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# Health Consequences of Deteriorating Indoor Air Quality: A Case of Michika Local Government Area of Adamawa State, Nigeria.

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**ABSTRACT:** Air pollution is linked with many of the United Nations Sustainable Development Goals. Strategies aiming at the improved air quality interact directly with climate mitigation targets, access to clean energy services, waste management, and other aspects of socio-economic development. Indoor air quality is not solely associated to rural-settlement configurations where fossil fuels are combusted indoors for cooking, lighting, or keeping the home warm when there's a drop in climate. But it's also an environmental and health issue that affects all and sundry. Globally, 43% of households, over 2.9 billion people rely on solid fossil fuels (coal) for heating and cooking. In developing countries in Sub-Saharan and Asia where these fuels are predominantly used by women who are customarily responsible for cooking, and their young children are most exposed to resultant health consequences of indoor air pollution as combustion of these means of fuels affect the status-quo of their health primarily because they spent most times indoors with their children and sometimes with the elderly. Michika Local Government Area of Adamawa State Nigeria is a typical Sub-Saharan African region were fossil fuels are used for everyday life and mostly indoor. This study assessed indoor air quality among selected land uses such as market, school, residential, and a controlled spot in Michika Area of Adamawa, Nigeria. Particularly, it examined indoor air quality variation in the heavily built areas, industrial areas, and control sites areas in Michika. The experimental research was employed with the aim of quantifying the level of indoor air quality and also compare it with the WHO's permissible limits. In order to achieve this feat, indoor air quality variables such as $NH_3$, $NO_2$, $SO_2$, $H_2S$ $CO_2$ and $PM_{10}$ and $PM_{2.5}$ were quantitatively gathered in the field using standard methods and equipment such as The Gasman auto sampler to monitor indoor air quality in houses and enclosed spaces. Data obtained were analyzed using averages, ANOVA, Pearson's correlation, cluster analysis and Factor analysis. Across the studied locations there were of course differences in results outcomes as it also reflects the land use configurations of the overall study area. Overall, there is a recorded high content of carbon monoxide ($CO_2$) as recorded in Moda followed by Watu and with mean values of 1.76 ppm and 1.50ppm respectively, while the lowest concentration of $CO_2$ was recorded in the Control site with a mean value of 1.18ppm. The range of $SO_2$ in the present study is above FME recommended level of 0.10ppm. The range is also within WHO's 24hrs allowable limit of 20ppm, the concentration of nitrogen dioxide ($NO_2$) varied significantly among the different locations ($F = 30.540$, $p<0.05$). The concentration of ammonia ($NH_3$) is ranged from 0.04 to 0.06ppm. The contents of atmospheric particulate matters (PM), $PM_{2.5}$ and $PM_{10}$also varied among the selected locations. For $PM_{2.5}$, it value ranged from 0.18 to 0.27μg/m$^3$ which is slightly above the threshold of 0.25μg/m$^3$ recommended by FME, mostly for ambient indoor air quality in Bazza and Watu areas. The range of $PM_{2.5}$ is within WHO's limit of 20μg/m$^3$ for 24hrs mean concentration. Result of

ANOVA showed that the concentration of $PM_{2.5}$ varied significantly among the various locations ($F = 10.758$ $p<0.05$). Furthermore, for $PM_{10}$, it value ranged from 0.16 to 0.26μg/$m^3$which is also slightly above the threshold of 0.25μg/$m^3$ recommended by FME, mostly in Moda and to some extent Bazza/ Watu. These areas have increased concentrations of $PM_{10.}$ The range of $PM_{10}$ reported in the present study is within WHO's limit of 24hrs mean concentration of 50μg/$m^3$. Also, result of ANOVA showed that the concentration of $PM_{10}$ varied significantly among the various locations ($F = 9.880$ $p<0.05$). For a cohesive sustainable indoor air quality to be achieved, the Federal, State and Local Government must: Sensitize the local populace about the dire health effect of indoor air pollutions, provide Solar powered home lightening and warming technologies that would replace firewood and coal warming systems as they tend to be the main culprit for (CO) Carbon-Monoxide emissions, and reduce use of wood for cooking by replacing with gas bottle burners (Gas Cooker). If these policies can be established and enforced in the grass-root level, then the incidences of indoor air pollution will be drastically reduced and curbed.

**Keyword:** Indoor Air Quality | WHO | Permissible Limits | SDGs | Air Quality Variables

# I. INTRODUCTION

Air is an important component of the atmosphere that supports life. A good quality air is essential for healthy living. Also, good quality air is useful in aiding the breathing processes in living things. Apart from its usefulness to humans directly, a good quality air is also useful as a component of the environment to all forms of life including plants and animals that are integral aspect of the ecosystem (Mannucci and Franchini, 2017). Clean air is a basic requirement for life and healthy living. According to Ana, Morakinyo and Fakunle (2015), the quality of air in homes, offices, schools, day care centres, public buildings, health care facilities and other private and public buildings where people spend over 80% (3/5) of their time daily is crucial for healthy living and people's well-being. In spite of the essentiality of air for human survival, a contaminated air however, constitutes some risks to human health resulting in death, disability and other related respiratory problems (Birnbaum, 2015; Mannucci and Franchini, 2017). Research by World health Organization in 2017 revealed that about 4.3 million deaths in the world per year results from breathing elevated levels of indoor smoke from dirty fuel. In the world today, indoor air quality (IAQ) has been considered as a critical safety and health issue affecting human existence on earth. As a result of its health implications, it has become one of the most important aspects that environmentalists, academics and even the general public is taking consideration on (Ibrahim, 2015). Given the fact that humans spends majority of their daily hours indoors, good indoor air quality and comfort is of high criticality. Apte and Salvi (2016) stated that there are at least sixty sources of household air pollution, and these vary from country to country. Indoor tobacco smoking, construction material used in building houses, fuel used for cooking, heating and lighting, use of incense and various forms of mosquito repellents, use of pesticides and chemicals used for cleaning at home, and use of artificial fragrances are some of the various sources that contribute to household air pollution or indoor air pollution. Also, Key factors that influence the level of indoor air quality include humidity, temperature, chemical pollutants and sources, ventilation, and biological sources (e.g. dust mites, mold, pollen, etc). The mere presence of people in a building can significantly alter indoor air quality (Ana et al., 2015). The National Health and Medical Research Council (NHMRC) (1996) cited in Ana et al., (2015) defined indoor air as 'air within a building occupied by people of varying states for a period of at least one hour'.

Buildings covered by this definition include residential buildings, offices, public buildings, homes, restaurants and schools among others (Ana et al., 2015). According to Birnbaum (2015), around 3 billion people cook and heat their homes using open fires and simple stoves burning biomass (wood, animal dung and crop waste) and coal. As a result, over 4 million people die prematurely from illness attributable to the household air pollution from cooking with solid fuels. Also, more than 50% of premature deaths among children under 5 are due to pneumonia caused by particulate matter (soot) inhaled from household air pollution. Additional 3.8 million premature deaths annually from non-communicable diseases including stroke, ischaemic heart disease, chronic obstructive pulmonary disease (COPD) and lung cancer are attributed to exposure to household air pollution. Indoor air pollution is present in virtually every indoor space, with the exception of strictly controlled and sterile spaces in pharmaceutical, medical and research facilities. Indoor pollutants may originate from human activities, building materials and carpets; they may also penetrate from outdoor environments by forced ventilation, diffusion or infiltration (Anyanwu, 2011). One of the major sources of household air pollution, especially in developing countries, is fuel used for cooking as well as heating practices. Homes from developed countries and many houses in the developing world use electricity, natural gas, or clean LPG (Clean liquefied petroleum gas) for cooking, whereas houses in rural communities and some houses of the developing world use biomass fuel for cooking (Apte and Salvi, 2016). Thus, humans are inevitably exposed to these pollutants, considering the amount of time spent indoors, but the influence of the pollution on human health may vary, depending on age, sex, nutritional status, physiological conditions, and individual predisposition (Ana et al., 2015). There is increasing evidence linking indoor air pollution to increased risk of respiratory tract infections, exacerbations of inflammatory lung conditions, development of chronic obstructive lung disease, cardiac events, stroke, eye disease, tuberculosis, cancer and hospital admissions especially in women and children who are the most exposed (Lin et al., 2008).The issue of indoor air pollution remains a serious problem in developing countries (Apte and Salvi, 2016). This is because most developing countries, on the other hand, use stones, bricks, concrete, and cement to build their houses.

Although the use of air conditioning is on the rise in warmer developing countries, most houses rely on natural ventilation through open windows and shutters. Overcrowding and increased industrialization have led to housing within close vicinity of industries and heavy traffic-dense roads. These conditions among several others result in indoor air pollution. In many developing countries, biomass fuel is the most commonly used accounting for more than one – half of domestic energy and as much as 95% in lower income areas. Globally, 3 billion rely on biomass (wood, charcoal, crop residues and animal dung) (WHO, 2012; 2017).However, there is evidence that in some countries, the declining trend of household dependence on biomass has slowed, or even reversed, especially among the poorer households (Sinton and Weller, 2003). According to Nepal Health Research Council (NHRC, 2015), solid fuel is a principal source of energy used for domestic purposes in low and middle income countries and that household air pollution mainly IAP is a major risk factor associated with causing Chronic Obstructive Pulmonary Diseases (COPD) in adult and acute respiratory Infection (ARI) in children. Low and Middle income countries (LMICs) are the main users of solid biomass for cooking and heating (NHRC, 2016). Nigeria like other developing countries is faced with several environmental, social and economic challenges such as inadequate electric power supply, poor waste disposal system, air pollution, water pollution and noise pollution among others (Stanley, Mbamali, Zubairu et al., 2010; Ana et al., 2015). Most households in Nigerian cities operate small capacity fossil fuel electric power generators for electricity supply (ECN, 2009). A study carried out by Stanley et al., (2010) revealed that small household generators in Nigeria operate an average of 6 h daily, while the average distance of generator away from building was 5.6 m. These alongside poor ventilation influence the quality of indoor air in the households (Okafor, Hassan and Hassan, 2008). Another major source of pollution in the indoor environment is household combustion of coal or biomass for cooking and heating. It is estimated that more than 50% of the world's population depends on animal dung, wood, crop waste or coal to meet their most basic energy needs (WHO, 2005). Firewood combustion for cooking is a common practice in most rural communities of developing nations including Nigeria. Its use as an energy source is widely reported to impinge on the environment, particularly the quality of air and the health of populations especially women (Ana et al., 2015).

