HETA 92-282-2297
MARCH 1993
WARREN CORRECTIONAL INSTITUTION
LEBANON, OHIO

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SUMMARY

In June 1992, the National Institute for Occupational Safety and Health (NIOSH) received a request from the Service Employees International Union, District 1199, to conduct a Health Hazard Evaluation (HHE) at the Warren Correctional Institution (WCI) in Lebanon, Ohio. The requester was concerned that workers, particularly staff in the Medical Department, were potentially exposed to *Mycobacterium tuberculosis*. This concern arose in May 1992, when an inmate was diagnosed with active tuberculosis disease.

On August 21, 1992, NIOSH investigators met with representatives of labor and management to collect information regarding the patient's illness, isolation, and treatment; and the tuberculosis screening programs currently provided by WCI. The heating, ventilation, and air conditioning (HVAC) system in the Medical Department was evaluated to identify possible deficiencies which may contribute to the transmission of *Mycobacterium tuberculosis*.

NIOSH investigators considered the patient to be noninfectious on the day of the visit. He had been on drug therapy since May 1992, his cough had resolved, and bacteria counts from his sputum smears were low.

The majority of air in the building was recirculated. Because of this, there was a potential for aerosolized *Mycobacterium tuberculosis* from the Medical Department to be transmitted throughout that department as well as the administrative offices. Other ventilation deficiencies identified which may increase the potential for *Mycobacterium tuberculosis* transmission included insufficient total and outside air supply, and incorrect pressure relationships between rooms and adjacent corridors.

Because the patient was no longer considered to be infectious at the time of the investigation, the risk of *Mycobacterium tuberculosis* transmission to employees at that time was low or non-existent. While the patient was infectious, however, there was a potential for *Mycobacterium tuberculosis* transmission to employees and inmates in the Medical Department and administrative offices. Recommendations to reduce the potential of *Mycobacterium tuberculosis* transmission in the future, including medical screening and improved ventilation, are provided in the report.

KEYWORDS: SIC 9223 (Correctional Institutions); prisons; tuberculosis; TB; *Mycobacterium tuberculosis*.

INTRODUCTION

In June 1992, the National Institute for Occupational Safety and Health (NIOSH) received a request from the Service Employees International Union, District 1199, to conduct a Health Hazard Evaluation (HHE) at the Warren Correctional Institution (WCI) in Lebanon, Ohio. The union representative was concerned that workers, particularly staff in the Health Department, were potentially exposed to *Mycobacterium tuberculosis*. This concern arose in May 1992, when an inmate was diagnosed with active tuberculosis disease.

This report contains the results of a NIOSH investigation conducted on August 21, 1992, that consisted of: 1) a medical assessment of the patient's TB illness and of its treatment; isolation procedures used; and the tuberculosis screening programs currently provided by WCI; and 2) an evaluation of the heating, ventilation, and air conditioning (HVAC) system in the Medical Department.

BACKGROUND

The WCI facility consists of 15 structures built on 60 acres of land in southwest Ohio. The main compound, opened in August 1989, is a close security correctional facility. There are three housing units which consist of two buildings each. Each building is comprised of two "pods," with 60 inmate cells in each pod. Outside the fence of the main compound is a minimum security camp that was opened in June 1988. At the time of the NIOSH investigation, there were approximately 1200 inmates in the main compound, and 140 in the minimum security camp; all inmates at WCI were male.

Inmates entering the Ohio Bureau of Prisons are initially admitted to one of several receptions centers, where they remain for six to eight weeks before being transferred to a correctional facility (most of the inmates at WCI were admitted through the reception center at Orient, Ohio). Inmates may be transferred to WCI from another state institution following a change in security status (inmates may be moved from either maximum or medium security to close security). Between June 1988 and July 1992, 3250 inmates had entered WCI.

Upon admission into WCI, an inmate's fingerprints and photograph are taken, clothing is issued to him, his medical records are reviewed, and he is assigned to a cell. The cells were designed for single occupancy, but at the time of the investigation all cells were being shared by two inmates because of facility limitations in the State of Ohio.

Inmates may re-enter the WCI facility after being away with leave (AWL). AWL is a temporary leave status for reasons such as making court appearances or obtaining medical care that can not be provided at WCI.

All inmates, unless given an exemption for medical reasons, either work in the facility or attend vocational courses. Inmates may also participate in sports or in a variety of other programs.

Employees in a variety of positions have opportunities for close contact with inmates. Correctional officers may work in pods where they are in an open room with as many as 120 inmates. Officers rotate between pods every six months and additional relief officers work "floating" rotations as needed to fill in. Work supervisors, psychology staff, chaplains, counselors, and medical staff perform jobs which routinely place them in close contact with inmates. At the time of the investigation, the WCI staff consisted of 293 employees, 156 of which were correctional officers.

The Medical Department is located in a brick building which is shared by administration offices. The building has two sections, a one-story section where the Medical Department is located, and a two-story section used for administration offices. The Medical Department has four examination rooms, which are used to provide primary medical care services to inmates, and nine holding cells. The WCI medical staff includes nine nurses and one office assistant. A private physician, radiologist, dentist, and podiatrist are contracted by WCI to provide part-time services in the clinic.

The HVAC system for the Medical Department is a variable air volume (VAV) system consisting of supply, return, and the exhaust ventilation. The supply system provides tempered (heated or cooled) air. According to engineering drawings, the total supply air can vary from approximately 6400 cubic feet per minute (cfm) to 16,000 cfm, depending on the heating or cooling requirements of each room and the temperature of outside and return air. The supply of outside air provided varies depending on air temperatures, however, according to the engineering drawings, there is a minimum set point on the outside air damper which provides, at a minimum, approximately 3000 cfm of outside air. The return system provides the necessary make-up air to the air handler (fan). The flow rate of return air is equal to the difference between the flow rates of total supply and outside air supply. The exhaust system exhausts room air from selected rooms directly outside the building through a discharge on the roof.

