Vehicle Emissions and Health Impacts in Abuja, Nigeria

by
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ABSTRACT

Vehicle emissions are a significant contributor to ambient pollution, especially in urban areas. In general, developing countries experience higher levels of traffic-related pollution compared to developed countries due to the lack of pollution control measures. Since numerous studies document adverse health effects from vehicle emission exposure, there is a need for reducing exposure in the developing world. Despite this need, in Sub-Saharan Africa (SSA) air quality management is not considered a priority and there is little data on the actual impact of vehicles on air quality and health, and little is being done to control emissions. Abuja, Nigeria, a rapidly developing city in SSA, presents a unique opportunity to investigate the impact of transport-related pollution because of the lack of industry and other major sources of pollution. Monitoring of ambient hourly concentrations of CO, NO_2, and SO_2 took place at six major intersections in Abuja during morning, low-traffic hours and during afternoon, high-traffic hours. These concentrations served as a model of exposure for traffic wardens, a high exposure group. A survey on perceived health status and air quality was also carried out for 185 traffic wardens to link measured concentrations to health effects.

Concentrations of SO_2 were alarmingly high in all locations tested, exceeding both the 1-hour Nigerian and WHO 10-minute air quality standards in 43 out of 46 measurements. Carbon monoxide concentrations were also high, exceeding WHO 1-hour standards in 7 out of 43 trials, with an instantaneous range up to 184 ppm. Concentrations of both CO and SO_2 were significantly higher during the afternoon than during the morning. The number of traffic wardens reporting pollution-related symptoms was high, with 70% reporting at least one symptom. Of this number, the greatest number reported that their symptoms are worse during work (49%), the dry season (42%), and during late afternoon, high traffic (39%). In general, the results show that vehicle emissions are having a negative impact on air quality, and traffic wardens have a high prevalence of symptoms that possibly relate to and are exacerbated by exposure. Clearly, air quality management should be a greater priority in Abuja, and the effect of vehicle emissions on air quality and health should be studied further if public health is to be protected.

INTRODUCTION

Vehicle emissions represent a serious environmental health problem, which is expected to increase in significance as vehicle ownership increases globally. The United Nations estimates that over 600 million people worldwide are exposed to hazardous levels of traffic-generated pollutants (1989). Some of the worst pollutants, and those that are closely monitored in the United States, are nitrogen oxides, carbon monoxide, sulfur dioxide, lead, and particulate matter. According to the Environmental Protection Agency, vehicles account for 51% of carbon monoxide, 34% of nitrogen oxides and 10% of particulate matter released each year in the US (2007). Clearly, vehicle emissions are a major source of ambient air pollution that must be controlled if air quality is going to be maintained.

Many studies have documented adverse health effects associated with high concentrations of transport-related pollutants. Nitrogen oxides and sulfur oxides, for example, are associated with immune system impairment, exacerbation of asthma and chronic respiratory diseases, reduced lung function, and cardiovascular disease (Schwela 2000). Exposure to carbon monoxide can result in fatigue, headaches, dizziness, loss of consciousness, and even death at very high concentrations (Schwela 2000). Particulates are especially dangerous because they have been implicated in the development of lung cancer and higher rates of mortality (Schwela 2000). Lead is similarly dangerous as poisoning causes irreversible neurobehavioral consequences, such as decreased IQ and attention deficits, and death at high levels of poisoning (Schwela 2000). In addition to these pollutants, vehicle emissions contain volatile organic compounds (VOCs), a class of petroleum combustion by-products which includes many known and probable carcinogens and reproductive toxicants. VOCs are also hazardous because they can react with sunlight to form ozone, which exacerbates asthma and has other adverse respiratory effects (WHO 2000).

A number of epidemiological studies have similarly linked exposure to vehicle emissions with adverse health outcomes. For example, in the US, chronic exposure to vehicle emissions over 10 years decreased lung function among tunnel officers (Evans, 1988). A comparison of the prevalence of chronic bronchitis and asthma among street cleaners, a high exposure group, and cemetery workers, who acted as controls, found that exposure to vehicle pollutants in concentrations lower than WHO-recommended guidelines resulted in a significant increase in respiratory effects (Raaschou 1995). Moreover, a significant relationship between residence proximity to high traffic roads and prevalence of asthma and cardiovascular disease in children has been documented (Schwela 2000), in addition to a strong relationship between proximity to congested roads and respiratory morbidity in infants. There is mixed evidence for a relationship between exposure and low birth weight, preterm birth and birth defects (Sram 2005). Clearly, the public health impacts of exposure to traffic pollution are serious and diverse.

Developing Countries

In developing countries, motorization growth has been largely unchecked by environmental regulations, creating high levels of pollution (Han 2006). Traffic contributes more to ambient pollution in developing countries, accounting for upwards of 40-80% of NO_2 and CO concentrations (Fu 2001, Goyal 2006, Abbaspour 2004). This can partly be explained by the vehicle profile. Because of economic constraints, poorly maintained, older vehicles are often imported, leading to an automobile fleet dominated by a class of vehicles known as "super emitters" which release higher concentrations of harmful pollutants in comparison to properly maintained vehicles. In developed countries, these super emitters represent 10% of the vehicles on the road, yet generate 50% of emissions (Brunekreef 2005). In Mexico City, although these super emitters account for roughly 60% of the kilometers traveled, they are responsible for 90% of hydrocarbon and CO emissions and 80% of NO_x emissions (OECD 1999). In addition, low quality fuel, lack of traffic regulation and infrastructure, and lack of air quality enforcement contribute to the high levels of traffic-related pollution.

Ambient pollution is further compounded by the rapid urbanization of many developing countries. The global urban population reached 50% in 2008 and is expected to increase to 60% by 2030. This increase will be particularly pronounced in developing countries, in which 80% of the urban population will be living in 2030 (UNFPA 2007). Accompanying this rise in urban populations will be a fourfold increase in the number of motorized vehicles in cities by 2050, making transport-related pollution a hazard even in countries with overall low motorization rates (World Bank 2004). For example, in Chinese cities, concentrations of particulates and other transport-related pollutants are up to six times higher than WHO-recommended guidelines, even though China only has 8 vehicles per 1000 persons compared to 750 vehicles per 1000 persons in the US (Faiz 2000). Citizens of cities in the developing world, particularly in Asia and Africa, are therefore at great risk for exposure to hazardous levels of transport-related pollution.

Sub-Saharan Africa

Despite the risk associated with rapid urbanization, few studies focus on Sub-Saharan Africa (SSA) and there is very little data on the status of air quality and its impacts on human health. This is because air quality is not considered a priority given SSA's low level of economic development and high burden of infectious disease. In general, developing countries first focus on natural resource management, then water pollution, and finally air pollution as their economies progress (Dasgupta 2001). Since SSA is in the early phases of economic development, air pollution is given low priority and there is little investment in understanding the scale of the problem or its control.

Yet, that does not mean that air pollution is not a problem. In fact, there is reason to believe that exposure to transport-related pollutants in SSA cities may be considerably higher than in other parts of the world and, because of malnutrition and high prevalence of disease[1], the populations may be more vulnerable. In Benin, there is data that exposure to traffic pollutants, specifically polycyclic aromatic hydrocarbons, has led to comparatively higher levels of DNA damage in urban residents (Autrup 2006). Other studies in Ethiopia, Mozambique, and Kenya found significantly higher prevalence of asthma in urban school children exposed to traffic pollution compared to rural children.

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[1]In SSA, 203.5 million people, or roughly one third of the total population, are reported to be moderately to severely malnourished (FAO 2005). Malnutrition is associated with decreased immune system function and ability to fight off infections (Chandra 1994). The development of respiratory disease following exposure to vehicle emissions is likewise attributed to impairment of the respiratory system's ability to fight infection. Consequently, individuals with immune systems already weakened by malnutrition may be more sensitive to emissions and experience respiratory effects at lower exposure levels than those documented in industrialized nations. Also, malnourished individuals have low intake of antioxidant vitamins, which typically protect against pollution exposure (Romieu 1999). Exposed individuals in SSA, therefore, are much more likely to develop respiratory health problems.

