

EXPLAINING HOUSING-RELATED ILLNESS: A DECADE OF ANALYSIS OF EMERGING PARADIGMS

Katherine Warsco

Abstract

Bibliographic techniques were used to isolate selected trends in research related to indoor air quality and housing-related illness in the United States. Representative studies and critiques were drawn upon to provide a conceptual overview of the state of the art in the field. The emergence of explanatory models for housing-related health complaints and a merger of disciplinary perspectives to address sick building syndrome phenomena are explored in this overview.

Introduction

The majority of the U.S. population spends more than 21 hours of the day indoors (Committee on Environment and Public Works, 1989). A large proportion of this time is spent within the home environment. Employed persons, full-time homemakers, and the medically at-risk populations (i.e., the very young, the very old, and the infirm) spend up to 60, 85, and 95 percent, respectively, of their time in their homes (Berry, 1990). Current concerns for environmental quality are shifting from those of the outdoors and industrial settings to commercial and residential buildings. Recent findings indicate that average levels for many air pollutants may be two to five times higher in homes than for ambient air levels (Committee on Environment and Public Works 1989. Agle 1990). However, policies and concomitant regulations to monitor and control indoor air quality within residential settings have made little progress. Relatively little is known about indoor air quality in terms of the effects of human exposure to a variety of multiple, low-dosage, intermittent pollutants that are found in the modern dwelling unit.

This paper examines the emergence, within the 1980s, of models for explaining environmental illness. To date, it is not clear how to study, or even how to conceive of factors (e.g., psychosocial dimensions) that are thought to interact with the sick building syndrome. However, what is clear is the inability of individual disciplinary perspectives to account for variance in the responses of building occupants to indoor air quality. A conceptual framework is needed to explain housing-related illness from an interdisciplinary perspective. Trends are identified which bring the dominant perspectives engaged in indoor air quality and environmental research together in a common explanatory model.

The Citation Record

Bibliographic techniques were used to search databases which were expected to access representative work in the area of indoor air quality and environmental illness. The scientific parties relevant to this subject focused on the building sciences, systems technology, interior and environmental design, organizational behavior, business economics, public policy formation and regulation, and occupational medicine and public health. Ten databases were selected that sampled known sources of empirical and non-empirical work in those disciplines (see Table 1). Sample searches indicated that the majority of a test list of seminal works in the field were cited in these databases.

Katherine Warsco is an Associate Professor in Interior Design at East Carolina University.

Table 1. Databases accessing empirical and non-empirical work on indoor air quality and environmental illness.

Database	Type of work indexed
ABI Inform	Business and economics
Agricola	Housing
Applied Science & Technology	Applied biology, chemistry, and physics for building products and systems
Architecture	Architecture, interior- and behavioral design
Art	Architecture, interior- and environmental design
ERIC	Psychology, sociology, and education
Government Documents	Government reports of legislation and government-funded research
Legal Track	Legal reports of research, legislation, and litigation
Medline	Occupational medicine, clinical ecology, epidemiology, and toxicology
Psychlit	Psychology and social psychology

Citations were collected by matching text in all database titles, abstracts and sort keys to key search terms. Citations were collected for the period 1982 through 1991. Citations not related to residential settings (e.g., industrial settings, healthcare settings) and those not presented in the English language were removed. Also, citations were screened for duplication across databases. This approach did not guarantee a comprehensive listing of citations in any given area, but coupled with a knowledge of major work in the field, it allowed a representative sample of both empirical and non-empirical work from relevant disciplines to be collected. The citations were classified according to subject matter and disciplinary perspective.

Figure 1 shows a dramatic increase in the number of studies from the early to mid-1980s and a stable interest in the topic of indoor air quality through the present. Over the course of this ten-year period, the following is evident: a) a relative stability of both amount and share of empirical work into the study of the causes and sources of pollutants within the residential environment as well as the effects on human health of indoor air pollutants; b) a fluctuation in the proportion of citations of a non-empirical nature represented by educational, legal, and fiscal perspectives; and c) a marked absence of work focusing on the psychosocial dimension of indoor air quality problems in residential settings.

The primary perspectives focusing on the problem of indoor air quality and environmental illness in non-industrial settings are identified in Figure 2. This paper discusses the development of explanatory models for building-related illness, trends in the measurement of the sick building syndrome (SBS), the merger of perspectives to address multifactorial origins of environmental illness, and incorporation of a multifactorial model within the building delivery process.

