IMPACT OF SOCIOECONOMIC FACTORS ON RESIDENTIAL INDOOR AIR QUALITY AND HUMAN HEALTH

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Summary

The quality of indoor air significantly impacts on human health. Indoor air may be contaminated with toxic gases or vapors, or with metals, and macromolecules or particles that become suspended in the air. These pollutants may be of biological or chemical origin. Inhalation of indoor pollutants may result in physiological effects ranging from odor perception and respiratory tract irritation to severe organ damage, immunological reactions, and cancer.

The home is a particularly important indoor environment. Most people spend the majority of their time inside the home. Significant exposures, including peak or chronic long-term exposures, often occur in the home. Each home is a fairly unique microenvironment due to the enormous diversity of potential indoor pollutant sources and indoor human activities. For the most part, social and economic factors determine the pollutant sources and activities that occur in each home, and thus the types of indoor

exposures.

Socioeconomic status does not dictate the presence or absence of significant indoor exposures. Exposures to some pollutants are more likely in households with little income while the reverse is true for other pollutants. Socioeconomic status is, however, associated with level of education, nutrition, and access to health care, all of which are known to impact on the health outcome of exposures.

The health of a society is critical to the economic, cultural, and social contributions that can be made by its members. The indoor environment may be considered an issue of public health concern with significant impacts on human health. For example, asthma prevalence has increased dramatically over the past 10 to 15 years and its onset (in an individual) appears to be linked to indoor exposures. A public health approach to this disease, that is to identify risk factors, and to implement community-wide prevention and control measures, is warranted and is underway.

It is to be noted that many measures to prevent or reduce indoor exposures are inexpensive, practical, and consistent with cultural traditions. Indoor air standards and guidelines, together with education, may be the tools needed to implement these measures and thus effectively address indoor air issues.

This article briefly discusses socioeconomic factors, and their relationship to indoor exposures and human health. It presents information on several of the most important indoor pollutants or pollutant groups, and discusses the importance of ventilation to indoor exposures. The impact of socioeconomic factors is highlighted where possible. Finally, using an underlying theme of global sustainability and cultural or societal integrity, future perspectives, and recommendations are made.

1. Introduction

Research on exposures and health effects associated with indoor air pollutants began in earnest in the 1970s when energy conserving measures prompted the construction of "tight" buildings with greatly reduced indoor–outdoor air exchanges. The research found that exposures to indoor pollutants, such as formaldehyde, environmental tobacco smoke (ETS), radon, nitrogen oxides (NO_X), and particulate matter, were associated with adverse health effects. Much of this research focused on office buildings in the United States and Western Europe. It was soon recognized that significant exposures could occur to occupants in other indoor environments. In non-office indoor environments, such as houses, vehicles, and schools, the type and level of indoor exposure is often strongly influenced by economic and social factors. For example, in some parts of the world, crop residues are used for cooking and heating because they have no cost, and are readily available. Burning of crop residues inside a home without proper ventilation may result in high levels of carbon monoxide and particulate matter in the indoor environment.

The prioritization of environmental protection and pollution control differs between developed and developing countries. Developed countries have greatly reduced the "diseases of poverty" (malnutrition and communicable diseases) have stable populations, and a relatively high standard of living. By contrast, most developing countries are striving to reduce morbidity from various diseases (including malnutrition); and to develop stronger and more stable economies. As has occurred in developed countries, economic gains are often obtained at the cost of severe degradation of natural resources and the environment.

Income and education level, type of occupation, employment status, access to health care, adequacy of nutrition, social support (e.g., family and community), and physical environment (e.g., housing) are some of the socioeconomic factors that have impact on indoor exposures and human health. The physical environment has a greater influence on the indoor exposure (specific pollutant, level of exposure) while personal conditions and habits (e.g., nutrition, personal, and home hygiene) tend to have a greater effect on the health outcome of the indoor exposure.