TUBERCULOSIS

Tuberculosis is an infectious disease caused by the bacterium *Mycobacterium tuberculosis*. *M. tuberculosis* is carried in airborne particles, known as droplet nuclei, that can be generated when persons with pulmonary or laryngeal tuberculosis sneeze, cough, or speak. The droplet nuclei are so small (1-5 microns) that normal air currents keep them airborne and can spread them throughout a room or building. Infection occurs when a person inhales aerosolized* *M. tuberculosis*.[1]

The most common site of tuberculosis infection is the lung, where the organisms come to rest after being inhaled. In a small proportion of newly infected persons (usually < 1%), the initial infection develops into active tuberculosis disease. The predominant symptom associated with tuberculosis disease is a chronic cough, usually with the production of sputum; fever, weight loss, and fatigue are also common. In the United States, 90 to 95 percent of those infected with *M. tuberculosis*, who are otherwise healthy, may never develop active disease because their immune system limits the infection; symptoms don't develop and a chest x-ray may only show a small area of calcification in the lung or in a nearby lymph node. For the remaining five to ten percent, illness develops after an interval of months, years, or decades, when the bacteria begin to replicate and produce disease.[1]

Populations in the United States known to have a high incidence of tuberculosis include blacks; persons born in Asia, Africa, the Caribbean, and Latin America; American Indians; Alaskan Natives; current or past prison inmates; alcoholics; intravenous (IV) drug users; the elderly; and immunocompromised individuals such as those with HIV infection. The risk of progression to active disease is markedly increased and infection outside the lungs is more common for persons with HIV infection,[2,3,4]

Tuberculosis transmission is recognized as an occupational health risk for health-care workers. The magnitude of the risk varies by type of health-care setting, patient population served, job category, and the area of the facility in which a person works. The risk may be higher for personnel routinely in close contact with infectious patients, in areas where patients with tuberculosis are provided care before diagnosis, such as clinic waiting areas and emergency rooms, or during diagnostic or treatment procedures that cause the aerosolization of *M tuberculosis*. These procedures include bronchoscopy, endotracheal intubation and suctioning with mechanical ventilation, open abscess irrigation, and autopsy. Sputum induction and aerosol treatments that induce cough may also increase the potential for tuberculosis transmission.[1]

Because infection requires the inhalation of aerosolized *M. tuberculosis*, the probability that a person will become infected depends upon the concentration of

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* "Aerosolized" refers to the dispersion of aerosols. The aerosols of interest in this report are droplet nuclei that may contain *M. tuberculosis.*

infectious droplet nuclei in the air. Environmental factors that enhance transmission include: the sharing of a relatively small, enclosed space by uninfected persons and an infectious person; inadequate ventilation that results in insufficient dilution or removal of infectious droplet nuclei; and recirculation of air containing infectious droplet nuclei.[1]

EVALUATION CRITERIA

The risk of transmission of tuberculosis disease can be reduced by preventing the aerosolization of *M. tuberculosis* through early identification and treatment of infected patients and reducing exposures to infectious droplet nuclei once they have been aerosolized.

Preventing the Aerosolization of *M. tuberculosis*

To prevent the aerosolization of *M. tuberculosis*, early identification and treatment of infected persons, both with and without active disease, is necessary. The identification of infected individuals without active disease is commonly accomplished using the tuberculin skin test. For the tuberculin skin test, a small amount of purified protein from *M. tuberculosis* is injected into the upper layers of the skin. If the tested person has previously been infected with *M. tuberculosis*, his or her immune system reacts against this protein; the reaction causes a reddish swelling at the site of the injection (a positive result). If the person has not been infected previously, there will be little or no reaction (a negative result). There are standardized guidelines for interpreting the test.[5] The injection does not contain live *M. tuberculosis* bacteria and cannot cause infection; furthermore, repeated skin testing will not cause a positive test in a person who has not been infected with *M. tuberculosis*.

Skin testing for tuberculosis can be complicated by the fact that, over a period of years, some infected people test negative because they have lost their sensitivity to the test. The test however, "reminds" the person's immune system to react, which will cause a positive result at the time of the next test. It might then be incorrectly concluded that the person had been infected in the time between the two tests. To avoid this problem, a "two-step" test procedure is recommended by the Centers for Disease Control and Prevention (CDC) for the first skin test administered to a person being enrolled in a tuberculosis surveillance system. If the first test is negative, a second skin test is given a week later. If the second test is also negative, the person is considered to be free of tuberculosis infection. The person can then be enrolled in the periodic screening program, and need only receive a single skin test at each subsequent screening.[2]

Routine screening of health care workers at least annually is recommended by CDC; workers who routinely perform procedures with a high risk of exposure to *M. tuberculosis* (e.g., bronchoscopy, sputum induction, or aerosol treatments given to patients who may have tuberculosis) should be retested at least every six months.[1] If a person with previously negative skin tests converts to positive, the test should be followed by a chest x-ray to determine whether active tuberculosis disease has developed. The chest x-ray of an infected person without active disease may show no abnormalities, or show little more than a small spot on the

lung where the infection has occurred, possibly with deposits in a nearby lymph node.[6] A series of prophylactic (preventive) drug therapies are generally prescribed upon diagnosis to prevent the infection from advancing to tuberculosis disease. The two drugs most commonly used for this purpose are isoniazid (INH) and rifampin.