In Michika, solid fuels are often burnt by most households in three-stones cooking fires (Three stones in triangle) with a fire in the centre or simple traditional stoves with incomplete combustion-producing concentrations of particulate matter, carbon monoxide and other organic compounds-observed during a reconnaissance survey of the study area. Although the world has moved to cleaner technologies with increase in awareness campaign of health effects of indoor air pollution (IAP), the fact remains that the population of Michika is typically a rural type with majority depending on biomass fuel for cooking and heating. This has no doubt conformed to the research findings by World Health Organization (WHO) in 2016 which revealed that about 3 million people of the world depend on solid biomass for cooking and heating with rural areas constituting the majority users. Also, Michika's population has continued rise accompanied with expansion on socioeconomic activities which have consequences on the environment, especially to indoor air quality. Exposure to indoor air pollutants (IAP) from the combustion of solid fuel and other sources mostly from diverse land uses haveresulted in several diseases in including acute respiratory infections (ARI) and chronic obstructive pulmonary disease (COPD), lung cancer (from coal smoke) asthma, cancer of the nasopharynx and larynx tuberculosis, and low birth weight, diseases of the eyes like cataracts and blindness (WHO 2007; Birnbaum 2015). This study will thoroughly assessindoor air quality of Michika from different land uses as well as identify the risk factors in line with acceptable threshold by WHO and suggest mitigation strategies of reducing vulnerability to the risks.

## II. STATEMENT OF RESEARCH PROBLEM

World over, it is suggested that people spend more than 90% of their daily life in indoor environments either inside office, school, college, commercial, industrial buildings or inside residential houses (Datta, Suresh, Gupta et al., 2017). Study suggests that the concentration of pollutants in the indoor environment is much higher than that of the urban outdoor ambient environment (EPA, 2013). Despite this, the indoor air quality received considerably less attention than that of the outdoor air quality until last decade. Poor indoor air quality can be especially harmful to vulnerable groups such as children, elderly, and those with cardiovascular and chronic respiratory diseases viz. asthma (Datta et al., 2017). Several studies have been carried out to examine indoor air quality and pollution from diverse sources and its effects on human health (Ana, Fakunle and Ogunjobi, 2013; Ibrahim, 2015; Ana et al., 2015; Apte and Salvi, 2016; Mannucci and Franchini, 2017; Bo, Salizzoni, Clerico et al., 2017). The study carried out by Ibrahim (2015) limited its investigation to office buildings neglecting other areas like residential buildings, market place, school and church that can impact on indoor air quality. Also, the study by Mannucci and Franchini (2017) was basically descriptive and highlighted the health effects of ambient air pollution in developing countries.

In Nigeria, Ana et al., (2015) studied indoor air quality and risk factors associated with respiratory conditions. The study relied on results of previous studies to show the effect indoor air pollution has on air quality and human health. It did not examine the Indoor Variation in indoor air quality among different land uses. Also, Ezezue and Diogu (2017) assessed indoor air quality in residential buildings in Enugu, Nigeria. The study only assessed air quality among different residential building neglecting other land uses and did not assess the temporal pattern in indoor air quality. Other studies (Ana, Fakunle and Ogunjobi, 2013; Birnbaum, 2015; Apte and Salvi, 2016 Bo et al., 2017) examined the effects of indoor air pollution on different pollutants and health problems such as respiratory symptoms. Other studies examined exposure to emissions from a single source like firewood cooking stove (Ana, Adeniji, Ige et al., 2012). Studies across different land uses have been documented. Some of the studies include assessment of indoor air quality in dormitories (Wang, Liu and Xu (2010), classrooms (Li, Cheng and Yan, 2008), offices (Li et al., 2008; Huang, Mo, Sundell et al., 2013), academic institutes (Huang, Li, Zeng et al., 2016), shopping malls (Yamashita, Kume, Horiike et al., 2011; Xiong, Zhang, Huang et al., 2016), hotels, photocopy centres (Lee, Dai, Chien et al., 2006), guesthouses, entertainment places, and other types of spaces (Zhu and Liu, 2014; Norbäck, Hashim, Hashim et al., 2017).

A critical look at these studies revealed that a good number of them did not examine the spatial dimension of indoor air quality and few of the studies were carried out in the rural areas. The fact remains that most of these studies are associated often with urban environment with little attention given to the rural areas where some of the highest concentrations of indoor air pollution occur involving women, especially pregnant ones and children as well as the elderly. Nevertheless, the study carried out by Dattaet al., (2017) made an attempt by examining the spatial and temporal pattern of indoor air quality in three non-residential (two commercial/official ($O_1$ and $O_2$) and one educational/office (A1). The study further examined indoor air pollution from the month of June to July. The shortcoming of the study is that it was carried out in the urban area and it did not identify the sources of indoor pollutants. Some of the few studies carried out in the rural areas did not look at the spatial pattern of indoor air pollution. For instance, Parajuli, Lee and Shrestha (2016) assessed indoor air quality and ventilation assessment of rural mountainous households of Nepal. **The study assessed indoor air quality from two sources improved cooking stove (ICS) and traditional cooking stove (TCS) neglecting other available sources and did not assess air quality from diverse land uses like restaurant and drinking bar where cigarette smoking among others result in IAP**. Meanwhile the findings revealed that, the mean concentration for Co and PM for ICS and TCS are 27.11 ± 14.24ppm and 825.4 ± 730 $\mu g/m^3$ with significant correlation ($P<0.0001$) and 36.03ppm and 1336 $\mu g/m^3$ (36.03 ± 19.068 and 1336 ± 52.8) with significant correlation ($P<0.481$) respectively. From the overall sample, the CO and $PM_{2.5}$ concentrations is reduced by 29.9% respectively. The ventilation analysis results shows more than 80% deficit in ventilation as per the minimal rate of ventilation as prescribed by American Society of Heating, Refrigerator and Air conditioning Engineers (ASHRAE).

## III. AIM AND OBJECTIVES OF THE STUDY

The study is aimed at examining the health implications of Indoor Air Quality Decline (Pollution) among different land uses and assesses its implications on health of inhabitants of Michika Local Government Area of Adamawa State, Nigeria.

This aim is to be achieved through the following set objectives.

1. To examine the health implications of indoor air pollution on the inhabitants, and also comparing the survey results obtained with the permissible limits of WHO
2. To identify the various indoor air quality parameters in the three land uses (Residential, Market, and School)
3. To examine indoor air quality concentration among the three land use.

## IV. RESEARCH HYPOTHESES

The following hypothetical questions will be tested and answered:

1. Is there any significant difference in the concentration of indoor air quality among homes and enclosed spaces on the different land uses?
2. Is there any significant difference between the indoor air quality of the area against the WHO and FME acceptable limit?

## V. STUDY AREA

### Location

Michika Local Government Area is situated in North Eastern axis of Adamawa State between latitude $10^0$ 36 'N - $10^0$ 40 'N and longitude $13^0$ 21'E - $13^0$ 35'E (Google map data 2011). See figure 3. It shares boundary with Madagali Local Government Area to the North, Lassa (Borno State) to the West, Republic of Cameroun, to the East and Mubi South Local Government Area to the South. It has a land area of about 142,199km$^2$. Michika Local Government is divided into 7 districts, 16 electoral wards and 145 polling units, with a total population of 155,238 according to 2006 population census.

### Climate

Michika area of Adamawa state experiences both the wet and dry seasons that characterized the thematic climatic state of Nigeria. Though it is amount of rainfall is not commensurate with what is obtainable in the South-Eastern part of Nigeria. Due to it closeness to the Sub-Saharan Desert regions dry seasons tend to be longer and acute as the dry season lasts for a minimum of five months (November to March) while wet season spans from April to October though scanty and mostly light showers. The mean annual rainfall in Michika ranges from 900 – 1050mm (Adebayo 2004). Generally, planting of crops begin earlier in the mountainous area, thus; forming the back-drop that postulates that, the Michika Community is agrarian in nature. As agriculture is the mainstay of about 80% of the inhabitants of the Local Government Area comprising largely women and children who operate subsistence farming system and often involve in harnessing common property resources such as fuel wood and water for domestic use and fulfillment of other Local economic needs like petty selling of the wood and charcoal to support local bread bakers and local liquor "burukutu" brew. The study area was selected for study because of the heterogeneity of the population and the practice of mixed cooking system both traditional and modern, the cooking styles, spatial and temporal variations and household characteristics which resemble other parts of the country. To the best of my knowledge, there is no such study conducted in the area. The settlements of Michika are low income earners by economic status (Adebayo, 2004). Season plays a significant role in determining rate of exposure to IAP by the inhabitants'.

