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ORIGINAL ARTICLE

Identification and Initial Characterization of Prominent Air Pollution Sources and Respiratory Health at Secondary Schools in Ibadan, Nigeria

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Objective. Research on air quality in and around schools, and the associated vulnerability of school-age children, is limited in less developed countries (LDCs), particularly Africa. The main objective of this study was to conduct an initial assessment of sources of air pollution in and around schools as a surrogate for air quality and report adverse health effects among students at selected secondary schools in urban Ibadan, Nigeria. **Methods.** The study was a descriptive cross-sectional survey involving eight secondary schools selected purposively, defined with eight acronyms (listed alphabetically): ABHS, AGS, BOHS, CDSS, IGS, LC, MGS, and OAHS. We used pre-tested, self-administered questionnaires, observational checklists to assess certain environmental health indicators, and interviews. The questionnaire was divided into five sections including environmental and health conditions. A total of 400 students from senior secondary classes, 50 from each school, were selected through stratified random sampling. **Results.** The school's location, especially if close to high traffic roadways, contributed to reported perceived poor air quality of school environments. The majority of students believed air pollution sources in the school environment were mainly refuse burning and car emissions from nearby roadways. Cough and asthma were the most frequently reported adverse health outcomes. The highest prevalence of reported recent asthma episodes (symptoms) were recorded at BOHS (84%) and at CDSS (62%); furthermore, at ABHS it was nearly 1-in-2 students and at OAHS about 1-in-5 students. BOHS and OAHS each reported over 10% for prevalence of bronchitis. **Conclusions.** Proximity of study schools to certain sources and activities such as refuse burning and major roadways seemed to present substantial risk factors for reported respiratory morbidity among secondary students in urban Ibadan, Nigeria. Future research should quantify source emissions and exposure and further characterize frequency and severity of respiratory symptoms, among other parameters, at schools in Nigeria and other sprawling urban areas of Africa.

Keywords schools, asthma, children, Ibadan, Nigeria, air quality, environmental practices

INTRODUCTION

Air pollution, outdoors and indoors, in less developed country (LDC) cities has been estimated to be responsible for millions of annual cases of chronic respiratory diseases in children younger than 14 years of age because pollution levels of particles and combustion-related gases have exceeded World Health Organization (WHO) air quality standards in many LDCs; most LDCs do not even have routine outdoor air quality monitoring (1–5). While school-age children, in general, incur health risks as a result of exposure to air pollution, children with diagnosed asthma and allergies are of particular concern. Both short-term and long-term increases in outdoor air pollution levels have been associated with an increase in asthma symptoms in children in many published studies (6), including studies with estimates of traffic-related emissions (7) and studies comparing countries around the world (8). However, most research to date was conducted in industrialized countries of Europe and North America, not LDCs where most urbanization continues to occur at an increasing rate. There have been relatively few studies conducted over the last 3 to 4 decades in Africa on school-age children. Among the identified published studies to date, most

were about clinical and/or behavioral management, not environmental management, of asthma. They were conducted in (listed in alphabetical order) Egypt (9–10), Ghana (11–13), Ivory Coast (14), Kenya (15–19), Libya (20), Morocco (21), Mozambique (22–23), Nigeria (24–43), South Africa (44–51), and Tanzania (52).

Air pollution is an indoor issue of concern as well—for example, the U.S. Environmental Protection Agency (EPA) has stated that indoor levels of air pollutants are 2 to 5 times, and sometimes more than 100 times, higher than outdoor levels (53). In addition, past survey research has consistently shown that most people spend about 90% of their time indoors, especially at home and school or another work microenvironment (53–54). Given that children are especially susceptible to air pollution, maintaining good air quality in and around schools is of particular concern because of the amount of time spent there daily; this includes environmental quality (e.g., lighting, thermal comfort), safety, and good operations and management of facilities and ventilation systems (55). Good air quality can contribute to a favorable learning environment for students, productivity for teachers and staff, and a sense of comfort, health, and well-being for school occupants.

