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I. SUMMARY

In June 1992, the National Institute for Occupational Safety and Health (NIOSH) received a request for technical assistance from the Puerto Rico Department of Health Secretary. The request was for NIOSH to evaluate the ventilation systems serving the acid-fast bacterium (AFB) isolation rooms for tuberculosis (TB) patients in the six regional hospitals for the Commonwealth of Puerto Rico.

On August 24-September 1, 1992, NIOSH investigators conducted environmental evaluations at the six regional hospitals and a private clinic. A visual inspection of the ventilation systems, as well as a review of the original specifications of the air-handling units, was completed for each facility. Where the ventilation systems were operating, airflow measurements from supply and exhaust diffusers were made. Smoke tube traces were used to determine room-to-corridor pressure relationships. General information was gathered on employee tuberculin skin testing programs.

The investigations found that the ventilation systems in all the hospitals evaluated were either not functioning or varied from the design airflow. At four of the six facilities, there was a general flow of air out of the designated isolation rooms into the main corridors of the hospital which is not recommended for the isolation of infectious patients. There was one hospital that met the definition for AFB isolation rooms. At several facilities, sputum induction was performed in the patient's room. It was observed on several occasions that isolation room windows and doors were left open. One of the facilities did not have any type of employee tuberculin screening program in place. The private clinic ventilation system was set up appropriately.

Some deficiencies were noted in the ventilation systems of these facilities which could potentially contribute to the transmission of tuberculosis from infectious patients to other patients, hospital staff, and visitors. Recommendations to modify the ventilation systems so that isolation evaluation criteria are met are offered in Section IX of this report along with recommendations to strengthen the facilities' infection control programs.

KEYWORDS: SIC 8062 (General Medical and Surgical Hospitals), tuberculosis, TB, ventilation, infection control.

II. INTRODUCTION

In June 1992, the National Institute for Occupational Safety and Health (NIOSH) received a request for technical assistance from the Puerto Rico (PR) Department of Health Secretary. Specifically, the Office of Acquired Immunodeficiency Syndrome (AIDS) and Transmissible Diseases, Division of Tuberculosis (TB) Control requested assistance in evaluating the ventilation systems for the TB isolation facilities at the six regional hospitals of the island. On August 24-September 1, 1992, NIOSH conducted environmental evaluations at the six regional hospitals and a private clinic. Preliminary findings were presented to the staff at each facility at the conclusion of the evaluation and to the PR Department of Health Secretary upon completion of all the surveys.

III. BACKGROUND

The following sections provide a brief description of each facility's characteristics such as the number of isolation rooms, TB infection control practices, and the ventilation systems which service these isolation rooms. All PR regional hospitals currently contract with Smith, Cline, and Beechman Laboratories, Inc. in Miami, Florida for TB culture analysis.

A. Arecibo Regional Hospital

The Arecibo Regional Hospital was built in 1976. The facility has 230 beds and services an area with a population of approximately 350,000. The hospital had undergone a managerial change from private to government approximately eight months before the NIOSH site visit. The 10 patient isolation rooms are located in a 5-floor tower section of the building, with 2 isolation rooms per floor. Each room incorporates an anteroom and has windows which can be opened. From discussions with the hospital engineer and the maintenance supervisor, it was determined that all rooms and areas of the tower, including the isolation rooms, utilize a one-pass ventilation system. Inlet air is drawn through a heat transfer wheel, and an air conditioning unit, then supplied directly to the isolation rooms by the general supply system. Air is exhausted from all rooms and discharged through the heat transfer wheel, which is used to transfer heat, in order to conserve energy. For each isolation room, air was supplied to the room and the anteroom from the same supply duct and exhausted through the bathroom. Additional supply air is provided by a separate constant volume system to fan coil units in patient rooms other than the isolation rooms. The emergency area has 1 "designated" isolation room with a separate bathroom down the hall. The emergency room (ER) area has its own constant volume recirculating ventilation system with a separate outside air supply from the rest of the hospital.

On the day of the site visit, there was one active TB patient in the hospital. Suspected cases of TB are automatically put in isolation rooms. According to hospital staff, the patients wear surgical masks when outside their room and hospital personnel wear surgical masks while in isolation rooms. There is no established tuberculin screening program for hospital employees.

B. *Bayamon Regional Hospital*

The Bayamon Regional Hospital had converted an existing wing to an infection control wing in July 1992. The wing is located on the first floor of the hospital and has 18 patient rooms. Sixteen of the rooms shared a bathroom with another room and two rooms had a private bathroom. There were 5 TB or suspected TB patients in this wing at the time of the site visit. All suspected TB cases admitted to the hospital are transferred immediately to the new wing. The ventilation system for the wing is directly exhausted to the outside at each end of the wing and supply air is provided from a central ventilation system that serves that area of the hospital. There were 2 additional isolation rooms on the third floor. One of these had a supplied air-conditioning unit and the other had an oscillating fan.

The hospital has an open area ER where patients wear surgical masks if TB is suspected. There are fan coil units in the ER designed to provide 100% recirculated air.

According to management and staff, the hospital has an annual tuberculin screening program for all hospital health care and support staff, which is done more frequently upon request. Of the 500 individuals which had been screened for TB by the time of the site visit, 8 (1.6%) had converted. If an employee converts their skin test, they undergo prophylaxis immediately. The hospital has no written protocol for infection control.

The hospital also runs an immunology clinic which services AIDS and AIDS/TB patients. The clinic has a covered courtyard waiting area with front access which is open to the outside. The AIDS/TB clinic also performs invasive procedures. Respiratory therapy is performed in a standard examining room with the windows open. The TB clinic sputum induction room was a redesigned bathroom. A single-pass ventilation system is used for the clinic. The clinic utilized an exposed UV bulb, as an engineering control, which is left on overnight when no one is in the room. The clinic staff reportedly had 2 skin test conversions in the past 2 years. The number of individuals tested was not available. The hospital also services a prison population.

C. *Caguas Regional Hospital*

The Caguas Regional Hospital had isolation rooms in two facilities. There were 7 confirmed or suspected TB patients in the facilities at the time of the site visit. The "Casa de Salud" or "House of Health," a separate one-story, 14-room building, housed the majority of the human immunodeficiency virus [HIV]/AIDS/TB patients. There are induction units in each room which are activated with treated 100% outside air supply from a central air handling unit in the basement. The units circulate air within each room and chilled water is used for cooling. Air was exhausted through the bathroom in all of the rooms.

