INDOOR BIOAEROSOLS

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Prepared by NJDHSS/ May 2003

INTRODUCTION

This information bulletin was prepared because of the increasing awareness of bioaerosols in the indoor environment. It is intended to provide general information on indoor bioaerosols, how to identify bioaerosol contamination and its sources, and the control of bioaerosols in the indoor environment. The information bulletin focuses on bioaerosols that get into buildings from the outside environment.

WHAT ARE BIOAEROSOLS?

Bioaerosols are microorganisms or particles, gases, vapors, or fragments of biological origin (i.e., alive or released from a living organism) that are in the air. Bioaerosols are everywhere in the environment.

Some examples of bioaerosols are:

Living Source	**Examples of Bioaerosols**
Microorganisms (microbes):	
Bacteria	*Legionella*, *Actinomycetes*
Fungi	*Histoplasma, Alternaria, Pencillium, Aspergillus, Stachybotrys*, aflatoxins, aldehydes, alcohol
Protozoa	*Naegleria, Acanthamoeba*
Viruses	*Influenza* (flu)
Algae	*Chlorococus*
Green plants	*Ambrosia* (ragweed) pollen
Arthropods	*Dermatophagoides* (dust mites) feces
Mammals	Horse or cat dander

Bioaerosols are always present in our environment and pose no problems in most cases when the quantity of them and the various types are kept within reasonable limits. However, some bioaerosols, when breathed in, can cause diseases including pneumonia, asthma, rhinitis (e.g., cold, hay fever), and respiratory infection.

In order for microorganisms to release indoor bioaerosols, they must get indoors, grow and multiply on some material and then get into the air. Microorganisms can get indoors through the heating, ventilation, and air conditioning system, doors, windows, cracks in the walls, the potable drinking water system, or be brought in on the shoes and clothes of people working or visiting in the building. Water, humidity, temperature, nutrient sources (e.g., sheetrock, wood paneling, cellulose ceiling tiles, carpets, upholstered furniture, and fiberglass-lined air ducts) and oxygen determine whether micro-organisms will grow in the indoor environment. The most common microorganisms found indoors are fungi and bacteria. Fungi produce spores that become airborne; some also produce mycotoxins (poisonous substances) or volatile organic compounds. Some fungi found indoors that can cause health problems are *Penicillium, Aspergillus,* and *Stachybotrys chartorum.* Some bacteria produce endotoxins (poisonous substances) and volatile organic compounds. Bioaerosols other than those from microorganisms (e.g., pollen, cat dander) get indoors in the same way as the microorganisms. These do not multiply but may become a problem if they accumulate.

WHAT ARE THE DISEASES CAUSED BY INDOOR BIOAEROSOLS?

Bioaerosols enter the human body mostly through being breathed in. So, the diseases they cause usually affect the respiratory system.

The diseases caused by indoor bioaerosols fall into two categories: hypersensitivity diseases and infectious diseases.

Hypersensitivity Diseases

Hypersensitivity diseases (allergic diseases) result from exposure to materials in the environment called antigens (in this case, certain indoor bioaerosols) that stimulate an allergic response by the body's immune system. Some people are more susceptible than others. In other words, some of the people exposed may become ill and others may not. These diseases usually are diagnosed by a physician. Once an individual has developed a hypersensitivity disease, a very small amount of the antigen may cause a severe reaction. Hypersensitivity diseases account for most of the health problems due to indoor bioaerosols.

- Building-related asthma may result in complaints of chest tightness, wheezing, coughing, and shortness of breath. These symptoms may occur within an hour of exposure or 4-12 hours after exposure. Building-related asthma can be caused by airborne fungi such as *Alternaria*, glycoproteins from fungi, proteases (digestive enzymes that cause the breakdown of proteins) from bacteria, the algae *Clorococus*, ragweed pollen, dust mites, and dander from cats.

