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Prevalence of Asthma-like Symptoms Among Schoolchildren
in a rural district of Andhra Pradesh, India

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Abstract

Prevalence of Asthma-like Symptoms Among Schoolchildren
in a rural district of Andhra Pradesh, India
By Nina Dutton

Background: As the demand for electricity in India has risen, the combustion of coal to generate it has followed suit. The addition of new coal-fired power plants, such as those proposed in Nellore District, would result in an increase in emissions that would present health risks to exposed populations, particularly to children. As a preliminary step in determining the respiratory health impacts the proposed power plants would have, a survey of asthma-like symptoms was conducted among children in the area near these proposed facilities to estimate baseline prevalence of the reported symptoms for later comparison with that of children in the same area if the plants become operational.

Purpose: The main aim was to estimate baseline prevalence of reported asthma-like symptoms among schoolchildren in the area expected to receive the most air pollution from the proposed power plants. Further aims involved investigation of the prevalences of reported symptoms and several personal, family, and environmental characteristics among schoolchildren in a location north of the area immediately around the plants, to determine whether the northern location could serve as a control site for possible future studies of the power plants' respiratory health impacts on children nearby. The final aim was to examine associations between reported symptoms and potential risk factors.

Methods: In a cross-sectional survey, a questionnaire concerning asthma-like symptoms, demographics, and potential exposures to air pollution was administered to public school students of the ages 10 to 14 in two areas of Nellore District – one set of schools less than 20 km from the clusters of proposed power plants and two schools at least 40 km north.

Results: In the south, 23% of subjects reported ever wheezing, compared to 13% in the north ($p=0.001$). Recent wheeze was reported by 18% of subjects in the south and 11% in the north ($p=0.011$). After adjustment for the effect of clustering by school, odds of ever wheeze differed significantly by location, but odds of recent wheeze did not. Univariate analyses showed associations between reported symptoms and male gender, family history of asthma, keeping chickens, and house roof type; negative associations were found for age and parental farming. Having a father working as a farmer appeared to be the only characteristic independently, negatively associated with reported recent wheeze.

Conclusions: Based on assessments of differences by location in the prevalences of reported symptoms and certain characteristics of subjects, the northern location could be tentatively recommended as a negative control site for comparison with the southern location in future studies of children's respiratory health impacts of the power plants, should they become operational. Associations found between reported symptoms and various characteristics of subjects may offer a basis for hypothesis generation regarding asthma risk factors in rural south India. Future studies of the proposed power plants' health impacts could provide evidence in support of cleaner energy sources.

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Introduction

The demand for electricity is growing around the world, including in India. As the third-largest consumer and producer of coal among all countries (U.S. EIA, 2011), India will most likely aim to meet much of this demand – at least in a short run –through continued reliance on coal-fired power plants. New coal-burning power facilities have been planned or recently built in areas across India, such as in Nellore District, Andhra Pradesh, where 24 greenfield coal-based thermal power plants have been proposed or are already under construction (Cerana Foundation, 2010).

Exposure to the pollutants that are emitted from coal combustion is associated with a wide variety of health outcomes, including adverse effects on the respiratory system (Dominici et al., 2006; Gauderman et al., 2004; Gent et al., 2003; Halonen et al., 2008; Peel et al., 2005; Trasande & Thurston, 2005). Consistent evidence demonstrates that exposure to pollutants such as nitrogen dioxide, ozone, and particulate matter can exacerbate asthma in those who already have it (Gent, et al., 2003; Peel, et al., 2005; Trasande & Thurston, 2005), while other studies suggest that exposure to these pollutants may contribute to asthma development (Brauer et al., 2002; Gilmour, Jaakkola, London, Nel, & Rogers, 2006; McConnell et al., 2002). Compared to adults, children are especially vulnerable to the effects of air pollution (Bateson & Schwartz, 2008; Trasande & Thurston, 2005). As such, the potential risks to children's health posed by the proposed power facilities in Nellore District are of particular interest.

Within this proposed development context, a survey of asthma-like symptoms among children in the area near the proposed clusters of coal-fired power plants in Nellore District was deemed necessary to estimate baseline prevalence of these reported symptoms for later comparison with that of children in the same area after the plants become operational. In the future, if the power facilities do begin to produce emissions, such a comparison could be critical in determining the degree to which pollution from coal-fired power plants impacts respiratory health in the region. This information could be used to support measures that protect human health, such as the use of cleaner energy sources and technology. Additionally, whether or not the proposed power facilities are ever utilized, this survey begins to address the lack of asthma prevalence studies among children in Nellore District by providing reported symptom prevalence estimates that could be compared with similar figures from other sites across India.

This project had four main aims. The first of these was to estimate the prevalence of reported asthma-like symptoms among public school students of the ages 10 to 14 (a) within the area expected to receive the greatest increase in ambient concentrations of particulate matter less than or equal to 10 nm in aerodynamic diameter (PM_{10}) due to projected emissions from the proposed coal-fired power plants in Nellore District and (b) in an area – expected to receive less pollution – at least 40 km away from the power plants. The second aim was to determine whether statistically significant differences in the prevalence of reported asthma-like symptoms currently exist between the two locations. The third aim was to examine relationships between possible risk factors for asthma and the reported symptoms. Finally, the fourth aim was to determine whether statistically significant differences in the prevalence of certain demographic characteristics and environmental characteristics (which may be indicative of potential exposure to certain air pollution sources) currently exist between the two locations.

For the current analysis, it was hypothesized that prior to the operation of the proposed power facilities, the prevalence of reported symptoms would not differ significantly between the location closer to the proposed plants and the location 40 km away. If the prevalences of reported symptoms, demographic characteristics, and environmental characteristics do not differ significantly between locations, the location farther from the power plants could potentially be considered a control or comparison site for any future studies of asthma-like symptom prevalence among schoolchildren closer to the power plants.

Background

In the midst of economic development, demand for electricity is on the rise in India. The country's shortage of generation capacity results in frequent blackouts, and 40 percent of residences in India did not have electricity as of 2007. The U.S. Energy Information Agency projects that India's electricity consumption will grow, on average, at a rate of 3.3 percent per year through 2035; to meet this demand, the country would have to increase its current generation capacity by 234 gigawatts. The majority of this energy will most likely come from coal. India generated 70 percent of its electricity from coal in 2008 and is both the third-largest consumer and producer of coal in the world (U.S. EIA, 2011).

Adverse health effects have been associated with each step in the process of coal use for electricity generation, from mining, transportation, and preparation to combustion and waste disposal. Coal mining has been associated with black lung disease and other chronic diseases in miners (Rappaport, 2006) and can impact surrounding communities in a variety of ways, including the effects of blasting and the collapse of old mines, the dust released in the process of surface mining (Ghose, 2000), and the soil erosion and water supply contamination that result from the removal of vegetation and topsoil that surface mining entails (U.S. EPA Region 3, 2005). Water and soil contamination are also known to stem from the release of metals from the exposed rock of abandoned mines, the process of washing coal to prepare it for combustion, the dispersion of coal dust during transportation of coal (Lockwood et al., 2009), and the leaching of heavy metals and other toxic components of the fly ash left after coal combustion (Praharaj, et al., 2002). Consideration of contamination from bottom and fly ash is especially important in India, where domestic coal has a high ash content of approximately 55% and coal-fired power plants are often located in densely populated areas; due to atmospheric fallout and leaching from ash ponds, trace elements – such as manganese, chromium, copper, lead, and arsenic – from ash have been found in soil around coal-fired power plants in India and elsewhere. Ash from coal-fired power plants in India and elsewhere has also been seen to decrease the pH of soil, acidification of which can both decrease agricultural yields and increase the solubility of toxic chemicals in the soil (Mandal & Sengupta, 2006).

Compared to the other stages of coal use, combustion is associated with arguably the most detrimental health effects (Lockwood, et al., 2009). Coal combustion releases gases and aerosols into the atmosphere; these byproducts include toxic chemicals, gases that undergo chemical reactions and form secondary pollutants, and greenhouse gases that contribute to anthropogenic climate change by trapping energy in the atmosphere. Coal combustion in power plants produces major quantities of nitrogen oxides (NO_X), sulfur oxides (SO_X), particulate matter (PM), and carbon dioxide (CO_2), and it results in the production of tropospheric ozone. NO_X and SO_X form as gases when sulfur and nitrogen naturally found in coal are released as the coal is burned, and NO_X can also form from atmospheric nitrogen and oxygen exposed to the high temperatures of combustion (Clean Air Task Force, 2001). PM, a mixture of solid and liquid particles – such as elemental carbon, metals, organic chemicals, and soil or dust particles – and droplets of acids, is directly emitted from coal combustion and can also form from atmospheric NO_X and SO_X (Environmental Health & Engineering, 2011). Though the exact composition of a given power plant’s emissions depend on the type of coal used, the PM emitted may include a variety of hazardous air pollutants (HAPs, which are a class of pollutants regulated by emission limits in the United States); according to smokestack tests released by the U.S. Environmental Protection Agency (EPA) in 1998, U.S. coal plants emitted 67 different HAPs, including many known or probable human carcinogens, neurotoxins, and reproductive toxins. In particular, the U.S. EPA has identified four coal combustion-related HAPs - mercury, dioxins, arsenic and nickel – as potential hazards to human health (Lockwood et al., 2009). With the highest carbon content of all fossil fuels, coal releases carbon dioxide – a major greenhouse gas – and carbon monoxide, along with elemental carbon (soot). Ozone forms from NO_X and other pollutants in the presence of sunlight (Clean Air Task Force, 2001).

Although health effects are associated with exposure to a wide range of air pollutants from coal combustion, the majority of the public health burden from coal-fired power plants in the United States can be attributed to $PM_{2.5}$ (Environmental Health & Engineering, 2011) according to assessments by the U.S. EPA (U.S. EPA, 1997, 1999a, 1999b, 2004, 2005). After PM is inhaled, coarser particles are deposited higher in the respiratory tract, while finer particles can continue into the lungs and then diffuse into the bloodstream; inhaled PM can irritate and cause inflammation in the airways, exacerbating chronic lung diseases – such as asthma – and reducing airway functionality, while various explanations have been proposed for the mechanisms by which $PM_{2.5}$ affects the cardiovascular system, including that inflammation of the lung tissue leads to the release of chemicals that influence heart function (U.S. EPA, 2010). Consistent associations have been found between long-term $PM_{2.5}$ exposure and increased mortality from cardiopulmonary diseases and lung cancer (Cohen et al., 2005), as well as between shorter-term exposure and increased morbidity from other respiratory diseases (Pope, 2000).

Most new coal-fired power plants around the world incorporate at least some modern pollution controls, such as electrostatic precipitators (ESPs), but use of flue-gas desulfurization (FGD) is far less common in less-developed countries (Balbus et al., 2009), such as India. According to available industry-provided environmental impact assessments for the proposed plants in Nellore District, all proposed plants include ESPs, but only one out of six proposals includes initial use of FGD, although some allow for future use (EIAs – see reference list). If included in a plant where no other mechanisms are in place to remove sulfur from the emissions, FGD can reduce a power plant's sulfur dioxide emissions by 90 percent, reducing associated health risks substantially (Balbus et al., 2009).

Exposure to coal-related pollutants can impact all major organ systems and is associated with numerous diseases of the respiratory, cardiovascular, and nervous systems. Chronic respiratory diseases and cardiovascular diseases accounted for 11 and 24 percent, respectively, of all deaths in India according to 2008 estimates (WHO, 2011). Among children, NO_2 and $PM_{2.5}$ have been found to negatively impact lung development and reduce forced expiratory volume (FEV) (Gauderman, et al., 2004); reduced lung function often precedes eventual development of other pulmonary diseases. In adults, coal-related pollutants have been found to contribute to the development and, possibly, exacerbation of chronic obstructive pulmonary disease, a condition in which the airways become narrower permanently (Dominici, et al., 2006; Halonen, et al., 2008; Peel, et al., 2005). Ozone and PM exposure are also associated with development of and mortality from lung cancer (Beeson, Abbey, & Knutsen, 1998; Dockery et al., 1993; Pope et al., 2002). Both short- and long-term exposures to coal-related pollutants are linked to cardiovascular health effects; associations have been found between ambient $PM_{2.5}$ concentration and hospital admissions for cardiac rhythm disturbances, acute myocardial infarction, ischemic heart diseases, disturbances of heart rhythm, and congestive heart failure (Dominici, et al., 2006; Peters, Dockery, Muller, & Mittleman, 2001; Peters et al., 2000), while chronic exposure to air pollutants associated with coal increases cardiovascular mortality (Dockery, et al., 1993). Just as exposure to coal-related pollutants appear to affect the overall cardiovascular system through stimulation of the inflammatory response and oxidative stress, these mechanisms can also act on blood vessels in the brain; studies have shown associations between PM and hospital admission rates for cerebrovascular disease and ischemic stroke (Dominici, et al., 2006; Wellenius, Schwartz, & Mittleman, 2005). Some coal pollutants impact the nervous system directly, as neurotoxins. For example, mercury exposure has been found to cause developmental delays in fetuses, infants, and children, with such effects as mental retardation, clinical neurodevelopmental impairment, and permanent loss of intelligence (Lockwood et al., 2009); approximately one-third of all mercury emissions attributable to human activity have come from coal-fired power plants (U.S. EPA Office of Air Quality Planning & Standards and Office of Research and Development, 1997). In addition, because coal combustion releases greenhouse gases, coal-fired power plants are also linked to the health outcomes associated with impacts of climate change. Projected exposures related to climate change will likely affect millions of people through increases in malnutrition; increases in deaths, disease and injury due to a rise in the likelihood of extreme weather events; an increase in the burdens of diarrheal disease and cardio-respiratory diseases (the latter from higher concentrations of ground-level ozone); and changes in the distribution of some vectors of infectious disease (Parry et al., 2007).

Among the respiratory diseases associated with coal pollution exposure is asthma, a common, chronic respiratory disorder characterized by “variable and recurring symptoms, airflow obstruction, bronchial hyperresponsiveness, and an underlying inflammation (NHLBI, 2007). Symptoms – which include coughing, wheezing, the sensation of tightness in the chest, and shortness of breath – typically occur as episodic reactions of varying intensity to triggers such as inhalation of air pollutants and allergens, weather conditions, and exercise (NHLBI, 2011). Consistent evidence demonstrates that exposure to NO_2, ozone, and PM can exacerbate asthma in those who already have it (Gent, et al., 2003; Peel, et al., 2005; Trasande & Thurston, 2005) by triggering attacks. Other studies provide evidence that exposure to NO_2, ozone, and $PM_{2.5}$ contributes to the development of asthma (Brauer, et al., 2002; Gilmour, et al., 2006; McConnell, et al., 2002), although these suspected causal links are not yet confirmed (Lockwood et al., 2009).

Children are more susceptible to asthma – and more vulnerable to the effects of air pollution in general – because their respiratory systems are more sensitive than those of adults, development is still ongoing, their exposure to air pollution is greater because they breathe at faster rates than adults do, and because they tend to spend more time outside than adults do (Bateson & Schwartz, 2008; Trasande & Thurston, 2005). Since children’s exposure to emissions from coal combustion and other air pollution can affect their health currently and later in life (Kim, 2004), air pollution exposure is a critical public health issue.

Among children, effects on asthma severity have been observed in association with increases in ambient concentrations pollutants commonly emitted as a result of coal combustion, such as particulate matter. In a study that examined temporal relationships between pediatric emergency room visits for asthma and air quality indices in Atlanta, Georgia, the relative risk of an emergency room visit with regard to PM10 was estimated to be 1.04 per 15 $\mu g/m^3$ ($p<0.05$) (Tolbert et al., 2000). A bi-directional case-crossover study in Turkey also showed significant associations between the odds of children's hospital admissions for asthma and ambient concentrations of PM_{10}, $PM_{10\text{-}2.5}$, and $PM_{2.5}$ on the day of admission, with an 18% rise in asthma admissions correlated with a 10 $\mu g/m^3$ increase in $PM_{10\text{-}2.5}$ and an adjusted odds ratio for exposure to an incremental increase of 10 $\mu g/m^3$ ambient $PM_{2.5}$ (Lokman et al., 2008).

The main methods of estimating asthma prevalence rest on either clinical diagnoses or self-reported information. According to *Expert Panel Report 2: Guidelines for the Diagnosis and Management of Asthma*, a clinician should determine the following in order to establish a diagnosis of asthma: presence of "episodic symptoms of airflow obstruction or airway hyperresponsiveness," at least partial reversibility of airflow obstruction, and exclusion of alternative diagnoses. Methods recommended for establishment of a diagnosis are use of a detailed medical history; a physical exam of the upper respiratory tract, chest, and skin; spirometry; and any other studies needed to exclude alternate diagnoses. Recommended as a method for diagnosis in adults and children 5 years and older, spirometry is used to show obstruction of the airway and to test reversibility, which is determined either by an increase in FEV1 of ≥12% from baseline or by an increase ≥10% of predicted FEV1 after inhalation of a short-acting bronchodilator (NHLBI, 2007). Outside of hospital-based studies, clinical examinations are less commonly used to identify asthma cases. Instead, many asthma and asthma-like symptom prevalence estimates are made based on self-reported – or family-reported – responses to questionnaires (Ravindran, 2000). Widely used and adapted for community-level surveys around the world are the questionnaires and procedures developed for the International Study of Asthma and Allergies in Childhood (ISAAC) (Asher et al., 2006). With official studies in more than 100 countries, ISAAC is a global epidemiological research program begun in 1991 to investigate asthma, rhinitis and eczema in children (ISAAC, 2012).