Suspected and confirmed TB patients are also housed on the 5th and 6th floors of the main hospital. The designated isolation rooms were regular patient rooms with a separate bathroom exhaust system. If these designated isolation rooms were full, any room in the hospital could be used for isolation. The original design had shared bathrooms but the adjoining door had been blocked off. All bathrooms in the hospital were exhausted through a single fan on the roof. Sputum induction is performed in the patient's hospital room. Recirculating constant volume air handling units are used in the hallways of the hospital.

The Intensive Care Unit (ICU) had 2 isolation rooms on the central hospital supply system with separate exhaust to the outside. The ER had 2 isolation rooms on the recirculating supply system, that serviced the rest of the ER, and a regular bathroom exhaust. The pediatrics isolation room was also part of the recirculating system.

A clinic is reportedly available for all hospital employees to obtain a tuberculin test during their annual physicals but no formal tuberculin screening program had been established. No data was available on conversion rates. According to hospital staff, the patients wear surgical masks when outside their room and hospital personnel wear surgical masks while in isolation rooms. The hospital has a written infection control policy.

D. *Mayaguez Regional Hospital*

The Mayaguez Regional Hospital is approximately 20 years old and has 350 beds which service 16 municipalities with a population of approximately 600,000. There were 4 suspected TB patients in the hospital during the site visit. The facility has 27 designated isolation rooms on floors 3 to 6 and 2 areas in emergency (1 adult and 1 pediatric).

There were 4 isolation rooms at each end of floors 3 and 4 (16 rooms total). The center 2 rooms at each end have a separate air supply and an exhaust that goes directly outside. The outside 2 rooms are on the same central constant volume recirculating system as the patient rooms along both sides of the corridor. All 16 rooms have anterooms. On floors 5 and 6, there were 4 isolation rooms at one end of each floor (8 rooms), identical in configuration to those on floors 3 and 4 except that all 8 were on non-recirculating supply and exhaust systems. At the opposite end of the fifth floor, there is a large ICU area which contained 2 isolation rooms with supply and return connected to the central recirculating system. In addition, the fifth and sixth floors have regular patient rooms designated as isolation rooms. All of these rooms are on the recirculating system and use fan coils to supply air. Most of these rooms share a bathroom. Sputum induction is done in the patient's room.

According to hospital staff, the patients wear surgical masks when outside their room and hospital personnel wear surgical masks while in isolation rooms. The hospital has a written infection control policy which followed CDC guidelines and has an annual tuberculin screening program for all staff. Staff conversion rates were not available at the time of the site visit.

In the ER area, the pediatrics isolation room has a dedicated exhaust system. The room has a window that opens to outside, one in the bathroom which is also functional, and a sealed window that looks into the waiting area. The supply is part of recirculating system. The adult ER isolation room has the same design as the pediatric ER isolation room.

E. *Ponce Regional Hospital*

The Ponce Regional Hospital has a total of 427 beds between the new and old hospital buildings. The hospital services an area with a population of approximately 1/2 million. The facility had 19 designated isolation rooms in the new (main) building which were on constant volume, recirculating systems with individual heating, ventilation, and air-conditioning (HVAC) units for each floor. The old building housed 4 TB patients (3 confirmed; 1 rule-out) at the time of the site visit and had the capacity for 16 beds in the TB ward. Some HIV/AIDS patients were also housed in this building. The old building used natural cross-ventilation only - there was no mechanical system. Pigeons were observed roosting along the open windows.

Suspected TB patients are reportedly occasionally housed in the new building. Pediatrics (1st floor) had 6 HIV/AIDS beds which were used for isolation. The ER had 2 isolation areas (adult and pediatric) and ICU had three designated isolation rooms on the central recirculating ventilation system.

In the summer of 1992, the hospital set up a bi-annual tuberculin screening program for all staff. The staff and patients used surgical masks. Sputum induction was conducted in the patient's room.

According to the design plans of the hospital, the obstetrics/gynecology section of the hospital was set up as an isolation ward with anterooms, a separate ventilation system, and was separated from the rest of the hospital by swinging doors. The ventilation system for this part of the hospital takes air from hospital corridors; passes it through a heat wheel where fresh outside air is added; and then returns it as conditioned supply air. The exhaust is separate from the rest of the ventilation system and goes directly outside.

F. *University Regional Hospital*

The University Regional Hospital had isolation rooms in two separate facilities - the new building and the old building. Both buildings had 80% recirculating ventilation systems. The old building had HEPA filtered return air in conjunction with a heat wheel energy recovery system. All of the isolation rooms had anterooms.

The new building had separate exhausts in the 8 isolation rooms located on 4 floors and a separate supply and exhaust in the anterooms. Each floor had a separate HVAC unit.

There were 4 floors with 2 isolation rooms on each floor in the old building. Each anteroom had a separate supply and exhaust. The exhaust for the isolation rooms was in the bathroom. Three HVAC systems served all of the old building. The rooms had supply fan coil units. The ER had 2 isolation rooms on a recirculating ventilation system.

The hospital had an established infection control program in place and performed tuberculin skin tests on the staff annually. Patients and staff used surgical masks. At the time of the site visit, there was one resident patient with multi-drug resistant TB who had been at the facility for 8 years.

G. *Ashford Presbyterian HIV Clinic*

The outpatient clinic has 4 examination rooms and 1 office on a central system. Bronchoscopy is done at the clinic but respiratory therapy patients are referred to the hospital. The clinic staff had annual tuberculin skin tests and there were no known conversions in the last 2 years. Suspected TB patients are sent to the adjoining hospital for treatment. The hospital is in the process of creating a patient isolation area.

IV. 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)

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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.*

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 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]

V. EVALUATION CRITERIA

The transmission of tuberculosis disease is thought to be controlled 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.

A. *Preventing the Aerosolization of* M. tuberculosis

To minimize the transmission 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 test subject 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 subject 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 tuberculosis.

