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IMPROVING IAQ THROUGH HEALTHY BUILDING ENVELOPE DESIGN AND SYSTEMS' SELECTION

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A simple systematic guide for architectural practice is proposed in the form of an indoor air quality-based design assistant that can be utilized when decisions regarding the selection of envelope materials and energy systems are made. It is intended to be the first step towards effective bridging of the existing gap between IAQ information and the architectural profession. The proposed guide is in a written form as well as a simple computer hyper text . The proposed guide is intended to be a quick reference for obtaining direct information on type of pollutants associated with each finish material, health risks, and possible alternative materials with less polluting impact on indoor air.

INTRODUCTION

Architects do not have at the present time immediate access to a design-related comprehensive information system on the IAQ aspects of the various building components, systems and materials. A resource is needed which brings together the relevant information in one easily accessible source, in a form that is modular, expandable and usable by architects as well as it can easily be updated. Building materials and energy systems were selected as two representative modules in this paper due to their importance. One of the essential measures, to improve indoor air quality, that has received little attention, is the architectural selection of building materials based on their pollutant levels and potential health risks. Virtually any material with a non-metallic composition has some potential for containing organic and/or chemical compounds that can emit gases or evaporate from its surfaces and get into the air. The choice of thermal energy systems for heating and cooling, based on their potential IAQ implications, has received little attention as well. The choice of the mode of heating or cooling delivery has been found to affect indoor air quality [1]. Currently, no building codes or standards do exist on what should be considered safe levels of indoor air pollutants and contaminants. The EPA set ambient air standards in 1970 under the mandate of the Clean Air Act, but there is disagreement on what the levels should be for indoor air. Further toxicological and epidemiological data is needed before levels can be set and used [2]. Building ecology is an important aspect of the overall building design process. Lack of air quality-conscious building designs increases the chances of creating unhealthy indoor environments. The intensity of airborne pollutants from building materials increases with reduced ventilation for the purpose of saving energy. Elimination of potential pollutants through proper selection of building materials is most effective as compared to the other three common alternatives shown in Fig. 1. Unhealthy environments could be easily created particularly in the absence of acceptable ventilation. The out-gassing and emission of vapors and particles from building materials in one zone of a multi-zone building can easily reach other zones through the building's ventilation and air circulation systems. Thus building envelope materials' interaction with building energy systems has a significant impact on air quality as shown schematically in Fig. 2 . When deciding on the most appropriate building materials for a building envelope, architects must take into consideration the materials' levels of pollutant output, the possible health risks involved, and the environmental impact of the selected energy system. It is unfortunate that architects have no practical means neither to account for the materials' effect on air quality nor to account for air quality criteria as part of the overall interdisciplinary list of design criteria. The architects' decisions, concerning the types of materials to be used in the design of building envelope components, have significant consequences on the quality of the indoor air. Although these decisions are presently ignoring air quality issues, they are implicitly specifying undesirable types and quantities of possible pollutants to be permitted into the indoor environment. Unfortunately, not all IAQ knowledge pertaining to the role of building design on indoor air quality and occupants' health are utilized by designers who are environmentally conscious. This can be mostly attributed to the lack of linkages and cross referencing that is needed to utilize the various multi-disciplinary technical design information.

