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ABSTRACT

This guide is intended to help the building design, engineering, and maintenance staff of school buildings maintain a common standard of high indoor air quality (IAQ) and a productive and comfortable workplace for students and staff. The report defines the four basic classifications of indoor environmental pollution, lists the factors impacting school environments, and provides strategies for preventing indoor environmental problems. Also outlined is the role of the school administration in preventing indoor environmental problems. The guide describes the building systems approach to attaining healthful IAQ control and examines the seven main indoor environment issues to consider during the program, design, and construction phases of a new school. (GR)

HBI Healthy Buildings International Inc

Indoor Air Quality (IAQ)

Schools and Universities

Overview of Indoor Air Quality Issues, and

Preliminary Design Guide by

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Purpose and Scope of Indoor Environmental Quality Guide Document

This guide document is intended as an educational tool and reference manual for building design, engineering and maintenance staff of School buildings. It is recommended that all School District operations and locations, whether owned or leased, comply with these guidelines.

Where any state, federal or local codes or laws having jurisdiction at the locations impose more stringent requirements than those cited in this manual those codes or laws shall be followed.

The primary aim of this manual is to provide information to the District design, management and operations staff such that all District buildings will strive to maintain a common standard of high indoor air quality and a productive and comfortable place of work for all students and staff.

Introduction

For many years efforts to eliminate environmental pollution focused on outdoor air quality. This was precipitated by public complaints about industrial smog, automobile pollution exhausts, toxic waste sites, etc. Ironically, while industrialized countries were spending large sums of money addressing outdoor air pollution problems, the air quality of indoor environments was going virtually unchecked, particularly when most people today spend 80 to 90% of their time indoors.

More recently, the focus of public attention and environmental concern has turned indoors to a hazard growing in public perception, so-called Sick Building Syndrome. The Environmental Protection Agency (EPA) has found that indoor air can be over 100 times more polluted than outside air, and that about 30% of new and remodeled buildings will have indoor air quality problems in their lifetime.

One of the reasons why indoor air started affecting occupants in the late 1970's and early 1980's is that after the energy crisis in 1973, HVAC systems in new, better sealed, and better insulated buildings started to be designed with minimum ventilation rates of 5 cubic feet per minute (cfm) per person of outdoor air (down from the previous 15 cfm per person standard) to save energy. Much less outside air was supplied by the ventilation systems while at the same time less unplanned infiltration of outside air through the envelope of the building occurred. Windows were not operable. In addition, these modern buildings contained much more plastic and wood laminates, synthetic carpets and wall coverings, chemically treated textiles, and artificial lighting not always appropriate for the tasks performed. Maintenance procedures specified new, stronger cleaning products and pesticides, which incorporate known toxic chemicals. The pollutants emitted by these new synthetic products become trapped in the building due to minimal ventilation. Since the late 1980's school buildings have been designed with greater amounts of outside air, typically 15 cfm per person. This has brought on its own unintended consequences as described later in this document.

Whatever the causes, the incidence of environmental associated illness is increasing throughout the United States. Those related to buildings are generally classified as one of four main types:

1. **Building Related Illness (BRI)** This is an illness caused by an agent that can usually be identified by medical diagnosis and laboratory tests. Examples include bacterial infections such as Legionnaires' Disease and Humidifier Fever. In the case of such illnesses the percentage of building occupants affected is highly variable and may even be confined to one individual, and the symptoms persist whether the victims stay in the building or not.

2. **Sick Building Syndrome (SBS)** This may include a wide set of symptoms, such as headache, fatigue, eye, nose and throat mucous membrane irritation, upper respiratory problems, and etc. Usually more than 20% of building occupants are affected over many weeks. Significantly, most of the symptoms disappear when an afflicted person leaves the building.

3. **Multiple Chemical Sensitivity (MCS)** This has been described as the failure of humans to adapt to modern synthetic materials. The theory being that the great influx of man-made materials has resulted in a new form of medically unexplained specific sensitivity. Once sensitized an individual generally reacts to lower and lower concentrations of the causative agent or group of agents, as well as to other chemicals and foods. It is with respect to this "spreading" effect that the theory is inconsistent with medically accepted doctrines concerning allergic sensitivity to individual substances.

