Association of Particulate Pollutants and Prevalence of Symptoms of Health Conditions among Occupants of Residential Buildings in Enugu, Nigeria

Austine M. Ezezue; Eziyi O. Ibem

Abstract— Occupants of residential buildings are exposed to different kinds of particulate pollutants on a daily basis because poor ventilation of interior spaces. However, the link between the presence of indoor particulate pollutants and health conditions of occupants in residential buildings has not been adequately investigated. This study assessed the association between particulate pollutants in isolated spaces and the prevalence of health symptoms amongst occupants of residential buildings in Enugu, Nigeria. The data were sourced via a questionnaire survey of adult 400 occupants of residential buildings in the study area and subjected to descriptive and logistic regression analyses. The findings reveal that burning of fuel and related activities in poorly ventilated kitchens, lounges, dining spaces and bedrooms are the main sources of particulate pollutants in residential buildings in the study area. A high prevalence of nasal congestion/ runny nose (93%) eye irritation (87%) and headache (85%) was reported amongst occupants of the buildings, while a significant association was found between the presence of particulate pollutants in the spaces and prevalence of these health symptoms amongst occupants of the residential buildings. The study implies that residential buildings lacking control measures for indoor particulate pollutants can be a major source of health risk in the study area, and that this can be addressed through the adoption of passive building design strategies and features.

Index Terms— Health symptoms, Interior spaces, Particulate pollutants, Passive design; Residential buildings
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1 Introduction

One of the basic requirements of buildings is to provide a conducive environment for the different kinds of activities and satisfy the occupants' physical and physiological needs. By providing a good thermal, visual, spatial and acoustic indoor environment for users, buildings contribute significantly to the health and wellbeing of people [1]. The need for buildings to promote health and well-being of occupants cannot be over emphasized, particularly in tropical regions in sub-Saharan Africa, where there is the absence of comprehensive and up to date building design and maintenance standards [2], [3]. In fact, according to Bonnefoy [4], a healthy home is not a specially designed house but it is a residential setting that is capable of fulfilling the expectations of the residents.

Evidence in the extant literature reveals that prior to the advent of modern building technology and services, sound design principles and construction practices helped people in sub-Saharan Africa to produce buildings of remarkable aesthetic and technical quality [5-7]. However, due to the influence of western culture and new technology, there has been a shift of emphasis from vernacular buildings as they are perceived as being evidence underdevelopment and poverty [8]. Consequently, the people in this part of the globe have accepted foreign building design strategies and construction methods and discarded indigenous ideas hitherto used in the design and production of vernacular buildings. This development has partly contributed to the production of air-tighten residential buildings with heavy reliance on mechanical devices for maintenance of healthy and conducive indoor environment. The current situation is made worse as the design and construction of these so called modern buildings do not take cognizance of the traditional methods of cooking, which often involve the use of dirty fuels such as coal, wood, animal dung and kerosene [9]. In addition, the designs of residential buildings usually ignore possible sources of indoor particulate pollutants associated with the preparation of traditional foods/dishes. to anecdotal evidence showing that emphasis in the design of most residential buildings in many Nigerian cities, including Enugu is concentrated on functional space, affinities and thermal comfort measures with less attention given to basic passive

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design features such as chimneys and leaky building envelopes and indoor air pollution source control measures known to be effective handling indoor air quality challenges arising from cooking/heating with dirty fuels. Resulting from this is the increasing number of building related discomfort, illnesses and deaths in the study area as reported the published literature [10-13].

Further, the existing studies [14-16] also reveal that indoor particulate pollutants can exacerbate different health conditions and diseases. However, the association of indoor particulate pollutants in isolated spaces where dirty fuels are consumed and the health of occupants in residential buildings has not been adequately investigated, especially in a developing country like Nigeria. As a result, there is little understanding of the possible sources of indoor particulate pollutants and design measures to mitigate their effects on housing occupants. This view was corroborated by Cunningham and Saigo [17] who noted that while the developed countries have been making steady progress in improving air quality in domestic buildings, air quality in buildings in the developing world has been getting much worse. It is against this background that this study sought to explore the association of indoor particulate pollutants in isolated spaces and health symptoms among adult occupants in residential buildings in Enugu, Southeast Nigeria. The specific objectives are to: (1) identified the specific health symptoms reported by occupants in selected residential buildings in the study area (2) investigate the association between the presence of particulate pollutants and prevalence of specific health systems among occupants of the buildings.