Over the course of most of the 1990s and into the beginning of this new millennium, the number of children under age 18 who have asthma has increased substantially (8, 53, 55–57). In the U.S., asthma has been reported as the number one cause of school absenteeism due to chronic diseases and a leading reason for children being admitted to the hospital (53). Furthermore, over the last two decades, the nationwide

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prevalence of childhood asthma has increased substantially (56), and for children under age 18 about one in eight have had asthma diagnosed sometime in their lives, with the proportion increasing with age group (57). Such data in LDCs such as Nigeria on school-age children are sparse, and routine surveillance data on asthma prevalence and symptoms and severity are limited to non-existent.

Worldwide, acute and lower respiratory infections are the most common acute and chronic diseases in children. Furthermore, pneumonia is a leading cause of childhood mortality. Economically disadvantaged sectors of society typically have suffered the most, in part due to living in degraded environmental conditions. Research on air quality in and around schools and the associated vulnerability of school age children, is limited in LDCs, in particular those in Africa, including Nigeria with its rapidly growing population and sprawling urban areas.

The main objective of this pilot study was to conduct an initial assessment to identify prominent sources of air pollution in and around schools as a surrogate for air quality and estimated exposure to mobile source emissions and to report selected adverse respiratory health effects among students, at selected secondary schools in urban Ibadan, Nigeria, to help justify and further focus future school-based research.

METHODOLOGY

This study went through proper required institutional review board procedures at the College of Medicine, University of Ibadan, before its initiation, and informed consent was obtained from participating study schools.

We conducted this study in eight selected secondary schools (Table 1). The schools, located in the metropolitan Ibadan area, included Methodist Grammar School (MGS), Ikolaba Grammar School (IGS), Bashorun Ogunmola High School (BOHS), Oba Akinbiyi High School (OAHS), Command Day Secondary School (CDSS), Loyola College (LC), Anglican Commercial Grammar School (ACGS), and Aperin Boys High School (ABHS). We received permission to refer to study schools by these defined acronyms.

Study Area

Ibadan is the capital of Oyo State in Nigeria and the largest city in West Africa with millions of inhabitants (based on lo-

cal demographic and housing census, most recently 2006). Ibadan is an old, primarily indigenous African city situated between latitude 7° and 9°30' east of prime meridian and covers a large land area of about 12 square kilometers at an altitude ranging from about 150 to over 200 meters with isolated ridges and peaks rising over about 270 meters. Ibadan presents a typical picture of many African cities each known for having the old town area (inner core) and then the transitional and peripheral areas. Most people are Yoruba; other ethnic groups constitute smaller proportions of the population. Ibadan has over 300 schools comprised of public and private nursery, primary schools, and secondary schools.

Study Design

We conducted a descriptive cross-sectional survey of sources of air pollution and perceived air quality in and around (outside) schools and reported acute and chronic adverse health outcomes among students attending selected schools.

Study Population

The study population (see Table 1) included students in eight senior secondary schools, especially classes I and II (equal to grades 10–11 in the U.S.). Participants were properly trained on how to fill the questionnaire before they were completed.

Sampling Procedure

A total of 400 participants were used for the study, 50 from each of the 8 study schools. A combination of stratified and simple random sampling was used in getting the appropriate sample for this study.

Materials, Techniques, and Tools

Well-structured questionnaires, technician walk through or observational check lists, and in-depth interviews were used in collecting data related to environmental and health issues; they were based on previous school-based research in the U.S. (55, 58). Informed consent was sought and obtained from the school administration and the participating students and staff based on interest before the survey commenced.

Questionnaires, which were self-administered, consisted of both open- and closed-ended questions. The 75-item

TABLE 1.—Data for the study period on participating secondary schools in Ibadan, Nigeria.