- Allergic rhinitis involves stuffiness of the nose, clear discharge from the nose, itchy nose, and sneezing. Itching and puffy eyes may also occur. All the indoor bioaerosols listed under building-related asthma except the bacteria proteases also cause rhinitis.

- Hypersensitivity pneumonitis (extrinsic allergic alveolitis) can be an acute, recurrent pneumonia with fever, cough, chest tightness, and fluids entering the lungs. Or, it can be a cough that progresses to shortness of breath, fatigue, weight loss and thickening and scarring of the lungs. The microorganisms associated with hypersensitivity pneumonitis are fungi such as *Penicillium* and *Sporobolomyces*, bacteria such as *Thermoactinomyces*, and protozoa such as *Acanthamoeba*.

- Humidifier fever results in fever, chills, muscle aches, and malaise (general feeling of being unwell), but no lung symptoms. The symptoms usually start within 4-8 hours of exposure and end within 24 hours without long-term effects.

Infectious Diseases

Infectious diseases are caused by the invasion of the body by a harmful organism. Some examples of infectious diseases caused by indoor bioaerosols follow.

- Legionnaire's disease, a bacterial pneumonia, is caused by *Legionella pneumophila*. It is a type of pneumonia that affects the lungs and may also affect the stomach and intestines, kidneys, and central nervous system. It can take 2-10 days after exposure to develop and frequently requires hospitalization. The source of the disease has been traced to aerosols from contaminated cooling towers, evaporative condensers, whirlpools, shower heads, faucets, and hot water tanks.

- Pontiac fever is also caused by *Legionella*. Pontiac fever is a "flu-like" illness with fever, chills, headache, myalgia (pain in the muscles), cough, nausea, and breathlessness. Pneumonia does not occur. It usually lasts 2-5 days. The sources are the same as for Legionnaire's disease.

- Histoplasmosis and Cryptococcosis, both fungal infections, may occur when contaminated bird droppings enter the indoor environment. Infection with *Histoplasma* often results in no symptoms or there may be mild respiratory illness (cough, fever, malaise). Rarely, a life threatening illness involving many parts of the body occurs. Infection with *Cryptococcus* results in inflammation of the brain and the membranes covering it and also can involve the lungs, kidneys, prostate gland, bones, or liver. The skin may also be affected with acne-like lesions, ulcers, or tumor-like masses.

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HOW IS IT DETERMINED THAT AN INDOOR BIOAEROSOL IS THE CAUSE OF A BUILDING-RELATED ILLNESS?

Health complaints related to indoor air quality usually have a real basis, though it may sometimes be difficult to find the cause. Sometimes, bioaerosols are suspected of causing symptoms that are really caused by other agents. For example, detergent residues left in carpets after cleaning can cause cough and dry throat symptoms. Carbon monoxide poisoning can cause headache, fatigue, and nausea. These, and similar agents, should be ruled out before investigating for bioaerosols. For more information, see the Public Employees Occupational Safety and Health Program's information bulletin entitled "Indoor Air Quality."

Several steps can be taken to make the determination that an indoor bioaerosol is the cause of a building-related illness. These steps include epidemiologic investigation and on-site investigation. Each of these steps is discussed below.

Epidemiologic Investigation

An epidemiologic investigation sometimes can clarify whether or not there is a building related illness, if it is due to an indoor bioaerosol(s), and, if so, how to deal with it. An epidemiologic investigation includes:

- $ definition of a case of disease;
- $ review of possible other non-building diseases that may be causing the problem;
- $ selection of controls (people without the disease) to compare to the cases;
- $ questionnaires for the cases and controls which include questions about the disease (e.g., symptoms, date started); and
- $ ordering of diagnostic tests, obtaining the results of physician evaluations, or arranging for one physician or clinic to evaluate all the employees with serious health complaints.

Sometimes the epidemiologic investigation is not necessary because it is obvious that a bioaerosol is causing the problem. For example, if mold is growing on a carpet or wall, an on-site investigation can begin without the epidemiologic investigation.

