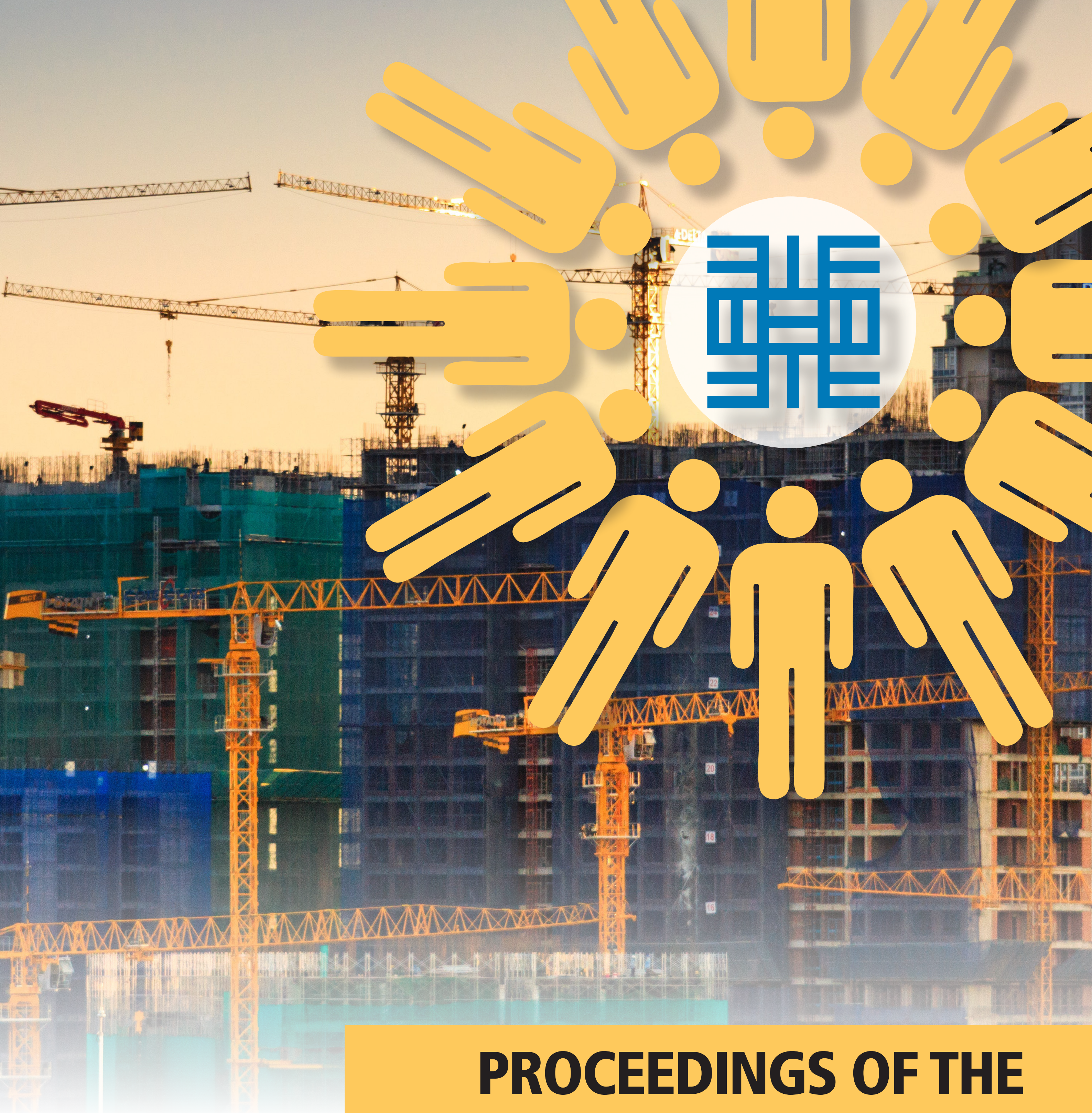

PROCEEDINGS OF THE

WABER 2021 CONFERENCE

WEST AFRICA BUILT ENVIRONMENT RESEARCH CONFERENCE

W W W . W A B E R C O N F E R E N C E . C O M

KNOWLEDGE, INTERACTION, PEOPLE & LEADERSHIP

EDITORS: S. LARYEA AND E. ESSAH

9-11 AUGUST
Labadi Beach Hotel
Accra, Ghana

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EDITORS

Sam Laryea
Wits University, South Africa

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Declaration

All papers in this publication have been through a review process involving initial screening of abstracts, review of full papers by at least two referees, reporting of comments to authors, revision of papers by authors and re-evaluation of re-submitted papers to ensure quality of content.

