IEc

EPA Indoor Air Quality (IAQ) Tools for Schools (TfS) Evaluation

Final Report

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Prepared for:

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OAR Indoor Environments Division

OPEI Evaluation Support Division

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EXECUTIVE SUMMARY

The EPA Indoor Environments Division (IED) of the Office of Radiation and Indoor Air (ORIA) manages the Indoor Air Quality (IAQ) Tools for Schools (TfS) program. The IAQ TfS program is a voluntary program that provides outreach, guidance, and tools to assist school systems in reducing exposure to indoor contaminants by identifying, correcting, and preventing IAQ problems (including asthma, allergy, and respiratory triggers) in the school environment.

The purpose of this evaluation is to assess the effectiveness of EPA's IAQ TfS program guidance and related efforts, specifically to gain a better understanding of the health and environmental outcomes that can be realized from implementing IAQ management plans, as well as strategies and practices that are effective for addressing IAQ challenges.

METHODOLOGY

As discussed in Chapter 2 of this report, this program evaluation is based on three case studies: implementation of IAQ TfS in Hartford Public Schools (HPS) and the Salt Lake City School District (SLC), and implementation of a more prescriptive IAQ management approach developed by the Minnesota Department of Public Health (MDH) at six pilot schools. Because localities use IAQ TfS differently and collect different data, we were limited in our ability to design an approach that allows for quantitative comparisons of results across study groups. Hence, IEc developed three detailed case studies on the implementation of IAQ management programs, synthesizing available data linking IAQ management to environmental, health, and perception outcomes. Where possible, the individual case studies used statistical analysis to link IAQ management to environmental and health outcomes.

IEc used a variety of data sources to develop case studies and perform the evaluation. Data sources included:

- Findings from school walkthroughs to visually identify IAQ problems;
- Information on how schools responded to IAQ problems identified, as contained in implementation logs and findings from follow up walkthroughs;
- Environmental sampling data, including results from air sampling for carbon dioxide, and dust and allergen sampling;
- Data on asthma-related nurse visits;
- Survey data on IAQ perception; and
- Interviews on IAQ management that IEc conducted with school nurses.

FINDINGS

Chapter 3 discusses findings of the evaluation, including findings on baseline IAQ conditions at schools, and environmental and health outcomes correlated with implementation of an IAQ management plan.

Prior to implementation of an IAQ management plan, the schools at the focus of the three case studies identified IAQ issues wherever they looked for them. A wide array of IAQ issues were identified in the case studies, however, a few types of IAQ issues were particularly prevalent, affecting numerous classrooms in many schools and in each case study. Ventilation problems were widespread during initial walkthroughs and air sampling, and initial walkthroughs also identified widespread cleanliness issues. A variety of other issues were visually identified during walkthroughs across case studies, including: improper storage of chemicals, cleaning, and art supplies; stained ceiling tiles; odors; and pest management/food storage problems. Schools also reported complaints from students and staff about health issues potentially associated with poor IAQ.

Following initial walkthroughs and environmental sampling, the schools studied took steps to correct IAQ issues identified. Generally speaking, the schools undertook three steps after the initial walkthroughs. First, they planned necessary changes, which involved prioritizing and budgeting for improvements. Next, school districts corrected issues identified by undertaking repairs, such as repairing HVAC systems, replacing carpet with smooth flooring, and removing stained ceiling tiles. They also implemented no-cost solutions to address IAQ issues by educating teachers and staff and changing IAQ policies. Lastly, schools checked their progress by conducting follow up walkthroughs.

IEc conducted a variety of analyses to determine if implementation of an IAQ management plan is correlated with environmental and health benefits. We found that all case studies demonstrated improvements in either environmental outcomes (Minnesota and SLC) or health outcomes (HPS) after implementing an IAQ management plan. HPS experienced fewer unplanned asthma-related nurse visits following IAQ TfS implementation. Salt Lake City schools enjoyed improvements in relative humidity in classrooms. Minnesota schools experienced decreases in levels of allergens after implementing an IAQ management plan. Moreover, both SLC and Minnesota realized improvements in carbon dioxide measures, the only common environmental measure across case studies. The progress achieved by schools studied for this evaluation demonstrates that IAQ planning and management, as embodied by EPA's IAQ TfS guidance and associated programming, represents an effective approach for identifying and addressing IAQ problems in schools.

IEc also conducted analyses to investigate whether the implementation of certain IAQ practices are strongly associated with environmental improvements. These analyses clearly demonstrate that IAQ practice recommendations in areas of smooth flooring, HVAC and ventilation, cleaning, and education/communications are important drivers of IAQ outcomes. Moreover, IAQ practice recommendations in the areas of moisture management, managing construction and renovation impacts, and plant and animal policy may also be important drivers of IAQ outcomes.

Although formulas for a successful IAQ management program may vary by district and by school, it is clear from our research that prerequisites of success include a credible and transparent process with accountability mechanisms (such as follow up walkthroughs), and long-term support from school district administration. The primary implementers of the IAQ management at the school level can vary; nurses, facilities/janitorial staff, or teachers could take the lead in implementation, although buy-in and involvement from all relevant parties makes for smoother program implementation.

RECOMMENDATIONS

As discussed in Chapter 4 of this report, this evaluation demonstrates a credible link between IAQ management, as promoted by the IAQ TfS program, and environmental and health outcomes. We offer four recommendations to assist EPA in improving IAQ TfS guidance and in strengthening data available to demonstrate the benefits of the IAQ TfS program and IAQ management in general. Recommendations are as follows, and are discussed in detail in Chapter 4:

1: Revise or expand IAQ TfS guidance to prioritize IAQ practices strongly correlated with environmental outcomes.

2: Encourage and support robust and consistent data collection on environmental, health, and perception outcomes of IAQ management.

3: Collect additional information on the potential link between IAQ management and student performance outcomes.

4: Publicize measurable successes of IAQ plan implementation.

LIST OF ACRONYMS

- ASHRAE - American Society of Heating, Refrigerating and Air-Conditioning Engineers, Incorporated
- CDC – The Centers for Disease Control and Prevention
- CO_2 - Carbon Dioxide
- EPA – The United States Environmental Protection Agency
- HPS – Hartford Public Schools
- HVAC – Heating, Ventilation, and Air Conditioning
- IAQ – Indoor Air Quality
- IEc – Industrial Economics, Incorporated
- IED – EPA Indoor Environments Division
- K-12 – Kindergarten through Twelfth Grade
- MDH – Minnesota Department of Health
- MSEAMP – Model School Environmental Asthma Management Plan
- ORIA – EPA Office of Radiation and Indoor Air
- ppm – Parts Per Million
- SLC – Salt Lake City School District
- TfS – Tools for Schools
- VOCs – Volatile Organic Compounds

CHAPTER 1 | INTRODUCTION

BACKGROUND AND HISTORY OF IAQ ISSUES IN SCHOOLS

Every school day, one in five Americans occupies a school building.[1] Children and educators spend a very large portion of their time indoors in schools, and indoor air quality in schools has become a major environmental health concern. Indoor air pollutants such as mold, mildew, dust, animal dander, radon, secondhand smoke, asbestos, and formaldehyde can trigger a variety of health problems, ranging from headaches and allergies to asthma attacks. Additionally, poor ventilation can cause an increase of the airborne transmission of viruses, which might predispose children to asthma attacks and allergic responses.[2]

Health problems aggravated by poor indoor air quality (IAQ) carry a large toll. According to the Centers for Disease Control and Prevention (CDC), asthma has become increasingly prevalent. From 1980 to 1996, asthma prevalence among children increased from 3.6 percent to 6.2 percent. Asthma is now estimated to affect 6.1 million children in the United States and accounts for 14 million missed days of school each year.[3]

Poor indoor air quality in schools is the result of numerous synergistic problems, including: high humidity and poor climate control; inadequate ventilation; inadequate housekeeping; improper use of pesticides; and failure to control pollution sources such as art supplies, cleaning supplies, and laboratory activities.[4] According to a study by the U.S. Department of Education, National Center for Education Statistics, "about 40 percent of schools report at least one unsatisfactory environmental condition, such as poor ventilation."[5] However, effective planning and management of indoor air quality can lower pollutant levels and decrease exposure to respiratory triggers, improving

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[1] The U.S. Environmental Protection Agency. *IAQ Tools for Schools: Managing Asthma in the School Environment*. August 2005. http://www.epa.gov/iaq/schools/pdfs/publications/managing_asthma.pdf

[2] Myatt TA, Johnston SL, Zuo Z, Wand M, Kebadze T, Rudnick S, et al. "Detection of airborne rhinovirus and its relation to outdoor air supply in office environments." *American Journal of Respiratory and Critical Care Medicine* 169: 1187-1190. 2004.

[3] The Center for Disease Control. "Asthma's Impact on Children and Adolescents." http://www.cdc.gov/asthma/children.htm

[4] U.S. Environmental Protection Agency. *Indoor Air Quality and Student Performance.* August, 2003. http://www.epa.gov/iaq/schools/images/iaq_and_student_performance.pdf

[5] Lewis, Laurie, Kyle Snow, Elizabeth Farris, Becky Smerdon, Stephanie Cronen, and Jessica Kaplan. "Condition of America's Public School Facilities." *Education Statistics Quarterly 2:* 9-20. 2000

occupant health. In addition, it is thought that improving IAQ and student health can also lead to tangible gains in student performance.[6]

BACKGROUND AND HISTORY OF EPA'S TOOLS FOR SCHOOLS PROGRAM

The EPA Indoor Environments Division (IED) of the Office of Radiation and Indoor Air (ORIA) manages the IAQ Tools for Schools (TfS) program. The voluntary program was launched in 1995 and provides outreach, guidance, and tools to assist schools in preventing, identifying, and addressing indoor air pollutants in the school environment. It teaches school-based stakeholders about indoor air quality and how to prevent and resolve IAQ problems using practical, low-cost or no-cost solutions.[7]

A key component of the program is the IAQ Tools for Schools Action Kit, which provides guidance to school personnel on adopting proactive IAQ management practices to improve indoor air quality. The Kit includes a series of checklists, among other tools, to help school officials identify IAQ problems and actions to take in response to problems identified. The Kit also provides guidance on various aspects of planning and implementing an IAQ management program, including but not limited to selecting an IAQ coordinator, communicating with the public, and hiring professional assistance.

The TfS program hosts the IAQ TfS National Symposium, an annual event that convenes stakeholders to share expertise on developing effective IAQ management practices for the school environment.[8] The IAQ TfS program also features a multi-tiered award program for schools and school systems. The Environmental Protection Agency uses the information from award applications to develop case studies and educate stakeholders about best IAQ management practices.

The Tools For Schools Logic Model

To illustrate the different components of the Indoor Air Quality Tools for Schools program, IEc has developed a logic model, i.e. a graphical representation of the way the program is designed to work, identifying relationships between resources, activities, outputs, and outcomes (see Exhibit 1). Although EPA offers information and resources to states and local school districts, it does not directly implement the TfS program. Rather, states and local school districts adapt the tools provided by EPA into their own indoor air quality initiatives. Thus, a complete representation of the TfS program necessitates a breakdown of activities and outcomes at the state and local levels.

To illustrate the IAQ efforts at the EPA, state, and local levels, we have broken down the logic model into four sections; EPA, state, local, and outcomes. The EPA, state, and

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[6] U.S. Environmental Protection Agency. *Indoor Air Quality and Student Performance.* August, 2003. http://www.epa.gov/iaq/schools/images/iaq_and_student_performance.pdf

[7] The U.S. Environmental Protection Agency. "Frequently Asked Questions." *IAQ Tools for Schools*. 22 May, 2003. http://env1.kangwon.ac.kr/project/sdwr2004/litsurv/intwebsites/epa-ost/epa.gov/iaq/ schools/scfaqs.html#faq#4

[8] The U.S. Environmental Protection Agency. *Indoor Air Quality Tools for Schools National Symposium*. http://www.iaqsymposium.com/index.html

local level logic models illustrate resources, activities, outputs, customers, and external factors at the specified level. Note that activities at the local level represent short-term outcomes from the federal and state perspective. Local, state, and EPA efforts lead to the same short-term and long-term IAQ outcomes, which we have portrayed in the outcomes section of the logic model.

