

SUMMARY OF ON-GOING FEDERAL RESEARCH INTO THE EFFECTS OF ENVIRONMENTAL QUALITY IN SCHOOLS ON THE HEALTH OR PERFORMANCE OF STUDENTS AND TEACHERS

Mark J. Mendell and Hal Levin

INTRODUCTION

Section 5414 of the No Child Left Behind Act of 2002 mandates that the U.S. Department of Education will design a national study of the health and learning impacts of environmentally unhealthy public school buildings on students and teachers. The Department of Education, in order to avoid duplication of effort and to obtain information about possible approaches for the study, wishes to investigate ongoing studies that relate to the study of unhealthy school buildings, especially those being sponsored by the U.S. Environmental Protection Agency, the U.S. Department of Energy, and the U.S. Department of Health and Human Services.

In order to determine what relevant studies are currently occurring or planned with federal funding (or at a national level without federal funding), we contacted representatives of the following government agencies and two private organizations (complete list of contacts and contact information in Appendix 1):

- U.S. Department of Energy (DOE)/Lawrence Berkeley National Laboratory (LBNL)
- U.S. Department of Health and Human Services (DHHS)/National Institutes of Health (NIH)/National Institute of Environmental Health Sciences (NIEHS)
- DHHS/NIH/National Institute of Allergy and Infectious Disease (NIAID)
- DHHS/Centers for Disease Control and Prevention (CDC)/National Institute for Occupational Safety and Health (NIOSH)
- DHHS/CDC/National Center for Environmental Health (NCEH)
- U.S. Environmental Protection Agency (EPA)
- American Society of Heating, Refrigerating, and Air-conditioning Engineers, Inc. (ASHRAE)
- Harvard University, School of Public Health
- The Building Diagnostics Research Institute, Inc.

This paper summarizes the available information on ongoing national studies, funded or supported by U.S. federal agencies or other national organizations, on the health and learning impacts of environmentally unhealthy public school buildings. It also describes other planned research efforts in this area, and mentions some research groups that hope to conduct such research in the future but have not planned specific projects.

I. CURRENT RESEARCH ACTIVITIES

Study 1: Health, Energy, and Productivity in Schools (HEPS) Study

Conducted by

H.P. Woods Research Institute, Herndon, VA.

Funded by

National Clearinghouse for Educational Facilities and U. S. Department of Education; U. S. Department of Energy; U.S. Environmental Protection Agency; and several private sector industry groups (National Energy Management Institute; Air Conditioning and Refrigeration Technology Institute; Lennox Industries; and the North American Insulation Manufacturers Association.).

Goals

The goals of this pilot study are to assess feasibility of a protocol for a longitudinal intervention study of effects of the environment in elementary schools on the performance of students, including collection of data from various sources: teacher questionnaires, records of student grades and achievement test scores, and multiple environmental measurements of classrooms. The eventual goal of the overall study is to quantify the benefits of the simultaneous control of multiple indoor exposures – i.e., thermal, indoor air quality (IAQ), lighting, and acoustics – on measures of human response, student and teacher performance, and productivity [Woods *et al*, 2002].”

Methods

The pilot study has been conducted in six elementary schools in Montgomery County Maryland. Two matched sets of three schools were selected, and within each school, three 3rd grade and three 4th grade classrooms, for a total of 36 classrooms [Woods *et al*, 2002]. Schools were selected from those without known air quality problems, but not with perfect indoor environments. Data collection includes exposure data, teachers’ questionnaire responses, student quarterly grade reports, and student standardized test scores. The teacher questionnaire includes classroom environment acceptability ratings, teacher and student health conditions, and changes in student performance. The study design will include three levels of intervention within each school – one control level, one partial treatment group with indoor air and thermal interventions, and one full treatment group receiving these as well as acoustic and lighting interventions. Interventions, to be tailored to each school, will bring a school into compliance with environmental criteria relevant for the treatment group. Analyses will quantify the changes in indoor environmental quality and student performance between pre and post intervention conditions of classrooms [Freitag *et al*, 2002].

Findings to date

Data from teachers, students, and classrooms have been collected for one year from 36 classrooms in 6 schools. Interventions have not been selected or performed. Full analyses of the data collected have not been completed. Findings thus far suggest the feasibility of collecting quantitative data on these environmental parameters in

elementary school classrooms. However, the available data show that some of the measured conditions are significantly different from those assumed during facility design. The data also show close correlation between some environmental measurements, such as lighting, noise, and carbon dioxide, apparently due to their mutual relationships to the activity levels of students in the classrooms [Woods *et al*, 2002].