Explanatory Models

Housing-related illness has been linked to the following contaminants (Meek, 1990): radon and its by-products, volatile organic chemicals and their trace constituents, minerals, combustion gases and particulates, and airborne biologicals. The prevalence of environmental illness within households has yet to be estimated. The following outlines the development of explanatory models that were used throughout the 1980s to account for housing-related illness.

Figure 1. Studies of indoor air quality and environmental illness in residential settings, 1982-1991.

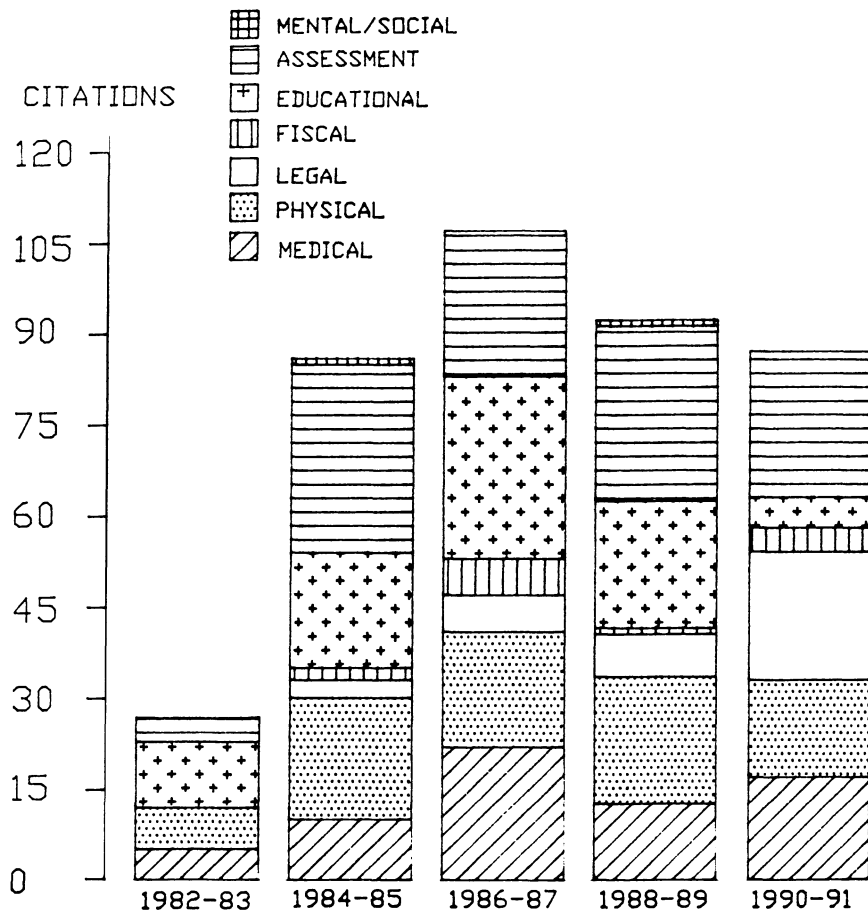
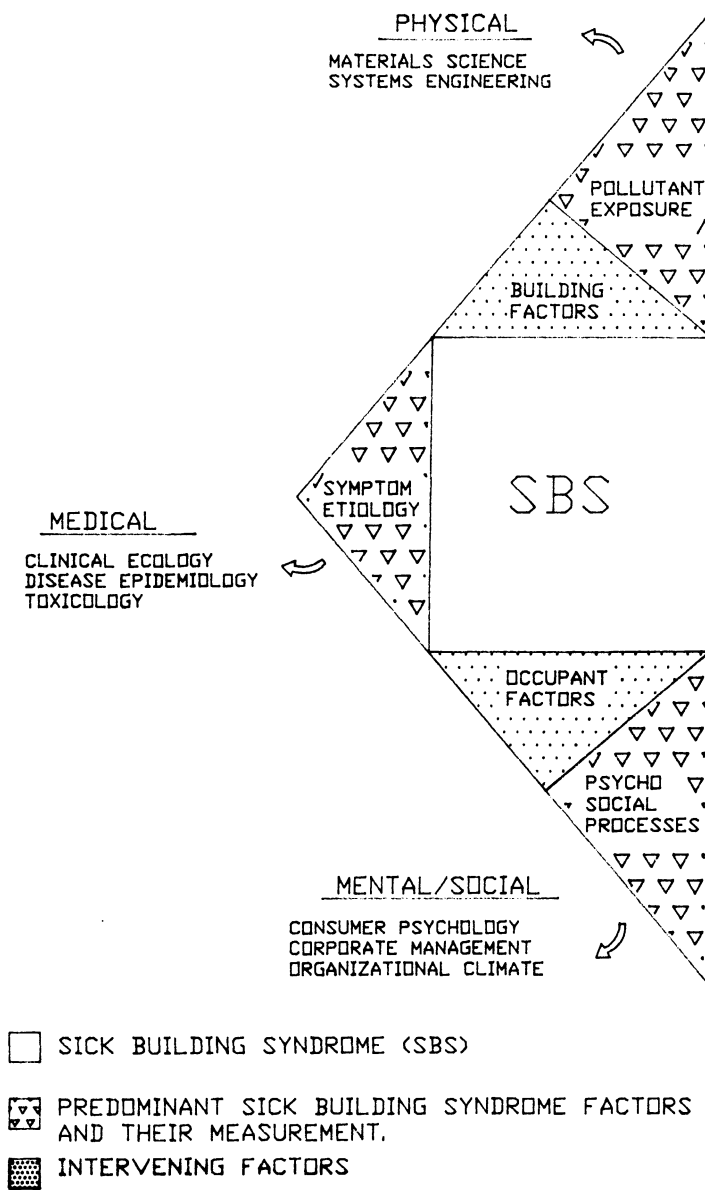