School, Grade level served (specific grade, if applicable)	No. of students	No. of teaching staff	No. of non-teaching staff	Location within metropolitan Ibadan	Sources and related air pollution activities around schools
IGS, senior secondary	1,371	43	14	Agodi Gate	Adjacent to main roadways, traffic dominated by automobiles here
ABHS, senior secondary (II or U.S. grade 11) ^a	500	40	10	Aperin	Outdoor market, which is also near roadway, i.e., traffic
OAHS, senior secondary (II or U.S. grade 11)	300	34	11	Oremeji	Adjacent to main roadways, traffic
ACGS, senior secondary (II or U.S. grade 11)	600	28	10	Yemetu	Open dumpsite
LC, senior secondary ^a	3,100	35	10	Agodi Gate	Adjacent to main roadways, traffic
CDSS, senior secondary	500	34	12	Ojoo	Adjacent to main roadways, traffic including heavy trucks; quarry.
BOHS, senior secondary	612	42	10	Ashi Road	Adjacent to main roadways, traffic
MGS, senior secondary	1,405	47	12	Bodija	Adjacent to main roadways, traffic; mechanics village; open dumpsite.

^aThese were two schools serving only boys—the other schools served boys and girls.

TABLE 2.—Types of air pollutants present outside schools from identified adjacent sources and perceived adverse impacts qualitatively reported by participants, at eight selected secondary schools in Ibadan, Nigeria. (Data presented as number and percentage of $n = 50$ per school, or of $n = 400$ overall.)

Name of school	Smoke	Dust	Yes, exposure concern affirmed	No, this type of exposure of concern not reported
IGS ^a	37 (74%)	0 (0%)	28 (56%)	13 (26%)
MGS	0 (0%)	10 (20%)	33 (66%)	17 (34%)
OAHS	28 (57%)	20 (40%)	49 (98%)	1 (2%)
AGS	47 (94%)	3 (6%)	38 (76%)	12 (24%)
LC	19 (38%)	27 (54%)	50 (100%)	0 (0%)
CDSS	11 (22%)	34 (68%)	36 (72%)	14 (28%)
BOHS	6 (12%)	40 (80%)	44 (88%)	6 (12%)
ABHS ^b	11 (22%)	33 (66%)	15 (30%)	18 (36%)
Total	159 (39.8%)	167 (41.8%)	293 (73.2%)	81 (20.2%)

^aThere were missing data, $n = 9$, for last two columns.

^bThere were missing data, $n = 17$, for last two columns.

questionnaire was divided into five sections. The sections were as follows:

- Section A was for general information about the schools;
- Section B was for socio-demographic information;
- Section C was for occupational features;
- Section D was for environmental characteristics; and
- Section E was for reported health outcomes of interest.

Observational checklists were also used to assess the environmental health indicators in the various microenvironments comprising schools.

The ideal school environment in terms of air quality should be the one with healthy buildings conducive for learning, including proper ventilation into the classes. It should be the one not close to activity areas such as major roads and highways, outdoor markets, open dumpsites, and various industries. Therefore, we investigated the presence and proximity of these potential pollution sources. In addition, we targeted air quality-related exposure effects. These acute and chronic adverse health outcomes and associated symptoms included cough, asthma, bronchitis, and whooping cough. We also were interested in immediate effects/symptoms resulting from exposure to poor air quality. Examples included mild cough, catarrh, eye irritation, ear pain, distraction, discomfort, and sneezing.

Data were collected, managed, and then analyzed using descriptive statistics in Microsoft Excel.

RESULTS

Table 2 presents data on types of air pollutants present outside of schools from identified adjacent sources and perceived adverse impacts qualitatively reported by participants. The highest report (94%) of smoke—from one or more sources—in the school environment was from AGS, while the highest report (80%) of dust was from BOHS. BOHS also recorded (88%) one of the highest impacts due to air pollution.

Figure 1 summarizes potential sources of air pollution nearby selected secondary schools. Most students reported that they believed sources of air pollution in the school environment were mainly from refuse burning and car emissions. About 60% of students at MGS, 94% of OAHS students, 78% of AGS students, 76% of LC students, 88% of CDSS students, 76% of BOHS students, and 80% of ABHS students believed refuse burning was the major source of air pollution in their schools. Conversely, 46% of IGS students believed that the most incriminating air pollution source in their school environment was from automobile emissions.