Asthma prevalence is increasing in many countries around the world (Asher, et al., 2006), and in certain developing regions, prevalence has appeared to rise in conjunction with increases in urbanization and "westernization" (Braman, 2006). The global burden of asthma is fairly substantial; based on data from the World Health Organization's 2004 Global Burden of Disease study, asthma was estimated to be responsible for the third greatest disease burden among people ages 10 to 14, costing children in that age group a total of 2,300,000 disability-adjusted life-years in 2004 (Gore et al., 2011).

Estimates of the prevalence of asthma and asthma-like symptoms among children in India vary widely. In a meta-analysis of asthma prevalence studies conducted across India between 1998 and 2004, Pal et al. (2009) calculated a mean prevalence of 7.24% (SD 5.42) and median prevalence of 4.75% (IQR = 2.65 – 12.35%). Although the data from these studies were widely dispersed, a few patterns emerged. Despite notable variation in prevalence by region, asthma was more common among children ages 6 to 7 than among those of age 13 to 14, prevalence was higher in urban children than rural children, and boys were more likely to have asthma than were girls (Pal, Dahal, & Pal, 2009). As part of Phase III of the multicentric ISAAC project, cross-sectional surveys of children ages 6 to 7 and 13 to 14 conducted between 2001 and 2007 at eight study centers across India yielded an average prevalence of 6.4% for reported wheeze within the past year. An average of seven years earlier, in ISAAC Phase I, the recent wheeze prevalence was 6.7% on average across India's study centers (Asher, et al., 2006).

Asthma prevalence estimates in India vary by region of the country, but rural-urban divides have also been observed repeatedly among studies conducted in southern India. In a 2002 Karnataka school-based survey, asthma prevalence was estimated at approximately 17% among urban children and 5.7% among rural children ages 6 to 15 (Paramesh, 2002). Other studies have also shown a lower prevalence of asthma-like symptoms at rural sites than in urban areas. For example, in Andhra Pradesh, wheeze was found in 12.5% of urban and 5.5% of rural children between the ages of 7 to 15 (Sudhir & Prasad, 2003). In Tamil Nadu, Chakravarthy et al. (2002) found a history of "breathing difficulty" (including wheeze and asthma) in 22% of urban and 9% of rural children ages 0 to 12, with higher prevalences among the urban subjects for wheeze in the past 12 months and nighttime dry cough as well (Chakravarthy, Singh, Swaminathan, & Venkatesan, 2002). Prevalence of reported wheeze were similar in a 2010 school-based study conducted with a small sample of 573 children ages 10 to 18 in rural Karnataka, where 8.4% of subjects reported ever wheezing, 5.2% reported wheeze in the past 12 months, and 16.7% of those who reported recent wheeze had one to three attacks in the past year on average, with a higher prevalence of wheezing among subjects ages 10 to 12 compared to the older subjects in the sample (Narayana, Prasanna, Narahari, & Guruprasad, 2010). Also similar are the estimates from a study in rural Manipal, where wheeze within the past 12 months was reported for 8.7% of subjects ages 10 to 12 and 5.6% of subjects ages 13 to 15 (Jain, Vinod Bhat, & Acharya, 2010). However, results from a 2000 study in Kerala showed higher prevalences among rural than among urban children ages 5 to 15. In this study, though, "ever wheezing" was defined as reporting a history of past wheezing but no wheeze at the time of the survey, whereas "current wheeze" was defined as reporting having current wheeze and taking medication to treat it. Under these definitions, 20.5% of rural and 11.2% of urban children had reportedly ever wheezed, while 9.4% of rural and 7.9% of urban children reportedly had current wheeze (Ravindran, 2000).

Several studies of rural children provide indications as to the kinds of risk factors that could be associated with asthma-like symptoms among schoolchildren in Nellore District. For example, in a study of children ages 6 to 15 in rural Manipal, a family history of asthma was strongly associated with reported wheeze within the past year, while an inverse linear trend was found with increasing age (Jain, et al., 2010). Though not conducted in southern India, a number of school-based studies show associations between asthma-like symptoms and certain demographic, familial and environmental factors. Among students in rural Harayana, exposure to environmental tobacco smoke (ETS), keeping dogs or cats in the home, and having no windows in living rooms were all significant risk factors for asthma (Pokharel, Kabra, Kapoor, & Pandey, 2001). In a study of seventh and eighth-grade students in an area of rural Maharastra, where 7.3% of subjects reported wheezing in the past 12 months and about one-third of these reported at least four attacks in that time, wheezing in the last 12 months and asthma were associated with numerous personal, family, and environmental factors, including family history of asthma, smoking, frequent chest colds, parental occupation, and smoking by each parent, as well as several variables indicative of lower socioeconomic status – subjects working for wages, exposure to goats or chickens, use of non-municipal or variable drinking water sources, and Scheduled Tribe (ST) caste. Only a few of these factors still had a significant association in multivariable analysis, with students' work for wages as the only environment-related factor identified as an independent predictor of both reported wheeze in the past year and reportedly ever having asthma; however, the association with students' work for wages may be a sign of the effects of other factors that are also linked with a lower socioeconomic status (Pakhale, Wooldrage, Manfreda, & Anthonisen, 2008). Another prevalence study of children in rural northern India showed significant, independent associations between wheezing in the last 12 months and frequent passage of trucks through the street near home, smoking by each parent, total number of cigarettes smoked by both parents of more than seven per day, acetaminophen intake more than once per month, and exposure to cats (Sharma & Banga, 2007). Although associations between asthma and exposure to traffic pollution have not been studied in rural areas of India to the same extent as in cities, results from a Bangalore study suggest an interaction between the effects of exposure to traffic and socioeconomic status: Among children ages 6 to 15, the estimated prevalence of asthma was greater at schools in heavy traffic regions than at schools in low traffic regions of the city, and within heavy traffic regions, prevalence was higher still among children from less affluent families than among those whose families were wealthier (Paramesh, 2002). Other studies conducted around the world also point to proximity to traffic as a risk factor for wheezing, asthma severity, and asthma prevalence (Brauer, et al., 2002; Shima, Nitta, & Adachi, 2003; Zmirou et al., 2004). Diesel exhaust pollution in particular has been found to exacerbate asthma by increasing airway obstruction and hyperreactivity (Riedl & Diaz-Sanchez, 2005). Although effects of smoke exposure on asthma-like and other respiratory symptoms may not have been found consistently among Indian children, but these effects have been observed in adults in India, with significant associations observed in a four-city study in relation to smoking, environmental tobacco smoke, and combustion of solid fuels (such as for cooking) (Jindal, et al., 2010).

Methods

Study location

The proposed power plants of interest are located in Nellore District, near the coast in Andhra Pradesh, a southeastern state in India (Appendix 1). In 2001, Nellore District had a total population of approximately 2,668,000, of which 77.5% lived in rural areas and 22.5% lived in cities (District Administration, 2011).

As of June 2011, 24 greenfield coal-based thermal power plants, sited in two clusters within a 20 km strip of land and with a combined capacity of 27,115 MW, were proposed or already under construction in Nellore District; if completed, the power generation capacity would likely be the largest at a single location in India (Cerana Foundation, 2010). Between the two clusters of proposed coal-fired power plants in Nellore District is the village of Krishnapatnam, which is located at 14.3°N, 80.1°E and is currently the site of a recently developed deepwater port (Krishnapatnam Port Company, 2011). The coastal location of these clusters was intended as a means of utilizing the port at Krishnapatnam for international trade while using the ocean as a water source. Available environmental impact assessments (EIAs) for the proposed plants assume use of at least some imported coal (30% to 100%) (EIAs – see reference list) and use of desalinized seawater for treating coal or cooling (EIAs – see reference list).

Site selection

The selection of study sites (Appendix 1) was based on an isopleth map created by the Cerana Foundation – a Hyderabad-based environmental non-governmental organization – that models the projected incremental increases in ambient PM_{10}

concentrations across areas of Nellore District that would result from operation of all 24 proposed coal-fired power plants (Appendix 2). To produce this map, incremental ground-level concentrations of PM_{10}, SO_X and NO_X were estimated village by village, based on figures provided by the power companies in environmental impact assessment (EIA) reports that were available for eight out of 24 proposed facilities (Appendix 3). Using these village-level estimates, isopleths were hand-drawn on maps of Nellore District to show the spatial distribution of projected incremental increases in pollutant concentrations by village across the district (Appendix 2).On the PM_{10} isopleth map, within the area demarcated by the isopleth closest to the clusters of proposed facilities, ambient PM_{10} concentrations are predicted to increase by at least 10 $\mu g/m^3$ if the 24 proposed power plants begin operation. The main study sites were selected from the area within the projected 10 $\mu g/m^3$ PM_{10} incremental isopleth because this area is the part of the district projected to receive the most pollution from the power plants.

Data were collected at 10 rural high schools in Nellore District (Appendix 1). Eight of these schools – students from which were considered the potential "exposed" group – were chosen because of their location within the projected 10 $\mu g/m^3$ PM_{10} incremental isopleth drawn by the Cerana Foundation. Using lists of the public schools in each of the five mandals (sections of the district) that intersect with the border of the projected 10 $\mu g/m^3$ PM_{10} incremental isopleth, it was determined whether or not there was a high school in each village that falls within or along the perimeter of the isopleth. The selected eight schools include all of the rural high schools within the projected 10 $\mu g/m^3$ PM_{10} incremental isopleth, as well as two along the outer edge of this isopleth. The schools within and on the perimeter of the projected 10 μg/m3 PM_{10} incremental isopleth are referred to here as the schools in the "southern study location."

Two schools, approximately 40 to 50 km north of Krishnapatnam ("northern study location"), were selected as control sites since these schools are located outside of or on the edge of the 5 μg/m3 projected PM_{10} incremental isopleth. As with the schools in the southern study location, these schools are also located near the coast and could thus be expected to serve families living in a coastal economy similar to that around the other sites.

Study population

The study population was defined as all students between the ages of 10 to 14 at the rural high schools we visited. In official ISAAC studies (Asher, et al., 2006), 13- and 14-year-old students provided self-recorded responses to the questionnaires. For the current survey, in order to cover a broader cross-section of the area's pediatric population, the age range was expanded to include 10- through 14-year-old students. Subjects older or younger than this age range were excluded.

Study design

A cross-sectional survey conducted using a questionnaire designed to elicit information concerning the prevalence of asthma-like symptoms, demographics, and potential exposures to air pollution was administered to public school students of the ages 10 to 14 in two areas of Nellore District – one set of schools less than 20 km from the clusters of proposed power plants and one set of schools at least 40 km away.

This survey was based primarily on ISAAC methods (Asher, et al., 2006), particularly in terms of questionnaire design (Appendix 4). Questions 1 through 8 concern respiratory symptoms that may be indicative of asthma and were drawn directly from the ISAAC Phase 3 manual (Ellwood et al., 2000). In Question 1 (Q1), subjects were asked if they had ever experienced wheezing in the past; subjects with affirmative repsonses to Q1 were categorized as having “ever wheeze.” Responses to Q2, concerning whether or not the subject had wheezed in the past 12 months, determined whether a subject had “recent wheeze.” Q3 through Q5 enter into more detail about recent wheeze by addressing the number of wheezing attacks, sleep disturbance due to wheezing, and limited speech due to wheezing in the past 12 months. Subjects who responded affirmatively to Q6 were considered as having “ever asthma,” while Q7 and Q8 addressed symptoms within the past year: wheeze associated with physical activity and dry cough at night without a cold or chest infection.

These questions on symptoms were accompanied by demographic questions, as well as by supplemental questions about potential asthma risk factors and types of possible air pollution exposures (Appendix 4). Some of these questions – involving family history of asthma, smoking, smoking among members of the household, animals kept at home within the past year, and passage of heavy vehicles on the road nearest to the home, and cooking fuels – were based on the methods and findings of other studies of asthma prevalence in similar populations (Behl, Kashyap, & Sarkar, 2010; Pakhale, et al., 2008; Pokharel, et al., 2001; Sharma & Banga, 2007). Other questions drew from the input from pulmonologists, pediatricians, and staff knowledgeable about local practices at Narayana Medical College and Hospital (NMCH) in Nellore District (R. V. Bharath, K.

Gowrinath, S. Gupte, B. Raja Sreedlar, personal communication, June 2011). These questions concerned house roof type, distance between home and nearest road, and pollutant-blocking obstacles between the home and the road, as well as a demographic question to indicate a subject's family's status above or below the state poverty line. Each family in Andhra Pradesh receives a ration card from the government, which indicates the level of public assistance (such as in the form of subsidized supplies) to which the family is entitled, based on their economic status; a white ration card is given to households below the poverty line (Rao, 2011).

All questions (Appendix 4) were translated from English to Telugu by the quality control manager at NMCH and back-translated by nurses and other NMCH staff members, with input from a medical director at the U.S. Centers for Disease Control and Prevention who is familiar with Telugu terms (Ramana Dhara, personal communication, June 2011). The translation used for "wood" was back-translated as "fuel," referring to plant-based biomass such as sticks, wood and charcoal. In order to set a standard for survey administration, the same instructions as are included on the official ISAAC questionnaires for 13- and 14-year-olds (Ellwood et al., 2000) were provided to the translator, who was asked to instruct the subjects to consider and respond to the questions in a certain order. All subjects would be asked to record their age, date of birth, gender, grade level, and teaching medium or class section. Next, all subjects would be asked for a response to Q1; if a subject responds affirmatively, then Q2 should be answered. If a subject responds affirmatively to Q2, then Q3 through Q5 should also be answered. All subjects would be asked for responses to all other questions. The instructions are included on the English version of the questionnaire but do not appear in the Telugu version.

Sampling

After permission was secured from appropriate district officials and from individual schools, the surveys were administered at the ten public schools in both the southern and northern sampling locations within Nellore District.

With regard to sampling, each school was initially treated as a separate population, in that an approximate sample size was calculated for each school based on the number of students at each school. Based on the size of each school's population of students within the 10-to-14 age range, OpenEpi (Dean et al., 2011) was used to determine a target sample size, assuming a desired power of 80 percent and ability to detect a 15% prevalence within each school. Because several studies conducted in rural south India show prevalence estimates of approximately 5% for asthma or current wheeze among children (Chakravarthy et al., 2002; Narayana et al., 2010; Sudhir & Prasad, 2003), the original intent for this study was to calculate sample sizes based on detection of an expected 5% prevalence. However, it was found that larger sample sizes would be necessary to detect a prevalence of 15%, compared to the sample sizes calculated based on 5% prevalence. Thus, the larger sample sizes – based on an expected 15% prevalence – were used in this study to accommodate for the possiblities of finding a prevalence greater than 5%.

This sample size turned out to be roughly 100 individuals for each of eight schools. At each school, the principal and staff were asked to allow for participation in the survey from approximately 100 students (again, with the target sample size dependent on the size of the school's student population) within the target age range. Principals and staff were told about the purpose of the study in advance, but it is unlikely that they specifically selected students with pre-existing asthma conditions because – typically – entire classes (e.g., all of one teacher's sixth-graders) were sent to participate at a time, rather than subjects being chosen individually. Data were gathered as a test of sensitivity of the methods at two additional schools in the southern location; only small numbers of subjects were asked to participate, and sample size was not calculated. There, at Schools D and G, staff selected students on an individual basis, but this selection generally appeared to be at the staff members' convenience, chosen from whichever students were nearby at the time. At every school, the staff were asked for a group of students with a roughly even distribution by age, gender, grade level, teaching language, and difficulty of course of study (e.g., lower-level classes as well as advanced classes, if a school made this distinction).

