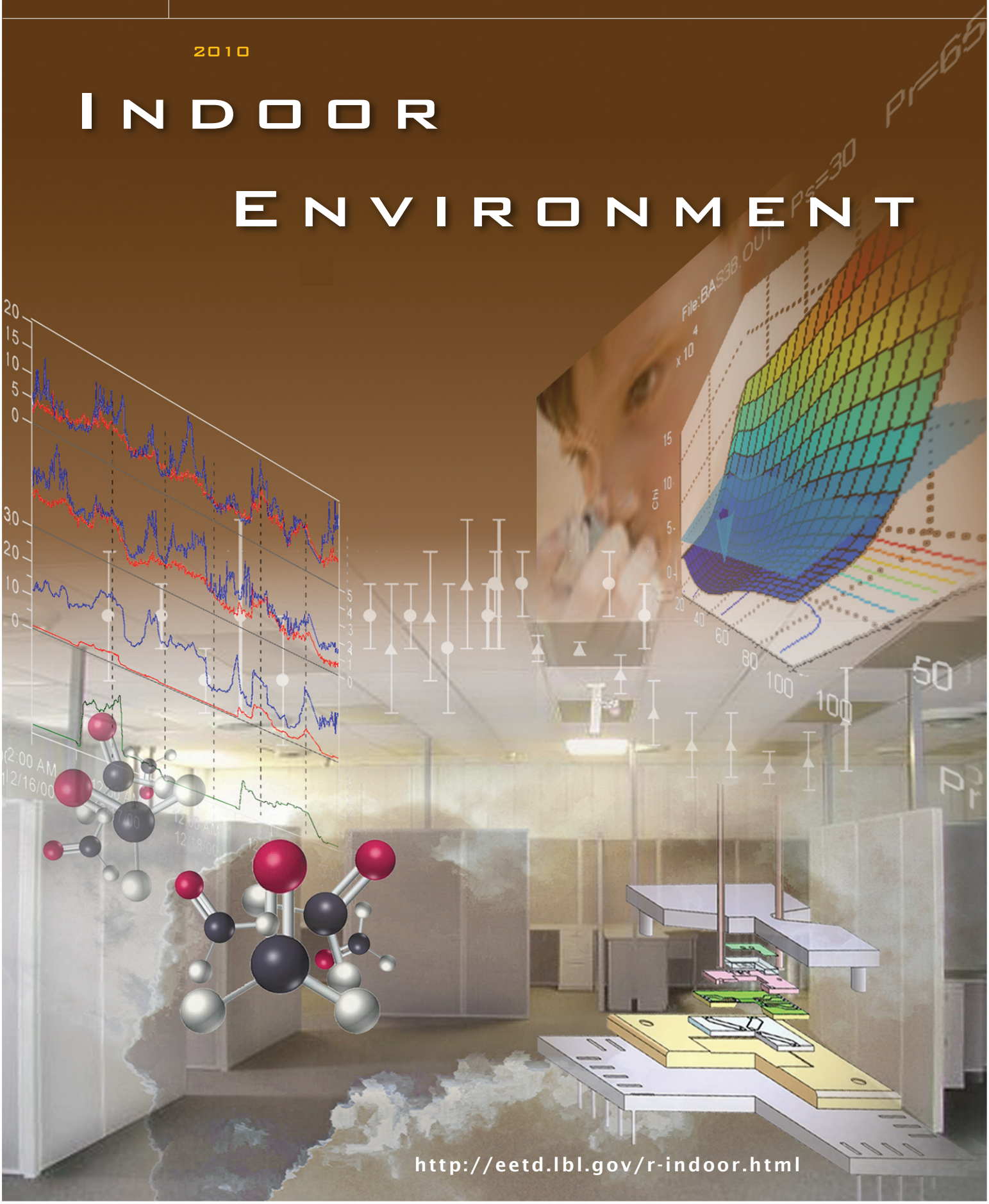
Lawrence Berkeley National Laboratory

Environmental Energy Technologies Division

2010

Indoor Environment



http://eetd.lbl.gov/r-indoor.html

Indoor Environment Department

- Airflow
- Air Cleaning
- Air Infiltration
- Air Quality
- Building-Related Symptoms
- Ducts and Duct Sealing
- Heating and Air Conditioning
- Indoor Chemistry
- Indoor Environmental Quality
- Indoor Pollutants
- Modeling Pollutant Transport
- Respiratory Problems, Mold, Allergies, Asthma
- Sick-Building Syndrome
- Ventilation