Key components of the logic model include the following:

- **Resources** include funds, information, and expertise that support IAQ initiatives at each level of government. For example, states have access to financial resources such as their budget and EPA grants, and educational resources such as EPA sponsored conferences.
- **Activities** are the specific procedures or processes used to achieve program goals. For example, local school districts' activities include developing and implementing an IAQ management plan and increasing in-house knowledge of IAQ resources.
- **Outputs** are the immediate products that result from activities and are often used to measure short-term progress. For example, EPA outputs include IAQ conferences, articles, reports, case studies, and publications. At the local and state level, outputs include IAQ policies.
- **Customers** are groups and individuals targeted by IAQ outreach. For example, EPA performs outreach to state and local officials to encourage them to implement IAQ policies. Local school districts communicate with parents to increase awareness and support for their IAQ initiatives.
- **External Factors** are those not directly controlled by the specified entity. For example, external factors affecting local school districts can include state IAQ requirements or parental pressure. These factors can impact a school district's ability to implement IAQ initiatives.
- **Short-Term Outcomes** are the changes in IAQ management practices or changes in IAQ awareness that are causally linked to the EPA TfS program. Given the organization of the TfS program, short-term outcomes from the federal and state perspective are activities from the local perspective.
- **Long-Term Outcomes** are the reductions of environmental IAQ triggers and ultimately decreases in asthma episodes, allergic reactions, and other IAQ-related symptoms. It is important to note that due to the complex nature of IAQ problems, research and analysis linking IAQ TfS recommendations to environmental and health outcomes in schools is limited. There is however, a strong research foundation linking certain IAQ management practice recommendations with improvements in indoor air quality.[9]

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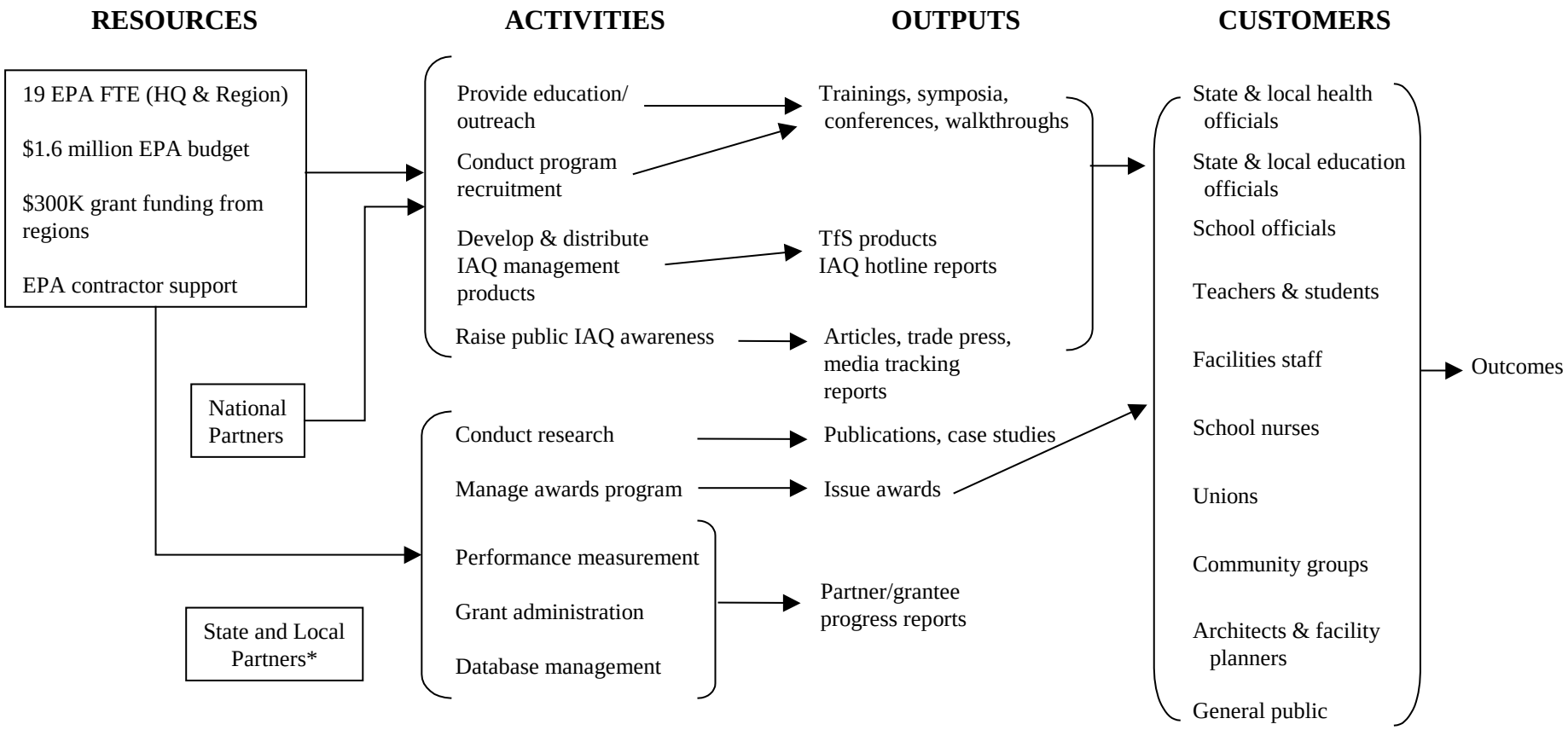
[9] Mendell, Mark et al. "Improving the Health of Workers in Indoor Environments: Priority Research Needs for a National Occupational Research Agenda." *American Journal of Public Health* 92: 1430-1440. 2002.

The resources, activities, outputs, external factors, and outcomes in the logic model relate to the evaluation questions discussed later in this evaluation report.

Exhibit 1

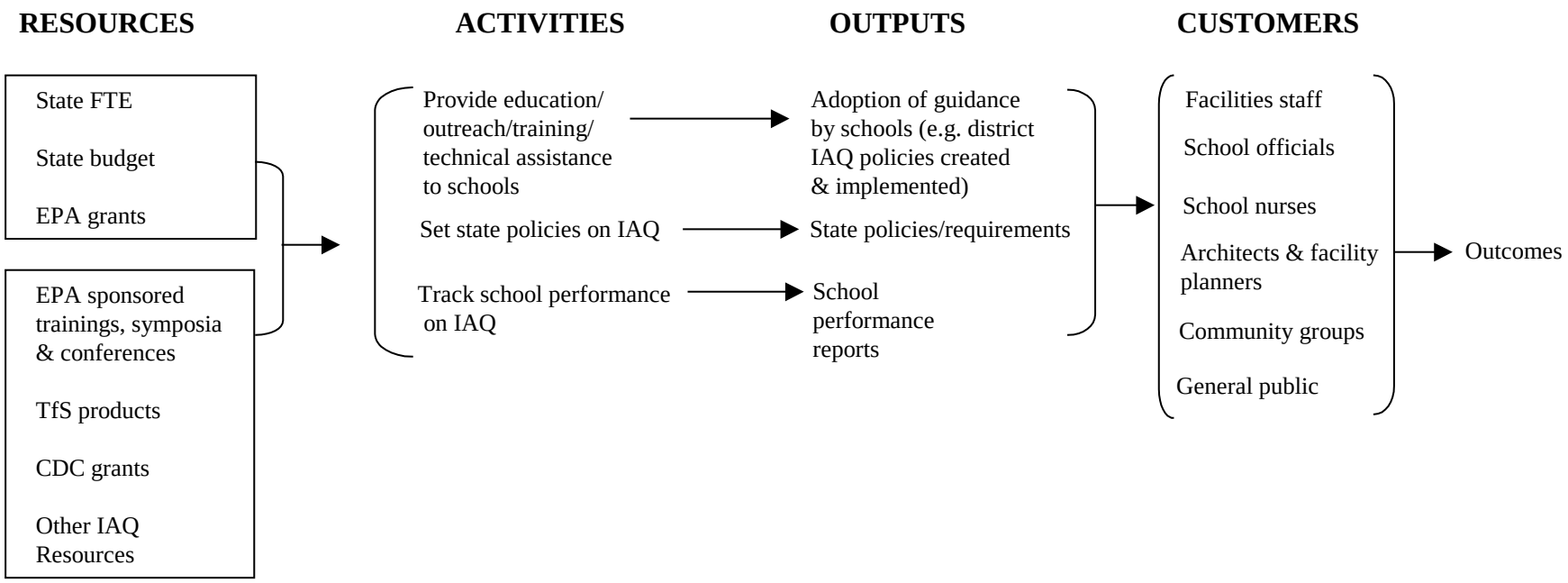
INDOOR AIR QUALITY TOOLS FOR SCHOOLS (TfS) PROGRAM
EPA-LEVEL LOGIC MODEL



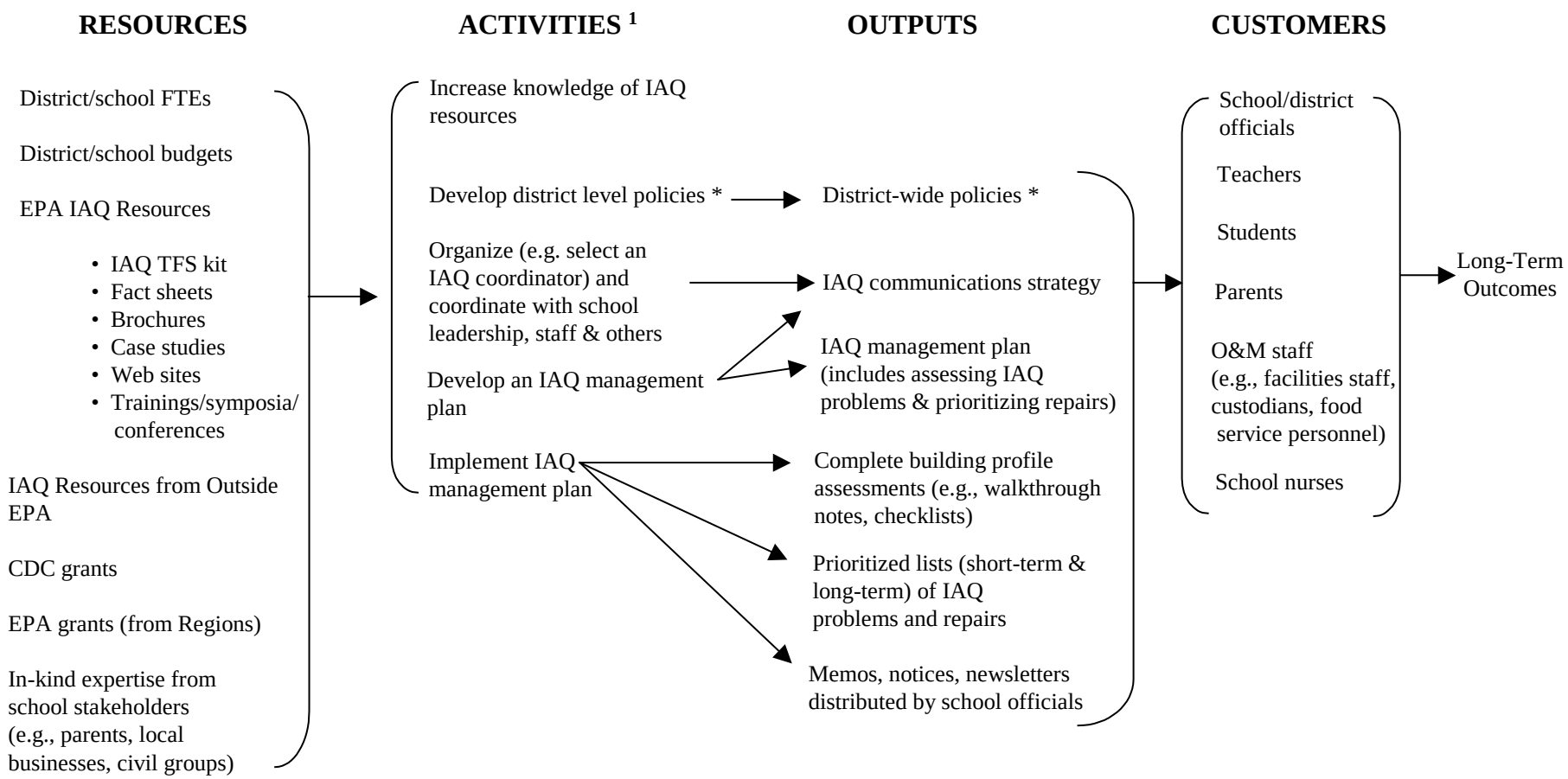
* See state and local Resources, Activities, Outputs, & Customers on following sheets.

External factors: budget constraints, existing mandates, competing priorities, bond issues

STATE-LEVEL LOGIC MODEL



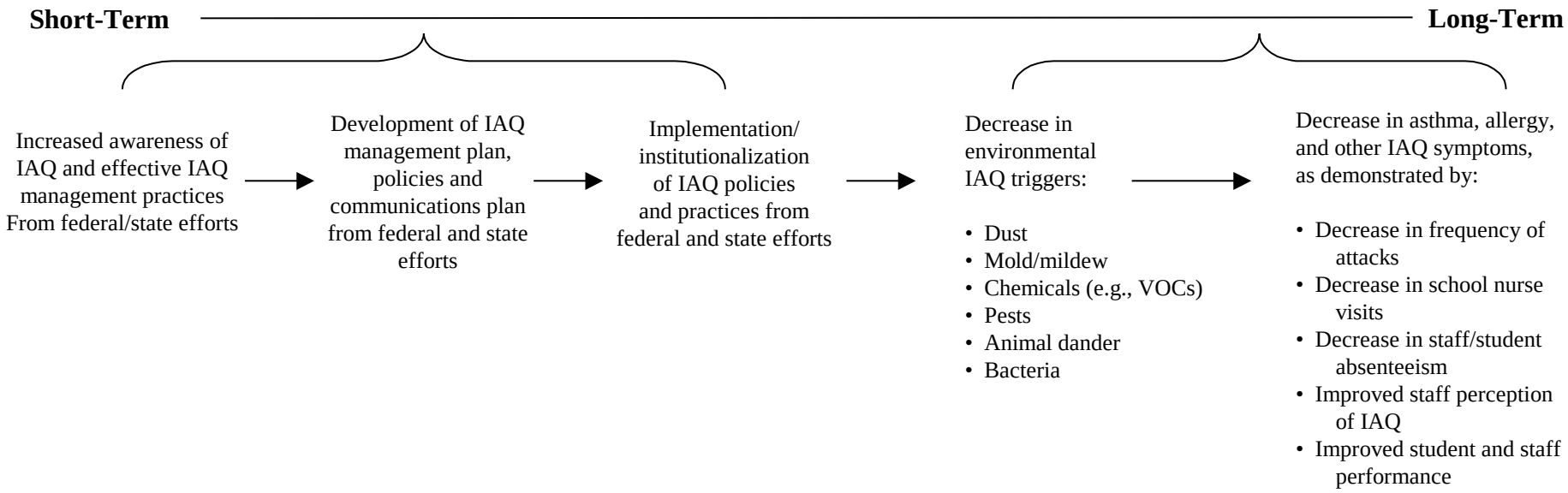
LOCAL-LEVEL LOGIC MODEL



External factors:
- Condition of facilities
- Competing demands on staff time and budget
- Parental support/pressure for improved IAQ
- History of IAQ problems
- State IAQ requirements

[1] Activities at the local level represent short-term outcomes from the federal and state perspective.
* Specifically for districts.

OUTCOMES



Strategic Plan Goal: By 2012, 35% (~ 40,000) of K-12 schools will be implementing effective IAQ management plans.

PURPOSE / OBJECTIVES OF THE EVALUATION

The purpose of this evaluation is to assess the effectiveness of EPA's IAQ TfS program guidance and related state efforts, and specifically to gain a better understanding of the health and environmental outcomes that can be realized from implementing IAQ management plans. The evaluation will increase awareness of IAQ management challenges in the school environment and illuminate strategies that appear to be effective for addressing them.

STRUCTURE OF THE REPORT

The remainder of the report is organized as follows:

- Chapter 2 presents the methodology used in this evaluation. Specifically, we present the evaluation questions, study designs, and quality assurance procedures. We also discuss the analytic methods applied in each case study and the strengths and weaknesses of these methods.
- Chapter 3 presents the evaluation findings organized in two sections. First, we provide a summary of IAQ plan implementation, which is further broken down into common IAQ challenges and activities that schools undertake to address IAQ. Next, we provide a summary of the outcomes attributed to the implementation of an IAQ management plan. The discussion of outcomes is further broken down into findings on environmental outcomes, health outcomes, and IAQ perception outcomes.
- Chapter 4 presents IEc's conclusions regarding the effectiveness of the IAQ TfS program guidance and recommendations for improving outcomes as well as the measurability of program results. We also suggest additional data collection efforts.