4. **Allergies** caused by buildings are acquired in much the same way as MCS. In neither case do we know how large the initial exposure dose is that causes the sensitization. We do know that individual response varies tremendously. Building allergies can be caused by dust, dust mites, microbial spores, animal dander, pollen, etc. Dust is generated from people's activities. Dust mites are microscopic creatures that live in carpets and thrive on human skin flakes. Microbial spores are emitted from growths of bacteria, mold and mildew on building materials and in the HVAC system. Animal dander is, for instance, cat and dog dander transported on people's clothes to the school. Inadequate filters or improperly fitted filters can allow pollen from outdoors to enter a building and cause hayfever type allergies. Studies in Sweden indicate that allergies have increased sharply in the past 20 years, and this increase may be related to the increase in sick buildings. It is believed that about 20% of the population in Sweden may be allergic today. Studies in the U.S. suggest a similar ratio.

Although members of the medical profession express doubt that SBS and MCS are distinct clinical entities, it is clear that a significant number of people show symptoms, from whatever cause, that do not conform to the present understanding of allergic diseases. Thus, while chemical exposure has often been attributed as the cause of these symptoms, other factors, such as biological contaminants, noise, lack of daylight, glare, poor lighting, low or high humidity, poor ergonomics, interpersonal relationships, stress and psychological factors, cannot be ruled out.

Furthermore, the number of true allergy and asthma cases is increasing dramatically in industrialized countries. No direct correlation to the school or work environment has been established or explored to explain this rise in allergies. However, as more people today spend large parts of their days in schools or indoor work environments, it seems logical that the rise is caused by the users' prolonged exposure to poorly ventilated, man-made environments containing pollutants. All the evidence shows that the indoor environment is continuously affected by a large number of different factors and forces that need to be balanced, minimized, or eliminated at the design and construction stages and then monitored throughout the life of a building in order for the building to be healthy. The indoor environment of a building is a result of outdoor environmental conditions of the site; decisions made during design and construction of both the HVAC system and the building; decisions made during renovations; the quality of operation and maintenance of the HVAC system; the quality of janitorial services; and occupant processes and activities. After it is built, a building is a constantly changing entity that has to be monitored regularly to maintain the integrity of the design intent and the quality of the indoor air.

Children are More Susceptible

Children may be especially susceptible to the effects of indoor air pollution for a number of reasons related to their physiology. This is because the same concentration of pollutant results in higher body burdens in children than in adults because children breathe a greater volume of air relative to their body weight. Also, children are less resistant to infections as their immune systems are still under development. It is also a fact that kindergarten and elementary school children spend much of the time occupied at floor level and thus their predominant "breathing zone" is not the normal adult one of about five to six feet above floor level.

This also means that these children are closer to the dust and dirt normally present on floors and carpets and, as is the nature of children, will inhale and ingest dirt and dust along with the accompanying bacteria and fungi, from fingers and objects.

Compromised indoor air quality may be harmful to the health of all children but it is of particular concern for children with asthma, hypersensitive mucous membranes, allergies and other chronic diseases of the nose, bronchi and lungs. This group is estimated to compose between 10 to 20% of all children and obviously to them the quality of the indoor environment is of even greater significance. The rate of colds and other airborne viral infections is much more likely to increase in schools with inadequate ventilation. Asthmatic children are at an increased risk since viral infections may not only be more severe in them but such an infection may trigger an asthmatic episode.

As an added burden to the ventilation system of public schools, occupants/students generally work together in small quarters. Simply reviewing the ventilation guides used in building codes reveals that a typical school can have up to seven times the occupancy level of a commercial office building. Another special problem faced by school ventilation systems is that heat gains vary over brief periods of time as relatively small rooms are fully occupied and then emptied multiple times throughout the day. This has caused condensation and fungal problems caused by poor control of latent loads which frequently prove very expensive to resolve. Throughout the country, however, budget limitations create perhaps the biggest challenge, forcing the selection of a low specification air handling system, if any, and minimal maintenance investment. The use of portable classrooms also has the potential to create IAQ concerns due to the use of high emitting interior products such as pressed woods and laminates, combined with low ventilation and a high interior surface to room volume ratio. These factors matched with the variety of space requirements, and therefore varying pollutant levels, and a frequently complex political environment creating lengthy decision-making periods create a unique problem solving process in the design of a school system.

Nevertheless, indoor air quality issues in schools should not be taken out of the context of indoor air quality of buildings in general. The Congressional Office of Technology Assessment (OTA) released a major report in September of 1995[1] that found that indoor air quality threats were no more serious than those found in other large buildings. The report grouped IAQ problems in schools arising from poorly designed and maintained ventilation systems, and from poorly handled indoor sources such as art, science and janitorial materials. Overall, however, the report stated that little evidence exists that these products are creating significant health hazards for children.