Significance of Indoor Environments

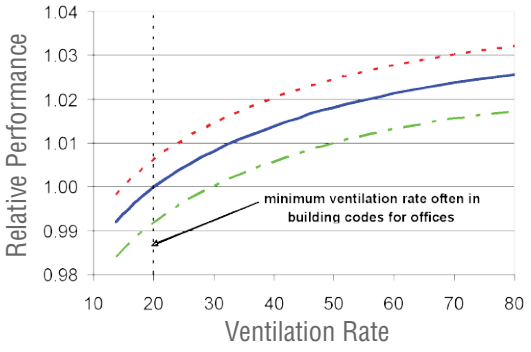
People spend approximately 90% of their time indoors. Characteristics of the indoor environment that affect people's comfort, health, and work performance include thermal conditions, concentrations of chemical and biological pollutants, outdoor air supply rates, acoustic conditions, and lighting conditions. Much of the energy use of buildings, such as all of the energy used for heating, ventilating, and air conditioning, is for maintaining acceptable indoor environmental conditions. Many of the changes that can be made to building designs and operational practices to reduce energy consumption will modify aspects of indoor environmental quality with potential impacts, positive or negative, on comfort, health, and performance. Consequently, building energy performance and indoor environmental quality must be addressed in a coordinated manner.

Indoor Environment Department Research Goals

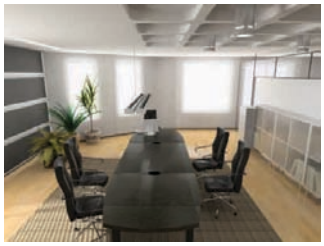
- reducing the energy used for thermally condition ing and distributing ventilation air in buildings,
- improving indoor air quality (IAQ), thermal comfort and the health and productivity of building occupants,
- improving the scientific understanding of factors and processes affecting indoor air quality, pollutant exposures, and health effects
- developing the most effective ways of reducing indoor exposures to very hazardous chemical and biological agents in the event of accidental or intentional releases.
- developing input for codes and standards that improve indoor environmental and energy perfor mance of buildings

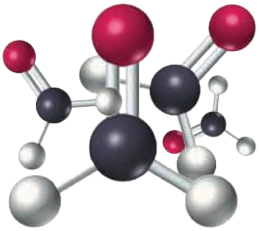
Research Areas

Building Infiltration and Ventilation



Building infiltration and ventilation affects energy consumption, concentrations of indoor air pollutants, and occupant health and performance. Research is conducted to characterize the rates of ventilation in buildings and to elucidate how ventilation affects energy consumption, indoor air quality, health, and performance. Ventilation technologies and control strategies that improve indoor air quality and minimize energy use are evaluated and developed. Models of building ventilation are developed. Input is provided for the development of building ventilation standards and codes.





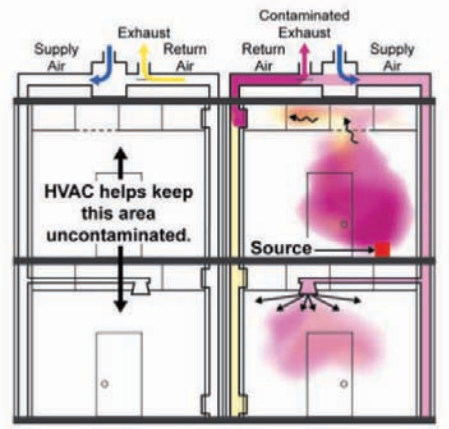
Thermal Distribution

Thermal distribution is the process of moving heat throughout a building for space heating or cooling, such as the movement of heated or cooled air through ducts to maintain thermal comfort. The goal of the Department's thermal distribution research is to assure that thermal distribution systems operate as intended with minimal energy loss. Research and technology transfer topics include diagnostic methods for evaluating thermal distribution performance in field settings, test procedures for certifying component performance, design guidance for practitioners, and improved thermal distribution technologies. Considerable emphasis is placed on technical contributions to related aspects of codes and standards.

