Advances in Life Sciences 2015, 5(1): 1-11
DOI: 10.5923/j.als.20150501.01

An Assessment of Indoor Air Quality in Selected Households in Squatter Settlements Warri, Nigeria

Akpofure Rim-Rukeh

Federal University of Petroleum Resources, Department of Environmenta Science, Effurun, Nigeria

Abstract An assessment of indoor air quality in selected households living in squatter settlements at Warri, Nigeria was analyzed experimentally. A total of 60 households were randomly selected for the study. In each household (living room and kitchen areas), six (6) air quality monitoring parameters; suspended particulate matter ($SPM_{2.5}$ and SPM_{10}), nitrogen dioxide (NO_2), carbon monoxide (CO), sulphur dioxide (SO_2), and ozone, (O_3) were monitored. Obtanied data were statitically analysed. Results indicate that measured levels of NO_2, CO and SPM in all sampled households were above regulatory limits of 0.06ppm, 10ppm and 250µg/m^3 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. Structurally similarity in the houses promoted the diffusion of pollutants from the kitchen into the living spaces. The air quality index (AQI) shows that the air is unhealthy for human habitation. At the policy level, the study has identified several sources of indoor air pollution exposure risk that can be mitigated by the dwellers of squatter settlements.

Keywords Slums, Air quality index, Households, Firewoods, Particulate matter, Kitchen, Living room

1. Introduction

Besides just looking at the clean and decorative facades of the buildings in a city, a closer look reveals a darker aspect of the urban scenario – the presence of squatter settlements or slums. Although the concept of slums or squatter settlements and its definition vary from country to country depending upon the socio-economic conditions of the society, slums are generally regarded as neglected parts of cities where housing and living conditions are appallingly poor. Slum household as a group of individuals living under the same roof that lack one or more of the following conditions; access to safe water; access to sanitation; secure tenure; durability of housing; and sufficient living area [1]. Slumshave also been viewed as areas where building are in any respect unfit for human habitation by reason of dilapidation, overcrowding, faulty arrangement and design of such buildings, narrowness or faulty arrangement of streets, lack of ventilation, light, sanitation facilities or any combination of these factors which are detrimental to safety, health and morals [2].

* Corresponding author:
arimrukeh@yahoo.co.uk (Akpofure Rim-Rukeh)
Published online at http://journal.sapub.org/als

Economically slums are areas inhabited by the poor in the urban system [3]. The poor are the unemployed, the unskilled, and illiterate and often the alcoholics, the vagabond and the delinquent [3].

The basic characteristics of slums are visually unpleasant buildings, lack of basic amenities (water supply, sanitary, electricity etc), acute overcrowding, services used illegally, high birth rate, high mortality rate, high infant mortality, unhealthy environment, low socio-economic conditions, environmental (land, air, water and noise) pollution, frustration among people, lack of civic sense and knowledge, grossly congested area and unsecured life. The living conditions in slums are usually unhygienic and contrary to all norms of planned urban growth [4].

The origin of slum settlements can be traced to the great industrial revolution in Britain [5]. The development of the wheel machine in London created opportunities for job and thus lured people who then settled themselves near to the factory. The limited residences built around the factory could not provide shelter for all the workers. Some people adjusted themselves in congested spaces although basic amenities were not available, thus a 'slumdon' was created. Today, slums are fast becoming major characteristics of an industrial growing city. There is no likelihood that the present trend of increasing urban population growth in Nigeria can be changed for some time to come. This is because for many Nigerians there is the belief that the only hope of improving their standard of living is to live in an urban environment.

Living conditions have a direct impact on public health. Slum dwellers usually experience a high rate of disease [6]. Diseases that have been reported in slums include cholera [7], HIV/AIDS, [8], measles [9], malaria, [10] dengue [11], typhoid [12], drug resistant tuberculosis [13], and other epidemics [14]. Slum dwellers have also been reported to be affected by indoor air pollution. Examples of short-term effects of indoor air pollutants include irritation to the eyes, nose and throat, and upper respiratory infections such as bronchitis, and pneumonia [15-18]. Long-term effects of poor indoor air quality include chronic respiratory disease, lung cancer, heart disease and even damage to the brain, nerves, liver or kidneys [19], [20]. Researchers have found that radon gas is responsible for over 1,800 deaths annually in United Kingdom [21].

Relative small-scale studies of indoor PM_{10} exposure from woodfuel combustion have been conducted in Kenya [22], Guatemala [23], Mexico [24] and Gambia [25]. Recently, a larger sample of houses has been studied in rural India [26], [27]. In Nigeria there is little or no empirical database. This fact has being collaborated [28]. In Nigeria, interdisciplinary studies of slum areas are very limited. An early attempt in indoor air pollution studies in Nigeria, paid attention on the physical aspects of slums [29]. This paper provides empirical evidence on the levels of indoor air quality insome households in squatter settlements within Warri metropolis. The general aim of the current study was to create a database of the indoor airconcentrations for suspended particulate matter, carbon monoxide ozone, sulphur dioxide and nitrogen dioxide insquatter settlement in Warri, Nigeria. This study was designed to answer several questions about air quality exposure in poor households. First, is the assessment of indoor air quality monitoring. Second, how different is indoor pollution in kitchen area and living room area? Are these concentrations significantly affected by typical variations in cooking practices, cooking locations, structural characteristics and ventilation practice (opening doors and windows)? If such effects are large, then simple alterations in household arrangements may provide a cost-effective alternative to fuel switching or investment in clean stoves. Thirdly, what is the health implication for the households. Finally, what are the prospects for increased use of improved stoves and clean fuels in Nigeria?