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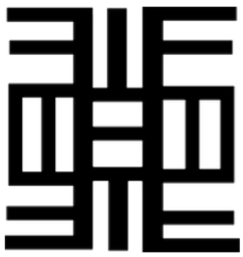

NEA ONNIM NO SUA A, OHU

"*He who does not know can know from learning*"

This is the Adinkra symbol of knowledge, life-long education and continued quest for knowledge. The Akan people in West Africa believe that the search for knowledge is a life-long process. This is evident from the Akan saying "Nea onnim sua a, ohu; nea odwen se onim dodo no, se ogyae sua a, ketewa no koraa a onim no firi ne nsa" which translates into "He who does not know can become knowledgeable from learning; he who thinks he knows and ceases to continue to learn will stagnate".

FOREWORD

I would like to welcome each participant to the WABER 2021 Conference. Since its inception in 2009, the WABER Conference series has done a great deal to nurture and support researchers, initially in West Africa, also, in other parts of Africa and elsewhere. I would like to thank all delegates for your participation which enables us to keep this Conference going.

The WABER Conference enjoys a positive international reputation and has continued to grow from strength to strength over the past 13 years. For this, I would like to thank our team, keynote speakers and participants over the years for every contribution you have made to the success of this Conference. This year's Conference has an excellent programme, line up of speakers and authors.

I would like to thank and commend the authors of all 72 papers in this Conference proceedings. If the research paper writing process was compared to a marathon, the authors of the 72 papers in this publication would be adjudged as the ones who have endured and finished the race.

We opened the call for papers for this Conference in December 2020 and over 100 abstracts were submitted by authors. However, it is one thing to propose to write a paper, and it is quite another thing to actually write the paper. Therefore, I would like to thank and congratulate all authors who succeeded in completing the process of getting published in this conference proceedings.

It is befitting that we have an excellent range of interesting topics in the 72 papers to be discussed at this conference.

We are honoured to welcome Professor Charles Egbu, Vice Chancellor of Leeds Trinity University, to give us a special opening address.

In the three days of this conference, we will have various plenary presentations by experienced international academics and I would like to thank and welcome each of them below.

Professor Albert Chan
Richard Lorch
Professor Taibat Lawanson
Professor Dato' Sri Ar Dr Asiah Abdul Rahim
Professor George Ofori

In addition to these speakers, we have other interesting sessions on the programme including a special session for doctoral students and supervisors several other experienced speakers addressing various topics that should be of interest to many of us.

I would like to thank all members of the organising team particularly Associate Professor Emmanuel Essah, Dr Yakubu Aminu Dodo and Dr Sam Moveh for their efforts which has helped to organise this Conference successfully. I would also like to thank all of our reviewers particularly Associate Professor Emmanuel Essah and Dr Haruna Moda for the considerable time and effort spent reviewing and checking all papers to ensure a high standard of quality.

The WABER Conference Team always plays an excellent role in the success of our events and I would like to thank and appreciate the contributions of Florence, Sam Boakye, Victor Ayitey and his team, Kwesi Kwofie and Issah Abdul Rahman to the success of this Conference.

I hope you enjoy our first hybrid conference and engage with our exciting speakers on the diverse topics that will be covered over the three days of this Conference.

Sam Laryea
University of the Witwatersrand, Johannesburg, South Africa
Chairman of WABER Conference
August 2021

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PEER REVIEW AND SCIENTIFIC PUBLISHING STATEMENT

9th August 2021

TO WHOM IT MAY CONCERN

The scientific information published in peer-reviewed outlets carries special status, and confers unique responsibilities on editors and authors. We must protect the integrity of the scientific process by publishing only manuscripts that have been properly peer-reviewed by scientific reviewers and confirmed by editors to be of sufficient quality.