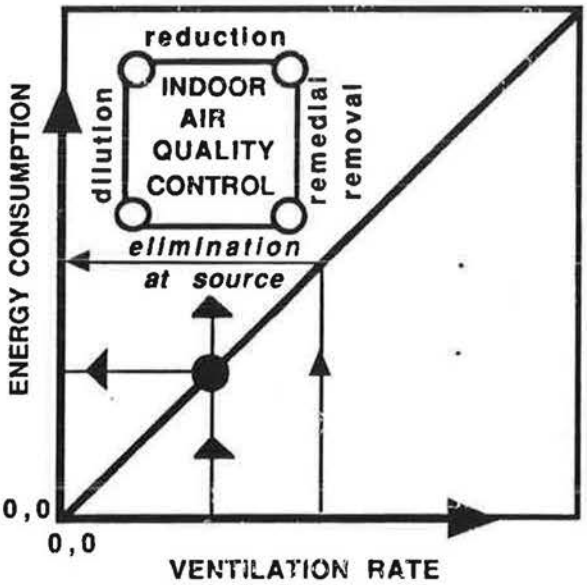

Fig. 1: Elimination at source reduce energy consumption

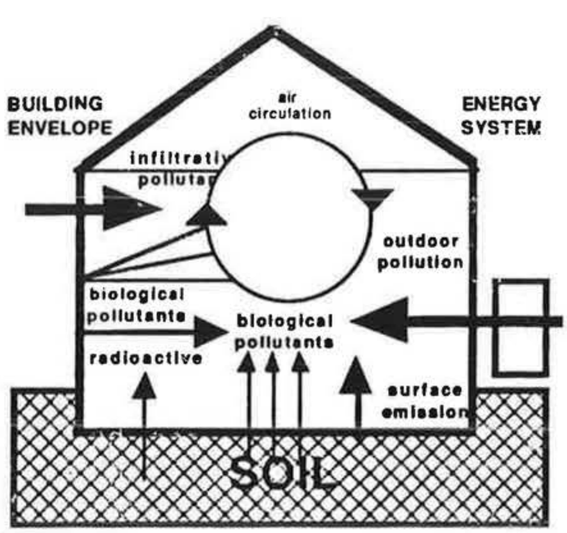

Fig. 2: Building envelope interaction with energy systems

In the recent years, increased concentration of different indoor contaminants has been found to be excessively high in many randomly selected buildings. In fact, indoor pollution levels often exceed standards set for outdoor air [3]. The major sources of indoor air pollution in buildings are: polluted outdoor air, indoor materials, indoor combustion byproducts and indoor biologic contaminants [4]. Polluted outdoor air can be mitigated, through architectural design, by avoiding heavily polluted areas for air intake vents, such as away from exhaust vents, loading docks, heavily traveled streets, busy intersections and filtering the air as it enters the building. Architects major participation in the creation of healthy indoor environments is to eliminate or at the least reduce any possible indoor contaminants through appropriate selection of building envelope components and materials. Current surveys indicate that up to 90% of the typical person's time is spent indoors [4] while in cold climates, it is estimated to be 93% [5]. The combination of increased levels of contaminants and an increased length of exposure create a situation in which occupants' health is affected and indoor air pollution complaints result. Complaints about the quality of the indoor environment have increased in the past decade, mainly among the occupants of new or newly renovated buildings. The term "Sick Building Syndrome" has been coined to describe such problems. A survey by the Environmental Protection Agency (EPA) ranked indoor air pollution as a greater health threat than both hazardous waste sites and outdoor air pollution [6]. Currently, research is conducted on the various factors that affect IAQ, such as ventilation rates [1], air filtering and air movement [4], the sources of pollutants [7-9], and mitigation strategies to eliminate, contain or dilute the offending pollutants [2]. Physical and psychological testing is also being used to determine the role of such aspects as light quality, stress and work station comfort on overall response to the indoor environment [10]. These approaches though propose solutions to the different indoor air problems, they rarely address their interdependency in an integrated holistic manner.

Since the late 1940's there has been a proliferation of synthetic substances which release various chemical gases and particulates into the indoor air [6]. The architect has a responsibility to be knowledgeable about which substances are potentially harmful and ways to avoid them whenever possible. Only recently, cataloging of materials as potential sources of indoor air pollution has picked up momentum [11]. One attribute of a "healthy" building is the use of relatively low pollutant-emitting building materials and finishes [12]. Generally speaking, the architect is in control of the selection of the materials and thermal energy systems for a building. Hence, the architect becomes a logical target for legal action over IAQ problems. Law suits against architects are often based on negligence, misrepresentation, fraud, breach of express or implied contract [2]. Additionally, the architects find it a professional responsibility to provide for the health and safety of building occupants. Only when architects becomes well informed about as many aspects of the IAQ, a better overall understanding of the role of design in improving the quality of the indoor environment can be attained.

