before identification of TB in employees, elephant area employees were not required to wear respiratory protection while working in the elephant barn. At the time of the health hazard evaluation site visit, only essential personnel were allowed to enter the elephant barn, and anyone entering the elephant barn was required to wear a fit-tested N95 respirator. All essential employees had been fit-tested, most with a qualitative fit test, to wear N95 respirators.

Respirators should be used in conjunction with an OSHA-compliant Respiratory Protection Program (29 CFR 1910.134) that includes medical evaluation, training, and fit testing. Some states may have applicable Federal OSHA-approved State plans. Information on Federal OSHA-approved State plans can be found at <https://www.osha.gov/stateplans>.

How? At your workplace, we recommend these specific actions:



Assign or hire a qualified employee knowledgeable in occupational health to be responsible for implementing a robust respiratory protection program.



Implement a respiratory protection program that includes an annual quantitative fit testing protocol and training program to educate employees and volunteers how to properly use PPE.

- OSHA's Respiratory Protection standard [29 CFR 1910.134], notes that a respiratory protection program should include the following:
 - Written policy;
 - Change-out schedule for cartridges/filters;
 - Medical evaluation prior to use to determine fitness;
 - Fit testing and training prior to use and annually; and
 - Establishment and implementation of procedures for proper respirator use such as prohibiting use with facial hair when this would impair the seal; ensuring user

seal-check and inspection of respirators prior to each use; ensuring proper cleaning, disinfection, and maintenance of respirators; and ensuring proper storage of respirators to protect respirators from damage, contamination, dust, sunlight, and extreme temperatures

- NIOSH has information about respiratory protection at the following websites:
 - Respirators
<https://www.cdc.gov/niosh/topics/respirators/>
 - Respirator trusted-source information – Section 3: ancillary respiratory information
https://www.cdc.gov/niosh/npptl/topics/respirators/disp_part/respsource3.html



Ensure all employees and volunteers potentially exposed to TB are included in the respiratory protection program.

- Consider establishing an exposure classification system to identify which employees and volunteers are potentially exposed to TB.



Establish and maintain records according to OSHA (29 CFR 1910.1020, Access to Employee Exposure and Medical Records) or applicable OSHA-approved state program.

Recommendation 3: Institute an updated TB surveillance program and require that all employees and volunteers potentially exposed to TB participate in the zoo's TB surveillance program.

Why? An employee TB surveillance program is necessary to ensure routine testing and monitoring is performed, any new TB infections are promptly identified, and corrective actions are taken to protect current and future employees.

The TB surveillance program in place before TB was identified was not comprehensive to include all employees who might be exposed to TB in the elephant barn and required modifications to include baseline testing at the time of hire for new employees, a standardized testing protocol, and improved record keeping.

How? At your workplace, we recommend these specific actions:



Assign or hire a qualified employee knowledgeable in occupational health to be responsible for the TB surveillance program.



Ensure all employees and volunteers potentially exposed to TB participate in the zoo's TB surveillance program.

- Establish an exposure classification system to determine which employees and volunteers may potentially be exposed to TB depending on the species they work with, their main work location, and whether they spend time working with or around a species that can carry TB bacteria (e.g., elephants, non-human primates).



Update the TB surveillance program to include screening and baseline testing upon starting employment or volunteering and annually for those individuals with a previously negative test using an IGRA screening tool.

- Screening questionnaires should be consistent with national guidelines and state or local health department regulations and guidelines. An example of an integrated tuberculosis (TB) screening and risk assessment form for new staff can be found in Appendix 3 (<http://links.lww.com/JOM/A782>) of the following reference:

Tuberculosis screening, testing, and treatment of US health care personnel: ACOEM and NTCA Joint Task Force on Implementation of the 2019 MMWR Recommendations. *J Occup Environ Med* 2020;62(7):e355-e369, <https://doi.org/10.1097/JOM.0000000000001904>.
- Ensure prompt medical evaluation if a volunteer or employee's TB infection test is newly positive. CDC has information about diagnosing LTBI and TB disease at the following websites:
 - Tools for Health Care Providers
https://www.cdc.gov/tb/education/provider_edmaterials.htm
 - Diagnosing Latent TB Infection & Disease
<https://www.cdc.gov/tb/topic/testing/diagnosingltbi.htm>
- Local or public health agencies can serve as a source for technical assistance, medical consultation regarding diagnosis and treatment of LTBI, and clarification of state or local regulations and guidelines. Information on state and local TB Control offices can be found at <https://www.cdc.gov/tb/links/tboffices.htm>.
- According to American Thoracic Society (ATS), Infectious Diseases Society of America (IDSA), and CDC clinical practice guidelines, use of IGRA over the TST is generally preferential for diagnosis of TB for persons at least 5 years of age. The TST is considered an acceptable alternative, though, in situations where IGRA testing is not

available or considered too costly or too burdensome. ATS/IDSA/CDC Clinical Practice Guidelines: Diagnosis of Tuberculosis in Adults and Children can be found at <https://academic.oup.com/cid/article/64/2/e1/2629583>.



Ensure employees with a history of LTBI receive annual symptom screening for TB disease.

- The annual symptom screening should include education to help individuals with treated or untreated LTBI understand which symptoms to monitor, whom to contact if symptoms of concern develop, and what LTBI treatment options to consider if untreated.
- An example of an annual tuberculosis symptoms screen form for individuals with LTBI can be found in Appendix 7(<http://links.lww.com/JOM/A786>) of the following reference:

Tuberculosis screening, testing, and treatment of US health care personnel: ACOEM and NTCA Joint Task Force on Implementation of the 2019 MMWR Recommendations. *J Occup Environ Med* 2020;62(7):e355-e369, <https://doi.org/10.1097/JOM.0000000000001904>.