Appendices 1, 2, 3, and 4 include (respectively) the evaluation's Quality Assurance Project Plan, the Minnesota case study, the Hartford Public Schools case study, and the Salt Lake City School District case study.

CHAPTER 2 | METHODS

This chapter discusses the evaluation methodology employed to assess the IAQ TfS program. First, we present the evaluation questions, followed by a discussion of the study's design and quality assurance procedures. We then provide case study-specific information on implementation of IAQ TfS and evaluation data collection. Finally, we discuss strengths and weaknesses of the evaluation approach.

EVALUATION QUESTIONS

IEc developed seven detailed evaluation questions to guide the evaluation, which include questions on IAQ plan effectiveness as well as questions on how schools address IAQ problems.

Questions on how schools address IAQ problems:

1. What IAQ issues did schools look for, including: sources of impaired IAQ (e.g., furnishings, chemicals), heating, ventilation, and air conditioning (HVAC) system features and functioning, pathways (e.g., air flow patterns and air pressure differences), and occupant behavior?
2. What IAQ issues did schools identify, through walkthroughs and other means?
3. What did school officials do as a result of findings identified, in terms of changing policies and practices, or replacing HVAC or other equipment?

Questions on IAQ plan effectiveness:

4. Is the implementation of an IAQ plan associated with changes in environmental conditions, as measured by air or surface dust sampling? If so, are changes in environmental conditions generally consistent within school buildings or do they vary by room or area? What could account for variations observed?
5. Is the implementation of an IAQ plan associated with changes in perceptions of indoor air quality among staff?
6. Is the implementation of an IAQ plan associated with changes in health outcomes, as measured by IAQ or asthma-related incidences, nurse visits, or absenteeism among staff or students? Are changes in health outcomes generally consistent across staff or students, or are some staff or students apparently benefiting more than others? What could account for variations observed?
7. Is the implementation of an IAQ plan associated with changes in student or staff performance, as measured by test scores or other empirical means? Are changes in performance generally consistent across staff or students, or are some staff or

students apparently benefiting more than others? What could account for variations observed?

STUDY DESIGN

Description Of The Case Study Approach

Because localities use TfS differently and collect different data, we were limited in our ability to design an approach that allows for quantitative comparisons of TfS results across study groups. Hence, IEc developed three detailed case studies on the implementation of IAQ management programs, synthesizing available data linking IAQ management to environmental, health, and perception outcomes. Where possible, the individual case studies used statistical analysis to link IAQ management to environmental and health outcomes.

Selection Of Case Study Locations and Schools

As discussed above, local schools and school districts implement EPA's IAQ TfS program. These local actors use TfS guidance, materials, and in some cases, grant funding, as a foundation for building unique IAQ programs that reflect local needs as well as state policies or mandates. Thus, the specific components of school IAQ management programs informed by IAQ TfS vary from place to place. However, all programs based on IAQ TfS share common elements including: designation of an IAQ coordinator or team, assessement of IAQ conditions, and development of an IAQ plan.

IEc developed three case studies for this evaluation. The first case study focused on the implementation of an IAQ management approach in six elementary schools in Minnesota that is based on IAQ TfS but is somewhat more prescriptive; this is known as the "Minnesota case study." The second case study focused on the implementation of a district-wide IAQ TfS management program in Hartford Public Schools (HPS) in Connecticut; this is known as the "Hartford case study." The third case study focused on the implementation of a district-wide IAQ TfS management plan in the Salt Lake City (SLC) School District in Utah; this is known as the “Salt Lake City case study.”

The Minnesota Department of Health (MDH), HPS, and SLC collected data on IAQ conditions before and after implementing an IAQ management program. The schools in the Minnesota case study implemented MDH’s Model School Environmental Asthma Management Plan (MSEAMP). Hartford Public Schools and SLC implemented the Tools for Schools program but focused their efforts in different areas. School nurses were actively involved in implementing TfS at HPS. Simultaneously, the district’s TfS program placed top priority on addressing those IAQ issues that impact occupant safety and health, such as the management of environmental asthma triggers. Alternatively, SLC worked vigorously to improve the ventilation systems in its schools with HVAC engineers taking the lead in implementing TfS. Industrial Economics, Incorporated selected these three case studies for many reasons, including but not limited to: their geographic diversity; their willingness to work with EPA and IEc and to provide us with information; and the availability of pre- and post-implementation data to provide evidence of IAQ-related outcomes.

The evaluation focuses on schools that have fully implemented an IAQ management plan. Industrial Economics, Incorporated categorized schools as fully implementing an IAQ management plan if they had designated an IAQ coordinator or team, completed an assessment of IAQ conditions, developed an IAQ plan, gained the commitment of the school administration or board for IAQ plan implementation, and had taken concrete actions to address IAQ problems. Schools included in the Minnesota case study had been pre-selected for IEc; all six had implemented an IAQ management plan. Similarly, all schools in Salt Lake City had implemented an IAQ management plan. In Hartford, IEc categorized schools by whether or not they had fully implemented an IAQ management plan; we were able to identify a group of "study" schools that had implemented an IAQ management plan as well as a group of "control" schools that had not implemented an IAQ management plan but for which data were available.

Analytical Approach

IEc adopted a four-pronged analytical approach to assess the outcomes associated with the implementation of an IAQ management plan:

1. Identify the Information Needed and Prepare for Data Collection
2. Collect and Analyze Data from Existing Databases and Files
3. Collect and Analyze Data from Surveys and Interviews
4. Report Results and Conclusions.

Identify the Information Needed and Prepare for Data Collection

The first step in our analytical approach was to determine the types of information needed to address the evaluation questions. To answer questions on how schools address IAQ problems, we needed information from school walkthroughs and follow up analyses and reports. To answer the questions on IAQ plan effectiveness, we needed data pertaining to environmental, health, perception, or performance outcomes, such as: results from air or surface dust sampling; nurse visitation data or absenteeism rates; IAQ perception surveys; and student test scores.

Collect and Analyze Data from Existing Databases and Files

After determining the data needed to answer each evaluation question, IEc assessed the availability of these data for each of the case studies. All case studies had sufficient existing data to answer evaluation questions pertaining to how schools address IAQ problems. Sources of data used to answer these questions include:

- **Walkthrough Findings,** which include results from visual inspections and environmental sampling conducted during walkthroughs. MDH conducted pre- and post-implementation walkthroughs at the six Minnesota pilot schools and provided IEc with information on room conditions (e.g., number of occupants at time of visit, floor type), notes on IAQ problems identified (e.g., cleanliness, odor, plants), and sampling data (e.g., carbon dioxide concentration, dog and cat allergens, dust) at each of the schools during each walkthrough. HPS provided IEc with TfS reports from many of its schools: these reports outline the timing of

various TfS implementation activities and provide information on IAQ issues identified. The Salt Lake City School District provided IEc with forms that were completed during initial building walkthroughs and follow up walkthroughs. These forms contain information on environmental conditions (e.g., carbon dioxide concentration, temperature, relative humidity) and notes on room conditions (e.g., whether the door was open or closed, floor type). These data informed IEc's analysis of evaluation questions one and two.

- **Information on how schools responded to IAQ problems identified.** MDH provided IEc with implementation logs that track what schools did with the IAQ recommendations they were given, including which recommendations were implemented, labor hours to implement the recommendations, costs of implementation, and barriers to implementation. MDH also provided IEc with the results of an IAQ plan questionnaire that was administered prior to the adoption of MSEAMP and after the implementation of MSEAMP. This questionnaire provides information on schools' IAQ practices in many areas, including ventilation, flooring cleaning and maintenance, and general cleaning. HPS provided supplemental information to explain how TfS was implemented in the district, such as a list of TfS activities undertaken at the district level each year and a list of building improvements. The Salt Lake City School District provided IEc with supplemental information, including its 2003 IAQ TfS Excellence Award application, and a PowerPoint presentation, that described the district's TfS implementation efforts. These sources of data informed IEc's analysis of evaluation question three.

We reviewed the above information to determine the types of IAQ management problems identified during walkthroughs and to evaluate how schools responded to problems identified. We also assessed the availability of existing data on environmental, perception, health, and performance outcomes for each of the case studies. Each of the case studies had sufficient existing data to answer at least one of the evaluation questions pertaining to IAQ plan effectiveness. We analyzed these data quantitatively and used statistical methods where appropriate. Sources of data used to answer these questions include:

- **Environmental sampling data,** which was provided by MDH and SLC. MDH conducted air and surface dust sampling in the six pilot schools both prior to MSEAMP implementation and after MSEAMP implementation and provided IEc with data on dust, dog allergens, cat allergens, and carbon dioxide. The Salt Lake City School District conducted air sampling in its classrooms and recorded the carbon dioxide concentration in the room and in the air supply, the temperature, and the relative humidity. Although SLC collected a vast array of environmental sampling data prior to the implementation of TfS, the IAQ team only conducted follow up walkthroughs in schools where problems were identified and thus the availability of post-implementation data was limited.
- **Perception survey data**, which were collected by MDH in the six pilot schools both prior to and following the implementation of MSEAMP. Teachers in the pilot

schools provided feedback on the air quality in their classroom and in the school overall.

- **Asthma-related nurse visitation data**, which was provided by HPS. These data contain a monthly total of the number of unexpected asthma-related nurse visits by school each month beginning in the 2003-2004 school year.

Collect and Analyze Data from Surveys and Interviews

After assessing the availability of existing data, IEc evaluated the need for additional data. Given the detailed information available for the six schools involved in the Minnesota pilot project, IEc did not conduct surveys or interviews as part of that case study. Due to resource limitations as well as the availability of environmental outcome data, IEc did not conduct surveys or interviews as part of the SLC case study. However, after evaluating the asthma-related nurse visit data provided by HPS, IEc recommended following up with nurses on data collection methods as well as their perception of IAQ TfS implementation. We interviewed seven nurses and reviewed their responses to identify trends in their responses. The interview protocol is included as Appendix 1 of the Hartford case study.

Report Results and Conclusions

IEc reported the results of our analyses and our conclusions in three case studies. The overview section of each case study provides a summary of our findings. Additionally, the results of our analyses are summarized in Chapter 3 of this final evaluation report.

QUALITY ASSURANCE PROCEDURES

In conducting the evaluation, IEc, EPA's Office of Policy, Economics, and Innovation, and IED agreed on a three key quality assurances:

- IEc and EPA agreed on the key data sources, which include data from MDH, HPS, and SLC on the implementation of IAQ management activities; measures of indoor air quality conditions before and after implementation of an IAQ management plan; measures of health and perception outcomes before and after implementation of an IAQ management plan; and interviews of school nurses at HPS.
- IEc designed its analyses in the context of the project's overarching evaluation questions and the program logic model, and used statistical techniques to describe the significance of analytical findings where possible and appropriate.
- EPA staff and representatives from MDH, HPS, and SLC reviewed IEc's outputs, including the three case studies and the methodology. These individuals provided IEc with comments, and we revised the methodology and case studies in response to their comments.

Appendix 1 contains the Quality Assurance Plan that was delivered to EPA in May 2006 as part of IEc's Methodology for Evaluating EPA's Indoor Air Tools for Schools Program.

CASE STUDY 1: MINNESOTA MODEL SCHOOL ENVIRONMENTAL ASTHMA MANAGEMENT PLAN

Background of the MSEAMP

The Minnesota state legislature requires that all school districts adopt a health and safety program, which must include IAQ management as part of environmental management planning. Starting in 2000, MDH surveyed schools about IAQ management, developed the MSEAMP, and collected baseline data from six pilot schools. MDH personnel performed an initial walkthrough at each of the six schools and made recommendations on how they could improve IAQ management in 2004. Schools reported progress on implementing the recommendations in 2005. MDH gathered a variety of data to track changes in environmental conditions and perception of IAQ from pre-implementation of the MSEAMP (2004) to post-implementation of the MSEAMP (2005). MDH also collected information on how the six schools approach and address IAQ problems.[10]

Minnesota's MSEAMP and TfS have similar guidance, including: developing and implementing an IAQ management plan to improve indoor air quality; selecting an IAQ coordinator; incorporating IAQ issues identified into the IAQ management plan; and developing internal communication procedures. However, the guidance and checklists provided in MSEAMP are more detailed, prescriptive, and comprehensive than TfS guidance and checklists. Three key differences are outlined below.

- **MESAMP is More Detailed than TfS.** For instance, MSEAMP recommends specific cleaning frequencies for a variety of different flooring types. For example, MSEAMP recommends that smooth flooring be spot cleaned daily as needed, dust mopped thoroughly on a daily basis, and wet mopped thoroughly at least once a week. In comparison, the TfS Background Information for Building and Grounds Maintenance Checklist fact sheet notes, "All flooring…requires daily attention to ensure cleanliness."
- **MSEAMP appears to be More Comprehensive than TfS.** MSEAMP provides guidance on IAQ triggers that are not covered by TfS. For example, MSEAMP contains guidance related to flooring that is not included in the TfS guidance.
- **MSEAMP is Likely More Prescriptive than TfS.** MSEAMP was developed as part of a pilot project in six schools that involved expert consultation with each school participating. After initial walkthrough inspections were conducted, school officials were given detailed, school-specific recommendations developed by IAQ experts, in addition to the overarching guidelines in MSEAMP. In contrast, TfS is designed so that schools can implement the recommendations on their own, without necessarily involving IAQ experts. Therefore, while a school would develop its own set of follow up actions based on initial walkthrough inspections, these might not be as detailed or prescriptive as the school-specific recommendations provided by MDH for schools involved in the pilot project.

[10] For detailed background information on school IAQ management in Minnesota schools, see the Minnesota case study.

A MORE COMPREHENSIVE DISCUSSION OF THE DIFFERENCES BETWEEN MSEAMP AND TFS CAN BE FOUND IN CHAPTER 1 OF THE MINNESOTA CASE STUDY.