Table 3 presents air quality-related acute health effects as self-reported symptoms. We observed, among the total population, that 29 (5.8%) experienced sneezing, 47 (9.4%) had mild cough, 28 (5.6%) had discomfort, 18 (3.6%) had eye pain/irritation, 2 (0.4%) had distraction, and 10 (2.5%) had catarrh. Thus, most reported symptoms were respiratory and/or non-specific in nature.

Sneezing and mild cough were also the most common symptoms or acute health effects reported to have resulted from air pollution among the respondents at individual study schools. The top three schools reporting sneezing were AGS (12%), LC (28%), and BOHS (8%). The top three schools that reported mild cough were OAHS (14%), LC (16%), and OAHS (14%).

Figure 2 presents air quality-related exposure effects as self-reported symptoms over the last month or physician-diagnosed chronic diseases. We observed about 15% (60 of 400) of the total study population reported cough, 27% (109) asthma, and 6% (25) bronchitis. Of study schools where participating students reported having cough, students at OAHS recorded the highest response (44%), followed by AGS with 28%; MGS and IGS had no reported symptoms of the targeted respiratory diseases.

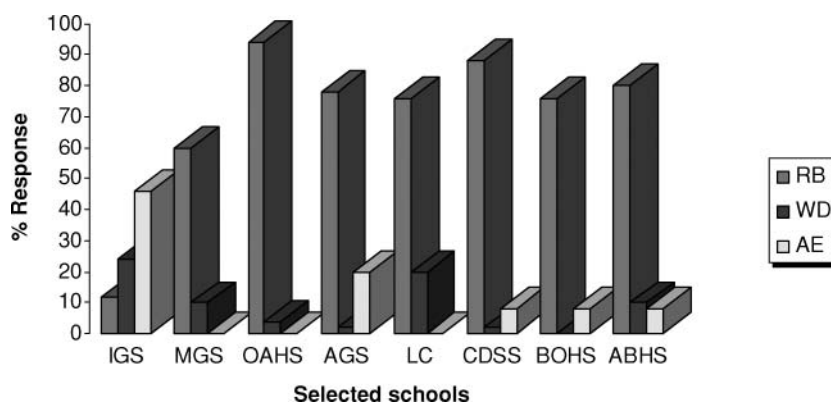


FIGURE 1.—Potential sources of air pollution nearby selected secondary schools in Ibadan, Nigeria. Legend: refuse burning (RB), waste decomposition (WD), automobile emissions (AE).

TABLE 3.—Air quality–related acute health effects, as self-reported symptoms, among participating students in selected secondary schools in Ibadan, Nigeria. (Data presented as number and percentage of $n = 50$ per school or of $n = 400$ overall.)

School	Sneezing	Mild cough	Discomfort	Eye irritation ("pain")	Distraction	Catarrh
IGS	0 (0%)	0 (0%)	28 (56%)	0 (0%)	0 (0%)	0 (0%)
MGS	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
OAHS	0 (0%)	7 (14%)	0 (0%)	0 (0%)	0 (0%)	3 (6%)
AGS	6 (12%)	0 (0%)	0 (0%)	18 (36%)	0 (0%)	0 (0%)
LC	14 (28%)	8 (16%)	0 (0%)	0 (0%)	2 (4%)	0 (0%)
CDSS	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
BOHS	4 (8%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
ABHS	0 (0%)	8 (16%)	0 (0%)	0 (0%)	0 (0%)	7 (14%)
Total	24 (6.0%)	23 (5.8%)	28 (7.0%)	18 (4.0%)	2 (0.5%)	10 (2.5%)

Five schools reported cases of asthma with one or more symptoms. From Table 3, we observed that students at BOHS had the highest prevalence at 84% and followed by CDSS with 62% and ABHS with 44%. The school with the least reported asthma was LC with 8%.

Bronchitis was reported in five of eight study schools, but the percent prevalence was relatively low across study schools. BOHS reported the highest prevalence of 14%, followed by OAHS with 12%; the other three schools had 8%.