Studies have shown that people in developed societies spend more than 75% of their time indoors, the exact proportion depending on factors such as age, season, weather, occupation, and health status. Of the time spent indoors, more than 70% is typically spent at home, with some variation among sub-populations within the society. For example, individuals with chronic diseases and infants are likely to spend more than 70% of their time at home indoors. It is unknown whether the same proportion of time is spent indoors by people who are disadvantaged socioeconomically, and/or who live in developing countries.

There are many different indoor environments, including industrial and non-industrial workplaces, schools, homes, and hospitals. Due to the complexity of factors affecting indoor environments and the uniqueness of each individual indoor environment, this article will focus on just one indoor environment: the residential indoor environment (i.e., the home). The home was chosen because it is where most people spend the majority of their time each day, and where numerous indoor pollutant sources exist. Though the concepts discussed in this article pertain to the home, these concepts can often be applied to other indoor environments.

2. Socioeconomic Factors and their Influence on the Association between Indoor Exposures and Human Health

There are many different definitions for socioeconomic factors and for levels of socioeconomic status. Socioeconomic factors are determined by social or cultural views and practices, and by level of education, income or assets. Some definitions use only one factor (e.g., income) as the measure of socioeconomic level, while others use combinations of factors, (e.g., education, occupation, and financial assets) as the measure. The factor itself may have varying definitions. For example, income can be defined as gross income or net income, or as individual or household income, or annual or monthly income. Income may be based on monetary earnings or alternatively on agricultural or natural resource products. The present article does not provide an exact definition of socioeconomic status or of socioeconomic factors, but gives examples of different socioeconomic situations that may affect indoor exposures and health effects. Further, when reviewing studies that have evaluated socioeconomic factors, it is important to consider the definition of these factors, specific to each study.

The relationships between socioeconomic factors, indoor environmental exposures, and health effects are complex and dynamic. Socioeconomic factors can indirectly or directly affect health outcomes arising from indoor contaminant exposures. Some factors tend to act indirectly by influencing the exposure (the type and level of pollutant, and the duration of contact) while others act more directly by influencing the individual's health (either the individual's susceptibility to disease or the severity of the disease outcome). In addition, one socioeconomic factor may influence other factors, thus complicating the already complex relationships between these factors and indoor exposures, and health effects.

Both lower economic, less technically advanced, and higher economic, more highly technical societies experience significant indoor environmental exposures to pollutants and consequent adverse health effects. It is often assumed that people living in lower economic areas are singularly at higher risk for adverse health effects associated with indoor environmental exposures, but social or cultural factors may have as much or more of an influence. For example, social determinants highly influence an individual's decision to smoke tobacco. Such social determinants include overall cultural acceptance of smoking, peer attitudes, family smoking history, advertising, and smoking policies. In many instances, tobacco smoking is the most important contributor to high- levels of pollutants indoors. These pollutants are known to have carcinogenic, reproductive, and/or acute or chronic respiratory effects.

Along with tobacco smoking, indoor cooking, and heating have the greatest influence relative to other combustion activities on indoor pollutant exposures. Socioeconomic factors often determine the type of stoves and fuels used for indoor cooking and heating, which in turn greatly affects the levels and types of pollutants released into the indoor air. Candles, incense, and mosquito oil- burning characteristically emit significant levels of particulate matter that has been shown to be associated with respiratory symptoms and other adverse health effects. The burning of incense and candles is a daily ritual in some societies, and thus is dictated primarily by social factors.

Social and economic influences often affect household hygiene and cleanliness. Low-income families may live in houses that have poor building design and inferior building materials. Deteriorating building structures and lack of building maintenance often lead to water intrusion and resultant fungal (mold) growth. Fungal toxins and allergens may be released leading to adverse health effects in exposed occupants. Rodent and cockroach infestations may result in exposures to rodent borne diseases (e.g., Hantavirus) and cockroach allergens. Chipping lead paint, found primarily in older and inadequately maintained homes, may contaminate household dust and expose occupants to high levels of lead.

