Indoor Air Quality in Connecticut Schools

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A Report By

The Connecticut Academy of Science and Engineering

For

Environment Committee
Connecticut General Assembly

INDOOR AIR QUALITY
IN
CONNECTICUT SCHOOLS

A REPORT BY
THE CONNECTICUT ACADEMY OF SCIENCE AND ENGINEERING,
CASE

FOR

ORIGIN OF INQUIRY: Senator Eileen M. Daily
Representative Jessie Stratton
Co-Chairs, Environment Committee
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MEMBERS OF THE CASE AD HOC COMMITTEE ON INDOOR AIR QUALITY IN CONNECTICUT SCHOOLS (THE STUDY COMMITTEE)

Mr. John E. Yocom*, *Chair*
Vice President (ret.)
Chief Consulting Engineer
TRC Environmental Consultants, Inc.

Mr. Gilbert Cormier
Occupational Risk Control
New Britain

Mr. Richard T. Palo
Occupational Health Supervisor
Connecticut Department of Labor

Mr. Michael S. Sherber
Sherber Associates, Inc.
Avon

Dr. Eileen Storey
Chief, Division of Occupational and Environmental Medicine
University of Connecticut Health Center

Mr. David R. Wedge
Manager, School Facilities Unit
Connecticut Department of Education

Dr. Jan A. J. Stolwijk*
Professor of Epidemiology and Public Health
Yale University School of Medicine

Dr. Robert L. DeBernardo
Clinical Assistant Professor of Medicine
Division of Occupational and Environmental Medicine
University of Connecticut Health Center

Ms. Paula Schenck
Division of Occupational and Environmental Medicine
University of Connecticut Health Center

Dr. MaryBeth Smuts
Regional Toxicologist and Indoor Environment Coordinator
Pesticides, Toxics and Radiation Unit
US Environmental Protection Agency, Region 1

Mr. Brian Toal
Division of Environmental Epidemiology and Occupational Health
Connecticut Department of Public Health

*Denotes member of the Academy.

ADVISORS AND OTHER INTERESTED PARTIES

Mr. Edward Adajian
President
Adajian Engineering, Inc.

Ms. Pamela Kilbey-Fox
New London Health Department

Dr. Michael Hodgson
Director of Occupational Health
Veterans Administration

Mr. Alan P. McIlveen
Walter McIlveen Associates, Inc.

The content of this report lies within the province of the Academy Technical Board on Environment, and has been reviewed by its Chair, Mr. Gale F. Hoffnagle, TRC Environmental Corporation. Dr. David Wetstone, past Secretary of the Council of the Academy, has edited the report, which is released with the Council's approval.

Michael J. Werle
Executive Director

EXECUTIVE SUMMARY

STATEMENT OF INQUIRY

Protection of Connecticut school children, and of adults who use or work at our schools, from indoor air pollution has been identified by the Environment Committee of Connecticut's General Assembly as an issue of high interest. The Committee invites CASE to conduct an investigation on this issue: 1) to assess health hazards to school children and adults from indoor air pollution in Connecticut schools, 2) to identify protective measures, and 3) to assign priorities among these measures.

SUMMARY OF RESPONSE

FINDINGS:

Exposure to outdoor air pollution and its effects on human health have been of significant concern to the citizens of the United States since the early part of the 20th Century. On the other hand, concern about indoor air quality (IAQ) has developed only over the past 30 years. This is surprising since people in this country spend most of their time indoors. Furthermore, concentrations of certain important pollutants may be significantly higher indoors than outdoors as a result of the many sources of these pollutants indoors.

The IAQ of schools is especially important for a number of reasons. Young children tend to be more sensitive than adults to irritating air contaminants. There is an increased risk of asthma episodes among children, due to elevated levels of agents found in indoor air that are capable of triggering asthma attacks. Symptoms of exposure to indoor air pollutants reduce students' and teachers' ability to concentrate, impairing the overall teaching and learning experience.

When serious IAQ problems develop in a school, parents want immediate action to solve the problem. Under this pressure, school officials and the consultants they hire may not be able to identify correctly the fundamental reasons for the problem, resulting in inappropriate advice on solutions. School districts often have limited funds for proper preventive maintenance in the mistaken belief that this will reduce their operating and maintenance costs. Unfortunately, when IAQ problems arise, as they will from improper operation and maintenance, the costs for remediation (through consultants' fees, emergency corrective action and litigation) will be many times the money the school districts thought they were "saving" in their misguided cost cutting efforts.

Many activities in schools emit air pollutants, e.g., laboratories, machine and wood working shops, kitchens, copy and printing shops, art studios and the like. One of the most frequent problems affecting IAQ in schools, however, is moisture intrusion from such routes as leaking roofs, penetration through the slabs on which many schools are built, or improper moisture control by heating, ventilating and air conditioning (HVAC) equipment. Such moisture on and in indoor surfaces encourages microbiological growth such as mold spores and bacteria. These biologically active agents may cause a number of serious allergic reactions including asthma attacks.

There is a wide range of health effects caused by poor IAQ. The two main categories of health effects experienced indoors are: Sick Building Syndrome and Building Related Illness. The former tends to cause a range of symptoms such as eye, nose and throat irritation, headaches and feelings of lethargy, while in the latter, there tends to be a clear cut relationship between symptoms and exposure to one or more infectious, toxic or immunologic agents. Sick Building Syndrome tends to disappear once the affected person leaves the particular building in which the symptoms are experienced. Nevertheless, Sick Building Syndrome affects a significant portion of a building's occupants and, at the very least, affects their mental concentration and overall well being while in the building.

Since the symptoms associated with Building Related Illness tend to be more severe and persistent, it is a much more serious situation than Sick Building Syndrome. Agents in the indoor environment can cause and/or exacerbate serious immunologic diseases, such as asthma and hypersensitivity pneumonitis. Children and teachers with these ailments may experience chronic, even life threatening, disease if the problems creating them are not recognized and corrected at early stages.

There are no legally enforceable standards for IAQ similar to the National Ambient Air Quality Standards developed for the outdoor atmosphere by the US Environmental Protection Agency (EPA) and which each state is required to meet. The American Society of Heating, Ventilating and Air Conditioning Engineers (ASHRAE) has developed Standard 62-1999 "Ventilation for Acceptable Indoor Air Quality" which has been widely adopted in state and local building codes. One application of the standard, the one most frequently used, requires minimum flow rates of fresh outdoor air into buildings for specific occupancy patterns. In the other application, various air quality standards applied in a number of countries throughout the world are used to calculate the required ventilation rate. In Connecticut there is no designated or funded "Indoor Air Quality Program" in any of the state agencies to encourage the use of ASHRAE guidelines or to provide other direct assistance to schools.

The most effective methods to achieve good IAQ are adequate ventilation with a properly designed and operated HVAC system that provides an adequate amount of outdoor air, removal of pollutants in recirculated air, and control of the emission of pollutants generated indoors. There are many available HVAC system designs that may be installed in a variety of configurations to provide good IAQ in schools, but this is rarely done in school construction due to cost reduction pressures in design and construction. However, even the best of system designs may not be effective unless diligently operated and maintained.

A number of schools in Connecticut experience IAQ problems. Several of the state agencies and private consultants have conducted studies of these problems. The state agencies include the Departments of Public Health, Labor, and Environmental Protection. In addition, the Occupational and Environmental Health Clinics of Yale University and the University of Connecticut medical schools, and several local health departments, have been heavily involved where health effects of exposure to indoor pollutants have been investigated.

EPA has produced a useful guide, the full title of which is "Indoor Air Quality Tools for Schools Action Kit". or "Tools for Schools" for short. This guide provides schools with step-by-step guidance to identify IAQ problems. An unofficial steering committee has been formed of representatives from the above stated agencies to assist schools in implementing the "Tools for Schools" (TFS) program in the schools of Connecticut.

The Department of Education has conducted surveys of the general condition of the schools of Connecticut, but little information is available on those specific conditions of facilities that are most closely related to IAQ problems such as the HVAC system. In a recent survey of the state's schools it was found that over 400 of the schools had not had a major code update within ten years. Currently, schools cannot apply to the state for reimbursement for mitigation of IAQ problems.

CONCLUSIONS:

The following conclusions are drawn from this cooperative effort of Academy members, representatives from a number of state and federal agencies, and private consultants who made up the Study Committee:

1. Poor indoor air is an extremely important environmental issue since people spend most of their lives indoors where air quality is usually quite different than that outdoors. Indoor concentrations of certain pollutants are often much higher indoors than outdoors. Indoor air quality in schools is an especially complex topic since it includes elements of a variety of disciplines: chemistry and physics in identifying and measuring indoor contaminants and studying their release mechanisms; medical science in defining the effects of the indoor environment on the health of school occupants; engineering in selecting and designing the most cost-effective methods to improve indoor air quality (e.g., improved ventilation and air cleaning); administration, both in schools and in state agencies who must implement plans and enforce regulations for improving indoor air quality. Another factor that complicates the evaluation of indoor air quality complaints is the potential psychological effect that tends to exacerbate the perception of such problems.

2. Poor indoor air quality in schools is an especially serious problem since it can have a deleterious effect on the health of students, teachers and other school staff. At the very least, it produces symptoms, while not life threatening, which can negatively affect the mental concentration of students and teachers.

3. A report by the US General Services Administration on the condition of schools nationwide indicates that in Connecticut 68 percent of schools reported indoor environmental problems. While not a great deal is known about the number of specific indoor air quality problems among schools in Connecticut, hundreds of calls have been received by state agencies and consultants requesting assistance in solving these problems. From those studies carried out in Connecticut schools in response to complaints about poor indoor air quality, such problems commonly arise from poor design and construction, not adhering to established codes, inadequate ventilation, moisture intrusion and poor maintenance and operation of HVAC systems. The most important direct cause of poor indoor air quality is inadequate fresh air ventilation, regardless of what other factors may contribute to this condition. Another problem that has been identified is the carrying out of renovations during the school year. Such activities create large quantities of indoor pollutants which can disperse throughout the school unless measures are taken to isolate and contain such emissions.

4. There are countless types of indoor pollution, both chemical and biological, but the most frequent problems encountered appear to be those related to moisture intrusion in schools that encourages the growth of molds and other microorganisms. These agents can produce serious allergic reactions and other symptoms in sensitive subjects. Schools built with poorly designed and maintained flat roofs and constructed on concrete slabs with their inevitable cracks and other penetrations, are susceptible to moisture intrusion. This set of conditions, together with poorly designed, operated and maintained HVAC systems, account for most of the reported indoor air quality problems in Connecticut's schools.

5. Connecticut's schools are heated, ventilated and air conditioned using a variety of HVAC systems. These systems are often selected based on cost and are therefore usually inadequate in many respects. Poor maintenance and operation by untrained personnel exacerbate indoor air quality problems related to HVAC systems. Modular portable classrooms present a unique set of indoor air quality problems, largely because of the inadequate HVAC systems incorporated in

such units.

6. Aside from problems related to moisture intrusion and the development of microbiological contaminants indoors, the selection of various materials used indoors such as carpeting, carpet adhesives and synthetic materials that emit odorous and irritating volatile organic vapors further degrade indoor air quality.

7. There is no formal organization in Connecticut with overall responsibility for indoor air quality issues. However, an *ad hoc* group has been formed, including personnel from the Department of Public Health, the Connecticut Council on Occupational Safety and Health, the University of Connecticut Health Center, the Yale Occupational Health Center, the Department of Labor and the Department of Education. The primary role of this group has been to encourage the application of the EPA's "Tools for Schools" program in the state's schools.

8. Except for some funding made available in recent years to a limited number of school districts, existing Connecticut laws permit state grant reimbursement only for code corrections, new construction, or for new features added to existing facilities. However, costs for the repair and maintenance of existing facilities (e.g., cleaning and repairing of HVAC systems) are not eligible for reimbursement at this time.

9. A number of other states have implemented formal programs with enforcement powers to control indoor air quality problems in schools. These programs could be models for Connecticut.

10. New construction and renovation of schools present unique opportunities to prevent indoor air quality problems before they develop. Renovation projects while the school is occupied must be carefully controlled to prevent exposure to students and teachers. With the large numbers of new schools currently planned or under construction, there is a great need to provide guidance to prevent future indoor air quality problems in buildings. EPA is about to release "Tools for New Schools" which should provide a basis for guidance in new construction (site selection, materials selection, roof design, ventilation design, and the like).

RECOMMENDATIONS:

It is the general policy of the Academy to avoid providing recommendations for action to the elements of state government, unless it is asked to do so. In this instance, the Inquirer, Representative Jesse Stratton, has asked the Academy to make specific recommendations to the General Assembly for dealing with the identified problems.

The following RECOMMENDATIONS are based on the FINDINGS and the CONCLUSIONS of this project:

1. As pointed out in Section VI of the main text, there are several Connecticut state agencies already involved in important aspects of indoor air quality evaluations in schools and other public buildings and in evaluating possible health effects on the occupants of these buildings. Therefore, the General Assembly should establish a formal organization to improve and coordinate all of these activities and provide adequate funding to support these efforts. The key responsibilities of such an organization should include but not be limited to the following:

a. Develop guidelines, management practices and/or regulations for maintaining acceptable indoor air quality in schools. Such guidelines should establish minimum operating standards for HVAC systems (e.g., ASHRAE 62-

1999), air cleaning as required, maintenance schedules and annual inspections of HVAC systems and other features of the schools that affect indoor air quality.

b. Establish guidelines and standards for new construction and renovations that minimize deleterious effects on indoor air quality from the materials and methods used in the construction. Such guidelines are available from the indoor air quality programs in other states and from certain construction trade associations.

c. Provide training to those who would be involved in carrying out various facets of the indoor air quality program in the state's school systems such as administrators, maintenance personnel, teachers, local health departments, consultants and state agency personnel.

d. Require schools and school districts to establish indoor air quality management plans and operational manuals, and designate an Indoor Air Quality Coordinator for each school or school district. Many of these requirements would be covered by mandatory implementation of EPA's "Tools for Schools."

e. Develop and implement a system to assess on a routine and "as needed" basis the indoor air quality in schools and the features of the building and its mechanical systems that affect indoor air quality. This system would provide for inspections of the school that would include evaluating the HVAC system, indoor air monitoring as required for air contaminants, including bioaerosols, and assessment of any health effects of students and other occupants of the school. This effort should include a system to evaluate and certify private consulting firms that provide inspection, monitoring and consulting services.

2. There are a number of possible approaches to the organization of a program to deal with indoor air quality in the schools of Connecticut. Two possible approaches are presented as follows:

a. Formalize the existing *ad hoc* committee identified in CONCLUSION 7., design a management structure to coordinate and oversee these operations, and provide adequate funding to support this effort. The scope of work to be done would be the same as that outlined above.

b. Designate one of the state's agencies currently involved on one of the key activities to be the lead agency for indoor air quality evaluation and control in schools and other public buildings, and provide adequate funding to support this effort. The scope of work to be done would be the same as that outlined above.