Data collection

After the staff at each school gathered the chosen students into groups in a classroom – at some schools the students were presented in a series of smaller groups of 10 to 30, whereas at others these groups consisted of more than 50 children at a time. The translator, who was an assistant teacher at and recent graduate of the Narayana Nursing College, introduced herself and the project to each group of students. Then, the students were shown the international version of the asthma symptom video used in many ISAAC Phase 3 studies (ISAAC, 2011). The sample of this video used was of low visual quality and shown in a small window on a laptop computer screen, but the main purpose was for the students to hear the audio, which included the sounds of wheezing and dry coughing. During the video, the translator identified the sounds of these symptoms for the students in Telugu. The video was not shown to two groups at School K, due to technical problems; for these groups, the translator described wheezing and dry coughs at night verbally in Telugu. At some schools, one group of students remained in the same room to receive the questionnaire before the next group entered or was presented; at others, one group after another entered the same room to hear the introduction and the video before assembling outdoors in one large group, sometimes of approximately 100 students, to receive the questionnaire together. For adminstration of the questionnaire, individual sheets of paper printed with the questions and answer choices in Telugu were distributed to the students, the translator read out one question and its answer choices at a time, and the students recorded their own responses individually. In some groups, either the translator or teachers present at the time asked the entire group of students whether anyone had responded affirmatively to Q1 (if anyone had ever wheezed); if the students' consensus was that none of them had ever wheezed, the translator did not ask Q2 through Q5 out loud. For all groups, though, the written Telugu questionnaire distrubuted to each participant included all symptom questions.

Data management

Questionnaire responses were first reviewed to determine which subjects gave valid responses to the age questions. Some invalid responses were recoded based on other information provided by subjects, whereas other subjects were removed entirely. If a valid birthdate with a month, date, and plausible year (e.g., "1996" was a plausible year, but "199" was non-specific and "2005" was not plausible) was given but it did not much the reported age, age was recalculated based on the given birthdate. The reported age was used for those subjects who did not provide a valid birthdate. Those with ages outside of the 10-to-14 range were excluded from analysis. If neither age nor birthdate were reported on a questionnaire, it was excluded. Of the final total sample, 524 subjects (60.7%) had ages that have been recalculated based on the birthdates they provided.

When possible, responses to questions about symptoms were recoded in three steps using information from other parts of a students' questionnaire:

1) If a subject had originally reported no recent wheeze but reported one or more wheezing attacks, sleep interrupted by wheezing, or speech limited by wheezing in the past 12 months, their response to Q2, about recent wheeze, was recoded to the affirmative. This recoding of Q2 responses to the affirmative based on responses to Q3 through Q5 was done for 64 subjects (7.42% of the total sample) – 50 (8.12%) in the south and 14 (5.67%) in the north. Other studies have made this same adjustment to recode responses about recent wheeze based on positive answers about wheezing attacks, sleep disturbances due to wheeze, and limitation of speech due to wheezing in the past 12 months (Pakhale, et al., 2008).

2) If a subject reported recent wheeze but did not report ever wheezing, the subject's response to Q1, related to ever wheezing, was recoded as affirmative. This recoding was done for 21 subjects (2.43% of the total sample) - 12 (1.95%) in the south and 9 (3.64%) in the north.

3) Because of slight differences in protocol among the schools, Q3 through Q5 were omitted at some schools. The subjects who reported never wheezing were split between those who responded to the questions about recent wheeze and those with missing responses to the questions on recent wheeze (Q2 through Q5). Thus, some

subjects who reported never wheeze also reported no recent wheeze, whereas the majority of those who reported never wheeze were missing responses to the recent wheeze questions. To address this discrepancy, if a subject reported never wheezing and had a missing response for recent wheeze, the subject's response to Q2 was recoded as negative. This was done for 550 subjects (63.7% of the total sample), with 368 (59.7%) in the south and 182 (73.7%) in the north.

No questionnaires were excluded on the basis of missing a response to the question about gender, although similar studies have excluded subjects based on this criterion. Questionnaires showing no response to the gender question were included in analysis because, according to the translator and the Cerana Foundation, schoolchildren in the 10- to 14-year-old age group in the surveyed areas could generally be expected to spend similar amounts of time outside and to engage in activities similar enough for gender not to affect exposure to outdoor versus indoor air pollutants (B. Raja Sreedlar, personal communication, June 2011).

All questionnaires from one school were excluded. At that site, all of the subjects (more than 100 of them) were in one group when the translator asked the questions out loud. None of the subjects indicated that they had an affirmative response to Q1 (“ever wheeze”), so the translator did not ask Q2 through Q5 (on “recent wheeze”) out loud to any subjects at this school. Thus, none of the subjects at this school responded affirmatively to any symptom question.

Several variables were dichotomized or created based on the subjects’ responses. One dichotomous variable was made for whether or not solid cooking fuels were used in a subject’s home; a subject’s household was considered one that used solid fuels if wood, dung, or both were used, as opposed to non-users of solid fuel, who did not report use of either wood or dung. Another dichotomous variable was made for whether or not heavy vehicles pass frequently on the road nearest the subject's home, since the two provided options (Appendix 4) on the higher end of the qualitative scale – "frequently through the whole day" and "almost the whole day" – seemed after the fact to be too similar to provide any useful information; those options were coded to indicate frequent passage of heavy vehicles, while responses of "never" and "seldom" were coded to indicate infrequent passage. Some subjects' responses to the questions on parental occupations were sorted into broader categories. If a subject's parent worked as a "cooli," "kooli," or a "wage worker," that parent was categorized as one who worked for wages, whether or not any additional occupation was listed for that parent. Similarly, if a subject's parent worked in "agriculture" or as a "farmer," that parent was categorized as one who farmed, whether or not any other occupation was listed. Three dummy variables were created that pertained to working for wages: one for whether a subject's father worked for wages, one for whether a subject's mother worked for wages, and one for whether a subject had at least one parent who worked for wages. A corresponding three dummy variables were created for farming among subjects' parents. Another occupational dummy variable was created for whether or not a subject reported that their mother was a "housewife." Dummy variables were also created for each type of animal kept at home, as well as for whether or not a subject's father smoked.

Data analysis

For this project, the four main aims were to estimate the prevalence of reported asthma-like symptoms among schoolchildren in the southern and northern locations, determine whether reported symptom prevalence currently differs between locations, examine any relationships between possible risk factors for asthma and the reported symptoms, and determine whether the locations differ demographically or with respect to possible environmental risk factors for asthma. Only descriptive statistics were required to address the first aim – the reported symptom prevalence estimates – but additional tests were needed to fulfill the rest.

Since no one has yet been exposed to any emissions from the proposed power plants, it is hypothesized that the prevalence of reported symptoms currently does not differ between locations. Additionally, since the northern location was intentionally selected to be similar to the southern location in terms of the demographics and way of life of its population, it is hypothesized that the two locations do not currently differ significantly in the demographic and environmental characteristics reported by subjects. If this hypothesis is true, then the northern location could be considered comparable enough to the southern location to serve as a potential control site for future studies of the power plants' respiratory health impacts, assuming the plants begin operation.

Chi-square tests of association were used to determine whether the prevalence of symptoms – as well as of personal, family, and environmental characteristics – differed between the southern and northern locations. A two-sample t-test at an $\alpha = 0.05$ level was used to determine whether the mean age differed significantly between the southern and the northern groups. Specifically, a Satterthwaite t-test was applied because the samples differed in variability, with a much larger southern sample. Univariate logistic regression analysis was used to examine relationships between the personal, family, and environmental characteristics of the subjects and their symptoms. The symptoms that were the focus of these and subsequent analyses were ever wheeze and recent wheeze.

The final tests of whether ever wheeze and recent wheeze prevalence differ by location were conducted with multivariate logistic regression models. Generalized estimating equations (GEE) were used in these models to adjust for clustering of data by school. Potential confounders were identified based on two a priori conditions: association with reported symptoms and association with “exposure” to the southern location. The only variables that met these conditions with regard to ever wheeze were age and house roof type; for recent wheeze, the variables for age, house roof type, one parent who farms, and a father who farms were the potential confounders. With regard to these farming variables, it should be noted that both were *negatively* associated with the southern location and reported recent wheeze. It was assumed that the differences in distribution of the variable for one farming parent were driven by the distribution of the variable for a father who farms; thus, only the variable for a father who farms was considered in multivariate analysis. These potential confounders – two for ever wheeze and three for recent wheeze – were included in the multivariate models for these reported symptoms.

Sub-analyses using univariate logistic regression – including tests before and after adjusting for clustering by school – were performed on several different groups but did not result in any additional removal of predictor variables from the final analysis. Several sub-analyses excluded 49 subjects from a group at one school that was not shown the

ISAAC video, the 20 subjects from School G (all of whom reported no symptoms), or the total of these 69 subjects from both groups (Table 6). Because all of these sub-analyses yielded results similar to those obtained from analyzing the total sample of 863 subjects, the “no-video” group nor School G were both included in the main analysis. The same was true for a sub-analysis including subjects from the southern schools that excluded all subjects from Schools D and G, where only one small group of subjects (48 and 20, respectively) was surveyed at each school as a “sensitivity test.” The proportions of students that reported ever wheeze and recent wheeze did not differ significantly between Schools D and G and the rest of the southern schools (i.e., Schools B, C, K, P and V) (Table 6). All analyses were performed using SAS 9.3 (Cary, NC).

Results

After the exclusions based on age and the exclusion of one school in the southern location, the total sample size was 863 subjects, with 616 subjects from the southern sites near the proposed power plants and 247 subjects from the control sites in the north.

Subjects in the southern and northern locations were similar in several demographic respects and family characteristics (Table 1). The mean age of participants in both groups was between 12 and 13, with a slight, albeit significant ($p<0.01$) difference in ages between the two study locations. More female than male subjects responded to the questionnaire in both locations (52% in the south and 58% in the north), and the vast majority of subjects in each group – more than 96% – reported that their families have white ration cards. In both locations, the two most commonly reported occupations for mothers were housewife (48%) and wage worker (39%), while the two most frequently listed occupations for fathers were farmer (53%) and wage worker (21%). Farming was a more common parental occupation in the north than in the south, with 64% of subjects in the north versus 51% in the south having at least one parent who worked as a farmer ($p=0.0006$); in the north, 63% of subjects' fathers worked as farmers, compared with 48% in the south ($p=0.0002$) . Meanwhile, the proportion of the subjects' fathers who worked for wages was significantly larger in the south than in the north (24% versus 13%, $p=0.0008$). Fifteen percent of subjects reported a family history of asthma, with no significant difference in this proportion between the south and north.

Reception of the survey among students was fairly positive, with reactions typically ranging from quiet ambivalence to vocal enthusiasm. The novelty of the situation was most likely the main factor to engage students' curiosity. Attitudes varied from classroom to classroom and on an individual basis, but since teachers and staff were present to supervise the activity, the participation rate was 100% among students selected for involvement at all schools, regardless of whether or not each student's questionnaire was useable in the final analysis.

The estimated prevalences for symptoms included in this survey are presented in Table 2. In the south, 23% of subjects reported ever wheezing, compared to 13% in the north ($p=0.0013$). However, reports of ever having asthma were more common in the north (31%) than in the south (21%) ($p=0.0024$). The proportion of subjects who reported wheezing within the past 12 months was 18% in the south, as opposed to 11% in the north ($p=0.0113$). Also more prevalent in the south was reported wheezing during or after physical activity (16% in the south versus 7% in the north, $p=0.0005$). Dry cough at night was the most common symptom and was reported by 40% of all subjects that responded, with no significant difference by location in the prevalence of reported dry cough.

As shown in Table 10, the majority of subjects did not respond to Q3 through Q5, resulting in high numbers of missing responses for the questions about recent wheezing attacks, recent sleep interrupted by wheezing, and recent speech limited by wheezing. Reflecting a divide in the methodology, this was the case at each school except for at Schools D and G, the "sensitivity test" schools, where every question was read out loud whether or not the subjects indicated that they had had recent wheezing. As seen in Table 2, out of the 229 subjects who responded, 28% reported 1 to 3 attacks, 7% reported 4 to 12 attacks, and 8% reported more than 12 attacks in the past year. Out of the 227 subjects who responded to the question regarding recent sleeping interrupted by wheezing, 37% reported their sleep being interrupted less than one night per week and 8% reported sleep interruptions one of more nights per week. Twenty-percent of the 254 subjects who responded reported that their speech had been limited by wheezing to one or two words between breaths in the past year. Between the south and the north, there was no significant difference in the proportions of subjects who reported any number of recent attacks, any number of nights per week recently when sleep was interrupted by wheezing, or whether their speech had been limited by wheezing recently.

Since the questions about recent attacks, recent sleep interruptions, and recent speech limited by wheezing were directed toward those who had experienced wheezing in the past year, and because of the recoding of Q2 responses based on Q3 through Q5, it would be most useful to consider the responses to Q3 through Q5 among only those who whose response to Q2 were affirmative. Out of the 131 subjects from the total sample (N=863) who reported wheezing within the past 12 months, 49% reported 1 to 3 attacks, 12% reported 4 to 12 attacks, and 14% reported more than 12 attacks of wheezing in the past year. Among the 131 subjects who reported recent wheeze, 64% reported recent sleep interrupted by wheezing less than one night per week, while 14% reported sleep interruption more than one night per week. Finally, 50% of the 131 subjects who reported recent wheeze also reported that, within the last 12 months, their wheezing had been severe enough to limit their speech to only one or two words at a time between breaths.

Environmental characteristics are displayed by location in Table 3. Subjects in the north were more likely than those in the south to have kept animals at home within the past 12 months (77% in the north versus 67% in the south, $p=0.0062$). In the north, 48% of subjects had kept chickens, compared with 25% in the south ($p<0.0001$); buffalo were also more commonly kept in the north (16%) than in the south (7%) ($p=0.0001$). Of the total sample, 27% of subjects had kept dogs, 13% had kept cats, 3% had kept cows or cattle, 2% had kept goats, and 1% had kept oxen in the past year, with no significant difference between locations in the proportion of subjects who had kept these types of animals. The majority of subjects – 65% of the total sample – reported that at least one person living in their households is a smoker, and 41% of subjects reported that their fathers smoke; neither of these proportions differed by location. None of the subjects reported that their mother smokes.

The types of houses in which the subjects live differed slightly ($p=0.0492$) by location. In the south, 56% of subjects lived in homes with reinforced concrete (RCC) roofs, 22% in homes with traditional "huts" with roofing made of vegetation, 19% in homes with roofs of sheeting, and 5% in homes with tiled roofs. In the north, 60% lived in housing with RCC roofs, 25% had traditional "huts," 13% had homes with roofs of sheeting, and 4% had tiled roof homes. Most subjects – 54% of the total sample – reported that wood or dung was used as cooking fuel at home, and this proportion did not differ significantly between the south and the north. A majority of subjects in the south (66%) reported that heavy vehicles pass frequently throughout the day or almost the entire day on the road nearest to their homes, compared to 41% in the north ($p<0.0001$). However, the distribution of the subjects' reported distances between their homes and the nearest roads did not differ significantly by location. Approximately half of the total sample reported living less than 10 m from the nearest road, while 30% lived directly adjacent to a road, 11% lived between 11 to 50 m from the nearest road, and the rest of the subjects reported living more than 50 m from the nearest road. Most subjects (77% of the total sample) reported that there were buildings or plants between their homes and the nearest roads; this proportion did not differ significantly by location. Most rural roads in the study area are generally either one-lane paved roads – without markings, sidewalks, or curbs – or dirt roads. Because they are often bordered on each side by bare ground, even paved roads may be fairly dusty during dry weather. (Appendix 5).

Table 4 shows relationships between characteristics of the subjects and the symptoms of ever wheeze and recent wheeze, based on univariate logistic regression analyses not adjusted for clustering by school. Results from these models showed that subjects in the south had greater odds of reporting ever wheeze than those in the north (1.98 OR, 95% CI: 1.30, 3.03), as well as greater odds of reporting wheezing in the past year (1.81 OR, 95% CI: 1.14, 2.88). Girls were less likely than boys to report recent wheeze (0.60 OR, 95% CI: 0.41, 0.89), but no significant difference was found by gender regarding reports of ever wheeze. The odds of a subject reporting ever wheeze or recent wheeze decreased significantly as age increased. Subjects who reported a family history of asthma were significantly more likely than subjects who reported no family history of asthma to also report ever wheeze (2.23 OR, 95% CI: 1.14, 4.36), but this difference was not observed for recent wheeze. Those whose households had kept chickens in the past year had greater odds of reporting ever wheeze (1.44 OR, 95% CI: 1.01, 2.05) and recent wheeze (1.49 OR, 95% CI: 1.01, 2.20) than those who did not. These relationships were not seen for subjects whose households kept other types of animals.

No significant relationship was observed between having a smoker in the household and reporting ever wheeze or recent wheeze (Table 4). Subjected living in a home with a roof of sheeting had higher odds than those in housing with RCC roofs of reporting ever wheeze (1.58 OR, 95% CI: 1.02, 2.46) and recent wheeze (1.83 OR, 95%

CI: 1.13, 2.95). Use of solid cooking fuels at home, the frequent passage of heavy vehicles on the road nearest the home, and having buildings or plants between the home and the nearest road were not significantly associated with reports of ever wheeze or recent wheeze. There was also no significant protective effect of living at a greater distance from the nearest road. However, with regard to reported recent wheeze, having at least one parent who worked as a farmer (0.61 OR, 95% CI: 0.41, 0.90) or having a father who worked as a farmer (0.56 OR, 95% CI: 0.38, 0.84) appeared to have a protective effect. None of the other examined variables for parental occupation was significantly associated with reports of either symptom.