Status and plans

Work on the study has been suspended and its future is uncertain, due to personnel changes within the organization funded to perform the study. It is not clear if additional data analyses or performance of interventions in the pilot study will proceed. The former principal investigator at the HP Woods Research Institute is now with a new organization, the Building Diagnostics Research Institute, Inc.

Potential usefulness for planned federal research effort

This is a thoughtfully designed multidisciplinary study intended to assess relationships of school environments to the performance of occupants. The study has received support from a broad set of funding groups and the active participation of the elementary schools in an entire county, and it has successfully collected one year of preliminary data. It seems unlikely, however, that this study as designed would be able to achieve all its planned interpretations, given the many complex, inter-correlated factors being changed and assessed simultaneously. The overall structure of this intervention study design appears quite sound and may be usefully applied to focused study questions. Its approaches thus merit careful but critical consideration by the Department of Education during the process of designing one or more national studies.

Study 2. Children's Environmental Health Study

Conducted by

Agency for Toxic Substances and Disease Registry (ATSDR)/Division of Health Studies (DHS)/Epidemiology and Surveillance Branch and the California Department of Health Services/Environmental Health Investigations Branch

Funded by

ATSDR/DHS

Goals

This is a study to evaluate whether the prevalence of asthma and other respiratory health indices differ between children who attended school near a chromium emitting facility and children in a control school not exposed to chromium.

Methods

Questionnaires distributed by teachers to 4th, 8th, 11th, and 12th grade students were taken home to parents.

Findings to date

Questionnaire responses analyzed to assess which children's responses indicate potential asthma.

Status and plans

Analyses relating health outcomes to school location have not been reported yet.

Potential usefulness for planned federal research effort

Example of a study assessing exposures and health effects to school children resulting from *site selection*, even before construction of school.

Study 3. Geographic Information System Analysis of the Proximity of Schools to Hazardous Waste Sites on the National Priority List

Conducted by

University of Minnesota

Funded by

EPA/Office of Research and Development (ORD)/National Center for Environmental Research

Goals

The objectives of the EPA- funded part of the study (part A) are to (1) document complex exposure patterns involving multiple acute exposures and exposures to chemical mixtures for school children (K-5) from two low-income, racially diverse neighborhoods in Minneapolis, (2) examine temporal variability in exposures over 12 months, (3) apportion relative contributions to personal exposures of outdoor community air, air inside the child's school, and air inside the child's residence, (4) evaluate the relationships between measured exposures and internal dose, and (5) compare children's exposures between a new school designed to enhance indoor air quality and an older more traditionally designed and furnished school.

Methods

Monitoring exposures for children in outdoor, home, and school settings three times over a twelve-month period.

Findings to date

Some findings have been reported on metabolites of environmental tobacco smoke. Other manuscripts are in process.

Status and plans

The exposure assessment part of the study, funded in 1998, is due to finish in January, 2003, with a report due in March. Separate funding for the epidemiologic component of the study has been obtained from the State of Minnesota, but the status of that component is not known.

Potential usefulness for planned federal research effort

Results could help characterize the role of outdoor exposures in total exposures of school children.

Study 4. Pilot study on the effects of germicidal ultraviolet (UV) light on absenteeism in school environments

Conducted by

Don Milton, Harvard University School of Public Health

Funded by

Small pilot grants from CDC/NIOSH and the Alfred P. Sloan Foundation.

Goals

To test air disinfection interventions in classrooms, and to measure the effect this technique has in reducing asthma and respiratory infections in children.

Methods

The project will consist of a single-blind crossover intervention study of the effects of reducing airborne concentrations of infectious droplet nuclei by *upper room germicidal UV light*. (Later study phases are planned to assess the effects of reducing airborne particles and microbiological contaminants with *high efficiency filtration*, and reducing airborne infectious agent concentrations and volatile organic compounds (VOCs) using *photocatalytic oxidation*). The intervention will be applied in classrooms in one school, to be chosen based on past known IAQ problems and complaints, as well as low ventilation rates. Health related data will be collected based on absence rates obtained from school attendance records.

Findings to date

Not completed.