In addition to identifying individuals for whom prophylactic treatment is appropriate, routine screening can also serve as a surveillance tool to identify areas or occupations for which there may be an increased risk of tuberculosis transmission. It should be noted that even if the drug treatment successfully kills the tuberculosis bacteria and prevents the development of active disease, the patient will continue to test positive on later tuberculosis skin testing because his or her immune system will "remember" the TB protein and react to the skin test.

When a patient develops active pulmonary tuberculosis, the infection in the lung destroys lung tissue as it grows, thus forming a cavity. When the cavity erodes into an airway, infectious material (which includes live *M. tuberculosis*) in the airway causes the patient to cough, which can aerosolize *M. tuberculosis*. A diagnosis of tuberculosis should be considered for any patient with persistent cough or other symptoms compatible with tuberculosis, such as weight loss, anorexia, or fever. Because diagnosis of tuberculosis disease is generally based on recognizing symptoms, there is a time period before diagnosis during which the patient is infectious. For this reason, early diagnosis of tuberculosis is critical for minimizing transmission. Upon diagnosis, drug therapy should be promptly initiated and the patient isolated until the drug therapy has killed enough bacteria to leave the patient non-infectious.[1]

The selection of drugs for treating a patient (either to prevent the development of active tuberculosis after identification of infection, or to treat active tuberculosis disease) depends on a number of factors, including the health status of the patient and the strain of *M. tuberculosis* causing the infection. Some strains of *M. tuberculosis* are resistant to the most commonly used drugs and require the use of other pharmaceuticals; drug therapy should be selected appropriately.[7] A patient is generally considered non-infectious after receiving drug therapy for two to three weeks, symptoms are noticeably reduced, and progressively decreasing numbers of *M. tuberculosis* appear in the sputum. (Non-infectious status is confirmed by finding sputum collected on three consecutive days to be free of *M. tuberculosis*.)[1]

<u>Reducing Personal Exposures to *M. tuberculosis*</u>

For many chemical and physical agents, there exist recommended workplace exposure limits based on epidemiologic research or toxicologic data from animal and human studies, which are designed to help provide a safe working environment. For droplet nuclei containing *M. tuberculosis*, however, there does not appear to be a safe exposure level. That is, any airborne concentration of droplet nuclei is assumed to present some risk of infection.[8,9]

Techniques historically used to reduce personal exposures to aerosolized *M. tuberculosis* have included patient isolation, ventilation, high efficiency

particulate air (HEPA) filtration, ultraviolet radiation, and respiratory protection. These control methods should reduce exposures to *M. tuberculosis*; however, currently there are no available environmental methods to quantify the level of reduction provided.

There are two general categories of ventilation which may be of use for reducing *M. tuberculosis* exposures: local exhaust ventilation (LEV) and general ventilation. LEV is used to capture emissions at the source of generation before they contaminate the room air. The use of scavenging booths for sputum induction is an example of LEV which can be used to control *M. tuberculosis* exposures.[1] General guidelines for LEV are provided in: "Industrial Ventilation, a Manual of Recommended Practice."[10]

In contrast to LEV, general ventilation attempts to lower the concentration of contaminants by exchanging contaminated air with "clean air." There are two basic designs for dilution systems. The first, a "single pass" system exhausts all room air to the outside. The second design recirculates most of the air, with a small portion being exhausted and replaced with outside air. The primary advantage of the single-pass design is that contaminated air is exhausted directly to the outside and not recirculated within the building, the principle disadvantage is the greater cost of heating or cooling the necessary additional outside air. Both the American Society of Heating, Refrigerating and Air-conditioning Engineers (ASHRAE) and the American Institute of Architects (AIA) have published guidelines for general ventilation in health care facilities.[11,12] These guidelines are discussed below under Guidelines for General Ventilation.

The use of HEPA filtration and ultraviolet (UV) radiation have been proposed as measures to control *M. tuberculosis* transmission. NIOSH does not currently recommend the use of UV radiation in occupied areas for this purpose because of, 1) the potential health hazards from overexposure to UV radiation itself, which include keratoconjunctivitis (inflammation of the cornea and conjunctiva) and erythema (reddening) of the skin, and 2) the lack of scientific data which demonstrate that current methods of UV irradiation in occupied areas are effective at controlling the transmission of *M. tuberculosis*. In theory, HEPA filtration should be effective at reducing air concentrations of *M. tuberculosis*. Research has shown it to be effective at reducing air concentrations of *Aspergillus* spores, which are of a similar size range to aerosolized *M. tuberculosis* particles.[13,14,15] However, HEPA filtration systems require proper installation, periodic leak testing and meticulous maintenance. They are susceptible to failure, the outcome of which is the potential transmission of large numbers of *M. tuberculosis*. HEPA filtration, therefore, should not be relied upon as the only means of purifying air which is known to contain *M. tuberculosis*.