3. Once an organization has been formed in state government to address indoor air quality in schools, the plans that have been developed in other states should be critically evaluated to determine those elements most appropriate for Connecticut.

4. The General Assembly should empower and provide funding to the Department of Education to make Indoor Air Quality improvements and provide maintenance in both new and existing schools.

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I. INTRODUCTION

A. Outdoor and Indoor Air Quality

1. Outdoor Air Quality:

The quality of outdoor air to which we are exposed has been the subject of concern and regulatory efforts for a century or more here in the United States. Initial efforts were on a localized, municipal basis and were directed at obvious sources of visible emissions such as smoke and fume and sources of odorous and irritating pollutants. Over the past fifty years or so, it became obvious that outdoor pollutants do not respect local political boundaries, and in a number of urban areas air pollution control agencies and regulations were established to attack the problem on a regional basis.

Then, in the early 1970s, with the establishment of the US Environmental Protection Agency (EPA) and ultimately the adoption of the Clean Air Act and its many modifications, the control of outdoor air quality was put on a nationwide basis. National Ambient Air Quality Standards (NAAQS) were established to protect the citizens from adverse health effects of exposure to a group of pollutants for which there was significant information on the relationship between exposure (pollutant concentration and duration) and any measurable health effects. EPA created partnerships with the states to pursue aggressively the attainment of NAAQS, and over the 25 years that this program has been in effect, the improvement in outdoor air quality throughout the country has accelerated significantly.

2. Indoor Air Quality (IAQ):

It has long been recognized that we in the United States spend most of our time in a variety of indoor environments. Depending on where we live, the kind of work we do, our mobility and a variety of other factors, the fraction of time spent indoors is in the range of 70 to 95 percent. In these indoor environments air quality may be quite different than that of the outdoors. In spite of the predominance of indoor exposures in the fabric of total exposure to air pollutants, significant interest in IAQ in this country has developed only in the past 30 years.

The source of indoor air is of course the outdoor atmosphere, and the concentrations of the gross constituents of the atmosphere (e.g., oxygen and nitrogen) are essentially the same at both locations. However, the low concentrations of pollutants that define the quality of the air may be quite different for the two locations. Concentrations of reactive outdoor pollutants such as ozone and sulfur dioxide tend to decay after they enter the indoor environment; thus, their indoor concentrations are usually lower than those outdoors. On the other hand, there are a host of pollutants generated indoors that can produce indoor concentrations many times greater than those found outdoors.

Examples of such pollutants include many complex, volatile organic compounds produced by indoor activities such as cooking, cleaning, hobbies, and use of personal products, and emanations from indoor surfaces such as carpeting and finishes on walls and indoor furnishings. In addition, indoor cooking with gas produces carbon monoxide and oxides of nitrogen, two of the pollutants for which outdoor NAAQS have been developed. Furthermore, such cooking, together with human respiration, produce carbon dioxide that elevates indoor concentrations to levels several times greater than the natural background.

Another class of pollutants peculiar to the indoor environment are biologically active agents such as molds, spores and bacteria. While such agents are present in the outdoor atmosphere, under the proper conditions, including moist indoor surfaces, elevated relative humidity and inadequate ventilation, their indoor concentrations become magnified. These agents may produce serious allergic and other physiological reactions.

Much has been written about the physiological effects of indoor air pollution on humans. While catastrophic toxic effects are not anticipated, subtle and often hard to explain symptoms are being experienced by building occupants in many areas of the country. "Building Related Illness" accounts for one category of symptoms. These symptoms are associated with diseases such as asthma which can often be related to a specific cause or source such as exposure to one or many microbiologically active agents that produce a specific allergic reaction. Another category of symptoms is called "Sick Building Syndrome" in which building occupants complain of a range of symptoms such as lethargy, eye, nose and throat irritation, and headache. In most cases no specific indoor pollutant can be identified as causing the symptoms. Poor ventilation and air mixing together with the presence of irritant compounds are usually cited as the causes of the problem.

Until fairly recently, little attention has been given by environmental regulators to IAQ in non-occupational settings, even though people in this country spend most of their time indoors, exposed to air pollutants in the indoor environment. Congress has given the Occupational Safety and Health Administration (OSHA) the authority to regulate IAQ in the workplace during normal working hours utilizing occupational standards for exposure to airborne contaminants. These standards, which are designed to protect healthy workers from exposure to these contaminants, set allowable levels far above those levels that have been implicated in non-industrial, non-occupational settings (e.g., office buildings, schools and the home).

On the other hand, Congress has never given EPA, which has the responsibility to protect the populace from the deleterious effects of exposure to air pollution, the authority to regulate IAQ in non-occupational settings, even though EPA has asked for such authority. Part of the explanation is in the definition of "ambient atmosphere" contained in the regulations implementing the Clean Air Act under which EPA operates. These regulations define the ambient air as "that portion of the atmosphere. external from buildings, to which the general public has access" (Yocom, 1982). This wording tends to preclude the development of NAAQS applicable to <u>both</u> outdoors and indoors.

Outdoor air pollution is caused by emissions from various sources into the generalized outdoor air. The control of these sources is amenable to a nationwide regulatory approach. IAQ is affected not only by outdoor air quality, but also by indoor sources, many of which are controlled by various human activities and that are not amenable to a nationwide regulatory approach. EPA has not been inclined to develop IAQ standards, but to provide guidance in improving IAQ by reducing emission of pollutants indoors and improving ventilation of indoor spaces.

B. Indoor Air Quality in Schools

1. Schools as a Unique Environment:

IAQ in schools presents a unique set of problems in comparison with other important indoor environments such as homes and office buildings. Schools are used intensively during the school year. Occupancy and activity levels are extremely high. In some schools there is serious overcrowding. Many schools house a wide variety of activities, such as gymnasiums, machine and woodworking shops, printing and copying rooms, laboratories, art studios and kitchens, each emitting their own characteristic group of air pollutants. The types of heating ventilating and air conditioning (HVAC) systems used in schools vary widely and the standards of maintenance of such systems in schools are notoriously variable.

The energy crisis of the 1970s, followed in 1981 by an earlier version of the ASHRAE[1] Standard (62-1981) which allowed reduced quantities of fresh air ventilation, produced a generation of school buildings with inherently inadequate ventilation. Inadequate HVAC design and maintenance often lead to moisture buildup and subsequent production of airborne microbiological agents. Schools in Connecticut built with poorly designed and maintained flat roofs and/or constructed on slabs are especially likely to develop moisture intrusion, which can become a source of bioaerosols in the indoor environment.

2. Importance of IAQ in Schools:

IAQ in schools is an important environmental issue for a number of reasons that include but are not limited to the following:

- Children are still developing physically and are more likely than adults to suffer the effects of exposure to indoor air pollutants.
- There is evidence that asthma among children is on the rise and that school age children are more susceptible to colds and other respiratory illness than adults. Exposure to agents causing such symptoms is increased under poor ventilation conditions.
- The concern of parents about the health of their children is increasing the pressure on school boards to improve the indoor environment of schools.
- Teachers unions and state and federal occupational health agencies are pressuring school boards to improve working conditions in schools.
- Poor IAQ in schools adversely affects the mental concentration of students and teachers, and contributes to absenteeism.
- The financial pressures on school districts tend to give a low priority to installation and maintenance of HVAC systems, remediation of moisture intrusion, and other means of improving the indoor environment. Thus, IAQ and other environmental conditions deteriorate over time.

In view of the importance of indoor air pollution in schools, several states have developed programs to address and improve IAQ in schools. Furthermore, EPA has developed an excellent guide for schools entitled "Tools for Schools" to use in addressing their own IAQ problems. These programs are discussed in a later section of this report.

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[1] American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.

II. SOURCES OF INDOOR AIR POLLUTION

A. Introduction

As pointed out in the previous section, the source of indoor air is the general outdoor atmosphere which contains many of the pollutants present outdoors that are generated by a host of industrial, transportation, power generation and domestic sources. These pollutants readily penetrate the building envelope, either through infiltration or through active ventilating systems. Gases that are unreactive chemically, such as carbon monoxide, penetrate readily and indoor concentrations, assuming no indoor sources, tend to follow (usually with a time lag) concentrations outdoors. Reactive pollutants, such as ozone and sulfur dioxide, tend to react with indoor surfaces, and indoor concentrations are lower than those outdoors. Particulate matter originating outdoors generally exhibits lower concentrations indoors than outdoors because particles tend to settle out or otherwise deposit on indoor surfaces at variable rates. These rates of deposition depend on several factors including particle size and reactivity of the particles (Yocom, et al., 1995).

While outdoor sources of pollutants may contribute significantly to IAQ, this Section will deal exclusively with pollutants generated indoors by a wide variety of sources. These indoor sources together with the ventilation characteristics of the indoor space are responsible for concentrations of many pollutants to be significantly higher indoors than outdoors. The sources of indoor pollutants will be discussed in terms of two categories of pollutants: Chemical Pollutants and Biological Pollutants. Additional discussion of some of these pollutants and their health effects is included in the following major section of the report.

B. Chemical Pollutants

1. <u>Volatile Organic Compounds (VOC)</u>:

As will be discussed in Section III, this category of pollutant is involved in a number of important symptoms experienced by occupants of schools. Some VOCs have odors that can be detected at the extremely low concentrations found indoors. Others, less odorous, have been associated with allergies and other immunological symptoms. Typical sources of VOC include:

- new carpet, carpet adhesives and new furnishings
- cleaning agents
- paints, waxes, caulking materials and other maintenance supplies and solvents used in shops and arts and craft studios
- application of pesticides indoors and outdoors
- printing and copying rooms
- science laboratories
- kitchens and cafeterias
- smoking lounges
- refuse disposal
- human occupants (body odor, perfumes, and the like)

2. Inorganic Gases:

There are a limited number of such materials that are of concern as indoor-generated pollutants. They are, nevertheless, important as to their effects on human health:

- carbon monoxide and nitrogen oxides from indoor combustion sources such as cooking stoves and automotive shops
- ozone and nitrogen oxides from photocopying machines
- chlorine from swimming pool treatment
- radon in soils, especially over certain geological formations, that penetrates into a school through cracks and other openings in the slab on which the school is constructed or through basement floors and walls

3. Particulate Matter:

While "particulate matter" cannot be called a "chemical pollutant" in the strictest sense, it might better be called "non-biological" particulate matter in the context of this section. Nevertheless, when one measures concentrations of particulate matter it is normally done by filtering out particles from an air sample. The particles thus captured contain both inorganic and organic material. Some portion of the organic component includes material of biological origin. Indoor-generated particles exist in a wide range of sizes. The larger particles, generally over 10 micrometers (0.01 mm), tend to be removed by the upper respiratory system and probably have little impact on human health unless bacteria and other biologically active agents are attached to such particles. It is the extremely small particles, generally less that 2 to 3 micrometers and that are able to enter the smallest recesses of the lung, that are of greatest concern. A variety of sources indoors, especially in schools, emit particulate matter:

- cleaning activities, including use of vacuum cleaners with self-contained filters
- human activities such as walking across floors which re-entrain settled and deposited particles making them available for inhalation
- ventilating and air conditioning systems (Filtration equipment in many of these systems collect only the largest particles and reduce the concentrations of small, respirable particles only marginally.)
- chalk boards and eraser cleaning
- woodworking, welding, soldering and machine shops (Saw and sanding dust from some types of woods are irritating and/or can produce allergic responses. Welding and soldering fumes are largely respirable and may contain toxic metal components.)
- maintenance activities such as wall refinishing (Removal of lead-based paints and asbestos have the potential for serious health consequences.)

C. Biologically Active Pollutants

This class of indoor pollutants includes molds, spores, bacteria and other microbial forms. While such pollutants are present in the indoor atmosphere in particulate or aerosolized form, and would be collected to some degree in particulate samplers as described above, the collection and quantification of biologically active indoor pollutants is usually carried out by special sampling techniques wherein the bioaerosol "particles" are collected on a unique nutrient surface. This collection is followed by incubation to allow the identification of the agents and determination of their airborne concentrations in terms of colony forming units for a given volume of air sampled.

Bioaerosols are probably the most important source of IAQ complaints, symptoms and disease, as will be discussed in the following section on health effects. Children and other building occupants bring particles in from the home, other indoor environments and the outdoor environment. Animal dander from pets and other animals kept both in the school and at home is a component of the particulate matter in the school indoor environment. Molds and spores are created generally on wet surfaces, in standing water and under high humidity conditions. Many bacteria and other microbial forms also multiply under these same conditions. Listed below are some of the sources or locations of such agents:

- cooling coils and condensate pans in air conditioning systems
- wet, porous ceiling tiles, plasterboard walls and carpeting
- wet, fibrous insulation in walls or inside air ducts
- moisture collection in tunnels used as conduits for utilities

A variety of methods are available to control releases of indoor generated pollutants. This topic will not be discussed in detail in this report, but some of the approaches that may be used are:

- stop water intrusion from the outside
- remove wet building materials indoors
- provide improved maintenance and house keeping, especially in those areas subject to wetting
- control indoor relative humidity

III. HEALTH EFFECTS OF INDOOR AIR QUALITY

Children and their parents, teachers and the clinicians who treat them face rising rates of respiratory disease. The American Lung Association reports that the prevalence of asthma in children increased 49% since 1982. Although there are many possible causes for this growing health problem, the environmental conditions in school buildings are likely contributors. A recent government study notes that one in five schools has IAQ problems (Bayer et al., 1999). This section of the report discusses some of the health effects that may be related to the building's environment. Illnesses commonly associated with building occupancy include immunologic diseases such as asthma, hypersensitivity pneumonitis, rhinitis, sinusitis, organic dust toxic syndrome, contact dermatitis and urticaria (hives). In addition, poor IAQ in buildings is implicated in a number of other symptoms such as eye and mucous membrane irritation, toxic syndromes affecting the central nervous system, and infectious diseases (Hodgson, 1995).

A. Illness Related to Indoor Air Quality

There are two categories of conditions in buildings that are usually responsible for symptoms commonly associated with IAQ: "Sick Building Syndrome" and "Building Related Illness."

