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WHAT ARCHITECTS CAN DO TO IMPROVE INDOOR AIR QUALITY

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Abstract

The impact of architects' work on indoor air quality is significant. Very little has been done to guide architects towards improving indoor air quality in practice. Much indoor air quality research and applied work reported in the literature can be interpreted or "translated" into concrete actions available to architects to improve indoor air quality in the buildings they design. This paper examines the role of architects in the building process and presents practical, task-oriented suggestions for effective actions. It is presented to increase researchers' understanding of the building design process and the architect's role and also to increase architects' implementation of practices which can improve indoor air quality. Measures discussed include design, building construction, pre-occupancy evaluation, operation, maintenance, and post-occupancy evaluation.

Introduction

Although building design and construction have major impacts on indoor air quality (IAQ), only a few efforts have been made to assist architects improve IAQ in the buildings they design. Conferences have been held, some papers have been published in professional journals, and monographs directed at professional designers have been prepared (1,5-7). There have been many monographs dealing generally with indoor environment (including IAQ) and health, some of them prepared years ago (2-4). Most of these previously published materials have not focused on what architects can do to improve indoor air quality. This paper provides some guidance, albeit very general, to building designers interested in improving IAQ. The paper can also inform indoor air researchers regarding architects' perspectives on IAQ so that research might better serve building designers' needs.

The practice of architecture varies considerably from country to country, within countries, and from project to project. Architects' roles are defined by the services they contract to provide in a particular project. Architects are responsible for construction as well as design, except in the United States where architects' construction responsibilities are usually limited to contract administration.

In this paper "architect" refers to the chief design professional(s) in a building project. We will consider "architects" in the broad sense of the individual (or firm) with primary professional responsibility for design and construction -- the single party responsible to the client for the new or remodelled structure. Since architects usually employ, direct, supervise and approve the work of the other members of the design team, explicitly included as responsibilities of the architect are the functions of mechanical, structural, electrical and civil engineers and the other specialists.

Architecture is a reiterative process, progressing from general, conceptual and strategic decisions early on to specific, detailed, tactical ones. The design process results in a set of drawings and specifications (known as construction documents) from which the building is constructed. Architects continue to be responsible to the client to see that the design intent and the construction documents are actually implemented.

Architecture, engineering, and interior design have major impacts on IAQ. Opportunities exist during every work phase for designers to improve indoor air quality. This is especially true of large buildings where sizeable quantities of building materials and equipment improve the architect's and the builder's negotiating strength with manufacturers and distributors. The work phases include project planning, site design, building design, production of contract documents, construction, launching or "commissioning," and evaluation of completed buildings.

The architect's influence is greatest during design and decreases as the building moves through construction into occupancy. Decisions early in the process on the design concept strongly impact IAQ. The details of the design and their implementation also have important IAQ consequences. Major design elements impacting indoor air quality include siting, orientation, building configuration, ventilation, illumination, thermal control, moisture control, structural and finish materials, building equipment, and furnishings. What follows describes many of the important phases of building projects and the opportunities for architects to improve IAQ.

Planning phase

Planning a building project involves economic, space and functional feasibility studies; scheduling the project from design through occupancy; determining construction and long-term financing; programming; and assembling the design team. The impacts of design decisions often outlive the original owner's or occupants' interest in the building.

Budgeting. The architect is responsible to design within the client's budget and to advise the client regarding the estimated cost of the project as the design process advances. Architects' efforts to improve IAQ can be constrained by the reluctance of clients to commit the additional resources necessary. Expenses not currently part of normal building project budgets can be required to employ specialized design expertise, assess candidate building materials and equipment, and schedule sufficient time to commission properly and to test completed buildings. The majority of building developers are not aware that early attention with front end expenditures can reduce or eliminate the negative economic consequences of post-occupancy IAQ problems.

The design team. The architect serves as the lead designer who assembles the design team and orchestrates its work. Architects have ultimate responsibility for the design and for determining that the completed building fulfills the design intent.

The design team consists of engineers, interior designers, specifications writers, specialized consultants, and construction experts. The architect can include consultants with special competence in understanding and resolving indoor air quality issues. Some authors suggest that architects recommend to their clients that indoor air quality or indoor environmental consultants be retained on every building project. Such an arrangement can help architects limit their professional liability, and can

provide the necessary expertise to assist architects while also providing the additional fees required for indoor air quality specialists.