Additionally, pre-existing health conditions, such as HIV, increases vulnerability to air quality associated disease. 24.5 million out of 38.6 million people living with HIV are in Sub-Saharan Africa (UNAIDS 2006). Since HIV leads to the development of AIDS and the inability of the immune system to fight infection, individuals are more susceptible to respiratory illness. Since exposure to traffic pollutants likewise leads to the development of respiratory illness due to decreased immune function, people with AIDS exposed to vehicle pollution will be even more likely to develop adverse respiratory symptoms since their immune systems are already weakened. Moreover, those individuals who develop respiratory effects are less likely to recover, due to severe immune system impairment, and may experience higher mortality rates.

(Bekele 1997, Mavale-Manuel 2004, Ng'ang'a 1998). In a small city in Ethiopia, individuals living closer to roads experienced more wheeze at levels comparable to those observed in developed countries with twice the traffic volume, resulting from the high proportion of super emitters (Britton 2005). Although the number of studies is limited, it does appear that urban residents in SSA have a high risk of health problems related to vehicle emissions. However, it is difficult to know the actual impact of traffic pollution on human health without further research.

Abuja, Nigeria

Abuja, the federal capital of Nigeria, is a new city with low industrial development and thus offers a unique opportunity to study the impact of vehicle emissions on air quality and health. In Abuja, it can be assumed that vehicles are the major source of ambient pollution at the local level as there are few domestic or industrial pollution sources. However, there is no air quality monitoring program in place to document the levels of pollution or identify individuals that are at risk for exposure.

Abuja is hailed as one of Africa’s few purpose built cities: planning began in the 1970’s and in 1991, Abuja became the official capital. The former capital, Lagos, was abandoned in part because of its severe pollution, overpopulation, and overall ineffective city planning (Taiwo 2005). Development was initially scheduled to take place in four phases in order to prevent environmental degradation and ensure sustainability. Although the development of Phase 1 is only 95% complete, Abuja’s estimated population of 5 million is already higher than the 3 million projected when all four phases are completed (WADSCO 2005, FCT-a). Yet, it must also be emphasized that this is only an estimate and the most recent Nigerian census reports a significantly lower population of about 800,000 (Nigerian National Bureau of Statistics). Regardless, Abuja is one of Nigeria's largest cities and is quickly growing with a per annum growth rate of 5% (FCT-a), putting its residents at high risk for exposure to transport-related pollution.

In addition to rapid urbanization, increased motorization puts Abuja at risk for high levels of vehicle emissions. According to the Vehicle Inspection Office, roughly 900 vehicles are registered per week in Abuja (Akoni 2008). Although there is no data on the total number of vehicles registered in the city, there are records on the number of vehicles in the country. In Nigeria, the total number of vehicles increased substantially from 38,000 to 1.6 million between 1950 and 1992 (Enemari 2001). The number of used vehicles imported from abroad is estimated to have represented 30% of the increase in vehicle numbers from 2001 to 2005 (Ajayi). Taking into account the increased vehicle registration in Abuja, the total increase in the number of vehicles in Nigeria, the likely proportion of super-emitters, and the concentration of vehicles in urban areas, it is likely that vehicle emissions in Abuja are very high by any standard.

Moreover, the fuel composition makes it likely that the vehicles in use in Abuja will release high levels of pollutants. Vehicle emissions are affected by fuel type, especially sulfur content. As sulfur content increases, the fuel efficiency decreases and emissions of sulfur oxides, particulate matter, and volatile organic compounds increase (World Bank 2003). In the US, gasoline has a standard of 15 ppm of sulfur, and in the EU, it has a standard of 50 ppm. The concentrations of sulfur in fuels in Nigeria most often range from 500-2,000 ppm, with a maximum allowable sulfur level of 5,000 ppm

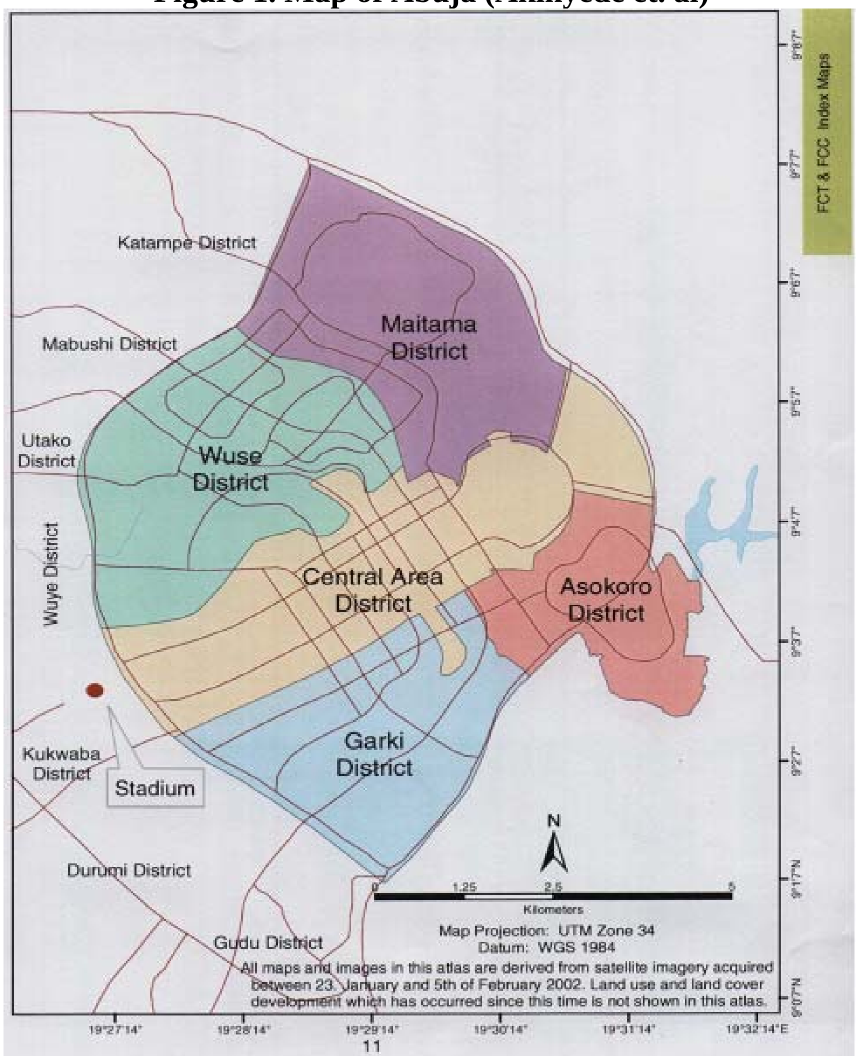
(UNEP 2007). Therefore, it can be expected that vehicles will release remarkably more pollution, especially sulfur oxides and particulates.

In order to protect air quality, the city of Abuja has adopted the Nigerian Ambient Air Quality Standards, comparable to those issued by the World Health Organization (see Table 1 in appendix), but these regulations are more or less symbolic in the absence of monitoring data and enforcement. In Abuja, as is the case across SSA, air quality is not considered a high priority and there is little data on ambient pollution levels. Without data, it is impossible to quantify the impacts of air pollution or determine whether control should be a priority, and if so, which strategies would be most effective. In this study, I will begin to characterize the level of transport-related air pollution in Abuja and the possible impact on health in order to assess the need for air quality control.

METHODS

Study Area

Figure 1. Map of Abuja (Akinyede et. al)



Abuja is 770km^2 located in central Nigeria within the Federal Capital Territory (FCT) (National Bureau of Statistics). The FCT experiences two seasons annually: the rainy season from April to October, characterized by moderate temperatures and high levels of precipitation, and the dry season, from November to March, characterized by extreme temperatures and low levels of precipitation. Between seasons, there is a brief

Harmattan caused by the North East Trade Wind, with intensified coldness and dryness creating dust and haze (FCT-b).

As a planned city, the overall road quality is very high and all main roads are paved. There are traffic lights at most intersections, though most do not work because of insufficient electricity. Instead, traffic wardens stand in the center of many intersections and direct traffic. Abuja has a public bus system, but in general most people rely on both 3-wheel and 4-wheel green cabs to move around the city. Mopeds and two-wheel motorbikes have been banned within the city (Murray 2006), but some continue to be used by military employees.

Abuja is divided into five major districts: Maitama, Wuse, Central Area, Asokoro, and Garki (Figure 1). The Central District is, as its name suggests, the center of the city and contains primarily federal buildings. Garki is known as the principal business district, Wuse the market area, and Maitama is considered to be the most expensive and exclusive residential area of the city. Asokoro is also somewhat exclusive and houses federal employees and serves as the main entry point into the city, with roughly 40,000 vehicles entering daily (FCT-b, Akoni 2008).