In this study, particulate pollutants refer to particles such as smoke, dust, dirt and soot resulting from the use of dirty fuels for cooking, the use of potable electricity generating sets, burning of mosquito coils and incense in isolated spaces in homes. This study is considered important going by the several deaths resulting from indoor pollutants due to domestic activities, especially among the low- and middle-income earners who have limited access to decent housing services, low per capita floor area and low accessibility to clean domestic fuel. It is therefore expected that the findings will inform new building design strategies capable of improving indoor air quality in residential buildings as well as the health and well-being of the inhabitants of domestic buildings in the tropics.

2.LITERATURE REVIEW

The concern about indoor air quality and efforts to improve this has always been a topical issue among architects and other built environment professionals. In fact, archeological records show how ancient buildings were built to handle indoor air quality as a result of fire and heat as well as how humans and animals have evolved strategies to handle indoor air quality of their homes. According to Turner [18-19], this can be seen in the ingenuity of tall mounds built by *Macrotermes natalensis*. It is also seen in the use of building height and wind towers to induce stack ventilation of the earliest buildings of the Minoan period [20] as well as the incorporation of chimneys by Banpo villagers in China about 4000-5000 BC [21].

Gilbert [9] explained that people are constantly exposed to chemicals and particulates in the air they breathe in buildings where they spend almost all of their time. He made it clear that in the less developed countries of the world, indoor exposure to air pollutants was more severe because traditional methods of cooking often involved the use of "dirty" fuels such as coal, wood, animal dung, charcoal and kerosene. These fuels are often burned in buildings without chimneys or proper channels for ventilation. The effects are particularly seen among the most vulnerable population, mainly women and children, who are most often exposed to extremely high concentrations of particulate pollutants and the other products of combustion in buildings that are not designed to handle the sources of these pollutants. The result of this is elevated levels of acute respiratory infections (ARI) and death in women and children. According to Masters [22], particulate pollutants are fluid in nature and can flow through the indoor spaces of buildings by means of wall and floor cracks, door/window openings and spaces linking the different parts of buildings. The existing studies have shown that many people in Nigeria are exposed to indoor smoke due to the type of fuel used for domestic activities [11], [13]. Knowledge of the relationship between human health and the indoor environment has continued to evolve. The study by Sundell [23] provides understanding of the historical development of knowledge of the health risks and indoor air quality, while others examined the indoor chemistry of particulate pollutants and their procession within residential buildings [24-25]. Research in the medical field has also shown that air pollution is considered a direct contributor to aging, asthma, berrylliosis, emphysema and a contributing factor to bronchitis, cancer of the gastro-intestine tract and cancer of the respiratory track [26]. Specifically, evidence linking air pollution to human health abound in the extant literature [27]. In fact, it was reported that poor indoor environmental conditions are largely responsible for three main classes of diseases; nervous diseases, diseases of the circulatory system and diseases of the respiratory system [28].

Recently, efforts have been made to characterize the complex interactions between the health of occupants and indoor spaces they live in. For examples, sick building syndrome

(SBS) and building–related illness (BRI) have been identified as health concerns associated with indoor air quality. Whereas the former deals with conditions in which the building occupants experience acute health and/or discomfort effects: irritation of eyes, skin, nose and throat and headache due to the time spent in a building, the latter is used to describe the symptoms linked to diagnosable conditions such as house dust mite, asbestos-related mesothelioma that are attributed directly to contaminants of the indoor air. The study by Mawson [29] established a link between the occurrence of SBS and indoor air quality; and thus, it was concluded that housing conditions contribute significantly to several factors influencing the health and well-being of people [30].
Human efforts to control airflow and exhaust smoke from indoor cooking fires have been reported by researchers. For example, inadequate sanitary and poor hygienic conditions indoor space of buildings have been reported to be responsible for spreading minor and chronic diseases could be reduced through proper investigation and architectural designs of buildings [28]. Other authors suggested that poor indoor air quality can be handled mechanically [31], [32] but Laolu [33] has argued that the sustenance of this active means of maintenance of conducive indoor environment may not be guaranteed in many developing countries due to incessant power outages and perennial scarcity of clean fuel. In view of this, architects and building designers are left with no option than to explore the benefits associated with passive design strategies in improving indoor air quality in residential buildings.