2. Materials and Methods

2.1. Study Area

The study area is Warri, which is located in the Southern part of Delta State, Nigeria (Figure 1). It is a major urban city in the Niger Delta area, where a number of industries such as Delta Steel Company, Shell Petroleum and Development Company (SPDC), Chervron Nig. Ltd., Warri refinery and Petrochemical companies, Nigeria Gas Company are located.

The study area is inundated with a number of squatter settlements (slums) that are usually located by river banksand on pipeline right of way. Examples of such slums are Maroko slum, Igbuduslum, Marcaver slum, Waterside slum, Hausa quarter etc. Geographically, the area is enclosed between latitude 4°40′N and 4°30′N and longitude 6°12′E and 6°20′E.The area is within the humid tropical zone with defined dry (November – March) and rainy (April – October) seasons. The rainy season is brought about by the south-west trade wind blowing across the Atlantic Ocean. The dry, dusty and often cold north-east trade wind blowing across the Sahara desert dominates the dry season and brings a short spell of harmattan, [30]. The relative humidity of the area is very high, with values ranging from 74.7% in January to 88.7% in July.

Figure 1. Google map of Delta State showing Warri

2.2. Methodology

Three (3) slums (Maroko, Igbudu and Marcaver) were selected for the study. The choice of the selected slums is based on their large sizes and high population. At each of the selected slum, twenty (20) households were randomly selected, bringing the total households investigated in the study to sixty (60). In each of the randomly selected household air quality was monitored in the living room and kitchen areas. In each household, six (6) air quality monitoring parameters; suspended particulate matter ($SPM_{2.5}$), suspended particulate matter (SPM_{10}), nitrogen dioxide (NO_2), carbon monoxide (CO), sulphur dioxide (SO_2), and ozone, (O_3) were determined using a series of hand held air quality monitoring equipment. These monitors include: An industrial scientificcorporation ITX Multi gas monitor for NO_2,SO_2, and CO. O_3 concentration was measured with Ebara Jitsugyo EG-2001 high-accuracy O_3 monitor, which provided O_3 mixingratio referenced to 1 atm and 295 K conditions with a1-ppb resolution. The GT-331 VI.04 A Met One Instrument, Inc. Aerosol Mass Monitor Model GT-331 was used in determination of suspended particulate matter (SPM). The monitor uses light scatter to measure individual particles instead of clouds like other monitors. The particle information is then grouped into size ranges and converted to mass concentration over 4 minutes at a flow rate of 2.83L/min into measuring ranges of: $SPM_{2.5}$ and SPM_{10} mass concentration. Measurements were done by holding the sensor to a height of about two meters in the direction of the prevailing wind and readings recorded at stability. The eight-hour monitoring period was carried out from early morning to evening during the monitoring period. The study was carried during thedry season of January, 2014.

2.3. Statistical Analysis

Obtained data were statistically analysed using the following statistical tools:

Correlation Coefficient (r): It is a measure of the strength and direction of the linear relationship between two variables that is defined as the (sample) covariance of the variables divided by the product of their (sample) standard deviations. Correlation values are bound between a value of -1 and +1. A correlation of +1 can be interpreted to suggest that both variables move perfectly positively with each other, and a -1 implies they are perfectly negatively correlated. Specifically, a correlation of 0.7 – 1.0 is describe as a strongly positive; 0.5 – 0.69 is described as moderately positive and 0.0 – 0.49 is described as weakly positive [31].

The coefficient of determination (R^2) is a measure of how well the regression line represents the data. If the regression line passes exactly through every point on the scatter plot, it would be able to explain all of the variation. The further the line is away from the points, the less it is able to explain.

Mean and Standard Deviations: The sample mean is the average and is computed as the sum of all the observed outcomes from the sample divided by the total number of events. We use x as the symbol for the sample mean. In mathematical terms,

$$\bar{x} = \frac{1}{n}\sum_{i=1}^{n} x$$

where n is the sample size and the x correspond to the observed valued.

The Standard Deviation is a measure of how spread out numbers are. The symbol for Standard Deviation is **σ** (the Greek letter sigma).

This is the formula for Standard Deviation:

$$\sigma = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(x_i - \mu)^2}$$

3. Results and Discussion

3.1. Results

Results of air quality monitored in the randomly selected households in the three squatter settlements (slums) are as presented in Tables 1-3. Results of the air quality for the houses in which kitchens and living rooms were concurrently monitored are included.

3.2. Discussion

Range of values of indoor air quality in the selected households in the squatter settlements and regulatory limits is presented in Table 4.