1. Sick Building Syndrome:

This condition is characterized by complaints from building occupants about any or all of the following (Yocom and McCarthy, 1991):

- building odor
- eye, nose and throat irritation
- skin irritation
- feelings of lethargy

This condition (at one time called the "Tight Building Syndrome") is frequently associated with inadequate fresh air ventilation and/or inadequate distribution of such fresh air. While the symptoms from Sick Building Syndrome tend to be temporary and usually disappear after the affected occupants leave the building, this condition is especially critical in schools where the effects adversely impact students and teachers and may increase absenteeism. Indoor air pollutants such as low concentrations of organic compound vapors or biologically active contaminants (molds and spores) are generally believed to be important contributors to the problem, but this condition can rarely be ascribed to single irritating agents. In addition, a number of other factors may also have a strong influence, such as:

- temperature, humidity, movement and mixing of air
- lighting
- sensitivity of occupants to airborne irritants
- attitudes about crowding and interpersonal relationships

Although not considered a serious medical threat, the symptoms of Sick Building Syndrome may be severe enough to cause building occupants to work inefficiently, or lose work/school time. Often the affected individuals report symptoms to school authorities or building managers, straining the organization's ability to respond to the problem.

2. Building Related Illness:

This condition differs from the Sick Building Syndrome in that there is documented, clear disease relationship between symptoms and exposure to one or more infective, toxic or immunological agents that trigger or exacerbate disease. Allergic diseases take on the form of rhinitis (runny nose), sinusitis or asthma. Goldstein (1994) characterizes asthma principally as inflammation and variable airway resistance. Another immunological lung disease, hypersensitivity pneumonitis (HP), may be developed by a small number of people. HP is triggered by microbiologically active agents such as molds, spores and by some chemicals, all of which may be present at significant concentrations in schools. Persons with HP experience coughing, shortness of breath and debilitating fatigue due to inflammation in and around the alveoli (air sacs of the lungs).

Some individuals who develop HP and similar lung diseases may sustain permanent lung damage if they continue to be exposed to substances that cause immune reactions. School occupants who inhale *stachybotrys atra* and other molds may have systemic and pulmonary toxic effects.

Infectious diseases are also associated with building environments. For example, buildings may harbor infectious agents that may be disseminated by a ventilation or air conditioning system. The most notorious example of this occurred at a Philadelphia hotel during a Legionnaire's Convention in 1976. An outbreak of pneumonia was caused by the bacterium *Legionella pneumonophilia*, until that time unrecognized. This caused widespread illness among the attendees of the convention and resulted in several deaths. The buildup of this bacterium in the water of the air conditioning system's cooling tower and its dispersal within the building was believed to be the cause of this epidemic (Burge, 1995).

Building Related Illness is a more serious situation than Sick Building Syndrome. Individuals with these diseases may experience similar symptoms, but the symptoms of Building Related Illness do not resolve easily. For example, asthma disrupts a child's sleep, play and overall ability to learn. Additionally, the demands of an asthmatic child often detrimentally affect the quality of family life (Juniper, 1997). As the number of children with asthma rises each year, school absences increase and respiratory problems disrupt the learning process for many students (Spee-van der Wekke et al., 1997). Those who develop asthma and HP may experience chronic, even life shortening disease if the problems are not recognized at early stages and the exposure to causative agents eliminated.

B. Asthma in School-Age Children

The number of asthmatic children is reported to have doubled over the last 20 years, from two to four million children (Baker, 1999). The report, "Clearing the Air: Asthma and Indoor Air Exposures," soon to be published by the Institute of Medicine of the National Academy of Sciences states that the prevalence of asthma has increased 75 percent between 1980 and 1994. A predisposition to allergy and asthma is a clear factor in childhood asthma, but genetic determinants do not explain the increase in asthma in recent years.

Numerous studies have investigated the increasing prevalence of asthma in school children across the developed world. Many have explored environmental factors, particularly indoor and outdoor air contamination, in search of a reason for the reported steady increase in asthma prevalence. Most of these studies identify family history and sensitization to indoor allergens as the strongest risk factors for respiratory ailments, including increased asthma in children and young adults. Some associate specific environmental factors in the school, such as humidity, higher concentrations of volatile organic compounds and viable molds and bacteria, with asthma and other respiratory diseases in school children. These epidemiological studies support an association of childhood respiratory illness and school environments.

Indoor allergens like mold/fungi, bacteria, dust mites, domestic animals, environmental tobacco smoke, chemicals, and cockroaches all have received special attention from investigators searching for the cause of the increase in asthma prevalence and severity. The presence of these factors can initiate the first attack in a child and/or can exacerbate existing asthma. Clinicians note that an asthma event often begins with a viral infection, or a heavy or persistent exposure to an indoor allergen (Bonner, 1984; Silvestri et al., 1996). Since children spend significant time at school, the IAQ in the school building poses a potential problem if it serves to expose students to antigens or irritants.

C. Respiratory Disease Mechanisms

1. Immunological Mechanisms:

Immunologically, the respiratory tract reacts to foreign substances in one of two ways. The most common response is via IgE antibody formation or type I reaction. This type of response is more commonly known as allergic asthma. The foreign substance can be a wide array of substances ranging from animal protein to mite antigen to mold. The second type of reaction is via an IgG or cellular response (type III or IV), and causes a lung disease known as hypersensitivity pneumonitis (HP). Most cases of HP due to indoor environments have been associated with mold antigen.

2. Allergic Response:

Allergy is a specific type of immune response that occurs in about 20% of the population (atopic individuals) when exposed to antigenic substances known as allergens. There is a strong genetic component that determines how an individual will react to a specific antigenic substance. The initial response to an allergen results in IgE antibody formation that binds to certain cells (mast cells) in the respiratory tract. When this allergen is encountered again, chemical substances are released from these mast cells, which cause blood vessels to dilate, some smooth muscles to contract, and fluid to move into tissue resulting in swelling in the area. In an asthmatic child, very small amounts of the allergen or recurrent infections can trigger asthma episodes. When this reaction occurs in the upper airway it causes sneezing, runny and congested nose, and itchy eyes, otherwise known as hay fever or allergic rhinitis. When it occurs in the lower respiratory tract, it triggers allergic asthma, which is characterized by wheezing and difficulty breathing.

Asthma is a reaction in the lungs that causes hypersecretions and constriction of the airway. The asthmatic response can be triggered not only by allergens in an allergic individual, but by irritating substances and infections as well. Hypersensitivity pneumonitis is an inflammatory disease of the lungs that can lead to pulmonary fibrosis or scar tissue in the lung. Like asthma, the initiating response is exposure to an antigen. The response is somewhat different in that the immunological response is lower down in the airway and interferes with oxygen exchange. Dyspnea (shortness of breath) and extreme fatigue are the characteristic symptoms.

3. Toxic/Irritant:

Toxic substances produce their reaction by direct damage to cells. The severity of the toxicity is related to the degree of toxicity of the compound, the concentration of exposure, and the route of exposure. The effect may be immediate and mild, such as irritation of the eyes and mucous membranes. Substances causing this effect are classified as irritants. If it is more severe and causes permanent damage, it is known as a toxic reaction. Some toxins can produce organ damage and others can result in cancer that may not be manifest until years later. Most compounds associated with Sick Building Syndrome are in low concentrations and thus are classified as irritants. However, potent toxins may be introduced in buildings by insecticide application or by cleaning agents. On rare occasions, toxins are released by certain molds such as *Stachybotris atra.*

4. Infectious Agents:

Infectious agents, in the order of frequency, fall into the categories of viral, bacterial and fungal. The occupants of the building introduce most infectious agents. Viral illnesses are the most common, such as the common cold and flu virus. Bacterial agents associated with buildings include the Legionnella organism, which can cause a flu-like illness or pneumonia and can be distributed by air handling systems. The most common bacteria and mold associated with buildings rarely cause direct infection. A recent theory proposes that certain molds may release agents that interfere with the immune system and render individuals more susceptible to viral infections.

D. Suspected Agents

1. Bioaersols:

Bioaerosols can include mold, bacteria, dust mite and cockroach excretions or parts, animal antigens, and pollens. Thus, bioaerosols are products produced by living organisms that become airborne. Some of these agents are in particulate form, such as the feces from dust mites, insect parts from dead insects such as cockroaches, or spores produced by molds. Others are water-soluble and become airborne in moisture such as secretions from cockroaches and endotoxins from bacteria, and animal antigen from saliva or excreta. Except for certain toxins released from toxogenic molds such as *Stachybotris atra*, or *Aspergillus versicolor*, most bioaerosols cause disease by immunologic reactions in susceptible individuals. Most can act as allergens and produce asthma in individuals who are genetically predisposed. Because they are not considered toxins, there are few OSHA or NIOSH[2] regulations or guidelines governing safe concentrations. (See Section VIA for OSHA.)

2. Volatile Organic Compounds:

Volatile organic compounds that off-gas from indoor materials are frequently detectable by their characteristic odors. This class of compounds include organic solvents used in finishes or carpet adhesives, and formaldehyde that is released from resins in building materials such as pressed board and plywood. Most of these compounds are found at low concentrations and act as irritants, but can cause asthma or reversible airway disease in susceptible individuals. Accumulation of these compounds indoors results when the air circulation and fresh air intake is insufficient to exhaust and/or dilute them.

[2] National Institute of Occupational Health and Safety

3. Inorganic Gases:

Carbon monoxide is an important gas in this category. As stated in the previous Section, it is released from indoor combustion sources such as gas stoves and automotive shops. Carbon monoxide is one of the pollutants for which the EPA has developed an outdoor National Ambient Air Quality Standard. While this gas is not normally present in concentrations high enough indoors to cause direct, serious health effects, at high concentrations that might occur in a poorly ventilated automotive shop measurable health effects may occur. Carbon monoxide combines reversibly with the oxygen-carrying sites on the hemoglobin molecules of the blood with an affinity of over 200 times higher than that of oxygen. The carboxyhemoglobin thus formed is unavailable for oxygen transfer from the lungs to the body. Symptoms of carbon monoxide exposure at low to moderate concentrations that might be expected in poorly ventilated areas in which strong sources are present include headache, nausea and decrease of attention.

Other inorganic gases with important health effects that may be found indoors are the oxides of nitrogen. These compounds are emitted from electrostatic photocopiers (Xerox machines) and combustion sources such as gas stoves and automotive engines. One of these gases, nitrogen dioxide, is a respiratory irritant and is another of the pollutants for which the EPA has developed a National Ambient Air Quality Standard. This compound is present in diesel exhaust from school buses. Depending on where the fresh air intake for a school is located, exhaust may be drawn in to the school ventilation system or may enter through open windows.

Diesel exhaust contains many other toxic substances such as sulfur oxides, aldehydes and other odorous organic compounds. The American Thoracic Society in a "State of the Art Review of Health Effects of Outdoor Pollution" (Bascom, et al., 1996) notes adverse health effects to respiratory, circulatory and central nervous systems from many of these components. Increased respiratory infections in children have been associated with exposure to heavy traffic exhaust, and diesel fumes has been shown to exacerbate chronic respiratory disease. Neurotoxic effects have been noted also for those with occupational exposure to diesel exhaust.

4. Particulate Matter:

The composition of particulate matter (often called "dust") depends on the origin and the form in which it is released. It exists in a wide range of particle sizes. The largest dust particles (generally larger than 10 micrometers in diameter) are found in dust and dirt tracked into the school from outdoor soil, and sawdust generated by the wood working shop. The smallest particles (generally less than 1 micrometer in diameter) exist in both solid and liquid or semi-liquid form and are generated by combustion processes such as smoking, cooking or fume generated in a welding shop. The largest particles of dust are usually inert and represent only an esthetic nuisance. Their large size prevents them from entering deep within the lungs where they could have an effect on health. However, even large particles that enter and lodge in the upper respiratory system may carry bacteria or other microbiologically active agents. Small particles (less than 2.5 micrometers in diameter) that enter the upper and lower respiratory system are much more significant physiologically than large particles since they enter the smallest recesses of the lungs and may create allergic or immunological responses.

Environmental tobacco smoke (ETS), or second hand smoke, is a form of particulate matter made up of extremely small diameter particles, mostly in the form of minute droplets of oily and tarry material. ETS has been shown to cause asthma in children whose parents smoke, and has been implicated in lung disease and cancer in adults as well. ETS exposure is associated with respiratory illnesses in various epidemiological studies of primary school children (Burr et al., 1999; Maier et al., 1997; Cuijpers et al., 1995). School buildings should be non-smoking. Mixed messages are given to students about the dangers of smoking when "smoking rooms" are provided for students and/or teachers.

Carpeting is a major source and reservoir for particulate matter. The materials imbedded in the carpet become re-entrained from disturbances such as traffic and cleaning. The filters on self-contained vacuum cleaners are inefficient in controlling small particle release. Central vacuum cleaners are far more effective in removing particulate matter from floors and the indoor environment. Carpeting becomes a major generator for microorganisms such as dust mites and mold. The usual carpeting has no place in heavy trafficked areas such as schools. A newer type of carpet with rubber rather than jute backing and short synthetic fibers is currently being evaluated. Even tile floors may be a source of airborne particulate matter when they are cleaned, waxed and buffed. Therefore, cleaning techniques used in schools should be evaluated carefully.

E. Strategies to Evaluate Health Effects

In evaluating health effects of building-related disease and Sick Building Syndrome, there are two types of scientific investigation that are used:

- the study of individuals and the specific pathophysiology and/or symptoms of illnesses affecting such individuals
- the study of groups or populations of children and teachers in the school environment and the application of statistical analysis to identify likely causes of illness

Both approaches yield important information that can be used to evaluate both the health consequences of the exposures and the effectiveness of interventions used to mitigate disease.

1. Individuals:

There are two aspects to the evaluation of an individual with health complaints that he or she ascribes to the environment. The clinical assessment consists of a careful history and physical examination to determine if there is an illness present, or if the symptoms consist of irritant symptoms without any objective evidence of disease. Physical findings in Building Related Illnesses may be decreased nasal airflow with swollen nasal membranes, wheezing or basilar rales[3] on physical examination. Evidence for asthma or other lung disease may be substantiated by chest x-ray, lung function tests such as spirometry, blood oxygen levels, and measures of diffusion capacity. If allergy is suspected, skin prick tests or radioallergosorbent (RAST) blood testing can be done to identify reaction to specific allergens. These tests have a high degree of specificity and sensitivity for pollens, dust mites and cockroach antigens, but are somewhat less sensitive for other allergens like mold.

[3] Literally, abnormal basal respiratory sounds

The second component of the evaluation is to assess the effect of the building environment on the symptoms and disease. This can be done by having the individual use a peak flow meter to measure lung function a number of times per day both at home and at school. A decrease in lung function when at school tends to indicate that the individual is experiencing a health effect related to the building. Similar but more objective information can be obtained by spirometric measurements on a Monday and Friday, to determine if there is a decrease in function as the week progresses. If symptoms are severe enough to warrant, or the relationship to the building is not clear, removing the individual from the building for a trial period of a week or more may be indicated.

2. Populations:

Epidemiological studies are designed to explore the association between health effects and exposures. These studies are limited in their ability to establish absolute cause and effect relationships, but are very useful in health effects studies. Data from questionnaires, medical tests, and exposure assessments are evaluated using biostatistical methods. Comparison studies of different school populations' health status and environmental exposures sort out the building-relatedness of the disease from other factors such as genetic predetermination, health care availability, and socio-economic status.

