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Introducing an environmental assessment and intervention program in inner-city schools

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Abstract

Home-based environmental interventions have demonstrated clinical benefit for children with asthma. Although much is known about school-based exposures, few studies have comprehensively examined the role the school environment plays in asthma and how effectively changing the environment may reduce morbidity, when adjusting for exposures in the home. This review summarizes the importance and common challenges of school-based environmental assessment and intervention studies linked to health effects. We focus on the key components of study development and the challenges and benefits to implementation.

Keywords

environmental intervention; school-based environmental intervention; pediatric asthma

Asthma is one of the most common childhood diseases, affecting up to 15% of children in the United States, is disproportionately more common in urban and inner-city environments, and is the leading cause of missed school days in America[1-3]. Decades of previous research have demonstrated that allergen, mold, and pollutant exposure in the inner-city home environment is associated with significant childhood asthma morbidity[4-9]. Many of these allergen and pollutants are also present in the inner-city school environment, where children spend 7-12 hours per day[10-24]. These exposures in the school environment may be contributing to asthma morbidity[10-24]. Home-based interventions to remove allergens and pollutants have demonstrated significant clinical benefit in asthmatic children; therefore, environmental intervention in schools is a logical next step[25, 26]. School and classroom based interventions, while challenging, have the unique opportunity to effectively and

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efficiently benefit a community of children in the school environment as opposed to individuals in single homes.

The focus of this perspectives article is to discuss the challenges and potential benefits of comprehensive environmental assessment and health outcomes in inner-city schools. The discussion is based on the relevant recently published literature and the experiences of the authors as investigators in this field. It also discusses the need for future comprehensive school-based environmental intervention studies and provides a perspective on interventions with potential benefit. The primary disease of interest in this perspectives piece is environmentally mediated asthma, although environmental interventions in schools may impact morbidity of other allergic and irritant-induced diseases as well.

Exposures in the School Environment

The school environment has been shown to be a significant reservoir for allergens and pollutants[10-24]. A comprehensive review of allergen exposures in schools has been published previously in the *Journal of Allergy and Clinical Immunology* and will not be discussed in detail here[27], aside from key concepts from recent data published since the review was written. As in home environments, it is unlikely that a single school or classroom based environmental exposure is solely responsible for asthma morbidity[28,29].

Indoor allergens known to be important in urban home environments may also be important in schools, including cockroach (Bla g 1, Bla g 2), cat (Fel d 1), dog (Can f 1), mouse (Mus m 1, MUP), dust-mite (Der f 1, Der p 1), and molds. Historically, cockroach and mouse allergen have been of particular interest, as these exposures have been linked to higher asthma morbidity in inner-city children than other commonly encountered allergens in home environments[9, 30-32]. Previous studies found cockroach and mouse allergens highly prevalent in school environments[12, 19]. The School Inner-City Asthma Study (SICAS), is a prospective, NIAID funded, comprehensive study of classroom and school specific exposures and asthma morbidity among students in urban schools[25]. This study has consistently found much higher levels of mouse allergen in schools, compared to the same students' home environments[21, 23], with levels similar to those seen in occupational lab animal settings[33]. School cat and dog allergen levels in this same study were variable[21], and not at levels previously shown to worsen symptoms[34]. While there was very little cockroach allergen discovered, we measured significant classroom specific dust and airborne mold levels in the schools[24], at levels well above those known to exacerbate symptoms in homes[35]. Other studies in Europe have demonstrated cat and dog allergen at high levels in schools, likely from passive transfer of students who owned pets in their homes[18]. Additionally, recent work has demonstrated that the greatest burden of dust-mite exposure may indeed be outside the home as well[36].

Furthermore, schools are typically centrally located within a community and may be in closer proximity to heavy traffic routes and commercial or industrial exposures. They also frequently serve as a hub for pick-up, drop-off, and idling of cars and buses, potentially contributing to a site-specific increase in ambient pollution. Inside, classroom activity re-suspends particles thereby increasing exposure[37]. Schools sometimes have poor

ventilation[38] and suffer inadequate building maintenance[39]. Finally, in contrast to homes, most schools no longer have active kitchens and smoking is prohibited, leaving little contribution of indoor sources to indoor air pollution. Children are frequently physically active in school, potentially increasing the inhaled dose of pollutants[37]. These factors make schools a unique microenvironment of indoor air pollutants and particulates, as well as associated mold and other allergens carried on these particles.