Status and plans

The school board, on November 25, 2002, approved the study of upper room germicidal UV, in four classrooms within a school that has the highest carbon dioxide levels in its school district (daily peak in excess of 2000 parts per million during the winter) but not other major problems such as dampness. Brochures and presentations have been provided for parents. Installation of the UV lights is scheduled during the winter holiday, with the intervention study to start in January.

Potential usefulness for planned federal research effort

Results of this study are not likely to be available in time to plan a new federal study, but the scientific ideas and study design concepts in this effort deserve careful consideration in the design of the federal effort.

Study 5. Review of literature on unhealthy school buildings and performance of students

Conducted by

Lawrence Berkeley National Laboratory (Mark Mendell, principal investigator)

Funded by

EPA through the National Institute for Standards and Technology (NIST) and the Indoor Health and Productivity Program of the Construction and Building Subcommittee of the National Science and Technology Council.

Goals

The goal of the review was to assess critically the existing scientific literature and synthesize what is known about relationships between school environments and the performance or absenteeism of students.

Methods

Due to the limited available literature on the key relationships of interest in schools, the review adopted an expanded scope – a critical literature review of the relationships between indoor environmental quality and the performance or absenteeism of occupants in buildings in general, plus a summary of literature on other relevant relationships, such as between indoor environmental quality and health.

Findings to date

The review, in order to examine relationships between indoor environments in schools and student performance, assessed available research on children and adults in schools, workplaces, residences, and laboratory settings. It critically reviewed evidence for direct relationships between indoor environments and the performance or attendance of occupants, and also summarized reported relationships between IEQ, health, and performance or attendance. The most persuasive *direct* evidence found related lower ventilation rates and increased nitrogen dioxide to reduced performance or attendance. The most persuasive *indirect* evidence related indoor dampness and microbiologic pollutants to asthma and respiratory infections, health effects that are linked to reduced performance and attendance. Overall evidence strongly suggested that IEQ in schools can influence the performance and attendance of students, primarily through health effects from indoor pollutants.

The review (full abstract in Appendix 2) concluded that sufficient evidence was available to justify

- (1) immediate actions to safeguard IEQ in schools and
- (2) focused research to guide policies and actions on IEQ in schools.

Status and plans

The review has not been released yet, as it has been submitted to an educational research journal for publication. The current title is “Do Indoor Environments in Schools Influence Student Performance? A Review of the Literature.” Key findings have been

summarized in a web-page which will be available through the EPA's web site. A supplement to the review, currently in preparation, will examine in more detail the relationship between absenteeism and performance in schools (see Study 6 below).

Potential usefulness for planned federal research effort

This review will help define current scientific knowledge and key scientific questions related to school environments and the health and performance of occupants, which in turn will help guide future studies on this topic by the Department of Education

Study 6. Review of student and teacher absenteeism and the performance of students

Conducted by

Mark Mendell, principal investigator

Funded by

U.S. Department of Education

Goals

The goal is to supplement the previous review funded by the EPA on the relationships between school environments and the performance or absenteeism of students

Methods

Literature review and summary.

Findings to date

Not completed.

Status and plans

Final report, to be titled "Effects of Student and Teacher Absenteeism on Learning and Academic Performance among Elementary and Secondary School Students," due to the Department of Education by December, 2002.

Potential usefulness for planned federal research effort

This paper will provides additional detail on one element of the EPA-funded review described above.

II. RESEARCH IN PLANNING STAGES OR UNDER CONSIDERATION

Project 1a. DHHS/CDC/NIOSH

NIOSH is the institute within the CDC that focuses on worker health and safety. Researchers in the Division of Respiratory Disease Studies of NIOSH, in Morgantown, West Virginia, would like to investigate the relationship between the indoor environment and the health and, possibly, performance of *teachers*. They plan to cooperate with NCEH, whose researchers will investigate the impact of school environments on the health and, possibly, performance of *students*. NIOSH has substantial experience and expertise in conducting environmental research and investigations. This division is likely to focus their research on respiratory health effects within schools, and on exposures related to moisture and mold. No funding has been earmarked nor sites chosen for this study. No timeline exists for implementation.

Project 1b. DHHS/CDC/NCEH

This Center, in cooperation with NIOSH, would investigate, or fund investigation, of the effects of school environments on asthma in *students*, as described above.