Specific school population studies are also useful when a teacher or student is found to have what is thought to be a Building Related Illness, and one would like to know whether this is an isolated case or whether a number of individuals in the same building have similar problems. In order to determine if a building is contributing to the illness of the people in the school environment, a questionnaire survey is helpful. More specific assessment can be obtained by doing spirometry or other tests on the population in question.

F. Interventions

A detailed discussion of methods to alleviate IAQ in school buildings by improvements in ventilation follows, in Section V. Remediation as an intervention is noted here because changing the environment or removing the ill child or teacher is often the necessary medical intervention for individuals stricken with serious building-related illnesses.

1. Remediation of the School Environment:

Remediation measures can be undertaken only after a careful assessment that correlates an individual's symptoms or disease with the building environment, and a careful assessment of the building to determine the potential causes of the symptoms or disease. For Sick Building Syndrome symptoms, the remediation may be as simple as increasing the supply of fresh air by any one of several means. If dirty and moist carpets are present, this may be a source of allergen for asthmatic individuals, and carpets may have to be removed. If mold is present, the source of moisture intrusion must be found and eliminated, and all damaged porous materials must be removed and replaced. Non-porous material may be cleaned with an anti-fungal agent, but care must be taken in the selection of the agent, method of application and occupancy of the school so as not to create a different and perhaps more serious IAQ problem. If changes are to be made to the heating and ventilating system, there should be adequate control for temperature and humidity. In summer months in the northeast, humidity must be reduced. In the winter, it may have to be increased.

2. Removal from Exposure:

Often it takes time to accomplish the necessary remediation, or because of financial or other reasons, remediation cannot be carried out. In this case, the individual who has been shown to have a Building Related Illness of sufficient severity should be removed from contact with the offending environment. This may mean moving to another area of the same building, or transferring to another building. In some circumstances, the ill individual must transfer to a different school system.

3. Medical Treatments:

Most Building Related Illnesses can be controlled but not cured with medical treatment. The health of the asthmatic is managed with medication. However, medical treatment is not a substitute for controlling the environment. Steroids and anti-inflammatory medications can keep the individuals functioning and comfortable, and improve their quality of life. These treatments may not prevent progression of disease and so cannot be used as a long-term strategy.

With the increased prevalence of childhood respiratory disease, schools have been viewed as an important part of the national response to managing the childhood asthma problem. The National Asthma Education Program provides detailed guidance for school principals, nurses, sports teachers and others caring for and treating children with breathing problems. State and local agencies and school systems have implemented programs designed to better 1) identify students with respiratory disease, 2) educate children, their families and communities on managing the problem, and 3) control symptoms. These programs use schools as an opportunity for reaching affected children and their families and providing necessary treatment. These educational programs do not address changing the environment, which is the only approach that relieves the underlying building-related disease.

IV. INDOOR AIR QUALITY STANDARDS

A. National Standards

As was pointed out in the Introduction, EPA has developed air quality standards for the outdoor air, and each state must develop enforceable plans and strategies to achieve these standards. There are no similar enforceable government standards for IAQ. However, in 1989 the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) developed Standard 62-1989, "Ventilation for Acceptable Indoor Air Quality," an update of an earlier version published in 1981 that responded to the energy crisis of the 1970s and allowed reduced quantities of fresh air ventilation. Standard 62-1989 has been widely used throughout the country as guidance for state and local building departments and design engineers. Both the International Mechanical Code and the State of Connecticut Building Code reference this standard. Over the intervening years there have been minor updates of this standard, the most recent occurring in 1999. Thus, the current version is referred to as Standard 62-99.

Standard 62-99 provides two separate methods for meeting its requirements. The first of these is known as the "Ventilation Rate Procedure." This part of the Standard includes tables listing the minimum rate of fresh outdoor ventilation air per occupant required for various kinds of building spaces including schools and other educational facilities. The other method is called the "Indoor Air Quality Procedure," which references various air quality standards used by a number of agencies including EPA, other international environmental agencies and occupational health organizations. This procedure allows a considerable amount of subjective judgment in selecting appropriate methods to achieve IAQ standards and is seldom used by engineers designing buildings and heating, ventilating and air conditioning (HVAC) systems.

The vast majority of building and ventilating system designers, when using Standard 62-99, employ the "Ventilation Rate Procedure" because it is easier to implement than the "Indoor Air Quality Procedure." In the case of school buildings, the minimum ventilation rate per occupant is 15 cubic feet per minute (cfm) of outdoor air. Thus, a classroom with a design occupancy of 30 would require a minimum outdoor ventilation rate of 450 cfm.

Another national standard that affects school IAQ is ASHRAE/IES[4] Standard 90.1, "Thermal Environmental Conditions for Human Occupancy." This is the national energy conservation standard and has a strong bearing on the selection of heating, ventilating and air conditioning (HVAC) systems since it provides standards for building comfort in terms of temperature and relative humidity, two fundamental parameters in defining the acceptability of the indoor environment.

[4] IES=Illumination Engineering Society

B. Local and Connecticut Building Codes

The 1999 Connecticut Building Code references the 1996 International Mechanical Code. Section 401 of the Connecticut Building Code spells out the general requirements for natural or mechanical ventilation in buildings including schools. For school buildings, like Standard 62-99, it requires 15 cfm of outdoor air per occupant. Likewise, new school buildings must also meet the energy efficiency requirements of ASHRAE Standard 90.1.

A number of Connecticut school districts and their school designers have used and still use natural ventilation instead of mechanical ventilation. Those who do must adhere to the requirements of Section 402 of the Connecticut Building Code that requires that the minimum openable area to the outdoors of a room's doors and windows shall be 4 percent of the floor area being ventilated. They also must meet the requirements of Section 5.1 of ASHRAE Standard 62-99 that requires that "sufficient ventilation shall be demonstrable" and that corresponds to 15 cfm of outdoor air per occupant. Unfortunately, it is difficult and often infeasible to demonstrate continuously that natural ventilation is providing sufficient ventilation in a school building. Thus, the use of natural ventilation is inherently unreliable under currently applicable IAQ standards.

V. HEATING AND VENTILATING IN RELATION TO INDOOR AIR QUALITY

IAQ problems occur in buildings because of the release of indoor pollutants without sufficient fresh air to dilute and dissipate such pollutants. At the same time, the indoor environment must be maintained at the proper temperature and humidity levels to assure comfortable conditions for the occupants. The most common means to achieve conditions that provide comfort and good IAQ in a building is some type of a heating, ventilating and air conditioning (HVAC) system. HVAC systems commonly include air cleaning devices such as filters that remove some portion of the particulate pollutants in the air that is recirculated to the indoor space. Sometimes such systems include equipment to remove odorous pollutants in the form of gases and vapors. Thus, HVAC systems together with removal or control of the emissions of indoor air pollutants are usually the only methods available to maintain a healthy and comfortable indoor environment.

Schools present a unique set of problems in considering the optimum HVAC systems for such applications. The wide range of activities and occupancy patterns of schools and the need for protecting the health of students and teachers, requires that the selection of the heating and ventilating concept and the proper HVAC system for a school must be taken seriously by school boards, school designers and school builders. Furthermore, the effectiveness of an HVAC system depends strongly on the proper operation and maintenance of such equipment.

There are countless combinations of systems and equipment available for the proper heating, cooling and ventilating of schools that cover a wider range of complexity and cost. The following sections present descriptions of HVAC systems applicable to schools, along with a discussion of problems related to design, operation and maintenance of such equipment.

A. Typical HVAC Systems in Schools

1. Unit Ventilators and Fan Coil Units:

Perhaps the most prevalent mechanical ventilation systems in school buildings are unit ventilators or fan coil units. These systems are widely used because of their perceived simplicity of design and because they do not use up the building floor space for mechanical rooms required by central station air handling units (which is why architects like them).

Unit ventilators and fan coil units are similar in construction and consist of a cabinet which can be wall or ceiling mounted. Inside this cabinet is a fan and blower motor assembly which draws in both outdoor air and air re-circulated from the space being conditioned. These devices also contain at least a heating coil which can be fed with hot water or steam from a central boiler. A less common configuration, due to the high energy costs common in Connecticut, is to provide heating with electric resistance coils.

Unit ventilators are distinguished from fan coil units in that the water moving through the hot water or chilled water coil is not controlled. Instead, a face and bypass damper, acting in response to a thermostat, modulates the amount of air going through the coils. In addition to the face and bypass damper, unit ventilators usually also have a fresh air damper and a return air damper. These dampers may be set in a minimum fixed position to allow a constant percentage of outdoor air to enter the room. Unit ventilators in schools equipped with air conditioning will have either a chilled water coil that is fed chilled water from a central chiller or a compressor-condenser assembly integral to the unit. Another variation of unit ventilators is the use of either air-to-air or water-to-air heat pumps integrated into the units.

Recently, in response to the increased outdoor ventilation requirements of ASHRE Standard 62-99, several HVAC manufacturers have introduced unit ventilators with integral air-to-air energy recovery ventilators designed to reduce the energy penalty from introducing so much more outdoor air than in earlier versions. Unit ventilators without energy recovery devices that are used as the primary ventilation source in classrooms may not be able to meet the ventilation requirements of Standard 62-99 and maintain adequate temperature and humidity control. Another limitation of unit ventilators is their limited filtration capability. Lack of filtration capability limits the ability to remove particulate matter such as soot, pollen and mold spores. Acceptable conditions of comfort and IAQ cannot be assured with unit ventilators.

Fan coil units, while similar to unit ventilators, differ in some respects. Unlike the unit ventilator, there are no face and bypass dampers inside the unit, only mixing dampers; thermostatically controlled water valves are used to accomplish temperature control. Furthermore, unit ventilators always handle outside air, whereas fan coil units may not. These devices operate at constant airflow. Outdoor air is introduced through a set of dampers. Fan coil units have several similar IAQ disadvantages compared with unit ventilators. They have the same limited filtration capability due to their low pressure drop fans and the limited size filter sections.

2. Water Source/Geothermal Heat Pumps:

A system design that has been used in school buildings, particularly where natural gas for space heating is not available, employs water source or geothermal heat pumps. A non-geothermal water source system will employ boilers for heat injection and cooling towers for heat rejection. A geothermal system has an open or closed loop of water piping placed in the ground to absorb or reject heat. These loops can be oriented either vertically or horizontally. The airside equipment associated with such systems can be unit ventilators, central air handling units or packaged unitary air handling units.

If water source heat pumps use unit ventilators as their terminal devices, the amount of air filtration possible, as with regular unit ventilators, is very limited. Even more important, their ability to properly handle the design heating and dehumidification loads of the relatively high quantities of outdoor air that are required by Standard 62-99 is very limited. Geothermal water source heat pumps are relatively expensive to install because of the high cost of the underground geothermal loop.

3. Central Air Handling Units:

The most versatile airside systems are central air handling units. Properly designed central station air handling units can offer both energy conservation and well-controlled acceptable IAQ. It is possible to specify medium or high-pressure drop fans on central air handling units. In these built-up systems this allows for the use of medium or high efficiency air filtration that simply is not available for unit ventilators, fan coil units, or even small rooftop units. Central air handling units are more amenable to the use of such strategies as energy recovery, humidity control, and ventilation control in high occupancy areas such as classrooms. Thus, they can have lower energy costs than many of the other system approaches described.

Unfortunately, these types of systems are not as prevalent as they should be because of their perceived expense of design and construction and their need for mechanical floor space in the building.

4. Packaged Air Handling Units:

Packaged air handling units (AHU) refer to air handling units that have their own integral air conditioning and/or heating sections, as opposed to applied air handling units that have separate boilers and/or chillers. In most school applications packaged air handling units are located on the roof and are known as rooftop units (RTUs). Less frequently, vertical packaged units may be located inside the building. The attraction of RTUs to architects and school districts is that they do not take up floor space and are relatively easy to install.

A limitation of most packaged units is that in Connecticut's climate they cannot properly deliver more than about 25% outside air due to the limited capacity of their cooling coils to fully dehumidify air under design cooling conditions. Yet, under Standard 62-99 a classroom may require 50% or more outside air ventilation.

Example: An 800 square foot classroom with 30 occupants will require 30x15 = 450 cfm of outside air ventilation. A typical design supply air rate might be 1 cfm per square foot. So there would be supplied 450/800 = 56% outside air rate.

It is possible to install high-end RTUs but these are expensive and, in effect custom units. As such, they are rarely seen in new school construction where there is an emphasis on minimizing construction costs. RTUs are also unsuitable for use with humidified environments since they are susceptible to condensation in the wintertime. If packaged units are desired in a school with humidification, they should always be installed indoors.

5. Modular/Portable Classroom Packaged HVAConditioning Units:

Modular or portable classrooms are used at a number of schools throughout Connecticut where there is an immediate need for additional classroom space. Most such units receive their heating, ventilating, and air conditioning (where applicable) with the assistance of packaged through-the-wall unitary HVAC units. These units range in size from 1 to 6 tons (of cooling capacity[5]) depending on the size of the portable/modular classroom to be ventilated and/or air-conditioned.

Electric resistance, heat pump or natural gas heaters in the unit commonly provide heating. Standard filtration in these units is 1″ throwaway filters with a relatively low particulate removal efficiency (only a 10% ASHRAE dust spot efficiency). This is insufficient to clean adequately the supply ventilation air to the space. Recently, these units have become available with 2″ pleated 55% dust spot efficiency filters. This is the minimum filter efficiency that should be installed, but usually it is not installed for short-term cost reasons.

These packaged, through-the-wall HVAC units are available with and without energy recovery modules. Those units without energy recovery modules will probably not be able to maintain required outside air ventilation rates and maintain adequate temperature and humidity control at near design conditions due to the limited dehumidification capacity of their air conditioning coils. Units without energy recovery modules will also tend to have very high energy costs, especially if electric heat or airsource heat pumps are used for space heating.

Only if energy recovery modules are included in the units will they be able to control space temperature and humidity at comfortable levels while meeting the required outside air ventilation rates. Therefore, any new modular/portable classrooms that have these packaged HVAC units installed should have energy recovery modules included. Unfortunately, energy recovery modules are not always added because they add about 30-40% to the cost of the unit.

6. Natural Ventilation:

A number of Connecticut school districts and their school designers have and still use natural ventilation instead of mechanical ventilation. Typically, these systems are heating and ventilating only. Heat is usually provided by a hot water or steam perimeter radiation system. As was pointed out earlier, naturally ventilated buildings must meet the ventilation requirements of ASHRAE Standard 62-99 and Section 402 of the Connecticut Building Code. Unfortunately, Standard 62-99 gives little guidance how ventilation shall be demonstrable.