In each of the five districts, the most heavily congested intersection was selected for monitoring based on the volume of traffic, presence of traffic wardens, and even distribution throughout the city. These criteria were selected with the express purpose of documenting the highest pollutant concentrations in each district that also relate to traffic warden exposure. Altogether, five intersections representing the five districts were selected. A newly built overpass in Wuse was selected as a sixth location to comment on the effectiveness of this structural response to traffic congestion. Table 1 lists the six locations as well as their general characteristics.

Table 1. Characteristic Features of Study Locations

Site	*District*	*General Characteristics*
Moshood	Garki	Filling station, many commercial vehicles, especially taxicabs.
AYA	Asokoro	Heavy construction, heavy traffic into and out of the city, very dusty.
Wuse	Wuse	Heavily peopled, near entrance of principal marketplace. Heavy traffic
Secretariat	Central Area	Greenery, government buildings, illegal sidewalk markets. Wide intersection
British Council	Maitama	Filling station, few commercial vehicles. Moderate traffic.
Berger Junction	Wuse	New overpass, construction on embankments, very dusty.

Monitoring

Design

Levels of CO, SO_2, and NO_2 were monitored at each intersection one day a week for one hour during morning, low traffic hours (9:00A.M.-1:30P.M.) and one hour during afternoon, high traffic hours (3:45P.M.-7:30P.M). Monitoring times were chosen to capture the range of daily exposure for traffic wardens. In total, 3 to 4 morning and afternoon measurements were conducted at each location over the course of 5 weeks, beginning July 4th, 2007. Concentrations were averaged over the one-hour measurement period. The instantaneous high and low concentrations were also recorded for each hour and qualitative observations on the traffic density and type of vehicles were recorded in 5 minute intervals. Temperature, humidity, wind, and weather conditions were recorded at the start and end of each trial. Wind speed was recorded using the following qualitative classes: none, low, moderate, or high, and as either intermittent or constant. Each hour of monitoring was treated as an independent trial

Instruments

The Q-Rae Plus Multi-gas Monitor, PGM-2000/2020, was used to continuously measure and record NO_2 and SO_2 concentrations. Gases are measured by electrochemical sensors with a range of 0 to 20 ppm and a 0.1 ppm resolution. The sensor response time is 35 seconds for SO_2 and 25 seconds for NO_2. Its operating temperature is between -20^{o}C to 45^{o}C (-4^{o}F to 113^{o}F) and its operating humidity is between 0% and 95%. The Q-Rae Plus was calibrated on June 11th at Brown University using the Rae Systems 5.0 ppm calibration gases of NO_2 and SO_2.

The Q-Trak Plus IAQ Monitor, Model 8552 was used to continuously measure CO. The machine uses an electrochemical sensor with a range of 0 to 500 ppm, a resolution of 0.1 ppm, and a response time of 60 seconds. Its operating temperature range is between 5^{o}C and 45^{o}C (41^{o}F to 113^{o}F), and its humidity is between 5 and 95%. The sensor has an accuracy of ±3% or 3 ppm at calibration temperature, with an additional increase in .28% per ^{o}F change in operating temperature. Temperature (^{o}F) and humidity were also measured using the Q-Trak Plus machine. Calibration occurred in early June at Brown University using a 35 ppm calibration gas.

Recalibration at the suggested monthly interval was not possible for either machine due to the unavailability of calibration gases. Following the completion of the study, 3 months after initial calibration, the accuracy of the monitors was tested by comparing measured concentrations to known gas concentrations.

Analysis

For each location and time of day, the means and standard errors of the pollutants were calculated and a one-tailed, two-sample, unequal variance t-test was performed to determine if concentrations were significantly higher in the afternoon than in the morning, reflecting the higher level of traffic. Hourly concentrations were also compared against health-based standards (see Table 1 in appendix). In the case of carbon monoxide, the more conservative WHO standard was used because it would more appropriately protect Abuja residents, who may be particularly vulnerable to exposure.

Health Effects

Study Population

Traffic wardens, part of the Federal Capital Territory Area Command (FCTAC), were included in the study to link measured pollutant concentrations with health impacts. Wardens are the highest exposure group because they stand in intersections and direct traffic, so they are directly and frequently exposed to vehicle emissions. Thus, it is reasonable to expect their health status to directly reflect that level of exposure. There are roughly 300 active traffic wardens in Abuja who work on average 8 hours per day between the hours of 7am and 8pm, 5-7 days per week, with 2 weeks of vacation per year (Akoni 2008).

Questionnaire

A questionnaire was developed in consultation with the Abuja Environmental Protection Board (AEPB) to assess the health status of traffic wardens, the effects of traffic and climate on their health, and their opinions of air quality (see Appendix). The AEPB wrote a letter to the FCTAC explaining the usefulness of including wardens in the study and asking for permission. In order to ensure anonymity, only limited demographic information was allowed to be collected as part of the questionnaire: age, sex, diagnosed health conditions, and years worked. Also, questions on smoking status (current smoker, former smoker, or never smoked), ownership of a household generator, and cooking frequency were included in order to assess exposure to air pollution outside the workplace. The questionnaire included self reported chronic and acute health symptoms experienced at work, including: asthma attack, headache, coughing, shortness of breath, wheezing, body ache and fatigue, eye irritation, nausea, chest pain, sore throat, runny nose, and lightheadedness or fainting. The severity of the symptoms was further defined by asking whether the individual was taking medications, visited the hospital, or missed work. To understand the triggers or aggravators of symptoms, the questionnaire also asked about the effect of work on symptoms (improve, no effect, get worse), the effect of season on symptoms (worse in rainy season, worse in dry season, no change) and the effect of diurnal variations in traffic (worse during morning and high traffic, worse during afternoon and low traffic, worse during late afternoon and high traffic, no change). Lastly, the questionnaire asked two questions about wardens' perception of air quality in Abuja. Roughly 40 questionnaires were filled out during interviews with an AEPB member on site between July 4th and August 7th; the remaining questionnaires were delivered to the head of the FCTAC in mid-August and distributed to wardens. The FCTAC encouraged workers to fill out the questionnaires. Completed questionnaires were then collected by a member of the AEPB after roughly two months.

Analysis

Questionnaire results were coded and entered into a spreadsheet. The results were first separated by gender in order to assess differences in exposure variables and health status as might be confounded by gender roles, i.e. cooking. The mean and standard error for age, years worked, percent ownership of personal generator, cooking frequency, and prevalence of health conditions were calculated for each gender. A two-tailed, two-sample, unequal variance t-test was performed to determine if there was a significant difference between genders and whether the groups could be combined.

Reported symptoms were separated into two groups – smokers and non-smokers – because of the potential for smokers to have significantly greater health effects. For each group, the prevalence (number of reported cases per total population) was calculated for each reported symptom. Since it can be assumed that smoking aggravates respiratory conditions, a one-tailed, two-sample t-test was used to determine if smokers have significantly higher prevalence of symptoms. The remaining questions on work, diurnal, and seasonal effects on symptoms and opinions of air quality were reported by percent respondents.

Data collected on medication use, hospital visits, and work days missed was not tabulated because of concerns about the truthfulness of the answers. In general, the self-reported responses may not be accurate for assessment of the severity of symptoms because respondents either may not have access to medication or healthcare, or are discouraged from seeking medical attention. On many of the questionnaires, respondents wrote variations of “I only see doctor and discharge immediately”, meaning that seeking medical attention would result in being fired from their work. Similarly, workers complained in informal interviews about not being allowed the routine physicals or medicine they were promised by the police department, or not having the money to purchase medicine. Consequently, seeking medical attention or missing work would not necessarily correspond to the severity of symptoms.

RESULTS

Monitoring

Accuracy of Results

Three months after calibration, the instruments drifted such that NO_2 measurements were the least accurate at 2.5 - 2.6 ppm measured compared to the actual 5.0 ppm standard, SO_2 measured 4.6 ppm compared to the 5.0 ppm standard, and CO measured 39 ppm compared to the 35 ppm standard. Thus, it can be assumed that recorded NO_2 may be lower than actual concentrations, while the values for SO_2, while slightly more accurate, may still be lower than the actual concentrations, and the CO values may be slightly higher. Therefore, the reported concentrations should be interpreted with caution and serve as a preliminary finding on air quality.

