

## Air quality and children's health in rural Kenya

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### Abstract

This paper investigated the impact of air quality on the respiratory health of young children living in rural Kenya. We examined particulate matter concentration and the concentrations of nitrogen dioxide, sulphur dioxide, and ozone in various areas frequented by pre-school age children in rural Kenya. We were most interested in comparing air quality in the bedrooms and cook houses. Children spent nearly four hours in cook houses with their mothers where air quality was significantly worse than bedrooms. Airborne particulate matter was highest in cook houses, followed by bedrooms, yards and roads, while it was lowest in the forest. Nitrogen dioxide and ozone levels were also higher in cook houses than in bedrooms although there was no difference in sulphur dioxide between the two areas. We examined children's respiratory illnesses, as indicated by health assessments and interviews with mothers, with their estimated exposure to poor air quality. We found no evidence of a link between our measures of air quality and respiratory illness although the short-term nature of the study may have contributed to our lack of association.

*Keywords: children's health, indoor air pollution, outdoor air pollution, Kenya.*



## 1 Introduction

Worldwide, one in 12 children born in 2001 died before their fifth birthday from eminently preventable and treatable illnesses. Diseases of the respiratory system, while widespread and often preventable, are often overlooked when addressing children's health even though they are a leading cause of mortality in developing countries [1–3]. Indeed, UNICEF [4] referred to pneumonia as the “forgotten killer of children” as it is responsible for the deaths of more than 2 million children under five.

Respiratory ailments must be examined in the context of a child's environment and health history. Exposure to various types of air pollution, both inside the house and outdoors, is the most important factor contributing to the high incidence of respiratory problems among young children. In developing countries, biomass (wood, charcoal, agricultural residues, and dung) used for cooking is often burned under poorly ventilated conditions and is an important causal agent of respiratory disease [2, 3, 5]. Indoor smoke is blamed for nearly 800,000 child deaths annually [6]. Outdoor air pollution also contributes to respiratory problems in children [7–9]. For example, prolonged inhalation of particulate matter generated by traffic on unsealed roads can cause respiratory problems or contribute to those that already exist [7–10].

In this study, we will attempt to estimate exposure rates of young children to both indoor and outdoor sources of pollution by quantifying levels of airborne particulates, as well as time children may spend in each region. These data, combined with respiratory assessments and health history information, provide a holistic opportunity to examine possible environment-health interactions and should lead to a comprehensive understanding of the potential role of environmental pollutants in affecting children's health in rural Kenya.

## 2 Methods

### 2.1 Study area and population

This research was conducted in Kiirua, using preschool children involved in the feeding program at the Muchaka orphanage. The Muchaka orphanage is a unit managed by St Teresa's Hospital in Kiirua and Muchaka is one of the poorest communities in the Kiirua area. Children living in this area walk to a school within the orphage and are provided breakfast and lunch. They receive some school instructions and are then sent home after lunch. It is these children who we focused on in this study.

There were 52 children involved in the feeding program and all lived in the nearby village. Two of these came from the same house while another five lived at the children's home. The latter of these were used only in the calculation of common childhood illnesses as determined by direct assessment. Thus, the total samples were 52 children for age, gender and direct health assessments and 48 children in 47 homes for all other measures. For each child we carried out a health assessment, asked the child and caregivers about past health problems and future



concerns, and did an air quality assessment (see below) of the cookhouse, sleeping quarters, and yard outside the house. Because of the time spent there by children, we also performed air quality assessments at the school and in the forest (where caregivers often worked). One of our main objectives was to provide parents with health booklets, explain them, and promote the monitoring of children's health.

## 2.2 Child health assessments

All children in the Muchaka feeding program had a detailed health assessment completed during the spring/summer of 2014. Basic health parameters included height, weight, blood pressure, and heart rate. Further evaluations included heart and lung auscultation, oxygen saturation, and palpation. As well, the history of recurrent respiratory infections, childhood illnesses, communicable diseases including malaria and intestinal worms, eye irritations and burns were obtained from the mothers/caregivers of the children.