Interpreting skin tests 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 (if the person is in a periodic screening program), which will cause positive results from a subsequent test. It might then be incorrectly believed 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 and can then be enrolled in the periodic screening program. (They need only receive a single skin test at each subsequent periodic 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 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 that the patient is infectious but has not been isolated. 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 requiring 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, their symptoms are noticeably reduced, and progressively decreasing numbers of M. tuberculosis appear on sputum samples. (Non-infectious status is confirmed by finding sputum samples collected on three consecutive days to be free of M. tuberculosis.)[1]

B. *Reducing personal exposures to* M. tuberculosis

For many chemical and physical agents, there exist recommended workplace exposure levels based on epidemiology 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.[8,9,20]

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, there are no methods currently available to quantify the level of reduction provided.

1. Ventilation

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 principal disadvantage is the greater cost of heating or cooling the necessary additional outside air.

Ventilation rates are expressed in terms of ACH. An ACH 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 spaces. 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. The units of ACH are used to provide a convenient way of relating the volume flow rate of air to the size of the room.

General ventilation, along with the use of appropriate administrative controls, local exhaust ventilation, and appropriate work practices will help reduce the probability of tuberculosis transmission in health-care settings. However, published data do not exist 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 the American Society of Heating, Refrigerating and Air-Conditioning Engineers [ASHRAE] and the American Institute of Architects [AIA] (i.e., six ACH for isolation and treatment rooms).[11,12] In fact, two hospital-ventilation studies published in the 1960's provide evidence to indicate that 6 ACH in hospital rooms do not effectively control airborne bacteria.[13,14] Additionally, published studies and recommendations indicate that general ventilation rates substantially higher than 6 ACH do improve dilution and removal of airborne bacteria, thus further reducing the probability of exposure to airborne bacteria.[13,14,15]

It is important to recognize that the available studies do not permit quantitative estimation of the risk of infection at any given level of general ventilation. Similarly, the available studies do not permit quantitative estimation of decreases in risk that would result from specific increases in general ventilation levels from 6 ACH to substantially higher values. However, the data do indicate the need to have general ventilation rates at the highest possible levels to reduce exposure to droplet nuclei. Therefore it is recommended that health-care settings be designed to achieve the best general ventilation air flows (striving for substantially greater than 6 ACH) in those areas where confirmed or potential tuberculosis patients are present (e.g., 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 (e.g., 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 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. Pressure differentials can only be maintained in entirely closed rooms;[11] therefore it is important that doors are kept closed as much as possible, and that the door closes tightly.

Air-to-air rotary wheel heat exchangers are susceptible to 1% to 10% cross-leakage according to ASHRAE.[16] Cross-leakage, cross-contamination, or the mixing of air between the supply and exhaust airstreams can occur in all rotation energy exchangers through two mechanisms; carryover and leakage. Carryover occurs as air is entrained within the volume of the rotation medium and is carried into the other airstream. Leakage occurs because the differential static pressure across the two airstreams drives air from the higher to the lower static pressure region. It can be a significant problem when exhaust gases are toxic or infectious. Methods for the control of cross-leakage to a level below 0.1% are described in the ASHRAE handbook.

2. High Efficiency Particle Air (HEPA) Filtration and Ultraviolet (UV) Radiation

The use of high efficiency particulate air (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 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 demonstrates that current methods of UV irradiation 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.[17,18,19] 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.

3. Respiratory Protection

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.[20] 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).[21] Guidelines for implementing a personal respiratory protection program are included in the NIOSH document referenced above.[20] In addition to the use of respirators by health care professionals, the wearing of respirators by infectious patients may also reduce M. tuberculosis exposures; it is important that respirators used for this purpose not have an exhalation valve.

VI. METHODS

At each of the facilities, a walk-through tour was conducted to visually inspect the ventilation systems, including the mechanical units, outside air dampers, filters, and patient room systems. The mechanical diagrams of the ventilation systems for the hospitals were reviewed with each hospital's engineering staff. Smoke tubes were used to qualitatively determine the pressure relationship between the isolation rooms, anterooms (where present), and corridors.

Where the ventilation systems were operational, a detailed evaluation of the ventilation parameters in all hospital isolation rooms was completed. Airflow measurements were made using a Shortridge Instruments, Inc. Flowhood® Model CFM 88. Using this instrument, airflow through a supply diffuser or exhaust grille can be read directly in cfm. 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 measured airflows were compared to the design specifications on the mechanical plans. The number of ACH were calculated based on the measured air flow values. An example calculation of ACH is provided in Appendix I. Temperature and relative humidity (RH) measurements were made with a Vaisala HM34 Humidity and Temperature Meter. Where available, general information was collected at each facility pertaining to the employee tuberculosis surveillance program and infection control practices.

VII. RESULTS AND DISCUSSION

The following sections provide the results of the environmental evaluation at each facility and a discussion of the findings.

A. *Arecibo Regional Hospital*

The 10 patient isolation rooms at this facility utilize a one-pass ventilation system and have anterooms. At the time of the site visit, the exhaust portion of the ventilation system was inoperative, therefore, the rooms were not evaluated for air flow or negative pressure. Visual inspection of the HVAC system indicated that system maintenance was inadequate; the heat wheel was completely clogged with dirt preventing air passage. The hospital reportedly had a prior problem with re-entrainment of chimney smoke which was partially responsible for the clogging of the heat wheel. The chimney had been relocated prior to the site visit. The supply and exhaust system incorporated filter pads with a 50% efficiency at the heat wheel supply inlet.

Smoke tube measurements indicated that air flow was from the isolation rooms and anterooms into the hallways as expected since there was no functional exhaust. The ER isolation room was also under positive pressure with respect to the hallway. It was observed that the patient with active TB had her window open to provide better air circulation. There appeared to be no recirculation or mixing of supply and exhaust air other than might occur in the heat recovery wheel system. The rooms appeared to be appropriately designed for isolation if the ventilation system was operating to provide significantly more than 6 ACH and balanced to achieve negative pressure according to current isolation room guidelines.

B. *Bayamon Regional Hospital*

The Bayamon Regional Hospital had an infection control ward with 18 patient rooms. Sixteen of the rooms shared a bathroom with another room and two rooms had a private bathroom. The ventilation system for the wing is directly exhausted to the outside at each end of the wing and supply air is provided from a central ventilation system that serves that area of the hospital. There were 2 additional isolation rooms on the third floor. One of these had a supplied air-conditioning unit and the other had an oscillating fan. The results of the ventilation measurements are presented in Table 1. For each of the rooms, the supply and exhaust measurements for the unit conditioner, the bathroom, and the room, the pressure relationship of the room with the corridor (+/-), and the air changes per hour (ACH) are shown.