The Health Effects of Indoor Air Pollutants (HITEA) group has an ongoing prospective study evaluating indoor air pollution in Europe. This study was borne out of a demand for research on indoor air pollution from the European Union 7th framework programme. Thus far, HITEA has found high levels of mold in schools, particularly those with moisture damage[40-43]. These mold findings corroborate the results from the SICAS study done in the United States[24]. A recent cross-sectional study in Taiwan additionally found that fungal spore levels in classrooms correlated with asthma symptoms and found relief of symptoms on weekends and holidays[44]. Additional studies suggest that high levels of microbial byproducts may correlate with respiratory symptoms, although results were mixed[40-43]. Recent meta-genomic studies, however, suggest that the effect of microbial exposures on asthma may depend not just on quantity, but rather on the biodiversity of microbial exposures, which may be characterized by sequencing and newer techniques that hold promise for the future[45, 46].

As it is evident that multiple and varied exposures are responsible for school-specific asthma morbidity, it is unlikely that one type of environmental assessment or intervention will be applicable in all schools[29]. Below is a discussion of the general principles of school-based environmental assessments and interventions based on the studies that have been done to date.

School-based Environmental Assessments and Interventions

The Challenges of Community Outreach and Buy-In

Before one can begin to comprehensively assess how the specific school or classroom environment impacts the students, investigators must establish a trusting relationship with the community[25]. Our experience has involved nearly a decade of ongoing community relationships. First, commitment from the senior school administrators is necessary to introduce any research program in the schools[25]. In our experience, investigation then involves local community support from the individual principals, teachers, school nurses, administrative support, facilities management, medical directors, and the students and their families. This commitment is born out of trust that the investigators will give back to the community in some capacity, through education, health care accessibility, or some other mechanism[25]. The second means for establishing trust is by raising awareness for the study, or the issue being studied, in a way that demonstrates the investigators' commitment to the community. For example, our ongoing work has utilized investigatorled neighborhood asthma initiatives, advocacy groups, informational parents' nights, and involve high school students in research mentorship programs to bolster interest and awareness[25]. Work in schools is only made possible because of longstanding community trust and relationships developed from these experiences[25]. The initial phase of our work enabled us to build the

community trust necessary to objectively evaluate the school environment and the effects on health, independent of home exposures.

Once the investigative team has community buy-in, investigators can then begin to design a study to fit the unique challenges of the school environment. Part of this design must include attention to the barriers to study participation and retention, commonly encountered in all inner-city studies, such as lack of transportation, unstable housing, neighborhood violence, language barriers, and lack of access to care[47-50]. Investigators often must adapt study materials to the languages of the participants and committed, multi-lingual, multi-cultural study staff are needed to maintain trust among participants' families and the community[47, 49]. Minimizing staff turnover and providing incentives to participants are resource intensive measures, but are ultimately necessary for success in these studies.

Once enrolled, investigators must continually work to retain study participants. The phenomena leading to study drop-out have been studied in various other inner-city studies[47-50]. In these studies, it was found that lack of social support, having few contacts, out-of-date contact information, and caretaker stress were predictors for study drop-out[47, 49]. School-based studies provide the additional challenge that students may change to a school outside the study[25]. Unlike home based studies, in which subjects may frequently be lost to follow up, schools generally know where children are and have state mandated enrollment and attendance records. In our experience, buy-in from the schools enables staff to maintain participation by the families and students, and as a result we have been successful in maintaining excellent engagement and follow-up from our families.

Environmental Assessment In Schools: Strategies and Challenges

To fully understand if school-based environmental interventions improve asthma morbidity, investigators must also collect information on the home environment. In SICAS, we utilized standard methods for objective environmental sampling and validated surveys and inspection forms for these measures, as has been used in home-based studies [25, 51]. Collection of these data enables adjustment for home exposure in the final results.

The clinical health outcomes data should be linked to the exposure data, and ultimately interventions should target changes in clinical outcomes, not just decrease in exposure burden. While ideally obtained at school, some procedures and surveys should be obtained in a clinic setting for more accurate data collection. Subjective data should include parent and student screening surveys focused on asthma and allergic disease morbidity[52-55]. Objective health outcomes data may include pulmonary function tests, peak flow, exhaled nitric oxide, nasal sampling, blood and or urine collection, skin prick testing, or other validated measures of asthma morbidity and associated conditions[25]. The precise outcomes data obtained are up to the discretion of the investigator. From our experience, with extensive community support from the school staff, surveys and some simple objective measures such as lung function may be obtained at school [25].