For instance, during the dry season occasioned by harmmatan, the people burn a lot of woods and agricultural residues to produce a warm condition inside and outside of house. This is to enable the people cope with the cold weather in the mornings and evenings when the cold effect is high. This practice of burning to produce heat plus the normal burning associated with cooking predispose the populace much more in the dry period (late November to February ending) when the weather is relatively cold than the wet period to exposure to IAP from both natural and man-made (burning) sources. Common health complaints during this period are catarrh and cold, cough, allergic eyes sneezing, nausea, etc resulting from emission of Carbon monoxide, Sulphur oxide, Nitrogen oxide and particulate matter from both natural and man-made sources. Not only that but people who have Asthma and Pneumonia also complain more than any other period, of the triggering effects of cold weather and dust particles on them which is in line with the testimonies given by local health attendants interviewed during preliminary studies in the area. Another important factor that cannot be neglected that affect exposure to IAP in the study area is ventilation system in households. Majority of the households have kitchens that are round huts roofed as thatched huts and having relatively small windows that makes it difficult for smoke to escape during cooking.

## POPULATION AND DEMOGRAPHIC CHARACTERISTICS OF THE STUDY AREA

Michika has an estimated area of 914km and a population of 227,216 as at the 2006 (FGN/NPC Census). The population has continued to grow through birth rates, and low death rates and immigration into the area. Of course population explosion also leads to anoverstretch of available resources. With the population growth rate of Michika it currently stand at a 9.3% increase (NPC, 2012).

Michika has a strong agrarian based economy. The original dwellers are mostly farmers and hunters as it is their traditional means o livelihood and sustenance. To this end, economic activities in Michika simply reflects the average socio-economic status quo of its' indigenous populace. Fossil fuel combustion which often leads to wood, and coal burning to cook and keep warm as a result of the drop in temperature in the North Eastern Part of Nigeria has often been the main cause of increasing IAP in Michika. Secondary VOCs from cigarettes is also a culprit in the increasing variances of IAP in Michika homes in a bid to keep populace warm. The choice of the study area is hinged on its heterogeneity in population and existence of mixed cooking systems both traditional and modern coupled with the fact that the area is semi-arid located in the north east where it is seasonally affected by harmmattan dust that increase the levels of exposure to particulate matter aside those resulting from cooking and heating using fuel wood. Thus, this study will focus on the study area to assess the risk factors of indoor air pollution and their health effects with a view to making some useful suggestions on how to minimize exposure to the risk factors.

**Fig.1: Map of North-Eastern Nigeria Showing Michika in Adamawa State (The StudyArea)**
**SOURCE:** Adamawa State Ministry of Land and Survey (2006)

## VI. LITERATURE REVIEW

### Assessment of indoor air quality across different cooking sources and land uses

Parajuli et al., (2016) examined indoor air quality and ventilation assessment of rural mountainous households of Nepal. Result showed that the mean CO and $PM_{2.5}$ concentration for improved cooking stove (ICS) and traditional cooking stove (TCS) were 27.11ppm and 825.4µg/$m^3$ and (27.11 ± 14.24ppm and 825.4 ± 730.9µg/$m^3$) with significant correlation and 36.03ppm and 1336µg/$m^3$ with significant correlation respectively. From the overall sample, the mean CO and $PM_{2.5}$ concentration was reduced by 29.9% and 39%, respectively. The ventilation analysis result showed more than an 80 percentage deficit in ventilation as per the minimal rate of ventilation as prescribed by American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE). In the United Arab Emirates, Fadeyi, Alkhaja, Sulayem et al., (2014) assessed indoor environmental quality conditions in elementary schools' classrooms.

Datta et al., (2017) studied indoor air quality of non-residential urban buildings in Delhi, India. The study was conducted in two office buildings and one educational building in Delhi during pre-monsoon. $CO_2$, $PM_{2.5}$ and VOCs were measured inside each building at every 5 min interval between 9:30 AM and 5:30 PM for 5 days every week. The average $CO_2$ concentration in both office buildings (1513ppm and 1338ppm) was recorded much higher than the ASHRAE standard. Ductless air-conditioning system couple with poor air-circulation and active air-filtration could be attributed to significantly higher concentration of $PM_{2.5}$ in one of the office buildings (43.8μg $m^{-3}$). However, there was significant variation in the concentration of different pollutants at different locations in a building. Among different non-residential buildings, significantly lower concentration of all pollutants was recorded in the educational building ($CO_2$: 672ppm; $PM_{2.5}$: 22.8μg $m^{-3}$and VOC: 0.08ppm).Emuren and Ordinioha (2017) studied the physico-chemical parameters of indoor air quality in a tertiary hospital in South–South Nigeria. The assessed pollutants were present in the ambient air of most of the study sites but were within the regulatory limits. The concentration of $NO_2$ in the study sites ranged from 133μg/$m^3$in the immunisation clinic to 151μg/$m^3$ in the gynaecology ward, with a mean concentration of 141μg/m3; while $PM_{2.5}$ was not detected in the gynaecology and urology wards and present in very low levels in the other study sites. There was, however, greater variability in the levels of VOCs ranging from 236.57mg/$m^3$ in the HIV clinic to 530.77mg/$m^3$in the male surgical ward.

Mandin, Trantallidi, Cattaneo et al., (2017) studied indoor air quality in office buildings across Europe and observed that compared to other studies in office buildings, the benzene, toluene, ethylbenzene, and xylene concentrations were lower in OFFICAIR buildings, while the α-pinene and d-limonene concentrations were higher, and the aldehyde, nitrogen dioxide and $PM_{2.5}$ concentrations were of the same order of magnitude. The terpene and 2-ethylhexanol concentrations showed heterogeneity within buildings regardless of the season. Considering the average of the summer and winter concentrations, the acetaldehyde and hexanal concentrations tended to increase by 4–5% on average with every floor level increase, and the nitrogen dioxide concentration tended to decrease by 3% on average with every floor level increase. The 5-day median and maximum indoor air concentrations of formaldehyde and ozone did not exceed their respective WHO air quality guidelines, and those of acrolein, α-pinene, and d-limonene were lower than their estimated thresholds for irritative and respiratory effects. $PM_{2.5}$ indoor concentrations were higher than the 24-h and annual WHO ambient air quality guidelines.

Chakraborty, Mondal and Datta (2014) examined indoor pollution from solid biomass fuel and rural health damage in rural area of Burdwan, West Bengal. Results showed that a higher concentration of $CO_2$ was released during burning of dry leaf, straw, cow dung compared to that from straw and LPG gas. Moreover, correlation study showed a strong negative relationship between CO and humidity.Mbakwem-Aniebo, Stanley and Onwukwe (2017) assessed indoor air quality of majors 'biological laboratories in Ofrima Complex, University of Port-Harcourt, Nigeria. Results showed that the total heterotrophic bacterial and total fungal count from Microbiology Majors' laboratory was 987 CFU/$m^2$/h (colony forming unit per square meters per hour) (80.18%) and 244 SFU/$m^2$/h (spore forming unit per square meters per hour) (19.82%) respectively while the total heterotrophic bacterial and total fungal count from Animal/Environmental Biology Majors' laboratory was 677 CFU/$m^2$/h (79.27%) and 177 SFU/$m^2$/h (20.73%) respectively, reported as contamination flow. In the examined area, the predominant cultural species of air borne microflora were members of bacteria genera; Bacillus, Staphylococcus, Escherichia, Micrococcus, Pseudomonas, Serratia,Acinetobacter and fungi; Aspergillus, Cladosporium, Fusarium, Penicillium, Rhodotorula, Trichophyton, Candida, Mucor, Rhizopus, Scopulariopsis and Trichoderma. The study showed that despite the high number counted plates in both laboratories, the data proved to be statistically insignificant for 9am and 4pm, while significant at 12 noon for laboratories 1 and 2.

## Green Theory in Relation to Indoor Air Quality

Green theory as it relates to indoor air quality basically looks at the use of environment friendly materials (with low emission) in building and construction activities in order to reduce indoor air pollutants. The use of green eco-friendly housing includes approaches to reduce indoor air pollutant sources and to increase energy efficiency (Jun and Yuguo, 2011; Chen and Huang, 2012). This because more than 80% life time is spent in indoor, indoor air quality directly affects human health. With the improvement of people's living standard and housing conditions there is serious indoor air pollution caused by residence decorating in all over (Jun and Yuguo, 2011). According to Jun and Yuguo (2011) the green theory simply emphasizes the integration of green interior design by using natural elements and natural material in space organization, decorate adornment respect and indoor display art, to create natural and plain living and working environment and to pay attention to rational utilization of natural energy and materials.

Green interior design is the unavoidable requirement of developing low carbon economy which can be evaluated in many-sides from material selection, transportation, product resources life, to recycling (Jun and Yuguo, 2011; Coombs, Chew, Schaffer et al., 2016). The theory argues that materials used in construction and building works should be plain for example it can be obtained materials from local sources or recycling materials. Then natural lighting and ventilation should be mostly utilized so that not only energy is saved but also environment suitable for living could be created. The green design thoughts melt into the interior design to build the green indoor space. Although sealing/tightening buildings can save energy and reduce the penetration of outdoor pollutants, an adverse outcome can be increased buildup of pollutants with indoor sources (Coombs et al., 2016). Environmental concerns for improved energy consumption and reduced carbon emissions have motivated increased adoption of green principles in new construction and remodeling practices. “Green” housing is designed by utilizing building materials with low-emissions, increasing energy efficiency and improving the health of occupants (Chen and Huang, 2012; Coombs et al., 2016).