CONTROLLING INDOOR AIR QUALITY THROUGH DESIGN

A void does exist between the IAQ research information and those in the variety of disciplines who could benefit from it. That void in the research process is one of making the information accessible through assessing, choosing and formatting it to meet the needs of specific disciplines. A selection guide can assist architects in the selection of non-polluting building materials, components, and systems and ultimately allow building design to be an effective tool to control indoor air quality. The information in the guide is structured in an organized, clear, concise and graphically accessible manner in order to obtain information quickly. Currently there is no reference of this specific nature and purpose available for professional architectural use. Indoor finish materials and energy systems are considered significant factors influencing IAQ over which architects have the most control. The guide concept intends to show a way to bring together some of the widely scattered research and technical information into a single technical source to be used as an architectural reference guide for choosing indoor finish materials based on their short and long term effects on the quality of the indoor air. It presents a simple approach for the utilization of current published research as the basis in identifying the significant factors that need to be known in order to evaluate indoor finish materials from an IAQ perspective. This approach can be extended to account for other design related issues. The guide allows to expand and accommodate other building materials and energy systems. The proposed concept is designed to be a cross reference that can serve as a valuable quick source of information on the IAQ implications associated with indoor finish materials. Finishing materials and energy systems are directly connected to the indoor environment and act as internal emitting and convecting sources of possible toxic chemicals, contaminants and pollutants. Building materials and accompanying furnishings have been identified as major contributors to indoor air pollution. By selecting the most healthful materials for a building early in the design phase of a project, potential IAQ problems can be at least minimized, if not fully eliminated at the source level without resorting to costly remedies at later stages. The information provided in the guide can help architects to weigh the economic and aesthetic considerations of a given selected finish material or energy system against the long-term potential for occupants' irritability, discomfort and health risks. The guide intends to be concise yet sufficiently comprehensive, design-oriented yet easy to understand, and simple to use. Materials and thermal energy systems are among the primary contributing factors to indoor air pollution. Fig. 3 shows these two factors along with other major factors that affect the indoor air quality.