DISCUSSION

At one of eight study schools (IGS), no respondent was reported to have any of the poor air quality–related exposure effects. The only non-specific problem highlighted by 56% of the respondents was discomfort as a result of identified sources and poor air quality around the school. This may be owing to exhaust fumes from heavy traffic along nearby Agodi-gate, given the school is enclosed and sited adjacent to a secondary road leading to a government building.

Another study school (MGS) was located on a major road with heavy traffic in close proximity to constantly busy Bodija market. Refuse burning occurs within and outside the school premises. Despite these potential exposures, there were no reports of cough, asthma, or bronchitis among the respondents. There were also fewer reports of acute health effects such as sneezing, discomfort, distraction, and eye irritation. However, a lack of symptoms does not mean that

the quality of the air within the school is acceptable. For example, known human odor thresholds of many organic pollutants previously measured inside and outside schools are either lower or higher than health-based air quality standards, if the latter even exist (59–62).

The location of a third study school (OAHS) at Oremeji, which is near a major road leading to Mokola, suggested that these students would be exposed to smoke from burning of refuse and exhaust from moving cars and trucks. We found that 44% of respondents reported cough, 20% had asthma, and 12% had bronchitis. Acute respiratory symptoms experienced and reported by respondents and potentially linked to these air pollution exposures were mild cough (14%) and catarrh (6%).

The school environment of a fourth study school (ABHS) was observed to be dusty, with dust being reported as the major air pollutant. Furthermore, our study found that 6% respondents reported cough, 44% reported asthma, and 8% reported bronchitis. Reports of acute respiratory symptoms included 16% for mild cough and 14% for catarrh. The high prevalence of reported asthma diagnosis and symptoms could certainly be related to this seemingly increased exposure to dust, or larger particles in the respirable fraction. These particles may contain both chemical and biological constituents that could trigger short-term and/or long-term allergic effects.

The fifth study school (AGS) is located near a huge dump site at Yemetu and is usually dusty indoors and outdoors. We found that 28% of the respondents reported cough but had not reported other ailments such as asthma and bronchitis. About 1-in-8 (12%) also reported acute respiratory problems. Acute symptoms such as coughing and sneezing are one of the body's ways of removing foreign material.

The population of the students at a sixth study school (LC) was 3,100, and thus was the study school with the highest reported enrolment. Overcrowding, due to higher occupant density, allows students to easily transmit communicable diseases to one another. The school is also along a major road, and thus the students are likely exposed to automobile emissions. For these and other reasons, LC was the only school where participants reported having each assessed air quality–related exposure effect, although in low proportions. For instance, 8% of the respondents reported cough, 8% of the

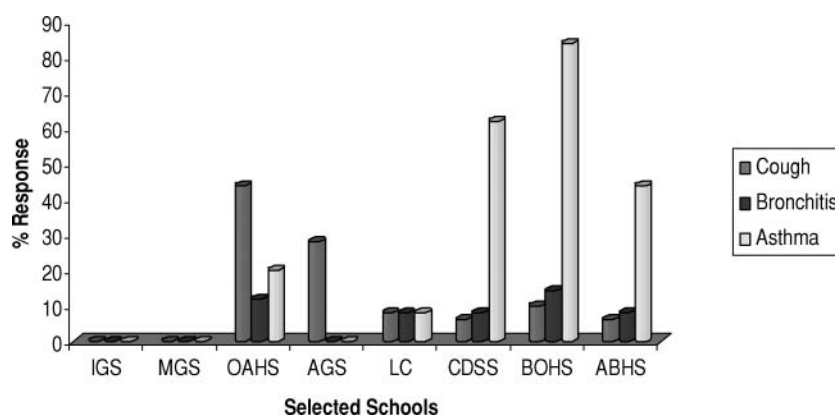


FIGURE 2.—Air quality related exposure effects, as self-reported symptoms over last month or physician diagnosed chronic diseases, among participating students in selected secondary schools in Ibadan, Nigeria.

respondents reported asthma, and 8% of the respondents reported bronchitis; of the acute symptoms, 28% reported sneezing and 16% mild cough.