Figure 2. Disciplinary perspectives and concepts relevant to the study of sick building syndrome.



Psychogenic Illness

U.S. health officials have been investigating indoor air quality complaints for over a decade (Committee on Indoor Air Quality, 1986). An etiological basis for the complaints rarely could be linked to a single contaminant source that exceeded known thresholds for air quality and public health. When an environmental explanation was not readily apparent by using occupational safety measures and public health standards, it was concluded that the illnesses were psychologically based and not a result of poor indoor air quality. Psychogenic illness--malaise attributed to psychosocial factors--was an early diagnosis for environmental illness (Kreiss, 1990). However, the prevalence of similar complaints among households occupying similar residential settings throughout the country pointed to the need for further investigation of the phenomenon (Drerup, 1990).

Tight Building Syndrome

The influx of indoor air quality complaints paralleled changes in the housing industry. The trend in residential construction throughout the 1980s has been to address increasing costs of energy and limitations in the supply of land and transportation (Stolwijk, 1990). This trend resulted in the construction of multi-family complexes that were larger, with greater occupant densities and the centralized control of zoned heating, ventilation, and air conditioning (HVAC) systems. In order to make single family detached dwelling units more affordable to middle class families faced with an economic recession in terms of the rising interest rates for mortgages, the construction industry provided smaller, airtight houses that cost less to buy and less to heat and cool. Also, many families attempted to decrease the proportion of their household income that was allotted to utility bills by using auxiliary space heating equipment that burned kerosene, wood, or coal. Usually, portable kerosene units were unvented and many fireplaces and stoves lacked dedicated fresh air intakes. Greater occupant densities, tighter constructed dwelling units, and the combustion of alternative fuels in inadequately vented space heating units resulted in greater concentrations of indoor air pollutants (Eichner and Morris, 1984).

In an effort to address energy conservation strategies, the American Society of Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE) adopted its minimum ventilation standard for the norm. Buildings erected after 1981 were equipped with HVAC systems that were designed for reduced air intake from the outdoors. Reduced air exchange, sealed windows, and improvements in insulation became associated with episodes of environmental illness that came to be known as Tight Building Syndrome (TBS). It was concluded that indoor air quality complaints were a result of a lack, or depletion, of fresh air supply within buildings (Kreiss, 1990). Increasing the ventilation rates was recommended by the National Institute for Occupational Safety and Health (NIOSH) to alleviate complaints. However, the current ASHRAE Standard 62-89 was not designed to protect building occupants from chronic health effects via ventilation controls. Epidemiologic studies of buildings and their occupants were not undertaken in the U.S. to verify that the threshold for carbon dioxide levels (a surrogate measure for fresh air) in industrial settings was satisfactory within the residential setting. Furthermore, no follow-up or experimental studies were performed in problem buildings to determine whether increasing the ventilation rates alleviated complaints (Kreiss, 1990). More recent evidence has indicated that overventilation would not insure acceptability of indoor air quality (Turk, et al., 1987). It has been suggested that ventilation rates adequate to reduce contaminants (such as combustion gases and particulates from environmental tobacco smoke and gas cooking appliances) to acceptable levels in indoor environments could lead to unacceptable air movement and draftiness (Gammage, 1986). Thus, the inadequate ventilation explanation has not been based on, nor confirmed by, empirical work. More sensitive techniques to characterize pollutant sources and their causes were sought (Baker, 1989).