All patient rooms, except one, had negative pressure with respect to the corridor, as designed. In 14 of the 20 rooms, there was little or no ACH (0 to 0.6 ACH), the remaining rooms had 1.8 to 11 ACH. The supply and exhaust measurements did not agree with the design specifications in all rooms. Several of the patient rooms had shared bathrooms which could create the problem of potential cross-contamination with the attached room. This is not recommended for isolation rooms used for infection control. The exhaust system was off on the day of the investigation. This caused a back flow through the bathroom exhaust system into 4 of the shared bathrooms, affecting 8 of the patient rooms.

The exhaust grilles in the rooms were located next to open windows, which would preferably draw in air from outside instead of the room. It was noted that the exhaust locations at each end of the wing were within 20 feet of open windows. It was observed that the patients were using personal fans and opening windows and doors to improve air flow which is inappropriate for infection control rooms. Visual examination of the HVAC system servicing the isolation wing found mold on the fan coil. Some of the ceiling tiles also showed signs of mold. For immunologically compressed individuals, this provides a potential source of contamination that could result in increased risk of infection.

The emergency room area was on a recirculating system which is not suitable for areas where infectious patients are examined. The AIDS/TB clinic sputum induction room is under negative pressure to the rest of the clinic as long as the bathroom exhaust is working. Opening windows during respiratory therapy in the clinic is not a good practice since, depending upon wind direction, contaminated air could be blown back into the room and does not help exhaust contaminants.

C. *Caguas Regional Hospital*

The Caguas Regional Hospital had isolation rooms in two facilities. The "Casa de Salud," a separate one-story, 14-room building, housed the majority of the HIV/AIDS/TB patients. Induction units in each room provided treated outside air. All of the rooms were exhausted through the bathroom. Suspected and confirmed TB patients are also housed on the 5th and 6th floors of the main hospital. The designated isolation rooms were regular patient rooms on a recirculating supply system with a separate bathroom exhaust system.

On the day of the site visit, the bathroom exhaust system in the "Casa de Salud" was not working due to a inoperative motor. The isolation room doors were open to the hallways. Using smoke tubes to test air flow patterns, all rooms were positive to the hallway as was expected since only the supply air system was working. The HVAC system in the basement of the "Casa de Salud" was examined and appeared to be well-maintained. The filters (33% efficiency rating) fit well with little leakage. The outside air inlet was below street level adjacent to the sidewalk and contained a small amount of debris.

The HVAC unit on the 9th floor of the hospital, which serviced the central hallway, was examined, and appeared to be well-maintained. Fresh air was introduced into the system through a series of louvered panels. The filters (33% efficient) are reportedly checked daily and have a good fit. They are changed about every three months. The HVAC system had no signs of microbial contamination and was free of debris.

The regular patient rooms and the ICU isolation rooms in the hospital as designed are not appropriate to use for infectious patients, since they are on recirculating ventilation systems. Smoke tubes tests revealed on the day of the survey, that only two of the designated isolation rooms were under negative pressure (airflow into the room) [Table 2].

The 2 adult ER isolation rooms had exhaust ductwork that fed into the recirculating system that serviced the rest of the emergency room. This connection between the isolation rooms and the recirculating system could create the potential for the spread of tuberculosis bacilli. Emergency Room #11 was negative to the hallway. Emergency Room #12 was positive to the hallway and had a hole in the ductwork which should be repaired. The pediatrics isolation room was part of recirculating system and was under negative pressure to the hallway.

D. Mayaguez Regional Hospital

The Mayaguez Regional Hospital had 27 designated isolation rooms on floors 3 to 6 and 2 areas in emergency (1 adult and 1 pediatric). There were 4 isolation rooms at each end of floors 3 and 4 (16 rooms total). The center 2 rooms at each end have a separate air supply and an exhaust that went directly outside. The outside 2 rooms are on the central constant volume recirculating system. On floors 5 and 6, there were 8 isolation rooms (4 on each floor) on non-recirculating supply and exhaust systems.

On the day of the site visit, the recirculating system that serviced the patient rooms was operating but the separate system that supplied air to the fan coils units was not operating. The separate supply system for the isolation rooms was operational but the exhaust system was not. Spot smoke tube checks indicated strong positive pressures in all rooms except one which was positive when the connecting bathroom door was closed (Table 3). The doors and windows were open throughout the hospital. Of specific note was a 4th floor room with 2 suspected TB patients which had both the window and door open and was under strong positive pressure to the hall. From the way the building is designed, there is a potential for reentrainment of contaminants from one open window to another. The adult ER extraction system was not working. The designated ER isolation room was positive to hallway.

The outside (or corner rooms) on floors 5 and 6 are connected to the recirculating system which serviced the rest of the patient rooms. The center 2 end rooms on the fifth and sixth floors as well as the 4 rooms at each end of the third and fourth floors are properly configured to serve as isolation rooms. However, since the exhaust system was not working, they were also under positive pressure to the corridor. Some of the rooms designed for isolation were used for doctor offices and supplies. From observations and discussions with the engineering staff, it appears that with correction of the exhaust fan problems and proper balancing these rooms can achieve negative pressure and provide effective isolation.

E. *Ponce Regional Hospital*

The Ponce Regional Hospital had 19 designated isolation rooms in the new building which were on constant volume, recirculating systems with individual heating, ventilation, and air-conditioning units (HVACs) for each floor. The confirmed and suspected TB patients are housed in the old hospital building which uses natural cross-ventilation for air flow. Natural cross-ventilation uses open windows to bring in fresh air. There is the potential for infectious patients to come in contact with HIV/AIDS patients who are housed in an adjacent area of the old building. Pigeons were roosting under the windows which can be a potential source of microbial and fungal contamination. For immunologically compressed individuals, these conditions provide potential sources of contamination that could result in increased risk of infection.

The designated isolation rooms, the ICU isolation rooms, and the ER isolation rooms in the hospital are not appropriate to use for infectious patients as designed since they are on recirculating ventilation systems. These rooms were under positive pressure to the corridor. The bathroom exhaust was not working in the emergency room.