Review of Existing Data

MDH collected a diverse and comprehensive array of data from the six MSEAMP pilot schools, including:

- **General information** such as type of furniture present, cleaning practices, flooring, school demographics, and custodial staffing.
- **Room conditions and sampling data** such as the number of occupants at time of site visit, average number of occupants, concentration of particulates, ratio of indoor to outdoor particulates, indoor and outdoor carbon dioxide concentrations, carbon monoxide concentration, humidity, air flow, visual observations (such as cleanliness, plants, animals, food, printer problems, floor and window condition, moisture problems, and ventilation problems), and samples of environmental conditions taken from the floor, air, and dust particles.
- **IAQ practices** based on a questionnaire about practices with regard to ventilation, flooring cleaning and maintenance, general cleaning of surfaces, materials used, history of pests/pesticides, chemical use, construction/renovation, whether or not certain materials, plants, and animals are allowed in school, and communications with staff.
- **Teachers' perceptions** about air quality in their classroom and overall.
- **Implementation logs** for tracking school responses to customized IAQ recommendations provided by MDH during walkthroughs, including whether each recommendation was implemented, labor hours needed to implement the recommendation, costs of implementation, and barriers to implementation.

The data are organized in a series of tables and include sampling data (e.g., cat allergens per gram floor dust), which can be analyzed statistically, as well as descriptive information (e.g. text responses to questions about IAQ policies or plan implementation), which can be used in interpreting IAQ conditions. Within the data provided by MDH, a few tables in particular contain critical information for answering the evaluation questions.

MDH took 12 samples of the levels of dust, cat, and dog allergens in between six and nine classrooms in each school in 2004 and 2005 and described factors in the classrooms that could contribute to IAQ conditions, such as floor type and the number of students living in households with pets. MDH's sampling results are compiled in the Dust Sampling tables. These data are critical for analyzing the environmental impacts of implementing the MSEAMP.

The perception data provided by MDH also help inform questions related to environmental outcomes. MDH administered an anonymous IAQ survey to school staff in each of the six schools in 2004 and again in 2005. The survey asked two questions: "How do you rate the quality of air in the entire school building?" and "How do you rate

the quality of air in the room(s) at the school where you work and/or teach?" Teachers rated air quality as good, average, or poor. Improved perception suggests greater satisfaction with IAQ and fewer IAQ complaints.

Finally, we used MDH's Implementation Log to answer evaluation questions related to activities that schools undertook to address IAQ problems. In 2005, each of the six pilot schools reported whether they fully implemented, partially implemented, or did not implement each of MDH's recommendations. When a recommendation was partially implemented or not implemented at all, schools were asked to indicate one of multiple reasons why. If a recommendation was implemented, schools were asked to report the number of labor hours and the materials cost associated with implementing the recommendation.

The MSEAMP contains optional guidance on how schools should track unexpected asthma-related visits to the school nurse. School nurses were instructed to record the date; asthma symptoms; whether the student or staff had been diagnosed with asthma by a doctor; whether or not the symptoms started while in the school building; the likely cause of symptoms; the outcome of the office visit; and any comments.[11] MDH gave the Asthma Office Visit Log to the school administration at each of the six pilot project schools. Three schools did not complete the Asthma Office Visit Log, and the other schools returned incomplete logs. Since full-time school nurses were not employed in every school, multiple people tracked asthma visits, which led to inconsistent tracking methods.[12] As a result, asthma-related nurse visit data are inconsistent and incomplete, and could not be included in IEc's analysis.

Evaluation Questions and Analytical Approach

Exhibit 2 provides detailed information on the analytical approaches used to address each evaluation question for the Minnesota case study.

EXHIBIT 2: MINNESOTA CASE STUDY ANALTYIC APPROACH BY QUESTION

EVALUATION QUESTION	ANALYTICAL APPROACH
1. What IAQ issues did schools look for, including: sources of impaired IAQ (e.g., furnishings, chemicals), HVAC system features and functioning, pathways (e.g., air flow patterns and air pressure differences), and occupant behavior?	All six pilot schools received technical visitation from MDH to conduct initial walkthroughs based on standard MSEAMP guidance. The pilot schools also completed initial questionnaires on IAQ practices. These materials guided schools as to what IAQ problems to look for. Both the MSEAMP guidance and questionnaire address sources, HVAC system and functioning, pathways, and occupant behavior. We examined the MSEAMP guidance and summarized how the MSEAMP materials used by the pilot schools address these elements.
2. What IAQ issues did schools identify, through walkthroughs and other means?	Minnesota pilot schools identified IAQ issues in response to the initial questionnaire and MDH staff identified IAQ issues during the walkthrough. We counted and summarized the frequency of IAQ issues identified through the initial questionnaire and walkthroughs.

[11] Indoor Air Unit. Model School Environmental Asthma Plan. St. Paul: Minnesota Department of Health, 2005. Page 25.

[12] Personal communication with Dale Dorschner and Dan Tranter of MDH on November 10, 2005.

EVALUATION QUESTION	ANALYTICAL APPROACH
3. What did school officials do as a result of findings identified, in terms of changing policies and practices, or replacing HVAC or other equipment?	Using information from the Implementation Log, IEc compiled the implementation rates for recommendations provided by MDH in 17 areas by individual school and overall. We also calculated the percent of recommendations by area (both by school and overall) that were partially implemented and the percent of recommendations that were fully implemented. Furthermore, we listed recommendations by area (both by school and overall) that were partially implemented and a list of recommendations that were not implemented, and noted any recommendations that were either partially or not implemented in three or more schools. This analysis demonstrates the relative difficulty of recommendations and presents information on how schools responded to IAQ problems. We also summarized the schools' efforts to incorporate MDH's recommendations into their IAQ management plan.
4. Is the implementation of an IAQ plan associated with changes in environmental conditions, as measured by air or surface dust sampling? If so, are changes in environmental conditions generally consistent within school buildings or do they vary by room or area? What could account for variations observed?	IEc used the following variables from the Dust Sampling Data workbook provided by MDH: total dust per meter squared area sampled; dog allergens per meter squared area sampled; and cat allergens per meter squared sampled. We sought to determine whether the sampling results revealed an improvement in environmental conditions in any of these three IAQ triggers from 2004 to 2005. To determine whether changes in environmental conditions were measured by dust sampling, we calculated a variety of summary statistics both by school and overall, including: the 2004 and 2005 mean level of each IAQ trigger; the 2004 and 2005 median level of dust and each allergy trigger; the average total difference in the mean and median levels of each IAQ trigger between 2004 and 2005; and the average percent difference in the mean and median levels of each IAQ trigger between 2004 and 2005. We also calculated the number and percent of classrooms by school and overall that revealed a reduction in the level of each IAQ trigger. Sampling results revealed a disparity in the changes in environmental conditions among classrooms and schools. We subsequently performed additional analyses to determine whether certain factors could explain the variation in results among classrooms schools. To determine whether flooring type was correlated with the levels of the four allergy triggers, IEc classified the classrooms listed in the Dust Sampling log into four groups: those with carpeting, those with vinyl tile, those with area rugs, and those that had carpeting in 2004 but vinyl tile in 2005. We calculated the following variables for each group: the average level of each trigger in 2004 and 2005; the median level of each trigger in 2004 and 2005; the percent change between the average level of each trigger in 2004 and 2005; and the percent change between the median level of each trigger in 2004 and 2005. We compared the results across the different flooring groups to determine whether there was a relationship between flooring types and the levels of or changes in allergy triggers. IEc analyzed data from the Dust Sampling log to determine whether the number of dog or cat owners was correlated with the level of dog or cat allergens per square meter, respectively. We conducted three linear regressions for each pet allergen to determine whether pet ownership in 2004 was correlated with the level of pet dander in 2004; whether pet ownership in 2005 was correlated with the level of pet dander in 2005; and whether the difference in pet ownership from 2004 to 2005 was correlated with the differences in the level of pet dander from 2004 to 2005.

EVALUATION QUESTION	ANALYTICAL APPROACH
	IEc explored whether the implementation of any specific types of recommendations was correlated with decreases in dust, dog allergens, or cat allergens. We performed statistical regressions to determine the direction of the relationship between the implementation of MDH's school-specific recommendations in various categories and environmental conditions. We also performed statistical regressions to determine the direction of the relationship between compliance with MSEAMP guidance as provided through the IAQ management plan questionnaire and environmental conditions. IEc also analyzed walkthrough data to determine whether the difference between indoor and outdoor carbon dioxide levels (i.e. the carbon dioxide differential) decreased between 2004 and 2005. We calculated a variety of summary statistics both by school and overall. We also performed statistical regressions to determine the direction of the relationship between the implementation of various categories of MDH's school-specific recommendations and compliance with MSEAMP guidance as provided through the IAQ plan questionnaire and the carbon dioxide differential.
5. Is the implementation of an IAQ plan associated with changes in perceptions of indoor air quality among staff?	IEc analyzed the perception data provided by MDH for the classroom and the school. We summarized the results from each question both by school and across schools for each year and across years (e.g., percent of respondents who reported that IAQ improved, worsened, or stayed the same). Note that we only included the results from individuals who responded to the survey in both 2004 and 2005.
6. Is the implementation of an IAQ plan associated with changes in health outcomes, as measured by IAQ or asthma-related incidences, nurse visits, or absenteeism among staff or students? Are changes in health outcomes generally consistent across staff or students, or are some staff or students apparently benefiting more than others? What could account for variations observed?	MDH did not collect health outcome data and no subsequent health outcome data have been made available from the six pilot schools. As such, IEc did not examine changes in health outcomes as part of this case study.
7. Is the implementation of an IAQ plan associated with changes in student or staff performance, as measured by test scores or other empirical means? Are changes in performance generally consistent across staff or students, or are some staff or students apparently benefiting more than others? What could account for variations observed?	MDH did not collect student or staff performance data and no subsequent performance data have been made available from the six pilot schools. As such, IEc did not examine changes in student and staff performance as part of this case study.

CASE STUDY 2: HARTFORD PUBLIC SCHOOLS

Background of HPS' Implementation of IAQ TfS

Hartford Public Schools' implementation of IAQ TfS began in 2001 with a pilot study that involved the successful implementation of IAQ TfS in one of its elementary schools. In 2002, HPS proceeded with implementing IAQ TfS at the district level. As part of the district's TfS implementation, HPS relied heavily on school nurses to serve as IAQ coordinators. A key component of HPS' implementation approach was the Train the Trainer program, which provided IAQ TfS training to IAQ leaders including school administrators and nurses, and was funded by a grant from EPA's Urban Environment Initiative. [13]

Review of Existing Data

Hartford Public Schools provided IEc with a number of documents and data pertaining to school IAQ management and asthma incidence, including:

- **Asthma-related nurse visitation data,** which list the monthly total of unexpected asthma-related nurse visits by school. Hartford Public Schools collected these data beginning in the 2003-2004 school year and also began to track pre-gym inhaler use during the 2005-2006 school year. No school had complete asthma-related nurse visit data, but many schools were missing only a few months of data. Schools missing four or fewer months of data were defined as having "almost complete" nurse visit data. When schools were missing at least four months of data, but had sufficient data for some analyses, we defined them as having "partial" nurse visit data.
- **Indoor Air Quality TfS reports,** which describe IAQ management activities at the school level. We received reports from many but not all of the schools in the district that had implemented IAQ TfS. Some reports outlined the timing of various IAQ TfS implementation activities, and IEc used this information to help define if and when specific schools fully implemented IAQ TfS. Using the information provided by HPS, IEc was able to determine that IAQ TfS was fully implemented in seven schools.
- **Supplemental information,** which IEc obtained through HPS personnel and through outside sources. District personnel provided us with background information about other air quality initiatives in the City of Hartford, and also spoke informally with IEc about HPS' experience implementing IAQ TfS. Furthermore, HPS provided IEc with a list of building improvements made during the 2005-2006 school year. Staff from the University of Connecticut Health Center also spoke informally with IEc about their involvement with the IAQ TfS program in Hartford and provided additional information on HPS' implementation of IAQ TfS.

[13] For detailed background information on school IAQ management in Hartford Public Schools, see the Hartford case study.

After deriving the IAQ TfS implementation timelines, we determined which schools we could include in our analyses and classified those schools as study or control schools. Study schools are those that had fully implemented IAQ TfS and for which we had partial or almost complete nurse visit data. Due to a recent extensive renovation, we had to eliminate one school, Milner Elementary, from the list of study schools. Control schools did not implement IAQ TfS but reported partial or almost complete nurse visitation data. Exhibit 1 in the Hartford case study contains a summary of the information we gathered from HPS pertaining to IAQ TfS implementation and asthma-related nurse visitation for each school, and provides a designation for each school (study school, control school, or cannot include in the evaluation).

Collecting and Analyzing Data from Surveys and Interviews

Industrial Economics, Incorporated interviewed seven HPS nurses from September 21 to October 3, 2006. The interviews focused on procedures for tracking asthma-related nurse visits as well as IAQ management. Appendix 1 of the Hartford case study contains the nurse interview protocol. We interviewed seven nurses that met the following criteria:

- Had some knowledge of or involvement with IAQ TfS;
- Had worked on IAQ issues for at least three years;
- Had experience tracking asthma-related nurse visits;

In addition, we selected nurses that worked in a variety of school types (e.g., elementary schools, middle schools, magnet schools, high schools) to obtain a representative sample across HPS schools.

Evaluation Questions and Analytical Approach

Exhibit 3 provides detailed information on the analytical approaches used to address each evaluation question for the Hartford case study.