Project 2. Indoor Environmental Effects on the Performance of School Work by Children (1257-TRP)

Conducted by

Contractor to be selected through a competitive Request for Proposal (RFP) process, for this project, which has been designed by ASHRAE Technical Committee TC2.1, Physiology and Human Environment.

Funded by

ASHRAE, Atlanta, GA.

Objective

The objective of this project is to perform intervention experiments to test the hypothesis that classroom upgrades resulting in improved thermal control or improved air quality would significantly improve the performance of schoolchildren, to determine as far as possible the causative mechanism or mechanisms by which this would occur, and to quantify the improvement in health, absenteeism and school performance that would be likely to occur in practice if such improvements were implemented by school authorities.

Scope

The project is to be carried out as a series of intervention experiments in school classrooms. Each experiment will simulate a classroom HVAC upgrade by reversibly

producing one or more of the below-listed effects on the Indoor Environmental Quality (IEQ) of a school classroom:

- Reduced indoor air temperature and/or humidity in hot weather;
- Better control (reduced variance in time or space) of indoor air temperatures;
- Increased outdoor air supply rate (leading to reduced indoor levels of particles, gases, vapors, odor);
- Improved supply air quality (achieved by means of better or cleaner filters)

The experiment will obtain quantitative measures which predict or assess school performance and absenteeism, such as health, SBS symptom intensity, subjective comfort, acceptability, classroom behavior and the performance of tasks similar or identical to those that when taken together constitute school work, both under control (normally existing) conditions and under the experimentally improved conditions. The interventions must be repeated to the extent necessary to avoid confounding by external weather conditions or events likely to affect school work, and should be planned to avoid such disturbing factors whenever possible. Additional measurements on an independent control group throughout the experiment, or crossover designs, should be used to further identify and reduce any effects of external factors.

Current Status

A Request for Proposals (RFP) has been issued. Because of the recognized difficulty in obtaining agreement on participation by schools, the length of time allowed for preparation of proposals has been extended by six months. It is anticipated that work could start on this project in the second half of 2003.

III. SUMMARY AND DISCUSSION

Avoiding duplication with ongoing studies

There is little risk of duplication due to the almost complete absence of relevant ongoing, full-scale studies on this topic. It will be useful to monitor the status of the currently interrupted pilot study on school environments and performance begun by the HP Woods Research Institute, the planned pilot study on school air cleaning and absenteeism being conducted by the Harvard School of Public Health, and the planned study of school environments and student performance to be funded by ASHRAE. These studies may provide valuable examples of study design, effective logistic strategies, and problems to avoid, as well as some preliminary findings, although all this information may not be available within the next year (1993).

Currently available information on possible approaches for a new Department of Education study

The most valuable information identified in this brief investigation was the study design strategies proposed by the HP Woods Institute and the ASHRAE studies. The former, by following classes of students over a three-year time frame, using two levels of interventions, and obtaining data on environmental characteristics, teacher self-assessed performance, and student test scores, hopes to identify relationships between a group of

simultaneous changes made in the environment and changes in student and teacher performance. Benefits of bringing classrooms up to a general set of environmental criteria could, in theory, be characterized, although effects of specific environmental changes performed will not be possible to characterize. In contrast, the latter ASHRAE-funded study uses a more focused strategy to assess the effects of specific environmental interventions, one at a time, with as many other factors as possible unchanged. These two intervention study strategies, along with any upcoming information available on the intervention design to be used in the Harvard study, deserve careful consideration in the design of future studies.

These current or planned studies will be most helpful in designing studies to characterize cause and effect relationships between school environments and student health and performance. Studies of other design may be appropriate for other questions. For instance, a study to quantify the occurrence in U.S. schools of exposures or conditions known or suspected to be harmful to student health or performance (e.g., inadequate ventilation, excessive nitrogen dioxide, moisture, or mold) is more likely to be a cross-sectional survey.

Also, the specific environmental factors and student outcomes emphasized in these current or planned studies deserve careful consideration, but should not be considered complete. For instance, a new national study might well include a strong emphasis on health effects of moisture and mold in school environments – these have been studied mostly outside the U.S. [Husman, 2002; Hyvärinen, 2002].

There may be possibilities for coordination of future Department of Education-funded research with some of these current or planned U.S. studies or with the related researchers. At a minimum, the *design* of a national study of the effects of school environments on health and performance could benefit from input given by those currently most knowledgeable about the scientific and practical issues involved in studying this multidisciplinary set of questions.