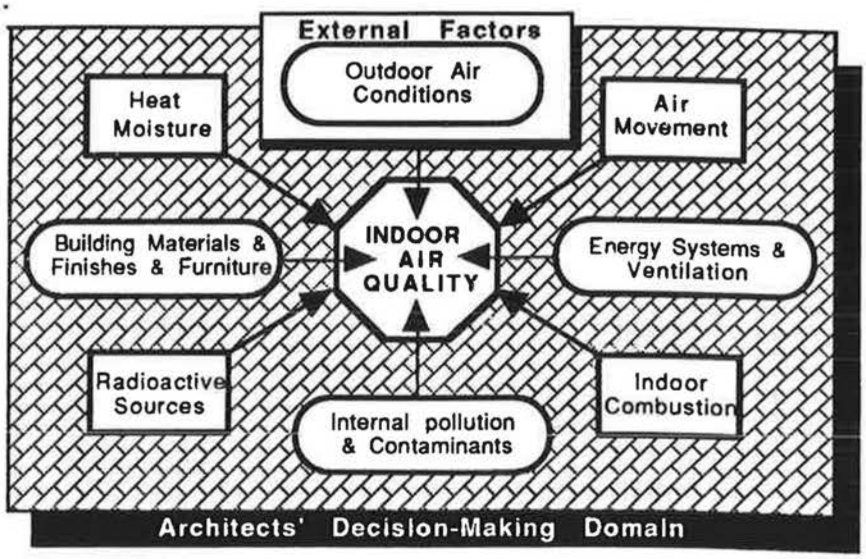

Fig. 3: Major Factors affecting the indoor air quality

UTILIZING IAQ DESIGN KNOWLEDGE

There are at least two other major parallel efforts being made in the U.S that will help to bridge the gap between IAQ research findings and design practitioners. Although the information on indoor finish materials is currently not available in one place, the American Institute of Architects (AIA) has begun a process of making a wide array of environmental information available to architects in the *Environmental Resource Guide* (ERG). A portion of it addresses the environmental and health implications various materials, but does not cover thermal energy systems directly at this time. Only two materials so far, aluminum and particle board, have been researched and published to date in the ERG. Generally, the information is still scattered throughout various research publications. The Environmental Protection Agency (EPA) is developing a series of documents summarizing available information on buildings materials and products brought into homes and office buildings as potential sources of indoor air pollution. The first document, a catalog of materials sources of indoor air pollution was completed in 1990. The additional portions of the completed handbook, information on the chemical constituents of these materials and emission rates of chemicals outgassed from these products, will constitute a multi-year project. The current EPA efforts are on the design of an organizational scheme and format for presenting information in a logical manner for the intended user groups which will include consumers, homeowners, designers and industry [4]. Unlike the ERG and EPA efforts, the present work focuses on serving as a guide which would allow architects to obtain IAQ information on indoor finish materials. The accessibility of the information in a design applicable form will promote the incorporation of the research findings into the architectural practice. The prime focus of the present study is the indoor finish materials (those materials that come into direct contact with the indoor air). All of these efforts are additional steps in promoting Building Ecology which emphasizes the interrelationships of all of the components and factors of a building, including the larger environment and the building occupants as part of a complex, dynamic system [2]. Most building design professionals give little consideration to IAQ issues. Part of the problem is the inadequate communication between building science researchers and design professionals [8]. The present study seeks to be a part of the solution to that problem by providing an informational bridge. It should be noted that this study is only a demonstrative example to show the usefulness of having the proposed guide available to architects. It is understood that other areas such as ventilation as a strategy for minimizing IAQ problems is a field of study in and of itself, and considered beyond the scope of this paper. It is also understood that ventilation plays a major role in IAQ problem mitigation, but reducing pollution sources is the focus of this reference guide and is also the primary step in creating healthful indoor environments. This demonstrative example does not claim to provide all of the available information on even the indoor finish materials. Such a comprehensive investigation would be a monumental effort, demonstrated by the multi-year team research development processes underway on the AIA *Environmental Resource Guide* and the EPA Database. Instead it is a demonstration of informational research procedures and some format possibilities for IAQ information delivery to the architectural community. It is a departure point from which further research and information compilation can continue. Also, the proposed guide does not intend to provide information on nor endorse or condemn any specific manufacturer of any product or system.

GUIDE LOGIC & METHODOLOGY

Current, pertinent information on indoor finish materials and energy systems for architectural design use were brought together in a single source. A number of logical steps were followed to find and document the desired information: 1) identification of the possible sources of information, 2) assessing the information and obtain the design relevant data, and 3) compiling that information into a usable form for architects to allow them to consider the IAQ implications of the indoor finish materials and thermal energy systems that they are specifying. Gathering information, assessing design related information and the compilation of the information into a useful guide for architects constitutes the three basic major steps that were taken during the course of this study. It is intended to be a working general information reference. As a working reference, space will be provided for adding the names of products and manufacturers obtained from personal research and for further research information gathered by the user of the guide. The guide is also not intended to provide recommendations as to the "best" choices of materials, but rather objective research and validated IAQ information on various indoor finish materials and thermal energy systems to allow an architect to weigh the IAQ factors when choosing the materials and thermal energy systems for a particular project.

PROPOSED GUIDE ORGANIZATION

IAQ research addresses a wide array of concerns and approaches. A general knowledge of the issues and factors involved in the IAQ research is helpful in understanding importance of healthful indoor environments.Information organization is an important factor influencing the potential utilization of the proposed guide. The emphases in the organization of the guide are: providing only the information that is applicable to architectural design decision-making, ease of use, and availability of the information in readily accessible forms. Since new information is constantly being made available, the guide has also been created to be easily updated with additional research information. The hypothesis behind the proposed organization of the guide is that research data can be cumbersome to use in the architectural practice since it generally contains technical information on testing procedures, testing data and analysis, analysis of the results, as well as specific information (research results). It is beyond the time constraints of most architects to access and read through vast amounts of published materials to find the IAQ information on specific building materials and products of interests. Information when it is too technical can discourage architects and design practitioners to use it unless it is provided in a format that allows it to be quickly read and easily understood. It is important to recognize the individuals' personal preferences in accessing information. Three ways of accessing the information were established to provide a usable, necessary link between scattered IAQ research information on indoor finish materials and thermal energy systems and the architectural practitioner. The three ways are;

1) information for one-page summaries of each of the indoor finish materials and each of the thermal energy system types which include: i) General Information, ii) Pollutants, iii) Health Effects, iv) Alternatives and Techniques for Use and v) References;
2) a written matrix, a table that summarizes the health, pollutant and alternatives information in a comparative manner; and
3) a HyperCard computer program in which the information can be accessed in a variety of ways: by material, energy system or pollutant. In this way an architect can access the information in the manner that is most appropriate for the application in question.

Standards are currently being adjusted to set a higher standard of air change rates. This is evidenced by the approval of ASHRAE standard 62-1989 by the American National Standards Institute (ANSI) in June 1991[13]. This standard specifies a ventilation rate increase to 15 cubic feet per minute (cfm) per person (up to 60 cfm per person) up from a previous minimum standard of 5 cfm. The earth is a closed system and all the chemical pollutants that can cause health problems indoors can potentially do the same outdoors [14]. The concentrations of those pollutants would be much lower outdoors, but they do not disappear.