It is not practical to ensure that a naturally ventilated building continuously provides adequate outdoor air ventilation. On cold days building occupants and/or building maintenance staff close operable windows and doors in order to avoid drafts and maintain thermal comfort. If the building designers allow for significantly more than the required 15 cfm of outdoor air per occupant then they risk winter space draftiness and energy wastage by the cooling of excessive outdoor air that infiltrates the building. The lack of effective control or heat recovery associated with natural ventilation makes this approach substantially less effective and energy efficient than other approaches.

[5] One ton of cooling capacity is defined as 12,000 BTU/hr

In those school buildings with summertime operation, natural ventilation may make the control of space humidity difficult. According to ASHRAE Standards 55 and 62, relative humidity (RH) should be less than 60%. A decrease in RH would require addition of heat; the last thing occupants would want on a warm, muggy day. Prolonged periods of high humidity in a building space may lead to the growth of mold or mildew on building furnishings. The presence of mold or mildew can in turn cause Building Related Illness. Also, the same building openings that allow the entry of ventilation air in a naturally ventilated building may allow rain water to enter, further increasing the risk of wet building surfaces and the growth of mold and mildew.

7. Window Room Air Conditioners:

Often in older schools that originally did not have installed mechanical cooling and then later chose to operate in the summer or add technology, it was sometimes decided to add window room air conditioners (WRACs) as a seemingly less expensive way of providing space cooling. While it is true that the installation cost of WRACs is less than that of installing central mechanical systems or new unit ventilators with air conditioning, they do have a number of drawbacks.

The first disadvantage of WRACs is their relatively low energy efficiency compared to other cooling methods. Energy efficiency ratios (EER) for classroom sized WRACs (approx. 1.0 to 1.5 tons each) is approximately 9.0-12 EER. This is two to four times the energy use of water-cooled central systems.

From an IAQ standpoint, WRACs are simply not capable of delivering or dehumidifying the large quantities of outdoor air required by Standard 62-99 in classrooms. WRACs are very noisy, which has a negative impact on the learning environment. Indeed, the recognition of the importance of noise has led the State of Oregon to introduce a classroom noise limit standard of 45 dB. A room cooled by WRACs can not meet this noise standard. WRACs also have very minimal filtration ability, even less than unit ventilators, due to their low pressure drop fans and inefficient filters.

8. Energy Recovery:

The increased quantities of fresh air required by ASHRAE Standard 62-99 has encouraged greater use of energy recovery technologies. Energy recovery reduces the increase in energy costs from the higher ventilation requirements of Standard 62-99. Furthermore, energy recovery equipment aids in the control of humidity by the AHU it is connected to in its ability to control space.

There are several types of energy recovery equipment. Plate heat exchangers utilize a metal or polymer stack of plate surfaces to exchange heat between the cold incoming fresh air and the warm exhaust air. Thus, they pre-heat the supply air and reduce heating costs in the winter. They usually have no moving parts and have a relatively low pressure drop. Because they ordinarily do not allow for latent heat exchange most of their benefit is achieved during the heating season.

Another type of energy recovery equipment is the heat wheel or desiccant wheel. Such devices allow for latent heat recovery and are therefore useful in both the heating and cooling seasons. They depend on a rotating desiccant wheel located between the supply and exhaust air streams. One drawback of the heat wheel is the relatively high pressure drop through the wheel, increasing fan energy costs.

Recently, attempts to combine the simplicity of the plate heat exchanger with the cooling season performance of the heat wheel without its high pressure drop have led to the development of indirect evaporative heat exchangers. These are plate heat exchangers that achieve considerable cooling season savings by evaporating water in the exhaust air stream. The evaporated water cools the exhaust air stream that then pre-cools the incoming warm humid air in the summer across the heat exchanger. Yet, because of the plate configuration the advantage of low pressure drop is kept. This also avoids the parasitic fan losses of heat wheels when the outside air temperature is between 50 and 65 degrees F. Furthermore, this approach lends itself well to 100% fresh air ventilation systems. This is the only full range energy recovery strategy available at this time. Its full range operation often permits fully offsetting savings on primary (heating and cooling) plant capacity and costs, and rapid recovery of its incremental costs.

9. Separate Ventilation and Temperature Systems/Dual Path HVAC Systems:

In recent years, Coad (1999) recognized that the use of a mixing chamber for providing both ventilation and temperature control in a single piece of HVAC equipment can lead to less than optimal ventilation, temperature control, or humidity control. A mixing chamber is a device integrated into an HVAC unit to add the ability to supply conditioned ventilation air to the space along with the conditioned recirculating air required for space temperature and humidity control. Among the types of HVAC equipment that employ mixing chambers are the previously mentioned unit ventilators, nearly all central air handling units, and most package unitary equipment. According to Coad, among some of the problems that can develop with HVAC systems containing mixing chambers are:

- Under warm, humid conditions where the outdoor-specific humidity exceeds the indoor-specific humidity, the mixing chamber will humidify recirculating air. If this equipment has on-off control or bypass control, this in turn will humidify the conditioned space instead of dehumidifying it.
- During the winter, if the indoor space is humidified, and that is the only way to maintain at least 30% RH in Connecticut, destructive condensation can occur in the mixing chamber as the mixed air temperature drops below the dewpoint temperature of the indoor air under conditions of extreme cold.
- During the winter, steam or water coils in air handling units or unit ventilators may be subjected to below freezing temperatures and must be protected from coil freeze-up and rupture. This protection often results in less reliable performance of the unit whether from actual safety shutoffs that protect the unit or nuisance system shutdowns.
- The mixing process also reduces overall system efficiency as much as thirty percent at a 25% outdoor air delivery rate, which as was demonstrated previously, may be low for schools in Connecticut.

An innovative solution to the operational problems caused by the use of HVAC mixing chambers is the use of dual path HVAC systems. Dual path HVAC systems consist of a space temperature control (STC) system and a ventilation air conditioning (VAC) unit. The STC system can be a combination of perimeter radiation heat plus an air system delivering 100% return air with a cooling coil and filters to reduce the space air temperature. The VAC unit would deliver 100% outdoor air ventilation through a set of filters, cooling coil and optional reheat coil. Because the VAC can be sized for the ventilation air quantity only it will be smaller and less expensive than a typical recirculation AHU unit. It will also be simpler to operate since it will not have the inherent pressure control problems that a recirculating system has. Energy use and costs of the VAC can be further reduced by the addition of energy recovery equipment to pre-heat or pre-cool the incoming fresh air.

Dual path HVAC systems can be installed as either central station air handling units with dual duct distribution or by using separate components for space temperature control and ventilation. In either case, energy efficiency can be dramatically enhanced with some form of energy recovery and/or evaporative cooling.

Use of separate STC and VAC units to control temperature and air quality respectively simplifies and improves the performance of HVAC systems over standard HVAC system designs and equipment that try to control temperature, humidity and IAQ at the same time with a single piece of equipment.

B. Problems Related to Design

1. Insufficient Fresh Air Ventilation:

There are several causes of insufficient fresh air ventilation associated with HVAC system design. The predecessor of ASHRAE Standard 62-1989 (and its update to 1999) was Standard 62-1981. Unlike 62-1999, which requires a minimum of 15 cfm outdoor per occupant, Standard 62-1981 required only a minimum of 5 cfm outdoor air per occupant in non-smoking spaces. Since this standard was the basis for many of the model codes and state codes, including Connecticut's, those buildings built between 1981 and the early 1990's typically have outdoor ventilation rates as low as 5 cfm per occupant.

Another more recent design problem is the failure of building designers to actually perform a Standard 62-99 design ventilation calculation. Many designers simply use a preset percentage of the total supply air they estimate is required for the space thermal loads. Sometimes that is enough, often it isn't. This practice is also a violation of Standard 90.1. For those buildings that are naturally ventilated, the question arises as to whether the design team can reasonably expect that the building occupants will actually keep the windows open enough to ensure adequate ventilation in the dead of winter when temperatures in Connecticut can get down to 0-10 degrees F during some school hours.

2. Inadequate Humidity Control:

In the Heating Season:

When cold dry air from the outside is brought inside and heated, its relative humidity is reduced even more. During the heating season, it is recommended that interior spaces maintain a minimum relative humidity of 30%. In Connecticut, given its cold winters, humidity control is possible only with a humidification system as part of the building's HVAC system. Recommended indoor humidity levels should be 40-50%. Indeed, the 30% minimum is a requirement of ASHRAE Standards 55 and 62. Maintaining interior conditions at a lower relative humidity than 30% can result in occupant respiratory discomfort consisting of dry nose, dry throat and eye irritation.

Unfortunately, most school buildings in Connecticut do not have humidification systems. In particular, school buildings of this category are those that rely upon unit ventilators and natural ventilation (with perimeter radiation for heating) as the primary ventilation delivery systems. Furthermore, these types of systems make it most difficult to install centralized humidification on a post-construction basis. At least with a central air handling unit system a humidification system may be installed in the mechanical equipment room. Unit ventilators and radiators are not so amenable to such modifications.

With the introduction of computers and technology into schools, there is a new need for humidity control to ensure the proper operation of computer and technology equipment. Excessively low humidity during the winter can result in static discharges that can cause the expense of harm and premature failure to the sensitive electronic components in personal computers and other electronic equipment. That is why data processing centers require such strict humidity control. Yet, many schools are installing technology and computers without any humidity control systems.

In the Cooling Season:

During the summertime the opposite problem occurs. Warm, humid air is brought into a cooler indoor space. The relative humidity of this warm, humid air as it is cooled is then increased further. Unless the air is dehumidified as it is cooled it can result in excessive space relative humidity and even condensation, which in turn can lead to microbial contamination with its resulting IAQ problems. The most important way to control humidity is a properly designed and operated air conditioning system.

Unfortunately, one of the unforeseen consequences of the higher outdoor air ventilation rates required by ASHRAE Standard 62-99 is that more outdoor air is brought into most HVAC equipment than can be properly dehumidified in the cooling season unless reheat is employed. The problem with using reheat is that it is an inherently energy wasting process. Energy is wasted to overcool the supply air at the HVAC piece of equipment. Then more energy is wasted heating the air to control humidity while bringing the air temperature up to that required by the space. Most unit ventilators and packaged air handling equipment are typically not capable of providing adequate dehumidification.

3. Moisture Vapor Penetration and Pressure Differences:

Even if the proper HVAC systems are installed, a school building can have humidity control problems if it was constructed without good vapor barriers. Lack of adequate vapor barriers can cause condensation, which in turn can cause mold and mildew which impact IAQ.

A factor that strongly influences moisture movement in and out of buildings is the static pressure within the building relative to that outdoors. A negative pressure indoors allows moist air to enter a building, an especially serious condition during warm weather. Although effective moisture vapor barriers reduce such penetration, a negative pressure in the building draws in moisture-laden air through various leakage paths, for example around doors and windows. If the school building is air conditioned, the inner walls may be cold enough to cause condensation and mold development in these locations. Under this condition, the HVAC system should be operated to provide a positive pressure in the building.

However, there may be a risk in maintaining a positive indoor static pressure, especially when adequate vapor barriers are not in place. During cold days in the winter when indoor relative humidity is higher than that outdoors, moisture condensation occurs when air moving from the inside to the outside comes in contact with surfaces near the outside walls, causing mold to develop in these locations. Both of these conditions point out the need for good vapor barriers in schools.

4. Outdoor Pollutant Source Near Outside Air Intakes:

The presence of outdoor pollutant sources near and/or upwind (from the prevailing wind direction) of school outside air intakes can have an adverse impact on IAQ. Often this problem results from careless building design by placing intakes near building exhausts (kitchen, toilet, laboratory or air handling exhaust ducts), flues, or places where motor vehicle use is heavy, such as loading docks. Care should taken in the design of the building to minimize the placement of outdoor air intakes near exhaust or pollutant sources.

Other potential outdoor sources are the school boiler stack and other vents emitting air pollutants. Such emissions may down-wash on the lee side of the school building and be drawn indoors through air intakes or other openings, such as windows and doors. Care should be taken in the design of school buildings to locate properly such stacks and vents and make them of sufficient height to avoid re-entrainment of pollutants from these sources into the building environment.

5. Inadequate Distribution of Conditioned Air:

One of the most energy efficient HVAC designs in the past has been the variable air volume (VAV) system. VAV systems when properly designed can meet and exceed the requirements of ASHRAE Standards 62 and 90.1. If poorly designed, however, they often suffer from poor air distribution, inadequate mixing, insufficient air velocity, stratification, or cold air dumping if they throttle back on the supply air volume in response to signals from the space thermostat. If, in practice, they fail in any of these ways, it is due to engineering failure, not limitations of the process. Unit ventilators are typically installed along the perimeter wall of a classroom. If this is the primary ventilation source for the room it may be difficult to distribute properly adequate conditioned air to the other side of the room due to the limited throw of its fans.

C. Problems Related to Operation, Maintenance and Construction

1. Obstruction of Outdoor Air Intakes:

In some school districts, maintenance personnel block off the outside fresh air intakes for the unit ventilators for the mistaken reasons of either reducing energy consumption or to prevent coil freeze-ups in the winter. The problem with this activity is that the unit ventilator or fan coil unit can no longer deliver the design outdoor air ventilation rate to the space in question and the occupants of the space can suffer from inadequate ventilation and poor IAQ.

2. Obstructions in Front of Unit Ventilators or Terminal Diffusers:

Very often occupants, especially in elementary schools, will use the top discharge grilles of unit ventilators as tables, a purpose for which these devices were not intended. Unfortunately, when this happens, the ventilation rate to the space is reduced and inadequate ventilation and poor IAQ can result.

3. Changes to the System that Affect the Quantity of Outdoor Air Ventilation and Distribution of Conditioned Air:

Many school districts have experienced increases in their student populations that have taxed the capacity of existing buildings. Sometimes, in an effort to deal with this increase in school population, classrooms are created out of spaces that were originally designed for other purposes such as libraries, art rooms, or shops. The result can be that there is inadequate ventilation for the new occupancy of these spaces as these spaces may have been designed for lower occupancies and design ventilation rates.

4. Inadequate Maintenance:

Unfortunately, the maintenance budgets and resources of most school facilities seldom meet recommended levels. Often this is consciously done to meet funding shortfalls or pressing needs in other school budget areas. Ironically, inadequate maintenance not only can result in IAQ problems with their associated liability costs but also can result in higher utility and replacement costs as well. Thus, a business decision that is often made to save money winds up costing taxpayers more money instead, from IAQ liability, increased utility costs and higher equipment replacement costs. Janczewski and Yareb (1989) and others have listed inadequate maintenance as a primary cause of IAQ problems. Even the best designed HVAC system will cease to provide acceptable IAQ if its components are inadequately or improperly maintained.