Within the school, classrooms, cafeteria, gymnasium, and other frequented areas should be evaluated. Each of these areas may harbor different exposures to varying levels, and ideally should be assessed independently[12, 20, 23]. The conditions of each room should be

considered with attention to the condition of every measurable feature, including the walls, ceilings, windows, floors, and presence of animals both domestic and pest[25]. This requires on-the-ground assessment of the rooms by research staff in a systematic and standardized fashion that is included in the study design.

Dust sampling may be done through vacuuming in a standardized format that includes dust from floors, desks, and chairs[25, 50, 56, 57]. Airborne allergens may be measured using air samplers, and the methods for using each of these devices have been previously described[25, 58-60]. Traditional mold sampling methods have utilized spore levels as a proxy for mold exposure levels[27, 61]; however, the complexity of mold sampling and its clear relation to health outcomes is not fully elucidated, and beyond the scope of this article[25, 62, 63]. Air pollution sampling is very well-established, as it is widely done for both research and personal purposes[25, 64, 65]. In our experience, however, there are many logistical and staffing challenges behind utilizing well-established methods such that they are not disruptive to a school environment. Our school visits required multiple staff and vehicles to transport equipment and monitoring supplies, which needed to be placed in safe, non-disruptive areas and run silently, yet still collect the data in a discrete and unobtrusive way. Using personal exposure monitors may be considered in the near future to provide additional information on a child's daily exposures[66], but similarly involve support from the families and students.

Environmental Interventions in Schools

Ideally, the intervention portions of school environmental studies would be prospective longitudinal randomized double-blind controlled trials, using sham interventions as controls. The school-based environmental interventional studies done to date have been small, cross-sectional, and did not control for exposures in the home environment[10-20, 25, 67-70]. A small randomized trial in Australia found that when controlling for the home environment, replacing school heaters and thus reducing NO_2 levels reduced asthma symptoms[68]. These types of heaters are not used in schools in the United States, and most schools do not utilize gas stoves, making indoor sources of NO_2 less likely. In Sweden, rigorous interventions to reduce pet dander in schools have been done, but such interventions—including pet avoidance measures or even banning pet ownership—would not be practical in the United States[69-71]. Several small longitudinal studies in Europe have found improvement in asthma symptoms with building maintenance, repair of air filtration systems, repair of moisture damage, and reduction in mold exposure[72-74]. The authors acknowledge that there are cases when a more extensive building-level intervention or repair may be needed to reduce allergen exposure. Environmental intervention studies, however, both in schools and homes, have primarily focused on practical and feasible study interventions rather than complete building reconstruction[10-20, 25, 68-70].

Given the paucity of comprehensive data on school-based environmental interventions and health outcomes, successful home-based strategies currently serve as the model for school-based interventions. One practical intervention to consider is the use of air filtration systems to reduce environmental exposures[75, 76]. A recent rostrum on air filtration published in the *Journal of Allergy and Clinical Immunology* outlined what is known in this field and called

for more rigorous trials and research[75]. With regard to types of air filtration systems, room HEPA air filters may be more practical for study purposes[75, 77], and may be utilized to control classroom-specific exposures. If successful within single classrooms, these results may inform future school-wide practices. Two recent well-designed home-based studies demonstrated that HEPA filters reduce particulate matter and demonstrated benefits on health effects[78, 79]. Similarly, a pilot study demonstrated that HEPA filters reduce mold spore counts in daycare centers, which have similar conditions to a school environment[80]. Our group is currently piloting strategies toward effective school-based environmental reduction techniques modeled from successful home-based strategies and adapted for tolerance and acceptability in a school and classroom setting. Some ongoing home-based studies include NCT01251224, which is evaluating the role of home-based integrated pest management, air filtration and cleaning in improving asthma morbidity. Other ongoing trials examine the impact of home placed HEPA filters on smoke exposure in children (NCT00006565) and dog allergen exposure in dog allergic adolescents with asthma (NCT00220753). Another trial, NCT01869543, is comparing portable bedroom placed HEPA filters with central air systems on asthma morbidity.