From the results as presented in Table 4, measured levels of NO_2, CO and SPM in all sampled households were above regulatory limits of 0.06ppm, 10ppm and 250μg/m^3 respectively [33]. Although, the levels of CO are higher than the regulatory limits, much higher levels of 50 ppm of CO have been recorded in Kenyan Masai homes [34]. Concentrations of 300 μg/m^{3}or greater for respirable airborne particulates (PM_{10}) are common in Bangladeshi households [35]. This is in sharp contrast with houses in non-slum areas where almost 91% of the houses are of a permanent nature and indoor air quality are below regulatory limits [2]. A pollutant measurement surpassing national ambient air quality standards for a specific averaging time is referred to as exceedance. Adopting the Nepal, Ministry of Population and Environment categorization of five different types of air quality based on the levels of PM_{10}: 0-6μg/m^3 as good, 60-120μg/m^3 as moderate, 121-350μg/m^3 as unhealthy, 351-425μg/m^3 as very unhealthy and greater than 425μg/m^3 as hazardous [36]. The indoor air quality in squatter settlement located in Warri metropolis can be described as unhealthy.

Table 1. Air Quality in the Kitchen and Living Rooms in the Maroko Slum

	PM_{10} (µg/m^3)		$PM_{2.5}$ (µg/m^3)		CO (ppm)		O_3(µg/m^3)		SO_2 (ppm)		NO_2 (ppm)	
No of Households	**Parlour (Living room)**	**Kitchen**	**Parlour (Living room)**	**Kitchen**	**Parlour (Living room)**	**Kitchen**	**Parlour (Living room)**	**Kitchen**	**Parlour (Living room)**	**Kitchen**	**Parlour (Living room)**	**Kitchen**
1	317	385	97	128	21	27	55	53	<0.01	<0.01	0.19	0.21
2	328	391	92	131	33	39	61	66	<0.01	<0.01	0.27	0.25
3	274	279	93	122	32	40	51	52	<0.01	<0.01	0.23	0.22
4	290	302	96	127	28	31	57	51	<0.01	<0.01	0.19	0.25
5	382	439	89	118	30	36	58	55	<0.01	<0.01	0.23	0.19
6	297	289	88	122	21	33	54	57	<0.01	<0.01	0.27	0.22
7	291	297	91	127	30	32	66	63	<0.01	<0.01	0.24	0.25
8	283	288	93	131	27	30	66	62	<0.01	<0.01	0.19	0.27
9	279	293	103	113	23	29	62	59	<0.01	<0.01	0.22	0.30
10	293	321	104	119	32	37	56	57	<0.01	<0.01	0.30	0.28
11	279	318	97	120	37	40	55	56	<0.01	<0.01	0.21	0.19
12	291	276	92	128	32	36	52	50	<0.01	<0.01	0.20	0.23
13	283	298	89	125	32	41	63	59	<0.01	<0.01	0.28	0.26
14	284	291	91	132	29	36	66	62	<0.01	<0.01	0.23	0.23
15	274	301	93	122	31	37	67	66	<0.01	<0.01	0.21	0.25
16	293	309	94	125	27	32	51	50	<0.01	<0.01	0.25	0.25
17	281	277	96	127	22	29	44	48	<0.01	<0.01	0.21	0.28
18	272	271	89	123	27	30	49	52	<0.01	<0.01	0.27	0.27
19	276	390	91	117	29	31	58	55	<0.01	<0.01	0.23	0.21
20	290	363	93	119	31	38	57	53	<0.01	<0.01	0.25	0.24
Mean	**292.85**	**318.90**	**93.55**	**123.80**	**28.70**	**34.20**	**57.4**	**56.3**	**<0.01**	**<0.01**	**0.2335**	**0.2425**
Std	**25.17**	**47.79**	**4.31**	**5.17**	**4.29**	**4.29**	**6.35**	**5.39**	**<0.02**	**<0.02**	**0.0323**	**0.0301**
t-test	**2.1023**		**19.5898**		**3.9515**		**0.5757**				**0.8886**	
Crit-t 0.01	2.423		2.423		2.423		2.423				2.423	
Decision	No significant difference		Significant difference		Significant difference		No significant difference				No significant difference	

Table 2. Air Quality in the Kitchen and Living Rooms in the Makaver Slum

	PM_{10} (μg/m³)		$PM_{2.5}$ (μg/m³)		CO (ppm)		O_3(μg/m³)		SO_2		NO_2	
No of Households	**Parlour (Living room)**	**Kitchen**	**Parlour (Living room)**	**Kitchen**	**Parlour (Living room)**	**Kitchen**	**Parlour (Living room)**	**Kitchen**	**Parlour (Living room)**	**Kitchen**	**Parlour (Living room)**	**Kitchen**
1	294	332	112	127	19	23	52	55	<0.01	<0.01	0.20	0.21
2	288	340	114	131	16	25	49	43	<0.01	<0.01	0.21	0.23
3	279	283	117	133	21	27	61	55	<0.01	<0.01	0.25	0.24
4	301	326	108	130	20	23	49	51	<0.01	<0.01	0.20	0.19
5	312	432	112	129	18	21	48	45	<0.01	<0.01	0.21	0.23
6	290	294	106	135	21	27	55	52	<0.01	<0.01	0.20	0.22
7	295	311	105	128	22	25	53	50	<0.01	<0.01	0.19	0.18
8	288	290	97	129	21	27	52	49	<0.01	<0.01	0.23	0.21
9	291	312	99	133	21	23	50	53	<0.01	<0.01	0.21	0.25
10	299	311	103	137	18	27	59	55	<0.01	<0.01	0.24	0.27
11	255	282	112	132	17	22	57	56	<0.01	<0.01	0.23	0.19
12	289	292	117	129	12	16	55	53	<0.01	<0.01	0.21	0.23
13	287	302	103	114	15	18	53	51	<0.01	<0.01	0.20	0.22
14	292	311	99	117	19	21	61	59	<0.01	<0.01	0.25	0.27
15	299	320	97	131	22	28	54	52	<0.01	<0.01	0.21	0.25
16	302	312	94	128	21	27	59	57	<0.01	<0.01	0.23	0.26
17	287	299	103	127	20	24	50	49	<0.01	<0.01	0.19	0.21
18	279	282	104	129	21	25	49	49	<0.01	<0.01	0.21	0.24
19	278	392	109	132	20	27	51	53	<0.01	<0.01	0.22	0.26
20	312	361	99	131	17	21	53	51	<0.01	<0.01	0.20	0.23
Mean	**290.85**	**319.20**	**105.5**	**129.10**	**19.05**	**23.85**	**53.5**	**51.9**	**<0.01**	**<0.01**	**0.2145**	**0.2295**
Std	**12.70**	**38.20**	**6.91**	**5.34**	**2.605**	**3.30**	**4.08**	**3.86**	**0.0**	**0.0**	**0.018**	**0.026**
t-test	**3.0697**		**11.7796**		**4.9765**		**1.2627**				**0.3987**	
Crit-t 0.01	2.423		2.423		2.423		2.423		2		2.423	
Decision	Significantly different		Significantly different		Significantly different		No Significant differnce				No Significant differnce	