Among the more common problems of inadequate maintenance are failure to change equipment filters often enough, failure to clean the air distribution equipment often enough, and failure to maintain the integrity of the building shell (roofs, walls, and windows) against water. When filters are not changed they eventually become clogged, restricting ventilation. Failure to clean air distribution equipment introduces dirt into the ventilation system that can then become a nutrient for microbial contamination in the building. Dirt in ducts and on coils also increases fan energy use and heating and cooling energy use as well. Water entering the building shell can wet building materials and become a medium for microbial contamination.

5. <u>Construction and Selection of Materials</u>:

While not specifically within the category of HVAC equipment, the inadequate design and construction of a school building (including HVAC equipment) often create serious IAQ problems. For example, poorly designed and maintained flat roofs are susceptible to leaks that allow the penetration of moisture and the development of molds and airborne spores. Duct work with interior fiber glass insulation allows the collection of particulate matter and moisture on the porous interior surface of such ducts. This is followed by the development of mold, the spores of which can be dispersed by the ventilating air passing through the ducts.

The materials selected for use inside the school are often sources of indoor pollution, primarily sources of volatile organic compounds. Examples of such materials include carpeting, organic solvent-based carpet adhesives, wood paneling, furnishings made with composition wood containing volatile resins, and fabric-faced partitions that are treated with organic compounds to discourage dust and dirt accumulation. In addition, cleaning and maintenance materials containing volatile and odorous compounds are often the sources of IAQ complaints.

Any program in Connecticut to oversee and/or coordinate all IAQ activities should be able to advise state agencies responsible for funding school construction and maintenance, and the contractors carrying out these activities, on practices and materials that minimize the impact on IAQ. In some states, e.g., California, “Best Management Practices” are being developed to assure good IAQ in schools. Such “Practices” would include, among other features, guidance on construction and maintenance methods, and selection of materials and furnishings used indoors that minimize release of pollutants that affect IAQ. In the summer of 2000, EPA plans to issue “Tools for New Schools” which will provide detailed guidance on construction methods and materials to avoid significant impact on IAQ in schools.

VI. REVIEW OF INDOOR AIR QUALITY PROGRAMS IN CONNECTICUT AND OTHER STATES

A. Infrastructure and Resources in Connecticut

There is no designated primary agency responsible for general IAQ issues in Connecticut, but significant elements of an overall program are currently being carried out by two agencies in the state. The Connecticut Department of Labor has the authority for protecting the health and safety of workers in all of the state's public buildings. The Connecticut Department of Public Health has programs to deal with specific contaminants (e.g., asbestos, lead, radon and environmental tobacco smoke), but there are no funded programs within this agency to deal with other IAQ issues.

Most IAQ issues that arise in Connecticut are dealt with on a case by case basis, with many potential agencies, organizations, health professionals and consultants involved. The governmental agencies potentially involved in IAQ issues include: Connecticut Departments of Public Health, Labor, Environmental Protection, and Education, US Environmental Protection Agency and US Occupational Safety and Health Administration (OSHA), and local health departments. The medical community also plays an important role, especially Occupational and Environmental Health Clinics (UConn, Yale). The private sector has an important role in IAQ issues, with private consultants doing most IAQ investigations in Connecticut.

The agency or organization that may respond to a given IAQ issue depends on many factors including: type of caller (general public, worker, tenant, employer, parent), type of complaint (odor, nuisance, health effect), severity of complaint and type of building (public, private, school, residential). Another important factor is whether there is regulatory authority to deal with a given IAQ issue. Issues covered by particular regulations or statutes will be directed to the agency overseeing that statute (e.g., OSHA for private sector industry, Department of Public Health for asbestos program for removals).

For questions related to non-regulatory consulting services, it is less clear which agency should respond. Since general IAQ issues are not usually covered by any regulation, the responding agency will be determined by any number of factors listed above. The most important factor in determining who will respond, however, is who gets the initial request. Any of the agencies listed above may receive the initial request and respond as appropriate or refer the request on to others.

Listed below are details of selected government agencies and other organizations that have a role or provide a service related to IAQ issues in Connecticut:

1. CT Department of Labor, Division of Occupational Safety and Health (CT OSHA); US Occupational Safety and Health Administration (US OSHA):

CT OSHA has programs to protect the health of workers in Connecticut. This agency's programs officially cover only public sector employees (state and local government). However, they have a "consultation" process also whereby private sector employers may request their services, for non-regulatory issues. CT OSHA responds to many IAQ requests from schools and other government buildings by conducting field inspections. They are sometimes limited, however, in the response they can provide because the only regulations they can enforce are those promulgated by US OSHA. These regulations and standards are intended to protect workers in traditional "industrial" environments and are usually not appropriate in the more common IAQ episodes (See Section VIIA for a summary of CT OSHA investigations).

US OSHA covers all private sector employees in Connecticut. They respond to complaints filed by three or more employees. They will respond to IAQ related requests but this is not their primary focus. Traditionally they respond to industrial sector complaints with much higher levels of exposure than those usually seen in typical IAQ episodes. Since US OSHA's regulations and standards were established to protect industrial workers, the use of these standards in most IAQ issues does not result in enforceable violations. This is because concentrations of indoor pollutants for which such occupational standards exist are usually far below the concentrations found in industrial environments. This lack of measured concentrations below the occupational standards can confuse IAQ investigations, because such concentrations do not necessarily mean there are no health problems.

2. Connecticut Department of Public Health (DPH):

DPH has programs that deal with specific IAQ issues not being covered in this report (e.g., asbestos, radon and lead). Although there is no formal program or statutory mandate to deal with other IAQ issues, DPH has traditionally responded in a number of ways to such issues. The Division of Environmental Epidemiology and Occupational Health (EEOH) and the Division of Environmental Health Services (EHS) receive numerous calls and requests related to IAQ.

Although there is no dedicated staff for this purpose, EEOH has taken the lead role in responding to most IAQ requests. Their response usually involves phone or written consultations on technical or health related aspects. EEOH will review environmental data collected by others (usually private consultants) but lacks field investigation capabilities. EEOH produces and/or distributes a number of fact sheets on common IAQ contaminants (e.g., carbon monoxide, molds, ozone generators and formaldehyde) for distribution to the public (see section VIIA for a summary of DPH investigations).

The EHS Division has established programs dealing with lead, asbestos and radon. However, they will provide technical assistance to callers with questions on IAQ, or they may refer such callers to EEOH.

3. Connecticut Department of Environmental Protection (DEP):

This agency's primary responsibility for air quality is with the outdoor atmosphere. However, DEP does have the responsibility for controlling the use of pesticides. In this connection, DEP administers a new law adopted last year by the General Assembly, Public Act 99-165, which covers the control of pesticide use in schools. The law grew out of a constituent request followed by the deliberations of a committee within DEP. It was clear that pesticide use in schools, including an integrated pest management (IPM) program and notification, are national issues, with legislative action taking place in several states. A recent check of DEP's active complaint file showed ten complaints involving pesticide use on school property. The total number of all DEP complaints has reached a total of approximately 2700.

The new law deals mostly with notification, but has also a few IPM provisions. The essential elements of the law are as follows:

- The definition of a pesticide excludes disinfectants, sanitizers and pest bait formulations.
- Pesticide applications are to be performed by certified applicators.
- A registry is to be created within each school of parents who wish to be notified when pesticides are applied at the school.
- Notice of this registry and the school's pesticide policy are to be provided at the beginning of the school year.
- For schools which have not adopted an IPM program, notice to parents on the registry shall be sent by first class mail to be received 24 hours before the application.
- No application shall be made during the school day or during planned activities except for emergency applications to control infestations that pose an immediate threat to health.
- When an emergency application is made, notification to parents on the registry shall be made by any means practicable, as soon as possible on or before the day of application.
- Records of application shall be kept at the school for five years.
- For schools with IPM programs, the provisions are similar, except that the notice to parents on the registry for non-emergency applications may made by any means practicable on or before the day of application.
- For application to day care facilities, no pesticide may be applied during regular business hours, except for emergency applications.

The law will take effect on July 1, 2000.

4. Occupational and Environmental Health Clinics (OEHC):

The network of OEHC that are currently funded by the Connecticut Department of Labor serve the state. The two clinics at Yale University School of Medicine and the University of Connecticut Health Center have had important involvement in investigations and resolutions of IAQ problems in Connecticut. They become involved in IAQ investigations when they see a patient with illness suspected or reported to be related to a building's environment. Then industrial hygienists and epidemiologists from the clinics consult with treating physicians to evaluate if IAQ is affecting a patient's health. In some instances OHEC clinics have been hired by school districts to conduct investigations of schools with IAQ problems.

5. Local Health Departments (LHD):

LHD are often on the front line in IAQ investigations in schools. However, they usually lack the staffing, expertise or legal mandate to deal effectively with such situations. When IAQ issues arise in a particular school, parents and teachers usually call the LHD first. Many LHD respond by conducting a site inspection. However, few LHD have any field testing equipment for indoor pollutants. Often the LHD works with the school administration to hire a qualified consultant. The LHD may then help interpret the consultant's report and work with the school on suggested remediation.

There is a wide variation in ability of LHD to become involved in such activities. Many LHD with part time health directors do not have adequate staffing to take on IAQ issues. There is no statutory mandate that calls for LHD involvement except for broad powers given to local directors of health in Public Health Code 2000 to protect public health in general (Para. 19-13-B2)

The New London Health Department has taken a lead role in forming the "Southeast Connecticut Indoor Air Coalition." This coalition includes representatives from many sectors and many towns in Southeast Connecticut. They are trying to develop broad support in the region for projects such as EPA's "Tools for Schools."

6. Connecticut Department of Education (DOE):

DOE does not have programs or oversight of IAQ issues in schools. They do have a grant program for construction and renovations work in schools. These moneys may be used indirectly to support projects that improve IAQ but not if that is the primary purpose.

7. Local School Districts:

Local school districts and school administrators have the ultimate authority and responsibility to supply a safe and healthful environment for students and teachers. School administrators usually oversee IAQ investigations and mitigation steps in schools. They hire and oversee consultants conducting IAQ investigations. They then make decisions on any mitigation steps recommended by the consultant and must weigh the costs of any IAQ improvements against available resources. As discussed in other sections of this report, IAQ improvements are generally not reimbursable from DOE.

School administrators are responsible also for maintenance and other IAQ prevention actions, e.g., school cleaning and ventilation system maintenance. They have oversight also of chemicals used in cleaning, pest control, science laboratories, art studios and machine and woodworking shops. The EPA's "Tools for Schools" (TFS) program, referred to a number of times in this report, is a proactive maintenance and prevention program for achieving and maintaining good IAQ in schools. School administrators play a key role in implementing the TFS program in individual schools. The Commissioners of Education and of Public Health recently sent a letter to all school superintendents, encouraging them to implement TFS.

School administrators usually do not conduct these activities without assistance. They often request technical assistance from the local health department and sometimes CT OSHA and DPH.

8. Private Consultants and Laboratories:

Private sector consultants carry out many of the IAQ investigations in Connecticut. At present, there is no governmental certification for consultants who conduct IAQ investigations. Many consulting companies who conduct IAQ studies have experience in traditional "industrial hygiene" areas. These areas include air sampling, ventilation engineering and toxicology. Some consultants and consulting firms belong to professional associations such as the "American Industrial Hygiene Association" (AIHA). The American Board of Industrial Hygiene, soon to be merged with AIHA, has a certification process whereby a qualified individual can become "Certified Industrial Hygienist" or CIH through experience in industrial hygiene and by examination. Many CIHs are well-versed on IAQ issues and are experienced in investigating IAQ problems.

AIHA has published a list of laboratories accredited to conduct analysis of air samples. It should be pointed out, however, that the standards for air contaminant exposure often used by industrial hygienists are the "Permissible Exposure Limits" (PELs) published by the National Conference of Governmental Industrial Hygienists. These standards, which are basically the same as those used by OSHA, have been developed for use in industrial atmospheres for exposure by healthy males over 8-hour per day, 40-hour per week work periods. The air concentration values in the PEL compilation are mostly orders of magnitude higher than would normally be found in a non-industrial indoor setting. Therefore, such standards have little or no application to IAQ in schools. However, if they do happen to be used, erroneous conclusions may be drawn about the nature and severity of an IAQ problem.

Another shortcoming of many IAQ investigations by consultants specializing in this field is the lack of personnel on the investigating team with experience in HVAC systems and the their operation and maintenance. Most IAQ problems have a significant component related to ventilation or lack thereof, and an analysis of this aspect of an IAQ problem requires the services of a highly experienced HVAC engineer.

DPH has published a list of laboratories certified to conduct analysis of specific contaminants in air samples. It is important to remember that a certified laboratory does not necessarily have experience or training in field investigations or the taking of air samples. EPA publishes a list of indoor air consultants. However, there are no minimum qualifications or requirements to be on this list which represents only those companies reporting to EPA that they conduct IAQ investigations.

B. Use of "Tools for Schools" in Connecticut

"Tools for Schools" (TFS) is an excellent self help program designed by EPA to assist schools in identifying, prioritizing and controlling IAQ problems. It is a voluntary program that helps to identify IAQ problems or avoid potential IAQ problems proactively. It is not a cure-all and is not necessarily intended to help schools with ongoing/current IAQ problems. EPA plans to introduce "Tools for New Schools" in the summer of 2000. This publication will provide guidance in the design and construction of new schools to avoid IAQ problems.

EPA has distributed TFS to schools nationwide that have expressed an interest in learning about it. Although most Connecticut schools have received TFS it is unclear how many have actually implemented it. TFS requires the school to dedicate a small amount of staff time to fill out checklists and conduct a walk-through inspection. Experience in other states indicates that many schools need assistance to get started with TFS.

Toward that end, a consortium of state agencies and other organizations have formed a "resource team" to provide such assistance. DPH and the Connecticut Council on Occupational Safety and Health have taken a lead in forming this resource team. The Division of Occupational and Environmental Medicine at the University of Connecticut Health Center provides training on implementing TFS in this resource team. Within the limited resources of the resource team, schools may request assistance. A pamphlet describing the resource team has been distributed to all school systems in Connecticut.

C. Federal Activities and Programs in Other States

1. Federal Activities:

There are specific federal laws and regulations for prohibiting smoking, pesticides and certain pollutants in the school indoor environment, such as the Asbestos Hazard Emergency Response Act of 1986, but there are no laws and regulations governing general IAQ. EPA, under the statutory authority of the 1986 Superfund Preauthorization Act, was mandated to establish a non-regulatory IAQ program that emphasizes research, information dissemination and development of technical guidance and training. The Indoor Air Quality Office, recently named the Indoor Environments Division, has focused most of its attention on developing technical guidance and training for school personnel and on implementation of TFS.

EPA assists schools in establishing in-school environmental teams that use the TFS kit's checklist and communication plans to evaluate in detail the environmental operations and maintenance of the school facilities and to prioritize changes in work practices or repairs. The TFS approach was developed in response to the growing number of requests for IAQ assistance from parents, teachers and school administrators being received by EPA's Regional Offices and the IAQ Information Clearing House.