## 2.3 Health books

The mothers/caretakers of the children were provided with a "Pathway To Health" booklet and information sessions on how to enter information. The booklets contain the child's name, picture, identity number, sex, date of birth, and the names of the mother, father and any other caregiver. They also contain geographic coordinates of where the child resides, a general home assessment including information on exposure to wood smoke, safety concerns and environment and additional information such as allergies, de-worming, admissions to hospital, and hearing and vision tests. After a detailed immunization schedule for Kenyan children, pages are then provided for mothers/caregivers to document information on any illnesses and accidents suffered by the child as well as advice and information on common minor and major health concerns that a child could encounter. These include, among others, rashes, pink eye, worms, runny nose and minor lacerations, sprains and burns. Educational information on major ailments outlines the care of children with burns, tuberculosis, HIV/AIDS, malaria, vomiting and diarrhea, and respiratory distress. The book concludes with the symptoms and incubation periods of common infectious diseases and a list of contact information for health care and support.

## 2.4 Environmental and air quality assessments

Homes of all children were visited to complete a home environmental assessment that included a complete description of the indoor and outdoor areas. Agawa passive air samplers were placed inside (in cookhouses) and outside (between road and house) for most children's houses. Each sampler measured three air pollutants expected to be important – NO<sub>2</sub> (nitrogen dioxide), SO<sub>2</sub> (sulfur dioxide) and O<sub>3</sub> (ozone). Samples were analyzed using a Dionex ICS-1000 ion chromatography system. In addition, real-time measurements of two sizes of airborne particles (0.5–2.5 microns and > 2.5 microns) in areas frequented by children both inside

and outside the house, were obtained using laser particle counters (Dylos Corporation, DC 1700).

## 2.5 Data analysis

Data that were normally distributed, or could be converted to normal distributions, were analyzed using parametric statistics; those that were not normally distributed were analyzed nonparametrically.

## 3 Results

### 3.1 Health problems of children (as determined by health assessments and discussion)

Nearly all of those caregivers that responded indicated that the child had their complete set of vaccinations (41/45); the other four indicated that the card was missing and they could not be sure. Fig. 1 provides information on what illness affected the child upon examination or what illness that the child had had. There is some overlap between these. For example diarrhea and/or vomiting often accompanies intestinal worms or malaria.

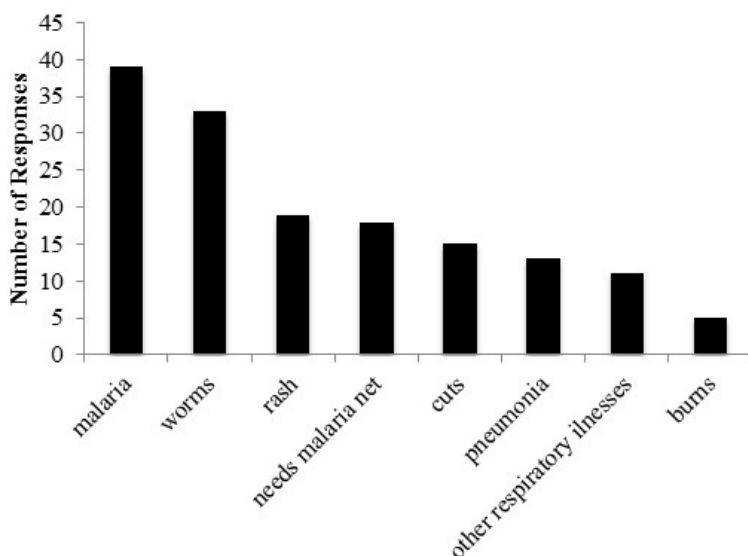


Figure 1: Current and previous health issues face by children around Muchaka.

These figures should be taken as a minimum as some caregivers may have forgotten or chosen not to mention certain illnesses. The main illnesses faced by children were malaria, respiratory problems (including colds, coughs, runny nose) and worms (including both intestinal worms and ringworm).