Ensure an adequate confidential record keeping system is used to document and track baseline and follow-up TB test results in the TB surveillance program.

- Implement a tracking system that includes why the employee was tested, employee exposure classifications, results, annual clinical evaluations, and information on required follow-up of positive tests.
- Designate a qualified person with a back-up to keep the tracking system up to date.

Recommendation 4: Provide a ventilation system for areas on the upper floor of the barn including the entrance hallway, locker room, restroom, office, and kitchen areas that is separate from the ventilation system for the elephant housing area.

Why? Preventing air from the first-floor elephant housing area mixing with the upper floor employee areas will reduce the risk of exposure.

At the time of the site visit, the zoo administration had moved the office space to a trailer outside the barn (Figure 1). However, by separating the ventilation systems, the upstairs office area could once again be used safely by employees.

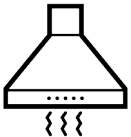
How? At your workplace, we recommend these specific actions:



Consult with a ventilation expert to explore options for ventilating the upper floor of the elephant barn separately from the elephant housing area. Positive pressure in the upper floor should be maintained to prevent the entry of air from the elephant housing area.



Consider installing an exhaust fan in the elephant housing area that can be turned on remotely by employees first thing in the morning to allow air movement from the space before employees enter the area to begin daily activities.



Consider relocating the building's exhaust to the roof so air from the elephant barn is not released directly into the parking area (Figure 2).



If the exhaust fan in the hay storage area is not routinely used, consider deactivating the power switch to prevent use.



Figure 1. Temporary trailer located outside of elephant barn used as office space by elephant barn employees for administrative activities. Photo by NIOSH.



Figure 2. Exhaust air louvers above employee parking lot. Photo by NIOSH.

Recommendation 5: Ensure employees understand the hazards associated with working with TB-positive animals and how to protect themselves.

Why? OSHA’s Hazard Communication Standard, also known as the “Right to Know Law” (29 CFR 19.10.1200), requires that employees are informed and trained on potential work hazards and associated safe practices, procedures, and protective measures.

After identification of TB, the zoo provided TB training to employees; however, employee survey results revealed inconsistent training frequency before the outbreak and varied knowledge level among employees on TB risk factors (e.g. high-risk activities, transmission), testing, and prevention (e.g. PPE use).

How? At your workplace, we recommend these specific actions:



Train employees and volunteers on potential workplace hazards, what precautions they should take to protect themselves, and workplace policies for reporting their concerns.



Implement TB training during working hours upon hire and then annually for all elephant area employees and other employees who would benefit from this training (ancillary veterinary staff, volunteers, facilities staff, or others).

- Training should include TB transmission risks specific to job tasks, symptoms, testing requirements, prevention, and what to do if an employee or volunteer believes they might be ill. Information on these topics can be found on the CDC TB website at <https://www.cdc.gov/tb/default.htm>.
- Document these trainings in employee records.



Conduct regular training for employees on proper respirator use and provide this information at all PPE donning (putting on) and doffing (taking off) stations.

- Training should occur during onboarding, annually, and when an employee switches from one type of respiratory protection to another (for example, from an N95 respirator to a personal air-purifying respirator [PAPR]).
- Training should include what to do if an N95 respirator becomes wet or compromised.
- NIOSH provides training materials on how to properly put on (don) and take off (doff) a disposable respirator at <https://www.cdc.gov/niosh/docs/2010-133/>.



Ensure employees replace N95 respirators daily and do not store used N95 respirators in the same location as clean, unused N95 respirators.

- NIOSH has a PPE Tracker mobile app that can help track your PPE inventory. This app can be found at <https://www.cdc.gov/niosh/ppe/ppeapp.html>.

Recommendation 6: Ensure standard procedures for PPE use are clearly identified, communicated to employees, and enforced by supervisors.

Why? PPE is the least effective means for controlling hazardous exposures. Proper use of PPE requires a comprehensive program and a high level of employee involvement and commitment. The appropriate PPE must be chosen for each hazard. Supporting programs such as training, changeout schedules, and medical assessment may be needed. PPE should not be the sole method for controlling hazardous exposures. Rather, personal PPE should be used until effective engineering and administrative controls are in place.

We observed PPE stations set up at entry points to the elephant barn (Figures 3 and 4), and employees properly donning and doffing PPE. However, we also observed an employee wearing an N95 respirator improperly.

How? At your workplace, we recommend these specific actions:



Develop designated areas for storing, donning, and doffing PPE.

- PPE storage and donning and doffing should take place in an area outside of elephant care areas. This space should be ventilated separately to prevent the potential for PPE to be contaminated. Employees should have access to a handwashing station.
- If the second-floor office space is ventilated separately and constantly maintained under positive pressure relative to the elephant housing area, the PPE storage and donning and doffing could be located on the second floor.



Require all employees wear gloves (dedicated work gloves or disposable latex or nitrile gloves), eye protection (goggles or face shield), and respiratory protection (N95 respirator or equivalent or higher level respirator) while working in the elephant area.