The 1995-96 series of US General Accounting Office (GAO) Reports on "School Facilities: Condition of America's Schools" and "America's Schools Not Designed or Equipped for the 21st Century" documented the status of schools across the nation as to their state of deterioration and uncorrected environmental problems. Connecticut schools surveyed by the GAO showed that 68% of them reported environmental problems. Connecticut schools ranked the 10th worst in the nation for the number of leaky roofs and ranked 11th worst for reported ventilation problems. The findings in these GAO reports provided the impetus for several school assistance bills to address environmental problems. The current bill is H.R.3143: "A Bill to Establish the High Performance Schools Program in the Department of Education and for Other Purposes."

This bill requires that the Secretary of Education make grants to assist school districts to promote the concept that new and existing elementary and secondary schools should be healthful, productive, energy efficient and environmentally sound. This bill acknowledges that inadequate ventilation and other school building problems can diminish students' and teachers' capacity to concentrate and that adoption of whole building concepts for improving a school's environment produces dramatic improvements in student and teacher performance.

2. Programs in Other States:

Because of the urgent need for improvements in school management of IAQ and the current lack of federal regulations for that purpose, several states have adopted regulations to improve school IAQ. At least 20 states have regulations regarding some aspects of school IAQ. Most are directed at specific problems or pollutants, however. For example, Florida adopted a statute in 1988 on mandatory testing for radon in schools, one of the first states to require such testing. Texas adopted a statute requiring the establishment of integrated pest management standards for schools in the state. This latter example was a groundbreaking and innovative action at the time of its 1971 enactment.

In a recent meeting organized by the Environmental Law Institute of state and local health officials involved in IAQ investigations and control, there were presentations on the many activities currently being carried out in various states (Environmental Law Institute, 2000). It is clear from the level of activity and high degree of organization exemplified in a number of these efforts that Connecticut lags far behind these states in the seriousness of the attention given to IAQ issues.

There are a few states, discussed in the following paragraphs, which have, in the judgment of the Study Committee, IAQ programs with elements that could be applied in Connecticut.

Washington and Texas:

The state of Washington has had statutes and regulations dating back to the 1980s that require testing of school and state owned buildings to assure safe and healthy IAQ. Furthermore, Washington was one of the first states to promulgate a comprehensive environmental approach to IAQ problems in schools. In a 1989 statute, the state was authorized to develop a model IAQ school program and require schools to adopt IAQ programs based on this model. To ensure that school districts have acceptable IAQ programs, the state of Washington in 1994 provided incentives for school districts of up to $70,000 for the development of the management practices to improve IAQ in newly constructed schools.

In 1995, Texas promulgated a similar legislative directive to the State Board of Health. In 1997, this state agency developed a comprehensive program to address IAQ management in schools with recommendations for design, construction, renovation, operation and maintenance. These Texas guidelines are voluntary and, while the school systems were not mandated to follow them, they are part of the State Health and Safety Code.

Minnesota:

In 1997, Minnesota adopted a comprehensive Act (97-7082MC) that requires an IAQ management plan as part of a school district's health and safety program. This Act also details IAQ issues to be considered in renovation and new construction projects, and requests a $130 million bond issue to improve school environments. School projects that address IAQ can qualify to receive revenue from property taxes, but some school districts with low revenues may receive state equalizing aid in this category.

The Act requires that the Commissioner of Children, Families and Learning, the oversight agency for K-12 education, provide IAQ information to school districts prior to their development of construction projects in excess of $400,000. The districts must then demonstrate that these IAQ issues are satisfactorily considered in the design. The Education Commissioner is charged with developing a maintenance manual and a planning and construction manual to assist schools.

Vermont:

In 1998, Vermont adopted "An Act Related to Toxic Materials and Indoor Air Quality in Vermont Public Schools. Under it, each school is to designate an air quality coordinator. All the coordinators in the state are themselves coordinated by the Department of Health. The Governor appointed an oversight committee, chaired by the Commissioner of Buildings, and divided into a Subcommittee on Schools and a Subcommittee on State Buildings. A report of the Subcommittee on School Buildings included technical sections on ventilation, maintenance and operations. These precedent-setting laws for assisting schools in improving IAQ have been models for action in a number of New England states.

Massachusetts:

Massachusetts is another state poised to enact legislation regarding school IAQ issues in existing schools and during construction and renovations. In 1999, the Massachusetts Teachers Association along with the Healthy Schools Network had a bill filed in the General Assembly to establish a commission on health and safety in schools. This commission was to recommend enforcement strategies to ensure that schools implement health and safety programs in school management plans. This bill received a favorable report from the Education Committee which forwarded it to the Ways and Means Committee where it is being reviewed.

In addition to this pending legislation, the Massachusetts Department of Education, in upcoming changes to its School Construction Regulations, proposed IAQ requirements which are expected to be adopted in March. During renovations and construction, containment procedures consistent with the current "Indoor Air Quality Guidelines for Occupied Buildings Under Construction" published by the Sheet Metal and Air Conditioning Contractors National Association, Inc. be implemented to protect the health of school occupants.

Maine:

Maine is the most advanced state in New England in addressing the IAQ needs of schools. Since 1991, this state has required that the heating and ventilating system in public schools be inspected annually and maintenance records kept for at least five years. Since 1995, schools are required to establish Energy Efficiency Programs that reduce energy cost while maintaining healthful IAQ. Unfortunately, even if a state adopts innovative regulations, without enforcement and school assistance to implement the requirements, school facilities still suffer from lack of attention and repairs.

In 1996, the Center for Research and Evaluation at the University of Maine conducted a state-specific survey of conditions in schools similar to that conducted by GAO on a nation-wide basis. The Facilities Inventory Study revealed that the costs for school construction and needed repairs exceeded $500 million. Of this total amount, at least $50 million is for urgently needed repairs for health and safety improvement due to leaking roofs or faulty heating systems.

The Governor's School Facilities Commission, formed in 1997, identified the need to develop a pro-active agenda for school assistance. Maine law at that time did not authorize the use of state construction funds for school repairs and renovations. Moreover, the Commission recognized that this restriction encouraged school systems to let schools continue to decay until new construction was necessary. Once the Commission's recommendations were received by the Education Committee and the Appropriations Committee of the General Assembly, in 1998, emergency rule processes were implemented to put into place an appropriation of $20 million into the Revolving Renovation Fund.

After the Legislature provided appropriations and bonds to support the Revolving Fund, in 1999 the Department of Education received its first applications for loans for high priority projects addressing health and safety problems in schools. Even with funds of $20.3 million, the project requests totaled $74 million, greatly exceeding the immediate funds available. To avoid continued deterioration in school facilities, schools now receiving the loans are required to commit to appropriate maintenance and capital improvement plans. The action taken by Maine to assure healthy environments in the schools of the state is an efficient model for changing a law under which a Department of Education operates. It converts a law that encourages school systems to let their schools decay in order to receive state assistance in new construction to one that permits timely repairs that promote a continuing quality learning environment.

VII. INVESTIGATIONS OF INDOOR AIR QUALITY IN CONNECTICUT SCHOOLS

Over the past few years, many investigations of IAQ problems have been carried out by both public and private organizations. The following sections summarize the types of these investigations.

A. Connecticut Department of Labor Division of Occupational Safety and Health (CT OSHA)

CT OSHA provides free safety and health consulting services for both public and private employers and enforces Connecticut's occupational safety and health regulations for the public sector. The mission of CT OSHA is to provide timely, courteous, and professional service to Connecticut employers and employees so that they may recognize and control workplace hazards and prevent injuries, illnesses, and fatalities. The consulting service is funded by the US Occupational Safety and Health Administration. CT OSHA may conduct inspections also, which are enforcement actions where standards are violated or suspected of being violated.

In the first quarter of 1999, the Connecticut Department of Labor reported that a total of 131,200 individuals worked in Connecticut's schools. The Connecticut education system employed 84,650 people in primary educational facilities. An additional 13,000 employees worked in private facilities. Secondary education employed 13,150 in public and 20,400 in private facilities. The Connecticut Department of Education has projected in the 2000-2001 school year there will be approximately 545,160 youths in the public primary education school system and 76,550 youths in private schools.

The considerable number of Connecticut's public sector employees working in educational facilities, coupled with the enormous student population, has created a significant concern for the indoor environment in schools. From October 1994 to October 1999, CT OSHA conducted 167 consultations in Connecticut schools and 235 inspections. In 1998, 62% of the CT OSHA health-related consultation visits and 39% of health-related compliance inspections were related to IAQ issues. Approximately 50% of these consultations were conducted in Connecticut schools, potentially affecting 1,400 employees and 8,320 students. CT OSHA inspections affected approximately 950 employees and 7,350 students.

Three concerns dominated employers' requests for IAQ assistance, as well as employee complaints, in 1998. The most common concern was inadequate ventilation or lack of fresh air. Additional concerns involved temperature extremes, and the presence of mold and/or fungi within work areas. Inadequate ventilation and temperature control were noted particularly in facilities lacking forced air heating, ventilation, and air conditioning (HVAC) systems. Poor maintenance of HVAC components, incomplete knowledge of HVAC operating principals, and the potential impact of renovations on IAQ were noted as problems, also.

Concerns about molds and fungi were noted in several instances and were related to plumbing leaks or seepage. The majority of evaluations, however, were due to moisture from the exterior of the building. Most prominent were roof leaks. Further problems encountered involved unidentifiable odors and renovation projects affecting adjoining occupied areas. Poor work area isolation during renovations and/or poor communication between staff and contractors have had a negative impact on IAQ. Renovation activities often result in elevated levels of noise, dust, and chemicals.

B. University of Connecticut Health Center Division of Occupational and Environmental Medicine (DOEM)

Some of the occupational and environmental health clinics around the state conduct investigations of schools where illnesses are reported among teachers and students. In particular, the clinics at Yale and the University of Connecticut have assisted schools with investigations of this type. (See Section VIA4.) A summary of investigations conducted by the UConn Health Center is included here as typical of this kind of work. The University of Connecticut Occupational Health Clinic is part of the Division of Occupational and Environmental Medicine (DOEM).

DOEM provides research, educational programs and training, industrial hygiene consulting, problem solving and clinical care for occupational and environmentally related illnesses in Connecticut. Over the last five years requests have increased dramatically for clinical services, problem solving and research related to illnesses associated with school environments.

1. Clinical Activities:

DOEM physicians have evaluated and treated 39 teachers for a variety of occupational illnesses, seventy-five percent of them over the last two years. The teachers work in 19 school buildings located across the state. The first teacher was clinically evaluated in 1994. Twenty-two other teachers were treated for respiratory ailments including asthma, chronic sinusitis (sinus inflammation), chronic rhinitis (runny nose), dyspnea (shortness of breath), and cough. Inflammation of the larynx (vocal cords) and voice loss was noted in four patients, and headaches, vertigo or dizziness (central nervous system disorders) were diagnosed in seven individuals.

To better understand the cause(s) of the health symptoms that teachers experience, a DOEM industrial hygienist and/or indoor air quality specialist may evaluate the teacher's worksite –the classroom and school building. This evaluation serves to guide the physician in treating the ill person and also can identify problems that may be adversely affecting others in the same work environment. Sources of bioaerosols and chemical contaminants, ventilation, and thermal comfort are reviewed.

In conjunction with patient care, the DOEM has recommended changes at over ten Connecticut school locations. This has included specific improvements in a teacher's work area such as repairing exhaust fans, removing old, soiled carpeting, replacing ceiling tiles, as well as recommendations for the school district to procure expert engineering advice. Where school systems have remedied the identified causes in the school buildings, many of these teachers have been able to remain in their jobs. Temporary removal from work for the dual purpose of recovery and remediation has been an important aspect of their treatment. In some instances, teachers have been successfully transferred to other school buildings. In others, teachers have had to leave their work.

2. Consulting and Research:

Some Connecticut school systems have asked DOEM to evaluate schools where health complaints from teachers, students and their parents have strongly suggested IAQ problems. Researchers at DOEM developed a protocol which includes risk factor and health questionnaire surveys of students and teachers, and pulmonary function testing cross week (Monday morning before school, Monday afternoon and Friday afternoon). Additionally, a current research program at DOEM entitled **Interstitial Lung Disease: Moisture, Molds, and Buildings,** and funded by EPA has included some exploration of the role of bioaerosols in the indoor school environment on respiratory health in teachers and students.

The results from two pilot research programs, one comparing teachers' health at schools with and without moisture problems and the second following a small group of asthmatic children over three years of middle school, imply a relationship between school building occupancy and respiratory health. In the first program, DOEM compared six Connecticut school buildings, looking at the relationship between building characteristics, moisture in particular, and the health status of the teachers and students who occupy the school. Three schools were initially identified by a teacher who visited the clinic and whose school had an identified moisture or mold problem; three other schools were selected in the same school districts that were thought, by the school administration, to have no significant moisture or mold problems.

An IAQ scientist completed the environmental evaluations at each school and then designated four "wet" and two "dry" buildings. DOEM surveyed teachers and staff and monitored their breathing function before and after school over a week. The study documented that teachers at the "wet" schools had significantly more frequent chest symptoms and were 3.9 (ci 0.9-17.9) times more likely to experience work-related asthmatic respiratory symptoms than teachers at "dry" schools. (The lack of statistical significance of the results may well be due to the small number of teachers in the two "dry" schools.)

In a longitudinal program, the DOEM tested the breathing function by spirometry of twelve asthmatic school children who attend a school known to have high mold and moisture levels by spirometry in 1996 (fifth grade) and in 1999 (ninth grade). The children experienced a small decline in spirometry (breathing function) from the Monday after returning to school from a week winter vacation to the Friday of that week in both years. When measured as a percent of that predicted for the child's age, sex and height, there was also a slight decline in pulmonary function from 1996 to 1999. The number of children was small and the results not statistically significant.

With the understanding that many factors may detrimentally affect a school-age child's respiratory health, DOEM researchers have evaluated some available information on the ethnicity of a school district in one Connecticut town. Ethnicity has been thought to account for high levels of asthma in some schools. However, preliminary analysis of the number of asthmatic children attending specific schools together with demographic characterization of the schools suggest that a substantial portion of variation in the asthma prevalence in this town's elementary school students is not explained by ethnicity, and may be reflective of building conditions.

3. Cross-State Coordination:

DOEM, with support from the Connecticut Department of Health, each year organizes an occupational health surveillance conference for the New England States plus New York and New Jersey. At the May 1998 conference a panel representing state health departments from Connecticut, Massachusetts and New York noted the increased number of reports of respiratory disease from poor IAQ.

C. Connecticut Department of Public Health (DPH)

DPH receives hundreds of calls and complaints regarding IAQ each year. Twenty percent of the calls are related to IAQ problems in schools. Since 1994, DPH has received approximately 190 calls related to IAQ in schools. These calls usually involve only those situations that have risen to a high degree of visibility. Therefore this number likely represents the "tip of the iceberg" of school IAQ issues.