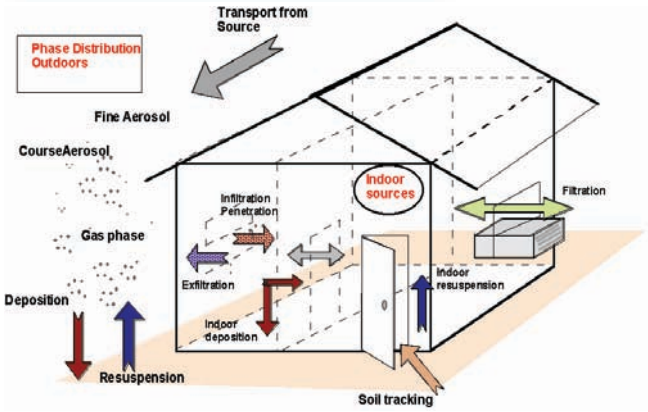
Indoor Pollutants, their Sources, Transport, and Chemical Reactions

Research is performed to characterize the concentrations of air pollutants in buildings and all of the factors that determine these concentrations. Surveys in populations of buildings establish baseline levels of pollutants and related factors such as outdoor air ventilation rates. Laboratory research quantifies the emission rates of pollutants from various indoor sources. Indoor chemical reactions that transform and create new pollutants are investigated. Indoor air and pollutant transport processes and their impacts on pollutant exposures are evaluated. The transport of pollutants from outdoors to indoors is also investigated. Related measurement techniques are developed or improved. Models are developed and employed to predict pollutant emission rates, transport processes, chemical reactions, pollutant concentrations and exposues.

Pollutant Exposure Assessment and Modeling

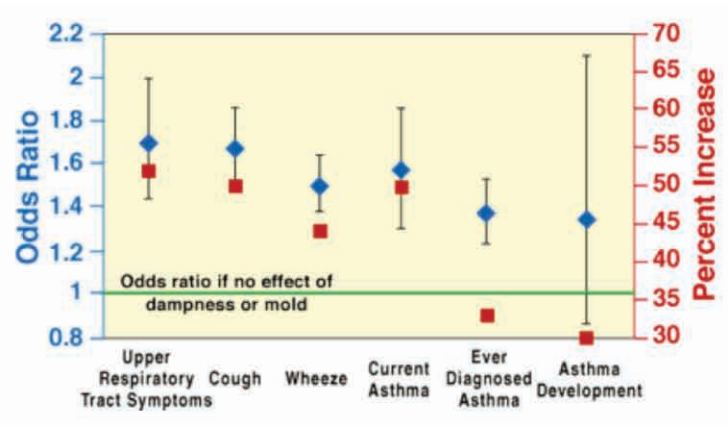


In order to characterize and model human exposures to a broad range of harmful substances, we conduct research to understand and quantify the emissions, dispersion, and fate of pollutants from both indoor and outdoor sources. We work on current and emerging technologies for anticipating and monitoring contaminant exposures for both human and ecological receptors. Our current research focuses the physical and chemical processes that govern pollutant concentrations and exposures. We also develop, evaluate, and apply cumulative exposure measurements and models in health-risk assessments. The motivation for this research is to understand and reduce the potential human health and ecological effects of energy, industrial, and agricultural systems.



Energy-efficient technologies and strategies for reducing unacceptable exposures to air pollutants are a major area of emphasis. Related research topics include advances in ventilation system design and operation, pollutant source identification and control measures, particle filtration, gas phase air cleaning, and applications of pollutant sensors. The research scope includes control measures for reducing risks from accidental or intentional indoor or outdoor releases of highly toxic chemical and biological agents.

Impacts of Indoor Environmental Quality on Health, Comfort and Performance

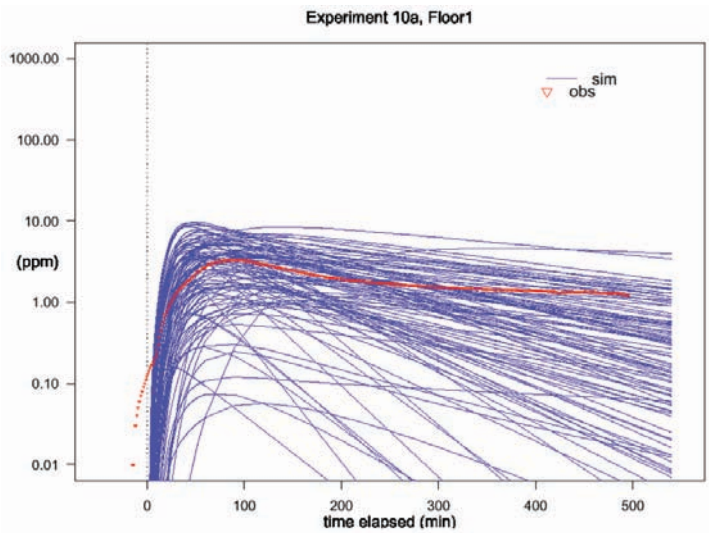


Knowledge of the relationship between indoor environmental quality and people's health, comfort, and performance provides the critical foundation for ventilation and indoor air quality standards and for many decisions about how to design, operate, use, and maintain buildings. To assess how the indoor pollutants, thermal conditions, and related features of buildings affect health, work performance, school performance, and school absence, the Department performs epidemiologic studies and experiments in buildings and completes critical reviews and meta-analyses of existing data.