3. MATERIALS AND METHODS

This study is on the residential buildings in the city of Enugu southeast Nigeria. Enugu lies in the tropical region of Nigeria in a hot-humid climatic zone characterized by dry and wet seasons. The city experiences constant high temperatures and relative humidity as well as its low wind speed all through the year. The temperature ranges between 23^0C and 27^0C and maximum 30^0C and 34^0C, with the mean relative humidity value of 84%. The rainy season is from April to November, while the dry season is from November to March.
The population of Enugu urban as at 2006 was 722,664 people with average growth rate of 2.56% [34] This implies that the yearly population increase in this city is approximately 1,850 people. Using this figure to project the population of Enugu urban in 2015 based on the 2006 population figure we have 16,650 people. Therefore, the projected population of the study area in 2015 is put at 739,314 people. In view of this, the sample size for this research was determined using the Yamane's [35] for finite population given as $n = \frac{N}{1+N(e)^2}$

where n = sample size N = population size 1 = Constant e = error margin (at 5%)

Substituting the values we have $n = \frac{739,314}{1+739,314(0.05)^2}$

$$n = \frac{739,314}{1+739,314 \ x \ 0.0025}$$

n = 399.9, which is a minimum of 400 participants
The research strategy used was a cross-sectional survey, which involved the administration of a pre-tested questionnaire. The questionnaire was designed by the researchers and the data presented in the paper were gathered from two sections of the questionnaire. The first section had questions on isolated spaces in the buildings where specific activities that can lead to the release of smoke takes place. The second section addressed the basic features of the indoor spaces, occupant health and air quality symptoms/challenges and was used to evaluate the prevalence of health symptoms: respiratory/ irritation problem, eye irritation, nausea, dizziness and headache as identified by previous authors [26], [29]. These symptoms were assessed using a combination of positive answers to specific questions.
The questionnaire was distributed to adult residents in buildings less than or 5 years and those 10 years or more than 10 years within the study area. The questionnaire was administered strictly to residents in the various locations of the study area Table 1 shows the number of questionnaires distributed in each of the three Local Government Areas in Enugu.

Table1: **POPULATION AND QUESTIONNAIRE ADMINISTRATION**

Study Location	Population	Area of LGA (Km²)	No. of Questionnaire Distributed
Enugu North	244,852	106	135
Enugu South	198,723	67	110
Enugu East	279,089	383	155

(Source: Field work, 2015; Adapted from [34]

The data were analysed using the Statistical Package for social Sciences (SPSS). The basic analyses conducted were descriptive statistics. The responses were analysed using frequencies and percentages. Logistic regression analysis was used to investigate the association between spaces where activities that bring out smoke take place and health symptoms experienced by the respondents in the survey. Odds ratios were estimated based on 95% confidence interval with *P* value < 0.05 as representing significance level. The results are presented using tables and charts.

4. RESULT AND DICUSSION

Table 2 shows that result of isolated spaces in residential buildings where activities that can lead to the release of smoke take place. From the result, it is evident that the spaces where smoke is released in the residential building sampled are kitchen, balcony, lounge and dining.

Thus result is consistent with the submission by Gilbert [9] indicating that people in this part of the world are exposed to indoor air pollutants associated with traditional methods of cooking, which often involves the use of fuels such as coal, wood, animal dung, charcoal and kerosene.