### 3.2 Concerns of mothers

Caregivers mentioned both large-scale concerns that could have an indirect effect on the health of the child, and more specific illnesses, fig. 2. In some cases concerns were only mentioned once; for these we used the following groupings:

- Living conditions/homelife – includes domestic violence
- Respiratory problems – includes asthma, coughing, road dust
- Other – includes dyspnea, chest pains, abdominal cramping, worms

Clearly the large-scale concerns were greater for mothers than individual health concerns. Receiving the proper education and adequate food/nutrition for their child was suggested to be most important in alleviating some of their child's health concerns. Of the more specific illnesses, "respiratory problems", including "pneumonia" ranked number one. This is possibly because it is thought that little can be done about malaria (rampant in this area) or worms (curable by taking some of the medicine available at the local clinic).

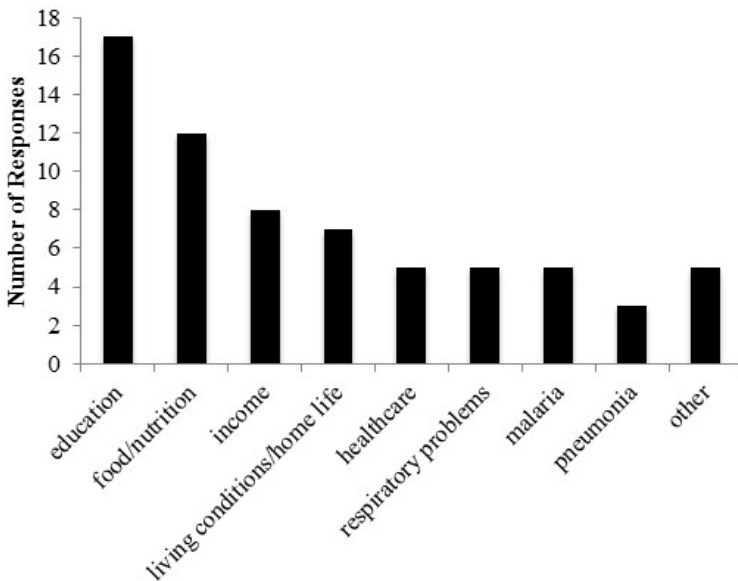


Figure 2: Biggest fears concerning child's wellness reported by mothers.

### 3.3 Air quality to which children were exposed

Of the 48 children looked after in the 47 homes (i.e. not including the five looked after at the children's home), 41 resided in houses in which caregivers cooked in a separate cookhouse, three (in two houses) in which their cooking facilities were outside, and four were exposed to cooking facilities in the same house in which they lived. All but two of the households used wood collected in the local forest as fuel; the other two relied on gas. Fig. 3 illustrates the time in the cookhouse each day for caregivers and the child for those households in which cooking

facilities were located in a separate building. The child generally was with the caregiver in the cookhouse although spent slightly less time exposed to wood smoke (average of 3.9 hours) compared with the caregiver (5.1 hours).

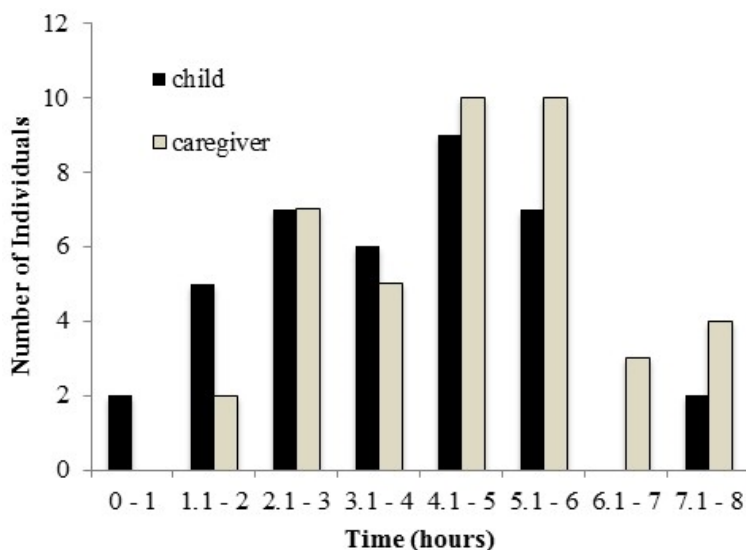


Figure 3: Time spent by children and caregivers in cookhouse.