Sick Building Syndrome

Other developments in the early 1980s have affected the quantity of indoor-generated air pollutants. Synthetic chemicals have comprised the majority of materials used in the con-

struction and maintenance of residential buildings, interior surface treatments, furnishings, appliances, and equipment (Stolwijk, 1990). This has led to an increase in organic compounds emitted within the residential interior. A continuation of trends in the previous decade to provide wall-to-wall carpeting throughout the dwelling has increased the amount of fleecy (rough) surfaces that would be viable habitats for the growth of biologicals (Norback and Torgen, 1987). The proliferation of kitchen, hygiene, entertainment, and home-office electronic equipment may have affected indoor air by increasing the potential for effects on health from electromagnetic radiation and negative ion depletion within the residential setting (Schimmelschmidt, 1989). Thus, carbon dioxide measurements have been limited as an indicator of acceptable air quality, since carbon dioxide as a measure of human and combustion sources of indoor pollution would not reflect perceived air contamination from building systems, furnishings, or electronic equipment (Kreiss, 1990).

The term sick building syndrome (SBS) has been used to describe the same phenomenon as TBS. However, its current usage has come to acknowledge that more than one aspect of construction has played a role in indoor air quality complaints (Cone and Hodgson, 1989). SBS has been characterized as an annoying mucous membrane irritation (Bardana et al., 1988). Residents would experience transient symptoms that would worsen with prolonged exposure to the dwelling and improve after leaving the dwelling for a short period of time.

Building Related Illness

Building-related illness (BRI) has been distinguished from TBS and SBS by the collection of findings that has underlied objectifiable disease epidemiology and clinical diagnoses. It has included hypersensitivity pneumonitis, asthma and allergic rhinitis, infectious syndromes, and dermatitis (Kreiss, 1989). These have been frequently related to humidification or HVAC systems (Silberman, 1991), as well as water damage from roof and plumbing leaks that have created hospitable environments for the growth of molds (Burge, 1989; Reynolds, et al., 1990). Also, substances whose exposures have had direct linkages to debilitating and life-threatening diseases (e.g., lung cancer, neuro-toxic poisoning, brain damage) can be included under the category of BRI. Sources of contaminants would include asbestos, lead, Urea Formaldehyde Foam Insulation (UFFI), pesticides, and radon (Meek, 1990).

Although the presence of objectifiable complaints and disease etiology have lent credence to the theory that attributes of the residential environment have played a causal role in the illness of its occupants, two thirds of the building-related health complaints of non-industrial settings have presented no such measurable cause and effect relationship (Boxer, 1990). Thus, SBS has continued to perplex a host of disciplines including public health officials, building engineers, and others (Bardana, et al., 1988). The remainder of this paper will focus on research that has provided insights into prevention and mitigation techniques for environmental illness phenomena.

Approaches to Problem Buildings

During the past decade, strategies for evaluating building-associated health complaints have focused on three predominant approaches: a) characterization of pollutant exposures monitored in the physical setting, b) diagnosis of patient symptoms and disease etiologies as well as characterization of human populations at risk, and c) identification of the causes of contaminants within the building shell, HVAC, plumbing and electrical systems, interior surface treatments, furnishings, and equipment (Cone and Hodgson, 1989). Psychosocial factors associated with environmental illness behavior have emerged in the literature as a fourth approach. This approach largely has focused on occupational dimensions such as organizational climate and work-related stress. A fifth approach has been presented here to represent a merger of the former perspectives in the presentation of a multifactorial model of indoor air quality and environmental illness.