Table 2: ISOLATED SPACES IN THE BUILDINGS WHERE SMOKE IS RELEASED

Indicate where you carry out the following activities	Frequency	Percent
Cooking (n = 400)		
Kitchen	390	97.5
Dining	0	0.0
Bedroom	0	0.0
Garage	3	0.8
Pantry	0	0.0
Passage/lobbies	2	0.5
Balcony	5	1.2
Using of kerosene lanterns (n = 220)		
Kitchen	27	12.3
Lounge	97	44.1
Dining	43	19.5
Bedroom	20	9.1
Garage	0	0.0
Pantry	0	0.0
Passage/lobbies	33	15.0
Keep your power generator set while it's on (n = 372)		
Garage	40	10.8
Balcony	208	55.9
Outside in the compound	114	30.6
In the generator house	10	2.7
Burning of mosquito coils (n = 67)		
Kitchen	0	0.0
Lounge	10	14.9
Dining	19	28.4
Bedroom	27	40.3
Garage	0	0.0
Pantry	0	0.0
Passage/lobbies	11	16.4
Burning of incense (n = 28)		
Kitchen	0	0.0
Lounge	18	64.3
Dining	0	0.0
Bedroom	10	35.7
Garage	0	0.0
Pantry	0	0.0
Passage/lobbies	0	0.0

Figure 2 shows the symptoms of health situations of the residents in the buildings sampled. From the result in Figure 1, it can be seen that the highest proportion (93%) reported experiencing nasal congestion / runny nose; followed by 87% and 85% who reported eye irritation and headache, respectively, 66% and 61% reported nausea and respiratory irritation. The result is in line with the evidence in the literature indicating that poor air quality is a contributor to several respiratory tract infections and acute health and/or discomfort effects: irritation of eyes, skin, nose and throat and headache as previously highlighted in [26] and [29]

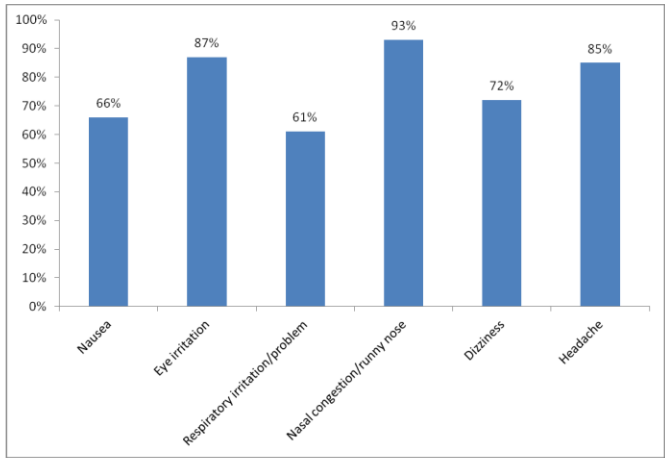

Figure 1: Health Symptoms associated with Indoor Air Quality in the study area

Table 3 is the display of the result of the Logistic regression analysis used to predict the association between the activities in isolated spaces and indoor air pollution symptoms in residential buildings in the study area. From the result in Table 3, it is evident that the *P* values for kitchen and garage at 0.001 is less than critical value of 0.01. This suggests statistical significant association with kitchen and garage and indoor air pollution. Furthermore, the result also shows that the kitchen is significantly associated with indoor air pollution symptoms such as nausea, eye irritation, respiratory/irritation problem, nasal congestion/runny nose, dizziness and headache ($P<0.05$). The key implication of this result is that one is 2 times more likely to experience nausea in the kitchen (OR = 1.988), 4 times for eye irritation (OR = 4.001), 3 times more for respiratory/irritation problem (OR = 3.144), 2 times more for nasal congestion/runny nose (1.879), 2 times more for dizziness (2.001) and 2 times more for headache (OR = 1.990). It can be inferred from this result that the kitchen is a principal space in residential buildings capable of exposing occupants to health conditions associated with indoor particulate pollutants in the study area. Table 3 also shows that lounge is significantly associated with eye irritation and nasal congestion ($P < 0.05$). In fact, from the result an occupant is 2 times more likely to experience both symptoms (OR = 1.998 and 2.138 respectively) in lounge. Similarly, the dining space is also two times more associated with eye irritation and nasal congestion ($P < 0.05$; OR = 2.430 and 2.111, respectively). The bedroom space was also found to be two times more associated with dizziness ($P = 0.041$, OR = 2.118) and three times more associated with headache ($P = 0.001$, OR = 3.199), while garage space was three times more associated with nausea ($P = 0.014$, OR = 0.445), six times more associated with eye irritation ($P = 0.001$, OR = 5.662), three times more associated with respiratory/irritation problem ($P = 0.001$, OR = 3.118) and three times more associated with nasal congestion/runny nose ($P = 0.025$, OR = 2.810). Further, pantry space was reported as being two times associated with eye irritation and nasal congestion/runny nose; passage/lobbies was significantly associated with respiratory/irritation problem, while toilet/bathroom was significantly associated with nausea (p = 0.001, OR = 2.213). However, balcony was not significantly associated with any indoor particulate pollutants symptoms; meaning that it is not part of the spaces in the residential buildings that is associated with indoor air pollution. This result did not come as a surprise because balconies are usually covered outdoor spaces in residential buildings. From the foregoing result, it can be inferred that there is a significant association between indoor air quality in isolated spaces and symptoms of health conditions among adult occupants of residential buildings in the Enugu, Nigeria