On-site Investigation

If it is believed that an indoor bioaerosol is the cause of the health complaints, an assessment of the bioaerosol status of the building should be undertaken. The investigators should study the structure, maintenance, and occupancy patterns of the building, look for possible sources of the indoor bioaerosol, and make recommendations about additional investigation or how to control the indoor bioaerosol. Sometimes bulk, wipe, or air sampling is part of the on-site investigation. The sampling strategy, laboratory analysis, and interpretation of the sampling results are complicated and require a high level of training and expertise. Industrial hygienists and/or other trained personnel (e.g., mycologist, engineer), building management, and maintenance personnel should be involved in the investigation. Areas that should be included in the on-site investigation are listed below.

- $ Outdoor investigation – Any disturbance that has recently occurred such as agricultural activity or construction work should be noted. Outdoor sources of bioaerosols can be stirred up during these activities. A sample of the outdoor air should be taken for comparison with the indoor air samples only if indoor air sampling is done (see the section on "Recommendations for Control"). The outdoor air sampling should be done at the same time and in the same way as the indoor air sampling. In general, the types of bioaerosols indoors should be similar to those outdoors and the amounts should be lower. If not, this indicates a potential problem.
- $ Heating, ventilation, and air conditioning (HVAC) system investigation – Generally a building's HVAC system mixes outdoor air with recirculated air, filters the air mixture, heats or cools the air mixture, and distributes it via ductwork throughout the building. Places to look within the HVAC system are the outdoor air intakes, filters, heat exchanger, air supply plenum and ductwork (including insulation), fan-coil and induction units, and return air. These parts of the system and the potential bioaerosol sources are described in more detail below.

- Outdoor air intakes – excessively contaminated outdoor air can be brought indoors through the intakes. Potential bioaerosol sources are cooling towers and evaporative condensers located close to or directly upwind from the outdoor air intakes, especially for Legionnaire's disease. Slime, foam, standing water, and other indicators of poor maintenance suggest microbial growth. Water samples and slime scrapings can be collected and analyzed in the laboratory. This is most helpful when a specific building-related disease such as Legionnaire's disease or Pontiac fever has been identified in the epidemiologic investigation. Sanitary vents located near the outdoor air intakes can contaminate the indoors with intestinal bacteria. Stagnant water, leaves, soil, or vegetable material near or in the intake can allow growth of bacteria and fungi which then enter the building. Birds may use the intakes to roost and nest. Their droppings can harbor fungi such as *Histoplasma* and *Cryptococcus* and bacteria.

- Filters – most buildings' filters are not efficient enough to remove small (1-2 microns) fungal and bacterial spores. Filters that contain organic dusts may become moist during the air conditioning season, allowing microbial growth on the filter itself. Filters are usually changed when there is a noticeable pressure drop in the HVAC system. By this time, many microorganisms can be growing on the filter. The dirt that has accumulated on the filters can be collected and analyzed to see if microorganisms are growing on the filter.

- Heat exchanger – the heat exchanger, with heating and cooling coils, adds or removes heat and moisture. Potential bioaerosol sources include stagnant water from drain pans that do not drain properly. The presence of slime or foam in standing water is an indicator of microbial growth. Water samples can be taken for analysis. Fungi and bacteria may grow in the porous insulation next to the cooling coils and drain pan. Microbial growth may be seen and/or bulk samples of insulation can be taken for analysis. Air washers and humidification devices are almost always contaminated with microorganisms. Bulk samples can be taken to confirm contamination.

- Air supply plenum and ductwork – this moves the filtered, conditioned air to the occupied rooms of the building. The reservoirs (the water supply) of humidification devices in the ductwork may be contaminated, and the ductwork next to these devices can become contaminated if water condenses on it. Reservoir water samples can be taken, the ductwork can be looked at for microbial growth, or bulk samples of the duct liner or accumulated debris can be collected. Ductwork usually has some dirt, but it should not contain a thick layer of deposited material. If dirt and debris collect in the ductwork and moisture becomes excessive, microbial growth can occur. If microbial growth can be seen, swab or bulk samples can be taken to confirm their identity.