Pollutant Concentrations

Average NO_2 concentrations were 0.1 ppm for all sites and times tested. During afternoon AYA and morning Secretariat monitoring, instantaneous NO_2 varied between 0 and 0.4 ppm, and during the mornings of Wuse, Berger Junction, and British Council, NO_2 varied between 0 and 0.2 ppm. The instantaneous range of NO_2 varied between 0 and 0.1 ppm for the remainder of sites and times tested. Because of the low resolution (0.1 ppm) of the NO_2 sensor, the results could not be further analyzed in terms of comparison of morning and afternoon values or in terms of differential risk between sites.

Because of the low accuracy and the limited precision, the NO_2 data will be excluded from further analysis.

Table 2. Average 1-Hour Ambient Gas Concentrations at Major Intersections

Location	*Time of Day*	*Avg CO (ppm)± SD*	*Range of Instantaneous CO (ppm)*	*Avg. SO_2 (ppm)± SD*	*Range of Instantaneous SO_2 (ppm)*
Moshood	Morning	24±4	3-122	0.4±0.2*	0-1.0
	Afternoon	32±10	3-182	0.9±0.3*	0.3-2.1
AYA	Morning	18±4	2-83	0.4±0.2	0.1-1.2
	Afternoon	38±20	2-184	1.0±0.6	0.1-2.9
Wuse	Morning	12±3	2-74	0.4±0.1	0-1.6
	Afternoon	16±6	0-83	0.4±0.1	0.1-1.3
Berger	Morning	14±3	0-100	0.4±0.1	0-1.6
Junction	Afternoon	19±8	0-158	0.5±0.2	0-2.3
Secretariat	Morning	12±1*	2-47	0.1±0.1*	0-0.4
	Afternoon	19±2*	3-67	0.3±0.1*	0-1.0
British	Morning	20±3	3-104	0.3±0.1*	0-0.9
Council	Afternoon	19±4	4-96	0.5±0.1*	0-1.3
Combined	Morning	16±5*	0-122	0.3±0.1*	0-1.6
	Afternoon	24±12*	0-184	0.6±0.4*	0-2.9

*Indicates afternoon concentrations significantly ($p<0.05$) higher than morning concentrations

In total, 20 morning and 23 afternoon CO readings were taken, and 22 morning and 24 afternoon SO_2 readings were taken. The number of trials differed because of equipment difficulties. In general, CO and SO_2 concentrations are significantly higher in the afternoon than in the morning, with an average afternoon CO concentration of 24 ppm versus 16 ppm and an average afternoon SO_2 concentration of 0.6 ppm versus 0.3 ppm (Table 2; p=0.01 CO, p=0.0 SO_2). Afternoon concentrations of SO_2 were also significantly higher at Moshood with 0.9 ppm versus 0.4 ppm (p=0.02), Secretariat with 0.3 ppm versus 0.1 ppm (p=0.01), and the British Council with 0.5 ppm versus 0.3 ppm (p=0.01). Afternoon concentrations of CO were significantly higher only at Secretariat, with 19 ppm versus 12 ppm (p=0.01).

Figure 2. Instantaneous and Average SO_2 Concentrations at AYA, 7/13 Morning

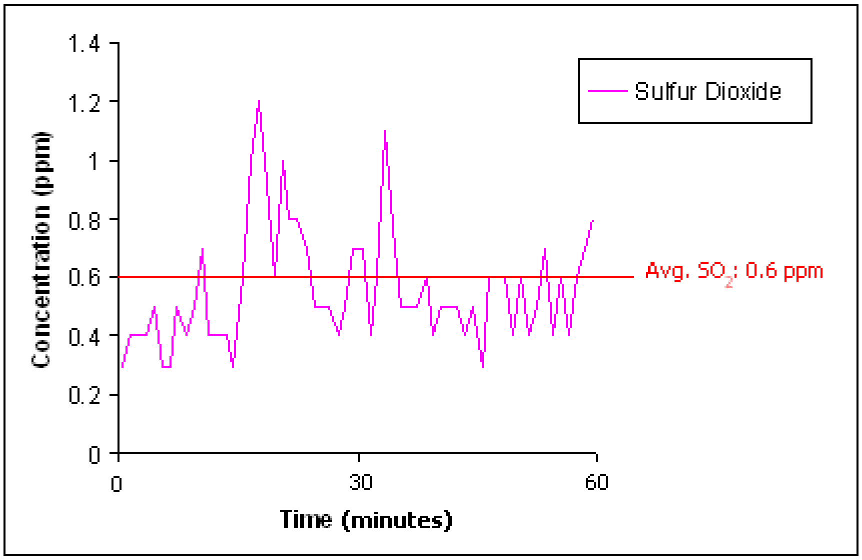


Figure 2 gives an example of instantaneous SO_2 readings compared to the 1-hour average.

The range of instantaneous concentrations of CO and SO_2 varied greatly at each site. AYA had the largest range in both CO and SO_2 values with 2 to 184 ppm and 0.1 to 2.9 ppm respectively. For example, during the morning reading for AYA on 7/13, SO_2 fluctuated over the course of the hour reaching 1.2 ppm, twice the recorded 1-hour average of 0.6 ppm, at roughly 15 and 30 minutes after monitoring began (Figure 2). The instantaneous readings appeared to be affected by the presence of super emitters and the direction of traffic flow. In general, concentrations spiked when poorly maintained, large vehicles passed near the monitor and when traffic speed decreased during turning or during queues.

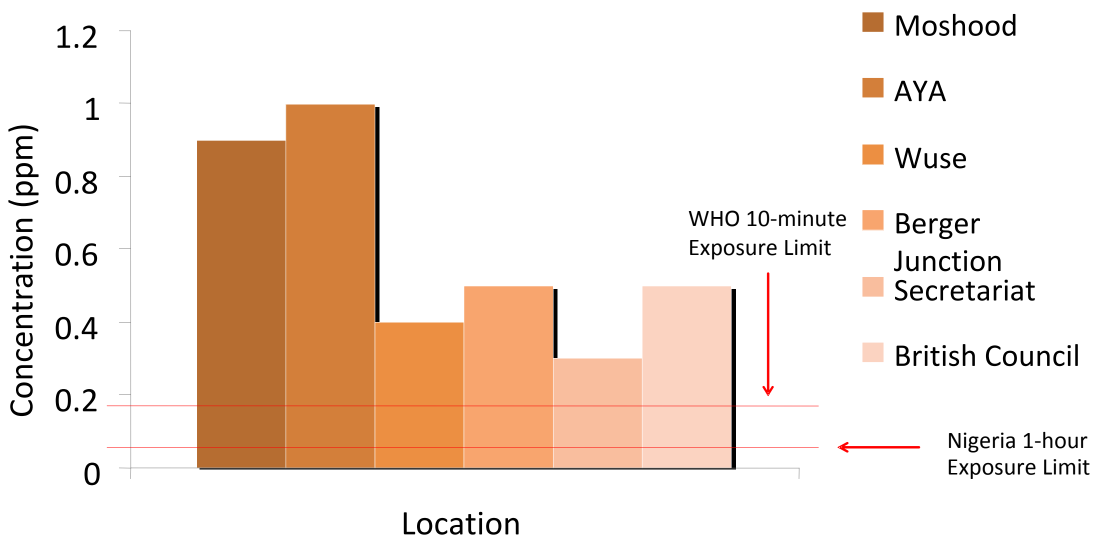
Table 3. Comparison of CO Concentrations to 1-hr Standard

Location	*Time of Day*	*Trials Exceeding CO Standard*
Moshood	Morning	1/3
	Afternoon	2/4
	Combined	3/7
AYA	Morning	0/3
	Afternoon	3/4
	Combined	3/7
Wuse	Morning	0/4
	Afternoon	0/5
	Combined	0/9
Berger Junction	Morning	0/4
	Afternoon	1/4
	Combined	1/8
Secretariat	Morning	0/3
	Afternoon	0/3
	Combined	0/6
British Council	Morning	0/3
	Afternoon	0/3
	Combined	0/6
Total	Morning	1/20
	Afternoon	6/23
	Combined	**7/43**

Table 3 lists the number of times the 1-hour average of CO exceeded the standard out of the total number of times the intersections were monitored

AYA and Moshood exceeded the CO standard most often at 3 out of 7 times. Berger Junction also exceeded the standard in one of its afternoon trials. In total, the CO standard was exceeded about 15% of the time, and all but one of the elevated trials occurred during the afternoon.