EXHIBIT 3: HARTFORD CASE STUDY ANALTYIC APPROACH BY QUESTION

EVALUATION QUESTION	ANALYTICAL APPROACH
1. What IAQ issues did schools look for, including: sources of impaired IAQ (e.g., furnishings, chemicals), HVAC system features and functioning, pathways (e.g., air flow patterns and air pressure differences), and occupant behavior?	Hartford Public Schools provided IEc with IAQ TfS reports that were submitted by many schools on an annual basis. Some of the reports specify the IAQ issues that schools looked for during their walkthroughs. We also formally interviewed school nurses and informally interviewed district personnel, who provided some insights about what IAQ issues the schools sought to identify. We then summarized information provided in these sources to answer evaluation question one.
2. What IAQ issues did schools identify, through walkthroughs and other means?	Hartford Public Schools provided IEc with IAQ TfS reports that were submitted by many schools on an annual basis. These reports specify the IAQ issues identified as a result of walkthroughs and other means and the schools' priorities to address the issues identified. We then summarized information provided in these TfS reports to answer evaluation question two.
3. What did school officials do as a result of findings identified, in terms of changing policies and practices, or replacing HVAC or other equipment?	Hartford Public Schools provided IEc with IAQ TfS reports that were submitted by many schools on an annual basis. In these reports, the schools specified the actions taken to resolve IAQ issues over the past year. Additionally, HPS provided IEc with information about district-wide IAQ achievements, which include changes in individual schools' IAQ management practices as well as changes in district-wide IAQ management policies and practices. Lastly, school nurses discussed what school officials did as a result of findings identified during interviews with IEc. We then summarized information provided in these sources to answer evaluation question three.
4. Is the implementation of an IAQ plan associated with changes in environmental conditions, as measured by air or surface dust sampling? If so, are changes in environmental conditions generally consistent within school buildings or do they vary by room or area? What could account for variations observed?	Hartford Public Schools did not gather data on environmental conditions as measured by air or surface sampling. As a result, we were unable to address evaluation question four.
5. Is the implementation of an IAQ plan associated with changes in perceptions of indoor air quality among staff?	Hartford Public Schools did not conduct perception surveys as part of their district-wide IAQ TfS implementation, and IEc did not conduct perception surveys as part of the evaluation. As a result, we were largely unable to address evaluation question five. However, school nurses interviewed did share their general perceptions about IAQ TfS implementation and asthma incidence during evaluation interviews.

EVALUATION QUESTION	ANALYTICAL APPROACH
6. Is the implementation of an IAQ plan associated with changes in health outcomes, as measured by IAQ or asthma-related incidences, nurse visits, or absenteeism among staff or students? Are changes in health outcomes generally consistent across staff or students, or are some staff or students apparently benefiting more than others? What could account for variations observed?	Industrial Economics, Incorporated undertook four different types of analyses to investigate changes in asthma-related nurse visits associated with IAQ TfS implementation. **Approach 1: Asthma-related nurse visit trends in individual schools** Using asthma-related nurse visit data, IEc evaluated whether study schools experienced decreases in asthma-related nurse visits following the implementation of IAQ TfS. Hartford Public Schools provided IEc with pre- and post-implementation asthma-related nurse visit data corresponding to the same month (e.g., pre- and post-implementation data for the month of March) or to the same season (e.g., pre- and post-implementation data for a fall month) for three study schools: Hartford Transitional Learning Academy on Tower Ave.; Kinsella; and Quirk. We used the following pre- and post-implementation data corresponding to the same month in our analysis: ▪ Hartford Transitional Learning Academy – IEc compared nurse-visit data from September, October, November, and December of 2004 (pre-implementation) with data from September, October, November, and December of 2005 (post-implementation). ▪ Kinsella – IEc compared nurse-visit data from November 2003 (pre-implementation) with data from November 2005 (post-implementation). We also compared data from March 2004 (pre-implementation) with data from March 2005 and March 2006 (post-implementation data). ▪ Quirk – IEc compared nurse-visit data from November and December 2003 (pre-implementation) with data from November and December 2004 and data from November and December 2005 (post-implementation). We also compared data from January 2004 (pre-implementation) with data from January 2005 and January 2006 (post-implementation). Using the data mentioned above, IEc calculated the following variables: ▪ The total and "normalized" number of asthma-related nurse visits at the three study schools during each of the pre-implementation and post-implementation months.[14] ▪ The average monthly change and the percent change in the total and normalized asthma-related nurse visits from the pre-implementation to the post-implementation periods by school. IEc also used the following pre- and post-implementation data corresponding to the same season in our analysis: ▪ Hartford Transitional Learning Academy – IEc compared nurse-visit data from September-November 2004 (pre-implementation) with data from September-November 2005 (post-implementation). We also compared data from December 2004 (pre-implementation) with data from January and February 2006 (post-implementation) and data from March 2004 (pre-implementation) with data from April and May 2006 (post-implementation). ▪ Kinsella – IEc compared nurse-visit data from November 2003 (pre-implementation) with nurse-visit data from September 2004 and September-November 2005 (post-implementation). We also compared data from March 2004 (pre-implementation) to data from March-May 2005 and March-May 2006 (post-implementation). ▪ Quirk – IEc compared nurse-visit data from November 2003 (pre-implementation) with data from November 2004 and November 2005. We also compared nurse-visit data from December 2003 and January 2004 (pre-implementation) with data from December 2004–February 2005 and from December 2005–February 2006 (post-implementation). Using the data above, IEc calculated the following variables: ▪ The total and normalized average number of asthma-related nurse visits by season at the three study schools during each of the pre-implementation and post-implementation seasons. ▪ The average seasonal change and the percent change in the total and normalized asthma-related nurse visits from the pre-implementation to the post-implementation periods by school.

[14] The "Normalized" number of asthma-related nurse visits is the total number of asthma-related nurse visits in a month times one thousand divided by the following factor: (the number of school days in the particular month * the number of students enrolled at the school). This variable enables easy comparison among schools and among months of data.

EVALUATION QUESTION	ANALYTICAL APPROACH
	Approach 2: Paired Case Studies Industrial Economics, Incorporated also compared the results between schools in the district that implemented IAQ TfS and schools that did not. We used a paired case study approach, which involved comparing asthma-related nurse visit data between pairs of schools that are very much alike except for their implementation of IAQ TfS. Using information provided by HPS and obtained through outside research, we paired study schools with control schools that were as similar as possible to the study schools. We examined factors such as the schools' construction (e.g., age of the building, building materials) and the type of school (e.g., elementary, middle) when pairing schools. We also considered the availability of comparable nurse visit data when pairing schools. We then qualitatively explained the findings. Our school pairings included: ▪ The Sports and Medical Sciences Academy (study school) and the Greater Hartford Classical Magnet School (control school) ▪ Quirk Middle School (study school) and Bellizzi Middle School (control school) ▪ Fisher Multiple Intelligences Magnet (study school) and Simpson-Waverly (control school) ▪ Dwight (study school) and Burns (control school) ▪ McDonough (study school) and Sanchez (control school) IEc calculated the normalized number of asthma-related nurse visits for the study and control schools in each paired case study. We then compared the normalized number of asthma-related nurse visits between the two schools whenever they both had data for a specific month. We also calculated the total normalized number of asthma-related nurse visits for all months when both schools had data. Finally, we calculated the total normalized nurse visits for the study school prior to IAQ TfS implementation, during IAQ TfS implementation, and once IAQ TfS had been fully implemented. We compared the results to the same time periods in the control schools.
	Approach 3: Statistical Approach Industrial Economics, Incorporated performed two statistical analyses to determine whether there was a significant correlation between IAQ TfS implementation and asthma-related nurse visits. Our first analysis only included elementary schools, specifically: Fisher Multiple Intelligences Academy; Batchelder; Burns; Clark; Dwight; Hooker; Kinsella; McDonough; Martin Luther King; Moylan; Naylor; Sanchez; Simpson-Waverly; Twain; and Wish. Because we could not be certain whether nurses actually tracked asthma-related nurse visits when they reported "0" asthma-related nurse visits in a month, we excluded all months of data where no asthma-related nurse visits were reported. We ran a linear regression using the following variables for all available nurse visit data for the schools included: ▪ Dependent Variable: The normalized number of asthma-related nurse visits in each month. ▪ Independent Variable 1: A series of two dummy variables and a constant to control for the season. One dummy variable corresponded to the months of September–November; another corresponded to the months of December–February; and the constant corresponded to the months of March–May. These variables isolated the seasonal variation in asthma-related nurse visits. ▪ Independent Variable 2: A series of two dummy variables and a constant to distinguish between different levels of IAQ TfS implementation. The constant indicated that IAQ TfS was not implemented (i.e., this corresponds to the months of data prior to the first walkthrough for study schools and all months of data for control schools); another dummy variable indicated that a school was in the process of implementing IAQ TfS (i.e., months of data between when the study schools conducted the first walkthrough and when the schools had fully implemented IAQ TfS); and another dummy variable indicated that IAQ TfS was fully implemented (i.e., months of post-implementation data for study schools). After conducting the linear regression, we performed a T test to determine whether we could be 90, 95, or 99 percent confident that IAQ TfS implementation is correlated with the dependent variable. We also conducted a version of this analysis that was broadened to include the other schools that were involved in one of the paired case studies. Specifically, data from Quirk Middle School, Bellizzi Middle School, the Sports and Medical Sciences Academy, and the Greater Hartford Classical Magnet School were included in the second statistical analysis.

EVALUATION QUESTION	ANALYTICAL APPROACH
	Approach 4: Nurse Interviews IEc interviewed seven nurses in the Hartford Public Schools regarding procedures for tracking asthma-related nurse visits and their perceptions of the link between IAQ TfS and asthma-related nurse visitation. The initial impetus to conduct the nurse interviews was to gain insights into data quality challenges that appear in the data and to formulate recommendations for collecting such data in the future. In addition, we also wanted to capture the nurses' perception of IAQ TfS implementation and its perceived impact on asthma in the schools in which they work.
7. Is the implementation of an IAQ plan associated with changes in student or staff performance, as measured by test scores or other empirical means? Are changes in performance generally consistent across staff or students, or are some staff or students apparently benefiting more than others? What could account for variations observed?	HPS did not gather data on student and staff performance. As a result, we were unable to address evaluation question seven.

CASE STUDY 3: SALT LAKE CITY SCHOOL DISTRICT

Background of SLC's Implementation of IAQ TfS

Prior to implementing key elements of IAQ TfS, SLC established a rigorous preventative maintenance program to regularly check school ventilation systems. They learned about IAQ TfS in 2000 and embraced the program because of its compatibility with existing HVAC maintenance efforts. The district recruited an IAQ team to conduct initial walkthroughs and environmental sampling in almost all school buildings from December 2001 to April 2002. Corrective actions were taken to address IAQ issued identified at schools. By 2003, the district expanded the scope of its inspections and outreach efforts to promote the IAQ TfS program to other school districts. [15]

Review of Existing Data

The Salt Lake City School District provided IEc with data sets and background information concerning IAQ management in the district's buildings, including:

- **Room Walkthrough Data Forms,** which were completed by the IAQ team during each building walkthrough. Initial building walkthroughs were conducted at 36 schools and follow up walkthroughs were conducted at six schools to check on issues identified. The IAQ team noted the date and time that they assessed each room. For each room evaluated, the team recorded the carbon dioxide concentration in the room and in the air supply in parts per million (ppm), the temperature of the room and of the air supply, the relative humidity, the number of

[15] For detailed background information on school IAQ management in Salt Lake City schools, see the Salt Lake City case study.

occupants in the room, and whether the doors were open or closed. The team also kept notes on the floor type in each room.

- **Other Building-Specific IAQ Information,** including EPA's IAQ TfS Action Kit Ventilation Log, which the IAQ team completed during building walkthroughs, and the Kit's IAQ Classroom Checklist, which was used by teachers in some buildings to record findings on general cleanliness, animals, drain traps, excess moisture, thermal comfort, ventilation, and local exhaust fans. Additionally, SLC provided IEc with basic facility information for each building (e.g., floor plan, number of students, square footage, typical construction, description of HVAC system).
- **Information on SLC's participation in IAQ management research,** including press releases and papers. The district provided IEc with information about the Utah Department of Health's guidelines on scheduling indoor activities based on outdoor air quality, as well as information on ongoing IAQ research at the three elementary SLC elementary schools.
- **The Salt Lake City School District's Application for a 2003 IAQ TfS Excellence Award,** in which the district describes its IAQ management program and its roots, the IAQ team dynamic, and its efforts to promote the IAQ TfS program to other school districts.
- **A PowerPoint presentation entitled, "Our Experience with EPA's IAQ Tools for Schools**, which was used during presentations about SLC's involvement with IAQ TfS. In the presentation, SLC describes why it became involved with IAQ TfS, how they implemented and adapted it to their district, costs associated with IAQ TfS implementation, and lessons learned.

For the purposes of this case study, the date of the first building walkthrough is considered to be the beginning of IAQ TfS implementation. According to SLC, the district fully implemented IAQ TfS prior to all follow up walkthroughs. Using the room walkthrough data forms provided by SLC, IEc identified the buildings and rooms that could be included in an analysis of environmental outcomes, which is presented in Exhibit 1 in the Salt Lake City case study. In our analysis, we assessed the pre-implementation (i.e. the first walkthrough) and post-implementation (i.e. any follow up walkthroughs) conditions in individual rooms to assess changes in environmental conditions. However, because SLC only conducted follow up walkthroughs at schools where problems were identified during the initial walkthrough, the availability of post-implementation data is limited.

Evaluation Questions and Analytical Approach

Exhibit 4 provides detailed information on the analytical approaches used to address each evaluation question for the Salt Lake City case study.

EXHIBIT 4: SALT LAKE CITY CASE STUDY ANALTYIC APPROACH BY QUESTION

EVALUATION QUESTION	ANALYTIC APPROACH
1. What IAQ issues did schools look for, including: sources of impaired IAQ (e.g., furnishings, chemicals), HVAC system features and functioning, pathways (e.g., air flow patterns and air pressure differences), and occupant behavior?	Using information provided by the Salt Lake City School District on ventilation logs, IAQ checklists, and walkthrough data forms, IEc described the issues that schools looked for as part of SLC's IAQ TfS program.
2. What IAQ issues did schools identify, through walkthroughs and other means?	Industrial Economics, Incorporated summarized issues identified by relying on the following sources of information: ▪ IEc examined the room walkthrough data forms to look for issues pertaining to carbon dioxide concentration, temperature, humidity, carbon monoxide, and other issues that the IAQ team recorded on the forms. ▪ By examining the IAQ classroom checklists, IEc summarized issues pertaining to general cleanliness, animals in the classroom, drain traps in the classroom, and excess moisture in classrooms. ▪ By examining the ventilation logs, IEc summarized issues pertaining to HVAC systems, specifically outdoor air intakes, system cleanliness, controls for outdoor air supply, air distribution, exhaust systems, and the quantity and adequacy of outdoor air supply. ▪ IEc reviewed supplemental school-specific information to identify any IAQ-related complaints made by teachers and/or staff in any of SLC's buildings.
3. What did school officials do as a result of findings identified, in terms of changing policies and practices, or replacing HVAC or other equipment?	Industrial Economics, Incorporated summarized the actions that the Salt Lake City School District took in response to its findings using: the Tools for Schools Program Narrative, a PowerPoint presentation entitled "Our Experience with EPA's IAQ Tools for Schools", and supplemental information provided by the district.
4. Is the implementation of an IAQ plan associated with changes in environmental conditions, as measured by air or surface dust sampling? If so, are changes in environmental conditions generally consistent within school buildings or do they vary by room or area? What could account for variations observed?	Using walkthrough data from Hawthorne Elementary School, Jackson Elementary School, Meadowlark Elementary School, and the Administrative Building, IEc evaluated whether environmental conditions in the classrooms studied improved following the implementation of an IAQ plan as measured by air sampling. We evaluated changes in carbon dioxide (CO_2) room levels (i.e. the amount of carbon dioxide in the classroom), the differential between CO_2 room levels and CO_2 supply levels, and relative humidity. We compared the pre-implementation (i.e. first walkthrough) and post-implementation (i.e. follow up walkthroughs) levels for each classroom studied and summarized the results using the following variables: ▪ The median and average pre-implementation and post-implementation levels of CO_2 in the room, the differential between CO_2 room levels and CO_2 supply levels, and relative humidity. ▪ The total change and percent change in CO_2 room levels, the CO_2 differential, and relative humidity.