Table 3. Air Quality in the Kitchen and Living Rooms in the Igbudu Slum

	PM_{10} (µg/m^3)		$PM_{2.5}$ (µg/m^3)		CO (ppm)		O_3(µg/m^3)		SO_2 (ppm)		NO_2 (ppm)	
No of Households	**Parlour (Living room)**	**Kitchen**	**Parlour (Living room)**	**Kitchen**	**Parlour (Living room)**	**Kitchen**	**Parlour (Living room)**	**Kitchen**	**Parlour (Living room)**	**Kitchen**	**Parlour (Living room)**	**Kitchen**
1	376	388	97	128	26	29	53	49	<0.01	<0.01	0.26	0.27
2	391	403	99	130	31	42	51	54	<0.01	<0.01	0.26	0.29
3	327	379	103	132	35	43	49	51	<0.01	<0.01	0.21	0.22
4	290	343	102	129	32	37	55	48	<0.01	<0.01	0.26	0.24
5	397	410	113	130	35	39	51	50	<0.01	<0.01	0.23	0.26
6	326	320	108	129	28	39	52	52	<0.01	<0.01	0.22	0.19
7	391	412	95	127	31	37	56	53	<0.01	<0.01	0.24	0.22
8	377	490	97	126	37	33	53	57	<0.01	<0.01	0.24	0.23
9	345	397	91	131	32	38	49	55	<0.01	<0.01	0.26	0.24
10	391	417	90	130	35	41	48	52	<0.01	<0.01	0.23	0.25
11	342	388	110	128	39	43	57	53	<0.01	<0.01	0.19	0.18
12	317	372	105	127	33	38	55	51	<0.01	<0.01	0.20	0.19
13	381	331	112	129	35	46	53	56	<0.01	<0.01	0.21	0.20
14	384	362	107	130	31	41	57	49	<0.01	<0.01	0.24	0.25
15	297	377	99	133	34	39	52	48	<0.01	<0.01	0.21	0.26
16	327	392	93	135	31	38	54	51	<0.01	<0.01	0.23	0.21
17	331	387	102	129	32	32	57	50	<0.01	<0.01	0.20	0.22
18	372	411	110	132	36	37	52	49	<0.01	<0.01	0.27	0.25
19	376	410	97	127	32	37	48	49	<0.01	<0.01	0.24	0.27
20	341	390	95	128	35	42	49	51	<0.01	<0.01	0.23	0.26
Mean	**353.95**	**388.95**	**101.25**	**129.50**	**33.0**	**38.55**	**52.55**	**51.40**	**<0.01**	**<0.01**	**0.2315**	**0.235**
Std	**33.47**	**36.025**	**7.055**	**2.259**	**3.12**	**4.02**	**3.0**	**2.60**	**<0.02**	**<0.02**	**0.0231**	**0.0305**
t-test	**3.1023**		**16.6228**		**4.7540**		**1.9251**				**2.0676**	
t-critical at 0.01	2.423		2.423		2.423		2.423		2.423		2.423	
Decision	Significantly different		Significantly different		Significantly different		No significant difference				No significant difference	

Table 4. Range of Values of Air Quality in the Kitchen and Living Rooms in the Selected Households

S/N	Parameters/Units	Range of Indoor Air Quality in Study Area		Air Quality Regulatory Limits
		Parlour (living room)	Kitchen	
1	$SPM_{2.5}$ (μg/m^3)	89 – 112	117 - 135	150 – 230 (μg/m^3) [32].
2	SPM_{10} (μg/m^3)	255 – 391	271 - 439	250 (μg/m^3) [33].
3	CO (ppm)	12 -33	18 -41	10 ppm [33].
4	O_3 (μg/m^3)	44 – 67	48 – 60	100(μg/m^3) [33].
5	SO_2 (ppm)	<0.01	<0.01	0.1ppm [33].
6	NO_2 (ppm)	0.19 – 0.30	0.18 – 0.30	0.04 – 0.06 ppm [33].