The architect's selection and direction of the mechanical engineering consultant is critical to indoor air quality. The architect must walk the delicate line between interfering in the engineer's area of expertise and abdicating responsibility for the habitability of the completed building. The mechanical engineer is employed by the architect, not the client. Some architecture firms have in-house mechanical (and other) engineering staff so that the responsibility, if not the work, is more integrated.

The architect's responsibility for the design consultants' work includes integrating their various design inputs. Building problems often arise from inadequate coordination of design consultants. Only the architect has the authority and responsibility to integrate successfully the many specialists work.

Programming. During the "programming phase," architect and client define the goals and objectives of the projected building; specify the spatial and functional requirements; and establish the criteria and standards to be used in evaluating alternative design proposals. Air quality and other indoor environmental quality performance standards can be explicitly set forth in programming.

During programming, occupant activities anticipated in the building should be identified in terms of their potential to generate indoor air pollutants or their sensitivity to indoor air pollutants. Food preparation, printing, duplicating, copying, mailing and other office associated activities can be sources of significant indoor pollution. Architects can identify and provide air quality control for such functions.

Design phase

During site planning and site design architects can assess and address adjacent and nearby environments including potential sources of air pollutants and develop a design which minimizes their negative impacts.

Control of on- and off-site environmental pollutants requires identification and characterization of pollution sources and control methods, and implementation of effective control methods. By assembling and reviewing weather, air quality, soil, and traffic data available from local, state and federal agencies, architects can evaluate the potential sources, characteristics, source strengths and points of origin for air contaminants.

Building design. The earliest "schematic design" stage of building design offers an excellent opportunity for architects to improve indoor air quality. The basic building concept includes siting, configuration, orientation, interior layout, fenestration, general thermal control, ventilation strategy, illumination, structure, and major materials, among others. Examples include such things as the use of operable windows for supplemental ventilation, or locating mechanical ventilation system intakes away from air pollution sources such as garages, roads or building exhausts. Outline specifications prepared with conceptual design drawings should include air quality related performance criteria of the ventilation system, major materials and furnishings.

Building configuration. The building form - its size, shape and exterior openings - can have significant impact on ventilation and air quality. The building configuration and orientation impact the general ventilation scheme, thermal control and illumination scheme, floor plans and activity layout. These factors in turn influence indoor air quality. By considering IAQ while designing the building form, architects can significantly improve indoor air quality. An energy-conserving basic building design can reduce the cost of maintaining acceptable indoor air quality through adequate ventilation.

Building ventilation. Ventilation's role in controlling air quality in buildings is significant. The specifics of the mechanical ventilation system are usually designed by mechanical engineers. The general approach and performance specifications to which the system is designed are the architect's responsibility. The designed air exchange rate, the choice of constant or variable volume air supply, the use of pneumatic or electronic controls, the general location of intakes and exhausts for the building and each space within it exemplify important indoor air quality determinants.

Architects should consider the following important factors in designing building ventilation systems: 1) The quality and quantity of outside air supply under various climate conditions and HVAC operational modes; 2) supply air conditioning (filtration, humidification, thermal control); 3) air distribution system type, materials, equipment, and controls; and, 4) operation, maintenance and monitoring of ventilation systems.

Architects should review the engineer's efforts to optimize indoor air quality, comfort, and the ventilation system operational cost. They should consider the distribution of costs between construction and operation, and between building management and tenants.

Thermal control. Occupant comfort, air pollutant emissions into indoor air from building materials and furnishings, occupant perceptions of air quality, and pollutant removal rates or dilution rates are affected by air temperature. Thermal regulation systems can generate, exacerbate, or reduce indoor air pollutants. Where ventilation systems are used for thermal control, designers should consider temperature and air quality together.

In the "design development" phase the schematic or conceptual designs are made more concrete. Selecting and sizing major building components such as ventilation fans and ducts, heating and cooling units, filters, insulation, HVAC system controls, principal building materials, and many other components translate the design concept into more specific details. The architect's concern should be continued consideration of indoor air quality implications of alternative design options.