Focus on the Pollutant

Over the past decade, fundamental problems associated with addressing indoor air quality problems have been the characterization and measurement of pollutants. A serious inventory of what aspects of the physical environment have been sources of indoor contamination has yet to be completed (Gammage, et al., 1989).

Data on health risks associated with particular pollutants in indoor, non-industrial settings have been limited. Epidemiological and toxicological data were extrapolated from studies of ambient air and industrial settings to conditions of ventilation and indoor sources to identify substances or conditions causing illness or discomfort (Wadden and Scheff, 1985). However, data have been lacking for long-term exposure in low concentrations that have been more typical in residential settings. (Turiel, 1985). Consequently, there have been large gaps in the knowledge of integrated exposures to air pollutants that would be common in non-industrial activities. Thus, the standards that have been applied to residences were not designed for the regulation of that environment.

The classification of products emitting volatile organic compounds (VOCs) according to contribution to indoor contamination has been problematic (Girman, 1989). Although sophisticated chamber models have been devised to predict contaminant outputs of home products and materials, product brands and their installations have been variable in contaminant output. Furthermore, product uses have been found to be quite variable in human-occupied settings. Monitoring contaminant output in residential settings has had limited results depending upon a) the timeliness of the measurement relative to the occurrence of the major exposure, b) the sensitivity of the monitoring device for measuring contaminants emitted at low levels, c) the location of the monitoring device relative to the breathing zones of occupied spaces, and d) the sophistication of the device for measuring additive effects of simultaneous exposure and the sink and capture effect of trace constituents (Gammage, 1986; Berry, 1990; Johnson, 1990). Thus, it has been difficult to compare predicted models to estimates of contaminants in a particular setting.

Focus on the Symptom

Establishing the health effects on humans of low levels of exposure to pollutants has been a major challenge facing investigators of SBS (Molhave, et al., 1986; Meek, 1990). Assumptions of cause and effect have been frequently made based on little data. Published accounts of SBS have not provided a random sample of the total population of a particular environment under study (Lambert and Samet, 1989). Because the techniques available for airborne sampling have been relatively crude, it has been difficult to document the presence of a specific causal agent in the environment in a dose sufficient to cause the observed disease (Burge, 1989). Furthermore, it has been difficult to prove that the affected people were exposed to this dose in the home environment in a particular mode of transmission (e.g., fine particle aerosols) because episodes of illness have not been distinguished by the setting in which they occur (Hodgson, 1989).

Members of the general population have varied in individual susceptibility to pollutant exposures (Committee on Indoor Air Quality, 1986). For example, women have been more susceptible than men to negative health effects of a variety of electrical and biological contaminants (Norback and Edling, 1991). Research has been limited in exploring typical populations at risk (e.g., the infirm and the elderly) as well as more unusual populations such as those patients who have developed multiple chemical sensitivity syndrome. Researchers need to evaluate the population risk for different pollutants and to evaluate the results of efforts for population risk reduction to further current research efforts (Hodgson, 1989).

Focus on the Building

Where source characterization was possible, measures of pollutants were taken and exposures were traced to specific building factors. This was feasible for radon, asbestos, lead, some combustion gases and particulates, and some biologicals. However, for other contaminants, in particular VOCs and electromagnetic radiation, knowledge of source characterization or clinical cause and effect was limited. In the absence of clear measurement

techniques for diagnosing the exposure of occupants to low level, intermittent pollutants, changes in building practices were promulgated as the answer. Physical causes of pollutants were addressed by altering the design of the building or manipulating the HVAC and plumbing systems (Woods, 1989). The following is a discussion of the design inadequacies and system operational problems that have been associated with residential indoor pollutants.

Radon and its daughter products have seeped into dwellings through crevices in basements, water pipes, and some natural building materials. Prevention of radon from infiltrating the living quarters has been addressed through a) avoiding the use of building materials with a high activity of radium, b) sealing openings that are accessible to soil gas, c) increasing ventilation, d) installing a depressurizing air system, and e) changing building practices to avoid disturbing foundation soils (Ericson, et al., 1985).

Asbestos and lead were used in buildings prior to 1980. Asbestos was used in the formation of house plaster, spackling compounds, floor tile, and furnace enclosure panels. Lead was used in paint and plumbing pipes (Godish, 1990). Mercury has continued to be used in latex paints (Agoco, et al., 1990). Material substitutions, containment, and removal have been dominant methods of addressing mineral contaminants.