Societies with higher incomes and a higher level of technology tend to use more consumer products and services. These products may directly affect indoor environmental exposures by the emission or aerosolization of toxic pollutants. For example, certain kinds of air fresheners/deodorizers emit P-dichlorobenzene for which there is evidence for possible carcinogenic effects and liver, kidney, and CNS effects from chronic exposure. Clothes that have been dry-cleaned may release 1, 1, 1-trichloroethane (a potential mutagen) and tetrachloroethylene (that has both acute and chronic effects). Mothballs contain naphthalene that has nasal and pulmonary effects. Other consumer products that are or can become aerosolized and that frequently contain various volatile organic compounds (see Section 3.5) include furniture polish, carpet, and oven cleaners, bathroom disinfectants, pest spray, nail polish, hair spray, and floor varnish strippers. Use of these products indoors without proper ventilation may result in exposure to hazardous airborne chemicals. These chemicals can easily be inhaled and result in nasal, upper respiratory, and eye irritation. Pesticides may contain organophosphates or carbamates that have known hepatoxic or other organ effects (household pesticides are discussed in Section 3.7). Products used in or on buildings, such as adhesives, paint, paint strippers, and solvent/thinners, often contain volatile organic compounds that have been associated with adverse, particularly respiratory, health effects.

During the 1970s, the cost of oil for heating buildings increased greatly, encouraging more highly technical countries to construct “energy efficient” buildings. These “tight” buildings have minimal airflow between the interior and exterior of the building. This effectively decreased potential dilution of indoor air by fresh outdoor air thus increasing the possibility for concentrating pollutants inside the building.

Social customs and ideas influence personal activities that in turn may affect indoor exposures. The relationship of social factors and environmental tobacco smoke, an important source of indoor pollutants, is discussed in Section 3.2. Other personal activities may be dictated by the individual’s role in society. For example, in many societies women are responsible for the cooking the family meal. This cooking, in some areas of the world, occurs indoors where long cooking times are common (e.g., slow roasting of corn and peppers) and where biomass fuel, kerosene or coal is used. These fuels emit toxic pollutants into the indoor environment in which the woman spends most of her time. Infants and young children may also be highly exposed if, as is customary in some societies, the mother carries the child on her back while performing household chores.

Other personal activities that impact indoor environmental exposures are hobbies and sports. Societies with greater disposable income and technology have hobbies such as furniture refurbishing or automobile repair and restoration. These activities often use highly toxic and/or carcinogenic chemicals, and may be performed in poorly ventilated areas such as garages.

Occupational activities may affect residential exposures when the occupation is in or near the residence. For example, part of the home may be used for business purposes and may expose occupants to dangerous chemicals (e.g., hair salons). On the other hand, living quarters may be within a building that also houses a business. The business may use toxic chemicals. For example, living above a car repair facility or dry-cleaning shop could expose residents to numerous hazardous materials, especially if the facility is poorly ventilated. It is also not uncommon for businesses, which use toxic chemicals to be located in residential areas.

Governmental regulations and social policies may affect indoor environmental exposures. For example, governmental regulation of pesticides generally tends to be much stricter in developed countries than in developing countries. Pesticides can be highly toxic and appropriate regulation can help minimize potentially toxic exposures. Another example is the tighter restrictions on un-vented heater use in the United States relative to other countries. Un-vented heaters have the potential to emit carbon monoxide and other toxic combustion by-products into the indoor environment.

In some societies the social norm may be for extended families to share living quarters. For example, elderly family members may share living quarters with younger family members rather than living on their own. Shared living quarters may also occur when household economic resources are low. Crowding, which is common in shared living quarters, often leads to increased pollutant levels and a greater potential for transmission of infectious diseases. This can directly affect health outcome by influencing an individual’s susceptibility to illness or the severity of the illness.