According to the design plans of the hospital, the obstetrics-gynecology section of the hospital was set up as an isolation ward with anterooms, a separate ventilation system, and was separated form the rest of the hospital by swinging doors. The results of the ventilation measurements for this area are listed in Table 4. For each of the rooms, the supply and exhaust measurements for the anteroom (if present), the bathroom, and the room, the pressure relationship of the room with the corridor (+/-), and the air changes per hour (ACH) are given. Three of the rooms met the design criteria for directional air flow from the hallway into the anteroom. However, on the day of the survey, the flow measurements did not agree with plan specifications. Air-changes per hour ranged from 2.8 to 15.3 in the rooms. The two rooms with the highest ACH rate were strongly positive in relation to the hallway (air was flowing from the rooms into the corridor). Due to its design, this area has the potential to become an isolation area with appropriate adjustments to the ventilation system.

The HVAC unit that services the designed isolation area was examined. Fresh air was introduced into the system through the heat wheel. The filters (40% efficient) are checked on a regular basis and have a good fit. The heat wheel appeared to be in good condition but needed to be cleaned. The HVAC system had no signs of microbial contamination and was free of debris.

F. *University Regional Hospital*

The University Regional Hospital had isolation rooms in two separate facilities - the new building and the old building. Both buildings had 80% recirculating ventilation systems. The old building had HEPA filtered return air in conjunction with a heat wheel energy recovery system. The results of the ventilation measurements for this hospital are presented in Table 5. For each of the designated isolation rooms, the supply and exhaust measurements for the anteroom, the bathroom, and the room, the pressure relationship of the room with the corridor (+/-), and the air changes per hour (ACH) are given.

In two of the isolation rooms (#326, #426) in the new building, the anteroom was positive to the hallway when the patient room door into the anteroom was open. One isolation room (#223) was positive to the anteroom, which in turn, was positive to the hallway. Two other rooms (#224 and #325) were positive to the anterooms and the anterooms were negative to the hallway. In the old building, the only exhaust for the isolation rooms was in the bathroom. All of the rooms were positive to the anteroom, which was negative to the hallway. Both the anteroom and patient room doors in Rm #210 (suspected TB patient) were open upon the arrival of NIOSH investigators. The patient room/anteroom was still negative to the corridor. The MDR TB patient was housed in a room (#G-9) in which the supply on the unit conditioner was completely taped off and the patient room was positive to the anteroom which could result in potential contamination of the anteroom. The ER had 2 isolation rooms which were positive to the main portion of the emergency room. The HVAC units that service the two buildings were examined and found to be well-maintained. The HVAC system had no signs of microbial contamination and was free of debris. Neither coarse or HEPA filters were well-seated in the filter housing. This provides a potential avenue for contamination to flow around the filters into the air supply system.

G. *Ashford Presbyterian HIV Clinic*

The outpatient clinic has 4 examination rooms and 1 office on a central system. Using smoke tubes, it was determined that the air from the rooms flows into the exhaust at the end of the hall as designed.

VIII. CONCLUSIONS

General ventilation, in conjunction with appropriate administrative controls, and the use of local exhaust and appropriate work practices, will help reduce the potential for tuberculosis transmission in health-care settings. There were few patient rooms at any of the hospitals surveyed that could be classified as isolation areas on the basis of ventilation evaluation criteria. The investigators found that the ventilation systems in the hospitals were either not functioning or varied from the design airflow. At four of the facilities, there was a general flow of air out of the designated isolation rooms into the main corridors of the hospital which is not recommended for the isolation of infectious patients. There was one hospital which had rooms that met the definition for AFB isolation rooms. At several facilities, sputum induction was performed in the patient's room with no local exhaust ventilation. It was observed on several occasions that isolation room windows and doors were left open which tends to defeat the effectiveness of the ventilation systems designed to provide isolation. One of the facilities did not have an employee tuberculin screening program in place, which CDC recommends for health-care facilities which provide care for patients at risk for TB. The other facilities had some form of employee tuberculin screening program in place. According to the data available at the time of the site visit, one facility had 8 out of 500 individuals convert their skin test (1.8%) and a clinic had two conversions in the two years prior to the site visit. The number of conversions was not available for any of the other facilities. The private clinic was set up appropriately, according to CDC guidelines.

IX. RECOMMENDATIONS

The following recommendations are offered to reduce the potential for airborne disease transmission in the regional hospitals. Many of the recommendations for the hospitals are similar. Therefore, two types will be provided: general recommendations which apply to all facilities and specific recommendations for each hospital. The ideal situation would be for each facility to construct correctly configured and operating isolation rooms on a dedicated hospital wing or floor. The short-term solutions will be to minimize the ventilation problems which now exist in the regional hospitals that treat TB patients.

A. General Recommendations

1. Each facility should review current work practices and procedures to assure that they are consistent with current CDC guidelines regarding isolation procedures, infection control, and medical surveillance of staff and patients. Specifically, isolation room doors and windows should remain closed. Health care workers

should always wear respiratory protection when entering TB isolation areas. Patients with infectious TB should not be allowed to directly interact with immunocompromised persons (such as housing HIV patients in the same ward as suspected TB patients) or general community environments (day room, corridor areas, or patient visiting lounges). Isolation rooms should be used for their intended use, not as offices or store rooms. An administrative policy should be developed to place confirmed or suspected TB patients in AFB isolation rooms instead of the first available patient room. Each facility should establish a formal employee tuberculin screening program in accordance with current guidelines.

2. Pentamidine administration, sputum induction, and other aerosol producing procedures should be conducted in properly ventilated and designed settings. For example, local exhaust techniques such as tents or booths with HEPA filtration could be used. Patients being administered pentamidine should remain in the controlled room until all coughing subsides, and only one patient at a time should be treated.

3. Each facility should have a policy for health care workers regarding the use of respiratory protection against potential inhalation hazards when working with known or suspected TB infected patients. Respirators which meet the requirements specified by NIOSH in 30 CFR 11, Respiratory Protective Devices should be worn and a respiratory program which meets the OSHA requirements (29 CFR 1910.134) should be in place at the facility.[21] For exposure to aerosols containing TB organisms, NIOSH recommends that the respirator offering the highest level of protection should be selected that is consistent and feasible with the tasks to be performed by the workers. Surgical masks do not meet these guidelines and may not provide adequate protection to the wearer due to poor face fit characteristics or leakage of small particles through filter media.