Studies have linked combustion gases and particulates to substandard inner city housing. Older buildings with heating and plumbing systems in poor repair have experienced flue gas spillage during heating seasons and sewer gas infiltrating the dwelling through sewer traps (Godish, 1990). Another source of these contaminants has been side stream tobacco smoke. Emission rates of these contaminants have depended upon a) the air exchange rate within the space, b) the amount of leakage through faulty ductwork, and c) the relative pressure of flues and traps to interior space (Godish, 1990). Establishing increased ventilation, creating negative air pressure, and replacing or repairing faulty ductwork have been common control measures (Girman, 1989).

Biologic contaminants have been traced to molds, dust mites, animal danders, and cockroach deposits. Standing water, moisture buildup on materials, and rough or porous surfaces could create conditions conducive for the growth of biologicals. Cleaning procedures, controlling relative humidity, and filtering the air have been methods of prevention and mitigation (Godish, 1990).

Studies have linked VOC concentrations to the age of building materials and changes in construction practices and ventilation system design (Pellizari, et al., 1984). Products that have been found most likely to emit significant quantities of irritating and toxic substances have included: self-leveling cement, subflooring, the carpet system, interior furnishings, ceiling tiles, storage systems, adhesives, caulking compounds, emulsions sprayed on fiberglass duct runs, paints, paint strippers, sealants, wood finishes, wood preservatives, wood products bonded with urea-formaldehyde glues, particleboard, medium density fiberboard, home care products, and moth balls and flakes (Gammage, et al., 1989; Godish, 1990). Emission rates of VOCs have depended upon a) the air exchange rate within the space, b) the room temperature, c) the curing speed of the chemical, d) the newness of the material containing the chemical, and e) the ability of the material to act as a sink for VOCs emitted from other sources, thereby emitting the chemical again at a later time (Girman, 1989; Godish, 1990).

Although current knowledge about VOCs in indoor air has contained many gaps, much has been learned about their control. The dominant approaches to control have been (a) selecting materials with low emissions, (b) airing out products before shipping to site, (c) maximizing outside air ventilation during and following installation, (d) protecting installed materials during the use of VOC-containing materials, (e) protecting fiber-lined HVAC ducts and return-air plenums from contaminated air flows, (f) "baking" the building with elevated temperatures and ventilation to accelerate the offgassing of chemicals, (g) operating newly occupied building areas at the lowest temperatures acceptable to occupants, (h) providing dedicated ventilation for storage that is designed to contain products with VOCs, and (i) sealing off materials known to offgas (Girman, 1989; Levin, 1989; Rousseau et al., 1990).

Studies have been equivocal concerning the biological effects on health of magnetic, electric, and electromagnetic fields as well as static and negative ion deficiency due to transformers, wiring, appliances, equipment, and synthetic materials. Approaches to avoiding contamination have included a) avoiding construction on sites located over electromagnetic grids, b) distancing sleeping quarters from high voltage sources, c) distancing television viewing from monitors, d) shielding cables and conduits, e) containing electrical equipment in storage units that have dedicated ventilation to the outdoors, and f) substituting natural for synthetic materials (Schimmelschmidt, 1989, Pearson, 1989).

Focus on the Psychosocial

There has been an increasing recognition of the relationships between indoor air quality and morale, satisfaction, stress, and health within commercial settings (Vischer, 1989). However, the family as a psychosocial unit within the detached dwelling, mobile home, and multi-tenant dwelling complex largely has been ignored within the context of building-related illness. Most of what has been learned about psychological and organizational factors in occupant health complaints has come from serendipitous findings during site investigations of problem buildings. Studies have not been designed with control groups and testable hypotheses regarding psychosocial variables within non-industrial settings (Boxer, 1990).

Psychosocial factors that have been thought to cause or modify the health complaints of occupants of commercial office buildings have included: a) organizational structure, b) communication patterns, c) management rapport with employees, d) job category, e) occupational sense of job security, belonging, and fulfillment, f) ability to manage workload and deadlines, g) sense of control over environmental conditions, h) ability to cope with technological and economic change in the workplace, and i) perception of risks to health (Boxer, 1990). Although several of these dimensions may have counterparts in residential settings (e.g., communication patterns, organizational structure, and management rapport of the tenant-landlord relationship; sense of control over residential setting; ability to cope with change; and perception of risk to health), the relevance of these factors to residential settings is speculative.