Factors Impacting School Environments

Building Factors Identified in Building Studies

Indoor contaminants can derive from the outdoors, from sources in the building structure or HVAC system, from the operation and maintenance of the building and its equipment, from the building contents, or from the building occupants or their activities. Contaminants can migrate horizontally or vertically within the building. The following are a list of common contaminant sources that need to be recognized, measured, and often controlled:

Contamination from Outdoor Sources

- Pollen, dust, fungal spores
- Industrial pollutants
- Ozone
- Vehicle exhaust
- Odors from dumpsters
- Contaminated cooling tower drift
- Dust from nearby construction sites
- Re-entrainment of building exhaust
- Radon gas in soil
- Leakage from underground fuel tanks
- Soil contaminants from previous uses

[1] Risks to Students in Schools OTA-ENV-633

- Pesticides in soil

Contamination from Indoor Sources

- Microbial growth in building shell, HVAC system, and materials
- Microbial growth on interior finishes
- Fibers from torn interior insulation in the HVAC system
- Improper use of toxic biocides, pesticides, and cleaning products
- Environmental tobacco smoke (ETS)
- Dust, VOC emissions, and noise from renovations
- Dust, dirt, and rust accumulation in HVAC system
- Improper venting of combustion products
- Volatile organic compounds (VOCs) emitted from interior finishes, furnishings, textile finishes and consumer products
- Ozone and VOCs emitted from office equipment such as printers and photocopiers
- Dust and dirt displaced by improperly filtered vacuum cleaners
- Emissions from special use areas such as kitchens, toilets, smoking lounges, labs, vocational arts processes, cafeterias, etc.
- Carbon dioxide generated by occupants
- Occupants' body odor and perfumes
- Occupants' illnesses

Additional Factors

Many other factors contribute to IEQ complaints, including

- Some HVAC energy efficiency measures
- Temperature
- Relative humidity
- Air speed (drafts)
- Electric lighting quality
- Lack of daylight
- Glare
- Unwanted solar heat load
- Noise
- Electromagnetic fields (EMF)
- Ergonomics
- Stress
- Psychological factors

Preventing Indoor Environmental Problems

Existing Buildings

The age of existing buildings has a bearing on how difficult or easy it is to provide good air quality. Older buildings may have such problems as fraying interior insulation in the HVAC system or obsolete and erratic controls, while a building built during the 1980's may have an HVAC system designed to bring in such small amounts of outdoor air (to save energy) that present minimum standards for proper dilution of contaminants cannot be reached. Some school buildings are configured with many windowless or nearly windowless spaces, and others are located so close to a major noise or air contaminant source that drastic measures must be undertaken to provide a healthy indoor environment.

Administrators of an existing school building generally have no choice but to make the best of the design of the building and its systems. Our experience is, however, that many IAQ, or more strictly indoor environmental (IEQ) problems can be resolved satisfactorily in most existing buildings at a relatively low cost.

The Role of the School Administration in Preventing IEQ Problems

The School District should assign a staff member or team responsible for the building's IEQ. This team would be responsible for:

- Supervising that the operation of the school buildings and their systems, executed in the manner described below, called the **Building Systems Approach**. This approach is based on a group of ASHRAE Standards with the common goal of good indoor air quality and comfort.
- Familiarization with IEQ issues by reading this design guide thoroughly, attending IEQ seminars such as those offered by HBI and other groups, and by acquiring and studying reference books on IEQ.
- Developing IEQ profiles of District buildings and their systems. This includes the collection and review of records, visual observations during walkthroughs, and an inventory of major pollutant sources in the District.
- Scrutinizing existing maintenance programs of the District buildings and their systems to check that they adequately protect IEQ and include lists of actions and proactive measures laid out in this guide.
- Educating teachers, parents and students about indoor environmental issues through pamphlets and seminars and explaining how a complaint would be handled.
- Establishing lines of IEQ communication between school administrators and staff, hich should be outlined in writing. The method by which occupants or staff can file a complaint and the time needed for a response should be outlined in writing.
- Identifying present or future activities within the District that may impact IEQ and should be monitored carefully by the District IEQ staff. Consider the list of factors that affect good IEQ. Some of them can be resolved at little cost, others may

have to wait until next time you renovate or build a new building. But they must be taken into account when trying to determine what may have caused a complaint.