In addition to engineering controls, NIOSH recommends that personal respiratory protection be used to reduce the risk of infection for health care workers. NIOSH considers this to be necessary because of the lack of available data to fully assess the efficacy and reliability of the engineering controls discussed above. Recommendations for respiratory protection for workers exposed to *M. tuberculosis* are provided in the NIOSH document: Recommended Guidelines for Respiratory Use for Prevention of Tuberculosis Among Health Care Workers.[16] In this

document, NIOSH specifies the type of respirator that should be used for various locations and procedures. For areas or procedures which NIOSH considers to have a medium potential for exposure to aerosolized *M. tuberculosis*, such as isolation rooms, NIOSH recommends a half-face powered air-purifying respirator with a HEPA filter as a minimum level of respiratory protection. For areas or procedures which NIOSH considers to have a high potential for exposure, such as sputum induction, NIOSH recommends that half-face positive-pressure air-line respirators be used as a minimum level of respiratory protection. If respirators are used, a complete respirator program should be implemented that meets the requirements of the Occupational Safety and Health Administration (OSHA) respiratory protection standard (29 CFR 1910.134).[17] Guidelines for implementing a personal respiratory protection program are included in the NIOSH document referenced above.[16] In addition to the use of respirators by health care professionals, use by infectious patients may also reduce *M. tuberculosis* exposures; it is important that respirators used for this purpose not have an exhalation valve.

Guidelines for General Ventilation

Recommendations for general ventilation in health care facilities have been published by ASHRAE in: Health Facilities chapter (7) of the 1991 Heating, Ventilating and Air-Conditioning (HVAC) Applications,[11] and by AIA in: Guidelines for Construction and Equipment of Hospital and Medical Facilities.[12] These guidelines are designed to provide for the sufficient exchange of potentially contaminated air with clean air to reduce the risk of exposure to odors, airborne microorganisms, and hazardous chemical and radioactive substances.

The recommended ventilation rates are expressed in terms of air changes per hour (ACPH). An ACPH is defined by the theoretical number of times that the air volume of a given space will be replaced in a one-hour period by air supplied to the space or transferred to the space from adjacent areas. The units of ACPH are used to provide a convenient way of relating the volume flow rate of air to the size of the room. This terminology, however, can be misleading because the total volume of room air may not actually be "changed" the theoretical number of times per hour.

Recommendations for general ventilation usually include minimum values of ACPH for both outside and recirculated air. For example, ASHRAE recommends that isolation and examination rooms be ventilated with enough outside air to provide a minimum of two outside air changes per hour (OACPH), with enough total air supply (outside air and recirculated air) to provide a minimum of six total air changes per hour (TACPH).

Although reduced exposures to airborne microorganisms is a goal of the ASHRAE guidelines discussed above, it should be understood that scientific evidence which supports the adequacy of these guidelines in protecting workers from *M. tuberculosis* does not currently exist. General ventilation, along with the use of appropriate administrative controls, use of local exhaust ventilation, and appropriate work practices will help reduce the probability of tuberculosis transmission in health-care settings. However, data do not exist (to our knowledge) that enable the confident definition of criteria for general ventilation which would assure a wholly

safe environment. Similarly, there are no laboratory or clinical data that can validate any significant control of worker exposure to droplet nuclei containing *M. tuberculosis* bacteria at the recommended air flow rates published by ASHRAE and AIA (six TACPH for isolation and treatment rooms). In fact, two hospital-ventilation studies published in the 1960's provide evidence to indicate that six TACPH in hospital rooms do not effectively control airborne bacteria. [18,19] Additionally, published studies and recommendations indicate that general ventilation rates substantially higher than six TACPH do improve dilution and removal of airborne bacteria, thus further reducing the probability of exposure to airborne bacteria.[18,19,20] The available studies do not permit quantitative estimation of decreases in risk that would result from specific increases in general ventilation levels from six TACPH to substantially higher values. However, the data do indicate the need to have general ventilation rates at the highest practical levels to reduce exposure to droplet nuclei. Therefore, health-care facilities should be designed to achieve the best general ventilation air flows (striving for substantially greater than six TACPH) in those areas where confirmed or potential tuberculosis transmitters are present (for example, isolation and treatment rooms).

In establishing air flow levels, the health-care facility must make risk management decisions with regard to the level of required control and the feasibility of achieving and maintaining the air flow. Achievement of specific air flows will involve decisions both in ventilation system construction and operation (such as energy requirements to move and to heat or cool the air). Feasibility also will vary with respect to new construction or retrofit of existing facilities. The requirements to achieve specific higher air flow rates for new construction may not be significant. However, retrofit of an existing facility to achieve similar air flow rates may be more difficult. Direct discharge of exhaust air versus recirculation and use of heat recovery techniques also must be considered.

In addition to supplying the specified airflow, ventilation systems should also provide satisfactory directional airflow patterns both from area to area and within each room. Airflow should be from "clean" to "less clean" areas, such as from hallways to treatment rooms. This can be accomplished by creating negative pressure in the area into which flow is desired relative to adjacent areas by exhausting more air from the area than is being supplied. Rooms where *M. tuberculosis* is likely to be present, such as isolation and examination rooms, should be under negative pressure with respect to adjacent corridors. According to ASHRAE, pressure differentials can only be maintained in entirely closed rooms;[11] therefore it is important that doors be kept closed as much as possible.

METHODS

Medical Assessment

During a meeting with the requester and the nurse manager of the Medical Department, NIOSH medical investigators collected information regarding the history of the patient's tuberculosis illness, isolation procedures used, the inmate screening program WCI subsequently conducted, and WCI's plans for employee screening.

Ventilation Survey

A ventilation survey was conducted in selected areas of the Medical Department including the holding cells, the examination and treatment rooms, the dental area, and the waiting area (see Figure 1). For each of these areas, the supply, return, and exhaust air flows were measured, and the effective pressure relationships (negative, positive, or neutral) between the rooms and adjacent corridors were qualitatively determined. The survey was limited to evaluation of the general ventilation in the Medical Department; no use of local exhaust ventilation was identified.