EVALUATION QUESTION	ANALYTIC APPROACH
	To compare results across buildings, IEc also calculated the average building-wide pre-implementation and post-implementation levels of CO_2, the CO_2 differential, and relative humidity based on the classrooms studied in each building. We also calculated the percent change between pre-implementation and post-implementation levels in each building.
5. Is the implementation of an IAQ plan associated with changes in perceptions of indoor air quality among staff?	The Salt Lake City School District did not collect perception data; thus, IEc was unable to answer evaluation question 5 for this case study.
6. Is the implementation of an IAQ plan associated with changes in health outcomes, as measured by IAQ or asthma-related incidences, nurse visits, or absenteeism among staff or students? Are changes in health outcomes generally consistent across staff or students, or are some staff or students apparently benefiting more than others? What could account for variations observed?	The Salt Lake City School District did not collect health data; thus, IEc was unable to answer evaluation question six for this case study.
7. Is the implementation of an IAQ plan associated with changes in student or staff performance, as measured by test scores or other empirical means? Are changes in performance generally consistent across staff or students, or are some staff or students apparently benefiting more than others? What could account for variations observed?	Due to limitations in available data, IEc was unable to answer evaluation question seven for this case study.

STRENGTHS AND WEAKNESSES OF THE METHODOLOGY

There are significant strengths and features of this project that make it unique. EPA is leveraging already collected data to document and analyze IAQ management activities in select K-12 schools that are using-either directly or indirectly-EPA's IAQ Tools for Schools guidance. EPA has collected data from these schools about their IAQ management activities and attempted to look across the breadth of their activities to report effectiveness in achieving improvements in environmental, health and/or performance outcomes. This is a rare opportunity to compare and evaluate activities across school IAQ programs.

The methodology used by IEc in this evaluation has many advantages. A key benefit of the case study approach is that it allows for a very detailed analysis of each group. The case study approach is also the most appropriate analytical method given the lack of similar data sets for each of the three groups. Another advantage of our approach is that we were able to compare activities across schools within each case study. Our approach also allowed us to validate and explain the previous analysis conducted by MDH while providing an original analysis of data provided by HPS and SLC linking IAQ TfS implementation to health and environmental outcomes, respectively.

Our methodology also has some disadvantages. Using a case study approach, the evaluation of IAQ program results across case studies is qualitative; we cannot draw statistical inferences about a broader population of schools. Moreover, the three case studies may not represent the full spectrum of IAQ TfS implementation approaches used throughout the country.

Due to the limitation of available data, we were not able to answer all evaluation questions in each case study, and we were not able to answer evaluation question seven for any case study. It is also possible that there was some bias in the interviews of school nurses in HPS, and the findings might have been different if we had interviewed another group of individuals such as administrators or teachers.

IEc also relied on self-reported asthma visits in Hartford and walkthrough forms in Salt Lake City. With the exception of interviewing Hartford Public School nurses, IEc did not gather primary data and did not analyze the rigor of the data collection (e.g., the strength of design or the method of data collection). Walkthrough forms are subject to human error and as mentioned in the Hartford case study, we have concerns about the quality of asthma-related nurse visitation data.

Minnesota MSEAMP pilot schools, Hartford Public Schools, and the Salt Lake City School District each took a distinct approach to implementing an IAQ management plan. While the schools examined in the Minnesota case study implemented a prescriptive IAQ management approach, both HPS and SLC adopted EPA's IAQ TfS district-wide. This section presents a summary of IAQ plan implementation and outcomes that are associated with IAQ plan implementation. A detailed discussion of the implementation approaches used in each case study, as well as detailed results by evaluation question, can be found in Appendices 2, 3, and 4.

SUMMARY OF IAQ PLAN IMPLEMENTATION

Below, we discuss common IAQ challenges faced by schools included in this evaluation, and activities that schools undertook to address those challenges.

Common IAQ Challenges

The process for identifying IAQ challenges was similar in all case studies. Initial walkthroughs were conducted in all schools studies in order to visually identify IAQ issues. At SLC and in the Minnesota pilot schools, the initial walkthrough was accompanied by air sampling. The Minnesota pilot schools also conducted surface dust sampling as part of the initial walkthroughs. Follow up walkthroughs were conducted in all of the Minnesota schools, and some of the schools in HPS and SLC.

In general, the schools in the three case studies identified IAQ issues wherever they looked for them. A wide array of IAQ issues were identified in the case studies, however, a few types of IAQ issues were particularly prevalent, affecting numerous classrooms in many schools and in each case study.

Ventilation problems were widespread during initial walkthroughs and air sampling. During initial walkthroughs, four out of the six Minnesota pilot schools had at least one classroom with a carbon dioxide differential that did not meet The American Society of Heating, Refrigerating and Air-Conditioning Engineers' (ASHRAE) recommendation that the indoor concentration of carbon dioxide be no more than 700 parts per million (ppm) above the concentration in ambient air.[16] The Minnesota Department of Health made 93 recommendations to the six pilot schools in the areas of HVAC troubleshooting and Ventilation Equipment Maintenance, and the schools were initially in compliance with less than 60 percent of the Ventilation recommendations of MDH's IAQ plan

[16] American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. "Interpretation 1C 62-1989-20 – January 29, 1995." 2006. http://www.ashrae.org/publications/detail/14504 and The Minnesota Department of Health. "Carbon Dioxide." April 5, 2006. http://www.health.state.mn.us/divs/eh/indoorair/co2/index.html

questionnaire. Ventilation problems, including blocked ventilation systems, malfunctioning air intake valves, dirty vents and filters, and thermal discomfort, were also identified in many classrooms in HPS. In SLC, 24 out of 36 schools had at least one room with a carbon dioxide concentration that was greater than 1000 ppm.[17]

Initial walkthroughs also identified widespread cleanliness issues. The Minnesota pilot schools were initially in compliance with less than half of the Deep Cleaning and General Cleaning Activities recommendations of Minnesota's IAQ management plan questionnaire. In addition, MDH made 96 recommendations, or 16 per school on average, in the areas of Flooring Maintenance, Furnishing Maintenance, and General Housekeeping. In HPS, dust and dirt issues were identified in most schools and in SLC, clutter was identified during initial walkthroughs in 22 out of the 36 schools.

A variety of other issues were visually identified during walkthroughs across case studies. For instance, improper storage of chemicals, cleaning supplies, and/or art supplies; stained ceiling tiles; odors; and pest management/food storage issues were identified in more than one case study. Schools also identified additional IAQ issues unique to certain schools and classrooms, which are discussed in the case studies.

Schools also reported complaints from students and staff about health issues potentially associated with poor indoor air quality. In SLC, teachers in two elementary schools expressed concerns about mold and alleged that the schools in which they taught were sick buildings.[18] In HPS, one school's Health and Safety Team distributed a letter in which they asked staff to describe any health symptoms they experienced that might be linked to poor IAQ. In response to the letter, eight staff members reported suffering from headaches, coughing, sinus infections, asthma attacks, shortness of breath, and persistent hoarseness.

Activities that Schools Undertake to Address IAQ Problems

Following initial walkthroughs and environmental sampling, schools studied took steps to correct IAQ issues identified. Generally speaking, the schools undertook three steps after the initial walkthroughs. First, they planned necessary changes, which involved prioritizing and budgeting for improvements. Next, school districts corrected issues identified by undertaking repairs, such as repairing HVAC systems, replacing carpet with smooth flooring, and removing stained ceiling tiles. They also implemented no-cost solutions to address IAQ issues by educating teachers and staff and changing IAQ policies. Lastly, the schools checked their progress by conducting follow up walkthroughs.

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[17] ASHRAE also published guidance that notes, "Carbon dioxide concentration has been widely used as an indicator of indoor air quality. Comfort (odor) criteria are likely to be satisfied if the ventilation rate is set so that 1000 parts per million (ppm) CO_2 is not exceeded." American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. "Interpretation 1C 62-1989-20 – January 29, 1995." http://www.ashrae.org/publications/detail/14504

[18] "The term sick building syndrome (SBS) is used to describe situations in which building occupants experience acute health and comfort effects that appear to be linked to time spent in a building, but no specific illness or cause can be identified." Accessed on April 2, 2007: http://www.epa.gov/iaq/pubs/sbs.html

The Minnesota pilot schools undertook a variety of activities to address IAQ problems. These schools fully or partially implemented MDH's recommendations in most IAQ areas; in fact, schools fully or partially implemented 70 percent or more of MDH's recommendations in 13 out of 17 IAQ areas. However, there was wide variability in the percentage of recommendations implemented across IAQ areas: for instance, recommendations made in the areas of Education/Communication; Expand Periodic Environmental Inspections; Moisture Management; and Plant Policy were fully implemented at least 80 percent of the time whereas around half of the recommendations made in the areas of Furnishing Maintenance; Equipment, Furnishing, and Flooring; and HVAC Troubleshooting were implemented. In addition, four out of the six pilot schools reported incorporation of MDH's recommendations into their IAQ management plans. These schools incorporated between 32.2 and 77.5 percent of the recommendations that they fully implemented into their IAQ management plans.

The schools in HPS prioritized changes that needed to be made in slightly different ways: some schools identified short-term, medium-term, and long-term priorities whereas other schools identified only IAQ issues that were high priorities. IAQ teams recommended some changes that required little or no cost and time, as well as some recommendations that required significant funding to address. Schools reported their priorities to the district, which maintained responsibility for issuing work orders to address IAQ problems at individual schools. The district then prioritized the issues centrally. Some of the improvements made at HPS include: installing a new roof at one school and replacing ceiling tiles at many schools; moving dumpsters; installing HEPA filters on vacuums; changing ventilation filters; replacing ceiling tiles; replacing some carpet with tile and eliminating areas rugs; taking measures to control pests; and training custodial staff.

Some nurses interviewed for the HPS case study reported disappointment in the lack of responsiveness of the district administration to IAQ priorities identified by individual schools. Nurses also cited budgetary and training challenges as barriers to more robust implementation of IAQ TfS. Hartford Public Schools did address a wide breadth IAQ issues and realized many good outcomes (as described later in this chapter); we cannot speculate as to whether funding and training challenges curtailed activities or dampened outcomes. However, communication from the district administration to HPS schools regarding IAQ priorities appears to have been lacking, and may account for some of the difference in perspectives between HPS nurses and district administration regarding the comprehensiveness of IAQ TfS implementation.

After initial walkthroughs at SLC, the district corrected all HVAC issues identified. They concurrently used IAQ TfS checklists and internal resources, such as PowerPoint presentations and handouts, to educate teachers and staff about IAQ. In some cases, a follow up inspection was conducted to ensure that problems had been resolved. The district also comprehensively addressed teachers' complaints about poor IAQ, which is described in detail in the SLC case study. As one measure of IAQ TfS implementation,

SLC spent at least 1,500 man-hours conducting follow up IAQ inspections and correcting problems. [19]

Across case studies, the evaluation revealed that implementation of an IAQ plan requires staff dedication of time, and the buy-in of administrators, teachers, nurses, and janitorial staff. We have incomplete information on the level of resources dedicated to implementing IAQ TfS across case studies; however, resource needs appear to vary considerably from district to district, and from school to school.

The Salt Lake City School District did not report challenges in dedicating resources necessary to implement IAQ TfS. Hartford Public Schools faced competing budget priorities, such as teacher recertification costs and staffing cuts, which delayed but did not prevent IAQ TfS implementation. Although resource challenges did not appear to be a significant barrier to overall IAQ management approach among Minnesota pilot schools, the costs associated with certain MDH recommendations caused Minnesota pilot schools to forego implementation of them. Common examples of recommendations that Minnesota schools did not implement citing costs include some recommendations to make capital investments in flooring, entryways and storage areas, and HVAC systems; and some recommendations to increase cleaning frequencies (which would have necessitated hiring additional janitors).

SUMMARY OF OUTCOMES

Summary of Environmental Outcomes

As previously discussed, MDH and SLC conducted environmental sampling in classrooms both before and after implementing IAQ management plans. Industrial Economics, Incorporated analyzed these data, using statistical methods were appropriate, to evaluate the link between IAQ plan implementation and environmental conditions. However, we did not gather primary environmental data and did not analyze the rigor of the data collection (e.g., the strength of design or the method of data collection).

Air sampling for carbon dioxide levels is the only measurement approach shared by Minnesota and SLC. We discuss carbon dioxide findings below, followed by relative humidity outcomes in SLC, and then dust and allergen sampling outcomes in Minnesota.