Therefore by using green technique for example opening window in the architectural design or modification of architectural design can make indoor and outdoor keep fully so that habitants have more fresh air and indoor pollutants are discharged easily. More natural model arts or designs like the use of pot plant, potted landscape, waterscape, flower display (or planting) and so on are introduced, the application of natural colour and natural materials is be emphasized and to imitate natural environment can have substantial impacts in reducing indoor air pollutants as well help in reducing the concentration of pollutants over (Jun and Yuguo, 2011). As buildings and habitable places become more “green”, there have been rising concerns about the long-term effects of changes in building materials as well as operations and construction practices. It has been suggested that “green” housing solutions may be detrimental to residents’ health if factors affecting the IAQ are not considered in the design if green models. Improper selection and implementation of retrofits such as continuous and adequate outdoor air flow can directly affect indoor environmental quality and may be detrimental to resident’s health (Mudarri et al., 2006; Coombs et al., 2016).

The importance of this theory to the present study of evaluating indoor air quality among different land uses such as residential area, market place, farm, school and palm oil processing mill explains the variation in IAQ in relation to the existence of green design or ecological designs that can reduce indoor air pollutant sources and increase energy efficiency. Since humans spend 80% of their dealings indoor, it is imperative to understand factors responsible for the variation in IAQ and suggest ways of reducing the concentration of pollutants through the use of application of green models that replicate the natural environment. The existence of green materials in houses, offices, commercial and industrial areas can reduce the substantial effects of IAP on residents’ health. As put forward by Jun and Yuguo (2011), irrespective of the extent of usage, the use of large areas of wooden panels and natural wall coverings that use cotton, cane products among others as base material can be very helpful. Green materials like plastic floor, composite floor, bamboo floor and so are able to save energy and reduce the concentration of IAP. Also, the planting of trees, flowers and grasses in areas of high risk like palm oil processing and the use of natural materials as wall coverings can reduce the concentration of IAP.

**Sustainable Policies, Scenarios and Methodology**

Air pollution is the fourth greatest overall risk factor for human health worldwide, after high blood pressure, dietary risks and smoking. Recent estimates attribute 6.5 million premature deaths to air pollution (WHO, 2016). In addition to human health, air pollution poses risks to the environment, economy and food security. Air pollution crisis cannot be addressed in isolation: it is closely linked to policies for energy, climate, transport, trade, agriculture, biodiversity and other issues. Well-designed air quality strategies have major co-benefits for other policy goals (Anenberg et al., 2012; Rafaj et al., 2006; Schmale et al., 2014; Shindell et al., 2012). Improving air quality, via greater efficiency and increased deployment of renewables, goes hand-in-hand with the broader energy sector transformation and decarbonization commitments adopted within the Paris agreement (Mace, 2016; McCollum et al., 2013; Rafaj et al., 2013). Reducing pollutant emissions improves water and soil quality, crop yields and, in turn, food security (Emberson et al., 2001). Tackling household air pollution (HAP), via the provision of modern energy for cooking and lighting, helps development efforts dealing with poverty, education and gender equality (Amegah and Jaakkola, 2016; Lam et al., 2016; Rao and Pachauri, 2017).In September 2015, 193 countries, developing and developed countries alike, adopted the Sustainable Development Goals (SDG), known officially as the 2030 Agenda for Sustainable Development (UN, 2015). Air pollution is recognized as a pressing sustainability concern and is directly mentioned in two SDG targets: SDG 3.9 (substantial reduction of health impacts from hazardous substances) and SDG 11.6 (reduction of adverse impacts of cities on people). Interlinkages of air pollution with other SDGs are described in detail in Supplementary material (Section S1). Action in the energy sector, including industry, transport and domestic subsectors, is essential to the attainment of the air pollution related SDGs (Amann et al., 2013; IEA, 2017). The majority of sulfur dioxide (SO2) and nitrogen oxides (NOx) emissions to the atmosphere are energy-related, as are some 85% of emissions of particulate matter (PM). Within the energy sector, power generation and industry are the main sources of SO2. Oil-products use in vehicles and power generation are the leading emitters of NOx. Consumption of biomass, kerosene and coal in the buildings sector, along with industrial combustion and process emissions, are responsible for the bulk of PM reaching the atmosphere. These three key pollutants are responsible for the most widespread impacts of air pollution, either directly or once transformed into other pollutants via chemical reactions and transport in the atmosphere. Fine particulate matter (PM2.5) is the most damaging to human health, and sulfur and nitrogen oxides (a precursor of ozone) are associated with a range of illnesses and environmental damages (Cohen et al., 2017; Kiesewetter et al., 2015).

Each of the main pollutants is linked to a main fuel and source. In the case of PM2.5, this is the wood and other solid biomass that some 2.7 billion people use for cooking and kerosene used for lighting (and in some countries also for cooking), which incurs indoor pollution that is associated with around 3.5 million premature deaths each year (Balakrishnan et al., 2013; Smith et al., 2014). These effects of energy poverty are felt mostly in developing countries in Asia and sub-Saharan Africa (Marais and Wiedinmyer, 2016). Fine particles, whether inhaled indoors or outdoors, are particularly harmful to health as they can penetrate deep into the lungs. Exposure to PM2.5 may not be regarded as solely an urban problem (Zhang and Day, 2015); poor air quality severely affects many rural communities, moreover, significant share of secondary pollutants can be transported over large distances from their sources (Brauer et al., 2012; Klimont et al., 2017). The main fuel associated with sulfur emissions is coal (although high-sulfur oil products, such as those still permitted for use in maritime transport, are also a major contributor): SO2 is a cause of respiratory illnesses and a precursor of acid rain. Fuels used for transport, first and foremost diesel, generate more than half the NOx emitted globally, which can trigger respiratory problems and the formation of other hazardous particles and pollutants, including ozone. These emissions are linked with industrialization and urbanization, and coal and oil are the main sources (natural gas emits far less air pollution than other fossil fuels, or biomass). The unabated combustion of coal and oil in power plants, industrial facilities and vehicles is the main cause of the ambient/outdoor pollution linked to around 3 million premature deaths each year (IEA, 2016; Landrigan et al., 2017). As the predominant source of air pollution and climate forcers, the fuel combustion must be at the forefront of action to improve air quality around the world. A range of proven policies and technologies are available to do so. In the United States, European Union and Japan, regulations have helped to achieve a major drop in emissions in some sectors, although challenges remain (Henneman et al., 2017; Rafaj et al., 2014; Wakamatsu et al., 2013). In developing Asia, less stringent regulations relating to fuel quality, energy efficiency and post-combustion treatment technologies generally mean that pollutant emissions have risen in line with very rapid growth in energy demand seen in recent years, though improvements in air quality are becoming an increasingly urgent policy priority in many Asian countries (Rafaj and Amann, 2018; Jin et al., 2016; Wang et al., 2014; Zhao et al., 2016). In other regions, particularly in Sub-Saharan Africa, urban air quality has been identified as a major threat to human health driven by rapid population growth and expanded transport and industry sectors, whereas lack of political will and institutional engagement poses major challenges to tackle impacts of air pollution (Amegah and Agyei-Mensah, 2017).

Since the SDG policy context has been introduced only recently, the scenario literature on the air-pollution-related SDGs interactions in medium/long-term is rather scarce and does not reflect yet, inter alia, the recent evolution in climate negotiations (see, e.g., Rao et al., 2016; van Vuuren et al., 2015; Roehrl, 2012). More recent studies, however, address implications of meeting the Paris agreement on a set of SDGs, including air pollution and health impacts (Grubler et al., 2018; McCollum et al., 2018), and suggest substantial co-benefits due to a rapid decarbonization of global economy and changes to consumption patterns. Evaluation of impacts – including potential tensions and tradeoffs

(Bowen et al., 2017; Klausbruckner et al., 2016) – of attaining multiple SDGs on the future air quality and associated health indicators requires an integrative and novel approach capable of quantifying interactions between key policy domains covered in this paper: access to clean energy carriers, climate change mitigation and abatement of air pollutant emissions. Using the policy scenario assessment, we attempt to contribute to this research area by quantifying and highlighting implications of multi-objective approach for sustainable development in contrast with a single-goal-oriented air pollution strategies.
Description of scenarios analyzed in this study together with key assumptions are provided in the next section; thereafter, the methodology and modelling tools are summarized. Subsequently, quantitative results are discussed in terms of future emissions of air pollutants, concentrations of fine particles, health impacts, and investment cost. Finally, conclusions and policy insights are drawn based on the numerical results.