   The minimum requirements for a respirator program include a written standard operating procedure for the selection and use of respirators; training and instructions on respirator usage; the cleaning, repair, and housing of respirators; the continued surveillance of work area conditions for worker exposure and stress, and for the evaluation of the effectiveness of the respirator program; and the medical evaluation of employees to determine that they are physically able to wear the respirator selected for use.

   According to NIOSH guidelines, any cough-producing or sputum induction procedure is classified as having a high potential for aerosolization of M. tuberculosis and positive-pressure, air-line, half-mask respirators should be used.[20] Intensive care units and AFB isolation rooms are classified as medium potential areas where powered, air-purifying respirators (PAPR) with a half-mask and HEPA filters are the minimally acceptable personal respiratory protection. OSHA Region II has recommended, at a minimum, the use of NIOSH-approved dust, fume, and mist air-purifying half-mask respirators for entering isolation rooms, when performing medical procedures such as bronchoscopy and sputum induction, and while transporting patients.[22]

4. A routine general maintenance program, including such items as checking and replacing filters, cleaning coils, and replacing belts when necessary, should be developed for all ventilation systems servicing the hospitals.

5. Pressure relationships of all isolation rooms to surrounding areas should be checked with smoke tubes on a monthly basis. These relationships should be determined at a cracked doorway with smoke tubes or manometers. Additionally, air flow rates in the isolation rooms should be monitored to ensure that significantly more than 6 ACH are supplied to each room. The hospitals should verify that outside air rates meet the current guidelines. HEPA filters should be inspected and leak-tested on a regular basis.

6. Air-to-air rotary wheel heat exchangers are susceptible to 1% to 10% cross-leakage according to ASHRAE.[16] It can be a significant problem when exhaust gases are toxic or infectious. Each hospital that uses a heat wheel for a single pass ventilation system should control for cross-leakage. Methods to reduce the cross-leakage to a level below 0.1% are described in the ASHRAE handbook.

B. *Specific Recommendations by Facility*

1. Arecibo Regional Hospital

   a. The heat wheel for the ventilation system needs to be repaired and the attached HVAC unit cleaned. Upon completion of these two activities, the system will need to be reevaluated to determine air flows and pressure relationships.

   b. To prevent possible contamination of the supply air through the heat wheel, a HEPA filter should be installed in the supply ductwork as a precautionary measure.

   c. Due to the fact that the ventilation system for the ER isolation room has exhaust ductwork that feeds into the recirculating system that services the ER, a separate exhaust system with a HEPA filter,as a precautionary measure, directly to outside should be installed that incorporates the exhaust for the separate bathroom. The return air vents in the ER isolation room should be sealed off to prevent air from returning to the main air handler.

2. Bayamon Regional Hospital

   a. Private bathrooms should be provided for each isolation room. Shared bathrooms provide a potential avenue for exposure to any infectious agent from the other room.

   b. The air flows should be brought up to design specifications or greater to achieve negative pressure and significantly more than 6 ACH.

   c. Visual inspection of the fan coil units revealed evidence of possible mold growth. A preventive cleaning schedule with an Environmental Protection Agency - approved disinfectant will maintain a cleaner system and reduce the potential for bioaerosol contamination of patient rooms.

   d. The ceiling tiles with possible mold growth should be replaced to avoid the potential for bioaerosol contamination.

3. Caguas Regional Hospital

   a. The exhaust for the ventilation system for the "Casa de Salud" needs to be repaired. Upon completion of this, the system will need to be reevaluated to determine air flows and pressure relationships. It may be necessary to install an additional exhaust fan to achieve isolation conditions.

   b. An additional exhaust fan to the roof should be installed for the fifth floor and ER isolation rooms to create negative air flow with respect to the corridors. The return air vents in the isolation rooms should be sealed off to prevent air from returning to the main air handler and HEPA filters, as precautionary measures, should be installed in the return air vents to be prevent possible contamination. It may be more energy efficient to provide separate air handling units for these areas in the hospitals.

   c. The debris that had accumulated adjacent to the outside air intakes located below the side walk of the "Casa de Salud" should be removed.

4. Mayaguez Regional Hospital

a. The exhaust fan and motor for the ventilation system needs to be replaced. Upon completion of this, the system will need to be reevaluated to determine air flows and pressure relationships. It may be necessary to increase exhaust flow to achieve isolation conditions.

b. An additional exhaust fan to the roof should be installed for the ER isolation rooms to create negative pressure. The return air vents in the isolation rooms should be sealed off to prevent air from returning to the main air handler and a HEPA filter should be installed to be prevent possible contamination. It may be more energy efficient to provide separate air handling unit for this area.

c. The windows in the ER isolation rooms should be sealed to prevent infectious agents from entering the rest of the ER area.

d. The outside (or corner rooms) on floors 5 and 6 although having the anteroom and isolation room designation should not be used for isolation rooms since they are connected to the recirculating system which serviced the rest of the patient rooms.

5. Ponce Regional Hospital

a. The obstetrics-gynecology ward of the hospital was designed as an isolation ward and should be used as an infection control wing instead of following the current practice of placing confirmed or suspected TB patients in patient rooms with no mechanical ventilation system.

b. The heat wheel for this area should be cleaned. Upon completion of this, the system will need to be reevaluated to determine air flows and pressure relationships. It may be necessary to increase exhaust flow to achieve isolation conditions.

c. The roosting pigeons should be removed and the area under the windows cleaned. Devises should be installed to prevent the pigeons from returning.

6. University Regional Hospital

a. An additional exhaust fan to the roof should be installed for the isolation rooms in the older building and the ER to create negative air flow with respect to the hallway. The return air vents in the ER isolation rooms should be sealed off to prevent air from returning to the main air handler and a

HEPA filter should be installed as a precautionary measure to prevent possible leakage of contaminants.

b. The air flows in the new building should be brought up to design specifications or greater to achieve negative pressure and significantly more than 6 ACH. As an interim measure, a wall exhaust fan could be installed in the MDR TB patient's room to establish negative pressure between the room and the anteroom.

c. The filter housings in the HVAC systems should be checked on a regular basis to make sure that the filters fit properly.