For a final assessment of the effect of location on the prevalences of reported ever wheeze and recent wheeze, Table 5 shows the results of multivariate logistic regression models adjusted for clustering by school. As mentioned, the only other predictor variables aside from location that were included in these models were those that met a priori conditions for confounding: age and house roof type for ever wheeze, and age, house roof type and whether the subject's father works as a farmer for recent wheeze. After adjusting for the effect of clustering by school and controlling for these confounders, the odds of ever wheeze was still significantly higher in the south than in the north (2.62 OR, 95% CI: 1.07, 6.44). Meanwhile, the effect of location on recent wheeze became non-significant; however, the lower 95% confidence limit of 0.97 is close to 1, suggesting the possibility of borderline statistical significance. According to these models, neither age nor house roof type was independently associated with either reported symptom. However, having a father who farms seemed to have a significant, independent protective effect for recent wheeze (0.63 OR, 95% CI: 0.45, 0.88).

Discussion

As the demand for electricity rises in India, so too has the combustion of coal to generate this energy. The addition of new coal-fired power plants, such as those proposed in Nellore District, would result in an increase in emissions that would present risks to the health of exposed populations – particularly to children, who are especially vulnerable to the effects of air pollution. In order to determine the respiratory health impacts that the proposed facilities would have, it is necessary to establish baseline information concerning the population that may possibly be affected, before the power plants begin to operate.

In this study, the main aim was to estimate baseline prevalence of reported asthma-like symptoms among schoolchildren in the area expected to receive the most air pollution from the proposed power plants. Encompassing two other aims was the investigation of whether a location to the north of the area immediately around the plants could serve as a control site for possible future studies of the power plants' impacts on respiratory health of children nearby. It was hypothesized that the prevalence of the reported symptoms and several socioeconomic, environmental, and other factors would not differ between schoolchildren surveyed at the northern and southern locations; if this were the case, then the two locations could be considered comparable enough for the northern area to serve as a control in relation to the "exposed" southern area. The final aim was to examine associations between reported symptoms and potential risk factors in order to begin exploration of factors that may influence children's respiratory health in the studied locations.

Overall, the prevalence estimates from this study are relatively high in comparison to those from other studies conducted among schoolchildren in rural India. The prevalence of reported wheezing within the last 12 months was 15.8% of the total Nellore District sample, with 17.8% in the south and 10.7% in the north. Of the total sample, 20.3% reported ever wheezing, whereas this proportion was 23.2% in the south and 13.2% in the north (Table 2). These estimates exceed those of Narayana et al. (2010), who found that 8.4% of subjects ages 10 to 18 reported ever wheezing, 5.2% reported wheeze in the past 12 months, and 16.7% of those who reported recent wheeze had one to three attacks in the past year on average (Narayana, et al., 2010). (By contrast, in the Nellore District study, 49% of the 131 subjects with reported recent wheeze reported one to three attacks in the past year) (Table 2). The Nellore District estimates also exceed those of Chakravarthy et al. (2002), who found a history of wheeze or asthma in 9.0% among children ages 0 to 12 in rural Tamil Nadu (Chakravarthy, et al., 2002). Since asthma-like symptoms tend to decline among children with age (Narayana et al., 2000; Ravindran, 2000) it is possible that the symptoms would be even less common among older children in the areas Chakravarthy et al. studied, thus further emphasizing how high the estimates from the southern location in Nellore District are in comparison. The estimates from Nellore District more closely match those from the study Ravindran (2000) conducted in Kerala, where 20.5% of rural children ages 5 to 15 had reportedly ever wheezed but were not experiencing wheeze at the time of the survey, while 9.4% of rural children reportedly had current wheeze and were taking medication to treat it. By these definitions, the Nellore District estimates would have been lower, since those with recent wheeze were categorized as having ever wheezed, and it is probable that not all those with wheeze in the past 12 months were experiencing wheeze around the time of the survey and also treating their symptoms with medication. The relatively high estimates from the Nellore District study may be the result of multiple factors in combination, including the terminology used in the questionnaires, the students' understanding of these terms and the symptom video, influence of peers and teachers on individuals' responses, and false positives produced by recoding.

The southern and northern locations appeared similar in many ways with regard to the subjects' personal, family, and environmental characteristics (Tables 1 and 3). A vast majority of subjects in each location reported that their households have white ration cards, indicating that they are below the state poverty line. However, a small but significant urban-rural division was seen between the south and the north, as demonstrated across several variables. For example, animals such as chickens and buffalo were more commonly kept by families in the north, while subjects in the south were more likely to report the frequent passage of heavy vehicles on the roads nearest to their homes. Agriculture was more predominant as an occupation in the north than in the south, whereas the opposite was true for fathers who worked for wages.

Associations were observed between several of the subjects' characteristics and reported symptoms (Table 4). Boys were more likely to report recent wheeze than girls were, the odds of reporting ever wheeze as well as recent wheeze decreased with increasing age, those who reported a family history of asthma were more likely to report ever wheeze, those whose families kept chickens in the past year were more likely to report both symptoms, and those who lived in housing with sheeting roofs were more likely than those who lived in buildings with RCC roofs to report both symptoms. The associations for gender (Pal, et al., 2009), age (Narayana et al., 2000; Ravindran, 2000), family history of asthma, and the keeping of chickens (Pakhale, et al., 2008) matched findings from other studies. The other observed associations may serve as the basis for hypotheses in any future studies that may be undertaken to investigate risk factors and causes of asthma-like symptoms in this area. Of the characteristics examined in this study, only parental farming (as tested with the variable for having a father who farmed) appeared to be independently, negatively associated with reported recent wheeze (Table 5). This apparent protective effect may be the result of residual confounding in this study, or it may be explained by reasons that require future study. Additionally, with regard to recent wheeze, the upper 95% confidence interval for the age odds ratio is 1.00, which suggests that a slight difference in the age distribution among the sample could easily have nudged the confidence interval away from the null just enough that an independent negative association between age and recent wheeze might have been observed among a slightly different sample from the same population.

Interestingly, exposure to secondhand smoke was not associated with reported symptoms in this study, despite evidence that exposure to tobacco smoke is a risk factor for asthma and asthma-like symptoms (Gilliland, Li, & Peters, 2001; Pokharel, et al., 2001). One possible explanation for the absence of an apparent association here is that family members might smoke outside of the home. Conversely, if the children's symptoms are indeed associated with smoking in the household, it could be that the subjects who are regularly exposed to secondhand smoke are also so used to their symptoms that they might underreport them. The lack of a significant association between reported symptoms and use of solid cooking fuel in the home contradicts some studies (Jindal et al., 2010), as does the lack of an association between symptoms and frequent passage of heavy vehicles on the road nearest the home (Paramesh, 2002; Sharma & Banga, 2007). Even so, these associations have been found only inconsistently in similar studies of asthma-like symptom rural children in India.

After adjustment for the effect of clustering by school, the odds of ever wheeze differed significantly between the southern and northern locations, but the odds of recent wheeze did not (Table 5). This finding may suggest that some factor that led to an increase in wheezing among children in the recent past was present in the south, but not the north, and is no longer having an impact. The same could be true of some protective factor that was present only in the north. For example, the factor that may have led to an increased prevalence of wheeze in the past could have been a localized meteorological phenomenon, some biological event (such as the introduction of a certain kind of plant), the introduction and then removal of industrial pollution, or another major source of triggers. If the difference in ever wheeze but not recent wheeze prevalence is indeed due to some past event, examination of accurate clinical histories of children in this age group from each location could provide some insight into the nature of the event. Alternatively, the incidence of wheeze may have once been higher in the south but has decreased in recent years, while remaining consistent in the north. It is also possible that residual or unspecified confounding is influencing the results, or that the self-reported responses are not even reliable enough to support inferences about differences by location between ever wheeze versus recent wheeze.

It is important to note how much adjustment for clustering by school affected the results for the models for symptom prevalence by location, in that a change in the model to include this adjustment caused the odds ratio for ever wheeze by location to shift from statistically significant to non-significant. On one hand, the conclusion that prevalence of ever wheeze does not differ significantly between locations is based only on the results of the model adjusted for clustering, a statistical manipulation without which the data would suggest – as in Table 4 – that prevalence does in fact differ between the south and the north. On the other hand, the great deal of variability among schools in the methods and execution of the survey could not be ignored in the analysis. Simply controlling for the variable of which school each subject attended would not be practical because a subject's location was predicated on the identity of the subject's school. The use of GEE to adjust for clustering by school was an approach of salvaging data that otherwise varied so much by school as to obfuscate any difference in prevalence between south and north. Still, finding a non-significant odds ratio for ever wheeze does not actually prove an absence of effect by location. More important, the finding of a statistically significant difference by location in terms of recent wheeze, but not ever wheeze does not clearly support a conclusion that asthma-like symptom prevalence truly differs by location. Perhaps the northern location selected for this study is indeed comparable to the southern location, but it is difficult to come to a definitive conclusion on this question by accounting for between-school variations after the fact.

If accurate, the observation of a difference in the prevalence of ever wheeze by location concurrent with no significant difference in the prevalence of recent wheeze suggests that incidence of asthma-like symptoms in general may be similar between the two locations, even if prevalence is not. Under such circumstances, measurements of symptom incidence in both locations over time would provide better indication of the potential health impacts of the proposed coal-fired power plants.

Based on the findings reported here, the northern location is tentatively recommended as a control site in possible future studies, but application of more consistent methodology would be advisable for the minimization of the school effect, as well as for investigation of true differences between students at different schools within the same study location. While the results of this study were inconclusive regarding differences in reported symptom prevalence between the south and north locations, the prevalence estimates do provide an estimate of background prevalence that offers context for the projected respiratory health impacts of the proposed power plants. Although the available environmental impact assessments (EIAs) provide estimates for increases in ambient concentrations of some pollutants, these EIAs do not fully represent the total effects that would result from operation of all 24 proposed power facilities. First, estimates of pollutant concentration increases are not available for all facilities, but more important is the fact that – as far as the Cerana Foundation could determine – no other estimates of increases in ambient pollutant concentrations or health risk analyses have been conducted for the combined effects of all 24 coal-fired power facilities proposed in Nellore District. In April 2011, the Cerana Foundation conducted a preliminary health risk analysis of projected PM_{10} emissions from the proposed power plants, based on the isopleth map showing projected incremental increases in ambient PM_{10} concentration and estimates of the population within each isopleth (summed from national census data at the village level). The Cerana Foundation estimates that, if the 24 proposed facilities were to operate, the projected increase in ambient PM_{10} concentration would result in

25,000 excess cases (falling in a range from 24,000 to 27,000 based on sensitivity analyses) of children's asthma per year and 1,200 excess deaths per year due to all causes attributable to air pollution (in a range from 350 to 2,000) (Dhara. 2011). These sobering estimates form at least the initial basis of an argument against the operation of the proposed power plants.

The projected health impacts of the proposed power plants must be considered in the socioeconomic context of Nellore District. The primary economic activities in the areas around the proposed plant sites are agriculture, aquaculture and fishing; farmers in the area are known in particular for growing rice and lemons (Cerana Foundation, 2010). Ash from coal-fired power plants in India and elsewhere has been observed to contaminate soil with trace elements and to decrease the pH of soil, acidification of which can both decrease agricultural yields and increase the solubility of toxic chemicals in the soil (Mandal & Sengupta, 2006). Aside from its direct health impacts, the effects of coal combustion-related pollution on agriculture and aquaculture could in turn be detrimental to the livelihoods of many in the area. In 2005, 37.2% of India's population lived below the national poverty line, but according to the Oxford Poverty and Human Development Initiative, 53.7% of India's population and 44.5% of Andhra Pradesh's population were poor with regard to education, health and standard of living (OPHI, 2011). Since poverty is generally more prevalent in rural than in urban India (OPHI, 2011), the rural Nellore District likely has a higher proportion of people living in poverty than Andhra Pradesh on average. According to pulmonologists and pediatricians at NMCH, it is already common among those with chronic respiratory diseases in Nellore District to avoid regular treatment of their conditions because they would rather take intermittent medication than regularly rely on an inhaler, they cannot afford to buy medication regularly, or both (R. V. Bharath, K. Gowrinath, S. Gupte, personal communication, June 2011). As such, the projected risks for increases in asthma and other health impacts from the proposed power plants may pose a significant public health challenge in light of the socioeconomic conditions and attitudes toward asthma treatment in Nellore District.

Strengths

The main strength of this study was the relatively large total sample. Given limited resources, time, and information about the school-going population of the study area, 1052 questionnaires were administered and filled by young students for this study. Although all 105 questionnaires from one school were excluded from analysis and many others were excluded for other reasons (mainly because of ages that were indecipherable or outside of the target range of 10 to 14), the final sample size of 863 was still large enough to have provided adequate power for prevalence estimation at eight of the surveyed schools.

Another strength of this project was that the southern sample could also be considered fairly representative of the 10- to 14-year-old rural public school student population in the area within the PM_{10} 10 $\mu g/m^3$ isopleth projected by the Cerana Foundation (Appendix 2). As mentioned, based on the maps used, all five rural public high schools within this area near the proposed power plants were approached, and students were surveyed at all of these schools. Although all questionnaires from one of these schools were later excluded from the final analysis because all subjects reported no symptoms, there was no expectation that the excluded school differed from the surveyed schools in any important way (such as in terms of size, demographics, or nearby sources of air pollution). Three of the schools surveyed were chosen from mandals on the perimeter of the projected PM_{10} 10 $\mu g/m^3$ isopleth, but these schools also did not seem to differ from the schools within the isopleth in any important way. However, students who were not at school when the surveys were conducted were not included in the study. Since some of these students may not have attended school because of asthma-like symptoms, non-participation as a result of non-attendance may have been a source of bias. Another possible source of bias is that sampling within schools was not done randomly, with groups of subjects chosen at the convenience of each school's administrators. Administrators generally sent groups of students by class to participate in the survey, which meant that, at a given school, students of a given age might be overrepresented because more classes at that grade level were selected. However, at each school, samples of students were requested that would be "roughly" even in distribution of gender, age, grade level, language of instruction, and the difficulty level of their class. With this in mind, although convenience sampling was employed, the schools did tend to provide groups of subjects that were fairly well mixed overall, resulting in the distributions at location level that are shown in Table 1.

The assumption that the southern sample could be considered fairly representative has bearing on the utility of the results of this study. If the reported symptom prevalence estimates are accurate and are based on data from a sample representative of the southern location, these estimates could be considered valid enough to be extended to the rest of the 10- to 14-year-old rural public school student population in the area within the PM_{10}

10 $\mu g/m^3$ isopleth (Appendix 2) – that is, the area where projected increases in ambient PM_{10} concentrations due to operation of the proposed power plants would be the highest, and in turn the area where the health effects of the power facilities' emissions are expected to be the most pronounced. Valid prevalence estimates are necessary for establishing baselines for future assessments of the health impacts of the power plants or of children's respiratory health in general in that area.

Limitations

As with many survey tools based on subject recollection, the accuracy of prevalence estimates within the sample may contain uncertainty and potential bias. A major weakness of this study was the variation in methods between schools, resulting in a school effect. The main sources of variation were whether all questions were asked out loud and whether the subjects were asked to publicly signify some of their responses. At multiple schools, either the translator or the teachers asked the students to indicate – either verbally or by raising their hands – whether they had answered "yes" to Q1, on ever wheeze; if no one in the group had, the translator would save time by skipping Q2 through Q5. In some groups, individual subjects called out some of their answers to some questions without prompting. These interferences may have silenced students who were less vocal or sure of their answers and may have caused them to alter their responses. Q2 through Q5 were never asked of some groups. Another variation in methods between schools was that for two groups at School K, the translator's descriptions of wheezing and dry cough were substituted for the symptom video. It is possible that the translator's commentary that accompanied the video differed between schools.

Some precision is lost with the adjustment for school effect, as can be seen with the large confidence intervals for the OR estimates in these models compared with those produced by the non-adjusted models (Table 6). Still, since the differences by school are too dramatic to be ignored, for this study the loss of precision may be a fair compromise for a potentially more valid model.

Another limitation to this study was that all responses, including those concerning symptoms, were self-reported. Reports of symptoms depended on the subjects' understanding of the terms used for symptoms, the translator's explanations of symptoms (which may have varied by school), and the low-quality video used to provide examples of the sounds of wheezing and dry cough. With limited reading and writing abilities, children would be expected to provide self-reports of symptoms that are even less reliable than those of educated adults equally unfamiliar with the terms or symptoms.

Potential bias may have resulted from administering the questionnaire to large groups of subjects in classrooms and outdoor school settings. The original intent had been to survey subjects one at a time or in small groups of 5 or less. However, when one school provided a room of 20 students for the pilot survey, the survey process seemed to run smoothly and was more efficient than individual interviews would have been. Based on this trial, as well as the translator's experiences with interviewing children, the study went forward with administration of questionnaires to groups of 20 to approximately 100 subjects at a time. In these large groups, subjects were often observed to read or discuss each others' answers while they recorded their own. This "peer pressure" may have affected some subjects' responses. This effect was extremely clear in one group at School C, in which, after some noisy discussion among the subjects, nearly an entire classroom's subjects had raised their hands to signal affirmative responses to Q1. Additionally, teachers at multiple schools joined the translator in explaining some questions in Telugu; these contributions from the teachers may have been another source of influence on the subjects, and teacher interference was another factor that varied widely between schools.