The decisions made at this stage will have significant impacts on ventilation efficiency which can indicate the potential of the ventilation system to provide acceptable indoor air quality. "Ventilation efficiency" is a term for the air exchange or pollution removal performance of the ventilation system. Ventilation efficiency concerns air quality in the so-called "breathing zone," between 0.8 and 1.4 M above the floor for most seated, walking or standing building occupants. Ventilation efficiency varies significantly among buildings, within buildings, and even in a single location under differing operating conditions. It indicates the presence of far less than the designed ventilation rate, often between 50 and 75%, in the breathing zone. Design and operating conditions affect ventilation efficiency.

Architects can improve ventilation efficiency by carefully locating and sizing air supply and return registers within the conditioned space. This might include architectural decisions to locate supply registers in the floor or walls rather than the common current practice of locating them in the ceiling.

Specification of ventilation efficiency along with outside air exchange rates or outside air supply rates allows architects to determine the actual air exchange rate to be achieved by the installed system. During design, measurement of ventilation efficiency in a mock-up or model of the designed space can assist in adjusting critical design variables to improve HVAC performance. Measurement in the completed space can be useful in determining actual HVAC system performance.

Production of contract documents

Production of working drawings and construction specifications, as they are often called, presents architects with many opportunities to make detailed decisions to implement earlier design concepts. Specific designations of materials, equipment and layouts are developed in the preparation of the contract documents. Products are considered and selected. Here architects can exert enormous influence on clients as well as on the providers of the products. Architects can require potential product suppliers to develop and provide bettter information on the chemical contents of their products and their performance (such as emission rates of critical substances). They can provide clients with clear analyses of the air quality implications or trade-offs in important materials or equipment selections. Specifications can include performance requirements such as ventilation efficiency of HVAC systems or chemical emissions of major finishes and furnishings.

Interior design. Interior design and use of space can have significant impacts on indoor air quality and comfort. The interior space layout and uses should be considered in terms of the pollution-generation and pollutant-sensitivity of occupant activities, pollution-exposed areas, and practical measures to mitigate contamination. Special activities which will generate pollution (e.g., printing, duplicating, mailing, food preparation) should be identified. Available alternatives to mitigate the impacts of occupant-generated pollutants should be descriped, analyzed, and recommended.

Building materials selection and specification: Materials employed in the construction of the building can have significant impacts on indoor air quality. Many materials are known emitters of toxic or irritating chemicals. Failure to evaluate and carefully select materials can result in unnecessary, costly, and troublesome contamination of indoor air.

Architects can evaluate candidate products and materials in terms of their projected chemical emissions rates and the chemicals' effects on occupants. Important materials are those whose use is extensive, whose emissions are large, either short or long term, and whose volatile contents are known toxins or irritants. Some of these materials are carpet systems (i.e., carpet, pad, and adhesive); flooring systems (i.e., floor covering, subfloor or underlayment, and adhesives); ceiling tiles; wall covering systems; thermal insulation, fireproofing, caulking materials and sealants exposed to indoor air; and, ductwork and additional materials in contact with the supply or recirculation air stream. In addition, furnishings and equipment within the scope of architectural services should also be evaluated.

Architects can develop supplemental instructions to issue to potential vendors with the bid documents. These instructions can require submittal of complete information on the components of the products being offered. The information thus obtained can be used for product and materials evaluation based on published information or lead to further inquiry with the component suppliers.

On the basis of the review described above, architects can evaluate bidders' or offerors' submittals and recommend selection, further evaluation, or testing. By review of product literature and published data, architects can determine whether candidate products produce an unacceptable level of air contaminants. Negotiation with suppliers can result in implementation of measures to limit the toxic or irritating chemical content or emissions of selected products by changes in design or manufacture. To reduce source strengths in the completed building, performance specifications may be issued with respect to material contents, emissions rates, design details, packaging, shipping procedures, and installation.

Installation of furnishings. Many newly-manufactured building materials and furnishings emit a major portion of their lifetime chemical emissions during the first few hours, days, or weeks they are exposed to the environment. Air circulation at their surfaces is critical to the release of chemicals. Elevated temperature, humidity, and exposure to ultra-violet light can also accelerate off-gassing.

Loading an enclosed structure with products which are releasing large quantities of chemical pollutants into the air results in contamination of the building fabric. Many of the chemicals are adsorbed on the surfaces of building materials and furnishings, then released into building air later. The length of time when a newly-finished or -furnished building contains high levels of chemical contaminants is thus extended.