I confirm that all papers in the WABER 2021 Conference Proceedings have been through a peer review process involving initial screening of abstracts, review of full papers by at least two referees, reporting of comments to authors, revision of papers by authors, and re-evaluation of re-submitted papers to ensure quality of content.

It is the policy of the West Africa Built Environment Research (WABER) Conference that all papers must go through a systematic peer review process involving examination by at least two referees who are knowledgeable on the subject. A paper is only accepted for publication in the conference proceedings based on the recommendation of the reviewers and decision of the editors.

The names and affiliation of members of the Scientific Committee & Review Panel for WABER 2021 Conference are published in the Conference Proceedings and on our website www.waberconference.com

Papers in the WABER Conference Proceedings are published open access on the conference website www.waberconference.com to facilitate public access to the research papers and wider dissemination of the scientific knowledge.

Yours Sincerely,

Sam Laryea, PhD
Chairman of WABER Conference

PEER REVIEW PANEL

WABER Conference is very grateful to each the following persons for your contribution to the peer review process. Thank you so much.

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- **Best Research Paper**

This prize is awarded to recognize the author(s) of an original piece of research which contributes a better understanding of the research question/problem investigated and demonstrates a high degree of scientific quality and innovative thought. This prize was created to acknowledge the continuing importance of high quality research to academic institutions, a researcher's reputation and the development of the built environment field.

- **Best Oral Presentation**

This prize is awarded to recognise the presentation which is the most coherent, clearly enunciated, well-paced, easy to understand, and effective. The award is given on the basis of quality of the presentation and not the written paper. It recognizes the best presentation based on communication of the content of a paper and the ability of the speaker to deliver an impactful, authoritative and engaging presentation. The award looks to encourage researchers to put as much effort as possible into the presentation of their work.

- **Gibrine Adam Promising Young Scholar Award**

This prize is awarded to recognize and encourage exceptional young researchers. The recipient should be a young academic who demonstrates promise, such that he/she is likely to become established as a research leader. The prize is provided by Mr Gibrine Adam – President of Zenith University College and CEO of EPP Books Services – who has made significant contributions to the education sector through his educational establishments and philanthropic work. Awarding this prize each year will serve as an important inspiration for young African built environment academics.

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HOUSEHOLDS' EXPOSURE TO INDOOR AIR POLLUTION FROM FOSSIL FUEL ELECTRIC GENERATOR USE IN MINNA NIGERIA

C. B. Ohadugha[1], Y. A. Sanusi[2], A. O. Sulyman[3], B. N. Santali[4], M. Mohammed[5] and S. O. Medayese[6]

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Lack of reliable access to modern energy in Minna Niger state results in households 'use of inefficient alternatives especially fossil fuel generators for domestic purposes. The study analyses indoor air pollution from households 'use of generator with a view to determining their exposure to Carbon monoxide. The concepts of energy access, poverty and generator pollution were reviewed. The research employed empirical approaches and adopted the multi-stage sampling technique. The study area has a population of 63,873 households. MSA Altair 5X Multigas detector was employed in the detection of pollution (CO) levels emanating from the generator use. It revealed that inefficient use of generator, generates 60 ppm, above the WHO and NAAQS threshold of 10 ppm. 66.4% of the generator using households are exposed to dangerous levels of CO pollution from generator use at ≤4 meters 'distance in Minna, Nigeria. The study concluded that households 'access to adequate electricity de-emphasizes the need for generator ownership and use. Households 'liveability is undermined by high level of pollution. It recommended enlightenment on the dangers of exposure to carbon monoxide and that generators should be operated at a minimum distance of 4 meters away from residential buildings.

Keywords: carbon monoxide, domestic energy, energy poverty, generator

INTRODUCTION

Epileptic power supply is being experienced by households in Minna, the capital of Niger state the acclaimed 'power state 'of Nigeria. They barely experience 24 hours of uninterrupted power supply despite being the host state of three hydro power stations. This lack of steady electricity energy plunges the households into domestic energy poverty situation as most domestic activities requiring energy

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revolves around electricity energy. Power outage makes them vulnerable security wise especially at night. Increased households 'energy expenditure and pollution exposure is experienced when inefficient alternatives are used especially fossil fuel generators. The generators are majorly resorted to because apart from illumination that other inefficient alternatives can offer, they offer other services such as powering appliances. Fumes from generators contributes to climate change and most importantly increases morbidity and mortality rate through indoor air pollution. Households are at risk when generators are used inefficiently such as in the garage, veranda, balcony, unused rooms, etc. Therefore, the study analyses indoor air pollution associated with generator use in Minna Nigeria with a view to determining households 'exposure to carbon monoxide indoor pollution that will champion the need to play safe in the operations and use of fossil fuel generators.