Carbon Dioxide Levels in Minnesota and SLC Case Studies

MDH and SLC conducted air sampling in classrooms both before and after the implementation of an IAQ management plan, to measure carbon dioxide concentrations in classrooms as well as in the air supply. Carbon dioxide may accumulate in building spaces if sufficient amounts of outdoor air are not brought into and distributed throughout the building. Carbon dioxide is a surrogate for indoor pollutants that may cause students or teachers to grow drowsy, get headaches, or function at lower activity levels. A large

[19] In the PowerPoint presentation entitled "Our Experience with EPA's IAQ Tools for Schools," the district indicates that it spent approximately 300 hours to conduct the initial inspections over a five month period, and that it has invested over 1,800 hours in IAQ inspections and correcting problems since 2001. Hence, the district has spent (over 1,800 hours total – 300 hours for the initial inspections) = at least 1,500 hours conducting follow up inspections and correcting problems.

difference between indoor and outdoor air carbon dioxide levels, known as the carbon dioxide differential, indicates that adequate fresh air is not being distributed throughout the school building. Therefore, indoor air quality pollutants, such as biological organisms, cleaning fumes, and pesticides, have more opportunity to accumulate. [20]

The American Society of Heating, Refrigerating and Air-Conditioning Engineers, Incorporated has two standards applicable to indoor air carbon dioxide measures; one is an absolute standard, and one is a relative standard that takes outdoor air quality into account. It is common to use both an absolute and relative standard to measure environmental conditions or performance. For example, environmental agencies are often interested to know the absolute air emissions from a power plant (e.g., tons of air emissions), as well as the plant's emissions per unit of power generated. In the case of IAQ, ASHRAE's absolute standard is that "Comfort (odor) criteria are likely to be satisfied if the ventilation rate is set so that 1000 ppm CO_2 is not exceeded."[21] ASHRAE's relative standard is that "Comfort (odor) criteria with respect to human bioeffluents are likely to be satisfied if the ventilation results in indoor CO_2 concentrations less than 700 ppm above the outdoor air concentration."[22]

For both case studies, IEc analyzed whether the number of classrooms meeting ASHRAE's recommendation on the carbon dioxide differential improved following the implementation of an IAQ management plan. We analyzed the data provided by SLC and found that the carbon dioxide differential highlighted the excellent performance of SLC's ventilation systems during both walkthroughs. [23] Both prior to and after IAQ TfS implementation, the differential in all rooms was below 700 ppm, in agreement with ASHRAE's recommendations. We also found that although SLC schools experienced an overall slight increase in the carbon dioxide differential following TfS implementation, the carbon dioxide differential became much more uniform among classrooms during follow up walkthroughs. Those rooms that originally had a poor carbon dioxide differential experienced meaningful improvements from better ventilation, while some classrooms with excellent ventilation experienced minor, unnoticeable increases in their carbon dioxide differential.

In the Minnesota case study, 15 more classrooms (or 7.5 percent of those tested) were in agreement with ASHRAE's recommendation on the carbon dioxide differential following the implementation of an IAQ management plan. However, progress varied dramatically among schools: in one elementary school, 81.8 percent more classrooms met ASHRAE's recommendation following MSEAMP implementation whereas three schools reported fewer classrooms in agreement with ASHRAE's recommendation following MSEAMP implementation. However, IEc also completed a statistical analysis (described in detail in the

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[20] The U.S. Environmental Protection Agency. "Fact Sheet: Ventilation and Air Quality in Offices." March 3, 2006. http://www.epa.gov/iaq/pubs/ventilat.html

[21] American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. "Interpretation 1C 62-1989-20 – January 29, 1995." http://www.ashrae.org/publications/detail/14504

[22] American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., ANSI/ASHRAE Standard 62-2001, p. 7.

[23] Pre- and post-implementation data were only available for 22 classrooms in four buildings for the SLC case study.

case study) that found that improvements in the carbon dioxide differential in the six Minnesota pilot schools were statistically significant at the 99 percent confidence level. This indicates that improvements in the carbon dioxide differential were not due to chance, and lacking any other factor that would cause the improvement, we can conclude that implementation of the MSEAMP likely led to the improvements identified.

Industrial Economics, Incorporated performed some follow up analyses on the carbon dioxide findings using the data provided by MDH. First, we conducted a limited analysis of resources spent to address IAQ issues, to see if differences in resource expenditures on HVAC improvements could explain some of the variation in carbon dioxide measurements across schools. Results indicate a potential association between time spent implementing HVAC recommendations, specifically recommendations to upgrade HVAC mechanics, and improvements in carbon dioxide levels. Results did not indicate that higher spending on HVAC upgrades led to proportionally better results. However, each school had different HVAC upgrade needs, and data on resources devoted to this area were incomplete; hence, additional analyses would be necessary to draw any strong conclusions in this area.

We also conducted an analysis to determine whether the implementation of certain IAQ practices recommended by MDH were associated with improvements in the carbon dioxide differential. We found that schools that were in compliance with the MSEAMP's guidelines on Ventilation were more likely to have lower carbon dioxide differentials than those schools that were not in compliance with them. Additionally, we found that the implementation of MDH's school-specific recommendations in the areas of Plumbing, Furnishing Maintenance, and Flooring Maintenance were strongly linked to improvements in the carbon dioxide differential. Plumbing leaks cause excess moisture, which may prevent optimal HVAC system performance.[24] Excess dust and dirt may also impair HVAC system functioning, so good housekeeping is important to HVAC system maintenance.[25]

Relative Humidity Outcomes in Salt Lake City

Industrial Economics, Incorporated analyzed the relative humidity data provided by SLC to determine if humidity in classrooms improved following the implementation of an IAQ management plan. EPA's guidelines suggest that humidity in classrooms should be maintained between 30 and 60 percent.[26] Higher levels of humidity can contribute to mold growth and cause dust mite problems, whereas lower humidity levels can cause dry eyes, irritated mucous membranes, and sinus discomfort.[27] Salt Lake City has a semi-arid

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[24] U.S. Environmental Protection Agency. "I-BEAM Text Modules: Heating, Ventilation, and Air-Conditioning (HVAC)." 3 March 2006. http://www.epa.gov/iaq/largebldgs/i-beam_html/ch2-hvac.htm#F2.6

[25] Massachusetts Division of Occupational Safety. *Safety & Health for the Commonwealth.* 2002. http://www.mass.gov/dos/forms/la-v05-2002summer.pdf

[26] U.S. Environmental Protection Agency. "I-BEAM Text Modules: Heating, Ventilation, and Air-Conditioning (HVAC)." 3 March 2006. http://www.epa.gov/iaq/largebldgs/i-beam_html/ch2-hvac.htm#F2.6

[27] U.S. Environmental Protection Agency. "An Office Building Occupant's Guide to Indoor Air Quality." 12 September 2006. http://www.epa.gov/iaq/pubs/images/occupants_guide.pdf

environment, and humidity in the city is generally low, which can cause some challenges in maintaining high enough relative humidity indoors.[28]

We reviewed the initial walkthrough data provided by SLC and found that 35 out of the 36 buildings had at least one classroom where the relative humidity was less than 30 percent. However, our review of post-implementation walkthrough findings found that the overall mean relative humidity increased from 22 percent to 27.9 percent, and the overall median relative humidity increased from 23 to 26 percent. Also, whereas only one classroom out of the 22 reported a relative humidity between 30 and 60 percent during the initial walkthrough, nine classrooms reported relative humidity between 30 and 60 percent during the follow up walkthroughs. We examined outdoor relative humidity levels on pre-and post-implementation walkthrough dates, and determined that they did not have the potential to skew results. Thus, improvements in SLC's relative humidity were likely a result of better IAQ management.

Dust and Allergen Outcomes in Minnesota

Industrial Economics, Incorporated analyzed whether the implementation of the MSEAMP was associated with improved environmental conditions as measured by MDH's surface dust sampling data. We performed a series of statistical analyses, which are described in detail in the Minnesota case study, and found that the implementation of the MSEAMP is strongly correlated with a decrease in asthma triggers in pilot schools, including dust, cat allergens, and dog allergens. We found that the improvements in dust per meter squared of flooring and in cat allergens per meter squared of flooring were statistically significant at the 90 percent and 95 percent level, respectively.[29] Given the geographic and demographic differences of the six pilot schools, and the lack of other initiatives or explanations that would account for these results, it is very likely that decreases in these allergens can be attributed to the implementation of the MSEAMP.

We examined whether flooring type played a role in the presence of allergy triggers. The Minnesota Department of Health had gathered data on the flooring type of each classroom sampled for allergens. We evaluated whether certain flooring types were associated with lower levels of allergens, and whether certain flooring types showed greater environmental improvements following MSEAMP implementation. We found that in both the pre- and post-implementation walkthroughs, rooms with area rugs had the highest level of dust, dog allergens, and cat allergens. Overall, carpeted rooms also had much higher levels of dust and allergens than rooms with vinyl composite tile. Improvements in performance among the different flooring types varied. The rooms that changed from wall-to-wall carpeting to vinyl composite tile demonstrated the greatest percentage improvement in dust and allergens whereas rooms with area rugs demonstrated the smallest percentage improvement in dust and allergens (and by some measures actually worsened following implementation of the MSEAMP).

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[28] Salt Lake City Corporation. "Salt Lake City's Climate." 2005. http://www.ci.slc.ut.us/info/area_info/climate.htm

[29] This means that it is 90 percent likely that the improvements in dust did not result by chance, and it is 95 percent likely that the improvement in cat allergens did not happen by chance.

Industrial Economics, Incorporated also investigated whether the implementation of certain types of MSEAMP recommendations was associated with environmental improvements. We looked at both dust sampling results and changes in IAQ practices as reported by schools. From dust sampling results, we found that the implementation of MDH's school-specific recommendations in the areas of Moisture Management, Education/Communication, HVAC Troubleshooting, Ventilation Equipment Maintenance, and General Housekeeping were particularly strongly linked to decreased levels of dust and cat and dog allergens in pilot schools. From school-reported information on IAQ practices before and after implementation, we found that IAQ practices in the areas of Ventilation, Smooth Flooring, General Cleaning Activities, Construction/Renovation, Communications, and Plants and Animals were associated with lower levels of dust, dog, and cat allergens.

IEc also examined whether dog or cat ownership was correlated with the levels of dog or cat allergens by conducting a series of linear regressions, which are explained in detail in the Minnesota case study. We found that rates of cat ownership among students, as opposed to school IAQ management, could explain some but not all of the difference in measurements of cat dander found in classrooms. Levels of cat dander were statistically correlated with cat ownership. However, variation in cat ownership across classrooms could explain only six to seven percent of the variation in cat dander measurements, indicating that other factors, such as IAQ management, play a large role in determining levels of cat dander in classrooms. Data were not robust enough to support a conclusive analysis of whether changes in cat ownership between 2004 and 2005 affected changes in dander levels found in classrooms before and after implementation of the MSEAMP. We did not find a link between the number of dog owners in a classroom and dog allergen levels.

Based on IEc's analyses described above, it is clear that IAQ practice recommendations in areas of smooth flooring, HVAC and ventilation, cleaning, and education/communications are very important drivers of IAQ outcomes. Moreover, IAQ practice recommendations in the areas of moisture management, managing construction and renovation impacts, and plant and animal policy may also be important drivers of outcomes as well.

Summary of Health Outcomes

Hartford Public Schools was the only case study that provided IEc with health outcome data, in the form of asthma-related nurse visitation data. Findings on the correlation between IAQ TfS implementation and decreases in asthma-related nurse visitation are discussed below. In addition, we discuss findings from IEc's interviews of seven HPS nurses on IAQ management and procedures for tracking asthma-related nurse visits.

Asthma-Related Nurse Visits in Hartford

Hartford Public Schools collected the monthly totals of unexpected asthma-related nurse visits by school. School nurses began tracking these data and reporting monthly totals to the district beginning in the 2003-2004 school year. We performed three types of quantitative analyses to investigate the link between IAQ TfS implementation and asthma-related nurse visits; our approach is summarized in Exhibit 3 and described in detail in the Hartford case study. The results of these analyses were mixed but on the

whole indicate that IAQ plan implementation is associated with decreased asthma-related nurse visits.

The collective, longitudinal results correlating IAQ plan implementation with asthma-related nurse visitation were conclusive. All of the study schools (schools that had implemented IAQ TfS) reported fewer normalized nurse visits during the post-implementation period than during the earliest time period for which data were available (either pre-implementation or during implementation). However, only half of the control schools reported fewer normalized nurse visits during the post-implementation period than during the earliest time period for which data were available. These results show that improvements in the frequency of normalized nurse visits were more common in schools that implemented IAQ TfS, although some improvements in asthma visitation were reported throughout the district. It is very possible that several other local initiatives and public health campaigns to address asthma in Hartford could account for decreases in asthma-related nurse visits at control schools; however, they would not account for better outcomes demonstrated at schools that implemented IAQ TfS.

Industrial Economics, Incorporated performed two statistical tests to determine whether IAQ TfS implementation was correlated with a decrease in asthma-related nurse visits across HPS schools: the first test included data from only elementary schools while the second statistical test included data from some middle and magnet high schools. In both instances, the implementation of IAQ TfS was correlated with a decrease in unexpected asthma-related nurse visits. However, the correlation was stronger and the results were statistically significant for the larger, second group.

We conducted additional analyses at the individual school level to investigate correlations further but found mixed results. We evaluated changes in nurse visits following IAQ TfS implementation for the same month across different years, and then completed the same analysis but used data from the same season across different years. Although we found some positive correlation between IAQ TfS implementation and decreases in asthma-related nurse visits for some schools, progress was not demonstrated in other schools. Additionally, some schools reported dramatic increases in asthma-related nurse visits following TfS implementation, which casts doubt as to the quality of the data provided by some schools.

Similarly, IEc's paired case study analysis found mixed results, and we suspect that data quality issues hindered this more focused analysis as well. In the paired case study analysis, we matched four schools that implemented TfS (i.e. study schools) to control schools. The results of the individual case studies were mixed: in two of the case studies, the study schools had a lower number of normalized nurse visits than the control schools during all time periods, but the reverse was true in the other two case studies.[30]

[30]The "Normalized" number of asthma-related nurse visits is the total number of asthma-related nurse visits in a month times one thousand divided by the following factor: (the number of school days in the particular month * the number of students enrolled at the school). This variable enables easy comparison among schools and among months of data.

Interviews with HPS Schools Nurses

In addition to analyzing nurse-visitation data, IEc also interviewed seven HPS nurses to obtain information about procedures for tracking asthma-related nurse visits and IAQ management in general. The nurses that we interviewed had some knowledge or involvement with IAQ TfS, had worked on IAQ issues for at least a few years, and had tracked asthma-related nurse visits. These nurses provided feedback on their perception of the link between IAQ management and asthma-related nurse visits as well as details on how they track asthma-related nurse visits.