Figure 3. Average 1-Hour Afternoon Concentration of SO_2 at Major Intersections



The hourly SO_2 concentrations exceeded the Nigerian ambient air quality standard during all readings and all locations, except for 3 out of the 4 morning trials at Secretariat. On average, all intersections exceeded the SO_2 1-hour limit during afternoon monitoring (Figure 3). Both AYA and Moshood had average readings roughly 10 times the standard, while both Berger Junction and British Council had readings 5 times the standard. Wuse and Secretariat also exceeded the standard by a factor of 3 and 2, respectively. Additionally, the afternoon 1-hour concentrations exceeded WHO 10-minute exposure limit of 0.175 ppm for all locations, indicating that measured SO_2 levels are particularly hazardous.

Although not measured quantitatively, it is also important to note the observed levels of white and black smoke in the city because of their potential health effects. Both types of smoke are related to diesel engine combustion and particulate matter concentrations (Roemer 2001). Larger vehicles, especially tucks and bulldozers, release considerable amounts of black smoke. The smoke appeared to be greater during acceleration from rest; thus, when traffic direction changed there was a noticeable decrease in visibility. White smoke was emitted from many taxicabs and motorcycles, creating haze that similarly reduced visibility.

Questionnaires

Of the roughly 300 questionnaires delivered, 185 were returned for a return rate of about 60%. Sixteen were excluded from the analysis of the results because age and/or sex was not indicated. Respondents failed to answer different questions; therefore, the number of respondents is given for each question. Some of the questionnaires appeared to not have been filled out by the respondent alone as two colors of pen were used on the form. These questionnaires were included in the study, as it was impossible to tell whether they were in fact altered.

Table 4. Characteristics of Sample Population

	Female (n=69)	Male (n=97)
Age*, (Mean years ± SD)	29±6	31±7 (n=93)
Years Worked, (Mean years ± SD)	8±6 (n=67)	8±7 (n=90)
Smokers*, (%)	7	20
Personal Generator, (%)	44 (n=68)	49 (n=94)
Cooking Frequency*, (%)	(n=65)	(n=95)
Never	1	27
1-4 times/week	28	30
5 or more times/week	71	43
Diagnosed Health Conditions, (%)		
Asthma	6	3
Allergies	3	1
Cardiovascular Disease	1	0
Respiratory Disease (within past year)	6	8
Bronchitis (within past year)	0	3
Lung Cancer	0	1

*Indicates statistically significant difference (p<0.05) between males and females.

The study population included 97 males (58%) and 69 females (42%). Age ranged from 18 to 52, with an average of 30 years and a standard error of 0.5 years. Females were on average 29 years old (SD=6) and males were significantly older (p=0.03) at 31 years (SD=7). Twenty four of the respondents (14%) identified themselves as current or former smokers, and this number was significantly different between males and females (p=0.02). The average number of years worked was 8 years with a range from 35 to less than a year and a standard error of 0.5 years. Cooking frequency also differed significantly between males and females, with 71% of females reporting cooking 5-7 times per week compared to 43 % for males (p=0.0). Several of the male respondents who selected “Never Cook” also wrote in “My wife”, clearly reflecting the gender roles in cooking status. There were no significant differences between prevalence of diagnosed health conditions between males and females. Because of the significant differences in age, smoking habit, and cooking frequency, males and females were separated during the analysis of symptoms.

Table 5. Prevalence of Reported Respiratory Symptoms (%) by Sex and Smoking Status (95% Confidence Interval)

	Females (n=69)			Males (n=97)			Total (n=166)		
Reported Symptoms	Non-Smokers (n=64)	Smokers (n=5)	Combined (n=69)	Non-smokers (n=78)	Smokers (n=19)	Combined (n=97)	Non-smokers (n=142)	Smokers (n=24)	Combined (n=166)
Asthma Attack	3 (0-8)	0 (0)	3 (0-7)	1 (0-4)	0 (0)	1 (0-3)	2 (0-5)	0 (0)	2 (0-4)
Headache	38 (25-50)	60 (0-100)	39 (27-51)	46 (35-57)	58 (33-82)	48 (38-59)	42 (34-50)	58 (37-80)	45 (37-52)
Coughing	25 (14-36)	20 (0-76)	25 (14-35)	21 (11-30)	53 (28-77)	27 (18-36)	23 (16-29)*	46 (24-67)*	26 (19-33)
Shortness of Breath	0 (0)	0 (0)	0 (0)	1 (0-4)	0 (0)	1 (0-3)	1 (0-2)	0 (0)	1 (0-2)
Wheezing	2 (0-5)	0 (0-76)	1 (0-4.3)	1 (0-4)	0 (0)	1 (0-3)	1 (0-3)	0 (0)	1 (0-3)
Body Ache/Fatigue	34 (22-46)	80 (24-100)	38 (26-49)	31 (20-41)	42 (18-67)	33 (23-42)	32 (25-40)	50 (28-72)	35 (28-42)
Eye Irritation	14 (5-23)	0 (0-76)	13 (5-21)	17 (8-25)	5 (0-16)	14 (7-21)	15 (10-22)*	4 (0-13)*	14 (9-19)
Nausea	2 (0-5)	20 (0-76)	3 (0-7)	0 (0)	5 (0-16)	1 (0-3)	1 (0-2)	8 (0-20)	2 (0-4)
Chest Pain	20 (10-30)	40 (0-100)	22 (12-32)*	9 (3-15)	16 (0-34)	10 (4-16)*	14 (8-20)	21 (3.3-38)	15 (10-21)
Sore Throat	6 (0-12)	20 (0-76)	7 (1-14)	10 (3-17)	0 (0)	8 (3-14)	8 (4-13)	4 (0-13)	8 (4-12)
Runny Nose	13 (4-21)	60 (0-100)	16 (7-25)	18 (9-27)	11 (0-26)	16 (9-24)	15 (9-22)	21 (3-38)	16 (11-22)
Lightheadedness or Fainting	8 (1-15)	20 (0-76)	9 (2-16)	5 (0-10)	0 (0)	4 (0-8)	6 (2-10)	4 (0-13)	6 (2-10)
Number of Symptoms per Individual	1.6 (1.2-2.1)	3.2 (.37-6.0)	1.8 (1.3-2.2)	1.6 (1.2-2.0)	1.9 (1.3-2.5)	1.7 (1.3-2.0)	1.6 (1.3-1.9)	2.2 (1.5-2.8)	1.7 (1.4-2.0)

Table 5 lists the prevalence of the traffic wardens' reported air quality-related symptoms separated by both gender and smoking status. A 95% confidence interval was calculated for each group to make comparisons. The average number of symptoms per individual was also calculated. *Indicates statistically significant difference ($p<0.05$) between groups.

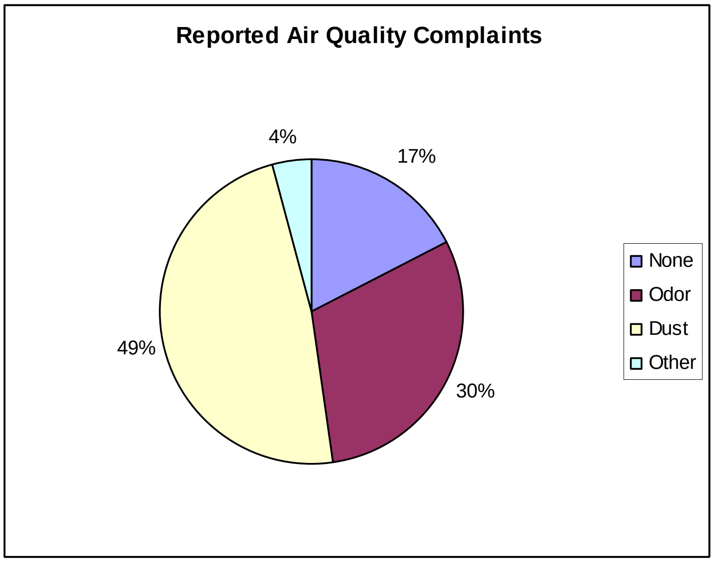
In general, reported health problems were very high for traffic wardens, with 70% (n=115) of individuals listing at least one symptom. This number was slightly higher in males (71%) than in females (67%), but this difference is not significant (p=0.8). Only prevalence of chest pain (p=0.05) differed significantly between males and females. On average, individuals reported 1.7 symptoms. Smokers reported having more symptoms (2.2) compared to non-smokers (1.6), but this was not statistically significant (p=0.06). Coughing is the only symptom that had a significantly higher prevalence in smokers (46%) versus non-smokers (23%) (p=0.02). Since the number of female smokers was small, they were excluded from within-gender comparisons. In males, only coughing was significantly higher in smokers (53%) versus non-smokers (21%) (p=0.01). The highest prevalence was reported for headaches (45%), followed by body ache and fatigue (35%), and then coughing (26%). The lowest prevalence was reported for shortness of breath (1%), wheezing (1%), asthma attack and nausea (2%).