IV. BIBLIOGRAPHY

Freitag, PK, JE Woods, B Hemler, NP Sensharma, BA Penney, G Marx, 2002. Health, Energy and Productivity in Schools: Measures of Occupant Performance. In Levin, H., ed., *Proceedings of Indoor Air 2002: The 9th International Conference on Indoor Air Quality and Climate*. Monterey, California, June 30-July 5, 2002. Vol. 1 pp.834-839. Santa Cruz: Indoor Air 2002, Inc. Available from www.indoorair2002.org.

Husman T. Respiratory infections among children in moisture damaged schools. In: Levin H ed. *Proceedings of Indoor Air '02: the 9th International Conference on Indoor Air Quality and Climate*, Monterey, CA: June 30-July 5, 2002. 1: 484-489. Santa Cruz: Indoor Air, 2002; Inc. Available from www.indoorair2002.org.

Hyvärinen A et al. Microbial exposure and mold specific serum IGG levels of symptomatic schoolchildren. In: Levin H ed. *Proceedings of Indoor Air '02: the 9th International Conference on Indoor Air Quality and Climate*, Monterey, CA: June 30-July 5, 2002.; 3: 404-409. Santa Cruz: Indoor Air, 2002; Inc. Available from www.indoorair2002.org.

Mendell MJ, Heath GA. Do indoor environments in schools influence student performance? A review of the literature (submitted for publication).

Woods, JE, BA Penney, PK Freitag, G Marx, B Hemler, NP Sensharma, 2002. Health, Energy and Productivity in Schools: Overview of the Research Program. In Levin, H., ed., *Proceedings of Indoor Air 2002: The 9th International Conference on Indoor Air Quality and Climate*. Monterey, California, June 30-July 5, 2002. Vol. 2 pp.56-61. Santa Cruz: Indoor Air 2002, Inc. Available from www.indoorair2002.org.

Appendix 1. Contacts for government agencies and other groups involved in research projects reported here

CDC/NCEH

Stephen Redd – Air Pollution and Respiratory Health Branch
1-404-498-1019
scr1@cdc.gov

CDC/NIOSH/DRDS

Jean Cox-Ganser, Morgantown, WV
1-304-285-5818
jjc8@cdc.gov

CDC/NIOSH/Extramural

Lee M. Sanderson
1-404-498-2546
Michael J. Galvin
1-404-498-2524

CDHS/EHIB

Marilyn Underwood
1-510-622-4415
munderwo@dhs.ca.gov

EPA/Indoor Environments Division

David Mudarri
1-202-564-9053
Mudarri.David@epamail.epa.gov

Robert Axelrad
1-202-564-9315
axelrad.bob@epa.gov

EPA/ORD/ National Center for Environmental Research
Chris Saint
1-202-564-6909
saint.chris@epa.gov

NIH/NIEHS
Pat Mastin – Extramural Programs
1-919-541-3289
mastin@niehs.nih.gov

NIH/NIAID
Ken Adams – Extramural Programs, Allergy and Inflammation
1-301-496-8973
kadams@niaid.nih.gov

ASHRAE
David Wyon
wyon@mek.dtu.dk

Building Diagnostics Research Institute, Inc.
Jim Woods
1-301-941-1804
JEWoods3@aol.com

Harvard University School of Public Health
Donald Milton
1-617-432-3324
dmilton@hohp.harvard.edu

Appendix 2. Abstract from “Do Indoor Environments in Schools Influence Student Performance? A Review of the Literature” [Mendell and Heath, submitted]

To examine relationships between indoor environments in schools and student performance, this paper reviews available research on children and adults in schools, workplaces, residences, and laboratory settings. We critically review evidence for direct relationships between indoor environments and performance or attendance of occupants, but also summarize reported relationships between IEQ, health, and performance or

attendance. The most persuasive direct evidence related lower ventilation rates and increased nitrogen dioxide to reduced performance or attendance. The most persuasive indirect evidence related indoor dampness and microbiologic pollutants to asthma and respiratory infections, health effects linked to reduced performance and attendance. Overall evidence strongly suggests that IEQ in schools can influence performance and attendance of students, primarily through health effects from indoor pollutants. Sufficient evidence is available to justify (1) immediate actions to safeguard IEQ in schools and (2) focused research to guide policies and actions on IEQ in schools.