As discussed previously, DPH does not have a formal IAQ program and does not have regulatory authority to investigate school IAQ complaints. However, DPH does provide technical guidance and information on these situations. IAQ calls from schools cover a wide range of topics but the most common subjects are mold/moisture problems and tight building or ventilation problems. School IAQ complaints come from a wide variety of sources including local health department, parents, teachers, school administrators and school nurses. Health complaints sometimes accompany these calls but these complaints are often hard to categorize, and fall into the broad category of "Tight or Sick Building Syndrome." Therefore, specific health investigations are not usually called for or conducted by DPH.

Exceptions to this occur when a specific contaminant is released into the school where well documented environmental and/or medical follow-ups are warranted. An important example of this type of situation is a mercury spill in a school, and DPH has received a number of such calls. These usually involve accidental spill of mercury in a science laboratory or breakage of medical equipment (blood pressure gauges). There have been a small number of apparently intentional releases of mercury, where students brought mercury to school. When significant exposure to mercury is thought to have occurred, DPH will recommend appropriate medical follow-ups, in consultation with the Connecticut Poison Control Center at the UConn Health Center.

IAQ complaints from schools, received by DPH, are usually referred to another agency or outside consultant, if a field investigation appears warranted. Most frequently the caller is referred to their local health department or the Connecticut Department of Labor. DPH will remain involved in the investigation as a consultant and technical resource. Reports of indoor air sampling conducted in schools are often sent to DPH for evaluation. Recommendations based upon such reports are communicated back through the local health department or school administration. DPH also distributes generic fact sheets and other literature to schools.

D. Private Consultants

There are a number of consultants and commercial laboratories in Connecticut and adjoining states with expertise in environmental science and engineering and industrial hygiene. Such organizations are called upon to conduct investigations of IAQ in a wide range of buildings, including schools. In the case of investigations in schools, the consultant is usually contacted by the school directly or by the Board of Education. In many cases, the consultant is contacted based upon a listing of the consultant's name in a file of such consultants maintained by DPH. Usually the consultant keeps the DPH and/or CT OSHA informed of the work in progress and the nature of specific problems identified in the investigation. The spectrum of problems encountered in such investigations mirrors those found in studies carried out by DPH and CT OSHA. One of the most frequent category of problems is that associated with moisture and the development of molds and spores.

VIII. DEPARTMENT OF EDUCATION FUNDING FOR IMPROVING SCHOOL IAQ

In Connecticut, local school districts are eligible to receive state grant assistance for the construction, purchase, extension, renovation or major alteration of a building to be used for public school purposes. Grant eligibility is defined pursuant to Chapter 173 of the Connecticut General Statutes (CGS), which includes the associated administrative regulations. The level of reimbursement a given school district is eligible to receive for a project is based on the district's wealth ranking relative to all other districts in the state. The neediest district is eligible to receive 80 percent reimbursement, while the wealthiest district is eligible to receive 20 percent. Reimbursement percentage bonuses are also available under certain conditions defined in the Statute.

In general, construction projects for new buildings, new features to existing buildings, or projects to correct code violations are eligible for reimbursement. Once a year, projects for new buildings and those to add new features to existing buildings are submitted to the Governor and Legislature for consideration of a state grant commitment. Projects required for the correction of code violations may be authorized by the Commissioner of Education at any time upon submission of a completed grant application. Costs that are characterized as repair, replacement, or maintenance are not eligible for reimbursement.

Most IAQ issues are thought to be "violations of the code." At the present time, however, except for extreme situations (i.e., asbestos), there are no code *requirements* defining IAQ for existing buildings. There are recommendations, guidelines, and suggestions, but no code requirements. Codes pertaining to air handling and ventilation address only fire safety requirements and air volume for ventilation purposes in new buildings. The requirements defining minimum air circulation are found in the State Building Code and apply only when constructing new space. Natural ventilation (opening of windows) was, and still is, an acceptable and legal method of meeting code requirements for providing ventilation. Many schools in use today were designed and constructed to utilize natural ventilation. Problems inherent in the use of natural ventilation in schools were described in Section V.

In Connecticut, a facility is deemed to be in compliance with the Building Code once a Certificate of Occupancy (CO) is issued. Also, changes in the Building Code are not applied retroactively to existing facilities. Unless major new work is to be done, a building is considered to be in compliance with the Building Code once a CO is issued. Regardless of how the codes may change or what may be subsequently discovered about the building, it is still deemed to be in compliance with the Building Code. Although the code has provisions that allow the local Building Inspector to cite Building Code violations in extreme situations, the Inspector must undertake drastic measures in order to do this (i.e., declaring the building unsafe or unfit for occupancy.)

Herein lies the major complication for districts: In most cases, IAQ work in existing buildings does not qualify for reimbursement under the law. Most IAQ issues are the result of either a) prolonged improper maintenance, such as not changing of filters, cleaning ducts, replacing carpeting, and the like, b) existing mechanical systems that are in need of repair or replacement, or c) buildings that were originally designed and constructed to rely on natural ventilation. The only situation that may be eligible for reimbursement is a district that desires to install a mechanical ventilation system as a new feature into a facility that was originally constructed to be dependent on natural ventilation. However, this type of project must first be submitted to and approved by the Legislature for a state grant commitment.

In addition to the CGS Chapter 173: School Construction grants, noted above, the Legislature has authorized a total of $38.7 million for fiscal years 98/99 through 2000/01 to be used for major repair and maintenance items that are not eligible under CGS Chapter 173. This funding is available, however, to only a limited number of school districts and, although some grant recipients have used this funding to address IAQ needs, others have used the funds for other major repair and maintenance items such as boiler replacements, roof repairs, and replacement of old or damaged windows, doors, lockers, ceilings and lights.

In summary, if it is the desire of the state to allow for increased state reimbursement of costs incurred by local school districts for IAQ issues, then resources need to be made available to fix problems in school buildings that are adversely affecting the IAQ. The Legislature could make a determination that for IAQ issues resulting from repair and maintenance activities, the repair, replacement and maintenance costs would need to be defined as eligible for reimbursement. If these changes are not made, most of the costs associated with IAQ in Connecticut's public elementary and secondary schools will continue to be ineligible for state grant reimbursement under the school construction grant program. Finally, if feasible, formal code standards for IAQ could be adopted and incorporated into the Connecticut State Health Code which is administered by the Department of Health.

IX. CONCLUSIONS AND RECOMMENDATIONS

A. Conclusions

The following conclusions are drawn from this cooperative effort of Academy members, representatives from a number of state and federal agencies, and private consultants who made up the Study Committee:

1. Poor indoor air quality is an extremely important environmental issue since people spend most of their lives indoors where air quality is usually quite different than that outdoors. Indoor concentrations of certain pollutants are often much higher indoors than outdoors. Indoor air quality in schools is an especially complex topic since it includes elements of a variety of disciplines: chemistry and physics in identifying and measuring indoor contaminants and studying their release mechanisms; medical science in defining the effects of the indoor environment on the health of school occupants; engineering in selecting and designing the most cost-effective methods to improve indoor air quality (e.g., improved ventilation and air cleaning); administration, both in schools and in state agencies who must implement plans and enforce regulations for improving indoor air quality. Another factor that complicates the evaluation of indoor air quality complaints is the potential psychological effect that tends to exacerbate the perception of such problems.

2. Poor indoor air quality in schools is an especially serious problem since it can have a deleterious effect on the health of students, teachers and other school staff. At the very least, it produces symptoms, while not life threatening, which can negatively affect the mental concentration of students and teachers.

3. A report by the US General Services Administration on the condition of schools nationwide indicates that in Connecticut 68 percent of schools reported indoor environmental problems. While not a great deal is known about the number of specific indoor air quality problems among schools in Connecticut, hundreds of calls have been received by state agencies and consultants requesting assistance in solving these problems. From those studies carried out in Connecticut schools in response to complaints about poor indoor air quality, such problems commonly arise from poor design and construction, not adhering to established codes, inadequate ventilation, moisture intrusion and poor maintenance and operation of HVAC systems. The most important direct cause of poor indoor air quality is inadequate fresh air ventilation, regardless of what other factors may contribute to this condition. Another problem that has been identified is the carrying out of renovations during the school year. Such activities create large quantities of indoor pollutants which can disperse throughout the school unless measures are taken to isolate and contain such emissions.

4. There are countless types of indoor pollution, both chemical and biological, but the most frequent problems encountered appear to be those related to moisture intrusion in schools that encourages the growth of molds and other microorganisms. These agents can produce serious allergic reactions and other symptoms in sensitive subjects. Schools built with poorly designed and maintained flat roofs and constructed on concrete slabs with their inevitable cracks and other penetrations, are susceptible to moisture intrusion. This set of conditions, together with poorly designed, operated and maintained HVAC systems, account for most of the reported indoor air quality problems in Connecticut's schools.

5. Connecticut's schools are heated, ventilated and air conditioned using a variety of HVAC systems. These systems are often selected based on cost and are therefore usually inadequate in many respects. Poor maintenance and operation by untrained personnel exacerbate indoor air quality problems related to HVAC systems. Modular portable classrooms present a unique set of indoor air quality problems, largely because of the inadequate HVAC systems incorporated in such units.

6. Aside from problems related to moisture intrusion and the development of microbiological contaminants indoors, the selection of various materials used indoors such as carpeting, carpet adhesives and synthetic materials that emit odorous and irritating volatile organic vapors further degrade indoor air quality.

7. There is no formal organization in Connecticut with overall responsibility for indoor air quality issues. However, an *ad hoc* group has been formed, including personnel from the Department of Public Health, the Connecticut Council on Occupational Safety and Health, the University of Connecticut Health Center, the Yale Occupational Health Center, the Department of Labor and the Department of Education. The primary role of this group has been to encourage the application of the EPA's "Tools for Schools" program in the state's schools.

8. Except for some funding made available in recent years to a limited number of school districts, existing Connecticut laws permit state grant reimbursement only for code corrections, new construction, or for new features added to existing facilities. However, costs for the repair and maintenance of existing facilities (e.g., cleaning and repairing of HVAC systems) are not eligible for reimbursement at this time.

9. A number of other states have implemented formal programs with enforcement powers to control indoor air quality problems in schools. These programs could be models for Connecticut.

10. New construction and renovation of schools present unique opportunities to prevent indoor air quality problems before they develop. Renovation projects while the school is occupied must be carefully controlled to prevent exposure to students and teachers. With the large numbers of new schools currently planned or under construction, there is a great need to provide guidance to prevent future indoor air quality problems in buildings. EPA is about to release "Tools for New Schools" which should provide a basis for guidance in new construction (site selection, materials selection, roof design, ventilation design, and the like).

B. Recommendations

It is the general policy of the Academy to avoid providing recommendations for action to the elements of state government, unless it is asked to do so. In this instance, the Inquirer, Representative Jesse Stratton, has asked the Academy to make specific recommendations to the General Assembly for dealing with the identified problems.

The following recommendations are based on the findings in the main body of the report, and the above conclusions:

1. As pointed out in Section VI of the main text, there are several Connecticut state agencies already involved in important aspects of indoor air quality evaluations in schools and other public buildings and in evaluating possible health effects on the occupants of these buildings. Therefore, the General Assembly should establish a formal organization to improve and coordinate all of these activities and provide adequate funding to support these efforts. The key responsibilities of such an organization should include but not be limited to the following:

a. Develop guidelines, management practices and/or regulations for maintaining acceptable indoor air quality in schools. Such guidelines should establish minimum operating standards for HVAC systems (e.g., ASHRAE 62-1999), air cleaning as required, maintenance schedules and annual inspections of HVAC systems and other features of the schools that affect indoor air quality.

b. Establish guidelines and standards for new construction and renovations that minimize deleterious effects on indoor air quality from the materials and methods used in the construction. Such guidelines are available from the indoor air quality programs in other states and from certain construction trade associations.

c. Provide training to those who would be involved in carrying out various facets of the indoor air quality program in the state's school systems such as administrators, maintenance personnel, teachers, local health departments, consultants and state agency personnel.

d. Require schools and school districts to establish indoor air quality management plans and operational manuals, and designate an Indoor Air Quality Coordinator for each school or school district. Many of these requirements would be covered by mandatory implementation of EPA's "Tools for Schools."

e. Develop and implement a system to assess on a routine and "as needed" basis the indoor air quality in schools and the features of the building and its mechanical systems that affect indoor air quality. This system would provide for inspections of the school that would include evaluating the HVAC system, indoor air monitoring as required for air contaminants, including bioaerosols, and assessment of any health effects of students and other occupants of the school. This effort should include a system to evaluate and certify private consulting firms that provide inspection, monitoring and consulting services.

2. There are a number of possible approaches to the organization of a program to deal with indoor air quality in the schools of Connecticut. Two possible approaches are presented as follows:

> a. Formalize the existing *ad hoc* committee identified in CONCLUSION 7., design a management structure to coordinate and oversee these operations, and provide adequate funding to support this effort. The scope of work to be done would be the same as that outlined above.
>
> b. Designate one of the state's agencies currently involved on one of the key activities to be the lead agency for indoor air quality evaluation and control in schools and other public buildings, and provide adequate funding to support this effort. The scope of work to be done would be the same as that outlined above.

3. Once an organization has been formed in state government to address indoor air quality in schools, the plans that have been developed in other states should be critically evaluated to determine those elements most appropriate for Connecticut.

4. The General Assembly should empower and provide funding to the Department of Education to make Indoor Air Quality improvements and provide maintenance in both new and existing schools.

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Connecticut Academy

The Connecticut Academy is a non-profit institution patterned after the National Academy of Sciences to identify and study issues and technological advancements that are or should be of concern to the state of Connecticut. It was founded in 1976 by Special ACT of the Connecticut General Assembly

The Connecticut Academy Vision

The Connecticut Academy will foster an environment in Connecticut where scientific and technological creativity can thrive and contribute to Connecticut becoming a leading place in the country to live, work and produce for all its citizens, who will continue to enjoy economic well being and a high quality of life.

Connecticut Academy Mission Statement

The Connecticut Academy will provide expert guidance on science and technology to the people and to the state of Connecticut, and promote its application to human welfare and economic well being.

Connecticut Academy Goals

- *Provide information and advice on science and technology to the government, industry and people of Connecticut.*
- *Initiate activities that foster science and engineering education of the highest quality, and promote interest in science and engineering on the part of the public, especially young people.*
- *Provide opportunities for both specialized and interdisciplinary discourse among its own members, members of the broader technical community, and the community at large.*

179 Allyn Street, Suite 512
Hartford, CT 06103
Phone or Fax: 860-527-2161
E-mail: acad@ctcase.org   Web page: www.ctcase.org