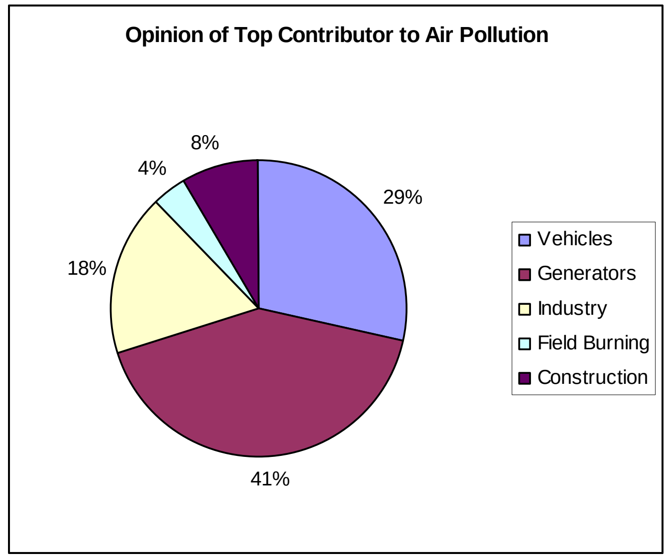
Table 6. Reported Effects of Work, Season, and Traffic on Symptoms

	% Respondents
Effect of Work (n=109)	
Symptoms Improve	30
Symptoms Get Worse	49
No Effect	21
Effect of Season (n=110)	
Dry	42
Rainy	30
No Effect	28
Effect of Traffic (n=108)	
Morning, high traffic	17
Afternoon, low traffic	11
Late afternoon, high traffic	39
No Effect	33

Of the 115 respondents reporting symptoms, 109 answered the question on the effect of work on their symptoms. Roughly half of respondents (49%) said that their symptoms get worse during work, while 30% said they improve, and 21% had no effect. 42% of 110 respondents reported that their symptoms are more severe in the dry season, 30% rainy, and 28% reported no effect. The greatest percentage of respondents reported that symptoms were worse during late afternoon, high traffic (39%) followed by no effect (33%).

Figure 4. Opinions on Air Quality in Abuja





In total, 79% of respondents (n=130) reported air quality complaints. Dust was the most comment complaint, made by 94 individuals (49%), followed by odor with 59 individuals (30%). A small percentage of individuals (4%) marked other as a complaint. One hundred and fifty seven individuals gave their opinion on the top contributor to air pollution in Abuja. Of that number, 41% (n=65) believed generators to be the main contributor, and 29% (n=45) believed vehicles to the largest contributor. Industry was ranked third at 18% (n=28), followed by construction at 8% (n=13) and field burning at 4% (n=6).

DISCUSSION

As the first pilot study on the impact of vehicle emissions on air quality and health conducted in Abuja, the data does not provide conclusive evidence on what is happening but does provide some insights into what issues may require further investigation.

It appears that transport-related pollution is in fact a problem in Abuja. Levels of sulfur dioxide were alarmingly high for all sites studied, exceeding the 1-hour standard for all afternoon trials. CO concentrations were also in the double-digits for all average concentrations, although they only exceeded standards in 7 trials (Table 2). Although the accuracy of the NO_2 monitoring is questionable, concentrations were similarly high at 0.1 ppm at all locations, compared to the 0.1 ppm WHO standard. In general, levels of pollution corresponded with levels of traffic with significantly higher concentrations occurring during afternoon rush hours. The concentrations also fluctuated greatly depending on the vehicle composition and speed. Generally, higher concentrations were observed with commercial vehicles, including taxis, trucks, and occasionally public buses, and during traffic queues. Commercial vehicles, therefore, might be the most effective first target for emission reduction.

AYA had the greatest concentrations of measured pollution out of all sites studied. This is because as the primary road into and out of the city, it also has the largest traffic volume per day and the most congestion. A study on CO_2 levels in Abuja similarly found that concentrations were highest in AYA out of the sites tested and peaked during morning and afternoon rush hours, corresponding with the highest levels of traffic (Akpan et al.). The long queues with idling cars and slow moving traffic may also explain CO and SO_2 concentrations, as slower moving vehicles emit more pollution (Ntziachristos 2000).

The high level of commuting traffic overall may result from Abuja's social and economic situation. Abuja has one of the most expensive costs of living in Nigeria; consequently, a large portion of individuals cannot afford to live within the city and instead commute daily (Murray 2007). This adds to the excessive levels of transport-related pollution witnessed in the city.

The SO_2 and CO concentrations at the newly constructed overpass, Berger Junction, were also high. SO_2 concentrations exceeded standards during all trials and CO exceeded the standard in one of the afternoon trials. Thus, although the overpass was meant to decrease congestion, pollution is still high in this area. This, along with the fact that the roads in Abuja are also of good quality, yet intersections had high levels of pollution, illustrates that structural responses to congestion, such as road maintenance, overpasses, and possibly even functioning traffic lights, may not alone be successful in decreasing pollution. Instead, the quality of the vehicles themselves as well as the fuel composition must be addressed.

Health Implications

The large percentage of traffic wardens reporting at least one symptom (70%, n=115), as well as the high prevalence for many of the reported symptoms implies that the general health status of wardens is poor and may relate to exposure. Similar studies conducted in India and Taiwan have shown significantly higher prevalence of symptoms in traffic workers occupationally exposed to vehicle emissions compared to controls

(Chen et al 2002, Attarde et al 2005). For example, a study on toll-booth operators in Taiwan found significantly higher prevalence of headaches (44.4%) compared to controls (Chen et al 2002), which is comparable to the prevalence of headaches reported in this study (45%). However, because a control group could not be obtained for this study, it is impossible to analyze the health risk of exposure or determine whether traffic wardens have significantly higher prevalence of symptoms compared to the general public. Therefore, to explain the potential health impact on traffic wardens, the health implications of the measured exposure will be discussed and linked to reported symptoms.

The high concentrations of both SO_2 and CO have obvious health implications. As has been documented by many studies, SO_2 exposure is associated with reduced lung function, difficulty breathing, eye irritation, and other adverse effects, while CO has neurobehavioral and cardiovascular effects, such as headache, dizziness, and heart palpitations (Schwela 2000). The WHO 1-hour guidelines were developed to protect sensitive subjects from health outcomes: because sulfur dioxide exceeded that standard during almost all monitoring trials, it is likely exposed individuals exhibit symptoms. Not surprisingly, then, traffic wardens reported a high prevalence of SO_2 related symptoms, such as runny nose (16%, n=27), chest pain (15%, n=25), coughing (26%, n=43), eye irritation (14%, n=23), and sore throat (8%, n=13).

Additionally, high concentrations of sulfur dioxide may indirectly cause health problems through particulate formation. Both sulfur dioxide and nitrogen dioxide can interact with other compounds in the air to form particular matter (WHO 2000). Considering the alarmingly high levels of SO_2 measured, and the black and white smoke observed throughout the city, the concentrations of PM are likely to be dangerously high. Since particulate matter has been linked to a multitude of adverse health effects and even mortality (Schwela 2000), the measured SO_2 concentrations may be especially dangerous.

Although the 1-hour CO concentrations only exceeded the standard in 7 out of 43 trials, the health implications may still be great when taking into account chronic exposure. The NAAQS has an 8-hour recommended limit of 9ppm exposure to CO; in other words, over the course of a normal work day, average exposure should not exceed 9ppm. However, assuming that morning concentrations are in fact the lowest daily exposure levels, afternoon concentrations are the highest, and all other concentrations fall within that range because of slow atmospheric decay of CO (El-Fadel 2008), the 8-hour average can be estimated to be within that range of values. In that case, wardens and individuals in all locations would be exposed to unsafe levels of CO over the course of a day. Moreover, chronic exposure to CO below the standard is associated with a host of neuropsychological responses, such as lethargy, headaches, difficulty concentrating, and poor memory (Maynard 2002). The symptoms traffic wardens most frequently reported may relate to this chronic exposure: 75 individuals (45%) reported headaches and 58 reported (35%) body ache and fatigue.