At the seventh study school (CDSS), the students are exposed to fumes and smoke from refuse burning. Smoke coming from refuse burning is classified as fine particulate matter (PM_{2.5}, particles with an aerodynamic diameter of less than 2.5 micrometers), which travels deeper into lungs to cause more damage. Furthermore, the potential exposure to dust was high, which may be due to fly ash from refuse burning and highway and heavy truck transportation coupled with the location of a quarry not too far from the school that makes the students potentially inhale higher concentrations of dust (coarse particulate matter or PM₁₀, particles with an aerodynamic diameter of less than 10 micrometers). However, we noted that about 6% of respondents had cough, 62% had asthma, and 8% had bronchitis.

The highest report of exposure to dust was recorded at the eighth and final study school (BOHS), which also recorded the highest reported prevalence of asthma (84%). Other reported adverse health effects were cough (10%), bronchitis (14%), and acute symptoms such as sneezing (8%). These data may be due in part to the increased level of particulate matter and combustion-related pollutants from traffic such as nitrogen oxides and sulfur oxides, which are documented environmental asthma triggers, outside and inside this school's environment.

We recognize and reiterate that there were known limitations to our pilot study. There was potential information bias for at least two reasons. First, student respiratory health data were self-reported, even if in response to previously validated (referenced) survey questions. Second, as described above in detail, we purposely selected the eight study secondary schools—but randomly selected 50 students across gender per school—to be located near major roadways, given both international concerns about mobile source emissions linked to respiratory and cardiovascular mortality and morbidity in industrialized countries. There were no schools identified and selected for comparison, i.e., far away from any outdoor pollution sources, given this research setting. Furthermore, resources available for this pilot study prevented a rigorous cross-sectional or long-term (prospective or cross-sectional, repeated measures) assessment of outdoor air concentration measurements near roadways and/or immediately outside the study schools. This was not exclusively an environmental science exposure study. As stated, this pilot study assessed, with a well-documented (referenced) and founded cross-sectional design, reported respiratory health—prevalence of selected adverse outcomes and symptoms—of secondary school students in Ibadan, Nigeria, a sprawling urban center in the most populous country in Africa with limited prior data on children's environmental health.

CONCLUSIONS

This study suggested that the quality of air in and around secondary schools in Ibadan, Nigeria could be affected by identified prominent sources and human activities such as refuse burning and waste decomposition (point and dispersed area sources) and nearby vehicle emissions in higher traf-

fic areas (mobile sources). Schools located relatively closer to major motor ways are potentially subjected to adverse health effects due to chronic exposure—continuous and/or intermittent—to automobile and truck emissions including particles and toxic air contaminant gases. The location of schools close to industrial premises such as a quarry also presented a risk factor for airway-related morbidities due to the presence of known environmental asthma triggers in the source emissions. Our pilot study can inform an exposure study, consistent with emerging literature in industrialized countries, on particles of different size fractions, their constituents, and other chemical and physical agents near roads in community settings such as primary and secondary schools where people spend time.

In addition, given reported asthma prevalence in this study, the dust prevalent at study schools was likely constituted of aeroallergens (triggers) like pollen and mold of various types. Future studies in urban Nigeria, as resources allow, should thus also assess school indoor air and environmental quality with quantitative, cross-sectional repeated (prospective) measures across seasons for an entire school year.

In summary, this study demonstrated poor environmental management practices remain a major challenge to be addressed in schools in Ibadan, Nigeria. Also, there is a need to review current urban laws available in Nigeria and elsewhere to examine alternative solutions, especially those involving industrial and sanitation-related land uses—where sources are sited—in the vicinity of schools. Future research would include longitudinal studies with quantitative and qualitative data examining in greater detail potential associations between air pollutants of greatest concern, such as particulate matter and constituent allergens, mold, pollen, metals, and toxic air contaminants as well as traffic-related gaseous fuel combustion emissions, and various adverse respiratory health outcomes across seasons and times of day.

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Declaration of Interest

The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the article.

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