Life Cycle Impact Assessment

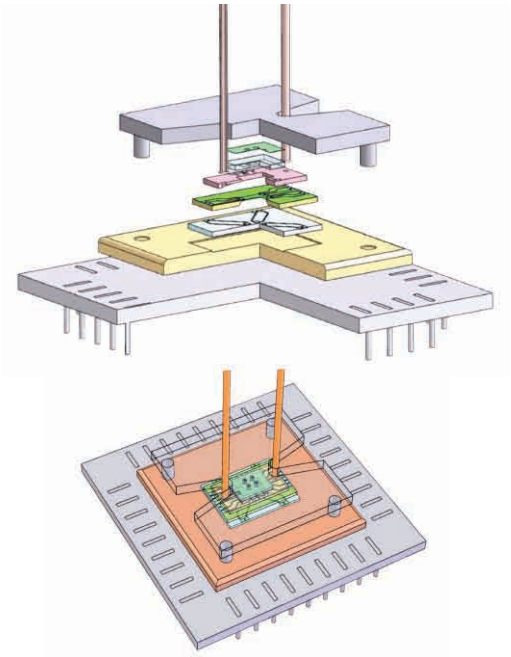
Life-cycle assessment addresses a broad range of impacts for technologies, industrial processes and products in order to determine their propensity to consume natural resources or generate pollution. The term "life cycle" refers to the need to include all stages of a product or service—raw material extraction, manufacturing, distribution, use and disposal. A life-cycle impact assessment (LCIA) provides characterization factors to compare the impacts of different product/service components. Our program is developing methods to study the life-cycle health and environmental impacts as well as economic feasibility and performance of the various pathways from sunlight to energy, with a current emphasis on biofuels. We are also assessing the environmental, economic, and health consequences of the construction, operation, and end-of-life treatment of buildings. A particular emphasis is on the improved knowledge of the interactions and potential trade-offs among economic, environmental, and health burdens linked to commercial and residential building energy performance and the environmental and economic impacts of building materials through the associated supply chains and building-use phase.

Statistical Data Analyses



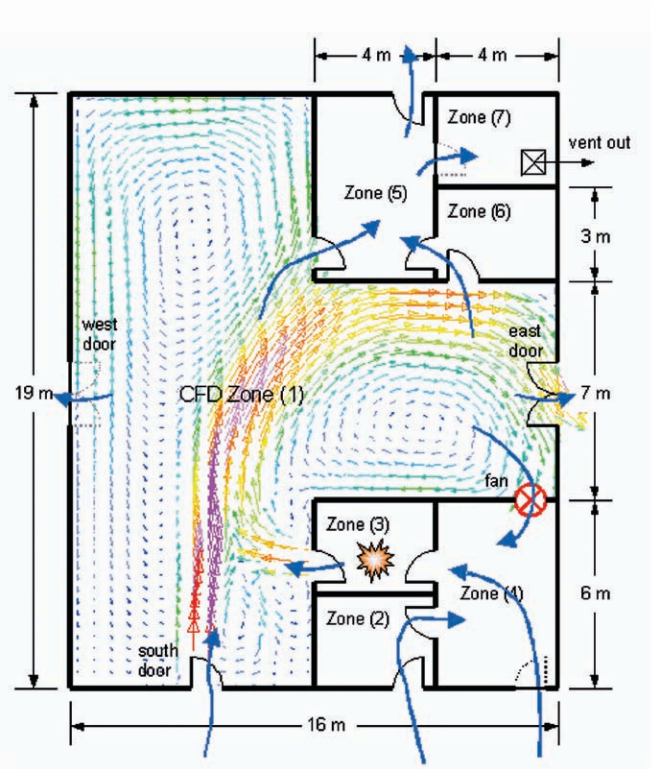
Data analysis, model uncertainty propagation, and decision analysis are integral components of the Department's research. We have developed innovative tools for analyzing data from experiments, propagating uncertainties of model inputs to output predictions, and decision making when faced with uncertain outcomes. Computational tools applied include Bayes Monte Carlo uncertainty analysis, conditional and regression trees, value-of-information analyses, and various multivariate and meta-analysis techniques. Recent applications include explaining data from various observational and field experiments, epidemiological studies (e.g., the effects of dampness and mold on health), and environmental pollutant fate predictions.