The number of particles to which children were exposed differed for large and small particles, fig. 4. Children were exposed to a larger number of large particles near the road while the number of smaller particles was higher in cookhouses. The house and classrooms had similar numbers of particulate matter while air quality in the forest was best.

Measurements were taken of nitrogen dioxide, sulphur dioxide, and ozone in the cookhouse and in the house close to where the child slept. To calculate average values in each area, we used only those monitors that were in place for at least two days. Not surprisingly, amounts were higher for all three air pollutants in cookhouses, although significant differences were apparent for only nitrogen dioxide and ozone, table 1.

### 3.4 Air quality and children's health

Children's respiratory health was assessed on the basis of interviews with caregivers and was estimated as the number of problems encountered by the child over the previous year (0–3). We examined potential correlations between respiratory health and airborne particulate matter in the seven areas (see fig. 4), corrected for the time spent in each area (from caregiver's or our own estimates). We found no link between air quality and children's respiratory problems. We also found no link between respiratory illnesses and the amounts of nitrogen dioxide, sulphur dioxide, or ozone measured in the house and cookhouse.

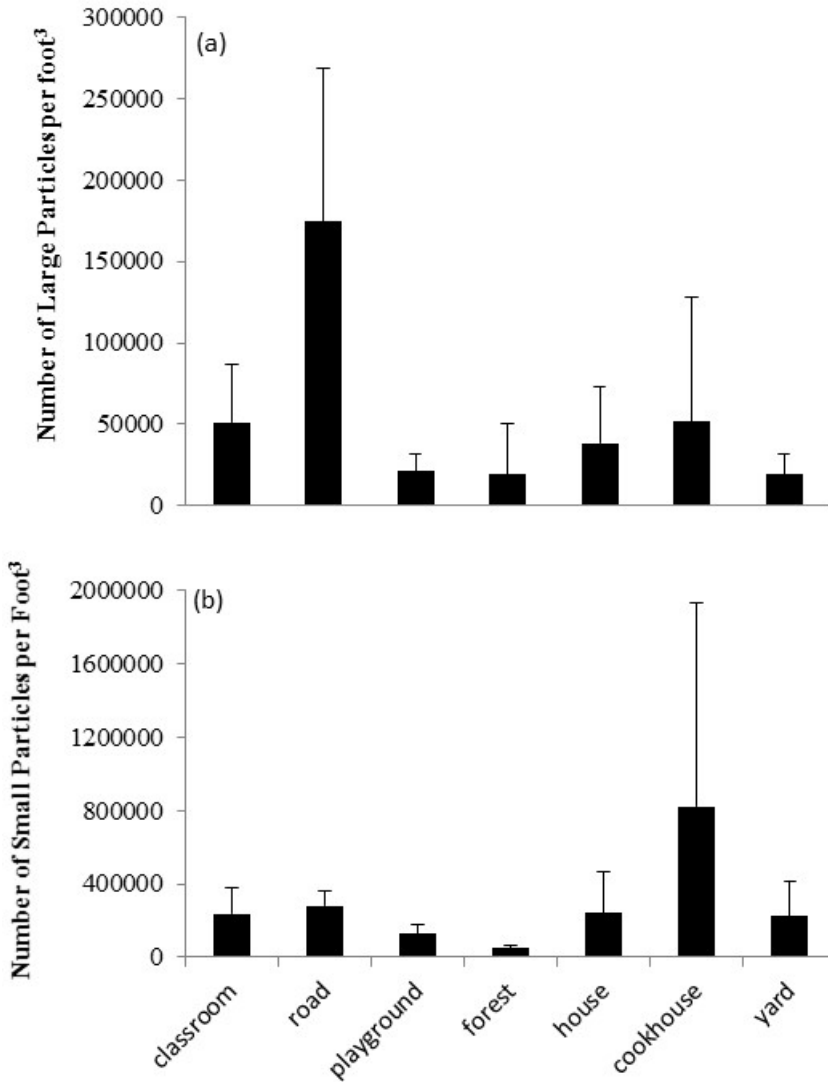


Figure 4: The number of (a) large ( $> 2.5 \mu\text{m}$ ) and (b) small ( $0.5\text{--}2.5 \mu\text{m}$ ) to which children were exposed in areas they frequented.