- The minimum level of respiratory protection acceptable for TB is a filtering face piece respirator selected from those approved by NIOSH under Title 42 CFR, Part 84.
- NIOSH has information on respiratory protection acceptable for TB at <https://www.cdc.gov/niosh/topics/tb/respprotection.html>.
- If employees are unable to wear N95 respirators, N95 respirators become wet during certain procedures, or enhanced comfort is needed because of heat or humidity, PAPRs with loose-fitting facepieces or hoods might be an alternative option. If PAPRs are used, consider equipping workers with radio headsets or earpieces to allow for easier verbal communication when working in close proximity to elephants.



Ensure employees are trained to properly wear N95 respirators, including what to do if N95 respirators become compromised or wet.



Ensure employees wear N95 respirators, disposable coveralls such as Tyvek, gloves, and eye protection (goggles or face shield) during any aerosol-generating activities, such as power-washing or using high-pressure water/cleaning sprays.



Make N95 or equivalent respirators or ones with greater protection (e.g., PAPR) available for protection against TB when working around any elephant exposed to TB.

- Because there is a lag time between when an elephant starts shedding TB and the positive trunk wash culture result, workers may be exposed to TB during that time-period. Wearing an N95 respirator would decrease the risk of TB exposure.



Ensure employees wear a respirator (N95 or equivalent, or higher-level respirator), eye protection, and gloves when performing maintenance and replacing filters in the ventilation system with potential for *M. tuberculosis* contamination.

- If employees have concerns about handling filters potentially contaminated with *M. tuberculosis*, the filters can be disinfected by spraying them with a 10% bleach solution or other appropriate mycobactericide before removal.

- If disinfection by spraying is done, the blowers in the air handling unit should be powered off before spraying begins, and they should remain off until the filters have been replaced.



Figure 3. Personal protective equipment storage and donning and doffing station in the first-floor entryway to the elephant barn. Photo by NIOSH.



Figure 4. Personal protective equipment storage and donning and doffing station at the upper level employee entrance to the elephant barn. Photo by NIOSH.

Recommendation Implementation

In addition to providing feedback during the site visit, we sent an interim letter in January 2020 providing a summary of the site visit and similar recommendations as above. The zoo administration subsequently took several actions to mitigate the risk of TB exposure including implementing a TB Exposure Control Program managed by a Work Group who oversees all administrative controls, improved PPE practices, facility upgrades, and ongoing activities. Ventilation upgrades were completed in the elephant barn to include separate systems for the elephant housing and employee areas.

Supporting Technical Information

Evaluation of *Mycobacterium tuberculosis* (TB)
Transmission from Asian Elephants to Zoo Employees

HHE Report No. 2019-0268-3380

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Section A: Workplace Information

Asian Elephant Barn & Yard (Elephant Area)

Size: 3,875 square feet

Floors: two levels

The lower level of the barn contained two elephant bedrooms, a holding room, an elephant restraint chute used during animal husbandry, and a small food storage area. The upper level contained the employee office space, a locker room area with a restroom and shower, an animal food preparation kitchen, hay storage area, and boiler room. A second story catwalk was located above and along the sides of the barn for employees to monitor the elephants. Entry points to the elephant barn were located at both the upper and lower levels on the south end of the building and in the courtyard on the north end of the building. Personal protective equipment (PPE) supplies were located just inside the entrance to the upper level and at the entrance next to the stairwell on the lower level on the south end of the building. Employees donned (put on) and doffed (took off) their PPE immediately after they entered the barn (Figures 3 and 4). The perimeter of the elephant barn included the elephant yard with three public viewing areas, a viewing area for visitors to see into the elephant barn, an employee parking area, and a courtyard with maintenance supplies and refuse disposal. At the time of the site visit, elephant barn staff were using a temporary trailer in the parking area behind the elephant barn for their office space (Figure 1) to complete administrative activities.

Employee Information

At the time of the site visit, access to the elephant barn was limited to essential personnel only. There were approximately 40 essential elephant area employees comprised of elephant keepers, veterinary staff, and facilities and operations staff. Volunteers were no longer allowed in the barn.

History of Issue at Workplace

In September 2019, eight of twelve zoo employees who worked primarily in the elephant barn tested positive for TB infection using IGRA tests. These employees were evaluated for TB and all received a diagnosis of LTBI. All employees diagnosed with latent TB infection had a negative TST result in 2018. In light of these newly diagnosed TB infections in people, both elephants were tested and found to be reactive on the serologic MAPIA test. Additionally, *Mycobacterium tuberculosis* DNA was detected by quantitative polymerase chain reaction (qPCR) performed on trunk wash samples obtained in September 2019. In November 2019, TB trunk wash cultures isolated *M. tuberculosis* from specimens collected from both animals, indicating both elephants had infectious TB disease. One of the elephants had a long history of being MAPIA-reactive, but the other elephant was newly positive.

At the time of the site visit on November 9, 2019, the lead zoo veterinarian in consultation with zoo administration and with guidance from local public health officials had decided the elephants would not be treated for TB because of concerns the antibiotics would be difficult to administer based on the

animals' history and temperament, and the potential for antibiotic-resistant TB development. This was the first known U.S. facility with elephants diagnosed with TB disease to not attempt to treat the elephants for TB disease, which posed challenges related to the risk of current and ongoing TB exposure for zoo employees working closely with or around the elephants or in the elephant area. The recommendations made in this report reflect consideration of ongoing TB risk.

At the time of the visit, the zoo had implemented increased precautions to reduce potential TB exposure to employees and the public by limiting access to the elephant barn to essential personnel only. All essential personnel entering the elephant barn were required to wear a fit-tested N95 respirator.