LITERATURE REVIEW

Energy access

In spite of modern energy services being germane to both human and economic development, still electricity is not accessed by over 1.3 billion people (World Energy Outlook (2002). Electricity is needed for lighting, heating, boiling, and cooking and mainly for various domestic appliances operation. However, the inadequacy in generating electric power likewise poor distribution network has subjected a large chunk of the citizenry to inefficient alternatives of Portable Power Electricity Generator (PPEG), kerosene lantern and candle use for their domestic lighting needs. This, puts them at health risk and invariably increases their household expenditure (Ohadugha 2018). Globally, fossil fuel dependent economy and the greenhouse gas emissions increase is drastically changing the climate system and having a noticeable global impact (UNDP 2016).

Resulting from the epileptic nature of electricity supply, a great percentage of urban dwellers and also industries rely on electricity generating plants (Ladan 2013). The result is that operating of the generators has become a source of both indoor and outdoor air pollution in the urban centres. Quantities of smoke and particulates are generated when generators are inefficiently operated as result of the age, lack of maintenance and operational factors (Ohadugha 2018). On daily basis, average level of indoor emitted pollutants often goes beyond current World Health Organisations guidelines and acceptable levels of 9-10 parts per million (ppm).

Table 1: Nigerian ambient air quality standard

Air Pollutants	Emission Limits
Particulates	250 (µg/m3)
SO_2	0.1 (ppm)
Non-methane Hydro carbon	160 (µg/m3)
CO	11-4 (µg/m3) or 10 (ppm)
NOX	0.04-0.06 (ppm)
Photo chemical Oxidant	0.06 (ppm)

Source: Federal Ministry of Environment (FME, 1991)

In Nigeria, the ambient air quality maximum limit as approved by the Federal Ministry of Environment, Housing and Urban Development (FME & UD) is 10 ppm - 20 ppm for an average time of 8 hours (Abdulkarim et al. 1990). The WHO standards in Table 1 were adopted as the national standards for residential buildings gaseous emissions against which air quality parameters monitored are compared in order to determine its "cleanliness" (Federal Ministry of Environment 1991).

Electric generator and air quality

Electricity supply is one public service that has witnessed uncomplimentary remarks from both members of the public and policy analysts over the years and this has generated a series of adaptations including proliferation of private small electricity generating plants (Sanusi 2008). This leads to environmental pollution and increased greenhouse gases due to emissions.

The emissions emanating from Portable Power Electricity Generator (PPEG) has become a major indoor air pollution problem in the country and areas experiencing bad electric power situation (Adefeso et al. 2012). Using PPEG to make up for power shortages, owners most often operate them indoors or very close to their homes in response to generator theft and serene disturbance to neighbours (Ashmore and Dimitroulopoulou 2009). Furthermore, indoor levels of air pollutants can be increased by inadequate ventilation. Supporting the observation above, inadequate windows aggravate indoor pollutants accumulation (White and Marchant 2009). United States Consumer Product Safety Commission (US CPSC) reported that generator positioned near open windows, doors, or vents outdoors accounted for 4.8% deaths caused by generator carbon monoxide poisoning (Marcy and Ascon 2004). The carbon monoxide emission factor from PPEG's powered with gasoline was determined and was proved that carbon monoxide concentrations within enclosures dissipates quickly with high rate of air exchange and further concluded that PPEG should be placed above 10 meters away, if wind direction is towards the building (Adefeso et al. 2012).