Furthermore, research that has been conducted on social and organizational factors has not been linked to environmental illness (Boxer, 1990; Gammage, 1986). A notable exception in the study of residential settings is the work of Eichner and Morris (1984), who have explored housing-related illness from the perspective of occupant satisfaction. Cross-disciplinary work between environmental health practitioners and social psychologists could help in bringing this conceptual model to a level of rigor comparable to that of the study of other environmental factors (Baker, 1989).

Indoor Air Quality and The Building Delivery Process

One common theme that is emerging from prior investigations of indoor air quality and environmental illness is that seldom should any of the traditional engineering, building science, industrial hygiene, epidemiological, or medical evaluation techniques be used alone, as multi-faceted surveys are frequently a better approach to adequately explore problems associated with building-associated health complaints. It is more effective to view environmental illness as evolving from a multifactorial origin over the life cycle of a building (Norback and Edling, 1991). Factors vary according to characteristics of the physical setting, as well as over time according to the nature of the pollutant, the activities of the occupant, and the dynamics of individual players and their organizational milieu. These factors will coexist in an interactive relationship as is true of the building structure, building operation, and the prevalence of building contaminants (Baker, 1989). It follows from this premise that the evaluation of building-associated health complaints should be based on a system's perspective in which the health status of residents is seen as the net result of an interaction of multiple direct factors such as biological, chemical, mineral, physical, psychosocial, and individual characteristics of the building and its occupants, and intervening factors such as the legal, economic, and political climate within which families and other organizations respond to the problem (Baker, 1989).

A conceptual framework is needed that acknowledges the full array of factors across disciplines that are thought to interact with building problems. This will reduce not only the chances of medical misdiagnoses of nonspecific symptoms (Baker, 1989), but also design recommendations that solve indoor air quality at the expense of exacerbating other dimensions of environmental quality (Loftness and Hartkopf, 1989; Dubin, 1990; Woods, 1989).

Two processes for factoring indoor air quality concerns into the building delivery process are shown in Figure 3. The first approach is precipitated by health complaints of building occupants due to the presumed presence of contaminants within the residential environment and results in reactive mitigation. The syndrome can evolve during the construction, maintenance, or remodeling stages of the building delivery process. The syndrome is diagnosed first by the residents using a folk knowledge base in the conceptualization of the problem and its perceived risks. The scientific community is brought in to diagnose the problem at a point in time when the folk syndrome has reached widespread acceptance.

The scientific investigation procedure consists of some, or all, of the following stages: a) a preliminary assessment incorporating documentation of health complaints, characterization of the residential setting, and a walk-through site inspection; b) personal interviews with the building residents or staff, identifying symptoms relative to time/space dimensions, individual characteristics of the residents, and a psychosocial profile; c) personal interviews with the building management (for multi-family complexes), including an organizational climate profile; d) recommendations for simple or complex measurements of biological, chemical, mineral, or physical sources of pollutants; and e) recommendations for change that are tailored to the political, legal, economic, and social climate of the building and occupants under study (Vischer, 1989; Baker, 1989; NIOSH, 1987).