Another example of a feasible school-based environmental intervention is integrated pest management. Our school-based studies have identified that children with asthma in inner-cities have markedly higher levels of mouse allergen in their schools compared to levels in their individual bedrooms[21, 23]. There are ongoing trials evaluating the role of integrated pest management in the home, including NCT01251224, which is focused on mouse allergic asthmatic children. Extrapolating from the home-based intervention studies, utilizing strategies that have been successful in reducing pest allergens home environments should be helpful for school-based studies as well[56, 81].

A landmark study from Inner-City Asthma Study Group published in the *New England Journal of Medicine* demonstrated that multifaceted removal of multiple allergens and pollutants through allergen-impermeable covers, HEPA filter vacuum cleaners, HEPA air purifiers, and professional pest control can improve asthma outcomes[26]. The results of these interventions had similar impacts on symptomatic days as inhaled corticosteroids[26]. The improvements in asthma symptoms seen during the intervention lasted at least one year after the intervention was discontinued, suggesting persistent benefits [26]. Modeling school-based studies after successful multifaceted home- based interventions such as this may include utilizing a comprehensive component, such as HEPA air filter, plus a tailored component, such as integrated pest management, to collectively reduce allergen and pollutant levels.

The Challenges of Environmental Intervention Studies in Schools

Implementing environmental interventions in schools is not a simple process. Using HEPA filters as an example, similar to the environmental assessment tools, the filters themselves must be physically unobtrusive. They must be placed carefully such that they can function effectively yet are not inadvertently turned off or altered by curious students[82]. The filters must be large enough to purify the air of an entire classroom, which may be much larger than the bedrooms studied in most home-based intervention studies. The filters must be acoustically tolerable, which may be challenging at the high flow rates required to filter the

air in a large classroom. Furthermore, previous studies have shown that air filters are affected by the volume and air exchange rates of a given room[77]. Thus the size, windows, doors, and actual dimensions of each classroom must be considered when analyzing study results. Filters themselves should be replaced and serviced taking into account these variables.

Despite these challenges, blinding is possible for select school-based interventions. For example, students may be blinded to sham and active filters in the classrooms. The school-based integrated pest management intervention may be done after hours so that the students, teachers, and parents are likely to be blinded. Additionally, interventions that cannot be randomized from classroom to classroom, such as integrated pest management, may be randomized between schools and focused on cafeterias. Large scaled interventions may be more difficult to blind, such as heavy duty building maintenance to remove mold and repair cracks.

The Future

Despite the logistical challenges of implementing comprehensive school-based interventions, evidence provides support towards the importance of school and classroom exposures and health outcomes[68-74, 80]. Our ongoing efforts are evaluating the additive role of the school environment, adjusting for home environment on health outcomes, and should provide additional support for school-based environmental intervention as a next step. The school may eventually be considered an effective target for asthma morbidity prevention. School-based interventions have the potential to reduce exposures for many symptomatic children, in contrast to the individual families impacted by home-based interventions. If effective, results from school-based interventional studies could inform public policy change, funding, and initiatives. Unlike home intervention strategies, these efforts would likely not be dependent on individual family practice and funds, privately or through health insurance.

While this may seem to be an expensive undertaking for cities, preliminary studies suggest that environmental interventions may be cost beneficial[83]. A recent study found that education regarding such things as allergen-impermeable covers and pest management yielded a net savings of over $14 million when accounting for direct medical expenses and indirect expenses, such as lost work productivity[83]. In inner cities where the burden of disease is so great, interventions may reduce the cost to the community even further. We have focused this perspective on inner-city school environments because the majority of previous home-based interventions have focused on inner-cities, which have a disproportionately high asthma burden[4-9, 84, 85]. Non-urban school environments may also be important if these interventions prove effective. This perspective is not intended to suggest that school-based interventions should replace home-based interventions, but that a comprehensive school-based environmental intervention would be an important first step to provide information on the additional or independent role of school-based environmental interventions. Finally, if the benefits from school-based interventions last beyond when the intervention is performed, as they did in the home-based study from Morgan et al, the impact will be even greater.[26]

At the time of this perspective piece, there is an unmet need for rigorous and comprehensive school-based environmental intervention with clinical outcomes studies. While the home environment has been extensively studied, the school environment is less well understood, largely due to the logistical and community hurdles described. Previous indoor environmental intervention trials focused on individuals in single homes. If it can be demonstrated that reduction of classroom-specific exposures leads to improved asthma outcomes, then findings can be translated into efficient and cost-effective strategies to benefit communities of children through improvement of the school environment, where children in America spend the majority of their day.

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