Most products receive limited exposure to the environment after manufacture. They are usually packaged and prepared for shipping or storage promptly after manufacture. Therefore, the packaging, shipping, and installation process presents many opportunities to limit the contribution of interiors materials to deteriorated indoor air quality in the completed structure. Architects can specify procedures to reduce the amount of unstable chemical contaminants entering the building or building air. These include packaging and shipping procedures, unpacking and loading into the building, installation practices, and building ventilation during delivery and installation in the building. Maximum exposure to air circulation and warming prior to entering the building will decrease negative indoor air impacts.

Construction process

General considerations. The construction process offers many opportunities to observe and correct problems before the building is completed and occupied. The review from an environmental quality assurance perspective of change orders, shop drawings and other submittals and of installations in the field can be cost effective in avoiding construction and occupancy delays, call-backs, and problems in the occupied building.

Implementation of methods and procedures available during construction can limit the pollutant load in the completed structure. Phasing and scheduling of activities like installation of carpet and ceiling tile, temporary ventilation, and control of strong air pollutant source materials entering the enclosed structure can be used effectively to reduce airborne pollutant levels during construction. Excess levels during construction will extend the time after completion when levels will be elevated.

Properly completing construction close-out, commissioning the new building, and training of operating personnel will further reduce problems in the newly-completed and -occupied building. Attention to indoor environmental quality assurance during this phase of the project is a frequently-neglected and critical determinant of the building performance.

Change-orders, shop drawings. Changes made and details supplied by contractors or designers during construction can significantly impact indoor air quality. These changes are often made in response to previously unanticipated problems or events during construction. The change order and shop drawing approval process often fails to ensure that the new detail meets the design intent and the established performance criteria.

Architects and their consultants can review, evaluate and follow-up on change orders, field orders and shop drawing approval requests for items determined significant to indoor environmental quality. This might include HVAC system components, insulations, sealants, finish materials, and furnishings, among others. The list of items requiring special attention with respect to IAQ should be identified by the architect and the HVAC consultant.

Temporary ventilation. The provision of temporary ventilation during construction can control air levels of chemicals which can contaminate building materials. Large surface area materials such as thermal, sound and fire insulations; textured plaster; wood; carpets or fabric can become "sinks" for chemicals as their air levels increase. Subsequent re-emission can cause elevated contaminant air levels in the completed structure. This increases the risk of occupant complaints or health problems and may require special ventilation to control contaminant air levels, an added but avoidable cost.

The architect can review the construction schedule and phasing to determine the need for temporary ventilation. Temporary ventilation recommendations described here are not intended as a substitute for oversight or review of compliance with labor laws applicable to construction workers. The purpose is solely to reduce the pollutant burden in the completed structure by mitigation measures during construction. Specific details can be made part of the general conditions of the construction contract. Review of construction documents and consultation with the client can help the architect determine feasible means of providing temporary ventilation. Analysis of available alternatives and recommendations for temporary construction ventilation procedures and schedule can also be specified contractors' responsibilities.

Progress inspections. Inspections by owner's agents and architects tend to focus on compliance of construction with contract documents, scheduling issues, and determinations related to field orders. The intent or function of the building materials or equipment is often overlooked and the result is poor building performance. If the performance goals and criteria are kept in mind, the architect's site visits can be useful in identifying construction or design problems which will affect indoor air quality. Architects can identify critical components to be inspected during construction and develop a plan of construction site monitoring or quality control related to indoor air.

Air balance work determines air velocities or static pressure changes to compute air flow volumes at various HVAC locations. This is done under full flow conditions to adjust the flows of individual HVAC system components to design specifications. Air balancing does not reliably estimate the delivery of air or removal of pollutants in the breathing zone. Nor does air balance work verify the performance of the system under load, heating or cooling. Architects can require that determinations of the systems performance under load and ventilation in the breathing zone be part of the HVAC balance and final approval process. (See the discussion of ventilation efficiency above.)

Commissioning and Break-in Process. While increased attention has focused on the commissioning process recently, time and economic constraints often limit the implementation of good practice. Many indoor air quality problems are probably due to false economies in the commissioning phase. It is this period during which the building owner can best determine whether the product (the completed building) represents what was contracted with the prime design and prime construction contractors. Contract documents should specify both the procedures to be used to ascertain this conformity and the means for resolving conflicts.