### The "Sick Building syndrome"

Since the early 1970s, numerous outbreaks of work related health problems have been described among employees in buildings or offices not directly contaminated by industrial processes. Two broad categories can be distinguished: those characterized by a generally uniform clinical picture for which a specific cause has been identified, and those in which affected workers reported nonspecific symptoms occurring only during the time when they were at work. The former episodes have been defined "Building - Related Illness" (BRI), the latter, "Sick Building Syndrome" (SBS). Symptoms reported in SBS have typically included mucous membrane and eye irritation, cough, chest tightness, fatigue, headache and malaise. In outbreaks of BRI, a wide spectrum of causative factors has been implicated: immunologic sensitizing agents, infectious agents, specific air contaminants, and environmental conditions, such as temperature and humidity. Outbreaks without an identifiable cause have frequently occurred in new, sealed office buildings and have for that reason also been called the "tight building syndrome" (TBS). Essential for SBS are the concepts of comfort, well-being and air quality. Comfort or well-being refers to a status of optimal physical conditions for the body. Acceptable indoor air quality is described as air in which there are no known contaminants at harmful concentrations and with which a substantial majority (e.g., 80% or more) of the people exposed do not express dissatisfaction. Thus, the "Sick Building Syndrome" is a term used to describe the reduced comfort and health status of occupants in this particular building or part of it where the occupants complain about indoor air quality and manifest symptoms which they assign to that reduced quality. A recent definition by WHO defines SBS as a reaction to the indoor environment among a majority of the occupants whose reactions cannot be related to obvious causes such as excessive exposure to a known contaminant or a defective ventilation system. The syndrome is assumed to be caused by a multifactorial interaction of several exposure factors involving different reaction mechanisms (Jun and Yuguo, 2011). The symptoms of SBS are mainly reports of discomfort or the feeling of being "less than well".

## VII. RESEARCH METHODOLOGY

### Preliminary survey

A preliminary survey of the study area was carried out with a view to get familiarized with the structure of interest relevant to the study. During the survey that lasted for 3days, residential land use was noted to be the most predominant, then followed by Market and lastly the school. High density areas in the entire location were Bazza, Moda, Watu and Michika (Control Point). Major markets and schools in the study area are located in these high dense areas.

### Types and Sources of Data

This study essentially made use of primary data to provide answers to the research problem. The following sets of primary data were collected:

1. Data on indoor air pollutants ($NO_2$, $SO_2$, CO, $H_2S$, $NH_3$, $PM_{10.}$ and $PM_{2.5}$) from residential area, market place, school.
2. Data on the temporal (morning, afternoon and evening) variation in indoor air quality among different land uses.

The aforementioned sets of primary data were obtained from the measurement of indoor air pollutants around residential area, market place, and school within the territorial boundaries of Michika Local Government Area of Adamawa State, Nigeria experiment using standardized equipment at different time of the day for a month.

### Materials and Methods

Gasman Auto Sampler was used to collect data set, the calibrated sampler was used to measure CO, $NO_2$, $SO_2$, $NH_3$ and $H_2S$. Gas Analyzer was used to collect Particulate Matter ($PM_{10}$ and $PM_{2.5}$). This equipment was clipped on a tripod and placed 2meter from the walls and ventilation devices in households to avoid excess air flow.A simple handheld thermometer was used to measure indoor temperatures. Indoor air monitoring was performed on daily basis continuously starting from period of 8:00am to 7:00pm for a 28day research period. In each location were monitoring was carried out; a GPS was used to geo reference point of collection for easy assessment of Indoor Variations.

**Sampling technique**

The stratified random sampling technique was employed in the study. Since the population appears to be mutually homogenous but internally heterogeneous in nature. This technique is part of the probabilistic sampling technique. Stratified sampling technique was used to assess indoor air quality or pollutants from residential area, market place, and school. These land uses were selected because different human activities that can have significant influence on ambient indoor air quality are carried out in and around them. In each land use, indoor air pollutants were randomly collected at three different locations. For instance, for residential area, air pollutants will be randomly collected from five rooms. Since, three land uses were considered for the present study, it therefore means that indoor air pollutants were collected from 45 sampling points. The indoor air quality data collected from these locations will be used to assess indoor air quality index among the land uses as well as understand the health risk level of indoor air pollution by comparing its levels with WHO/FME acceptable limits. Through this technique, indoor air pollutants were also collected at different times of the day (morning, afternoon and evening for a period of one month).

**Data Collection**

Data collection was carried out by the researcher with the aid of two research assistants. The collection of indoor air quality for this study was carried out in the month of 12th October 2018 lasting for 28days with the aid of Gasman auto sampler. The Gasman auto sampler will be used to monitor the concentration of nitrogen dioxide ($NO_2$), sulphur dioxide ($SO_2$) carbon monoxide (CO), Hydrogen sulphide ($H_2S$) and Particulate matter. These gases are known to induce or cause respiratory disease in exposed humans and also contribute to the problem of global warming. These five gases will be collected from 45 sampling points or locations but randomly selected in three locations (5 points from each land use) as well as monitored thrice a day (morning, afternoon and evening) in replicates for a month (once a week), in one selected location. In this study, three-hour monitoring period will be carried out from early morning to late evening during the monitoring period. That is, the collection of daily indoor air quality data was from 7am to 10am in the morning; 12 noon to 3pm in the afternoon and 6pm to 9pm in the evening. During data collection, the sampling locations were geo-referenced using GPS. In addition, the site characteristics of each location will be noted during data collection in order to relate variation in indoor air quality of site factors.

**Method of Data Analysis**

Data obtained from the laboratory analysis of indoor air quality was analyzed using descriptive and inferential statistical tools. Descriptive tools included averages, tables and charts for easy understanding of the pattern and variability in indoor air quality. The inferential tools included One-Way Analysis of Variance (ANOVA), Pearson’s correlation and Principal components analysis. ANOVA was used to compare the mean variations in indoor air quality among the land uses. Pearson’s correlation was used to examine the association among the variables, while principal components analysis will be used to identify dimensions in indoor air pollutants and to identify the principal indoor air pollutants that are most varied across the land uses.

**Assessment of Pollution Index (PI)**

The measured indoor air quality data will be used to determine the pollution paramters across the different land uses. A pollutant’s index is its concentration expressed as a percentage of the relevant air standard (Kanchan and Goyal, 2015). The index rating presented in Table 3.1 will be used to assess indoor pollution index across the different land uses. The information shows the numeric index and what each value stands for.

**Values, index and health risks for PI**

| Numeric Value | Quality Indicator | Numeric Index | Health Risk |
|---|---|---|---|
| 0-50 | Optimum | 1 | No risks for people |
| 51-75 | Good | 2 | No risks for people |
| 76-100 | Moderate | 3 | No risks for people |
| 101-125 | Mediocre | 4 | Generally there aren’t risks for people, people with asthma. Chronic bronchitis. Croniche cardiopathy may feel light respiratory symptoms only during an intense physical activity |
| 126-150 | Not mush healthy | 5 | There risks for people with heart diseases. Olds and children |
| 151-175 | Unhealthy | 6 | Many people may feel light adverse symptoms, however reversible. Weak people may feel gravest symptoms. |
| >175 | Very unhealthy | 7 | People may feel light adverse effects for health. There are more risks for olds, children and people with respiratory diseases |

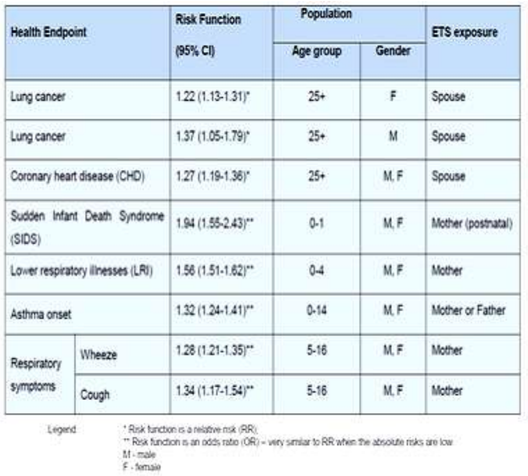
**Source:** Kanchan and Goyal (2015:105)

## VIII. DATA ANALYSIS, PRESENTATION AND INTERPRETATION OF RESULT

### The burden on health of never-smokers attributable to ETS in the home, living with a smoker as an index of exposure

### Population

To link with available risk functions, the research team aimed to estimate the number of children (<15y) and adult (25y+) never-smokers exposed to ETS inside the home. Sources of relevant information were scarce and different for each country. Estimates of the population of adult never-smokers in Michika who were exposed to ETS in the home were based on data on never-smokers taken from research studies (Akhtar et al., 2007; Haw and Gruer, 2007). In Michika, this information was not available and estimates for exposed never-smokers were based on data for non-smokers6 living with a smoker (Shafrir et al., 2011a). This in turn had to be derived using complex cross-referencing (see Section 2.0, Hurley et al., 2011) using multiple sources. All children aged <15 were assumed to be never-smokers.