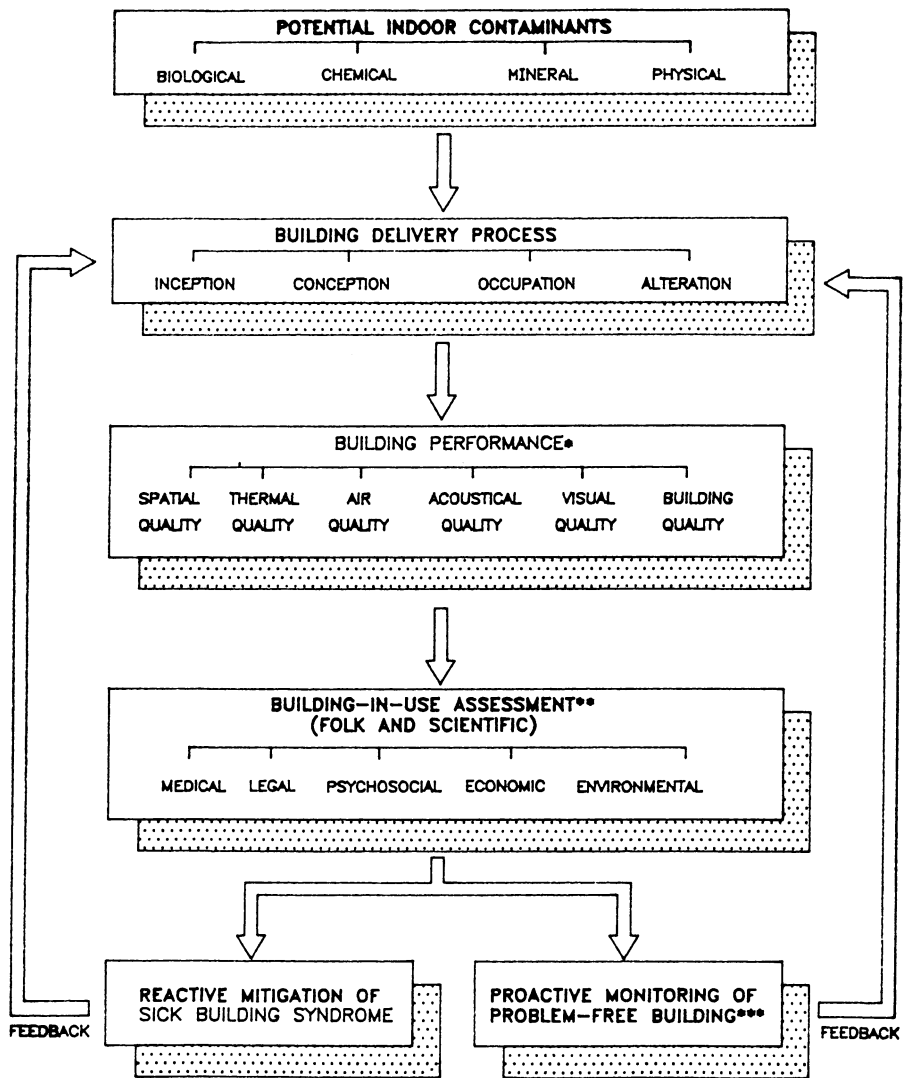
The second approach to factoring indoor air quality into the building delivery process reflects a trend evident among builders and building diagnosticians to promote proactive techniques that are preventive rather than reactive in focus. The goal for single family dwelling units is to create a safe haven, or "sanctuary," that is tailored to the health needs of individual family members that are at risk for environmental contaminants (Pearson, 1989). The emphasis for multi-family complexes is on monitoring buildings and occupants in an ongoing routine. This is to detect early signs of indoor air quality problems and to address them within a scientific framework that reduces the chances for misdiagnosis by the building occupants and the maturation of a full blown disease etiology. Thus, the SBS phenomenon is headed off before it translates into social issues and costs in terms of housing satisfaction, employment sick leave, medical and insurance expenses, and litigation.

Conclusions

The decade of the 1980s has reflected an increase in the amount of research undertaken by a variety of disciplines and research groups on the subject of indoor air quality of non-industrial settings in Europe and North America. However, little systematic theory for studying environmental illness in residential settings has been developed. As the proportion of hours spent within U.S. dwellings continues to increase for a large segment of society, the economic, legal, and social costs of ignoring housing-related health problems also may be expected to increase (Hedge, 1989).

Housing educators have the opportunity to make an important contribution to improving future residential environments by assuming a proactive role in addressing building-related health and wellness issues (Danko, Eshelman, and Hedge, 1990). However, providing guidance in the face of ongoing developments in materials and systems technology requires an empirical foundation that is based on systematic research into the salient interconnections among housing factors, occupant factors, and the causes and sources of building-related health complaints. Towards this end, the conceptual framework presented in this paper has been developed, based on the merger of existing explanatory models of building-related health complaints. This new model may be used in the exploration of the complexity of housing-related illness from both multifactorial and proactive perspectives.

Figure 3. Factoring indoor air quality into the building delivery process.



* Source of concept: Hartkopf, V.; Loftness, V.; Mill, P. in Rush, R. (Ed.), 1985.

** Source of concept: Vischer, J., 1989.

*** Source of concept: Silberman, R., 1991.

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