The majority of air flow measurements were made using a flow hood. For measurements that could not be made with a flow hood because of space restrictions, the average face velocity was determined using a hot-wire anemometer, and the flow rate was calculated by multiplying the average velocity by the area of the vent. The number of TACPH and minimum OACPH were calculated based on the measured air flow values. The minimum OACPH values were calculated based on an outside air supply of 19% of the total supply air (this was calculated by dividing the minimum outside air flow by the maximum total supply air flow, using the values reported in the engineering drawings [3,020 cfm / 15,940 cfm = 19%]). TACPH and OACPH values were then calculated for each room by dividing the respective air flow rate by the room volume measured in units of cubic feet. (An example calculation of TACPH and OACPH is provided in Appendix 1.) Calculations of minimum TACPH and OACPH based on design air flows were also made for each room. For TACPH, the minimum supply rate for each room was calculated by dividing the minimum total supply rate (6380 cfm) by the maximum total supply rate (15,940 cfm), then multiplying this value by the reported flow rates for each room. The minimum outside air flow for each room was calculated by multiplying the minimum total supply rates for each room by 47%. The value of 47% was calculated by dividing the minimum outside air supply, which reportedly does not change when total supply rates change, by the minimum total supply (i.e., 3020 cfm / 6380 cfm = 0.47).

The effective pressure relationships between the rooms and adjacent corridors were determined by releasing small streams of smoke and observing whether the smoke moved into or out of the rooms. For rooms where the door was reported to usually be closed, the smoke was released along the crack between the floor and the bottom of the door; for rooms where there was no door, or the door was reported to be usually open, the smoke was released at three different height locations along

the vertical center of the doorway: near floor level, at chest height, and near the top of the door casing.

RESULTS and DISCUSSION

Medical

Diagnosis, isolation, and treatment of the presenting case

In May 1992, the inmate presented to the medical clinic with cough and symptoms which were initially diagnosed as an upper respiratory infection. When the inmate failed to respond to two outpatient courses of antibiotic treatment, tuberculosis was suspected and the inmate was transported to the Frazier Medical Center (located at the reception center in Orient, Ohio), where he was examined by a pulmonologist. Initially, his sputum smears were negative for acid fast bacteria (AFB). Smears from bronchial washings were also negative for AFB. Despite these results, the patient was started empirically on anti-tuberculous therapy and housed in an isolation cell in the infirmary upon his return to WCI. Sputum cultures subsequently grew *M. tuberculosis* and subsequent sputum smears were positive for AFB.

WCI does not have a written respirator program that addresses exposures to *M. tuberculosis*. However, in an attempt to provide some level of protection to workers, respirators were reportedly worn by both staff and patient whenever there was personal contact. If the exposure was of short duration, surgical masks were used. For exposures of longer duration, such as the trip to Frazier Medical Center, disposable particulate respirators (3M 8710) were used. (The 8710 does not have an exhalation valve).

Medical Screening

At the reception center, each inmate receives a medical evaluation which includes a physical examination, skin test for tuberculosis, and chest x-ray. The reception centers perform approximately 18,000 medical examinations each year. One reason for this large number of examinations is the high turnover of inmates within the Ohio Bureau of Prisons System (approximately 30% of the inmate population are incarcerated for six months or less, and 41% are discharged within 12 months). The skin test is interpreted as positive for *M. tuberculosis* infection with 5 mm of induration (swelling) for close contacts of tuberculosis cases and for immunocompromised individuals, and with 10 mm of induration for all others (these criteria are consistent with current CDC guidelines).[1] Inmates who enter the reception center at the same time are housed together; an inmate is isolated only if the skin test or chest x-ray is positive for *M. tuberculosis*.

At present, WCI, like the rest of the Ohio Bureau of Prisons system, does not provide periodic tuberculosis screening of either employees or inmates (the Ohio Bureau of Prisons is currently writing such a policy, which will address both inmates and employees). However, following the diagnosis of an infectious inmate, WCI elected to test all inmates in a voluntary screening program. The

testing was conducted during the month of July 1992, during which time the inmate census varied little (the census on July 1 was 1432 inmates, while on July 31 it was 1434 inmates). Of the total inmate population, 361 were excluded from testing either because: 1) they had arrived at WCI from a reception center (where they had recently received a skin test) after the patient had been relocated to the isolation cell, and therefore would not have been in contact with him; or 2) they were known to be positive from previous skin tests (most of the 361 were reportedly in the latter group). The remaining 1073 inmates received a single skin test; two-step testing was not employed. Of those 1073, 66 tested positive. Of the 66, 58 received chest x-ray examination and were negative on that test; the remaining eight either had a recent chest x-ray examination or were later found by records to have previously reacted positively to a tuberculosis skin test. None had signs or symptoms of tuberculosis disease. Forty of the new reactors were started on prophylactic isoniazid therapy. Prophylactic therapy was judged to be contraindicated for the remaining new reactors because of their age or medical conditions; these conditions could include existing liver disease or certain other medical conditions, or the use of other medications which could react adversely with anti-tuberculosis medications.[6]

During the time that inmates were being tested, employees were advised to obtain skin tests if they were concerned about their infection status. Employees were informed that the test was available at the WCI Medical Department, and that those who did not wish to be tested at WCI could be tested by their own doctors or at their local health department. (Employees were not reimbursed for skin tests conducted outside of WCI, however, the tests at local health departments are generally available at nominal cost.) In August, WCI began a series of week-long employee in-service training classes, in which employees were offered voluntary skin testing. All employees were scheduled to participate in a class by January 1993.