Generator use impacts both negatively and positively (Ohadugha 2018). Negatively, the use of PPEG impacts on the health of both the users and those around it through the air pollution and noise. In Nigeria, households operate generators for six hours on the average daily (Stanley et al. 2010) with average distance of 5.6m from building contrary to 10m minimum proposed by Adefeso et al. (2012). Along with poor ventilation, these factors have negatively influenced households 'indoor air quality implying that the households are exposed to some concentrations of carbon monoxide (Ladan 2013). The most commonly identified reasons of CO poisoning from PPEG in the observations of Hampson and Zmaef (2005) are ignorance of CO poisoning and ventilation requirements likewise operating generators indoor, especially in the garage. Accordingly, increase in indoor carbon monoxide level in India is attributable to PPEG use in their urban areas (Lawrence et al. 2004). In 2008 alone in Nigeria, more than 60 people suffocated to death resulting from the CO effects due to their exposure to its high concentrations (Adefeso et al. 2012). An individual's health condition, length of exposure as well as the CO concentration determines the health effects (Ohadugha 2018). The effects on people differ though dependent on the CO level and the individual peculiarities (WHO 2000).

MATERIALS AND METHOD

Study area

Minna doubles as the capital of Niger state and the headquarters of Chanchaga Local Government Area (Niger state statistical year book year 2011). Chanchaga Local Government Area is encapsulated by Bosso Local Government Area of Niger state. It lies between Latitude 9o 33 ′and 9o 40 ′North of the Equator and Longitudes 6o 29 ′and 6o 35 ′East of the Greenwich Meridian on a geological base of an undifferentiated basement complex of mainly gneiss and magnetite (Max Lock Nigeria Limited 1979). The state has an area of about 76,363km2. With Shiroro, Kainji and Jebba Hydro-Electric Dams of Nigeria located in Niger State, the state is the acclaimed "Power Generating House" of the Nigeria with the slogan "Power State".

Methodology

This study analyses households ′exposure to indoor air pollution which entails detecting and measuring the level of pollutants concentration indoors, specifically carbon monoxide resulting from domestic use of electric generators. The research is a household and empirical survey as both primary and secondary data were sourced using semi structured questionnaire from the eventual randomly selected households. Also, portable hand-held gas detector/monitor (MSA Altair 5x Multigas Detector) was used to detect and capture carbon monoxide concentration in the generator using households while the generator is running irrespective of the reason for using generator.

The analysis was done with Statistical Package for the Social Sciences (SPSS) as a tool. In order to examine households ′exposure to indoor pollution induced by generator use in Minna, the generators mode of use was examined. Gas concentrations indoors were discerned using MSA Altair 5X Multigas Detector which aided determining the level which urban residents are exposed to indoor pollution in the study area. The MSA Altair 5X Multigas Detector Version: SW 1.27.06.50 S/N: 0056759 manufactured by Mine Safety Appliances Company; 1000 Cranberry Woods Drive Cranberry Township, PA 16066 USA is a portable hand-held device used to measure the concentration of gases in the environment. The device is available with a maximum of four sensors, which can display readings for five separate gases (one Dual Toxic Sensor provides both CO and H2S sensing capabilities in a single sensor), Oxygen (O2) and 2 combustible gases including Pentane.

Population and sampling technique

The 2018 projected population of the study area which is 319,366 and with national household size average of five (https://dhsprogram.com/pubs/pdf/FR148/02 Chapter02 .pdf) resulted to approximately 63,873 households.

Using online sample size calculator with confidence level of 95% and 5% margin of error, the sample size is 382. Extra 18 questionnaires were added to make up for possible unanswered rounding it up to 400. Eventually, they were all correctly filled and returned. Hence, 400 copies of the research instrument were proportionally distributed to households in the neighbourhoods making up the study area according to their population. Multi-stage sampling technique involving clustering (neighbourhoods), stratifying (residential houses) and purposive randomising (households using generators) was adopted for the study in selecting the sampled units.

RESULTS AND DISCUSSION

This section evaluates households 'exposure to indoor pollution in Minna metropolis. It involves analysing the generator use, operating position and distance and their emission (carbon monoxide concentration) to determine the safety or otherwise of the households.

Alternative lighting energy

With the incessant power outage experienced in the study area, the primary domestic energy types used for lighting during power outage include solar, inverter, generator, kerosene lantern, rechargeable lanterns, torchlight and candle. For the purpose of the study which involves pollution, generator was considered. Other prevalent pollutant emitting lighting energy types such as candles and kerosene lanterns with average CO emissions of 2 ppm and 1 ppm respectively were not considered because their emissions are very minimal to endanger human health.