Translation of the questionnaire posed another concern in this study, specifically with regard to terms for asthma. In the Nellore area, the main vernacular terms for “asthma” are “ayyasam” and “ubbesam,” the first of which is also used to refer to more general feelings of fatigue, and the second of which seems to have a meaning similar to “asthma” in English but is not used as commonly as the term “ayyasam.” Because its definition and usage are more specific, “ubbesam” was used in Q6 (personal history of asthma) and Q9 (family history of asthma) on the final version of the questionnaire. However, the first two groups of subjects surveyed (at School C) saw the term “ayyasam” in Q6 and Q9 because these groups did not receive the final version of the questionnaire; although these subjects were asked to cross out “ayyasam” and write in “ubbesam,” the fact that they saw the first term meant that they might still have been thinking about it when responding to those questions. Because of the inconsistent or imprecise colloquial meanings of these terms, responses to Q6 and Q9 should be considered poor indicators of the true prevalences of childhood asthma and family history of asthma in Nellore District.

Recoding of responses to the two main symptoms questions – concerning ever wheeze (Q1) and recent wheeze (Q2) – had noteworthy effects on the prevalence estimates for these symptoms, with a larger effect from recoding Q2 responses and a smaller effect from recoding responses to Q1. For Q2, the question regarding recent wheeze, responses for 64 subjects (7.4% of the total sample of 863) were recoded to the affirmative based on these subjects' responses to Q3 through Q5, after these subjects originally responded "no" or did not provide an answer to Q2. The proportions of subjects whose Q2 responses were recoded did not differ significantly by location (p=0.2146). However, recoding of Q2 responses resulted in an increase from 8.1% to 15.8% in the overall estimate of recent wheeze prevalence, as well as increases from 9.9% to 17.8% in the south and from 4.7% to 10.7% in the north. These are the maximum possible increases, calculated under the assumption that all recoded Q2 responses were originally negative. For Q1, the question regarding ever wheeze, responses for 21 subjects (3.1% of the total sample of 863) were recoded to the affirmative based on these subjects' responses to Q2, after these subjects originally responded "no" to Q1. The proportions of subjects whose Q1 responses were recoded did not differ significantly by location (p=0.1330). The effect of recoding responses to Q1 was less pronounced than that of recoding responses for Q2. Recoding of Q1 responses resulted in an increase from 17.8% to 20.3% in the overall estimate of recent wheeze prevalence, as well as increases from 21.1% to 23.2% in the south and from 9.4% to 13.2% in the north.

Although, as mentioned, evidence points to exposure to tobacco smoke as a risk factor, the variable for smoking among subjects was excluded from analysis. Before the survey began, the translators and others familiar with the local culture (S. Dhara, Anjani, & B. R. Sreedlar, personal communication, June 2011) explained that most children in the target age group would not admit to smoking if they did and that the smokers at this age would be boys, but the few subjects who reported smoking and also reported a gender were female. Also taking into the account that most groups burst into laughter when asked whether any of them smoked, this variable was not included in final analyses.

Conclusion

In India and around the world, reliance on coal-fired power plants to generate electricity continues and new facilities are built in response to rising demands for energy, despite the variety of risks to human health associated with exposure to pollution produced as a result of operation of these plants. Because of their vulnerability to the respiratory health effects of air pollution, children were the focus of this study. The prevalence of reported asthma-like symptoms among schoolchildren was estimated within the area expected to experience the greatest impact of emissions from the power plants proposed in Nellore District, as well as in an area with lower projected levels of pollution from those facilities. Based on assessments of the differences in the prevalences of reported symptoms and in personal, family, and environmental characteristics between these two areas, the findings from this study suggest that the location farther from the proposed facilities could be tentatively recommended as a negative control site for comparison with the nearer location in any future studies undertaken to examine children's respiratory health impacts of the power plants, should they become operational.

Provided that other investigators use more consistent methods and that they either know the local language or clearly communicate about well-planned procedures with a translator prior to data collection, this study could prompt future investigations in a number of directions. The associations observed here – in univariate analyses – between reported symptoms and several personal, family, and environmental characteristics may offer a basis for the generation of hypotheses for further examination of asthma risk factors in rural south India. Although subject to limitations such as inconsistency in data collection procedures, this study does provide prevalence estimates that can serve as a baseline for future comparisons, whether to examine the health effects of the power plants if they begin to emit pollution or simply for other studies of asthma-like symptom prevalence in Nellore District and elsewhere in India. Future studies of the proposed power plants' health impacts could offer evidence in support of cleaner energy sources in India.

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Tables

Table 1: Demographics and family characteristics by location

Personal or family characteristic	South N=616	North N=247	Chi-square test result for difference by location	Total N=863
Mean age (SD) [95% CI]	12.35 (1.20) [12.26, 12.45]	12.56 (1.03) [12.43, 12.69]	**(p=0.0098)***	12.41 (1.16) [12.33, 12.49]
Age (%)				
10	45 (7.32)	9 (3.64)		54 (6.26)
11	110 (17.89)	26 (10.53)		136 (15.78)
12	168 (27.32)	77 (31.17)	**14.54 (p=0.0058)**	245 (28.42)
13	168 (27.32)	87 (35.22)		255 (29.58)
14	124 (20.16)	48 (19.43)		172 (19.95)
Female (%)	296 (51.93)	127 (57.99)	2.34 (p=0.1263)	423 (49.02)
Family history of asthma				
Yes	98 (16.20)	31 (13.25)	2.2122 (p=0.3308)	129 (15.38)
Don't know	443 (73.22)	183 (78.21)		626 (74.61)
White ration card (%)	232 (97.07)	574 (96.63)	0.10 (p=0.7467)	806 (96.26)
Parental occupation				
At least one parent farms	291 (51.14)	152 (64.41)	**11.86 (p=0.0006)**	443 (55.03)
Father farms	279 (48.44)	148 (62.71)	**13.68 (p=0.0002)**	427 (52.59)
Mother farms	28 (4.74)	17 (6.97)	1.68 (p=0.1945)	45 (5.39)
At least one parent works for wages	298 (51.56)	119 (49.79)	0.21 (p=0.6459)	417 (51.04)
Father works for wages	136 (23.61)	31 (13.14)	**11.25 (p=0.0008)**	167 (20.57)
Mother works for wages	228 (38.58)	105 (43.03)	1.43 (p=0.2319)	333 (39.88)
Mother is a housewife	295 (49.92)	107 (43.85)	2.54 (p=0.1108)	402 (48.14)

** P-value from Satterthwaite t-test, which showed a difference in means of -0.2115 (95% CI -0.3717, -0.0513)*

Table 2: Prevalence of symptoms by location

Reported symptom	South N=616	North N=247	Chi-square test for difference by location	Total N=863
Ever wheeze (%)	138 (23.15)	31 (13.19)	**10.33 (p=0.0013)**	169 (20.34)
Ever asthma (%)	129 (21.46)	74 (31.49)	**9.23 (p=0.0024)**	203 (24.28)
Recent wheeze (%)	106 (17.82)	25 (10.68)	**6.42 (p=0.0113)**	131 (15.80)
Recent attacks				
1 to 3 attacks	55 (28.95)	9 (23.08)	p=0.2799*	64 (27.95)
4 to 12 attacks	13 (6.84)	3 (7.69)		16 (6.99)
>12 attacks	12 (6.32)	6 (15.38)		18 (7.86)
Recent sleep disturbed by wheeze			p=0.0897*	
Less than one night per week	72 (37.31)	12 (35.29)		84 (37.00)
One or more nights per week	12 (6.22)	6 (17.65)		18 (7.93)
Recent speech limited by wheeze	57 (26.89)	8 (19.05)	p=0.3374*	65 (25.59)
Wheeze during/after exercise	98 (16.31)	17 (7.11)	**12.23 (p=0.0005)**	115 (13.69)
Night cough	243 (41.82)	82 (35.34)	2.90 (p=0.0885)	325 (39.98)

**P-value from Fisher exact test.*

Table 3: Relationships of environmental characteristics to location

Environmental characteristic	South N=616	North N=247	Chi-square test for difference by location	Total N=863
Animals kept in past 12 months	394 (67.01)	181 (76.69)	**7.50 (p=0.0062)**	575 (69.78)
Chickens	152 (24.68)	119 (48.18)	**45.21 (p<.0001)**	271 (31.40)
Dog	174 (28.25)	58 (23.48)	2.04 (p=0.1536)	232 (26.88)
Cat	87 (14.12)	25 (10.12)	2.50 (p=0.1138)	112 (12.98)
Buffalo	45 (7.31)	39 (15.79)	**14.44 (p=0.0001)**	84 (9.73)
Cows/Cattle	21 (3.41)	7 (2.83)	0.19 (p=0.6665)	28 (3.24)
Goat	12 (1.95)	2 (0.81)	p=0.3714*	14 (1.62)
Ox	6 (0.97)	3 (1.21)	p=0.7206*	9 (1.04)
Smoker among members of household	395 (64.44%)	164 (66.94%)	0.4825 (p=0.4873)	559 (65.15%)
Father smokes	260 (42.41)	92 (37.55)	1.71 (p=0.1908)	352 (41.03)
House roof type				
RCC (concrete)	326 (53.71)	143 (59.58)		469 (55.37)
Hut (traditional)	136 (22.41)	60 (25.00)	**7.85 (p=0.0492)**	196 (23.14)
Rekulu (sheeting)	117 (19.28)	32 (13.33)		149 (17.59)
Tiled roof	28 (4.61)	5 (2.08)		33 (3.90)
Solid fuels used for cooking	336 (56.00)	118 (49.79)	2.65 (p=0.1042)	454 (54.24)
Heavy vehicles pass frequently on nearest road	398 (66.33)	99 (40.91)	**46.09 (p<.0001)**	497 (59.03)
Distance from home to nearest road				
Home is right next to road	180 (30.05)	72 (30.13)		252 (30.07)
<10m	299 (49.92)	124 (51.88)	1.53 (p=0.9096)	423 (50.48)
11m to 50m	66 (11.02)	27 (11.30)		93 (11.10)
51m to 100m	23 (3.84)	8 (3.35)		31 (3.70)
101m to 200m	14 (2.34)	4 (1.67)		18 (2.15)
>200m	17 (2.84)	4 (1.67)		21 (2.51)
Buildings or plants between home and nearest road	465 (76.99)	187 (77.92)	0.09 (p=0.7713)	652 (77.25)

**P-value from Fisher exact test.*

Table 4: Relationships of location, family characteristics, and environmental characteristics to reported ever wheeze and wheeze in the past 12 months

	Ever wheeze			Wheeze in past 12 months		
Characteristic	N	%	OR (95% CI)	N	%	OR (95% CI)
Location						
South	138	23.15	**1.98 (1.30, 3.03)**	106	17.82	**1.81 (1.14, 2.88)**
North	31	13.19	1.00	25	10.68	1.00
Gender						
Female	78	19.02	0.80 (0.56, 1.13)	52	12.78	**0.60 (0.41, 0.89)**
Male	80	22.79	1.00	69	19.55	1.00
Age*			**0.85 (0.74, 0.99)**			**0.82 (0.70, 0.96)**
Family asthma Yes	42	33.6	**2.23 (1.14, 4.36)**	37	29.84	1.90 (0.96, 3.75)
Don't know	109	18.08	0.97 (0.53, 1.77)	78	12.94	0.66 (0.36, 1.22)
No	15	18.52	1.00	15	18.29	1.00
Animals kept in past 12 months	124	22.26	1.37 (0.93, 2.02)	95	17.21	1.35 (0.88, 2.08)
Chickens	64	24.52	**1.44 (1.01, 2.05)**	51	19.62	**1.49 (1.01, 2.20)**
Dog	50	21.93	1.14 (0.79, 1.66)	40	17.78	1.22 (0.81, 1.83)
Cat	22	20.37	1.00 (0.61, 1.66)	16	14.95	0.93 (0.53. 1.64)
Buffalo	15	18.52	0.88 (0.49, 1.58)	11	13.58	0.82 (0.42, 1.60)
Smoker among household	112	20.93	1.09 (0.76, 1.55)	89	16.60	1.17 (0.78, 1.74)
Father smokes	73	21.66	1.13 (0.80, 1.59)	58	17.11	1.16 (0.80, 1.70)
House roof type						
Hut (traditional)	41	21.35	1.23 (0.81, 1.88)	32	16.67	1.32 (0.82, 2.10)
Rekulu (sheeting)	38	25.85	**1.58 (1.02, 2.46)**	32	21.77	**1.83 (1.13, 2.95)**
Tiled roof	6	21.43	1.24 (0.49, 3.15)	5	17.86	1.43 (0.52, 3.91)
RCC (concrete)	81	18.04	1.00	59	13.2	1.00
Solid fuels used for cooking	95	21.74	1.21 (0.85, 1.71)	68	15.6	0.97 (0.66, 1.42)

(Table 4 continues on following page.)

Data are presented as the number of subjects (N), % with symptom, and OR with 95% CIs.
**OR for one unit increase in the variable.*

(Table 4, continued.)

	Ever wheeze N	%	OR (95% CI)	Wheeze in the past 12 months N	%	OR (95% CI)
Heavy vehicles pass frequently on nearest road	90	18.83	0.78 (0.55, 1.10)	81	16.91	1.17 (0.80, 1.72)
Distance from home to nearest road						
Home is right next to road	46	19.17	1.00	37	15.42	1.00
<10m	92	22.44	1.22 (0.82, 1.81)	67	16.38	1.07 (0.69, 1.66)
11m to 50m	16	17.58	0.90 (0.48, 1.69)	14	15.56	1.01 (0.52, 1.97)
51m to 100m	5	17.24	0.88 (0.32, 2.43)	4	13.33	0.84 (0.28, 2.56)
101m to 200m	2	11.76	0.56 (0.12, 2.55)	2	11.76	0.73 (0.16, 3.33)
>200m	3	14.29	0.70 (0.20, 2.49)	3	14.29	0.91 (0.26, 3.26)
Parental occupations						
At least one parent farms	76	17.84	0.72 (0.51, 1.03)	54	12.65	**0.61 (0.41, 0.90)**
Father farms	71	17.32	0.70 (0.49, 1.00)	49	11.92	**0.56 (0.38, 0.84)**
Mother farms	10	22.73	1.14 (0.55, 2.35)	7	16.28	1.02 (0.45, 2.35)
At least one parent works for wages	85	21.25	1.10 (0.78, 1.55)	63	15.79	0.97 (0.66, 1.43)
Father works for wages	37	22.7	1.23 (0.81, 1.87)	27	16.77	1.14 (0.71, 1.81)
Mother works for wages	67	21.07	1.04 (0.73, 1.47)	50	15.72	0.97 (0.66, 1.43)

Data are presented as the number of subjects (N), % with symptom, and OR with 95% CIs.

Table 5: Multivariable analysis showing relationships between symptoms, location, and potential confounding variables, after adjustment for effect by school

Characteristic	Ever wheeze OR (95% CI)	Wheeze in past 12 months OR (95% CI)
Location (south vs. north)	**2.62 (1.07, 6.44)**	1.94 (0.97, 3.86)
Age*	0.88 (0.67, 1.15)	0.84 (0.70, 1.00)
House roof type		
Hut (traditional)	1.22 (0.66, 2.28)	1.13 (0.61, 2.10)
Rekulu (sheeting)	1.32 (0.75, 2.31)	1.49 (0.87, 2.54)
Tiled roof	1.08 (0.60, 1.92)	1.21 (0.58, 2.55)
RCC (concrete)	1.00	1.00
Father works as a farmer	N/A	**0.63 (0.45, 0.88)**

Data are presented as the OR (odds ratio) with 95% CIs (confidence intervals).
**OR for one year increase*

Table 6: Sensitivity test results – relationships between location and symptoms
Relationships between location and symptoms were examined using univariate logistic regression. In some tests, generalized estimating equations (GEE) were used to adjust for school effect. Data are presented as the OR (odds ratio) with 95% CIs (confidence intervals).