Two of the most important socioeconomic factors that have a tremendous impact on the susceptibility to, or severity of, disease resulting from indoor exposures are health care and education.

- **Health Care**: Preventive health care is an inexpensive and effective measure to optimize health. The use of health care is often determined by economic factors. Health care is by and large more accessible to those with higher incomes. However, societal beliefs may also greatly affect health care use. Some societies place greater emphasis on health and, in general, give responsibility for health to the individual. Other societies may give health care responsibility to health authorities, employers, or communities. The quality of care can vary from the village medicine man to university-trained doctors. Still other societies may relinquish control to spiritual beliefs or powers.

- **Education**: Education and literacy can give access to information about environmental and personal hygiene, the toxicity of products, the proper use and care of products, the selection of residence, and the proper care of building structures. Education is highly associated with one’s choices for nutrition, and views on health care and prevention. Nutrition and health care are known to influence one’s susceptibility to, and outcome from, disease. Further, education of policy makers and home occupants is critical to achieving healthy indoor environments.

Socioeconomic factors also influence household hygiene and building maintenance. Income level and education affect the purchasing of cleaning materials and building supplies. Poor building maintenance may lead to water intrusion, which encourages mold growth, and deteriorating building structures, which provides access to the interior of the building and optimal nesting sites for rodents and insects. Improper cleaning may lead to increased exposure to lead, particularly that from chipping paint in older inadequately maintained homes.

3. Selected Important Indoor Exposures

The levels of individual pollutants, specific ventilation conditions, and the duration of contact time with the pollutant determine indoor environmental exposures. Socioeconomic factors influence all three of these parameters. Descriptions of some of the most important indoor pollutants and a description of indoor ventilation follow below. For each description we include information on the socioeconomic factors that may influence exposure to that pollutant, and the resultant health effects.

3.1. Lead

Though lead is found ubiquitously in the natural environment, it does not play a role in the normal chemistry of the human body. Lead enters the body through ingestion or inhalation. It is then carried into the blood stream where it remains until being taken up and stored in bones and teeth or in soft tissues (e.g., liver, kidneys, and brain). Lead can accumulate in bones or teeth where it may remain for over 20 years. Absorption of lead from the digestive tract is suppressed by diets rich in iron and calcium.

One source of lead is from gasoline (or petrol), particularly in countries where leaded gasoline has not been banned. Lead is also found in paints and from lead emission sources, such as battery shops. Lead can be deposited in soil or become part of household dust particles. Lead-containing soil from outdoors may be tracked indoors. Other sources include lead solder (used in food and soft drink cans or copper water pipes), some home remedies in Hispanic and Asian cultures, lead-based glaze for pottery, lead-based cosmetic make-up, and hobbies that involve the burning of lead (e.g., the making of leaded glass ornaments).

Many studies have documented adverse neuro-developmental effects in children and increased blood pressure, and related cardiovascular conditions, in adults at blood lead concentrations at or near 10 μg deciliter^{-1}. There is evidence for carcinogenicity at higher lead doses in animals but there is no evidence of this in humans. In children, neurological effects, at blood lead levels of 40 μg deciliter^{-1} and below, include decreased intelligence, short-term memory loss, reading, and spelling under-achievement, impairment of visual motor functioning, poor perception integration, disruptive classroom behavior, and impaired reaction time.

Lead has a much greater health impact on children than adults because:

- They have a faster resting inhalation rate (breaths per minute) and they inhale a greater volume on a body weight basis per unit of time. Further, they tend to breathe through their mouths more than most adults (e.g., when at play). Therefore, they receive greater lead inhalation doses than adults.
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- They have hand-to-mouth behaviors that result in more ingestion of lead from soil and dust.
- They absorb substantially more lead from the gut into their bloodstream than adults, especially children below two years of age.
- They have a higher metabolic rate, resulting in a proportionately greater daily intake of lead through food.
- They have a less developed blood-brain barrier and therefore are more likely to have lead enter and damage their central nervous system.