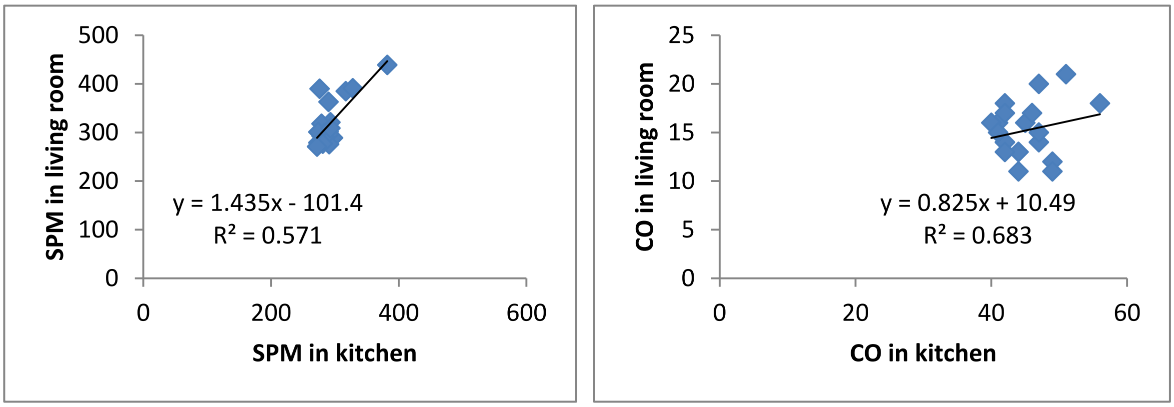

Figure 2. Correlation of SPM and CO values in the kitchen and living room in Marako Slum

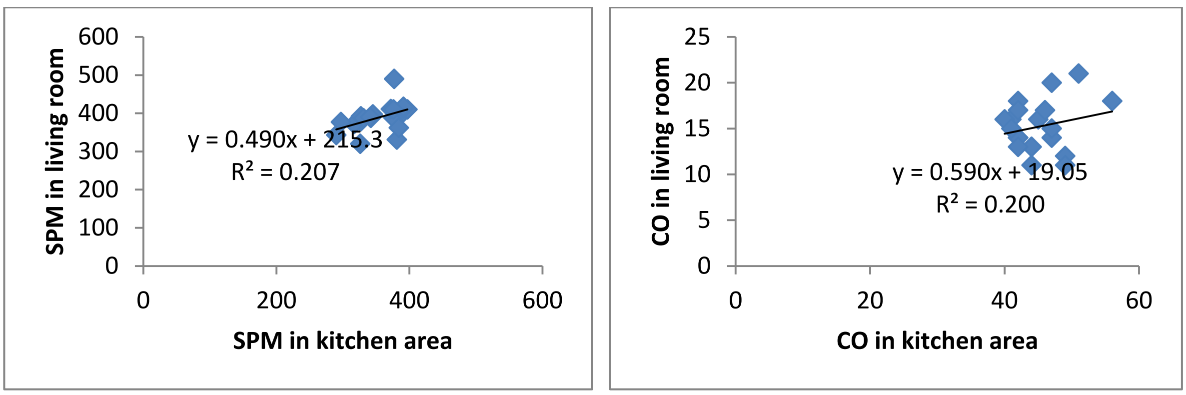

Figure 3. Correlation of SPM and CO in the kitchen and living room in Igbudu Slum

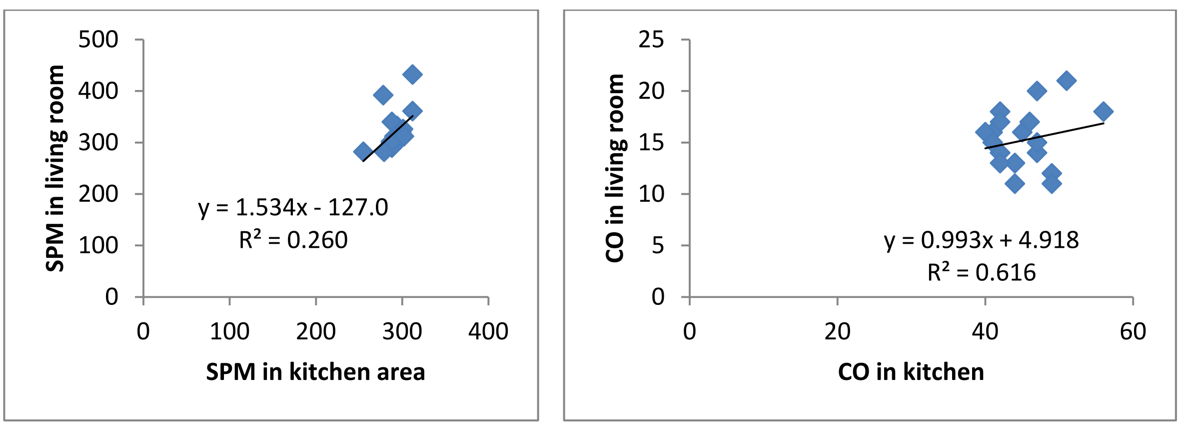

Figure 4. Correlation of SPMand CO values in the kitchen and living room in Makaver Slum

Measured levels of O_3in all sampled households were below regulatory limits of 100 ($\mu g/m^3$) [32]. Although, there are no known sources of ozone in the area, it is assumed that the obtained values of 44 – 67 ($\mu g/m^3$) may have been created by chemical reactions between oxides of nitrogen (NOx) and volatile organic compounds (VOC) in the presence of sunlight. As have been similarly observed [37]. Levels of SO_2 in all sampled households were below equipment detection limits of 0.1ppm [33].