IEc asked school nurses to explain whether they had noticed any changes in the number of asthma-related nurse visits since the district implemented IAQ TfS. Over half of the nurses surveyed noted that the number of asthma-related nurse visits had decreased since HPS implemented IAQ TfS. Five of the seven nurses interviewed responded that there is a link between IAQ TfS and the frequency of asthma-related nurse visits. These perceptions reinforce IEc's analytic findings linking IAQ TfS implementation to decreased unplanned asthma visits to school nurses. One nurse also mentioned that she had witnessed decreases in absenteeism and lessened severity of asthma attacks. However, another nurse noted that the City of Hartford's asthma initiatives also contributed to the improvements.

We also asked nurses whether or not they believed that improvements were benefiting all students. Only one nurse felt that the changes in the frequency of asthma-related nurse visits were generally consistent across students. The others felt that inequalities existed and provided three main causes of inequalities: age, parental support, and length of enrollment in HPS. A couple of nurses explained that older students are capable of learning how to manage and control their asthma whereas younger students are not. School nurses also noted that they work with parents of students with asthma to educate them on how to help improve their child's asthma. However, some parents are more receptive to education and compliance with asthma action plans than others. Lastly, one nurse noted that students who are newly enrolled in HPS, and whose parents have not received HPS outreach, couldn't fully benefit from HPS' efforts to improve asthma.

We asked nurses about how they track nurse visitation data, as data quality issues introduced some uncertainty into our quantitative analyses. Asthma-related nurse visit data are self-reported and incomplete, and nurses vary in their methods of tracking these data. District personnel noted that the accuracy of reported data has improved from 2003 through 2006, which is evident in the data sets provided to IEc, but it is also evident that more recent data sets still suffer from some level of incompleteness and inaccuracy.

Nurses reported that a chief cause of data unreliability is that their offices can become very busy without notice, and that they are sometimes unable to track asthma-related nurse visits as they occur. Some nurses provided additional explanations for data unreliability and provided suggestions to improve data reliability, which are included in the Hartford case study and informed IEc's recommendation on improving data quality, which is presented in Chapter 4.

Summary of IAQ Perception Outcomes

Minnesota is the only case study for which we have quantitative perception data (as opposed to qualitative information on nurses' perceptions provided above). As part of MSEAMP implementation, each of the six pilot schools in the Minnesota case study administered a survey to staff before and after MSEAMP implementation; the same staff were surveyed in both years. The survey asked staff to rate indoor air quality in the classroom and in the building as "good," "average," or "poor." IEc applied a few different analytical approaches to determine whether MSEAMP implementation was associated with an improvement in IAQ perception.

First, IEc calculated the percentage of respondents whose perceptions of IAQ in their classrooms worsened, stayed the same, or improved following MSEAMP implementation. Overall, 40.7 percent of respondents' perceptions of IAQ in their classrooms improved, 37.7 percent of respondents' perceptions stayed the same, and 21.6 percent of respondents' perceptions worsened. We found similar results when we analyzed respondents' perceptions of IAQ in their buildings. Overall, 38.1 percent of respondents noted that their perceptions of IAQ in their building had improved, 40.8 percent of respondents' perceptions stayed the same, and 21.1 percent of respondents' perceptions worsened. However, the greatest number of respondents overall described IAQ in the classroom and in the building as "average" in both years. These results demonstrate that far more staff indicated that IAQ improved than worsened after the implementation of the MSEAMP.

Although it is extremely difficult to prove causation between the implementation of an IAQ management plan in schools and changes in IAQ perception, as other factors (e.g., increased education, changes in attitude) could explain perception changes, IAQ perception improvements were associated with environmental improvements at five out of six schools. In other words, out of the five schools that had this relationship, the four Minnesota schools that experienced overall improvements across dust, dog allergens, and cat allergens had higher rates of improved IAQ perception than the one school where environmental conditions worsened between 2004 and 2005. This mutual reinforcement of positive measured results strongly argues for the efficacy of the MSEAMP in addressing IAQ challenges.

CHAPTER 4 | CONCLUSIONS AND RECOMMENDATIONS

The progress achieved by schools studied for this evaluation demonstrates that IAQ planning and management, as embodied by EPA's IAQ TfS guidance and associated programming, represents an effective approach for identifying and addressing IAQ problems in schools, and confers environmental and health benefits.

Although formulas for a successful IAQ management program may vary by district and by school, it is clear from our research that prerequisites of success include a credible and transparent process with accountability mechanisms (such as follow up walkthroughs), and long-term support from school district administration. The primary implementers of the IAQ management at the school level can vary; nurses, facilities/janitorial staff, or teachers could take the lead in implementation, although buy-in and involvement from all applicable parties makes for smoother program implementation.

In this concluding chapter, we first address the question of whether a more prescriptive approach than IAQ TfS conveys greater benefits. Subsequently, we offer four recommendations to assist EPA in improving IAQ TfS guidance and in strengthening data available to demonstrate the benefits of the IAQ TfS program and IAQ management in general.

IS A MORE PRESCRIPTIVE APPROACH ASSOCIATED WITH BETTER RESULTS?

As discussed in Chapter 2, Minnesota's MSEAMP and TfS have similar guidance, including: developing and implementing an IAQ management plan to improve indoor air quality; selecting an IAQ coordinator; incorporating IAQ issues identified into the IAQ management plan; and developing communication procedures. However, the guidance and checklists provided in MSEAMP are more detailed, prescriptive, and comprehensive than TfS guidance and checklists.

Because this program evaluation is based on case studies that addressed diverse measures of environmental outcomes, and one case study (HPS) addressed health outcomes but not environmental outcomes, it is difficult to assess whether outcomes associated with the more prescriptive approach implemented in Minnesota are superior to those associated with the IAQ TfS model. All case studies demonstrated improvements in either environmental outcomes (Minnesota and SLC) or health outcomes (HPS) after implementing an IAQ management plan. Moreover, both SLC and Minnesota realized improvements in carbon dioxide measures, the only common environmental measure across case studies. Comparing relative degrees of improvement in carbon dioxide measures between Minnesota and SLC case studies is difficult. While Minnesota case study schools more uniformly demonstrated measurable improvements in the carbon dioxide differential following IAQ plan implementation, the average baseline carbon

dioxide differential was much better in SLC schools than in the Minnesota schools included in our analysis. Thus, SLC did not have as much room to improve.

In sum, IEc found no evidence that a more prescriptive approach to IAQ management yields better results. However, additional analysis comparing the same outcome measures across schools with different approaches (e.g., IAQ TfS versus MSEAMP) would be needed to make any definitive conclusions. In addition, based on our findings on the relative importance of some IAQ practices, we recommend that EPA provide more detailed recommendations and guidance related to some IAQ areas, which is discussed below.

RECOMMENDATION 1: REVISE OR EXPAND IAQ TFS GUIDANCE TO PRIORITIZE IAQ PRACTICES

As described in Chapter 3 and in detail in the Minnesota case study, IEc found that not all IAQ recommendations contributed equally to environmental improvements in the three case studies. It is clear that IAQ practice recommendations in areas of smooth flooring, HVAC and ventilation, cleaning, and education/communications were important drivers of IAQ outcomes. Moreover, IAQ practice recommendations in the areas of moisture management, managing construction and renovation impacts, and plant and animal policy also appeared to be important drivers of outcomes as well. Recommendations in some of these priority areas, including changing cleaning regimens, and conducting additional IAQ communication and education to change behavior, represent low- or no-cost approaches that all schools should be able to implement, regardless of resource constraints.

Currently, the IAQ TfS program does not provide guidance to help schools prioritize the types of IAQ improvements that should be made first. Given that most schools have limited resources to expend on IAQ management, prioritizing practices that are demonstrated to be particularly effective would help school districts allocate IAQ resources wisely. Using results from this program evaluation and any other available research on the effects of various building improvements on improving indoor air quality, EPA should compile a short additional guidance to the IAQ TfS tool kit that identifies categories of IAQ practices, as well as specific practices within those categories, that have been most robustly linked to demonstrated results.

RECOMMENDATION 2: ENCOURAGE AND SUPPORT ROBUST AND CONSISTENT DATA COLLECTION ON ENVIRONMENTAL, HEALTH, AND PERCEPTION OUTCOMES

When developing the three case studies in this evaluation, IEc confronted three major challenges. First, it was difficult to identify school districts that had collected quantitative data on environmental, health, and perception outcomes associated with IAQ plan implementation. Secondly, many schools in SLC and HPS could not be included in certain analyses because they did not collect environmental or health data prior to TfS implementation (baseline data). Finally, schools that had collected quantitative data used different measures and used inconsistent methods, which made comparison across case studies impossible. The lack of quantitative data on IAQ outcomes makes it very challenging to establish a body of evidence on the benefits of IAQ plan implementation in schools. As a result, IEc recommends that EPA encourage and support robust and consistent data collection on IAQ outcomes by developing key indicators of IAQ

outcomes, providing guidance on the types of data that schools should collect, and encouraging schools to share data with EPA.

Develop Key Indicators of IAQ Outcomes

EPA should identify a few key IAQ management indicators that schools can track on a monthly basis. Some of these indicators should be easily measured without expensive air or dust sampling, for example:

- number of unexpected asthma-related nurse visits per month
- number or percent of rooms or schools in compliance with frequency of cleaning recommendations
- average or median rate of ventilation (in cubic feet per minute) in classrooms
- average or median relative humidity in classrooms

On a less frequent basis, such as an annual basis, the following indicators may be useful to track:

- number or percent of classrooms with smooth flooring
- number or percent of classrooms with stained ceiling tiles
- number of IAQ complaints per school
- number or percent of teachers that perceive that their classroom has healthy IAQ
- average or median levels of dust and animal dander in classrooms

Provide Guidance on the Types of Data that Schools should Collect

EPA should develop tools and resources to help schools track TfS outcomes. Schools need assistance, in the form of guidance and possibly software, on collecting information on environmental conditions, as well as collecting information on health-related outcomes such as nurse visitation for asthma. They also need guidance on how to collect information in a manner that supports the correlation of IAQ plan implementation with potential outcomes.

During the course of this evaluation, IEc encountered difficulties identifying districts that had collected IAQ outcome information, and those districts that had collected information did not always collect it in a structured, scientifically defensible way. For example, HPS lacked a TfS implementation timeline for most schools, which is crucial for making the link between TfS implementation and health outcomes. Additionally, SLC only collected post-implementation data for schools that initially had IAQ problems, as opposed to a mix of schools that had IAQ problems and those that did not. The Minnesota pilot study is quite unique in its comprehensive collection of environmental information. It is not necessary or reasonable to expect that most schools will collect the quantity of information collected by MDH; however, there is a broad spectrum of data collection possibilities between the less organized arrangements demonstrated by Hartford and Salt Lake City, and the state-of-the-art approach demonstrated by the Minnesota pilot schools.

One approach EPA could take is to make basic recommendations on how schools should collect data on IAQ outcomes. For instance, they could recommend that schools collect data prior to implementing an IAQ management plan so that they can demonstrate improvement over time. In addition, EPA could recommend that schools develop an IAQ management timeline that provides the dates when TfS implementation began and when TfS was fully implemented. Lastly, they could recommend that schools or districts establish data collection procedures to ensure that data are consistently tracked.

An alternative approach that EPA could pursue is to develop software or an online tracking tool for schools to track information on IAQ-related procedures and outcomes. These results tracking tools could help schools track their progress towards implementing IAQ management procedures (e.g., obtaining administrative support, training teachers and staff, adopting an IAQ plan, conducting walkthroughs); IAQ issues identified (e.g., walkthrough findings, complaints); and indicators of environmental, health, perception, and/or performance outcomes (e.g., ventilation rates, unexpected asthma-related nurse visits, environmental perception survey results, standardized test scores). Such tools could help schools consolidate important IAQ information and easily share outcomes with their constituents.

Finally, although EPA's position on air sampling is that schools should pursue other IAQ-related activities before conducting air sampling, the IAQ TfS program should develop more detailed guidelines on air sampling for those districts that decide to undertake it. Guidance should emphasize that air sampling should be conducted multiple times, rather than one single time, to track the school's progress towards improving IAQ. Guidance should also address the types of measurements that should be included (e.g., carbon dioxide, allergen levels) and how results should be interpreted.

Encourage Schools to Share Data with EPA

In order to be able to demonstrate the outcomes associated with IAQ plan implementation, EPA must have access to school data on IAQ outcomes. EPA should ask schools to share quantitative data with them, and in addition EPA could provide some incentives to encourage schools to share data. For example, EPA could provide recognition on its website to those schools and districts that share their data. Data sharing could also become a requirement of IAQ TfS grants or excellence awards. Lastly, if EPA were to develop software or an online reporting tool that schools could use to report on IAQ procedures, issues identified, and outcomes, EPA could request that schools use these resources to share data collected (or require it in the case of grantee recipients and award applicants).

RECOMMENDATION 3: COLLECT ADDITIONAL INFORMATION ON PERFORMANCE OUTCOMES

Although impacts on occupant health are important considerations for school policy decision-makers, effects on student test scores are also one of the most important drivers for school decision-makers. If positive changes in student performance (e.g. improvement in test scores) can be linked to sound IAQ practices, these research data could help persuade school policy decision-makers to adopt effective IAQ management

plans consistent with EPA's IAQ TfS guidance, and help the IAQ TfS program develop and use powerful, defensible education and outreach messages. Therefore, IEc recommends that EPA encourage schools to collect additional information on the link between IAQ management and performance outcomes.

RECOMMENDATION 4: PUBLICIZE MEASUREABLE SUCCESSES OF IAQ PLAN IMPLEMENTATION

The IAQ TfS website currently contains case studies from schools that successfully implemented an IAQ management plan, but the case studies focus on activities (e.g., improving communication, addressing mold) rather than measurable environmental and health achievements linked to IAQ management. School districts considering implementing TfS may respond more favorably to examples where schools achieved measurable environmental and health improvements than to process-related case studies. The three case studies that IEc developed provide evidence that schools were able to achieve measurable improvements in environment conditions, asthma, and IAQ perception by implementing an IAQ management plan. Therefore, the IAQ TfS program should showcase the results of the three case studies conducted as part of this evaluation on their website. In addition, EPA should highlight the results of any other studies that link IAQ management to measurable environmental, health, perception, or performance improvements on their website. Finally, EPA should distribute additional analyses and case studies developed in the future (as discussed in Recommendation 2) to school districts in addition to posting them on the program's website.

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