MAJOR SUBJECTS IN THE IAQ GUIDE

The indoor finishes materials were defined as those in most direct contact with the indoor air: Twenty different finishes materials and eight different energy systems that are most common are compiled in the guide so far. The compiled materials are concrete, particle boards, plywoods, carpets, tiles, resilient flooring, wood, gypsum boards, plasters, acoustical ceiling tiles, plastic laminate, wall coverings, doors, windows, paints, varnishes, stains, adhesives, sealants, and caulking. The energy systems includes, forced air heating and cooling systems, electric convective heaters, heat pumps, wood stoves, fire places, electric baseboard heaters, hot water radiators, and in-floor hot water systems.

Finish materials are of concern in their release (emission) of pollutants. Emission factors per unit area of material can vary by a factor of many thousands from one material to another. The emission rate depends on how much material is present and the conditions of the indoor environment. These, along with the duration of the emission, become the important factors in the overall amount of pollution and the effect on the building occupants. Synthetic materials are increasingly utilized for indoor finishes, furnishings and construction materials. The chemical constituents and their potential health risks are mostly unknown to those who specify, install and use them. Investigations of materials that have indoor applications have documented emissions of a large variety of organic compounds, many of which are known or suspected carcinogens [15]. Formaldehyde is one example of a well-studied toxic chemical which releases urea-formaldehyde resins. It is found in particle board, plywood and foam insulation as well as a number of adhesives. It has been found that low-level exposure under controlled experimental conditions produced significant eye, nose and throat irritant responses which increased with dose [16]. There are currently no set standards for the levels of exposure to VOC's (volatile organic compounds), such as formaldehyde, although a total emission of 1 mg/m^3 (microgram per cubic meter) has been recommended as an interim guideline until more definitive health response date from exposure to low-level organics becomes available [15]. Vapors or gases can be absorbed or adsorbed on materials and released later; and they can react with other airborne pollutants and be changed in character, most often with unknown results [2]. Indoor air chemistry is substantially different from outdoor air. The presence of increased surface-to-volume ratio as compared to the outdoor environment (enclosure materials to air volume), the presence of reactive indoor surfaces and the increased concentration of certain volatile organic compounds suggest the possibility of chemical modification of the indoor air [8]. This modification produces secondary pollutants such as new chemicals or the re-release of chemicals or particles adsorbed onto the surfaces of other materials. With respect to health risks, there are two main concerns in dealing with indoor air quality: the levels of exposure and the length of time exposed. At present, information is limited on the short-term effects and seriously lacking on the long-term effects. The respiratory system is the key element in most of the health effects experienced due to indoor air pollution. Gaseous and particulate airborne pollutants enter the body via the respiratory system. The immune systems must work overtime to form antibodies to these substances. A steadily increasing percentage of the U.S. population is developing "multiple chemical sensitivity" (MCS) in which virtually all synthetic substances become a source of irritation [6].

One of the ways to help ensure good indoor air quality through pollutant control is to use materials and energy systems with low emissions of substances that can cause minimal health or comfort problems [17]. Source control is the best strategy for reducing indoor air pollution. Careful selection of building materials can reduce quantities of indoor generated pollutants. This is a preventative strategy that involves the use of materials that emit no or low levels of pollutants, particularly VOC's. Natural materials such as wood and cotton are preferable to synthetics and metal is preferable to plastics [18]. Unfortunately, due to their low cost, synthetics have the current economic advantage [18]. The approach to controlling indoor air pollution at a source level is not new and has been proposed by others in the past [19-21] . There are also investigations into the effects of the energy systems used for providing heating, cooling and ventilation to a building on IAQ [22]. Source control strategy seeks to prevent IAQ problems before they begin by using the least offensive materials possible. Although IAQ is not the only factor involved in choosing the materials and energy systems for a building, if the IAQ information is readily available it can be considered. It will need to be weighed against such factors as the cost of alternative materials or applications, aesthetic preferences, availability, and so on. Source control does not provide complete relief from indoor air pollution, but ellminating at least the most offending substances or permanent internal sources from an architectural project will greatly reduce the overall IAQ problem.