Emission from lighting devices

There are varying CO emission levels from the 'dirty 'alternative lighting fuel households use in times of power outage. As shown in Plate I, a candle stick measuring 19cm (length); 1.5cm (base diameter) and 1cm (tip diameter) burned for 3 hours in an enclosure (windows and door closed) with average carbon monoxide concentration of 2 ppm.

With the same specification of candle but in an opened enclosure (windows and door opened), the candle burned for 2 hours 45 minutes and yielded zero emission. The implication is that candles, in terms of carbon monoxide emission are safer than generators that are used inefficiently though they are rarely used because of the low illumination and the risk of fire hazard if not administered properly.

Similarly, kerosene lantern used by 1.3% of the households observed for one hour emits an average carbon monoxide emission of 1 ppm.

Plate I: Measuring CO Emission from Candle
Source: Authors 'field work, 2018.

Plate II: Observing CO level

Generators come in various sizes and capacities but the commonest in use is the TG950 model (I pass my neighbour) because it is more affordable and portable to most urban residents. Also of interest is its operating principle regarding emission because engine oil is added to the petrol which aggravates emission of carbon monoxide. Equally, its size makes it flexible position-wise as it can be adjusted at will. For example, bringing it closer or even within the dwelling corridors and veranda during adverse weather conditions such as rain.

The research adopted two scenarios to represent the generator operating position within and outside dwellings. Observing CO level in an indoor environment (worst-case scenario) was done in a 400 m2 hall where a TG950 model (I pass my neighbour) generator was used alongside measuring tape and a gas detector (Plate II).

The generator is placed at the centre of the hall and the readings were recorded at an interval of one meter up to ten meters distance from the generators four sides. This was done to observe possible variations in the readings. The measurement range of 1 - 10 meters as depicted in Table 2 was based on the assumption that generators placed above 10m has minimal adverse impact in terms of air pollution.

Table 2: Varying carbon monoxide concentration from a generator in an enclosure

Distance (m)	Side A	Side B	Side C	Side D	Avg conc/dist (ppm)
1	125	25.2	62.4	87.2	74.95
2	68.6	20.4	59.4	88	59.1
3	50.6	16	53.2	99	54.7
4	50.4	26.4	58	110.2	61.25
5	51.8	27.6	57.8	108.8	61.5
6	21.4	29.6	58.6	114.2	55.95
7	4	32.4	69.2	118.6	56.05
8	4	37.2	65.2	120.2	56.65
9	6	36.6	72.6	124.2	59.85
10	24.8	39	60.2	123.8	61.95
Avg conc/ side	40.66	29.04	61.66	109.42	60.19

Source: Authors 'field work, 2018.

As shown in Table 2, it was discovered that at one meter away from the exhaust pipe side, the CO concentration was highest at 125 ppm and the side adjacent to the exhaust pipe has the overall highest CO level. The mean emission is observed to be approximately 60 ppm.

For the best-case scenario (out-door), the generator is placed with the exhaust pipe directed away from building openings (windows and doors) at intervals of one meter up to ten meters and gas detector readings indoors were recorded. The result of the observation in both best- and worst-case scenarios (out-door and in-door) at distances of one meter to ten meters from the source point is shown in Figure 1. In the same way, for in-door environment, the generator was at the centre of the hall from where measurements were taken from the exhaust pipe direction, opposite and both adjacent directions. The indoor environment result is the average of the results from the four directions of the source point.