- Fan-coil and induction units – heating and cooling for the building may also take place in these units which are located in enclosures. These units can become contaminated with microorganisms in the same way other parts of the ventilation system can become contaminated.

- Return air – air exits from the occupied space of the building in various ways. Bioaerosols from the occupied space can enter the return air system and settle on duct or plenum surfaces. Back-flow through the return air system could cause the settled microorganisms to get in the air again.

$ Occupied space – the most important potential microbial source in occupied space is water from leaks, high relative humidity, humidifiers, floods, and spills. Microbes can multiply within a short time after water has gotten inside the building. Water-damaged ceiling tiles, sheetrock, wall coverings, wickerware, and wood are good places for microorganisms to grow. They also can grow on water-damaged chair fabric, modular furniture, and in carpets. Usually water damage and microbial growth are obvious, but water-damaged materials can support microbial growth long after they appear dry.

If the relative humidity in the occupied space is over 70 percent, materials containing carbon may absorb enough moisture to support microbial growth. Musty or moldy odors are associated with excess

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Indoor Bioaerosols

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REFERENCES

Public Employees Occupational Safety and Health Program, New Jersey Department of Health and Senior Services, "Indoor Air Quality," January 2001. This information bulletin and other information on indoor air quality can be obtained by calling (609) 984-1863 or by writing to the PEOSH Program, New Jersey Department of Health and Senior Services, PO Box 360, Trenton, NJ 08625-0360. The information may also be obtained from the PEOSH Web Site at www.state.nj.us/health/eoh/peoshweb.

American Conference of Governmental Industrial Hygienists, *Bioaerosols, Assessment and Control*, Cincinnati, Ohio, 1999. The *Guidelines* can be obtained from the American Conference of Governmental Industrial Hygienists (ACGIH) by calling (513) 742-6163 or by writing to ACGIH, Kemper Woods Center, 1330 Kemper Meadow Drive, Cincinnati, OH 45240.

Morey PR, "Statement on Biocontaminant Control for Occupational Safety and Health Administration Public Hearings on the Agency's Indoor Air Quality Proposal," Clayton Environmental Consultants, Inc. October 13, 1994.

Office of Air and Radiation, United States Environmental Protection Agency, *Introduction to Indoor Air Quality – A Reference Manual,* EPA/400/3-91/003, July 1991. This and other information on indoor air quality can be obtained from the United States Environmental Protection Agency by calling (800) 438-4318 or by writing to USEPA, Indoor Air Quality Information Clearinghouse, P.O. Box 37133, Washington, DC 20013-7133.

New York City Department of Health, Bureau of Environmental and Occupational Disease Epidemiology "Guidelines on Assessment and Remediation of Fungi in Indoor Environments," 1999. [www.nyc.gov/health]

relative humidity and indicate that contamination exists. Condensation can occur on exterior walls and the building envelope (the area between the exterior and interior walls), especially in humidified buildings during the cold, winter months. Visible microbial growth is an indication of contamination, and swab or bulk samples can be taken to confirm the identity of the organisms. Microorganisms are abundant in portable cool mist and ultrasonic humidifiers unless they are cleaned and disinfected daily. People are sources of viruses such as influenza and measles, and bacteria such as *Staphylococcus*, *Streptococcus,* and *Mycobacterium tuberculosis*. People can also bring in contaminants on their clothes, such as cat dander, that become airborne. The number of people occupying the building affects the potential for transmission of diseases, as does inappropriate use of occupied space.