Ventilation

The results of the airflow measurements are listed in Table 1. The number of TACPH and OACPH calculated from the measurement data, and the apparent pressure relationships between rooms and surrounding areas, are presented in Table 2. The number of TACPH and OACPH calculated from minimum design supply rates, are tabulated in Table 3.

The results should be interpreted with caution. Although the ACPH results listed in Table 2 are based on actual airflow rates, these results do not consider imperfect mixing of air within the room, which is affected by supply and exhaust location, diffuser design, objects in the room, etc.

Ventilation rates measured in the inmate holding cells ranged from 1.8 to 17 TACPH and from 0.04 to 3.5 OACPH (assuming 19% outside air). The "isolation" cell (21052), where the inmate with tuberculosis was housed, had the lowest ventilation rates of any of the cells. Ventilation rates measured in the examination rooms ranged from 4.3 to 7.3 TACPH, and from 0.91 to 1.5 OACPH.

All but two of the holding cells (21045 and 21048) were under negative pressure relative to the adjacent corridor. Cells 21045 and 21048 were both under positive pressure relative to the corridor. The door for cell 21048 consisted of metal bars; therefore, it is unlikely that a negative pressure differential could be maintained for this cell. Two of the examination rooms (21081 and 21082) were at positive pressure with respect to the corridor, and the remaining two (21080 and 21088) were at neutral pressure. (The smoke tube measurements for the examination rooms were made with the doors closed.)

Calculations based on minimum design air supply rates indicate that the ventilation system was designed to provide a minimum of 2.4 to 4.4 TACPH and 1.1 to 2.0 OACPH in the holding cells. Corresponding design values for the examination rooms were 2.9 to 3.7 TACPH and 1.4 to 1.7 OACPH.

Most of the air from all of the rooms (except for bathrooms) was recirculated in the building. The average percentage of air recirculated, based on measurement data, was approximately 80% from the holding cells, and 100% from the examination rooms.

CONCLUSIONS

Medical

Given the amount of person-to-person interaction reported to take place at the facility, there is potential for tuberculosis transmission from a non-isolated inmate or employee with infectious tuberculosis to other inmates and staff. Although most inmates receive PPD screening at the reception center before being transferred to WCI, several opportunities exist for the introduction of tuberculosis infection into the WCI population. An inmate may be infected with *M. tuberculosis* any time he is moved to a facility where he may be exposed to someone with infectious tuberculosis, or housed in a facility where the ventilation system is inadequate to prevent airborne transmission of tuberculosis. Inmates awaiting hearings in a county or municipal court are transferred to the local jail until the hearing is concluded. Inmates may also receive emergency medical care at area medical facilities. Depending on the policies and structural features of a particular facility, the inmate could be exposed to conditions where the transmission of *M. tuberculosis* occurs, become infected, and bring the infection back to WCI upon his return. Transmission within WCI could occur if that inmate later develops infectious tuberculosis disease. This scenario has occurred in a state correctional facility in New York, where an outbreak of tuberculosis resistant to several drugs was associated with presence of infected inmates who had been transferred from facilities where other inmates were infectious.[21] Given the potential for transmission of tuberculosis at WCI, the infirmary staff and physician acted appropriately to refer the patient for evaluation of possible tuberculosis disease as soon as it was suspected.

Ventilation

Although the tuberculosis patient at WCI was physically isolated from other inmates and medical staff, the room used for this purpose was inadequate because air exhausted from this room was recirculated into the building instead of being directly exhausted to the outside. Most of the air exhausted from all rooms in the Medical Department (except bathrooms) was returned to the air handler (ACU-2-1). This air was then mixed with return air from the administrative wing and outside, and then distributed throughout the medical department and administrative wing. Thus, there is a potential for aerosolized *M. tuberculosis* particles from the Medical Department to spread throughout that department and the administrative offices.

In addition, exposures of medical department personnel to *M. tuberculosis*, and subsequently, their risk of infection, are likely to be reduced by increasing ventilation rates in areas where *M. tuberculosis* is likely to become aerosolized, such as an isolation cell or examination rooms. As discussed in the Evaluation Criteria Section of this report, available scientific data does not allow for an estimation of infection risk at any given level of general ventilation. However, the data indicate the need to have general ventilation rates at the highest practical levels to reduce exposure to droplet nuclei.

RECOMMENDATIONS

The following recommendations should be implemented at WCI to reduce the risk of *M. tuberculosis* transmission in the future. Recommendations 1-6 are based on the 1989 CDC publication "Prevention and Control of Tuberculosis in Correctional Institutions: Recommendations of the Advisory Committee."[22]

1. Skin testing of inmates and staff should be carried out at entry or upon employment, respectively. To reduce the potential for misinterpreting the results, a two-step process is recommended (see the Evaluation Criteria Section of this report). Each skin test should be administered and read by appropriately trained personnel and recorded in millimeters induration in the personal medical record. All inmates and staff should participate, except those providing documentation of a previous positive reaction to the tuberculin test.

2. In addition to screening upon entry, a periodic skin testing program should be established for skin-test-negative inmates and employees who have contact with inmates. These inmates and employees should have repeat skin tests at least annually. Once periodic screening programs are in place and sufficient data have been collected, results can be reviewed to determine if a change in testing frequency or other factors are necessary. An increase in AIDS cases or tuberculosis cases should be viewed as indicating a need for more frequent skin testing and intensified tuberculosis casefinding activities.

3. As the immune system of patients infected with HIV progressively weakens, they lose the ability to react to the tuberculin skin test even if they have a tuberculosis infection. Although this may be a relatively late development in the progression from HIV infection to AIDS, the time is not definite. Consequently, inmates with known or suspected HIV infection (including those with nonreactive tuberculin tests) should receive a chest radiograph as part of initial screening, regardless of tuberculin skin test status.