The NHANES III survey, which gathered data on sources of lead exposure in children in the United States during the late 1980s and early 1990s, found that African–American, and Hispanic children residing in large metropolitan areas were most at risk from elevated environmental sources of lead. Living in urban areas is associated with greater exposure to ambient lead from car exhaust. Children from economically disadvantaged backgrounds are especially vulnerable because they are more likely to have diets that are deficient in elements such as iron and calcium. Children of lower-income households are more likely to live in older un-maintained homes that have deteriorating lead-based painted surfaces. Parents with limited education may lack the literacy or background information necessary to comprehend product labels and educational materials that provide information on avoiding lead exposures. On the other hand, children of higher-income households may be living in homes more likely to be remodeled. Remodeling, if not done properly, can create lead dust exposures and therefore pose a potential hazard.

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assessment of the relationship between health (which is dependent on how people can obtain food, water, and shelter) and the quality of the environment, in the context of development.]

Biographical Sketches

Amy Arcus-Arth, DVM, MPVM has been a Research Scientist in the Office of Environmental Health Hazard Assessment of the California Environmental Protection Agency since 1994. She was a member of the Indoor Air Risk Assessment Group within the Office for four years. She is currently involved in deriving breathing rates specific for children and infants. Dr. Arcus earned her doctorate in veterinary medicine in 1982. She practiced veterinary medicine for nine years before returning to school to study preventive medicine. Her Masters degree thesis was a descriptive analysis of tuberculosis in children. She worked as a California Epidemiologic Investigation resident for two years where she investigated a cluster of iron poisonings in children. After accepting a position at the Office of Environmental Health Hazard Assessment, she helped to develop statistical distributions of breast milk consumption rates, coordinated the production of a technical report on indoor air quality in schools, and developed a questionnaire and study design for a survey of indoor air quality in California schools.

Rachel Broadwin, MPH, has been a Research Scientist in the Office of Environmental Health Hazard Assessment of the California Environmental Protection Agency (Cal/EPA) since 1994. She is a member of the Indoor Air Risk Assessment Group, and is the lead in drafting a formal telecommuting policy for her division. Ms. Broadwin earned her Master of Public Health degree (Environmental Health Sciences) in 1991 from the University of California, Berkeley. From 1988 to 1994, as a Research Specialist for the California Department of Health Services, she worked on several projects involving contamination of the environment and associated health effects from hazardous waste sites, accidental chemical releases, and sources of lead. She has designed health symptom and exposure questionnaires, and maintained databases of epidemiological variables. Since joining Cal/EPA, she has been an active member of the California Interagency Working Group on Indoor Air Quality and the Indoor Environmental Quality in Schools Committee. In addition to her work concerning indoor air, she has developed statistical distributions of breathing and food consumption rates.

Richard Lam, Ph.D., is Staff Toxicologist in the Office of Environmental Health Hazard Assessment of the California Environmental Protection Agency (Cal/EPA). He is the lead scientist in the Indoor Air Risk Assessment Group and is involved in various indoor environmental issues including evaluating human health risks from exposure to indoor pollutants. Dr. Lam earned his Ph.D. in Toxicology in 1976 from the University of Bradford, England, and did his postdoctoral training at the National Institute of Environmental Health Sciences, Research Triangle Park, North Carolina. From 1979 to 1989 Dr. Lam was Research Scientist at the Massachusetts Institute of Technology, Cambridge doing research on the effects of fine particles and gases on the pulmonary system. Since joining Cal/EPA Dr. Lam has worked on various environmental projects involving chemical contamination in water, air, and soil. He is an active participant in the California Interagency Working Group on Indoor Air Quality and is a member of the Indoor Environmental Quality in Schools and Building Design and Operations Committees. He has published numerous articles in his area of expertise.