Recommendations for Control

As a result of the epidemiologic and/or on-site investigations, one or more potential bioaerosol sources may be identified, and there may be enough information to make recommendations for the control of the bioaerosols. Additional information may be needed to identify the bioaerosols and to determine if they are causing the problem. The results of the wipe and bulk samples collected during the on-site investigation may provide the additional needed information. Air sampling may be appropriate. If no apparent sources for bioaerosol contamination are found during the investigation, nonbioaerosol causes for building-related complaints should be investigated. Sometimes, it is not possible to determine for sure what is causing the building-related complaints. Control recommendations still may be made based on the findings of the on-site investigation.

WHAT ARE THE POSSIBLE CONTROLS FOR BIOAEROSOLS?

Actions to control indoor bioaerosols are of three types:

- design buildings and HVAC systems so that indoor contamination does not occur;
- maintain indoor conditions so that contamination does not occur and reoccur; and
- clean-up existing contamination.

Each of these actions is discussed in more detail below.

Building and HVAC System Design

Buildings and HVAC systems can be designed to prevent the entry of outdoor bioaerosols and to maintain conditions within the building that do not help microbial growth. Preventing the entry of bioaerosols from outdoors involves the appropriate location of air intakes and good air filtration. Design factors that help to prevent microbial growth are:

- Dilution – Adequate fresh air is needed to dilute human-source bioaerosols. For example, outdoor air should be provided at a rate of 20 cubic feet per minute (cfm) per person working in an office building.
- Maintenance – Good maintenance is necessary to eliminate areas where microorganisms can grow and multiply. Air handling units and ductwork should allow easy access for inspection and cleaning. The drain pan below the cooling coils should be designed and placed so that the collected water can drain easily, preventing the water from accumulating and becoming stagnant.
- Minimize and Protect Substrates – Substrates are any materials that trap dirt and moisture, thus providing a good place for microorganisms to grow. Acoustical/thermal fibrous glass insulation on the inside surface of the housing of the air handling, fan-coil, and induction units should be smooth-surfaced, or insulation should be placed on the outside. Fibrous glass lining should not be used in ductwork where there is high relative humidity or within ten feet of either side of the cooling coils. Carpeting should not be used where there is persistent moisture (e.g., buildings built on a slab with no basement).
- Humidification – Humidifiers provide moisture to the air, usually in the dry, winter months. Humidifiers should, if possible, use clean steam. Cold water humidifiers should use potable (drinkable) water that should be run to a drain line after passing through the humidifying device. Humidifiers using recirculated water are not recommended because they can become good sites for microbial growth.

The use of console humidifiers or vaporizers should be discouraged in the building. The use of water spray humidifiers or air washers as components of HVAC systems is not recommended because these units almost always provide a good place for microorganisms to grow. They have been associated with outbreaks of humidifier fever and hypersensitivity pneumonitis.

$ Dehumidification – Moisture in the interior building must be controlled. Relative humidity in the occupied space should be maintained below 60 percent throughout the year. To accomplish this, most HVAC systems remove moisture or heat from the air through the use of a cooling coil section. Another approach to control humidity is to have reheat coils or desiccant dehumidification immediately after the heat exchanger. It is difficult and expensive to do this in an HVAC system already in place.

$ Filtration – The location of the filters in the HVAC system is very important in protecting building occupants from bioaerosols. In order to remove fungal and bacterial spores, filters should have a 50-70 percent efficiency rating. In most air handling units, filters are located before the heat exchanger section. Consequently, building occupants will not be protected from bioaerosols produced in areas beyond the heat exchanger section, such as cooling deck coils, humidifiers, and water spray systems.

Maintenance

Preventive maintenance is probably the single most important method to control bioaerosols in existing buildings. Maintenance involves keeping the indoor environment clean by removing dirt and water and maintaining equipment so that conditions that help microbial growth do not occur. Cleaning includes the routine prevention of the build-up of dirt and moisture and immediate attention to unusual situations that could result in bioaerosol problems.