Total sample (N=863)

With adjustment for school effect						
	Ever wheeze			Wheeze in past 12 months		
Location	N	%	OR (95% CI)	N	%	OR (95% CI)
South	138	23.15	1.90 (0.70, 5.15)	106	17.82	1.79 (0.81, 3.93)
North	31	13.19	1.00	25	10.68	1.00
No adjustment for school effect						
	Ever wheeze			Wheeze in past 12 months		
Location	N	%	OR (95% CI)	N	%	OR (95% CI)
South	138	23.15	**1.98 (1.30, 3.03)**	106	17.82	**1.81 (1.14, 2.88)**
North	31	13.19	1.00	25	10.68	1.00

Excluding the groups that did not see or hear the symptom video (N=814)

With adjustment for school effect						
	Ever wheeze			Wheeze in past 12 months		
Location	N	%	OR (95% CI)	N	%	OR (95% CI)
South	126	22.99	1.92 (0.70, 5.24)	94	17.18	1.65 (0.72, 3.79)
North	31	13.19	1.00	25	10.68	1.00
No adjustment for school effect						
	Ever wheeze			Wheeze in past 12 months		
Location	N	%	OR (95% CI)	N	%	OR (95% CI)
South	126	22.99	**1.96 (1.28, 3.01)**	94	17.18	**1.73 (1.08, 2.78)**
North	31	13.19	1.00	25	10.68	1.00

Excluding all subjects from School G (N=843)

With adjustment for school effect						
	Ever wheeze			Wheeze in past 12 months		
Location	N	%	OR (95% CI)	N	%	OR (95% CI)
South	138	23.96	2.18 (0.83, 5.74)	106	18.43	1.97 (0.92, 4.25)
North	31	13.19	1.00	25	10.68	1.00
No adjustment for school effect						
	Ever wheeze			Wheeze in past 12 months		
Location	N	%	OR (95% CI)	N	%	OR (95% CI)
South	138	23.96	**2.07 (1.36, 3.17)**	106	18.43	**1.89 (1.19, 3.01)**
North	31	13.19	1.00	25	10.68	1.00

Excluding all subjects from School G and all subjects that did not hear or see the symptom video (N=794)

With adjustment for school effect						
	Ever wheeze			Wheeze in past 12 months		
Location	N	%	OR (95% CI)	N	%	OR (95% CI)
South	126	23.86	2.21 (0.84, 5.86)	94	17.84	1.84 (0.83, 4.12)
North	31	13.19	1.00	25	10.68	1.00
No adjustment for school effect						
	Ever wheeze			Wheeze in past 12 months		
Location	N	%	OR (95% CI)	N	%	OR (95% CI)
South	126	23.86	**2.06 (1.35, 3.16)**	94	17.84	**1.81 (1.13, 2.91)**
North	31	13.19	1.00	25	10.68	1.00

Excluding all subjects from Schools D and G (N=795)

With adjustment for school effect						
	Ever wheeze			Wheeze in past 12 months		
Location	N	%	OR (95% CI)	N	%	OR (95% CI)
South	127	24.05	2.20 (0.79, 6.10)	95	18.03	1.88 (0.84, 4.24)
North	31	13.19	1.00	25	10.68	1.00
No adjustment for school effect						
	Ever wheeze			Wheeze in past 12 months		
Location	N	%	OR (95% CI)	N	%	OR (95% CI)
South	127	24.05	**2.08 (1.36, 3.20)**	95	18.03	**1.84 (1.15, 2.94)**
North	31	13.19	1.00	25	10.68	1.00

Additionally, the proportions of students who reported symptoms were compared between the small-sample schools (D and G) and the rest of the schools in the southern location (B, C, K, P, and V). Chi-square tests were used to determine whether these proportions differed significantly between school groups.

	Ever wheeze			Wheeze in past 12 months		
	N	%	p-value from chi-square test	N	%	p-value from chi-square test
Schools D and G	11	16.18	0.1473	11	16.18	0.7075
Other schools in south	127	24.05		95	18.03	

Results by school (Tables 7 through 9)

Table 7: Demographics and family characteristics by school

Characteristic	School B (N=120)	C (N=125)	D (N=48)	G (N=20)	I (N=110)	K (N=101)	N (N=137)	P (N=115)	V (N=87)
Mean age (SD) [95% CI]	12.01 (1.21) [11.79, 12.23]	11.48 (1.08) [11.29, 11.67]	12.46 (1.18) [12.11, 12.80]	12.05 (1.23) [11.47, 12.62]	12.59 (1.17) [12.37, 12.81]	12.61 (1.01) [12.41, 12.81]	12.54 (0.92) [12.39, 12.69]	12.77 (0.96) [12.60, 12.95]	13.22 (0.78) [13.05, 13.39]
Age (%)									
10	15 (12.61)	25 (20.00)	3 (6.25)	2 (10.00)	7 (6.36)	0	2 (1.46)	0	0
11	26 (21.85)	43 (34.40)	8 (16.67)	6 (30.00)	14 (12.73)	15 (14.85)	12 (8.76)	11 (9.57)	1 (1.15)
12	36 (30.25)	33 (26.40)	11 (22.92)	3 (15.00)	22 (20.00)	33 (32.67)	55 (40.15)	36 (31.30)	16 (18.39)
13	27 (22.69)	20 (16.00)	16 (33.33)	7 (35.00)	41 (37.27)	29 (28.71)	46 (33.58)	36 (31.30)	33 (37.93)
14	15 (12.61)	4 (3.20)	10 (20.83)	2 (10.00)	26 (23.64)	24 (23.76)	22 (16.06)	32 (27.83)	37 (42.53)
Female (%)	52 (46.43)	56 (48.28)	26 (55.32)	14 (82.35)	58 (59.18)	55 (60.44)	69 (57.02)	50 (49.02)	43 (50.59)
Family history of asthma									
Yes	33 (27.73)	14 (11.29)	6 (12.50)	0	7 (6.60)	5 (5.32)	24 (18.75)	28 (24.56)	12 (13.95)
Don't know	77 (64.71)	89 (71.77)	36 (75.00)	19 (95.00)	87 (82.08)	84 (89.36)	96 (75.00)	80 (70.18)	58 (67.44)
White ration card (%)	111 (97.37)	113 (96.58)	48 (100)	16 (80.00)	102 (98.08)	90 (93.75)	130 (96.30)	110 (97.35)	86 (100)

(Table 7, continued.)

Characteristic	School B (N=120)	C (N=125)	D (N=48)	G (N=20)	I (N=110)	K (N=101)	N (N=137)	P (N=115)	V (N=87)
Parental occupation									
At least one parent farms	64 (55.65)	47 (41.96)	28 (65.12)	15 (78.95)	65 (61.32)	32 (33.68)	87 (66.92)	57 (53.77)	48 (60.76)
Father farms	63 (52.94)	43 (36.75)	27 (64.29)	13 (72.22)	65 (61.32)	29 (30.53)	83 (63.85)	57 (53.77)	47 (59.49)
Mother farms	6 (5.41)	4 (3.36)	4 (8.89)	4 (22.22)	1 (0.93)	3 (3.03)	16 (11.76)	1 (0.88)	6 (7.06)
At least one parent works for wages	49 (43.75)	80 (65.57)	14 (33.33)	3 (17.65)	51 (48.11)	41 (42.71)	68 (51.13)	68 (62.39)	43 (53.75)
Father works for wages	24 (20.17)	47 (40.17)	0	1 (5.56)	9 (8.49)	28 (29.47)	22 (16.92)	17 (16.04)	19 (24.05)
Mother works for wages	34 (30.63)	63 (52.94)	14 (31.11)	3 (16.67)	44 (40.74)	19 (19.19)	61 (44.85)	59 (51.75)	36 (42.35)
Mother is a housewife	64 (57.66)	48 (40.34)	24 (53.33)	9 (50.00)	58 (53.70)	66 (66.67)	49 (36.03)	48 (42.11)	36 (42.35)

Table 8: Prevalence of symptoms by school

School	B (N=120)	C (N=125)	D (N=48)	G (N=20)	I (N=110)	K (N=101)	N (N=137)	P (N=115)	V (N=87)
Ever wheeze (%)	11 (9.57)	33 (26.83)	5 (10.42)	0	2 (2.00)	25 (25.25)	20 (14.81)	45 (42.86)	7 (8.14)
Ever asthma (%)	50 (43.10)	34 (28.10)	14 (29.17)	0	35 (33.33)	10 (10.00)	39 (30.00)	17 (15.18)	4 (4.76)
Recent wheeze (%)	11 (9.48)	31 (25.83)	11 (22.92)	0	6 (5.94)	17 (17.00)	19 (14.29)	30 (28.57)	6 (6.98)
Recent attacks (%)									
1 to 30 attacks	4 (30.77)	16 (45.71)	4 (8.51)	0	3 (25.00)	12 (41.38)	6 (22.22)	14 (35.90)	5 (71.43)
4 to 12 attacks	4 (30.77)	0	2 (4.26)	0	0	2 (6.90)	3 (11.11)	5 (12.82)	0
>12 attacks	3 (23.08)	1 (2.86)	5 (10.64)	0	0	0	6 (22.22)	3 (7.69)	0
Recent sleep disturbed by wheeze (%)									
Less than one night per week	8 (61.54)	21 (60.00)	8 (16.67)	0	1 (11.11)	11 (40.74)	11 (44.00)	19 (44.19)	5 (71.43)
One or more nights per week	2 (15.38)	2 (5.71)	1 (2.08)	0	1 (11.11)	3 (11.11)	5 (20.00)	3 (6.98)	1 (14.29)
Recent speech limited by wheeze	9 (47.37)	21 (51.22)	6 (12.77)	0	1 (7.69)	6 (17.65)	7 (24.14)	14 (32.56)	1 (12.50)
Recent wheeze during/after exercise	53 (46.09)	12 (9.76)	7 (14.58)	0	6 (5.56)	20 (21.05)	11 (8.40)	3 (2.63)	3 (3.49)
Recent night cough	33 (31.73)	64 (53.33)	42 (89.36)	1 (5.00)	32 (30.48)	28 (30.11)	50 (39.37)	50 (43.86)	25 (30.12)

Table 9: Environmental characteristics by school

School	B (N=120)	C (N=125)	D (N=48)	G (N=20)	I (N=110)	K (N=101)	N (N=137)	P (N=115)	V (N=87)
Animals kept in past 12 months	41 (38.68)	90 (75.63)	39 (81.25)	20 (100.00)	69 (66.99)	69 (71.88)	112 (84.21)	69 (61.06)	66 (76.74)
Chickens	8 (6.67)	35 (28.00)	2 (4.17)	0	46 (41.82)	27 (26.73)	73 (53.28)	50 (43.48)	30 (34.48)
Dog	17 (14.17)	39 (31.20)	26 (54.17)	11 (55.00)	16 (14.55)	33 (32.67)	42 (30.66)	17 (14.78)	31 (35.63)
Cat	6 (5.00)	31 (24.80)	13 (27.08)	6 (30.00)	14 (12.73)	14 (13.86)	11 (8.03)	12 (10.43)	5 (5.75)
Buffalo	8 (6.67)	11 (8.80)	3 (6.25)	1 (5.00)	10 (9.09)	2 (1.98)	29 (21.17)	4 (3.48)	16 (18.39)
Cows/Cattle	4 (3.33)	0	0	7 (35.00)	1 (0.91)	4 (3.96)	6 (4.38)	2 (1.74)	4 (4.60)
Goat	0	0	1 (2.08)	1 (5.00)	0	3 (2.97)	2 (1.46)	1 (0.87)	6 (6.90)
Ox	2 (1.67)	0	0	3 (15.00)	1 (0.87)	0	2 (1.46)	1 (0.87)	0
Smoker among members of household	90 (75.63)	72 (58.06)	24 (50.00)	13 (65.00)	75 (68.18)	65 (65.00)	89 (65.93)	73 (63.48)	58 (66.67)
Father smokes	59 (49.58)	53 (42.74)	13 (27.08)	8 (40.00)	31 (28.18)	37 (37.00)	61 (45.19)	52 (45.22)	38 (43.68)
House roof type									
RCC (concrete)	58 (50.43)	63 (50.81)	28 (58.33)	11 (55.00)	57 (54.29)	44 (44.44)	86 (63.70)	57 (60.00)	65 (74.71)
Hut (traditional)	30 (26.09)	30 (24.19)	10 (20.83)	5 (25.00)	31 (29.52)	21 (21.21)	29 (21.48)	25 (21.93)	15 (17.24)
Rekulu (sheeting)	26 (22.61)	25 (20.16)	8 (16.67)	3 (15.00)	12 (11.43)	32 (32.32)	20 (14.81)	22 (19.30)	1 (1.15)
Tiled roof	1 (0.87)	6 (4.84)	2 (4.17)	1 (5.00)	5 (4.76)	2 (2.02)	0	10 (8.77)	6 (6.90)
Solid fuels used for cooking	19 (16.38)	79 (66.39)	17 (35.42)	12 (60.00)	57 (53.77)	59 (60.20)	61 (46.56)	88 (77.19)	62 (72.94)

(Table 9, continued.)

School	B (N=120)	C (N=125)	D (N=48)	G (N=20)	I (N=110)	K (N=101)	N (N=137)	P (N=115)	V (N=87)
Heavy vehicles pass frequently on nearest road	89 (78.76)	82 (67.21)	44 (91.67)	13 (65.00)	48 (43.64)	62 (62.63)	51 (38.64)	71 (63.96)	37 (42.53)
Distance from home to nearest road									
Home is right next to road	26 (23.21)	42 (35.29)	19 (39.58)	10 (50.00)	35 (33.02)	38 (38.38)	37 (27.82)	35 (30.70)	10 (11.49)
≤10m	52 (46.43)	59 (49.58)	13 (27.08)	5 (25.00)	51 (48.11)	48 (48.48)	73 (54.89)	63 (55.26)	59 (67.82)
11m to 50m	14 (12.50)	10 (8.40)	12 (25.00)	4 (20.00)	13 (12.26)	6 (6.06)	14 (10.53)	12 (10.53)	8 (9.20)
51m to 100m	6 (5.36)	2 (1.68)	3 (6.25)	0	2 (1.89)	3 (3.03)	6 (4.51)	3 (2.63)	6 (6.90)
101m to 200m	8 (7.14)	1 (0.84)	1 (2.08)	1 (5.00)	3 (2.83)	1 (1.01)	1 (0.75)	1 (0.88)	1 (1.15)
≥200m	6 (5.36)	5 (4.20)	0	0	2 (1.89)	3 (3.03)	2 (1.50)	0	3 (3.45)
Buildings or plants between home and nearest road	89 (76.72)	95 (77.87)	41 (85.42)	19 (95.00)	68 (64.76)	64 (65.31)	119 (88.15)	84 (74.34)	73 (83.91)

Table 10: Missing values *(Table 10 continues on following two pages.)*

Variable	Total	South	North	Schools with sample sizes by school: B 120	C 125	D 48	G 20	I 110	K 101	N 137	P 115	V 87
Age	1 (0.12)	1 (0.16)	0	1 (0.83)	0	0	0	0	0	0	0	0
Ever wheeze	32 (3.71)	20 (3.25)	12 (4.86)	5 (4.17)	2 (1.60)	0	0	10 (9.09)	2 (1.98)	2 (1.46)	10 (8.70)	1 (1.15)
Recent wheeze	34 (3.94)	21 (3.41)	13 (5.26)	4 (3.33)	5 (4.00)	0	0	9 (8.18)	1 (0.99)	4 (2.92)	10 (8.70)	1 (1.15)
Recent attacks	634 (73.46)	426 (69.16)	208 (84.21)	107 (89.17)	90 (72.00)	1 (2.08)	0	98 (89.09)	72 (71.29)	110 (80.29)	76 (66.09)	80 (91.95)
Recent sleep interrupted by wheezing	636 (73.70)	423 (68.67)	213 (86.23)	107 (89.17)	90 (72.00)	0	0	101 (91.82)	74 (73.27)	112 (81.75)	72 (62.61)	80 (91.95)
Recent speech limited by wheezing	609 (70.57)	404 (65.58)	205 (83.00)	101 (84.17)	84 (67.20)	1 (2.08)	0	97 (88.18)	67 (66.34)	108 (78.83)	72 (62.61)	79 (90.80)
Ever asthma	27 (3.13)	15 (2.44)	12 (4.86)	4 (3.33)	4 (3.20)	0	0	5 (4.55)	1 (0.99)	7 (5.11)	3 (2.61)	3 (3.45)
Recent wheeze during physical activity	23 (2.67)	15 (2.44)	8 (3.24)	5 (4.17)	2 (1.60)	0	0	2 (1.82)	6 (5.94)	6 (4.38)	1 (0.87)	1 (1.15)
Recent night cough	50 (5.79)	35 (5.68)	15 (6.07)	16 (13.33)	5 (4.00)	1 (2.08)	0	5 (4.55)	8 (7.92)	10 (7.30)	1 (0.87)	4 (4.60)

(Table 10, continued.)