- Appointing additional staff and contractors as needed to help evaluate the building and its systems, pollution sources, manuals etc.

- Contributing to the continual improvement of the formal District management policy on IEQ problems and their handling.

Building Systems Approach to Provide Good IAQ Control

A school building is a dynamic entity with often-changing pollutant, heating and cooling loads. The ventilation system is the lungs that allow the building to breathe. A well designed and functioning ventilation system will respond to any change in loads before it affects the occupants. This ideal condition is often difficult to attain in schools, however the Building System Approach should be applied at the design stage and continued through construction, commissioning, operator training, and on-going building operation and maintenance. However, HBI has found in its extensive experience with existing buildings that the Building Systems Approach can be applied to most existing buildings with great success. It requires interaction between many disciplines and proper IAQ education of key systems operators. The common goal is to ensure the health and comfort of building occupants over the life of the building.

Elementary Rules of the Building Systems Approach

Adherence to the following standards and guidelines is instrumental to a successful application of the Building System Approach.

- ASHRAE Standard 62-1999 (for ventilation)
- ASHRAE Standard 55-1992 (for comfort)
- ASHRAE Standard 52-1992 (for filtration)
- ASHRAE Guideline 1P (for commissioning)

These standards and guidelines should be studied by all relevant building personnel and equipment operation and maintenance manuals should be changed accordingly. Some equipment may need to be modified.

There is more attention being paid in the construction industry to the issue of IEQ at the design and construction stages of a building's life. This approach recognizes the benefits of prevention over cure in treating building system ailments. Often such a strategy can head off air quality problems before the building is occupied and an operating history is established. Such foresight also sets the foundation for a permanently healthy building and lessens the chances of problems later during its occupied life. Perhaps most important is the use of formal attention to environmental design as a communication tool to building occupants. This tool can leverage the aforementioned heightened awareness of the indoor environment among parents, students and teachers to help get buildings accepted and keep them that way.

There are seven main indoor environmental issues to consider during the program, design and construction phases of a new school.

1. **Site Plan** The physical site that the future building will occupy and its outdoor environment must be studied with respect to how they will likely impact the future indoor environment. Prevailing weather and wind patterns, ambient air quality, and major outdoor sources of pollution should be considered.

2. **Building Configuration** The building configuration may impact the migration of pollutants both from the outside to the inside, and within the building both vertically from one floor to another and horizontally across floors. Issues to be scrutinized include: location and orientation of building air intakes, exhausts, and stacks, planning of vehicle access, parking, and garages, pollutant pathways, apertures and glazing in relation to solar heat load and IAQ.

3. **Heating, Ventilating, and Air Conditioning (HVAC) System** In today's tight, sealed, energy efficient buildings the majority of the indoor air is introduced through the HVAC system. Proper design of these mechanical systems, therefore, is imperative to the creation of a healthy indoor environment. The design team must review the projected occupant densities, activities, and locations in the building and ensure proper respective ventilation rates and distribution. This task includes critical attention to ventilation flexibility, core versus perimeter loads, control systems, humidification/dehumidification, filtration systems, dedicated exhausts, occupied space layout, and energy recovery technology. Particular areas of concern are laid out in more detail as follows:

   - Outdoor (Fresh) Air in Building Air Supply The minimum requirements of outdoor air for all types of buildings and spaces can be found in ASHRAE Standard 62-1999. The specification section of this documentation package describes these requirements as they pertain to minimum requirements of outdoor air for various school spaces.

   - Temperature and Relative Humidity (RH) What is considered appropriate temperature and relative humidity levels indoors may vary from location to location in the larger School Districts, but they must remain constant in each season, with slightly higher temperatures being acceptable in summer. ASHRAE Standard 55-1992 recommends comfort ranges and the specification section of this documentation package will spell these requirements out. Studies in the U.S and Europe have shown however, that by targeting the temperature in a building at the lower end of these seasonal ranges, one can significantly reduce health and comfort related IAQ complaints. This however may not be consistent with energy goals set for specific School Districts, and a balance will have to be achieved.