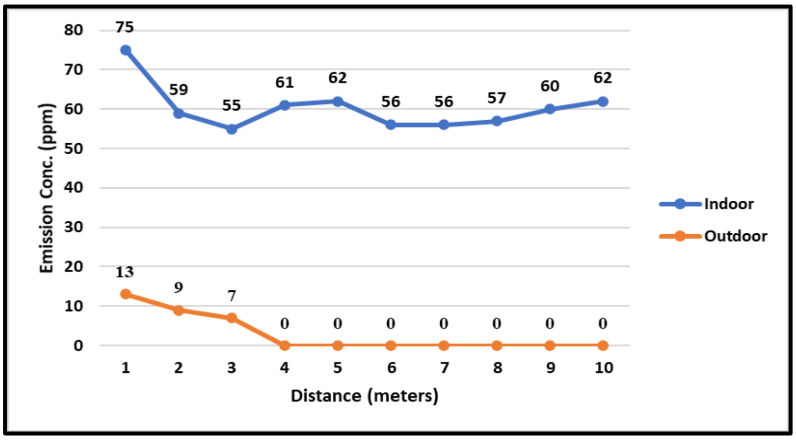

Figure 1: Average concentration levels at various distances in both scenarios
Source: Authors 'field work, 2018.

Apart from indicating the various concentration levels at various distances in both scenarios, Figure 3 also shows that from the source point in an enclosed environment, the concentration fluctuates as the distance increases but rises at the extreme (wall barrier). It was also observed that wind (speed and direction) influences emission concentrations levels. The indoor experience implies that operating generators within the buildings is a health risk because emissions within the dwelling build up to dangerous levels.

Generator operating positions and distances

Portable Petroleum Electricity Generators (PPEG) are operated from varying positions and distances during power outages. From the survey, the generator operating positions were identified and classified in Table 3 as follows: Generator house – enclosure purportedly built for generators to be operated from; outside the building (dwelling) – open operating position outside the dwelling from varying distances dependent on the convenience of that position and; within the building – operating positions under the same dwelling roof such as corridors, underutilized rooms, verandas, balconies, in-built garages and in tangent to dwelling walls.

Table 3: Generator operating position

Generator Position	Frequency	Percentage
Generator house	59	23.6
Outside the Building	148	59.2
Within the building	43	17.2
Total	250	100

Source: Authors 'field work, 2018.

Out of the generator users, 23.6% operate their generators from generator house, 17.2% within the dwellings such as in the corridors, verandas, lobbies and unused rooms within the building while 59.2% operate PPEGs outside the dwellings from various distances. It is worthy of note that distance wise, those PPEGs operated from purposeful generator houses are assumed to be safe in terms of indoor pollution while those operating within the buildings are assumed to be at zero distance. Generators operated within and outside the dwellings apart from generator houses are the bases for the analysis.

Based on the worst-case scenario observations stated earlier, 17.2% of the households that operate their PPEGs within the dwellings are at risk of greater exposure to carbon emission from generating plants. From the enclosed environment, carbon monoxide concentration observed from the study recorded an average of 60 ppm. For a minimum of 30 minutes exposure with such concentration, symptoms of headache and dizziness would be experienced by the occupants and would tend to a hazardous level for 8 hours exposure (Goldstein 2008; Struttmann et al., 1998). This result suggests that 66.4% generator using households representing 41.5% of the entire households in the study area are exposed to hazardous level of PPEG induced indoor pollution.

The observations further revealed that generators placed at 4 meters away from dwellings with other conditions met, zero (0 ppm) carbon monoxide concentration was recorded. It is imperative to reiterate the conditions to include; air/wind influence, exhaust pipe directed away from dwelling openings and against the wind direction. These conditions especially the wind influence in terms of speed and direction are major constraints to the record taking. This was addressed by taking measurements at intervals and eventually using their average.

In summary, Figure 2 reveals that 66.4% of the generator using households are at great risk of exposure to indoor pollution as they operate their PPEGs within the observed generator operating distance of less than or equal to 4 meters. This represents 41.5% of the entire households in the study area.