Before zoo employees were diagnosed with LTBI, the municipal corporation had a written respiratory protection program included in the District Accident Prevention and Safety Plan. This document described the purpose of the respiratory protection program, medical surveillance, respirator selection, training, and qualitative fit testing protocols. The District Accident Prevention and Safety Plan and an updated respiratory protection program draft were shared with NIOSH for review before the site visit.

This event was the first time this zoo identified TB transmission from elephants to workers.

Tuberculosis

TB is a disease caused by *Mycobacterium tuberculosis* bacteria that can affect people and animals. Although generally found in the lungs, TB bacteria can attack any part of the body. TB is spread through inhalation of bacteria that occurs during close, prolonged contact with a person or animal with TB disease. LTBI occurs when a person is infected with TB, but not sick. Individuals with LTBI do not have symptoms and cannot spread TB to others but are at risk for developing TB disease. On average, 1 in 10 people with LTBI will get sick with TB disease in the future, and people with weakened immune systems are more likely to develop TB disease [CDC 2021]. People with LTBI are treated with one or two antibiotics for a shorter period (3–4 months) to decrease the likelihood of developing TB disease in the future. TB disease causes the person to become sick and able to spread TB bacteria to others. TB disease is treated with multiple antibiotics for 6 months or longer. Reports of TB-like illnesses in Asian elephants have been documented for thousands of years [Chalke 1962], and the point prevalence of TB among captive Asian elephants in the United States during 1997–2011 was estimated to be 5.1% for Asian elephants and 0% for African elephants [Feldman et al. 2013].

Transmission of *M. tuberculosis* has been documented between elephants and humans [Michalak et al. 1998]. Since 2015, the United States Department of Agriculture (USDA), Animal and Plant Health Inspection Services (APHIS), no longer regulates the surveillance, diagnosis, and treatment of TB in elephants within the United States [NIOSH 2018]. That responsibility now rests with the lead veterinarian treating the elephant with TB. However, the Stakeholders Task Force on Management & Research Priorities of Tuberculosis in Elephants published Recommendations for the Diagnosis, Treatment and Management of Tuberculosis in Elephants in Human Care in 2017 [Backues and Wiedner 2019]. This detailed document gives recommendations for diagnostic testing, treatment, and monitoring of the elephant and herd during treatment, as well as human health considerations [Backues and Wiedner 2017].

TB in elephants is usually diagnosed by trunk wash culture, and elephants in captivity should be tested at least annually. Routine trunk wash culture consists of a series of three trunk wash samples collected on separate days within a one-week period [Backues and Wiedner 2017]. Culture is the only definitive method to diagnose TB disease and although trunk wash culture can lack sensitivity, it is still considered the gold-standard for diagnosing TB in elephants. Other ancillary tests such as Dual Path Platform™ (DPP) and Multiantigen Print Immunoassay™ (MAPIA) can be used in conjunction with trunk wash cultures. The DPP is a rapid test to detect antibodies to *M. tuberculosis* in blood, while the MAPIA detects antibodies to a panel of 12 defined *M. tuberculosis* antigens. One of the elephants had a long history of being MAPIA reactive and had been regarded as potentially infected with *M. tuberculosis*. Before identification of this outbreak, neither elephant had trunk wash cultures positive for TB; however, *M. tuberculosis* was isolated from trunk wash samples collected from both elephants in September 2019 (results were reported as positive for both elephants in November 2019). At the time of our site visit, both elephants with TB disease received three trunk wash cultures per week to determine how often the elephants were shedding TB bacteria.

Because diagnosing and treating elephants with TB can be difficult, time-consuming, and expensive, more research is needed to better understand the science of TB in elephants, risk to humans, and to develop improved screening methods for TB in elephants.

Section B: Methods, Results, and Discussion

Methods: PPE Use and Work Practices

We observed employee PPE use and work practices to learn more about activities and job duties that might lead to increased risk of TB exposure.

Results: PPE Use and Work Practices

PPE Use

While working inside the barn, employees wore N95 respirators, gloves, and eye protection. While working in the outdoor elephant yard, employees wore gloves while collecting manure and gloves and an N95 respirator while emptying manure into a refuse container.

Work Practices

We observed elephant keepers performing their regular duties including animal husbandry and medical treatments. We also observed aerosol-generating procedures, including a trunk wash demonstration and potentially aerosol generating activities such as cleaning elephant stalls using a high-power hose (not a pressure washer, Figure 5) and removing elephant manure from the yard. While observing work practices, we noted employees touching or readjusting their N95 respirators while inside the contaminated area.