5. CONCLUSIONS

This study investigated the association between indoor particulate pollutants in isolated spaces and symptoms of health condition of occupants in selected residential buildings in Enugu, southeast Nigeria. From the result it was found that isolated spaces were smoke is released due to certain activities constitute health risk to the occupants. It was also found out that a significant exist between indoor particulate pollutants in the identified isolated spaces and symptoms of health conditions of occupants in the residential buildings investigated. The outcome of this research suggests that the design of interior spaces in residential buildings in the study area did not match the intended purpose of the spaces when viewed from the lens of the cultural and climatic imperatives of the study area. Hence, there is urgent need to adopt architectural design strategies and principles that have been proven to work on the area. This requires that building designers should pay attention to building characters that reflects the way of life of the end-users instead of adopting verbatim the features of modern buildings and popularization of tight fitted spaces. It is highly recommended the reintroduction of passive design strategies and features such as chimneys and flues, window type and position, stove type, nature of ventilation, indoor air pollution source control, leaky building envelopes solutions in residential buildings that had hitherto proven to be effective in improving indoor air quality the study area. Going forward, the following suggested are made.

- Complete exclusion of the kitchen (main source of pollution) in these tight fitted building structures. This is in line with the submission in the literature on the removal of sources of pollutant in indoor environment as a best sustainable means. Architects should consider kitchens that are detached from the other main activities areas in residential buildings as was the case in most traditional buildings [36].
- Adoption of the traditional leaky design strategy to aid induce ventilation of indoors of residential buildings in line with EUROVEN, which recommended for increased air quantity to 30L/s per person.
- Review of the existing planning and building legislation to address such topical environmental issues like indoor air quality in residential buildings.
- Periodic post-performance evaluation of buildings by the building designers as a systematic mechanism of measuring performance of occupied buildings.

Table 3: *RELATIONSHIP BETWEEN ISOLATED SPACES AND INDOOR PARTICULATE POLLUTANTS IN RESIDENTIAL BUILDINGS IN ENUGU*

Spaces	Nausea		Eye irritation		Respiratory/ irritation problem		Nasal congestion/ runny nose		Dizziness		Headache	
	P value	**OR**	**P value**	**OR**	**P value**	**OR**	**P value**	**OR**	**P value**	**OR**	**P value**	**OR**
Kitchen	0.001	1.988	0.001	4.001	0.021	3.144	0.015	1.879	0.001	2.001	0.010	1.990
Lounge	0.889	0.742	0.003	1.998	0.022	2.138	0.662	0.264	1.018	0.236	1.011	0.451
Dining	0.556	1.001	0.032	2.430	0.013	2.111	0.876	0.227	0.982	0.714	0.695	0.333
Bedroom	1.511	0.515	0.662	1.010	0.911	0.138	0.532	0.877	0.041	2.118	0.001	3.199
Garage	0.014	3.881	0.001	5.662	0.001	3.118	0.025	2.810	0.068	1.017	0.713	0.323
Pantry	0.105	0.445	0.022	2.109	0.036	1.962	0.553	0.115	0.763	0.421	0.179	0.777
Passage/lobbies	4.111	0.008	7.021	0.045	0.001	2.041	1.899	0.389	2.111	0.451	8.112	0.003
Toilet/Bathroom	0.001	2.213	1.223	0.022	2.311	0.369	3.447	0.036	3.661	0.004	0.487	0.196
Balcony	7.889	0.001	2.677	0.012	5.223	0.002	4.231	0.223	0.998	0.010	2.113	0.255

*OR = Odds Ratio; P value = Probability value ($P < 0.05$ = significant)

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