The high instantaneous values of CO and SO_2 observed may also have serious health implications, even in locations where average concentrations are lower. For example, although the morning of Berger Junction has an average 1-hour CO concentration of 14 ppm, well below the 1-hour standard, it has a range of up to 100 ppm (Table 2). Elevated levels of CO and SO_2, even for acute exposure lasting less than 15 minutes, has been associated with a range of adverse symptoms, especially in individuals with underlying health conditions. Exposure to high, short-term concentrations of SO_2 has been linked with triggering asthma attack and even death in asthmatic individuals, while CO has been linked to myocardial infarction in individuals suffering from cardiovascular disease (Schwela 2000). Of the wardens studied, a minority of individuals were at elevated risk for adverse health effects with 1% reporting cardiovascular disease and 4% reporting asthma (Table 4), yet this may not reflect the actual prevalence since individuals are discouraged from seeking medical attention and do not receive regular checkups. Of the asthmatic individuals, about half reported having a work-related asthma attack within the past year. Clearly, these individuals may be at extreme risk for adverse health effects and should be protected.

The response to the questions on work, traffic, and seasonal effects on symptoms further illustrates the health implications of exposure. Roughly half of respondents (49%) said that their symptoms got worse during work, which can be expected given the pollution levels. However, it is important to note that 30% said that their symptoms actually improve during work. This may relate to a misinterpretation of the question, or, based on informal interviews, wardens may have selected this answer because they were afraid of being punished for answering that there were negative impacts of their jobs or they felt that their income enables them to buy medication, which improves their health. The effect of time of day and traffic on symptoms supports the monitoring data, as the majority of respondents reported that symptoms were worse during late afternoon, high traffic (39%), which corresponds with the higher pollutant concentrations measured. Because dry season data is not available, the question on the effect of season highlights the possible seasonal variation of pollution. The greatest percentage of respondents

(42%) reported that their symptoms are more severe in the dry season. This implies that documented concentrations may actually be lower than what is observed in the dry season, which is supported by similar monitoring studies. For example, Mexico City, which likewise experiences two distinct seasons, found strong seasonal variations in SO_2 and particulates with the highest levels occurring during the dry season, particularly with thermal inversion (Bangdiwala et al. 1997).

The concentrations of CO and SO_2 in this study have important health implications not only for exposed traffic wardens, but for the general public. Typically, informal street markets occur at busy intersections during rush hours, which expose a large population to traffic emissions. Street markets were present at Secretariat, AYA, and at Wuse during the evening, with AYA having one of more populous markets. Moreover, street vendors frequent high traffic intersections, working both on the sidewalk and walking through the intersections during slow traffic. Street vendors, therefore, may be at high risk of developing health effects, which has been documented by a study in India (Chantanakul 2006). Traffic-related pollution may also adversely affect commuters themselves. Significantly higher concentrations of CO and SO_2 have been documented in vehicles during rush hour versus the ambient air (Han 2006). Considering the elevated ambient levels documented in this study, in-vehicle concentrations may be extremely hazardous. The health impacts of exposure, therefore, may be particularly severe so it is important to collect more data and in turn control vehicle emissions.

Policy Implications

Based on the pollution levels and health implications detailed in this study, it is important to initiate a monitoring program and to develop policies to reduce emissions and protect health. Some of the more common and effective ways of reducing emissions are reduction of sulfur content in fuel, mandated emission control technology, and increased taxes to incentivize individuals to purchase cleaner vehicles and fuels. Of course, these may be beyond the financial means for many in Nigeria and the economics and feasibility of any suggested policy recommendations need to be fully understood.

Sulfur reduction is arguably the most effective means of reducing pollution in Abuja, as it is a prerequisite for emission control technology. The sulfur content of fuel in Nigeria ranges from 500-2,000ppm, with a maximum allowable sulfur level of 5,000 ppm (UNEP 2007). If this concentration is reduced to 150 ppm, not only would the emissions of SO_2 be decreased, but also CO, hydrocarbons, and NO_2 from gasoline vehicles equipped with catalytic converters and PM from all types of diesel vehicles would be decreased. Even lower sulfur content of 50 ppm allows for the introduction of technology to diesel vehicles to further reduce SO_2 and NO_2 emissions. Near zero sulfur content (~10ppm) allows for increased NO_2 and PM control through even greater technology implementation (Blumberg 2003). The most basic catalytic converters can only be employed in gasoline vehicles if sulfur content is below 1,000 ppm and in diesel vehicles if sulfur is below 500 ppm (UNEP 2007), which represents a considerable reduction from current levels. Consequently, mandated emission control technology is not reasonable unless the fuel content is first changed.

Economic incentives, which have been useful in other cities, may be less effective for Abuja. Economic controls have been proven successful in Singapore, where auctioning of certificates to purchase vehicles and congestion pricing has reduced pollution (Willoughby 2000). Yet, this may not be realistic for Abuja where pollution is not only caused by the excess of vehicles, but the poor quality fuel and vehicles in use. Moreover, the most recent increase in fuel prices in June 2007 led to public backlash and a fuel strike, which created a fuel shortage that completely immobilized Abuja as well as rest of Nigeria (BBC 2007). Thus, economic constraints must be balanced with the necessity of transport to stimulate the economy, which makes taxing difficult. Additionally, even if taxes are implemented, it is still likely that poor quality fuels and vehicles will still be purchased on the informal market, as has happened in other SSA countries (Georgiades 2006). This makes economic control of pollution particularly challenging.

In general, government actions are largely not viable in the short term given both the lack of government and public support and the lack of funds. Although sulfur reduction and control technology should be implemented, this could only occur if there is first data supporting the change, which will take a long term investment of resources. In the short term, other actions may be taken to control pollution and protect health, which will be discussed in the following section.

Suggestions

Because of the difficulties in enacting general vehicle emission technology and maintenance requirements, emissions policy should first target commercial vehicles and enforce maintenance and scrapping of older vehicles. Commercial vehicles, especially taxis and trucks, were observed to emit more black and white smoke and were associated with higher levels of SO_2 and CO. Also, they are more likely to travel longer distances per day than private vehicles, and thus burn more fuel per day than private vehicles. Therefore, reducing emissions in commercial vehicles will likely have a significant impact on vehicle emissions overall. In order to prevent backlash, the government should work with the Road Traffic Workers union and educate them about the health consequences of pollution and the benefits of control. The argument for emissions reduction could also be presented in terms of cost reduction from better fuel efficiency. Commercial vehicles for big businesses, such as Coca Cola[2] and Pepsi, should be targeted first since they are more likely to have the capital to comply with testing and maintenance, and may be valuable partners in improving air quality. Overall, this must be executed while ensuring that mobility and income are not drastically affected.

In order to respond to the immediate threat of ambient pollution to health, traffic wardens should be educated and protected against vehicle emissions. Wardens should be supplied with simple protective gear, such as face masks to shield against large particulate inhalation. Similar studies on traffic police and health effects in India have noted success in significantly reducing the prevalence of symptoms by requiring police to wear masks (Attarde 2005). Moreover, the rotation work schedule should be organized to reduce constant exposure to high pollution intersections. For example, wardens should

[2] The branch manager of Coca Cola expressed interest in improving vehicle maintenance and even mentioned that he had tried working with the traffic worker union in the past. If the AEPB or another organization can step in and foster a relationship between Coca Cola and other big business and smaller commercial vehicle operators, while providing the environmental and health evidence, then air quality control policy may gain the support necessary to be enacted in the city. Air quality and tailpipe emission data is crucial for making the argument to reduce emissions, as even the Coca Cola manager believed that sulfur content in fuels is very low, so he would not expect there to be significant pollution.

work at AYA at most one day per week, and be placed in lower-traffic areas for the remaining days. High risk individuals, such as asthmatics, should not be assigned to areas with extreme pollution like AYA, and their health should be monitored closely to respond to acute symptoms if they arise. Anti-oxidants may similarly be useful for reducing vulnerability to respiratory diseases, as studies in the US have found it to be protective against exposure to ozone (Romieu 1998), and several studies in Nigeria have documented the effectiveness of ascorbic acid in decreasing lead poisoning in filling station attendants, a high exposure group (Ademuyiwa 2004).