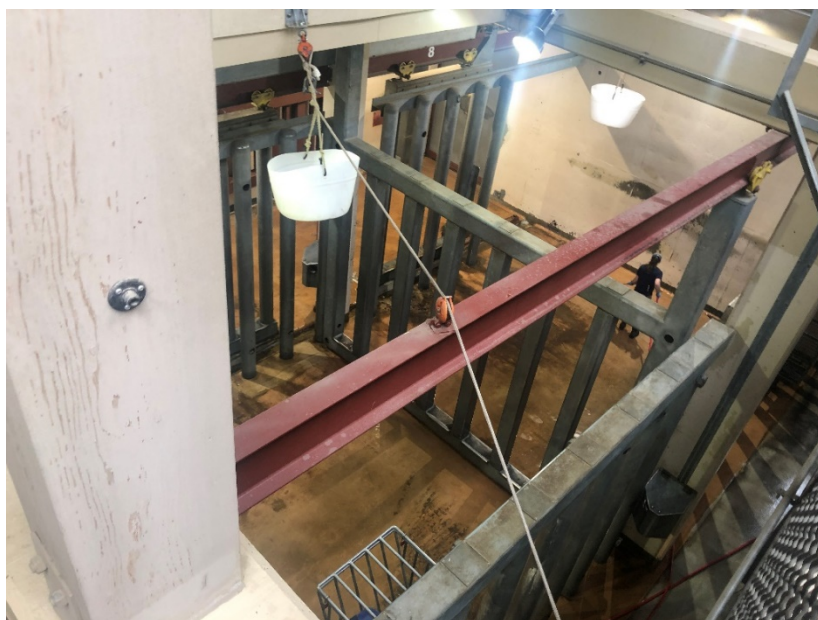


Figure 5. A zookeeper cleaning the elephant housing area with a hose inside the elephant barn. Photo by NIOSH.

Methods: Ventilation Assessment

We took physical measurements of all areas and visually assessed the air-handling unit (AHU) serving the elephant barn. Air flow measurements were not taken during the visit. We reviewed mechanical drawings and the AHU specifications and operational data summary. We measured pressure differentials at all doorways on the second level.

Results: Ventilation Assessment

The Heatex Inc. series 5000 AHU appeared to be in good working order. Components of the system included two blowers, duct dampers, particulate filters, an energy recovery heat exchanger (HX), and hot water heating coil. The system was designed to supply and exhaust air in a single-pass fashion at a rate of 5000 cubic feet per minute (CFM). At the supply and exhaust air inlets, the AHU was fitted with 3-ply 20-inch × 30-inch ventilation filters with a Minimum Efficiency Reporting Value (MERV) rating of 7. The filters were reportedly checked every 30 days and typically replaced every 60 days. At time of removal, filters were reportedly bagged prior to disposal. The HX transfers heat from exhaust air to incoming supply air during the heating season (the opposite is true during warmer times of the year). Air was not recirculated in the building. The blowers were either “on” or “off” and set to move the same amount of air through the supply and exhaust sides of the unit. Supply air intake louvers were located on south end of the barn at the loft level.

Fresh, outside air flowed through the filters and supply-side HX, before passing through the hot water heating coil and then out to the occupied areas of the building. The AHU originally supplied air to three supply vents in the second level staff areas of the barn. However, during our visit all three supply vents had been sealed off due to past insect infestation in the ducts. There were two operable windows located in the hallway just outside of the office area. The main duct run with supply vents for the lower level of the elephant barn had seven vents. Four of the vents were open while three had been covered with metal plates. The AHU also supplied air to a continuous sill diffuser located underneath the public viewing window on the first floor of the barn.

Return air was fed back to the AHU through one large louver located at loft level above the elephant stalls. There were no return vents to the AHU in the second level staff areas. After passing through a filter and the HX, the exhaust air was forced out of the building through louvers on the west side of the building above the employee parking lot adjacent to the barn (Figure 2). Using physical measurements of the space and the manufacturer specifications for the existing ventilation system we determined there were approximately 4.5 air changes per hour for the barn.

We measured pressure differentials at all doorways on the second level. The hay storage area on the second level was used to store hay for multiple animals at the zoo. Employees other than elephant caretakers periodically entered the area for short periods of time to collect hay. The hay storage area was negative to the first floor of the barn meaning that air from the elephant area was entering the hay storage room. Air entering the hay storage room from the elephant barn increased if the exhaust fan in the hay storage area was turned on, although staff reported the fan was never used. The office area and kitchen were also slightly negative or neutral to the catwalk area which means that air from the first level elephant area could enter the office and kitchen areas. The pressure in the enclosed areas on the second level should be positive to the catwalk and first floor to prevent air from the main elephant area entering the space.

Methods: Employee Survey

At the time of the site visit in November 2019, CDC/NIOSH staff interviewed a convenience sample of the employees who spent all or some time working in the elephant area. Survey data were analyzed

using SAS 9.4. Fisher's exact tests were used to evaluate associations between groups ($p < 0.05$ was considered significant). The survey sample size was too small to conduct multivariable logistic regression to assess associations between exposures and IGRA test results. Wilcoxon two-sample test was used to compare employees' time spent in the elephant barn housing area with IGRA test results.

Survey respondents were divided into exposure groups based on two criteria: 1) whether they reported the elephant barn was their primary workplace, and 2) whether they reported contact with the elephants. The High Exposure group was assigned if they answered yes to both criteria, the Medium Exposure group was assigned if they answered yes to one criterion, and the Low Exposure group was assigned if they answered no to both criteria.

Results: Employee Survey

Demographic characteristics of survey participants

We interviewed 19 of the 40 employees (47.5%) who spent all or some time working in the elephant area including elephant area employees, veterinary staff, and ancillary staff such as facilities and operations. Of the 19 employees we interviewed, 12 had been tested for TB in September 2019 using IGRA tests. Summary characteristics of the survey participants are presented in Table C1.

Exposure groups

We classified four respondents to the High Exposure group, six respondents to the Medium Exposure Group, and nine respondents to the Low Exposure Group (Table C2). The High Exposure group was mainly comprised of job titles associated with elephant barn employees, the Medium Exposure group was mainly comprised of veterinary staff, and the Low Exposure group was mainly comprised of facilities and operations staff.