4. Health-care workers should be particularly alert to the need for preventing tuberculosis transmission in health-care settings in which persons with HIV infection receive care. Rooms housing persons who are HIV positive should be under positive pressure with respect to adjacent corridors, unless the patient also has tuberculosis or other infectious disease which can be transmitted by aerosolized particles.

5. Persons with suspected or confirmed pulmonary or laryngeal tuberculosis should be immediately placed in respiratory isolation. If an inmate is diagnosed with infectious tuberculosis in the future, it may be necessary to move him to another facility or hospital with a respiratory isolation facility until an adequately ventilated isolation room is provided at WCI.

6. Because tuberculosis is transmitted by the airborne route, persons at highest risk for acquiring infection are "close contacts" (for example, persons who sleep, live, work, or otherwise share air in close proximity with an infectious person). Additionally, persons in areas which are

supplied air that is recirculated from areas occupied or visited by an infectious patient are likely to have an elevated risk of infection. When a person with suspected or confirmed tuberculosis appears to be infectious (for example, has pulmonary involvement on chest radiograph and cough, and/or positive sputum smear), close contacts should be skin tested unless they have a documented history of a positive tuberculin test. Close contacts with a positive tuberculin reaction or a history of a previous positive test, and symptomatic persons regardless of skin-test results, should receive an immediate chest radiograph to detect evidence of pulmonary tuberculosis.

When tuberculin converters are found among the close contacts, other persons with less contact may need to be examined. During these examinations, every effort should be made by medical and nonmedical staff to protect the confidentiality of the persons being tested.

7. If there is a potential for patients with active tuberculosis to be housed in any of the cells, or to receive treatment or testing in the examination rooms, 100% of the air from these rooms should be exhausted directly to the outside. The return air vents in these rooms should be sealed off to prevent air from returning to the main air handler (ACU-2-1). Air from these rooms should be exhausted directly outside the building at flow rates that will maintain negative pressure in the room with relation to adjacent corridors.

8. Ventilation rates should be increased (striving for substantially greater than six air changes per hour) in those areas where confirmed or potential tuberculosis transmitters are present, such as isolation and treatment rooms. Because the ventilation needs of the administrative wing and medical department are different, it may be more energy efficient to provide separate air handling units for these areas. This should also reduce the risk of spreading contaminants between the two areas.

9. A respirator program that meets the requirements of the OSHA Respiratory Protection Standard (29 CFR 1910.134)[17] should be implemented in the Medical Department at WCI to improve the efficacy of respirator use at the facility. The NIOSH document: Recommended Guidelines for Respiratory Use for Prevention of Tuberculosis Among Health Care Workers[16] provides guidelines for implementing such a program and recommendations for choosing the type of respirator that is appropriate for a given area or procedure.

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3) Director, WCI Medical Health Services
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5) OSHA Region Five

For the purpose of informing affected employees, copies of this report shall be posted by the employer in a prominent place accessible to the employees for a period of 30 calendar days.

Table 1. Results of the Ventilation Measurements

Warren Correctional Institution
Lebanon, Ohio
HETA 92-282
August 21, 1992

ROOM #	ROOM TYPE	SUPPLY CFM**	RETURN CFM	EXHAUST* CFM
21045	HOLDING CELL	288	136	11
21046	HOLDING CELL	155	147	14
21047	HOLDING CELL	204	82	14
21048	HOLDING CELL	52	6	9
21049	HOLDING CELL	290	196	11
21050	HOLDING CELL	6	21	19
21051	HOLDING CELL	7	38	8
21052	ISOLATION CELL	3	27	6
21053	HOLDING CELL	6	57	23
21054	CORRIDOR	290	125	--
21055	DENTIST	139	171	--
21056	DENTIST'S OFFICE	71	39	--
21057	DENTIST'S LAB	126	73	--
21059	JANITOR'S CLOSET	--	--	30
21060	BATHROOM	--	--	23
21061	VESTIBULE	--	--	--
21062	STORAGE	--	29	--
21063	VESTIBULE	--	--	--
21064	WAITING AREA	651	294	--
21065	VESTIBULE	--	--	--
21067	RECEPTION AREA	118	--	--
21070	TUB ROOM	96	--	201
21073	CORRIDOR	39	--	--
21074	SOILED UTILITY	27	--	266
21075	CLEAN UTILITY	24	--	--
21076	RECORDS OFFICE	367	--	184
21077	X-RAY	82	84	--
21080	EXAMINATION ROOM	64	33	--
21081	EXAMINATION ROOM	78	20	--
21082	EXAMINATION ROOM	72	21	--
21083	STAFF AREA	0	14	--
21084	CORRIDOR	82	61	--
21085	CORRIDOR	68	--	--

21088	EXAMINATION ROOM	93	87	--
21093	EQUIPMENT ROOM	36	11	

* Exhausted directly to the outside
** Cubic feet per minute (CFM)