Additionally, a public awareness campaign linking air quality to health would be useful in gaining public and government support for pollution control and making air quality a real priority. High exposure groups, especially traffic workers and filling station attendants, should be educated about the health effects of air pollution and when to seek medical attention. Moreover, residents living near construction sites and other areas with high dust should be educated about the health effects of particulate matter and ways they can protect themselves and their homes (i.e. sealing windows). The general population should also be educated about air pollution and how to improve air quality and protect their health, with a clean vehicles campaign linking vehicle emissions to health, and maintenance and fuel efficiency to reduced costs of traveling. There are many potential partners for this campaign, such as the Road Traffic Workers union, Coca Cola and/or Pepsi Manufacturing, JMG Generators, UNEP, World Health Organization, and USAID.

Future Research

Future efforts should focus on generating dependable and long-term air quality data, especially documenting seasonal variations, in order to analyze the effects of policy and predict public health impacts. Monitoring should be carried out during the dry season and, if possible, fixed monitoring stations should be set up throughout the city. Monitoring data would be beneficial to determining the long-term effects of traffic on air quality and health, as well as the effectiveness of control measures by analyzing pollution trends. Future monitoring should also be used to calculate pollutant dispersion, so that modeling can be established to predict exposed populations.

Once monitoring has been established, it is important to quantify the public health impact of air pollution by conducting local epidemiological studies. Data from hospitals can be used to link admissions and deaths from air pollution to daily air quality. This can then be useful in creating scenarios that project the health benefits of increased emissions control, as well as the expected health degradation from increased motorization. Additionally, GIS mapping of predicted pollution and surrounding population density would be useful in identifying high risk areas.

The health status of traffic wardens should be further characterized as a preliminary investigation into the health effects of exposure. Traffic wardens should have their blood lead levels and CO blood and respiratory levels tested to evaluate the extent of exposure. Moreover, their respiratory status can be evaluated by studying their forced expiratory volume and comparing this to controls. The questionnaires should also be edited and re-administered to wardens to ensure reliability and administered to a control group to determine risk of exposure. Research should also include noise monitoring at intersections, which can be expected to be high based on observation.

Many studies have found that chronic exposure to high levels of traffic noise significantly increases the risk for cardiovascular diseases and death by myocardial infarction. (Babisch 2000, Fogari 1994, Davies 2005). Considering that air pollution alone has been linked to increased risk of cardiovascular mortality and morbidity (Schwela 2000), traffic police are at especially high risk of cardiovascular effects as they are exposed to two significant risk factors.

In addition to research on transport-related pollution, studies should focus on the impact of personal generators on carbon monoxide levels and health effects. Given that 50% of wardens own personal generators, and that the majority (41%) consider generators to be the top contributor to pollution in Abuja, there may be a great health risk because of generator-related pollution. Studies on indoor air quality and personal exposure would also be useful in calculating daily exposure for individuals and assessing overall health risk.

CONCLUSION

This study shows that transport-related pollution in Abuja is indeed significant with possibly severe health consequences. Without intervention, it is likely that air quality will only deteriorate as the city continues to grow. The AEPB should thus recognize air quality management as a priority and work to prevent further environmental degradation by adopting effective policy, such as targeting high-emitting commercial vehicles. As a whole, Nigeria should work to improve fuel quality through sulfur reduction and adopt more stringent vehicle import requirements and enforcement. Moreover, this research suggests that traffic wardens are at great risk for contracting air pollution associated illness, and their health should be further studied. Immediate action should be taken to minimize individual chronic exposure by implementing shift rotation and through educating wardens about health effects and when to seek medical attention. Hopefully, this study will generate interest and additional research on the impact of vehicle emissions on air quality and health in Abuja and other SSA cities, and ultimately inspire a plan for air quality management.

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APPENDIX

Table 1. Ambient Air Quality Standards of SO_2, NO_2, and CO

Compound	Health Effects	WHO (2005) Guideline Value (ppm)	Nigerian Ambient Standard (ppm)2	Averaging Time
Carbon monoxide	Headache, weakness, dizziness, fainting, confusion, and nausea	90 50 26	- - 35	15 min 30 min 1 hour
Nitrogen Dioxide	Aggravation of asthma and allergies, coughing, shortness of breath, increased respiratory infections	0.10	0.04-0.06	1 hour
Sulfur Dioxide	Change in lung function, difficulty breathing, aggravation of respiratory diseases, eye irritation	0.175 -	- 0.1	10 min 1 hour

Air Quality and Health Questionnaire

Please fill in the questionnaire completely and honestly. Your answers are anonymous and will be kept private. For all questions, Y and N mean Yes and No. Please tick one of them. For questions with blank spaces (__), write in your response. For questions with boxes, tick inside the box next to your answer. Your responses will be helpful in reducing air pollution & protecting your health. **Thank you!**

Age: ____ **Sex**: M F **Occupation**: _________ **Hours worked/week**: _____

Starting date of employment: ____________
Month/Year

Do you smoke? Y N

If No, have you ever smoked for as long as one year? Y N

Does anyone in your household smoke? Y N

1. Do you have (or have you had in the past year)any of the following health conditions:
Select as many conditions as you have been diagnosed with within the past year.

- ☐ Asthma
- ☐ Allergies
- ☐ Cardiovascular disease
- ☐ Respiratory infection: times/year: _____
- ☐ Bronchitis: times/year: _____
- ☐ Lung Cancer

2. Do you have (or have you had in the past year) any of the following symptoms:
Select as many symptoms you have felt within the past year. The symptoms should not be caused by a cold you had at the time.

- ☐ Asthma attack: times/year: _____
- ☐ Headaches
- ☐ Coughing
- ☐ Shortness of breath
- ☐ Wheezing
- ☐ Body weakness/fatigue
- ☐ Itching/irritated eyes
- ☐ Nausea
- ☐ Chest pain
- ☐ Sore throat
- ☐ Runny nose/sneezing
- ☐ Light headedness/fainting

3. Are you taking (or have you taken in the past year) any medications for any of the above symptoms or conditions? Y N

4. Have you visited the hospital for any of the above symptoms/conditions? Y N

If Yes, number of days at hospital/year: _________

5. Have you missed work because of any of the above symptoms/conditions? Y N

If Yes, number of days missed/year: _________

6. How do your symptoms change while at work? ☐ Improve ☐ No change ☐ Get worse
If your symptoms get better while at work, tick Improve. If there's no change, then tick No Change. If you feel more sick while at work, tick Get Worse, then answer questions 6a and 6b.

6a. If they get worse, do they improve 1-2 hours after leaving work? Y N
6b. If No, do they improve overnight or over the weekend? Y N

7. How do your symptoms and conditions change with season?
If you feel worse in the dry season, tick dry season. If you feel worse in the rainy season, tick rainy season. If there's no difference, tick no change.

- ☐ More frequent and severe in dry season
- ☐ More frequent and severe in rainy season
- ☐ No change with season

8. How do your symptoms and conditions change with time of day and traffic?
If you feel worse during a certain time of day and level of traffic, tick that response. If you feel the same throughout the day, tick nochange.

- ☐ More frequent and severe in the morning during high traffic
- ☐ More frequent and severe in the afternoon during low traffic
- ☐ More frequent and severe in the late afternoon during high traffic
- ☐ No change with time of day and traffic

9. Does your household have a personal generator? Y N

If Yes, how many hours/week does it run? ______

10. How often do you cook at home? ☐ Never ☐ 1-4x/week ☐ 5-7x/week

11. Do you have air pollution complaints? Y N
What is your opinion of Abuja air pollution? If you think there are no problems with air pollution, tick N. If you think that there are problems and it could be improved, tick Y and then tick whatever complaints you have.

If Yes, what are they? ☐ Odors ☐ Dust in air ☐ other: _____________

12. What do you believe are the top three contributors to air pollution in Abuja?
Write 1, 2 and 3 in the box next to what you believe are the number 1, 2 and 3 contributors to pollution. If you choose other, please write in what you believe is the other contributor.

- ☐ Industry
- ☐ Generators
- ☐ Field burning
- ☐ Construction
- ☐ Vehicle emissions
- ☐ Other: ____________________