Exposure group was associated with positive TB blood test result

IGRA results were available for 12 of the 19 survey respondents; four (33%) had a positive IGRA result. Exposure group was significantly associated with IGRA result ($p = 0.0364$) (Table C2. Exposure group associated with positive TB blood test result). All three employees with test results in the High Exposure group tested positive, while none of the three employees with test results in the Low Exposure group tested positive. Of six employees with test results in the Medium Exposure group, five employees (83%) had a negative IGRA result and reported having close contact with the elephants, but the elephant barn was not their primary workplace. One employee (17%) in the Medium Exposure group reported the elephant barn was the employee's primary workplace but did not have close contact with the elephants themselves. This employee had a positive IGRA result. While this employee did not report close contact with the elephants, the employee reported performing high-risk tasks such as cleaning and disinfecting the elephant barn daily and power washing the elephant housing area (before identification of TB, at which point power washing was no longer permitted).

Time spent in elephant barn, elephant housing area was associated with positive IGRA result

The amount of time spent per week inside the elephant barn elephant housing area ranged from 0 to 20 hours with a median time of 1.0 hour and mean time of 4.2 hours. For those employees with a negative IGRA test result, the mean time spent in the elephant barn housing area was 0.875 hours per week compared to 16.0 hours per week for those employees with a positive IGRA test result. The median

number of hours spent in the elephant barn housing area was statistically significantly higher for employees with a positive IGRA test result than for employees with a negative IGRA test result (Wilcoxon two-sample test, one-sided $p = 0.0031$, two-sided $p = 0.0062$). We categorized employees' elephant barn elephant housing area exposure as Long (>4 hours) or Short (≤ 4 hours) based on the average number of hours they reported spending in the elephant barn elephant housing area each week. Those in the Long Exposure group were associated with a positive TB blood test result ($p = 0.0020$).

Tasks associated with positive IGRA result

From a list of 10 elephant-related tasks, respondents were asked to identify tasks currently being performed and tasks performed during the previous 12 months. Current tasks associated with a positive IGRA result included preparing elephant food ($p = 0.0182$), performing elephant trunk washes ($p = 0.0182$), sweeping stalls ($p = 0.0101$), cleaning the barn ($p = 0.0020$), disinfecting the elephant barn on weekends ($p = 0.0182$), and bathing the elephants ($p = 0.0182$). Tasks performed during the previous 12 months associated with a positive IGRA result included preparing elephant food ($p = 0.0020$), sweeping stalls ($p = 0.0101$), cleaning the barn ($p = 0.0020$), and bathing elephants ($p = 0.0182$).

Feeding elephants and administering medications were not significantly associated with IGRA test results for either current or past 12-month tasks; however, both of these tasks were associated with positive IGRA test results when analyzed by task frequency (daily, several times a week, once a week, once a month). Feeding elephants and administering medications were associated with a positive IGRA test result for those employees who reported doing these tasks daily currently (feeding, $p = 0.0238$; medications, $p = 0.0286$) and daily in the past 12 months (feeding, $p = 0.0238$; medications, $p = 0.0286$).

Disinfecting the elephant barn on weekends during the previous 12 months ($p = 0.0909$) and pressure washing the elephant barn during the previous 12 months ($p = 0.0667$) were associated with a positive IGRA test result at p less than 0.1. Pressure washing is an aerosol generating activity and therefore should be considered a high-risk activity.

PPE Use

Before identification of TB transmission occurring between elephants and employees, respiratory protection was not routinely worn by employees working in the elephant barn. The responses recorded at the time of the survey referred to the period after identification of TB when zoo administration implemented respiratory protection protocols.

Two employees (50%) in the High Exposure group and five employees (83%) in the Medium Exposure group reported always using an N95 while within 25 feet of the barn, including inside and outside the barn. Of those in the Low Exposure group, one employee (11%) reported wearing an N95 most of the time, and four (44%) reported always wearing an N95 while within 25 feet of the elephant barn.

Employees who reported not wearing an N95 while within 25 feet of the barn answered 'yes' to participating in tasks associated with a positive IGRA result, indicating they performed these tasks at least some of the time without proper respiratory protection to prevent TB exposure. The tasks included pressure washing, food preparation, feeding and administering medications to the elephants, performing trunk washes, cleaning and disinfecting the barn, sweeping stalls, and bathing elephants.

Most (84%) of the employees who responded reported training on proper PPE use in the past year; however, two employees in the High Exposure group and one employee in Medium Exposure group reported no training on the proper way to wear an N95 respirator in past year.

Employee TB Training

Five of the 19 employees surveyed (26%) reported not attending any general training on TB in humans and elephants, including one employee each from the High and Medium Exposure groups and three employees from the Low Exposure group.

When asked about frequency of training, responses varied from never, once, annually, and every two years, across the three exposure groups. Only three employees (16%) reported annual training, two employees from the High Exposure group and one person from the Medium Exposure group.

Most employees were knowledgeable about activities that increase risk of TB transmission (68%), symptoms (80%), and what to do if they develop TB symptoms (95%). However, six employees in the Low Exposure group were not familiar with tasks that increase transmission risk. Employees in the High Exposure group had more knowledge about TB testing frequency than the other two groups where knowledge varied.

Employee TB Testing

Employees reported varied TB testing frequency. Out of the nineteen employees surveyed, 21% reported never having a TST: one employee in the High Exposure group and three in the Low Exposure group. Of the 14 respondents who answered this question, the majority (64%) reported they did not have a pre-hire or baseline TST or other TB infection test at the time of hire, including one person in the High Exposure group. Sixty-three percent of employees reported having had an IGRA since the start of this TB investigation at the zoo, including three employees in the High Exposure group, six in the Medium Exposure group, and three in the Low Exposure group.