Pollution causing materials carry additional cost penalties that are not immediately evident. The threat of litigation is one potential concern that could be very costly. Loss of productivity among workers due to illness or general malaise caused by indoor air pollution is a potential major cost that has not been fully explored. An increased cost for assessing air quality, identifying the problem and implementing the appropriate corrective measure to alleviate IAQ problems is a great potential for cost liability.

INFORMATION FORMATTING

Information was gathered on the health risks, pollutants and alternatives and/or special techniques for using these materials and thermal energy systems to improve IAQ. it is necessary to select only that indoor air quality related information which would be helpful to architects in choosing materials and energy systems in the design phase of a project. The main task was to extract the pertinent information from the information available on IAQ. The final step in the process was to sort the relevant information and reorganize it into an easy-to-use reference guide. The overall emphases were ease of use, pertinence of the information, understandability, and flexibility. The information is compiled in three different ways to meet the needs of a variety of potential individual preferences in accessing information: one-page summaries, a written information matrix, and a HyperCard computer program.

<u>The one-page summary</u>: They include information in a concise written form to allow for quick referencing of the information on each specific indoor finish material or energy system on a two-sided single sheet. As shown in Appendix A, a sample of a one-page summary (for carpets) is given to show the way the information is divided into five sections: General Information, Alternatives and Techniques for Use, Pollutants, Health Risks, and References. On one side of the page the "What" information such as the general Information and Alternatives and Techniques for Use are provided. On the other side of the sheet the "Why" information such as Pollutants, Health Risks, and References are provided.

<u>The data matrix:</u> It provides an initial comparative overview of the information on each specific material or system. It is in the form of a table with columns for each informational category: i) Pollutants, ii) Health Risks, iii) Alternatives, and iv) Techniques for Use. This allows for very quick, comparative reference of the information for those who prefer very concise, specific data. A sample is shown in Appendix B.

<u>The HyperCard®program</u>: It is used to create an IAQ HyperCard stack for building finishes and energy systems that can be browsed through on a Macintosh® computer which is widely used by architects. The "cards" will be set up to access the same information provided in the written guide with somewhat more ease of use for those with access to the HyperCard software. The information on the HyperCard stack is accessible by a variety of access points. The user begins with the "Home" card and supplemental choice cards which provide instructions on how to use the stack and allows the user to make access choices. The choices available are: specific indoor finish material, thermal energy system, or pollutants. The information on the health risks of specific pollutants and alternatives/techniques for use is gained by browsing the stack. Some schematic sample paths through the HyperCard Stack are shown in [illegible]

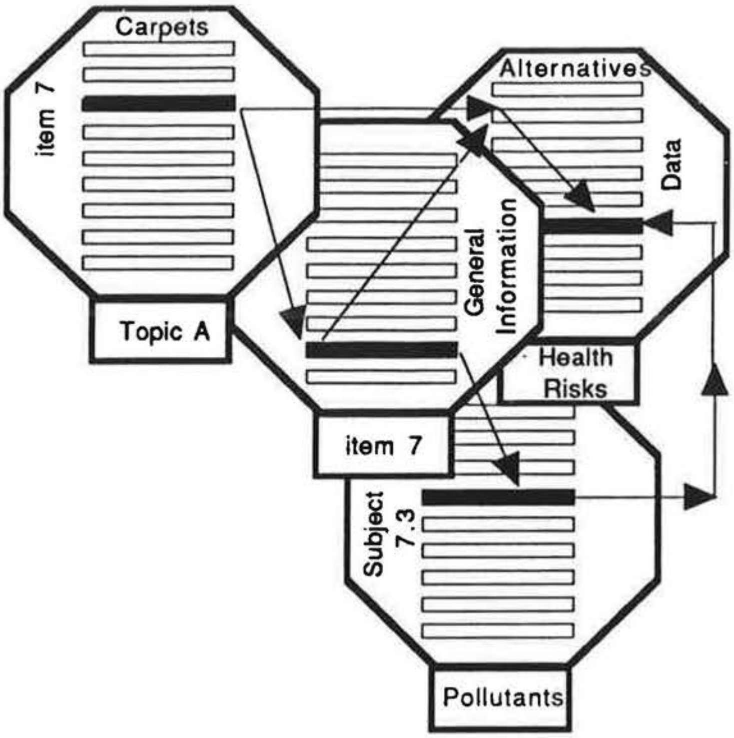

Fig. 4: Conceptual schematic for the IAQ guide HyperCard program showing direct sequential and indirect cross referencing potential