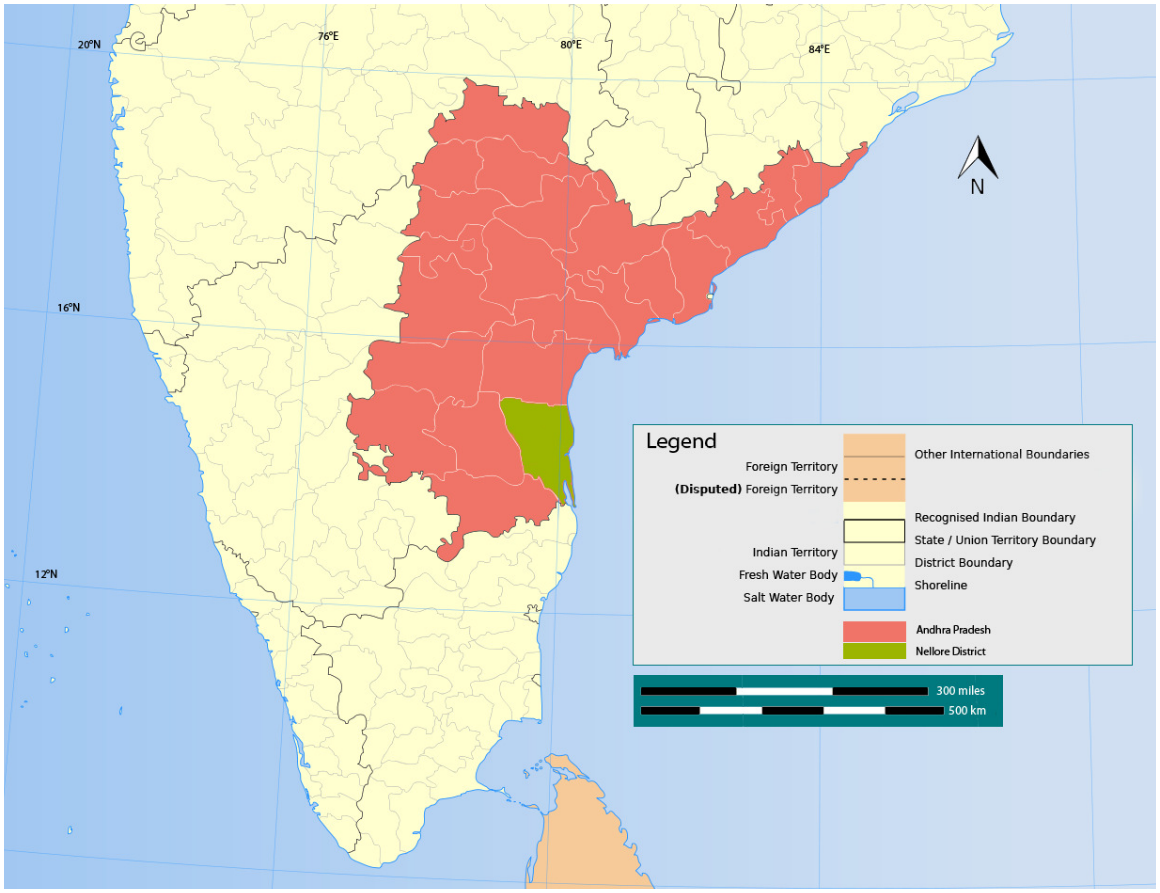
Variable	Total	South	North	B 120	C 125	D 48	G 20	I 110	K 101	N 137	P 115	V 87
Animals in 12 months	39 (4.52)	28 (4.55)	11 (4.53)	14 (11.67)	6 (4.80)	0	0	7 (6.36)	5 (4.95)	4 (2.92)	2 (1.74)	1 (1.15)
(All variables for types of domestic animals have no missing values.)												
Family smoke	5 (0.58)	3 (0.49)	2 (0.81)	1 (0.83)	1 (0.80)	0	0	0	1 (0.99)	2 (1.46)	0	0
Father smokes	5 (0.58)	3 (0.49)	2 (0.81)	1 (0.83)	1 (0.80)	0	0	0	1 (0.99)	2 (1.46)	0	0
Family history	24 (2.78)	11 (1.79)	13 (5.26)	1 (0.83)	1 (0.80)	0	0	4 (3.64)	7 (6.93)	9 (6.57)	1 (0.87)	1 (1.15)
Solid fuels	26 (3.01)	16 (2.60)	10 (4.05)	4 (3.33)	6 (4.80)	0	0	4 (3.64)	3 (2.97)	6 (4.38)	1 (0.87)	2 (2.30)
House type	16 (1.85)	9 (1.46)	7 (2.83)	5 (4.17)	1 (0.80)	0	0	5 (4.55)	2 (1.98)	2 (1.46)	1 (0.87)	0
Heavy vehicles	21 (2.43%)	16 (2.60%)	5 (2.02%)	7 (5.83)	3 (2.40)	0	0	0	2 (1.98)	5 (3.65)	4 (3.48)	0
Distance between home and nearest road	25 (2.90%)	17 (2.76%)	8 (3.24%)	8 (6.67)	6 (4.80)	0	0	4 (3.64)	2 (1.98)	4 (2.92)	1 (0.87)	0
Buildings or plants between home and road	19 (2.20%)	12 (1.95%)	7 (2.83%)	4 (3.33)	3 (2.40)	0	0	5 (4.55)	3 (2.97)	2 (1.46)	2 (1.74)	0

(Table 10, continued.)

Variable	Total	South	North	B 120	C 125	D 48	G 20	I 110	K 101	N 137	P 115	V 87
At least one parent farms	58 (6.72)	47 (7.63)	11 (4.45)	5 (4.17)	13 (10.40)	5 (10.42)	1 (5.00)	4 (3.64)	6 (5.94)	7 (5.11)	9 (7.83)	8 (9.20)
Father farms	51 (5.91)	40 (6.49)	11 (4.45)	1 (0.83)	8 (6.40)	6 (12.50)	2 (10.00)	4 (3.64)	6 (5.94)	7 (5.11)	9 (7.83)	8 (9.20)
Mother farms	28 (3.24)	25 (4.06)	3 (1.21)	9 (7.50)	6 (4.80)	3 (6.25)	2 (10.00)	2 (1.82)	2 (1.98)	1 (0.73)	1 (0.87)	2 (2.30)
At least one parent works for wages	46 (5.33)	38 (6.17)	8 (3.24)	8 (6.67)	3 (2.40)	6 (12.50)	3 (15.00)	4 (3.64)	5 (4.95)	4 (2.92)	6 (5.22)	7 (8.05)
Father works for wages	51 (5.91)	40 (6.49)	11 (4.45)	1 (0.83)	8 (6.40)	6 (12.50)	2 (10.00)	4 (3.64)	6 (5.94)	7 (5.11)	9 (7.83)	8 (9.20)
Mother works for wages	28 (3.24)	25 (4.06)	3 (1.21)	9 (7.50)	6 (4.80)	3 (6.25)	2 (10.00)	2 (1.82)	2 (1.98)	1 (0.73)	1 (0.87)	2 (2.30)
Mother is a housewife	28 (3.24)	25 (4.06)	3 (1.21)	9 (7.50)	6 (4.80)	3 (6.25)	2 (10.00)	2 (1.82)	2 (1.98)	1 (0.73)	1 (0.87)	2 (2.30)

Appendix 1: Maps

Map 1A: Location of Nellore District in Andhra Pradesh, India.



Modified figure. Original figure source: CC-by-sa PlaneMad/Wikipedia. (2008, Dec. 29). *Andhra Pradesh locator map*. Retrieved April 12, 2012, from http://en.wikipedia.org/wiki/File:India_Andhra_Pradesh_locator_map.svg. Licensed under the Creative Commons Attribution-Share Alike 3.0 Unported license.

Map 1B: Study sites in Nellore District in context of isopleths showing projected incremental increases in PM_{10} ground-level concentrations. Isopleth lines are based on Cerana Foundation maps (Appendix 2).

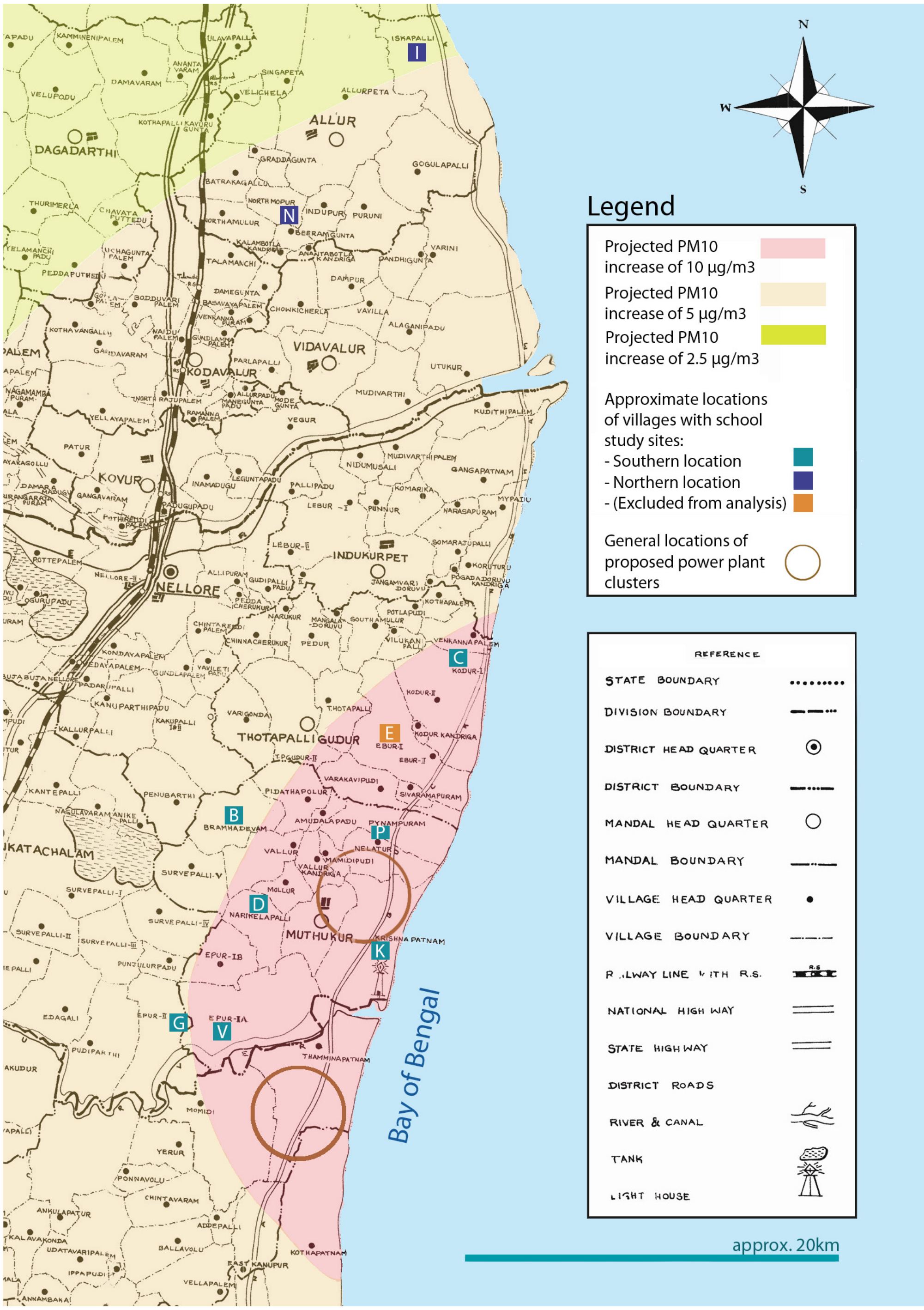
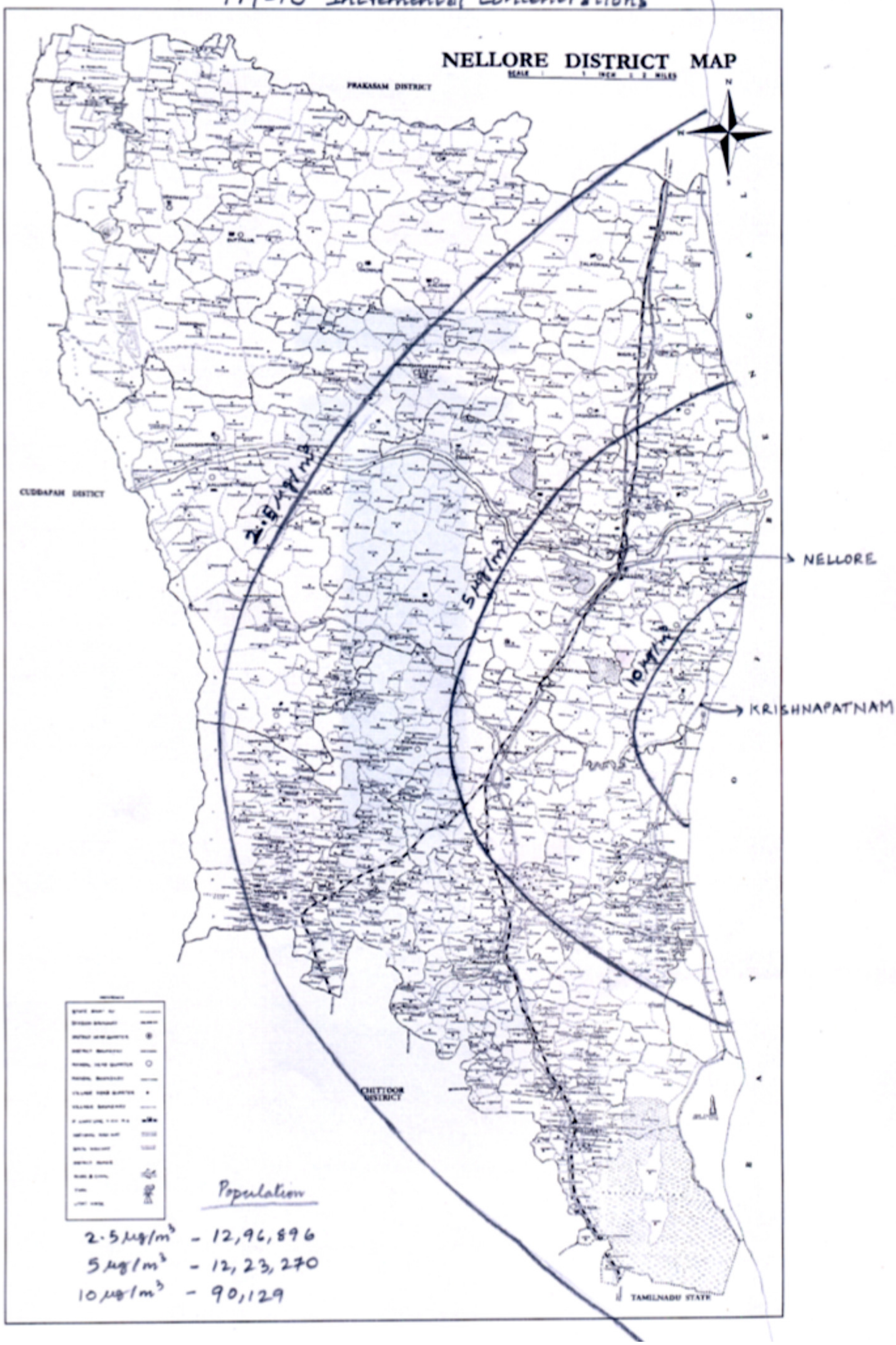
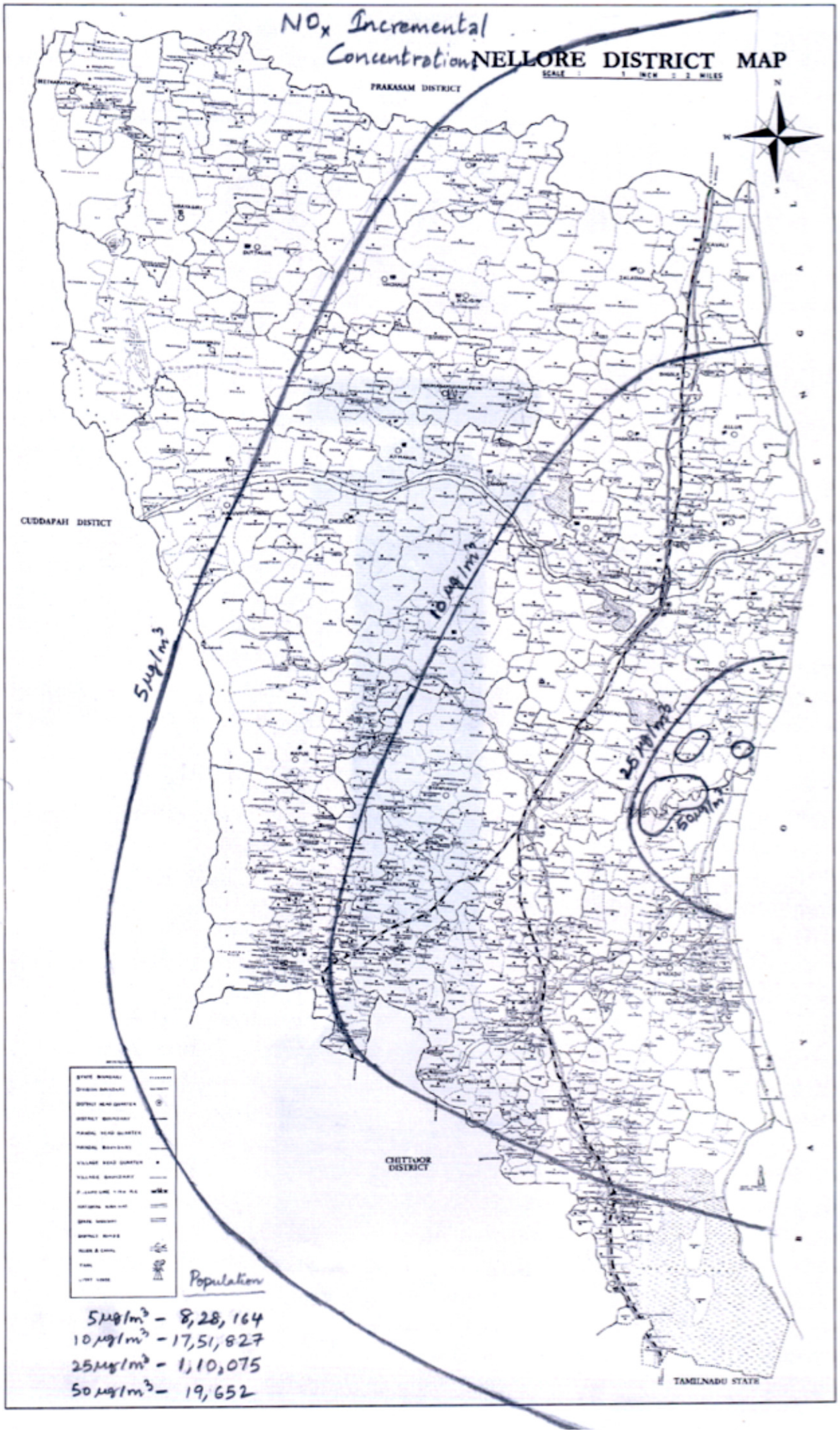