Obtained values of NO_2, CO and SPM in this study may have resulted from the form of domestic fuels use for cooking. Field observation shows that common sources of fuel are firewood, wood charcoal and sawdust. This observation is consistent with that reportedin literature [38], [39-41]. Biomass and coal smoke have been reported to emit many health-damaging pollutants, including particulate matter (PM), carbon monoxide (CO), sulphur oxides, nitrogen oxides, aldehydes, benzene, and polyaromatic compounds [42], [43].

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 Momentcorrelation. 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. Computed values shows strong positive correlation between the air quality monitored in the kitchen and living room areas for the measured parameters. When the values of the correlation were squared, coefficient of determination of 57.10% and 68.23% were obtained for the levels of SPM and CO respectively for households in Marako slum. At Igbudu slum, coefficient of determination of 20.70% and 19.98% were obtained for SPM and CO respectively while at Makaver slum coefficient of determination of 26.01% and 61.47% for SPM and CO respectively. Obtained values of measured parameters in both the living room (parlour) and kitchen area of the selected households were subjected to significance test using a two-tailed under a probability of 0.01, calculated valuesindicate signicant difference in some cases as presented in Tables 1-3.

The strong positive correlation between the concentrations of SPM and CO in the kitchen and living areas may be attributed to the characteristics of houses that are similar in structure in the study slums. Such structural arrangement of the houses affects ventilation. In most of the households that were randomly selected for the study, structural configurations show that kitchen are located within dwelling and attached. They do not have separate kitchens; cooking takes place inside the single dwelling room during the rainy season and outside during the dry season. Similar structural arrangements of poor households in Bangladesh have been reported [35]. This kind of structural arrangement promotes the amount of smoke diffusing from the kitchen into the living spaces.

Health risk assessment of the results was explored using the guidelines for reporting of daily air quality - air quality index (AQI) (see equation 1) [44]. The descriptor of air quality index is presented in Table 5 and illustrated in Figure 5.

$$I_P = \frac{I_{Hi} - I_{Lo}}{BP_{Hi} - BP_{Lo}} (C_P - BP_{Lo}) + I_{Lo} \quad (1)$$

Where: I_P = the index for pollutant P
CP = the rounded concentration of pollutant P
BP_{Hi} = the breakpoint that is greater than or equal to C_P
BP_{Lo} = the breakpoint that is less than or equal to C_P
I_{Hi} = the AQI value corresponding to BP_{Hi}
I_{Lo} = the AQI value corresponding to BP_{Lo}

Descriptor	AQI	Risk Message
Good	0 - 50	No message
Moderate	51 - 100	Unusually sensitive individuals (ozone)
Unhealthy for Sensitive Groups	101 - 150	Identifiable groups at risk – different groups for different pollutants
Unhealthy	151 - 200	General public at risk; groups at greater risk
Very Unhealthy	201 - 300	General public at greater risk; groups at greatest risk

Figure 5. Air Quality Index Descriptor

Table 5. Air Quality Index descriptor

These Breakpoints								
O_3(ppm) 8 -hour	**O_3(ppm) 1 -hour**	**$PM_{2.5}$ (μg/m^3)**	**PM_{10} (μg/m^3)**	**CO (ppm)**	**SO_2 (ppm)**	**NO_2 (ppm)**	**AQI**	**Category**
0.000 -0.064	-	0.0 – 15.4	0- 54	0.0 – 4.4	0.00 – 0.034	-	0-50	Good
0.065 – 0.084	-	15.5 – 40.4	55 – 154	4.5 – 9.4	0.035-0.144	-	51-100	Moderate
0.085 – 0.104	0.125 – 0.164	40.5 – 65.4	155- 254	9.5 – 12.4	0.145 – 0.224	-	101-150	Unhealthy for sensitive groups
0.105 – 0.124	0.165 – 0.204	65.5 – 150.4	255 – 354	12.5 -15.4	0.225 –0.304	-	151 - 200	Unhealthy
0.125 – 0.374	0.205 – 0.404	150.5 – 250.4	355 – 424	15.5 – 30.4	0.305 – 0.604	0.65 – 1.24	201 - 300	Very unhealthy
-	0.405 – 0.504	250.5 – 350.4	425 – 504	30.5 – 40.4	0.605 – 0.804	1.25 – 1.64	301 - 400	Hazardous
-	0.505 – 0.604	350.5 – 500.4	505 – 604	40.5 – 50.4	0.805 – 1.004	1.65 – 2.01	401 - 500	Hazardous

The air quality index (AQI) calculated for the squatter settlements in Warri metropolis for Particulate matter ($PM_{2.5}$ and PM_{10}), Ozone (O_3), and Carbon monoxide (CO) is presented in Table 6.

Table 6. Air Quality Index of Studied Squatter Settlements

Parameters	Air Quality Index		Air Quality Descriptor
	Parlour (Living room)	Kitchen	
$PM_{2.5}$	170	186	Unhealthy
PM_{10}	174	178	Unhealthy
CO	277	302.5	Very unhealthy
O_3	436	426	Hazardous

Using carbon monoxide, the air quality can be described as unhealthy for active children, women and adults, and people with respiratory disease such as asthma. Since today's air quality is expected to be the same as long as the source and forms of fuel remain the same, sensitive groups should consider limiting staying indoor especially during cooking periods.