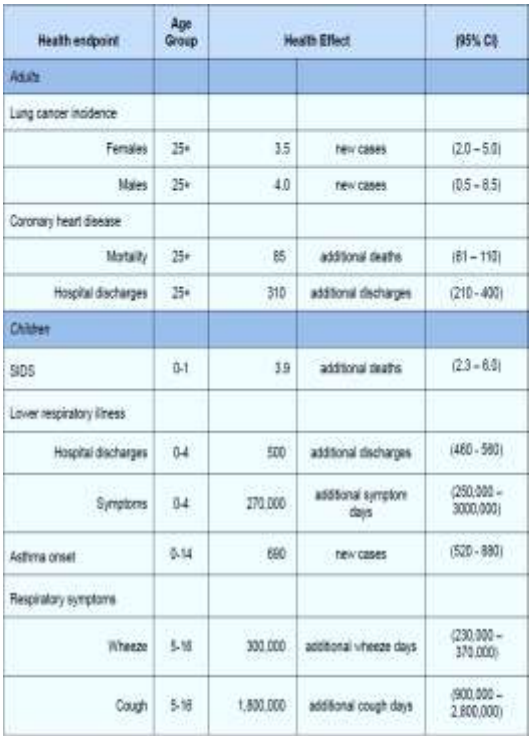
| Health Endpoint | | Risk Function (95% CI) | Population | | ETS exposure |
|---|---|---|---|---|---|
| | | | Age group | Gender | |
| Lung cancer | | 1.22 (1.13-1.31)* | 25+ | F | Spouse |
| Lung cancer | | 1.37 (1.05-1.79)* | 25+ | M | Spouse |
| Coronary heart disease (CHD) | | 1.27 (1.19-1.36)* | 25+ | M, F | Spouse |
| Sudden Infant Death Syndrome (SIDS) | | 1.94 (1.55-2.43)** | 0-1 | M, F | Mother (postnatal) |
| Lower respiratory illnesses (LRI) | | 1.56 (1.51-1.62)** | 0-4 | M, F | Mother |
| Asthma onset | | 1.32 (1.24-1.41)** | 0-14 | M, F | Mother or Father |
| Respiratory symptoms | Wheeze | 1.28 (1.21-1.35)** | 5-16 | M, F | Mother |
| | Cough | 1.34 (1.17-1.54)** | 5-16 | M, F | Mother |

Legend
* Risk function is a relative risk (RR)
** Risk function is an odds ratio (OR) – very similar to RR when the absolute risks are low
M - male
F - female

**Fig 4.1**: Risk functions for the health endpoints included in the report

### Results: Estimated Health Burden

This process, simple in principle (Figure 4.2) but in practice very complicated to implement, resulted in the estimated annual burden of disease in Michika Adamawa State presented in Table 4.1. as Results for the study area.



| Health endpoint | Age Group | Health Effect | | (95% CI) |
|---|---|---|---|---|
| Adults | | | | |
| Lung cancer incidence | | | | |
| Females | 25+ | 3.5 | new cases | (2.0 – 5.0) |
| Males | 25+ | 4.0 | new cases | (0.5 – 8.5) |
| Coronary heart disease | | | | |
| Mortality | 25+ | 85 | additional deaths | (61 – 110) |
| Hospital discharges | 25+ | 310 | additional discharges | (210 - 400) |
| Children | | | | |
| SIDS | 0-1 | 3.9 | additional deaths | (2.3 – 6.0) |
| Lower respiratory illness | | | | |
| Hospital discharges | 0-4 | 500 | additional discharges | (460 - 580) |
| Symptoms | 0-4 | 270,000 | additional symptom days | (250,000 - 3000,000) |
| Asthma onset | 0-14 | 690 | new cases | (520 - 880) |
| Respiratory symptoms | | | | |
| Wheeze | 5-16 | 300,000 | additional wheeze days | (230,000 – 370,000) |
| Cough | 5-16 | 1,800,000 | additional cough days | (900,000 – 2,800,000) |

**Fig 4.2:** Health effects attributable to exposure to ETS through never-smokers living with a smoker in Michika Adamawa State

## Using PM2.5 as an Index of Exposure, the Burden on Health Attributable To Burning Solid Fuels in the Home, Or Using Gas for Cooking.

### Population

As detailed in Section 2.0, Hurley et al., (2011), there is very limited information on the number of households using specific solid fuels (as distinct from overall residential solid fuels usage) in Michika.

In 2004/2005 (Central Statistics Office, Michika, 2007), a representative random sample of all private households in Michika, giving detailed information on household population and the fuel used for heating and cooking, classified as gas, electric, oil and solid fuels, but not by type of solid fuels (coal, or wood). The population exposed to peat-burning as primary fuel was estimated by cross-reference with fuel usage data. For Michika, the research team used data from two or three years of the Adamawa Ministry of Health and Environment (Amabile et al., 2009), a representative annual national survey of about 3,000 households with separate information on the use of coal and wood/peat for cooking and heating, and gas for cooking. Estimates of the percentage of the population living in households burning solid fuels for heating, or using gas for cooking, were calculated by the SHCS team. Through these sources, relevant percentages of the population exposed were estimated (Table 4.3).

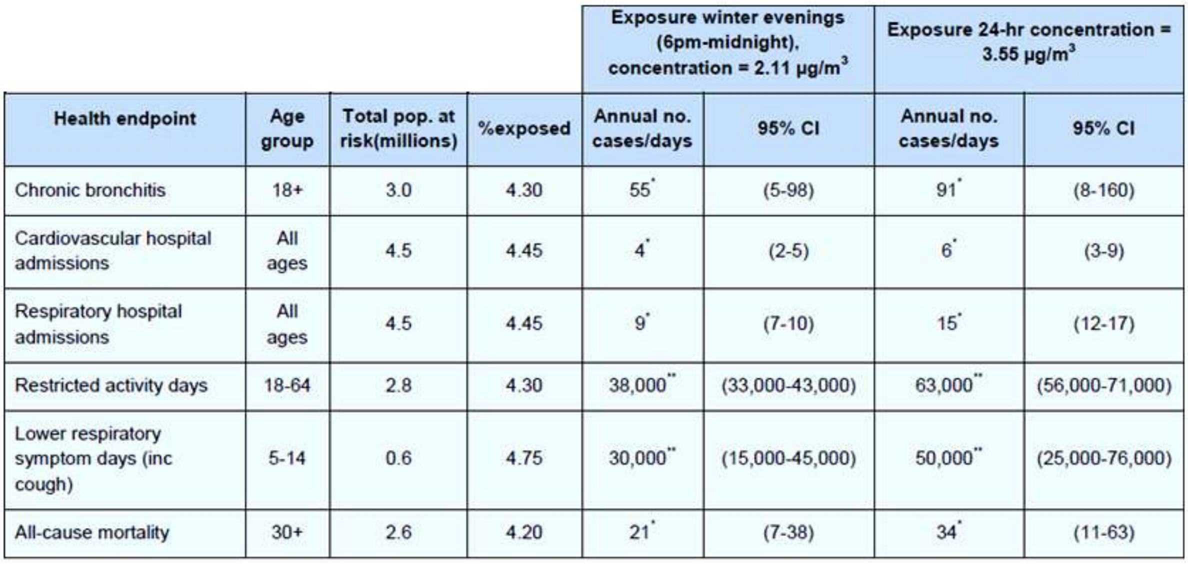
| **Michika** | <14 years (%) | 14-20 years (%) | Male[1] 21+ (%) | Women[1] 21+ (%) | Household Sampled (%) |
|---|---|---|---|---|---|
| **Heating** | 9.5 | 11.8 | 8.5 | 9.3 | 8.4 |
| **Gas Cooking[2]** | 23.7 | 22.2 | 26.0 | 25.3 | 26.0 |

| **Michika** | <15 years (%) | 15-25 years (%) | Male[1]>25+ (%) | Women[1] >21+ (%) | Household Sampled (%) |
|---|---|---|---|---|---|
| **Heating** | 9.5 | 11.8 | 8.5 | 9.3 | 8.4 |
| **Gas Cooking[3]** | 57.5 | 53.3 | 54.9 | 53.8 | 49.3 |

**Table 4.3**: Exposure Rate to Age and Means of Heating in Michika

### Health outcomes; Risk functions; Background rates; Impact functions

From the extensive world-wide research linking particulate air pollution outdoors with mortality and morbidity (WHO, 2006), there is a reasonable consensus internationally on what concentration-response functions (CRFs) to use for HIA in various regions. IAPAH was based on the most important set of CRFs used in the HIA of the European Commission's Clean Air for Europe (CAFE) programme (Hurley et al., 2005). This followed detailed review within the HEIMTSA EU project of the key relationships of mortality with $PM_{2.5}$, using more recent evidence, which concluded that no change was needed Selected functions in $PM_{10}$ were 'translated' to $PM_{2.5}$ using a conversion factor of 0.65; and all were converted to exposure-response relationships (i.e. ERFs rather than CRFs).



| | | | | Exposure winter evenings (6pm-midnight), concentration = 2.11 µg/m³ | | Exposure 24-hr concentration = 3.55 µg/m³ | |
|---|---|---|---|---|---|---|---|
| Health endpoint | Age group | Total pop. at risk(millions) | %exposed | Annual no. cases/days | 95% CI | Annual no. cases/days | 95% CI |
| Chronic bronchitis | 18+ | 3.0 | 4.30 | 55* | (5-98) | 91* | (8-160) |
| Cardiovascular hospital admissions | All ages | 4.5 | 4.45 | 4* | (2-5) | 6* | (3-9) |
| Respiratory hospital admissions | All ages | 4.5 | 4.45 | 9* | (7-10) | 15* | (12-17) |
| Restricted activity days | 18-64 | 2.8 | 4.30 | 38,000** | (33,000-43,000) | 63,000** | (56,000-71,000) |
| Lower respiratory symptom days (inc cough) | 5-14 | 0.6 | 4.75 | 30,000** | (15,000-45,000) | 50,000** | (25,000-76,000) |
| All-cause mortality | 30+ | 2.6 | 4.20 | 21* | (7-38) | 34* | (11-63) |

### The burden on health of never- and non-smokers attributable to ETS in the home, using PM2.5 as an index of exposure

### Population

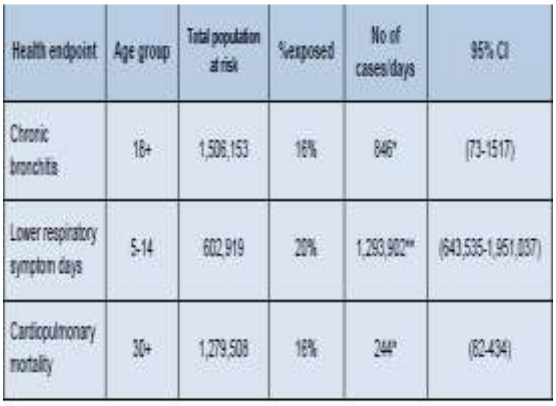
The initial population at risk (children; adult never-smokers living with a smoker) is the same as for the source-based approach to ETS (see Section 3.6.1). In addition, attributable annual average PM2.5 were used to estimate the health burden in (i) non-smokers; and (ii) never smokers

### Health outcomes; Risk functions; Background rates; Impact functions

Similarly, the health outcomes, risk functions in PM2.5,, and general population background rates used were generally the same as before (see Section 3.7.3), but there were two major differences in how they were applied. First, the background rates used were those for non-smokers rather than for the general population as used for solid fuels. Secondly, for the estimates assuming all-day (24-hour) exposures, the annual average exposures were substantially higher than 30 µg/m3 and so, as indicated in Section 3.4.3, a non-linear relationship based on Pope et al,. (2009) was used for mortality. That relationship from Pope et al., (2009) used cardio-respiratory mortality rather than all-cause mortality, and this was the relationship also used in IAPAH. Using non-linearity led to lower estimated impacts than an estimate based on linear relationships. The ratio of non-linear to linear impacts for cardio-respiratory mortality was then applied to all other estimated impacts, which otherwise would have assumed linearity. Details are given in Shafrir et al., (2011b).