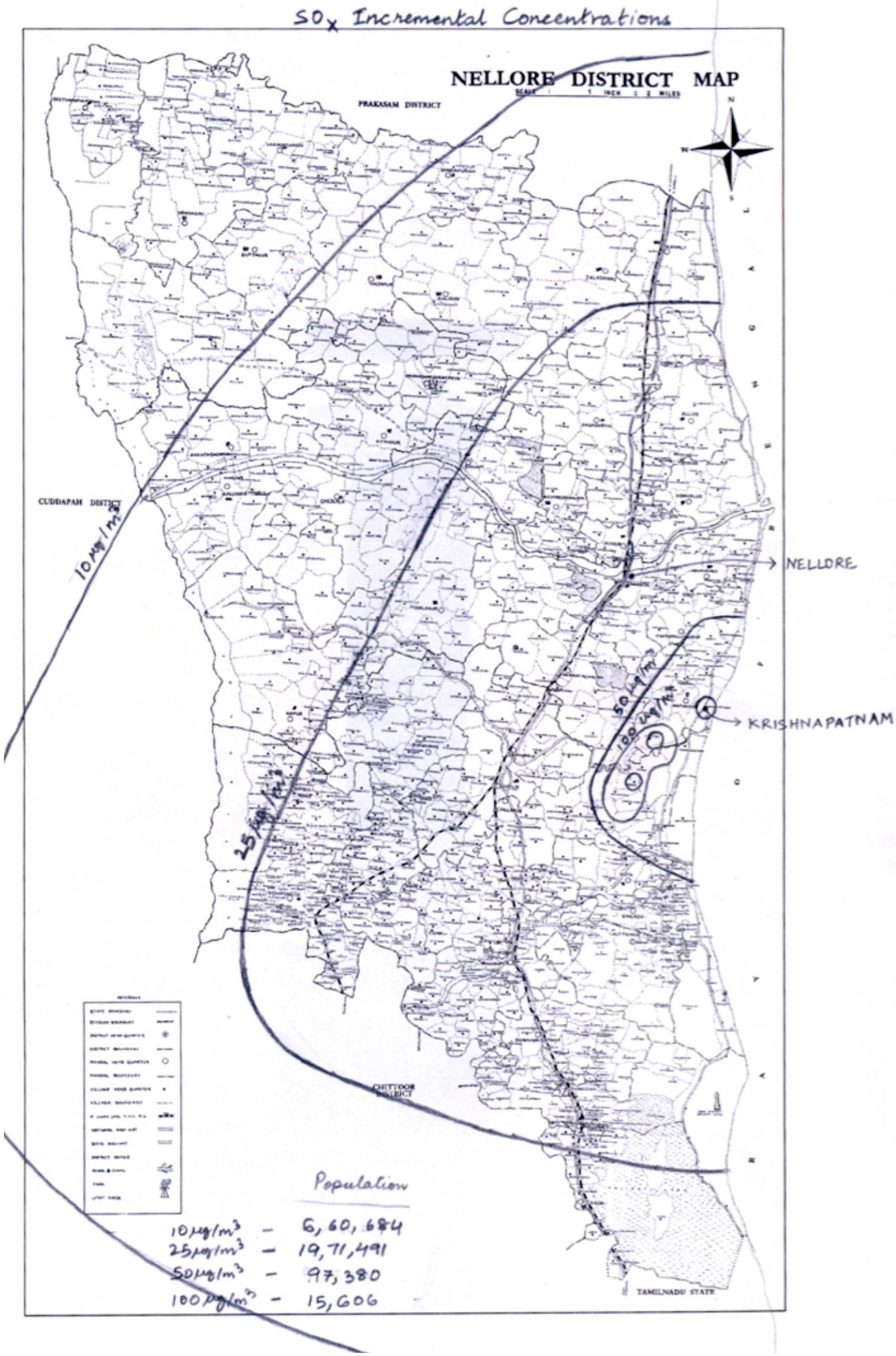
Figure adapted from original source:
District Administration, Collectorate, Nellore, Andhra Pradesh. Nellore District Map. Sri Potti Sriramulu Nellore District. Retrieved April 6, 2012, from http://nellore.nic.in/maps/NELLORE_District.JPG.

Appendix 2: Cerana Foundation isopleth maps showing projected increases in ground-level concentrations of PM_{10}, NO_X and SO_X.

PM-10 Incremental Concentrations




NOx Incremental Concentration
NELLORE DISTRICT MAP
PRAKASAM DISTRICT
CUDDAPAH DISTICT
CHITTOOR DISTRICT
TAMILNADU STATE
N
W
S
5 μg/m3
10 μg/m3
25 μg/m3
50 μg/m3
Population
5 μg/m3 - 8,28,164
10 μg/m3 - 17,51,827
25 μg/m3 - 1,10,075
50 μg/m3 - 19,652



SOx Incremental Concentrations
NELLORE DISTRICT MAP
PRAKASAM DISTRICT
CUDDAPAH DISTRICT
CHITTOOR DISTRICT
TAMILNADU STATE
NELLORE
KRISHNAPATNAM
10 μg/m3
25 μg/m3
50 μg/m3
100 μg/m3
Population
10 μg/m3 - 6,60,684
25 μg/m3 - 19,71,491
50 μg/m3 - 97,380
100 μg/m3 - 15,606

Appendix 3: Methodology for computing incremental ground-level concentrations for villages in Nellore District.

Developed by the Cerana Foundation. *(Notes added in italics.)*

1) Data from the available environmental impact assessments (EIAs) were consolidated into one worksheet of a spreadsheet. *(Note: These data included the names of the eight power plants for which EIAs were available, the capacity of each in megawatts, and the predominant wind direction at each location.)*

2) Classification of Power Plants into North and South Clusters.

    1. The location of the power plants is such that they can be grouped into two clusters: North and South.
    2. Similarly, the division has been extrapolated to all 24 proposed power plants.
    3. The North and South cluster capacities were totaled according to EIA reports and the list of power plants as published in Enadu paper. *(Note: The total capacity of the north cluster of proposed power facilities is 10,060 MW. For the south cluster, the total capacity is 17,055 MW.)*

3) Computation of North and South Cluster contribution at villages according to EIA reports.

    1. According to data given in the EIA Reports, the pollutant contributions of power plants in North and South Clusters at each village were computed. *(Note: Seven of the EIA reports provide baseline measurements of ambient concentrations of certain pollutants at a number of the villages near the site of a given proposed power facility, as well as estimates for the increase in ambient concentration at each village that would be attributed to the facility's emissions. The pollutants considered were suspended particulate matter, respirable suspended particulate matter (PM_{10}), sulfur oxides (SO_X) and nitrogen oxides (NO_X).)*
    2. The contributions from the North cluster and South cluster were totaled for each village.
    3. Each value was normalized with respect to total proposed North or South cluster capacities. For example, if x is the EIA reported north cluster capacity at a particular village, its normalized value was (Total Proposed North cluster capacity/ Monitored North cluster capacity) * contribution of North Cluster.

4) Final Predicted Increments for a Total Capacity of 27115 MW
    1. Electrostatic precipitator (ESP) efficiency is assumed to be 99.5%. Therefore, PM_{10} incremental values were multiplied by 5.
    2. All PM_{10}, SO_X, and NO_X values were divided by 1.25 for wind rose normalization.

Appendix 4: Questionnaire in English and in Telugu.

Grade: ______

Section or Medium: _______

Questionnaire

Your age: _______ Your date of birth: __(day)___(month) ____(year)

Your gender: ___ Female ____ Male

1. Have you ever had wheezing or whistling in the chest at any time in the past? ___ Yes
___ No

IF YOU HAVE ANSWERED "NO" PLEASE SKIP TO QUESTION 6

2. Have you had wheezing or whistling in the chest in the past 12 months? ____ Yes
____ No

IF YOU HAVE ANSWERED "NO" PLEASE SKIP TO QUESTION 6

3. How many attacks of wheezing have you had in the past 12 months?
____ None
____ 1 to 3
____ 4 to 12
____ More than 12

4. In the past 12 months, how often, on average, has your sleep been disturbed due to wheezing?
___ Never woken with wheezing
___ Less than one night per week
___ One or more nights per week

5. In the past 12 months, has your wheezing ever been severe enough to limit your speech to only one or two words at a time between breaths?
___ Yes
___ No

6. Have you ever had asthma?
___ Yes
___ No

7. In the past 12 months, has your chest sounded wheezy during or after exercise?
___ Yes
___ No

8. In the past 12 months, have you had a dry cough at night, apart from a cough associated with a cold or chest infection?
___ Yes
___ No

9. Have any of your relatives had asthma?
___ Yes
(If so, who? __________________)
___ No
___ Don't know

10. In your home, what fuel is usually used for cooking? ______________________________

(For example, you might say "wood," "LPG," "gober gas," "dung," "electricity," "kerosene," or some other answer.)

11. Do you smoke (cigarettes or bidi)?
___ Yes
___ No

12. Does anyone living in your home smoke (cigarettes or bidi)?
___ Yes
(If so, who? ______________________)
___ No

13. In the past 12 months, what kinds of farm animals or pets has your family kept at home?
____
____
____

14. What kind of house do you and your family live in?
___ A hut (traditional house)
___ A house with a tile roof
___ A house with an RCC roof (reinforced cement concrete)
___ A house with a roof of sheeting (e.g. metal or asbestos)

15. How often do heavy vehicles (such as buses, trucks, or tractors) pass through on the street nearest to your home?
___ Never
___ Seldom
___ Frequently through the whole day
___ Almost the whole day

16. What is the distance between your home and the nearest street?

___ Home is right next to the street
___ 10 m or less
___ 11 m to 50 m
___ 51 m to 100 m
___ 101 m to 200 m
___ More than 200 m

17. Are there buildings or plants between your home and the nearest road?
___ Yes
___ No

18. Does your family have a white ration card?
___ Yes
___ No

19. What is your father's occupation? ______________________

20. What is your mother's occupation? ______________________

అభిప్రాయ సేకరణ

School Code:
Subject:

వయస్సు:________ పుట్టిన తేది:____________ నెల:____________ సంవత్సరం:________

లింగము: ఆడ / మగ

మీరు ఏ ఊరిలో నివసిస్తున్నారు ________

మీరు ఎంత కాలము నుండి నివసిస్తున్నారు________

1. మీకు గతంలో ఎప్పుడైనా ఛాతిలో పిల్లికూతలు వంటివి గమనించారా ? అవును / కాదు
(మీ సమాధానం కాదు అయినచో 6వ ప్రశ్నకు వెళ్ళండి)

2. గత 12 నెలలో మీకు పిల్లికూతలు వంటివి మీ ఛాతి నందు గమనించారా? అవును / కాదు
(మీ సమాధానం కాదు అయినచో 6వ ప్రశ్నకు వెళ్ళండి)

3. గత 12 నెలలలో మీకు ఎన్నిసార్లు పిల్లికూతలు గమనించారు ?
ఎ) ఎప్పుడూలేదు బి) 1 నుండి 3 సార్లు సి) 4 నుండి 12 సార్లు డి) 12 కంటే ఎక్కువసార్లు

4. గడిచిన 12 నెలలో పిల్లికూతల వల్ల ఎన్నిసార్లు మీ నిద్రకు భంగం కలిగింది ?
ఎ) ఎప్పుడూ లేదు బి) వారానికి ఒక రాత్రి సి) వారానికి రెండు కంటే ఎక్కువ రాత్రులు

5. గడిచిన 12 నెలలలో పిల్లికూతల వల్ల శ్వాస మధ్యలో ఒకటి, రెండు పదాల కంటే ఎక్కువ మాట్లాడలేక పోవటం జరిగిందా ? అవును / కాదు

6. మీకు ఎన్నడైనా ఆయాసం/ఉబ్బసం వ్యాధి వచ్చిందా ? అవును / కాదు

7. గడిచిన 12 నెలలో వ్యాయమం/ఎక్సర్‌సైజ్ చేస్తున్నపుడు గాని లేక తరువాత గాని పిల్లికూతలను గమనించారా ? అవును / కాదు

8. గడిచిన 12 నెలలలో పొడి దగ్గు వచ్చిందా? (గళ్ళపడని దగ్గు అంటే రొంపగాని ఛాతివ్యాధితో గాని వచ్చు దగ్గు కాకుండా) అవును / కాదు

9. మీ బంధువులలో ఎవరికైనా ఆయాసం / ఉబ్బసం ఉందా? (ఉంటే ఎవరికి) లేదు / తెలియదు

10. మీ గృహము నందు వంటకు ఉపయోగించే ఇంధనం
ఉదా: వంట చెఱకు, గ్యాస్ (L.P.G), గోబర్ గ్యాస్, పిడకలు, కరెంట్, కిరోసిన్, ఇంకేదైనా

11. మీరు ధూమపానం చేస్తారా? (సిగరెట్/బీడి) అవును / కాదు

12. మీ ఇంట్లో ఉండేవారు ఎవరైనా ధూమపానం చేస్తారా? (ఐతే ఎవరు_______________?) అవును / లేదు

13. గడిచిన 12 నెలలలో ఎటువంటి వ్యవసాయ మరియు పెంపుడు జంతువులు మీ గృహము నందు కలిగి ఉన్నారు. _______________

14. మీ కుటుంబం ఎటువంటి గృహము నందు నివసించుచున్నారు?
ఎ) గుడిసె బి) పెంకుటిళ్ళు సి) మిద్దె (స్లాబు ఇల్లు)

15. మీ ఇంటి వద్ద ఉన్న రోడ్డు మీదుగా ఎన్నిసార్లు పెద్ద బండ్లు (ట్రక్కులు మరియు బస్సులు) వెళుతాయి ?
ఎ) ఎప్పుడూ లేదు బి) ఎప్పుడైనా సి) తరచుగా డి) రోజంతా

16. రోడ్డు నుండి మీ గృహము ఎంత దూరములో ఉన్నది _______________?
ఎ) రోడ్డుకు ఆనుకొనే ఉన్నది బి) 10 మీటర్ల కంటె తక్కువ
సి) 11 మీటర్ల నుండి 50 మీటర్లు డి) 51 మీటర్ల నుండి 100 మీటర్లు
ఇ) 101 మీటర్ల నుండి 200 మీటర్లు ఇ) 200 మీటర్ల కంటే ఎక్కువ

17. రోడ్డుకి మీ గృహమునకు మధ్య చెట్లు మరియు భవనములు ఉన్నాయా ?
ఎ) అవును బి) కాదు

18. మీ వద్ద తెల్ల రేషన్ కార్డు ఉందా ? ఉంది / లేదు

19. Father: _______________

20. Mother: _______________

Appendix 5: Photographs of study site and rural road.

The translator (in yellow and blue) asks survey questions out loud to students assembled in the courtyard of their school. Girls are sitting on the left, while the boys sit on the right. The students are recording their own responses on paper copies of the Telugu-language questionnaire.

Children walk along a typical paved road in a rural area of Nellore District. Buildings along this road include homes, businesses, and schools. Unpaved roads are also common in this area.