Table 1: Comparison of nitrogen dioxide, sulphur dioxide and ozone (mean  $\pm$  std) in cookhouses and houses. (\*\*  $< 0.01$ ).

Air pollutant	Cookhouse (ppb)	House (ppb)	p
nitrogen dioxide	$97.7 \pm 79.5$	$10.8 \pm 5.5$	**
sulphur dioxide	$1.02 \pm 1.25$	$0.89 \pm 1.02$	
ozone	$1.89 \pm 1.82$	$0.91 \pm 0.46$	**

## 4 Discussion

We quantified the levels of particulate matter at various locations frequented by children as well as levels of nitrogen dioxide, sulphur dioxide and ozone in cookhouses and houses where children are expected to spend at least half their time. Not surprisingly, we found air quality in cookhouses low although measures of particulate matter in different areas depended on the size fraction being examined. We also attempted to quantify respiratory illnesses in children although found no correlation between levels of air pollutants and respiratory function.

Exposure to poor air quality was highest while children were in cookhouses. Because mothers often look after the cooking and their children at the same time, young offspring are often exposed to woodsmoke. This can be particularly problematic for young children for whom respiratory infections are more likely to permanently damage lungs and make them more susceptible to future respiratory tract infections [11, 12]. Numerous studies have assessed pollutants emitted from the inefficient burning of biomass with some documenting their effects on human health. Indeed, Naeher *et al.* [13] suggested that about 200 studies of indoor air quality (IAQ) had been conducted in developing countries. There is strong evidence suggesting that exposure to biomass burning, either from cooking or general heating, decreases respiratory function in children [14–17].

We are aware of no studies that have attempted to measure children's exposure to both indoor and outdoor sources of air pollution. While exposure to pollutants from indoor sources, particularly the use of solid fuels, is likely to be many orders of times higher than that to outdoor sources [18], the exposure to outdoor air pollution in certain areas may still be substantial. Ironically, as stoves become more efficient by venting smoke through chimneys, "neighbourhood pollution" increases as the smoke may sit between the houses [13]. One potential contributor to respiratory problems in young children in rural areas is dust that may be inhaled while walking or playing near unsealed roads or agricultural fields. Nickling and Gillies [19] found mean levels of dust in Mali reached levels well above those recommended by WHO [20] and suggested that such levels likely posed a serious health threat to local people. In addition, dust from unpaved roads or agricultural fields may contain a wide range of toxins originating from vehicle exhaust and/or pesticides. In this study, the concentration of large particles (i.e. those greater than 2.5  $\mu\text{m}$ ) was highest near unpaved roads.

We acknowledge several weaknesses of this investigation, generally stemming from its short-term nature. Establishing a causal relationship between a specific environmental variable (in this case air pollution) and health problem (respiratory impairment) requires long-term and detailed etiological studies that go beyond the scope of this project. Rather, our intention was to evaluate potential sources of environmental contaminants that may explain high rates of respiratory problems experienced by young children in the Kiirua area. Our gender differences can play an important role for respiratory health and young boys may be more likely to suffer from respiratory infections for a variety of reasons (see discussion in [16]).

The relative effect of indoor and outdoor sources of pollution on children's health will depend on both the main sources/types of air pollutants in the region



as well as the time spent in both environments. The link between lower respiratory tract infections and woodsmoke in young children is well established but partitioning exposure rates to various pollutants will provide a more comprehensive dataset which may be used in providing recommendations to caregivers that will assist in safeguarding their children's health. Future studies may be designed to provide more detailed information concerning causal links between environmental and health parameters.

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