### Results

Impacts associated with ETS exposure in Adamawa and Michika were estimated for both non-smokers and never-smokers. Results for never-smokers are given in Table 3.7a and Table 3.7b. Health burden for non-smokers is approximately 50% higher than for never-smokers.



| Health endpoint | Age group | Total population at risk | %exposed | No of cases/days | 95% CI |
|---|---|---|---|---|---|
| Chronic bronchitis | 18+ | 1,506,153 | 16% | 846* | (73-1517) |
| Lower respiratory symptom days | 5-14 | 602,919 | 20% | 1,293,902** | (643,535-1,951,037) |
| Cardiopulmonary mortality | 30+ | 1,279,508 | 16% | 244* | (82-434) |

Legend: *number of cases; **number of days

**Fig 5:** Estimated burden on health of indoor air pollution in never-smokers in Michika from ETS (results presented to 2 significant figures): Morning Exposure (concentration = 29.82 µg/m$^3$)

| Health endpoint | Age group | Total population at risk | %exposed | No of cases/days | 95% CI |
|---|---|---|---|---|---|
| Chronic bronchitis | 18+ | 1,920,576 | 12% | 810* | (70-1,453) |
| Lower respiratory symptom days | 5-14 | 558,101 | 27% | 1,542,813** | (767,334-2,326,364) |
| Cardiopulmonary mortality | 30+ | 1,700,810 | 12% | 346* | (115-615) |

Legend: * number of cases; ** number of days

**Fig 6:** Estimated burden on health of indoor air pollution in never-smokers in Michika from ETS (results presented to 2 significant figures): Evening Exposure (concentration =29.82 μg/m$^3$)

### Indoor Air Quality Variation of Ambient Air Quality in Michika

### Indoor Variation of CO

This range is within the comparative range of 1.83 to 2.17ppm as obtained by Magaji and Hassan (2015) around abattoir area in Gwagwalada, but lower than the 10.25 – 31.67ppm reported by Attah (2015) across different land uses in Kaduna Metropolis. The concentration of CO in this study is within the 10ppm recommended by FME (Atubi, 2015: Ebong and Mkpenie, 2016).

The result in Table 4.1 shows the concentration of air quality across different locations and Control (Michika) in Michika, area of Adamawa State. The result shows clear variation in the concentration of air quality across the different locations considered in the study. The content of CO across the different locations ranged from 1.18 to 1.76ppm. It is also within WHO 90ppm limit for 15 minutes (Balogun and Orimoogunje, 2015). Across the studied locations, high content of carbon monoxide (CO) was recorded in Michika Marketfollowed by Michika School and with mean values of 1.76 and 1.50ppm respectively, while in the lowest concentration of COwas recorded in the Control (Michika) with a mean value of 1.18ppm.

This implies that the **Control (Michika)** witnesses reduced traffic congestion and presence of industrial activities that favour the increase in COpollutants or concentration in the atmosphere. COcontentis acknowledged by Han, (2010) to be present in heavy traffic congestion, residential and industrial activities. In a study carried out by Akpan and Ndoke (1999) in Northern Nigeria, high concentration of CO was reported in heavily congested areas. Hence, the high COcontent recorded in Michika Marketis associated with the industrial activities in the area. This is the case with Michika School and other areas with increasing concentration of CO in the atmosphere.

The results from the analysis of variances (ANOVA), showed that the concentration of COvaried significantly among the various locations ($F = 19.350$, $p<0.05$). This is expected due to the varied human activities carried out in these locations. Due to human activities such as the combustion of fossil fuels, deforestation, wood burning, natural gas, coal, or wood-burning stoves and heaters, the concentration of atmospheric carbon dioxide has increased by about 35 per cent since the era of industrialization began (Amin, 2009; Atubi, 2015).

Han and Naeher, (2006) stated that CO results from the incomplete combustion of diesel or gasoline in traffic engines, non-transportation fuel combustion, bush burning and some indoor sources such as a leaking gas stove.

### Indoor Variation of $SO_2$

The result from the analysis of variance (ANOVA) showed that the concentration of $SO_2$ varied significantly among the different locations ($F = 20.840$, $p<0.05$). The range of $SO_2$ in the in the present study is above FME recommended level of 0.10ppm. The range is also within WHO 24hrs allowable limit of 20ppm.

The concentration of Sulphur dioxide ($SO_2$) showed varied concentrations across the studied locations with high concentration of 0.54ppm recorded within Arab Quarry District. $SO_2$ concentration was comparatively the same in other locations with the exception of the Control (Michika) which had the lowest concentration of 0.12ppm. $SO_2$ values ranged from 0.12 to 0.54ppm. The Control (Michika) experienced the lowest $SO_2$ concentration probably as a result of reduced anthropogenic activities. EEA (2008) and US EPA (2009) noted that anthropogenic sulphur emission principally originate from fossil fuel combustion (electricity, fossil fuel combustion, industrial process, non-road equipment and fire among others). The existence of several industrial activities in Michika Marketcould be responsible for the relatively high contents of sulphur dioxide in the atmosphere. Department of the Environment and Heritage (2005) stated that about 99% of the sulfur dioxide in air comes from human sources such as industrial activity that processes materials that contain sulfur. In addition, $SO_2$ is introduced into the environment from industrial activities that burn fossil fuels containing sulfur as well as motor (Atubi, 2015).

**Table 4.1: Concentration of Air Quality across different locations in Michika**

| Locations | Mean concentration of parameters | | | | | | |
|---|---|---|---|---|---|---|---|
| | **CO** | **$SO_2$** | **$NO_2$** | **$NH_3$** | **$PM_{2.5}$** | **$PM_{10}$** | **$H_2S$** |
| Bazza | 1.39 | 0.32 | 0.36 | 0.06 | 0.25 | 0.20 | 0.11 |
| Watu | 1.46 | 0.36 | 0.44 | 0.06 | 0.27 | 0.23 | 0.16 |
| Moda | 1.50 | 0.35 | 0.44 | 0.05 | 0.27 | 0.23 | 0.11 |
| Michika Market | 1.44 | 0.34 | 0.36 | 0.04 | 0.22 | 0.20 | 0.13 |
| Michika School | 1.76 | 0.54 | 0.55 | 0.05 | 0.26 | 0.26 | 0.16 |
| Michika Residential (Control) | 1.18 | 0.12 | 0.15 | 0.05 | 0.18 | 0.16 | 0.08 |

**Source**: Researcher's fieldwork, 2017

### Indoor Variation of $NO_2$

Likewise, the contents of nitrogen dioxide ($NO_2$) varied across the different locations. It showed that high concentrations of nitrogen dioxide ($NO_2$) were recorded in Michika Market and Michika School/Watu with mean values of 0.55ppm and 0.44ppm respectively. As usual, the lowest concentration of $NO_2$ was recorded in the Control (Michika) site with a mean value of 0.15ppm. The concentration of nitrogen dioxide ($NO_2$) varied significantly among the different locations ($F = 30.540$, $p<0.05$). In all, $NO_2$ ranged from 0.15 to 0.55ppm which is above the limit of 0.06ppm recommended by FME (Ebong and Mkpenie, 2016). The range is however within WHO 1hr mean allowable limit of 200ppm.

It also agrees with the range of 0.14 to 1.09ppm reported in Kano metropolis, Nigeria by Okunola, Uzairu, Gimba et al., (2012); while, the range of 0.73 to 0.84ppm reported by Adelagun et al., (2012) was far above the range reported in the present study. The high concentration of $NO_2$ in Michika Marketand Michika School/Watu may be attributed to high traffic congestion and construction activities. The activities in these areas basically road transportation and increase vehicular use, manufacturing and construction industries release large quantities of $NO_2$ into the atmosphere. In an earlier study, EEA (2008) identified the anthropogenic sources of nitrogen oxides to include public electricity and heat production, road transportation, manufacturing and construction activities and agricultural activities among others.