     When relative humidity falls below 20%, the mucous membranes of the nasal passages, throat, and eyes begin to dry out, possibly rendering them more susceptible to microbial infections and often causing contact lens wearers particular discomfort. At these dry conditions, static electricity also builds up and causes discomfort, and airborne dust and spore levels will increase and aggravate any health problem. At the other end of the scale - at relative humidity levels of 70% and above - the amount of moisture in the air is so great that condensation is likely to occur on cooler surfaces. The resulting film of moisture will allow ever present microbes, such as molds, mildews, bacteria and fungi to multiply and add their spores and by-products to the air to be breathed by occupants of the building.

- Filters in HVAC Systems Filters should be selected based on the ASHRAE Standard 52-1992, which requests that filter manufacturers specify both a weight test and a dust spot test for each class of filter. Filter efficiency requirements will be found in the specification section of the documentation package. Filters should also be well fitting. The outdoor air quality should be considered, when specifying filter efficiency.

- HVAC System Controls Digital control equipment linked with sensors based on air velocity movements are proving to be far more reliable than the older style pneumatic systems. However, any well functioning control system will help provide good air quality; the problem is that many older systems do not function well. The latest generation combined systems controls, such as Energy Management Systems in place at more developed School Districts can be very helpful in maintaining good IEQ. Furthermore, new systems are being adopted that fully control for outdoor air volumes even when pressure differentials in mixing chambers vary, as is common in VAV systems. VAV systems with economizers, which today are very common in school buildings, can cause serious IAQ problems unless well controlled and understood however.

- Maintaining Correct Pressurization Within Building A school building should be under slightly positive pressure. Some areas, including special use areas with dedicated exhaust such as art areas, should be under negative pressure in order for cleaner building air to flow toward the more contaminated areas, helping dilute the contaminants, and finally being exhausted. Air from special use areas should not be recirculated, unless it has been subjected to cleaning with filters appropriate for the contaminant produced.

- Commissioning of HVAC Systems Commissioning applies to newly constructed buildings but existing buildings can apply these same standards. Design documentation can be compared to actual usage and conditions of occupancy, and the equipment can be adjusted to any changes that are found. Original design criteria should include ventilation rates under all projected modes of operation of the HVAC system; basic HVAC system and component selection, along with sizing and capacity ratings; summarized projected occupant activity, density, and locations on which the HVAC design was based; location of outdoor air intakes; any major outdoor sources of pollutants in the vicinity; and prevailing winds. Should this information not exist, an effort should be made to contact engineering and architectural firms involved with the original design. These steps have a highly beneficial effect in overall long term building operation.

4. **Maintainability** The ability to conduct frequent and effective maintenance on the HVAC system during the building's operational life is another critical step towards a healthy indoor environment. This ability can be greatly enhanced via full consideration of maintainability at the design stage. Proper access points to critical areas of the HVAC system must be included in the design. Building and mechanical system materials best suited for resistance against corrosion, microbial contamination, and other IAQ factors should be identified. Insulation material characteristics should be included.

5. **Interior Material Selection** The materials for the interior spaces should be selected carefully with regard to their future impact on the indoor pollutant loads. The general principles of making sound environmental material selection decisions must be customized to the specific indoor environment planned. Material selection criteria to be judged include offgassing, fiber release, microbial support, sink effect, durability, proper installation, and maintenance for good IAQ. There is a growing database of environmentally friendly interior materials to reference for this task. Such as architectural coatings and roof coverings, federal and state laws are being passed to limit the amounts of pollutants that they may contain.

6. **Building Commissioning** This process, also mentioned above for HVAC systems, is especially important in newly constructed schools. The period of time shortly before a building's completion and subsequent occupation can be the most problematic. New interior materials, HVAC system, and building administration personnel combine with the usual stresses of a school start-up create a sensitive situation. Often a "sick building" reputation can be acquired during this phase and future efforts to shake the reputation are difficult. A formal plan encompassing final HVAC installation and start-up, initial ventilation strategy, design documentation, operation and maintenance training, and remaining pockets of construction go a long way towards avoiding unnecessary complications.

7. **Proactive Monitoring** The key to a good indoor air quality proactive monitoring program is the establishment of a baseline database from an initial inspection. This can be conducted by in house staff or an external third party. This database is then used as a reference point against which all subsequent inspections can be judged. The initial indoor air quality investigation should involve an analysis of the building's air supply systems' maintenance, operation, and filtration, in addition to a full range of testing for indoor pollutants. Subsequent inspections can monitor recent trends (positive and negative), compare the building with similar structures in the District inventory, and verify the effectiveness of any plant, maintenance, and/or operation changes which have been made in the building since the last inspection.

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