Architects should review and analyze the effectiveness of training programs included in control system or HVAC equipment construction contracts. This includes an evaluation of materials, equipment and procedures used in training. They should also evaluate operating personnel preparedness to perform routine and extraordinary tasks required of them in the new building.

Architects are responsible for inspection of construction, approval of payment to contractors, and for determining the "habitability" of completed structures. Too often, indoor air quality problems occur or begin due to premature occupancy of completed structures. By requiring evidence that a building's ventilation system is fully functional and that air quality is acceptable prior to initial occupancy, architects can improve IAQ. This can be accomplished through "performance testing" during or immediately after the "commissioning" of the completed building.

Building Operations. Initial occupancy can be the most difficult period for maintaining acceptable indoor air quality. Problems arise from off-gassing from new materials; an occupant population which has been stressed by a recent, sometimes reluctant move; incomplete or inadequate air balancing; and malfunctions in newly commissioned air handling or control equipment.

The initial occupancy period can be very useful in identifying construction problems and initiating corrective actions before warranties expire. A responsive building management approach to complaints can create positive occupant attitudes toward the building and the building management. Attitude and perception play as significant a role as physical reality in determining occupant physiological and psychological responses.

Architects can assist building owners and operators during the initial occupancy period by recommending provisional ventilation system operating

protocols which maximize outdoor air supply and hours of operation and minimize operating temperatures. They can also recommend procedures for quick and economical evaluation of indoor air quality including objective (instrumented) methods and systematic, subjective methods (inspections, rating systems, and questionnaires).

HVAC maintenance. Many indoor air quality problems have resulted from inadequate or inappropriate maintenance of HVAC systems. Biological aerosols implicated in cases of building-related illness result from inappropriate HVAC maintenance. Architects and their consultants should review the manufacturer's recommended HVAC maintenance program and suggest improvements as required.

Building maintenance. Some indoor air pollutants come from building maintenance materials. Examples include floor waxes, furniture polishes, carpet shampoos, and washroom disinfectants. Maintenance practices and schedules can exacerbate or minimize the contamination of occupied spaces. A careful review of maintenance plans can screen potential indoor air quality problems and reduce or eliminate many of them. Volatile chemicals should be minimized, and their application should occur when buildings are vacant, where possible, with good ventilation and maximum time until normal occupancy recurs.

Pest control. Insecticides, fungicides and rodenticides, while useful in controlling pests, can cause serious indoor air quality problems through misapplication or inappropriate timing of application. Careful planning and monitoring can avoid unnecessary problems while maximizing the benefits of pest control applications. Architects can consider minimizing the need for on-going pesticide applications by selection of materials and construction details during design. Examples are materials not subject to attack by micro-organisms and design details which do not provide locations for pests to hide, colonize or move about.

Evaluation of completed buildings offers an excellent opportunity for architects to learn from their prior work. Post-occupancy evaluation, as it is called, is rarely done. Architects can learn how to improve indoor air quality by studying the impacts of different design approaches on subjectively and objectively measured IAQ.

Barriers. A major barrier to more effective indoor air quality control is architects' inadequate appreciation of the subject including characterization of indoor air quality; its health impacts and other consequences; and cost effective, proven technology for control. Targeted IAQ research and communication of its results can increase the utility of research for architects and improve IAQ in buildings.

The potential effectiveness of architects in improving indoor air quality is substantial. There are many things which architects can do. The degree to which architects can do them depends on a number of conditions including the following:

1) The architect's control over the decisions as defined by the contract and other agreements or understandings with the client.

2) Legal and code requirements imposed by governmental entities on the practice of architecture or the design, construction and operation of buildings.

3) The architect's knowledge and access to useful information which in turn is limited by the information available from research and other sources on which architects can rely.

4) The architects' values and commitment to providing quality indoor air.

5) The project or client's requirements and budget.

Conclusion

Architects can make substantial improvements in indoor air quality. By approaching every phase of work with concern for indoor air quality, the design, construction and operation of the building can be modified to reflect the understanding now available from indoor air research. Researchers can enhance architects' efforts to improve indoor air quality by focusing research on design issues and by communicating research results to the design and construction community.

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