Updated since November 2019 Site Visit

The zoo was responsive to the recommendations we provided at the November 2019 site visit closing meeting and in an interim letter dated January 6, 2020. Below is a summary of follow-up activities after our site visit in November 2019, as of May 2021.

TB Exposure Control Program

A new TB Exposure Control Program created in partnership with a contracted industrial hygienist outlined all administrative controls, PPE, facility upgrades, and ongoing activities. The Program has a TB Exposure Control Work Group that meets monthly. The Work Group has representation from elephant barn employees, operations, veterinary staff, and zoo administration. In addition, a contracted public health nurse with subject matter expertise in TB control participates in work group meetings, reviews TB symptom checks with employees diagnosed with LTBI and addresses questions or concerns from employees who enter the elephant barn and yard regarding TB exposure risk.

Under this program, access to the elephant barn and yard area is limited to only essential employees. No volunteers, guests, or nonessential employees are allowed to enter the area. All employees who enter the barn or yard are included in the TB Exposure Control Program. TB testing policies vary based on how frequently the staff person enters the elephant area. All new employees must be screened at the time of

hiring; this may be a TST or IGRA screening test. All elephant area employees are screened quarterly using the IGRA screening test. Ancillary elephant area employees including those with regular but not prolonged contact with the elephants or who perform routine work in the elephant barn such as veterinary staff, operations, and maintenance, receive a semiannual IGRA screening test. Employees who work with nonhuman primates and hoofstock are screened annually using IGRA. Employees who do not work with elephants, primates, or hoofstock and do not work in the elephant barn do not need repeated TB screening after their initial screening before their hire date.

The zoo administration is responsible for providing information to all employees who enter the elephant barn or yard on the risks of TB exposure, how to mitigate and implement mitigation measures, and long-term effects of exposure. This information is also included in job descriptions and discussed with potential candidates during interviews. Employees are given the option to be reassigned if they do not wish to work in the elephant barn or yard following discussion of the risks. Training for new staff includes extensive training on TB Exposure Control Program elements in addition to baseline and ongoing surveillance testing.

Since the site visit, one of the elephants was euthanized because of health concerns unrelated to TB, but the other elephant remains at the zoo. Antibiotic treatment for TB was initiated in this elephant; however, it was discontinued after seven weeks because the treatment side effects affected animal welfare, and the animal became noncompliant. The zoo has continued periodic trunk washes and the shedding of TB was observed to decline then cease during treatment but has since resumed. All strains have tested as non-drug resistant thus far. The zoo continues to monitor TB shedding in the elephant and drug resistance on a quarterly basis.

PPE Use

After the site visit, the zoo updated its PPE policy so that all employees working in the elephant barn or yard were required to wear a powered air-purifying respirator (PAPR) for respiratory protection. This requirement was implemented because an additional staff person IGRA positive result following our site visit. This staff person was IGRA negative during initial testing when TB infections were first identified, and but subsequently had an IGRA positive result on surveillance screening. During the period this person might have been exposed, tasks were completed in N95 respirators. Additionally, the coronavirus disease 2019 (COVID-19) pandemic's effect on the PPE supply chain made it difficult to obtain N95 respirators. Therefore, the zoo implemented a policy that all employees working in the elephant barn or yard were required to wear PAPRs for respiratory protection.

Dedicated areas were constructed to allow for the proper donning and doffing of PPE.

Employee Training on TB

Annual zoonotic disease training for zoological, operations, and veterinary staff has been updated to include more robust information about TB. All employees who enter the elephant barn or yard are provided annual in-depth TB training and meet with the county TB nurse to ask any specific questions.

Ventilation Assessment

Separate ventilation systems were installed for the elephant housing area (first floor) and administrative areas located on the second floor. The new ventilation configuration allowed the elephant housing area to remain under negative pressure to the administrative areas to ensure air from the two areas do not mix. Pressure monitors were installed to enable employees to confirm the system is operating correctly.

The employees can activate a high-air-change flush to dilute the air in the elephant housing area before entry.

Discussion

This health hazard evaluation request concerned transmission of *Mycobacterium tuberculosis* (TB) from elephants to zoo employees who were working with and around elephants. In November 2019, we conducted a site visit to provide technical assistance on how to prevent further TB infections in zoo employees.

In previous TB outbreaks at zoos and sanctuaries, infected elephants have been treated with antibiotic protocols to varying degrees of success [Backues and Wiedner 2019]. In this case, zoo administration initially elected not to treat the infected elephants for several reasons including concerns about noncompliance from the animals due to the length of time they would need treatment and large quantity of medication they would need on a daily basis. Daily treatment posed an increased risk of additional TB exposure to elephant barn staff due to prolonged time in close contact needed to administer the medication. Animal welfare was also a concern due to potential for side effects from the medications. Finally, zoo administration was concerned about the potential for the development of antibiotic-resistant TB strains. The decision not to treat was taken into consideration as we conducted the site visit and in the recommendations we provided because it was unknown how much bacteria was being shed into the environment or if bacterial shedding would increase over time without treatment.