4. Policy Implications

At the policy level, the study has identified several sources of indoor air pollution exposure risk that can be mitigated bythe dwellers of squatter settlements in Nigeriaat feasible cost. I strongly believe that self-interest will motivate the slum dwellers to act, once they become convinced that the problem is serious, and that their actions will be cost-effective. The following should form the policy thrust:

- Restructuring of the buildings using porous construction material and providing proper ventilation in cooking areas. This will yield a better indoor health environment. The use of chimneys or vent-holes may improve indoor air in individual households.
- The use of wood, dung and other biomass fuels should be discouraged.
- Results imply that measures that could significantly reduce indoor air pollution exposure would be; use of cleaner fuels; purchase of more fuel-efficient stoves; peripheral location of cooking facilities; and ventilation of cooking smoke through astack tall enough to reduce the particulate concentration, by dispersing smoke over a relatively broad area.

5. Conclusions

Findings of the study show that measured levels of NO_2, CO and SPM in all sampled households were above regulatory limits which may have resulted from the form of domestic fuels (firewood, wood charcoal and sawdust) use for cooking. Air quality index (AQI) indicates that the indoor air can be described as unhealthy for active children, women and adults, and people with respiratory disease such as asthma. At the policy level, the study has identified several sources of indoor air pollution exposure risk that can be mitigated by the dwellers of squatter settlements. Alternatively, cooking smoke could be ventilated through a stack tall enough to disperse smoke over a broad area, thereby reducing particulate concentration in slum households. In addition, the solution is to switch to cleaner-burning stoves and modern fuels andto increase their affordability. This work would be an important supply to the indoor air pollution studies, and would be helpful in policy making.

REFERENCES

[1] UN-habitat (2003). The Challenge of Slums: Global Report on Human Settlement.Earthscan, London: UN-Habitat. 2003.

[2] Chandramouli, I. A. S (2003) Slums in Chernai: A Profile in Martin, J., Bunch, V., M. Suresh and T. V. Kumaran (eds.) Proceedings of the Third International Conference on Environment and Health, Chennai, Indian: 82-88.

[3] Portes, A (1971) The Urban Slum in Chile: Types and Correlates. Land Economics (47): 697-720.

[4] Warah, B. (2003) Slums and Housing in Africa: The Challenge of Slums. London: Earthscan Publications Ltd.

[5] Ashton, J. R. (2006). Back-to-Back Housing Courts and Privies; the Slums of 19th Century England. Journal of Epidemiol. Community Health 60: 654 – 659.

[6] Desai, V.K. (2003). Study of measles incidence and vaccination coverage in slums of Surat city.Indian Journal of Community Medicine28 (1): 17 - 23.

[7] Sur, D. (2005). The burden of cholera in the slums of Kolkata, India: data from a prospective, community based study. Archives of Disease in Childhood90 (11): 1175–1181.

[8] Madise, N., A. Ziraba, J. Inungu, S. Khamadi, A. Ezeh, E. Zulu, J. Kebaso, V. Okoth and M. Mwau. 2012. Are Slum Dwellers at Heightened Risk of HIVInfection Than Other Urban Residents? Evidence from Population-Based HIVPrevalence Surveys in Kenya. Health and Place 18(5): 1144-52.

[9] Khalique, F (2008). Effects of paternal smoking on the pulmonary functions of adolescent males, Indian Journal of Physiology 52 (4): 413 – 419.

[10] Bhattacharya, S. K., Sur, D., Dutta, S., Kanungo, S., Ochiai, R. L., Kim, D. R., andDeen, J. (2013). Vivax malaria and bacteraemia: a prospective study in Kolkata, India. Malaria journal, 12(1), 176-178.

[11] Alzahrani, A.G. (2013). Geographical distribution and spatio-temporal patterns of dengue cases in Jeddah Governorate from 2006–2008. Transactions of The Royal Society of Tropical Medicine and Hygiene, 107(1), 23-29.

[12] Corner, R. J., Dewan, A. M., and Hashizume, M. (2013).Modelling typhoid risk in Dhaka Metropolitan Area of Bangladesh: the role of socio-economic and environmental factors.International journal of health geographics, 12(1), 13.

[13] Quinn, T and Bartlett, J. (2010), Global infectious diseases and urbanization, Urban Health: Global Perspectives, 18, 105.

[14] Sanderson, D. (2000), Cities, disasters and livelihoods, Environment and Urbanization, 12(2): 93-102.

[15] Giri D, Krishna, M.V, Smith K (2006). The influence of meteorological conditions on PM10 concentrations in Kathmandu Valley. Int J Environ Res. 2008;2:49–60.

[16] Ostro, B.D; Lipsett, M.J; Mann, J.K (1991). Ambient air pollution and hospilization for respiratory causes in Minneapolis – St Paul and Birminghan. Epidermeology, 8: 364 – 370.

[17] Roemer, W., Hoek, G., and Brunkreef, B. (1993) Effects of Ambient Winter Air Pollution on Respiratory Health of Children with Chronic Repsiratory Symptoms. American Review Respirarory Diseases, 147, 118-124.