CONCLUSIONS AND RECOMMENDATIONS

In this study, compilation of design-related IAQ information on building finishes and energy systems from major research entities and publications has been accomplished. It has demonstrated a method of systematically obtaining and sorting the compiled information in order to create a practical reference for use by architects when selecting indoor finish materials and thermal energy systems. Also, It has provided a useful knowledge transfer link between the scattered IAQ research information related to envelope and energy systems design and the practicing architectural community. The information provided in the guide so far makes it possible to tentatively evaluate major finish materials and energy systems based on their effect on the quality of the indoor air quality and consequently the health and comfort of the occupants The proposed guide also serves to increase the level of consciousness and awareness of the issues involved in indoor air quality. It promotes a design-based approach directed specifically to the architectural community. It also promotes a Building Ecology approach to design, one which recognizes the inter-ralationships of all components of a building, the building occupants and the larger environment. The Building Ecology approach emphasizes the impact of indoor environmental factors on the building occupants health and well being. Building for health is becoming as much of a design priority as building for energy conservation has.

The guide can be used as a reference in an architectural office to obtain information on specific indoor finish materials and thermal energy systems. It can also serve as a working base from which to continue and encourage further research by the user. This guide utilizes the premise that minimizing indoor air pollution sources by selecting low or non-polluting materials and energy systems can reduce the level of internally-generated pollutants and thereby improve the quality of the indoor air. The guide provides the overview information needed to make choices regarding the overall compared impact of one indoor finish material or thermal energy system vs. another. This information will allow for an assessment of these choices that previously may have gone unconsidered and consequently may have contributed to the IAQ problem through a lack of informed decision-making. Although the HyperCard program is an attached element, it an integral part of this study. It is set up to guide the architect through the process of using it with minimal prior knowledge of HyperCard except the ability to open the software and use some of the basic functions to move through a HyperCard stack. It gives the user the opportunity at various places to add to the data cards if more information becomes available. This allows for an ongoing interactive process which will encourage the use and updating of the information due to its ease in doing so.

It would also be an asset to have a clearinghouse established for research information in which the process of this study could be consolidated and executed for a variety of disciplines simultaneously, funnelling the appropriate information to those who can make direct use of it. Collecting this information for professional architectural use can be done by requesting Material Safety Data Sheets (MSDS) which provide information on the individual chemical constituents in the products. It is also recommended that the manufacturer's Quality Assurance System (QAS) be requested. This study has shown one example of filling a part of the vast need for information in the area of improving indoor air quality through the selection of materials and thermal energy systems. In general, a synergistic approach of design, management, product modifications, maintenance and monitoring are all necessary to technical control of indoor air pollution. An overall combination of good ventilation and low or non-polluting building and finish materials and thermal energy systems will dramatically improve the quality of indoor environments.

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APPENDIX A: ONE-PAGE SUMMARIES

FINISH MATERIALS: Carpets

General Information[19]

Carpet is one of the major outgassing materials in a building, along with plywood, acoustical ceilings, built-in cabinetry and paints. Reducing the quantity of carpet will eliminate most indoor air problems. New synthetic carpet can outgas a variety of toxic vapors due to chemical additives (pesticides, fungicides, soil repellents, dye, backing, synthetic or treated natural padding, and adhesives). The chemical additives can cause many health problems. Their intended affects also decrease in their effectiveness over time. Shampoos (mainly organic solvents and ammonia), and the resulting wet carpeting, can allow mold spores and fungi to proliferate.

Carpet padding has various pollutants and disintegrates as it wears. The breakdown of the carpet fibers and padding generates synthetic house dust. Carpet can contain 10,000 organisms per square foot and each footstep creates an invisible cloud of potentially allergic material. This dust in turn can be burned by the heating systems (furnaces, on electric coils, etc.) releasing toxic vapors. Sunlight falling on carpeting can also cause it to disintegrate and release particles or vapors.

Pollutants[6,7,19,27]

The pollutants in carpeting vary with the type of carpet and its chemical constituents. The major common pollutants include: formaldehyde (in glue, backing and padding), petrochemicals (in carpet fibers), toluene, xylene, methylmethacrylate, ethylbenzene, benzene and a number of others. One study found 10 unidentified chemicals outgassing.