Sensors and Sensor Networks



The Department develops and evaluates sensors for various environmental and energy applications. Examples of related research include refining and miniaturizing a personal particle exposure monitor, evaluation of the accuracy of carbon dioxide sensors used for control of building ventilation, and evaluation of sensor systems that determine the number of occupants in a building or building zone, which may be used to prescribe the amount of ventilation needed to maintain indoor air quality. The Department also has active research programs in designing environmental sensor networks and interpreting measurements from them. For example, we have a program in interpreting readings from various building sensors (energy, temperature, CO_2, etc.) to detect when and where a building energy system is operating properly or faulting. We also have a program to develop probabilistic algorithms to determine the optimal placement of air monitoring sensors to detect and locate a pollutant release in a building.

Modeling



Mathematical and statistical modeling are essential components of the Department's research. The Department holds an important scientific philosophy in how models are developed and employed in our research. In a nutshell, the complexity of a model should be regulated by the research question being explored. Questions we ask ourselves when developing models include "What level of detail is needed to answer this question? What are the model-input uncertainties and variability? What data exist to confirm or refute the model predictions? Our scientists sit on various National Academy and EPA Science Advisory Panels to provide guidance on the appropriate use of models for environmental studies and regulatory purposes. Models used in our research include multimedia environmental fate and exposure models, building multi-zone airflow and pollutant dispersion models, computational fluid dynamics models, and various statistical and regression models.

Codes, Standards, and Guidelines

ASHRAE
Advancing HVAC&R to serve humanity and promote a sustainable world

Codes, standards, and guidelines are important tools for changing industry practice in a manner that improves environmental quality and reduces energy consumption. The Department provides extensive technical input to organizations responsible for codes, standards, and guidelines. In many cases, Department staff provide the initiative and leadership for development new professional consensus standards and guidelines by organizations such as the American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE) and the American Society of Testing and Materials.

Examples of Achievement

Examples of recent achievements of the Indoor Environment Department are listed below:

- characterized the relationship between rates of outdoor air supply to office buildings and the office worker's health symptoms and work performance
- quantified the relationship between dampness and mold in homes and prevalence of asthma and respiratory health effects
- identified the opportunity to simultaneously improve comfort, health, and building energy performance through better control of air temperatures in offices
- evaluated technologies for measuring and controlling office building ventilation rates, providing guidance for equipment selection
- developed an improved method for measuring the rates of air leakage in residential duct systems
- led the development of the first ASHRAE ventilation and indoor air quality standard for homes
- quantified the emission rates of air pollutants from office equipment
- evaluated the energy performance of residential air handling systems, leading to changes in fan efficiency specifications in California Title 24 codes and to the development of a new ASHRAE standard on residential air handler cabinet leakage
- developed extensive technical guidance for the ongoing greening of the U.S. Capital Building Complex
- used model-based interpretations of biomonitoring data to examine and develop hypotheses about the relative impact of indoor and food-based exposures to pesticides
- applied the "intake fraction" metric to refine methods for estimating human exposure impacts from (a) indoor pollutants, (b) ambient emissions from transportation fuels and (c) subsurface leaks from pipes and tanks.
- in collaboration with a team of researchers supported by the United Nations Environment Program and the Society for Environmental Toxicology and Chemistry, developed an internationally-harmonized life-cycle-impact model called USEtox.

Additional Information

Introduction to the Indoor Environment Department and link to many downloadable publications:
http://eetd.lbl.gov/IED/

Indoor Air Quality Scientific Findings Resource Bank with critical reviews of the relationship of indoor environmental quality with health and productivity:
www.iaqscience.lbl.gov

Introduction to residential duct systems:
http://epb.lbl.gov/ducts/index.html

Advice for designing and operating office buildings to protect occupants from releases of highly toxic chemical and biological agents:
http://securebuildings.lbl.gov/

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The mission of Berkeley Lab's Environmental Energy Technologies Division is to perform research and development leading to better energy technologies that reduce adverse energy-related environmental impacts. Our work increases the efficiency of energy use, reduces its environmental effects, provides the nation with environmental benefits, and helps developing nations achieve similar goals through technical advice.