[18] Wolf, P. C (1971) Carbon Monoxide measurement and monitory in Urban air, Env. Sci. Tech. 5 (3): 231 - 233.

[19] Armstrong, J.R.M and Campbell, H. (1991). Indoor Air Pollution Exposure and Lower Respiratory Infection in Young Cambrian Children, Int. J. Epidemiol. 20: 144-150.

[20] Das, J. (2004). Indoor Air Pollution and its Effect on Health, Geographical Review of India, 66: 93-98.

[21] Spengler, J.D., Samet, J.M. (1991). Indoor air pollution: A health perspective. Baltimore: Johns Hopkins University Press.

[22] Boleij, J., Ruigewaard, P. andHoek,F. (1989). Domestic air pollution from biomass burning in Kenya, Atmospheric Environment, 23: 1677-1681.

[23] Smith, K.R. (1993), Fuel Combustion, Air Pollution Exposure, and Health: The Situation in Developing Countries, Annual Review of Energy and Environment, 18:529-566.

[24] Santos-Burgoa, C., L. Rojas-Bracho, I. Rosas-Perez, A. Ramirez-Sanchez, G. Sanchez-Rico, S.and Mejia-Hernandez (1998). Modelling particulate exposure and respiratory illness risk in a general population,GacetaMedica Mexicana,134(4): 407-417.

[25] Campbell, H., Armstrong, J.R. and Byass, P (1997). Indoor air pollution in developing countries and acute respiratory infections in children. Lancet1989; 1: 1012.

[26] Balakrishnan, K., S. Sambandam, P. Ramaswamy,S. Mehta, and K. R. Smith. (2002). ExposureAssessment for Respirable Particulates Associatedwith Household Fuel Use in Rural Districts of AndhraPradesh, India." Journal of Exposure Analysis and Environmental Epidemiology 14 (Suppl. 1): S14–25.

[27] Parikh J, Balakrishnan K, and LaxmiV (2001). Exposure to air pollutants from combustion of cooking fuels: a case study of rural Tamil Nadu, India. Accessed online at: [http://www.repp.org/discussiongroups/resources/stoves/Countries/exposure.doc].

[28] Onokerhoraye, A. G. (1988). Case Studies of Urban slums and Environmental Problems in Nigeria cities in Sada, P. O. and Odemerho, F. O (eds) Environmental issues and Management in Nigerian Development. Ibadan: Evans Brothers (Nig) Ltd.

[29] Marris, P. (1961). Slum Clearance and Family Life in Lagos. London: University Press.

[30] Oguntoyinbo, J. and Hayward, D. (1987) Climatology of West Africa, Jersey, Hutchinson and Noble Books.

[31] Wilks, D.S. (1995). Statistical methods in atmospheric sciences, an introduction. Academic Press, New York.

[32] WHO (World Health Organization). 2000. Indoor AirPollution and Health: Scope of the Problem. WHOFact Sheet No. 292. Geneva: WHO.

[33] WHO (2006) Air Quality Guidelines: Global Update 2005. WHO Regional Office for Europe, Copenhagen Vahlsing/Smith MS AIRQ - 186.

[34] Bruce N., Perez-Padilla R., and Albalak R (2002). Indoor air pollution in developing countries: a major environmental and public health challenge. Bulletin of the World Health Organization, 78 (9); 1078-1092.

[35] Dasgupta, S., M. Huq, M. Khaliquzzaman, K. Pandey, and D. Wheeler.(2006). Indoor Air Quality for Poor Families: New Evidence from Bangladesh.Indoor Air16(6): 426–44.

[36] URBAIR (1997). Urban air quality management strategy in Asia: Kathmandu Valley Report. World Bank Technical paper No. 378, Washington, D. C. USA.

[37] Reeves, Claire. E.; Penkett, Stuart A.; Bauguitte, Stephane; Law, Kathy S.; Evans, Mathew J.; Bandy, Brian J.; Monks, Paul S.; Edwards, Gavin D.; Phillips, Gavin; Barjat, Hannah; Kent, Joss; Dewey, Ken; Schmitgen, Sandra; Kley, Dieter

(2002). Potential for photochemical ozone formation in the troposphere over the North Atlantic as derived from aircraft observationsduring ACSOE.Journal of Geophysical Research 107 (D23): 4707.

[38] World Bank. 2002. Rural Electrification andDevelopment in the Philippines: Measuring the Socialand Economic Benefits. Energy Sector ManagementAssistance Programme (ESMAP) Report No. 255/02.Washington, DC: World Bank.

[39] Brauer M and Saxena, S (2002). Accessible tools for classification of exposure to particles. Chemosphere 49:1151-62.

[40] Moschandreas, D.J,Watson J and D'Aberton P (2002). Methodology of exposure modeling. Chemosphere 49:923-46.

[41] Freeman, N.C. G and Saenz de Tejada S (2002). Methods for collecting time/activity pattern information related to exposure to combustion products. Chemosphere49:979-92.

[42] Smith, K. R.(1987), Biofuels, Air Pollution, and Health: A Global Review, New York: Delware Publishers.

[43] Nilsson, S and Pitt, D (1994). Protecting the atmosphere. London: Earthscam Publications Ltd.

[44] United States EPA (Environmental ProtectionAgency). 2006. PM Standards(http://www.epa.gov/oar/particlepollution/standards.html).