7. Ashford Presbyterian HIV Clinic

a. To provide better control of possible contaminants, dedicated exhausts to the treatment rooms should be installed to guard against tuberculosis bacilli from being entrained into other areas of the clinic.

X. REFERENCES

1. CDC [1990]. Guidelines for preventing the transmission of tuberculosis in health-care settings, with special focus on HIV-related issues. Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control. MMWR 39, No. RR-17, December 7, 1990.

2. Comstock GW [1982]. Tuberculosis. In Evans AS, Feldman HA. Bacterial Infections of Humans. New York: Plenum Medical Book Company. pp. 605-632.

3. Anonymous. Tuberculosis [1990]. In Benenson AS, ed. Control of Communicable Diseases in Man. Washington, DC: American Public Health Association. pp. 457-465.

4. Barnes PF, Bloch AB, Davidson PT, Snider DE [1991]. Tuberculosis in patients with human immunodeficiency virus infection. N E J M 324:1644-50.

5. CDC [1990]. The use of preventive therapy for tuberculous infection in the United States. Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control. MMWR 39, No. RR-8, May 18, 1990.

6. Hopewell PC [1988]. Mycobacterial diseases. In Murray JF, Nadel JA. Textbook of respiratory medicine. Philadelphia: W.B. Saunders Co. pp. 856-915.

7. CDC [1992]. Management of persons exposed to multidrug-resistant tuberculosis. Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control. MMWR 41, No. RR-11, June 19, 1992.

8. Nardell EA [1990]. Dodging droplet nuclei: reducing the probability of nosocomial tuberculosis transmission in the AIDS era. Am Rev Repir Dis 142:501-503.

9. Broom BR, Murray CJL [1992]. Tuberculosis: commentary on a reemergent killer. Science 257:1055-1064.

10. ACGIH [1988]. Industrial ventilation; a manual of recommended practice. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

11. ASHRAE [1991]. Health facilities. In: ASHRAE Applications Handbook. Atlanta, GA: American Society for Heating, Refrigerating, and Air-Conditioning Engineers, Chapter 7.

12. AIA [1987]. Committee on Architecture for Health. Guidelines for construction and equipment of hospital and medical facilities. Waldorf, MD: American Institute of Architects.

13. Kethley TW [1964]. Air: its importance and control. Proceedings of the National Conference on Institutionally Acquired Infections, Minneapolis, Minnesota, September 4-6. Atlanta, Georgia: U.S. Department of Health, Education, and Welfare, Public Health Service, Communicable Disease Center, PHS Publication No. 1188, pp. 35-46.

14. Galson E and Goddard KR [1968]. Hospital air conditioning and sepsis control. ASHRAE Journal, July, pp. 33–41.

15. Riley RL, O'Grady F [1961]. Airborne infection—transmission and control. New York: Macmillan, pp. 47 and 134.

16. ASHRAE [1992]. Air-to-air energy recovery. In: 1992 ASHRAE Handbook. Heating, ventilating, and air-conditioning systems and equipment. Atlanta, GA: American Society for Heating, Refrigerating, and Air-Conditioning Engineers, Chapter 44.

17. Sheretz RJ, Belani A, Kramer BS, et al. [1987]. Impact of air filtration on nosocomial *Aspergillus* infections. Am J Med 83:709-718.

18. Rhame FS, Streifel AJ, Kersey JH, McGlave PB [1984]. Extrinsic risk factors for pneumonia in the patient at high risk of infection. Am J Med 76:42-52.

19. Opal SM, Asp AA, Cannady PB, et al. [1986]. Efficacy of infection control measures during a nosocomial outbreak of disseminated Aspergillus associated with hospital construction. J Infect Dis. 153: 634-637.

20. NIOSH [1992]. NIOSH recommended guidelines for personal respiratory protection of workers potentially exposed to tuberculosis. Atlanta, GA: U.S. Department of Health, Education, and Welfare, Public Health Service, Health Services and Mental Health Administration, National Institute for Occupational Safety and Health, September 14, 1992.

21. Code of Federal Regulations [1992]. OSHA respiratory protection standard. 29 CFR 1910.134. Washington, DC: U.S. Government Printing Office, Federal Register.

22. OSHA [1992]. OSHA Region II: Enforcement guidelines for occupational exposure to tuberculosis. New York, NY: Occupational Safety and Health Administration. May 1992.

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Appendix I
Example of Calculations for ACH

Puerto Rico Regional Hospitals
San Juan, Puerto Rico
HETA 92-298
August 24, 1992

The values for total air changes per hour (ACH) 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 212 cfm.

Total measured exhaust was 184 cfm.

The calculated volume for this room was 1139 $ft.^3$

The larger value between the total measured supply and the total measured exhaust was 212 cfm.

$(212 \text{ cfm} / 1139 \text{ ft}^3) * (60 \text{ minutes/hour}) = 11.2 \text{ ACH}$

Table 1

Bayamon Regional Hospital
Bayamon, Puerto Rico

Ventilation Measurement Results for Isolation Rooms

HETA 92-298

August 26, 1992

Room Number	Unit Conditioner		Bathroom		Room Supply (cfm)	Other Exhaust (cfm)	Pressure Relationships to Hallway	Room Volume (ft^3)	Air Changes per Hour
	Supply (cfm)*	Exhaust (cfm)	Supply (cfm)	Exhaust (cfm)					
121	260	170	52	N/A	N/A	201	-	1699	1.8
122	261	158	52	N/A	N/A	214	-	1699	1.8^
123	270	185	0	N/A	N/A	247	-	1699	0.0
124	263	216	0	N/A	N/A	248	-	1699	0.0**
125	N/A	N/A	38	N/A	71	68	-	1699	3.8**
126	N/A	N/A	24	N/A	289	202	-	1699	11.1^**
127	269	186	17	N/A	N/A	78	+	1699	0.6**
128	212	108	17	N/A	N/A	92	-	1699	0.6**
129	263	136	0	N/A	N/A	100	-	1699	0.0
130	197	116	0	N/A	N/A	105	-	1699	0.0
131	195	116	0	N/A	N/A	100	-	1699	0.0

cfm* - cubic feet per minute
^ - Oscillating fan in room
** - Windows open
N/A - Not Applicable