Table 2. Results of Ventilation Survey

Warren Correctional Institution
Lebanon, Ohio
HETA 92-282
August 21, 1992

ROOM #	ROOM TYPE	TACPH[1]	OACPH[2]	EFFECTIVE PRESSURE[3]
21045	HOLDING CELL	17	3.5	+
21046	HOLDING CELL	9.3	1.9	-
21047	HOLDING CELL	12	2.5	-
21048	HOLDING CELL	3.0	0.63	+
21049	HOLDING CELL	9.4	2.0	-
21050	HOLDING CELL	2.8	0.09	-
21051	HOLDING CELL	2.5	0.08	-
21052	ISOLATION CELL	1.7	0.03	-
21053	HOLDING CELL	3.3	0.05	-
21054	CORRIDOR	3.1	0.66	4
21055	DENTIST	4.6	0.70	-
21056	DENTIST'S OFFICE	4.0	1.0	-
21057	DENTIST'S LAB	5.8	1.2	-
21059	JANITOR'S CLOSET	7.1	*	-
21060	BATHROOM	4.3	*	-
21062	STORAGE	5.0	*	-
21064	WAITING AREA	8.9	1.9	-
21067	RECEPTION AREA	4.8	1.0	4
21070	TUB ROOM	13	1.3	-
21073	CORRIDOR	1.8	0.37	4
21074	SOILED UTILITY	23	0.49	-
21075	CLEAN UTILITY	2.1	0.44	+
21076	RECORDS OFFICE	12	2.5	+
21077	X-RAY	5.2	1.1	-
21080	EXAMINATION ROOM	5.9	1.2	E
21081	EXAMINATION ROOM	7.3	1.5	+
21082	EXAMINATION ROOM	6.7	1.4	+
21083	STAFF AREA	0.37	0.0	E
21084	CORRIDOR	2.3	0.49	4
21085	CORRIDOR	2.3	0.40	4
21088	EXAMINATION ROOM	4.3	0.91	E
21093	EQUIPMENT ROOM	2.0	0.42	-

* Supply ventilation was not connected to this room.
1. Total air changes per hour measured.
2. Outside air changes per hour measured.

3. **Effective pressure of room relative to the adjacent corridor or adjacent room. (+ = positive pressure, - = negative pressure, E = equal pressure).**
4. **No test performed at this location.**

Table 3. Calculated Ventilation Rates Based on Design Specification at Minimum Total Air Flow (6,380 cfm).

Warren Correctional Institution
Lebanon, Ohio
HETA 92-282
August 21, 1992

ROOM #	ROOM TYPE	TACPH[1]	OACPH[2]
21045	HOLDING CELL	4.0	1.9
21046	HOLDING CELL	3.7	1.8
21047	HOLDING CELL	3.7	1.8
21048	HOLDING CELL	3.7	1.8
21049	HOLDING CELL	4.4	2.0
21050	HOLDING CELL	4.4	2.0
21051	HOLDING CELL	3.4	1.6
21052	ISOLATION CELL	3.1	1.4
21053	HOLDING CELL	2.4	1.1
21054	CORRIDOR	1.8	0.9
21055	DENTIST	3.1	1.5
21056	DENTIST'S OFFICE	2.8	1.3
21057	DENTIST'S LAB	3.7	1.7
21059	JANITOR'S CLOSET	*	*
21060	BATHROOM	*	*
21062	STORAGE	*	*
21064	WAITING AREA	4.6	2.1
21067	RECEPTION AREA	1.4	6.4
21070	TUB ROOM	1.9	0.9
21073	CORRIDOR	1.6	0.7
21074	SOILED UTILITY	1.4	0.7
21075	CLEAN UTILITY	1.4	0.7
21076	RECORDS OFFICE	6.7	3.2
21077	X-RAY	3.6	1.7
21080	EXAMINATION ROOM	3.7	1.7
21081	EXAMINATION ROOM	3.7	1.7
21082	EXAMINATION ROOM	3.7	1.7
21083	STAFF AREA	1.5	0.7
21084	CORRIDOR	1.3	0.6
21085	CORRIDOR	1.2	0.6
21088	EXAMINATION ROOM	2.9	1.4
21093	EQUIPMENT ROOM	1.3	0.6

1. **Total air changes per hour based on design specifications.**
2. **Outside air changes per hour based on design specifications.**

* **Supply ventilation not connected to this room.**

Appendix I
Example of Calculations for TACPH and OACPH

Warren Correctional Institution
Lebanon, Ohio
HETA 92-282
August 21, 1992

The values for total air changes per hour (TACPH) were calculated by first measuring the cubic feet per minute (cfm) of air supplied to and exhausted from each room by the heating, ventilating, and air conditioning system (HVAC). Total measured supply air was the cfm of air flow through the supply diffusers, and total measured exhaust air was the sum of the air recirculated from the room back to the air handling unit (measured at the return grill) and the cfm exhausted directly to the outside (measured at the "exhaust" grill). The larger value of either total measured supply or total measured exhaust was then divided by the room volume in cubic feet (ft^3), and multiplied by 60 minutes/hour to get units of "per hour." An example calculation for the isolation room is provided here:

Total measured supply was 3.4 cfm.

Total measured exhaust was 33 cfm (27 cfm recirculated through the return system and 6 cfm exhausted directly outside).

The calculated volume for this room was 1137 $ft.^3$

The larger value between the total measured supply and the total measured exhaust was 33 cfm.

(33 cfm / 1137 ft^3) * (60 minutes/hour) = 1.7 TACPH

Similarly, the number of minimum OACPH were calculated by dividing the minimum supply of outside air (OA) to each room by the room volume, then multiplying this value by 60 minutes/hour to get the answer in units of "per hour."

The minimum supply of OA supplied to each room was estimated by multiplying the total measured supply by 19%. The value of 19%, according to the ventilation drawings, is the percentage of total air supply that would be from the outside, when the total supply is at a maximum (15940 cfm) and the amount of outside air is at a minimum (3020 cfm). An example calculation of OACPH for the isolation room is provided here:

(3.4 cfm / 1137 ft^3) * 0.19 * (60 minutes/hour) = 0.034 OACPH