During the site visit, we reviewed policies and protocols for TB surveillance and PPE use, conducted a ventilation assessment of the elephant barn and yard, observed work practices and PPE use, and administered an employee survey on TB knowledge, prevention measures, and health status. Key findings included employees who primarily worked in the elephant barn and had contact with elephants were more likely to test positive for TB infection, the respiratory protection program and TB surveillance program could be improved to better protect employees from TB transmission, the ventilation system in the elephant barn needed upgrading to prevent air from the elephant area to enter employee work spaces, PPE supplies including N95 respirators and gloves were being stored inside the barn entrance areas leaving them vulnerable to contamination and putting employees at risk of exposure to contaminated air, and employees needed more robust and frequent training on TB risk and prevention.

We recommended several options to improve each of these key findings. Reduce potential employee exposure to *M. tuberculosis* by ceasing all nonessential tasks, removing all nonessential items from the elephant barn, limiting the number of employees who work in the barn, and by limiting aerosol generating activities. Implement an OSHA compliant Respiratory Protection Program and TB surveillance program and requiring participation from all employees at risk of exposure to TB. Assign or hire a person knowledgeable in occupational health to administer these programs. Include annual quantitative respirator fit testing and a training program to educate employees on how to properly use PPE as well as on key concepts related to TB disease and prevention. Employees and volunteers should receive baseline TB testing and screening using an IGRA test as appropriate based on exposure risk.

According to the 2017 ATS/IDSA/CDC clinical practice guidelines, IGRA is generally preferred over TST for TB diagnosis in persons over aged 5. The TST is considered an acceptable alternative, though, in situations where IGRA testing is not available or considered too costly or burdensome. Program administrators should keep adequate record keeping for all test results. Ensure standard procedures for PPE use are identified, communicated to employees, and enforced by supervisors.

Ventilation assessment recommendations included ventilating the entrance hallway, locker room, restroom, office, and kitchen area on the upper floor of the elephant barn, to reduce the potential for exposure to TB. Maintaining the elephant housing area in a negative-pressure zone will prevent contaminated air from entering other areas of the building. Activation of the high-air-change flush before elephant care staff enter the housing area will also help reduce the potential for exposure to TB. All PPE should be properly stored in a clean environment. The construction of the dedicated areas for donning and doffing PPE will also help mitigate the potential for exposure.

At the time of the site visit, the zoo administration was in the process of updating the respiratory protection program and TB surveillance program and had implemented mandatory use of N95 respirators for employees entering the elephant barn. However, an additional staff person tested positive on the IGRA test after the site visit. This staff person was a zookeeper who worked exclusively in the elephant area. They had a negative IGRA test result when the TB infections were first identified, but subsequently had an IGRA positive result on surveillance screening. It is unknown whether this person was exposed to TB before N95s were routinely used in the elephant barn or whether the exposure occurred after N95s were required, but the respirator was used incorrectly. This additional case of LTBI further reinforced the need for ongoing training among zoo employees and volunteers and a strong TB exposure control program.

At time of this report, the zoo administration had taken several actions to mitigate the risk of TB exposure including implementing a TB Exposure Control Program overseen by a Work Group who oversees all administrative controls, PPE, facility upgrades, and ongoing activities.

Limitations

Limitations of the employee survey conducted included a small survey sample size limited to a convenience sample of employees available at the time of the site visit. TB test results were not available for everyone surveyed. The evaluation occurred at a point in time and might not be indicative of practices at other times (e.g. PPE use).

Conclusions

The findings of this health hazard evaluation support the recommendation that a robust TB control program should be implemented at zoos and other facilities that house elephants. At minimum, the TB control program should include a ventilation assessment, TB surveillance program and respiratory protection program, sustained use of appropriate fit-tested respiratory protection (N95 respirator or equivalent or higher-level respirator) for anyone who has contact with elephants or works in their enclosure, and a comprehensive employee training program. Although the prevalence of TB among

captive elephants in the United States is thought to be relatively low, diagnosing TB in elephants is difficult, and the gold standard test has low sensitivity; therefore, elephant cases might be missed and could result in employees being unknowingly exposed to elephants with active TB disease.

Implementing PPE use early in these settings will help to mitigate the potential for staff exposure to TB during the lag time between when an elephant starts shedding TB and a positive trunk wash culture result. The ongoing efforts of this zoo in implementing measures to protect current and future employees and volunteers from TB exposure without compromising animal welfare or the relationship between the caretakers and the animal illustrates that this can be accomplished successfully.

Section C: Tables

Table C1. Demographic characteristics of survey participants (n=19)

	No. (%)
Sex	
Male	9 (47)
Female	10 (53)
Median Age (years)	42 (range = 28–60)
Median Tenure in Current	
Job (years)	3.5 (range = 0.1–23.3)
Median Total Tenure (years)	8.2 (range = 0.2–30.7)
Median Hours Worked per	
Week	40 (range = 24–65)
Job Category	
Zookeeper	5 (26)
Veterinary staff	5 (26)
Operations/maintenance staff	9 (47)
TB IGRA blood test status	
Negative	8 (42)
Positive	4 (21)
Not tested or Missing information	7 (37)

Table C2. Exposure group associated with positive TB blood test result

Exposure Group	Description	IGRA Blood	Test Result*		Total
		# Positive	# Negative	No results available	
High	Elephant barn primary workplace AND Direct contact with elephants	3	0	1	4
Medium	Elephant barn primary workplace OR Direct contact with elephants	1	5	0	6
Low	Neither elephant barn primary workplace AND No direct contact with elephants	0	3	6	9

*Fishers exact test $p = 0.0364$

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