Note: Unit conditioners were 100% recirculating. Supply/exhaust difference could be due to reentrainment around the housing.Table 1 (continued)

Bayamon Regional Hospital
Bayamon, Puerto Rico

Ventilation Measurement Results for Isolation Rooms

HETA 92-298

August 26, 1992

Room Number	Unit Conditioner		Bathroom		Room Supply (cfm)	Other Exhaust (cfm)	Pressure Relationships to Hallway	Room Volume (ft^3)	Air Changes per Hour
	Supply (cfm)*	Return (cfm)	Supply (cfm)	Exhaust (cfm)					
132	196	116	0	N/A	N/A	130	-	1699	0.0
133	192	106	0	N/A	N/A	133	-	1699	0.0
134	124	80	0	N/A	N/A	147	-	1699	0.0^
135	74	47	0	N/A	N/A	201	-	1699	0.0**
136	293	188	39	N/A	N/A	155	-	1699	0.4
137	186	134	39	N/A	N/A	109	-	1699	1.4
138	290	205	N/A	32	N/A	184	-	1699	0.0
340	290	205	N/A	38	251	194	-	1699	8.9
341	0	0	N/A	5	0	0	-	1699	0.0^

cfm* - cubic feet per minute
^ - Oscillating fan in room
** - Windows open
N/A - Not Applicable

Note: Unit conditioners were 100% recirculating. Supply/exhaust difference could be due to reentrainment around the housing.

Table 2

Cuguas Regional Hospital
Cuguas, Puerto Rico

Ventilation Measurement Results for Isolation Rooms
HETA 92-298

August 23, 1992

Room Number	Pressure Relationship
5-134	Positive (+)
5-145	Positive (+)
5-146	Positive (+)
5-147	Slightly Negative (-)
5-148	Negative (-)
5-149	Positive (+)
5-150	Positive (+)

Table 3

Mayaguez Regional Hospital
Mayaguez, Puerto Rico

Ventilation Measurement Results for Isolation Rooms
HETA 92-298

August 26, 1992

Room Number	Pressure Relationship to Hallway
502	Positive (+)
503	Slightly Positive (+)
504	Positive (+)
505 - Shared Bathroom/Recirculating System	Negative (-)
625	Positive (+)
627	Positive (+)
637 - 2 HIV-suspected TB patients	Very positive (+)

Table 4

Ponce Regional Hospital
Ponce, Puerto Rico

Ventilation Measurement Results for Isolation Rooms
HETA 92-298

August 28, 1992

Room Number	Anteroom Supply (cfm)	Anteroom Exhaust (cfm)	Bathroom Exhaust (cfm)	Room Supply (cfm)	Other Supply (cfm)	Pressure Relationships		Room Volume (ft^3)	Air Changes per Hour
						Room to Anteroom/Hallway	Anteroom to Hallway		
301	N/A	N/A	65	500	33	+	N/A	2022	14.8
309	138	92	90	79	0	-	+/+#	2022	2.3
310	113	155	452	289	0	+	-/-	2022	8.6
311	N/A	N/A	14	96	0	+	N/A	2022	2.8
312	N/A	N/A	15	223	0	+	N/A	2022	6.6
313	109	179	97	190	0	-	+/-	2022	5.6
314	58	195	195	193	0	-	+/-	2022	5.7
320	N/A	N/A	65	515	28	+	N/A	2022	15.3

cfm* - cubic feet per minute
- The first sign indicates the pressure relationship for the anteroom to the patient room and the second sign indicates the pressure relationship for the anteroom to the hallway.

Table 5

University Regional Hospital
New Building
San Juan Puerto Rico

Ventilation Measurement Results
HETA 92-298

August 25, 1992

Room Number	Anteroom		Bathroom Exhaust (cfm)	Room Supply (cfm)	Other Exhaust (cfm)	Pressure Relationships		Room Volume (ft^3)	Air Changes per Hour
	Supply (cfm)*	Exhaust (cfm)				Room to Anteroom/ Hallway	Anteroom to Hallway		
501 (office)	56	N/A	17	212	184	-	+/+#	1139	11.2
502	49	N/A	25	183	138	-	+/+	1139	9.6
425	71	N/A	35	200	200	-	+/+	1139	10.5
426	60	N/A	42	192	192	-	+/+	1139	10.1
325	52	N/A	36	163	163	+	-/+	1139	8.6
326	65	N/A	27	114	114	-	+/+	1139	6.0
224	92	N/A	60	244	244	+	-/+	1748	8.4
223	90	N/A	3	177	177	+	-/-	1748	6.1

cfm* - cubic feet per minute
N/A - Not Applicable
- The first sign indicates the pressure relationship for the anteroom to the patient room and the second sign indicates the pressure relationship for the anteroom to the hallway.

Table 5 (continued)

University Regional Hospital
Old Building and Emergency Room
San Juan, Puerto Rico

Ventilation Measurement Results for Isolation Rooms

HETA 92-298
August 25, 1992

Room Number	Anteroom		Room Unit Conditioner		Bathroom Exhaust (cfm)	Fresh Supply (cfm)	Other Exhaust (cfm)	Pressure Relationships		Room Volume (ft^3)	Air Changes per Hour
	Supply (cfm)*	Exhaust (cfm)	Supply (cfm)	Return (cfm)				Room to Anteroom/ Hall	Anteroom to Hall		
411 (nursery lounge)	5	58	187	0	42	187	N/A	+	-/-#	1399	8.0
412 (office)	80	157	212	73	107	139	N/A	-	+/-	1399	6.0
311	2	50	142	0	22	142	N/A	+	-/-	1399	6.1
312	88	96	187	0	107	187	N/A	-	+/-	1399	8.0
209	0	47	193	0	34	193	N/A	+	-/-	1399	8.3
210	42	84	398	195	33	203	N/A	+	-/-	1399	8.3
G-9^	30	62	0	0	31	0	N/A	+	-/-	1399	8.7
G-10	47	75	281	0	43	281	N/A	+	-/-	1399	12.1
Emergency Room	N/A	N/A	N/A	N/A	47	491	12	+	N/A	---	---

cfm* - cubic feet per minute
^ - The unit conditioner supply was completely taped off
N/A - Not Applicable

- The first sign indicates the pressure relationship for the anteroom to the patient room and the second sign indicates the pressure relationship for the anteroom to the hallway.