### Indoor Variation of PM $_{2.5}$ and $PM_{10}$

For $PM_{2.5}$, it value ranged from 0.18 to 0.27μg/m$^3$ which is slightly above the threshold of 0.25μg/m$^3$ recommended by FME, mostly for ambient air quality in Watu and Michika School areas. The range of $PM_{2.5}$ is within WHO limit of 20μg/m$^3$ for 24hrs mean concentration (WHO, 2006). Result of ANOVA showed that the concentration of $PM_{2.5}$ varied significantly among the various locations ($F = 10.758$ $p<0.05$). Furthermore, for $PM_{10}$, it value ranged from 0.16 to 0.26μg/m$^3$which is also slightly above the threshold of 0.25μg/m$^3$ recommended by FME (Magaji and Hassan, 2015), mostly in Michika Market and to some extent Watu/ Michika School. These areas have increased concentrations of $PM_{10.}$ The range of $PM_{10}$ reported in the present study is within WHO limit of 24hrs mean concentration of 50μg/m$^3$. Also, result of ANOVA showed that the concentration of $PM_{10}$ varied significantly among the various locations ($F = 9.880$ $p<0.05$).

From the result therefore means that Michika Market and Watu/ Michika School have high PM concentrations. Watu and Michika School areas are expected to have high PMbecause these areas have high concentration of human activities that emit gases favourable to the formation of PM.

### Indoor Variation of $H_2S$

According to Okunola et al., (2012), $H_2S$ are gases emitted during the decay of organic matter. They argued that the decay of food stuff, waste and refuse left for a long time result in high $H_2S$ emission. The $H_2S$ level in this study is lower than the range of 0.167 – 0.265ppm reported in Abeokuta metropolis, Nigeria by Oguntoke and Yusuf, (2008). In comparison to earlier and related studies, the concentration of $H_2S$ could be said to be low in Michika. Studies show that Nigeria has no permissible limit for $H_2S$ (Ohimain, Izah and Abah, 2013). More so, the concentration of $H_2S$ (Hydrogen sulfide) ranged from 0.08 to 0.16ppm with high and low values recorded in Michika Market/Watu and Control (Michika) sites with mean values of 0.16 and 0.08ppm. The range of $H_2S$ reported in the present study is far below the range of 0.33 to 3.17ppm reported by Okunola et al., (2012) along high traffic roads in Kano. The high concentration of $H_2S$ in Arab Quarry District/Watu is attributed to the decay of decay of food stuff, waste and refuse. In these areas, heaps of organic wastes are found and this contributes to the emission of $H_2S$.

**Air Quality Index (AQI)**

AQI is an index established by USEPA (2000) cited in Atubi (2015) which is used for assessing the status of ambient air pollutants and the associated health problems. The ambient air pollutants are classified into categories ranging from very good to very poor (Table 4.4). From (0-15) AQI rating is A which is very good, (16-31) AQI is B which is good, (32-49) AQI is C which is moderate, (50-99) AQI is D which is poor and (100 or above) AQI is E is very poor.

**Table 4.3: Air quality index**

| AQI categories | AQI Rating | PM (μg/m3) | CO (ppm) | $NO_2$ (ppm) | $SO_2$ (ppm) | $NH_3$ (ppm) |
|---|---|---|---|---|---|---|
| Very good (0-15) | A | 0 - 15 | 0 - 2 | 0 - 0.02 | 0 - 0.002 | 0 – 50 |
| Good (16-31) | B | 51-75 | 2.1-4.0 | 0.02-0.03 | 0.02-0.03 | 0 – 50 |
| Moderate (32-49) | C | 76-100 | 4.1-6.0 | 0.03-0.04 | 0.03-0.04 | 51 – 100 |
| Poor (50-99) | D | 101-150 | 6.1-9.0 | 0.04-0.06 | 0.03-0.04 | 201 – 300 |
| Very poor (100 or over) | E | >150 | >9.0 | >0.06 | >0.06 | 301 - 500 |

**Source:**USEPA, (2000)

Table 4.4 show the AQI for standardized analyzed air pollutants. The range obtained for the respective air pollutants was compared with the AQI index. The result obtained as depicted above, revealed that $PM_{2.5}$ and$PM_{10}$,COand $NH_3$ were in the A category (very good). This implies that the concentration of $PM_{2.5}$ and$PM_{10}$,COand $NH_3$ is considered satisfactory, and air pollution poses little or no risk to inhabitants in the area. It also showed that $NO_2$ and $SO_2$ were in the E category (very poor). The results in the E category imply health warnings of emergency conditions as inhabitants in the area are more likely to be affected by the contents of $NO_2$ and $SO_2$. The status of $NO_2$ and $SO_2$ being very poor with health implications is similar to the status of reported by Magaji and Hassan (2015) in Gwagwalada, Abuja and Ebong and Mkpenie (2016) in Uyo metropolis, Akwa Ibom State. The ranges reported for PM and CO were within the very good category. AQI class for other air parameters is not available however. The result obtained therefore indicates that the concentration of CO, $PM_{2.5}$, $PM_{10}$ and $NH_3$ in Michika may not pose a serious health problem to people when they are exposed to these gases for a long time.

**Table 4.4: Air quality status in Michika**

| Parameters | Measured range | Air quality rating |
|---|---|---|
| $PM_{2.5}$ (μg/m$^3$) | 0.03 – 0.40 | A (Very good) |
| $PM_{10}$ (μg/m$^3$) | 0.09 – 0.56 | A (Very good) |
| CO (ppm) | 1.00 – 2.90 | A (Very good) |
| $NO_2$ (ppm) | 0.01 – 0.90 | E Very poor |
| $SO_2$ (ppm) | 0.01 – 0.91 | E Very poor |
| $NH_3$ (ppm) | 0.00 – 0.19 | A (Very good) |

**Pollution Index (PI)**

Pollution index (PI) was developed and applied by Cannistraro and Ponterio (2009) for reporting air quality status in a given area. The pollution index method is based on a simple indicator of the air quality in an urban context that is useful for communicating to citizens' information about the state of air quality of a waste urban area (Kanchan and Goyal, 2015).

In the present study, the calculation of Pollution Index was carried out using the formula given by EPA (2017) as follows:

$$Index = \frac{\text{Pollutant Concentration}}{\text{Pollutant Standard Level}} \times 100$$

The standard pollutant levels for some of the studied ambient air quality variables are shown in Table 4.6. In estimating the pollution index (PI), the PI of the respective pollutants at different time periods was carried out, after which their averages were determined. The estimation was done for the respective locations.

**Table 4.5: Standard pollutant levels**

| Pollutants | Standard level |
|---|---|
| Nitrogen dioxide | 120ppm |
| Sulfur dioxide | 200ppm |
| Carbon monoxide | 9ppm |
| Particles ($PM_{10}$) | 50 µg/$m^3$ |
| Particles ($PM_{2.5}$) | 25 µg/$m^3$ |

**Source:**EPA (2017)

The results on PI of all the respective locations are shown in Table 4.6. The decision for ascertaining the PI according to Kanchan and Goyal (2015) is shown in Table 4.5. The PI values in Table 4.7 ranged from 0.06 to 19.5 which indicated the absence of pollution. The values for the respective pollutants fall within the 0 – 50 category implying no risk attached to the ambient air quality parameters in the area. The values of the pollution index do not show much fluctuation implying to some extent similar level of anthropogenic pollution in area. However, among the locations studied Michika Markets how slight increase in ambient air pollution (21.79) as compared to other areas with low inputs from anthropogenic sources. In general, there is low PI value in the area indicating high dilution and dispersion of air pollutants in the area. Thus, the PI of Michika obtained from different locations indicates the complete absence of pollution concern despite the numerous human activities in the area. Furthermore, a look at the level of pollution of the respective pollutants indicated that while other pollutants showed very low level of pollution, COindicated moderate pollution concern.

## IX. SUMMARY OF RESEARCH FINDINGS

Results obtained showed that average TVOC, $CO_2$, CO and particle concentrations measured in the classrooms were 815mg/$m^3$, 1605ppm, 0.05ppm, 1.16ppm, and 1730mg/$m^3$, respectively. Whereas, local authority known as Dubai Municipality recommended 300mg/$m^3$, 800ppm, 0.06ppm, 9ppm, and 150–300mg/$m^3$ for TVOC, $CO_2$, CO and particle respectively.

Dubai Municipality recommended temperature and relative humidity (RH) levels of 22.5$^0$C to 25.5$^0$C and 30%–60%, respectively. Average temperature and RH levels measured in the classrooms were 24.5$^0$C and 40.4%, respectively. Average sound level in the classrooms was 24 Db greater than recommended sound level limit of 35 dB. Six (6) classrooms had average lux levels in the range of 400–800 lux. Two (2) classrooms had average lux levels in the range of 100–200 lux.

In Warri, Nigeria, Rim-Rukeh (2015) assessed of indoor air quality in selected households in squatter settlements and found that the levels of $NO_2$, CO and SPM in all sampled households were above regulatory limits of 0.06ppm, 10ppm and 250µg/m3 respectively as a result of the form of domestic fuels (firewood, wood charcoal and sawdust) use for cooking. The distribution of the measured air quality parameters ($PM_{10}$ and CO) in the living (parlour) room and in the kitchen area, was computed using the Pearson Moment correlation. A correlation (r) of 0.571 and 0.756 were obtained for SPM and CO respectively for households in Marako slum. In Igbudu slum a correlation (r) of 0.455 and 0.447 were obtained for SPM and CO respectively, while in Makaver slum a correlation (r) of 0.510 and 0.784 were obtained for SPM and CO respectively. Oguntoke, Opeolu and Babatunde (2010) examined indoor air pollution and health risks among rural dwellers in Odeda area, south-western Nigeria.

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