$ Routine cleaning – A maintenance schedule must be established to remove dirt and debris from the internal components of air handling units, fan-coil units, and induction units. Carpeting should be maintained dry and free of accumulated dirt. Steam or other water-based carpet cleaning adds moisture to the environment and must be used with extreme care. The carpet should be dried with heat and fans within 24 hours. Duct cleaning (vacuuming) is necessary only when so much dirt has collected that the duct surfaces are no longer visible. Careful attention to proper filter selection and maintenance can reduce the need for duct cleaning.

$ Heat exchange systems – Stagnant water should not be allowed to collect in drain pans or air handling and fan-coil units.

$ Humidifiers – Cold water humidifiers should have a fastidious preventive maintenance program, including regular inspection of mechanical components and removal of stagnant water and slime.

$ Dehumidification – Moisture levels in the air must be low enough so that condensation on cold interior surfaces such as cold water pipes does not occur. Protection of filters against moisture damage and scheduled replacement of filters is required for acceptable filter maintenance.

$ Emergency situations – Prompt repair and prevention of leaks that cause floods are essential. If a flood is due to potable water, wet vacuums should be used to remove as much water as soon as possible, preferably within 24 hours. Water-damaged materials such as ceiling tiles, and insulation should be removed and replaced. Water-soaked carpeting and carpet padding should be replaced if it is not completely dried within 48 hours. Water-damaged papers should be discarded unless they are essential, in which case they should be spread out to dry as soon as possible. If microbial growth becomes visible, the papers should be discarded. Contaminated items can be frozen to stop microbial growth until drying can occur. A diluted bleach solution (1 part bleach to 10-50 parts water) may be used to disinfect hard surfaces when necessary. If the flood is due to dirty water such as sewage, the clean-up procedures are different. All contaminated porous materials, including carpets, should be removed. Other floor covering, such as tiles, can be disinfected with a diluted bleach solution, rinsed with clean water, and allowed to dry. Dehumidifiers can be used to dry water-damaged areas. All clean-up personnel should be protected using appropriate personal protective equipment such as respirators, gloves, and protective suits. Only trained individuals should perform the clean-up. If respirators are used, the Occupational Safety and Health Administration's (OSHA) or Public Employees Occupational Safety and Health (PEOSH) Program's Respiratory Protection Standard (29 CFR 1910.134) must be followed.

Clean-up of Existing Contamination

Potential sources of bioaerosols found during the on-site investigation, or following a more intensive investigation, should be removed and/or cleaned. Contaminated cooling towers should be cleaned and decontaminated to prevent the microorganisms from returning. Air intakes and/or cooling towers should be moved so that contaminants from the cooling towers or other places cannot enter the air intakes. Within the HVAC system, mechanical or detergent cleaning may be required to remove dirt and debris, and microorganisms before decontamination. Steam can be used for cleaning if that treatment does not damage the heat exchanger. Chlorine-generating materials or hydrogen peroxide may be used for disinfection. It is not clear that biocides (substances that kill living cells) are effective over the long term. HVAC system mechanical components should be turned off during cleaning and people should not be in the building. Cleaning chemicals and disinfectants should be removed from the HVAC system prior to its being restarted. Otherwise, the chemicals from the cleaning could become airborne and cause health problems for the people in the building.

Microbial contamination on hard surfaces may be removed with a vacuum cleaner that has a high-efficiency particulate air (HEPA) filter. Any porous material in a building that is contaminated with microorganisms should be discarded. Contaminated ceiling plenums are almost impossible to clean and contaminated insulation must be removed.

If the problem is due to bird droppings, the best approach is to isolate the affected area, and treat and remove the bird droppings. The bird droppings must be wet down and treated with a bleach solution before removal. The surrounding area should also be disinfected with a bleach solution. Personnel doing the removal should use personal protective equipment such as respirators, gloves, and protective clothing. All clean-up should be performed by trained individuals. If respirators are used, the OSHA or PEOSH Program's Respiratory Protection Standard (29 CFR 1910.134) must be followed.

Revised 11/00

G8826