Vinyl carpeting has been identified as a major emission source. It often contains more than 20% plasticizers by weight, such as phthalate esters which may hydrolyze and emit ethylhexanol by moisture induced degradation especially over concrete. Compounds such as dodecene, TXIB, and ethylhexylacrylate have been quantified at high rates of emission even years after installation.

Health Risks[2]

The outgassing of formaldehyde, toluene and xylene can cause severe irritations and sensitivities. Formaldehyde is a water-soluble gas that can be detected by most people at levels well below 1 ppm. It can cause sensitization of the respiratory tract and burning eyes at concentrations as low as .05 ppm, although responses and complaints can vary widely. Sensitization may occur as a result of repeated exposure. Concentrations higher than a few ppm often produce coughing, constriction in the chest, and wheezing. Over time formaldehyde may cause chronic respiratory disease. Some health effects due to sensitization can include increased frequency of asthma and dermatitis.

Toluene causes fatigue, muscle weakness, and confusion at concentrations of 200 to 300 ppm for 8 hours. When its vapors are inhaled, toluene causes central nervous system depression, psychosis, and liver and kidney damage as well as potentially causing anemia. Xylene can cause damage to the liver, heart, kidneys and nervous system. Both toluene and xylene have a narcotic affect. Ethylbenzene can cause eye and respiratory irritation. Other general symptoms include headaches and nausea.

Alternatives and Techniques for Use[2,19,28,29]

Alternatives:

1. Eliminate carpet and use hard surface floors such as tile or hardwood with removable rugs that can be washed, shaken, etc.
2. The least hazardous emanation is from synthetic-fiber carpet with thin composition backing
3. 100% nylon carpeting with natural jute backing is reportedly less offensive than other types
4. 100% wool or cotton carpeting are better, but they pose some problems for sensitive individuals. Wool is treated with toxic moth-proofing chemicals and cotton contains pesticide residues from crop spray and dyes. Either can be intolerable to some individuals.

Techniques for Use:

1. Avoid carpet in rooms with heavy personal traffic especially from persons coming in from outside. Keep carpets thoroughly clean.
2. Tack carpet down in lieu of gluing with a toxic adhesive
3. New synthetic carpet should be aired at least 1 month to allow major contaminants to outgas
4. Install carpet without padding, but be aware that it will not wear as well or last as long
5. There are products that can be applied to seal in any outgassing odors but the best solution is to remove the carpet

* number shown referes to the reference source and further reading

APPENDIX B: DATA MATRIX EXAMPLE

Finish Material :Concrete and Particleboard

INDOOR FINISH MATERIALS

CONCRETE

POLLUTANTS	HEALTH RISKS	ALTERNATIVES	TECHNIQUES
Colorants: chromium and other heavy metals Oils from formwork Dust Asphalt-impregnated joints Sealants: petrochemicals Radon in some aggragates	Chromium and heavy metals build up in the system causing chronic problems later on Radon and radium can cause lung irritation and potentially cancer	1. Use redwood expansion joints in place of asphalt-impregnated material 2. Sodium silicate seals, helps cure and harden concrete in lieu of petrochemical sealants	1. Curing compounds should be avoided and curing can be accomplished by simply keeping the concrete damp 2. Be sure concrete is dry before applying floor coveing 3. A coat of paint or wax can perform the same function as oil on the formwork or use uncoated forms with special care

PARTICLEBOARD

POLLUTANTS	HEALTH RISKS	ALTERNATIVES	TECHNIQUES
Formaldehyde, toluene, ethanol, isopropanol, 2-butanone, n-hexane 2-methyl pentane (isohexane), benzene, benzaldehyde, styrene n-propulbenzene, limoene, pinene, terpene,undecane, propanol	Formaldehyde can cause eye and respiratory irritation and possibly more serious long term health effects Benzene is a recognized carcinogen Styrene can cause headaches, fatigue, depression, stupor Toluene is a narcotic and may cause anemia	1. Use particleboard with phenol-formaldehyde 2. Specify ANSI A208.1-1989 particleboard 3. Use resin-laminated products 4. Use solid lumber	1. Seal undervloor layment 2. Avoid use in high humidity areas and over below grade concrete slabs 3. Use only if no substitute available

FIGURE 4. Sample Page From Summary Data Matrix