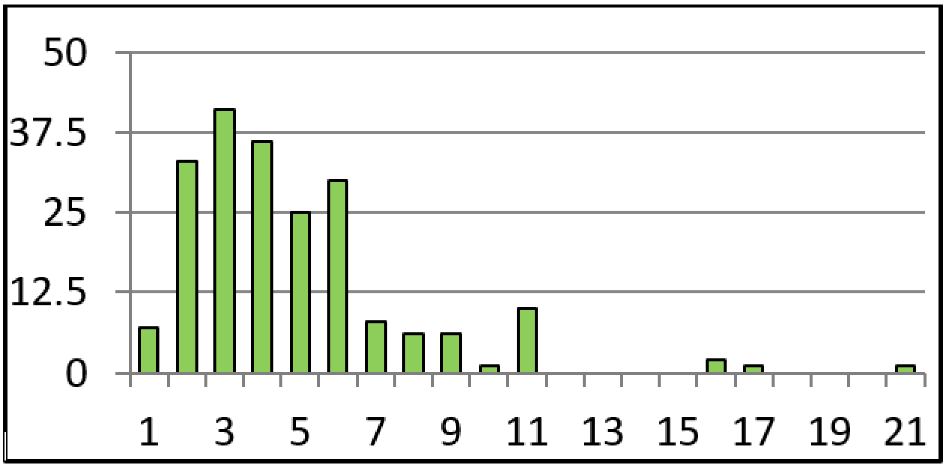

Figure 2: Dangerous Generator Operating Distance
Source: Author's field work, 2018.

Generator use characteristics as observed by the survey vary as such variations are indicators of how safe or not households are in terms of emission exposure with reference to generator operating distances outside the dwellings. The analysis is based on the observed safe operating distance of 4 meters in Minna metropolis. The study discovered that 66.4% of the households using generator as their primary lighting energy type are at risk of emission exposure based on 4 meters generator safe operating distance from houses.

CONCLUSION AND RECOMMENDATIONS

Promoting access to electric power in particular is a very important dimension to consider in enhancing households 'access to energy. Poor accessibility to modern energy is the main rationale for households 'reliance on pollutant emitting domestic lighting energy types that endangers their health through indoor pollution. It could be deduced that neighbourhood quality and liveability is undermined by the extensive and high level of pollution. Abnormal use of PPEGs such as its proximity to building openings, faulty and subserviced plants, positioning the exhaust pipe against wind direction also aggravates morbidity rate of households through indoor pollution.

In order to improve both human and environmental health likewise reducing dependence on emission generating domestic lighting energy sources in Minna metropolis, the study recommends operating generators above 4 meters away from users and dwellings and ensuring compliance to reduce pollutants concentration. Also, enlightenment on the dangers of exposure to carbon monoxide is imperative likewise encouraging installation of affordable carbon monoxide detector(s) in homes. This alerts the households when carbon monoxide level exceeds safe limit of 9 ppm.

REFERENCES

Abdulkarim, B. I., Chiroma, T. M., & Joseph, T. (1990). Assessment of CO, CO2 and Suspended Particulate Matter Emissions. http://lejpt.academicdirect.org/A11/109_116.htm WHO offset Publication, Geneva, 1990. p9.

Adefeso, I., Sonibare, J., Akeredolu, F., & Rabiu, A. (2012). Environmental Impact of Portable Power Generator on Indoor Air Quality, 33 pp60–5. Int Conf on Env, Energy and Biotech IPCBEE 33 (2012)

Ashmore, M. R., & Dimitroulopoulou, C. (2009). Personal exposure of children to air pollution. Atmos Env. 2009, 43: pp128-141.

Federal Ministry of Environment (1991). Guidelines and Standards for environmental pollution control in Nigeria.

Goldstein, M. (2008). Carbon monoxide poisoning. J of Emergency Nursing: JEN 34 6: pp538–542. doi:10.1016/j.jen.2007.11.014. PMID 19022078.

Hampson, N. B., & Zmaeff, J. L. (2005). Carbon monoxide poisoning from portable electric generators. AJPM 2005 Jan; 28 1:pp123-5. https://dhsprogram.com/pubs/pdf/FR148/02Chapter02.pdf) Retrieved on 2/9/18

Ladan, S. I. (2013). Examining Air Pollution and Control Measures in Urban Centres of Nigeria, 4 6, pp621–8.

Lawrence, A. J., Mashi, A., & Taneja, A. (2004). Indoor/Outdoor relationship of carbon monoxides and oxides of nitrogen in domestic home with roadside, urban and rural locations in a central India region. Indoor Air. 2004, 15: pp76-82.

Marcy, N. E., & Ascon, D. S. (2004). Memorandum: Incidents, deaths, and in-depth investigations associated with carbon monoxide from engine-driven generators and other engine-driven tools, 1990-2004. Bethesda, MD, US CPSC 18.

Max Lock Nigeria Limited (1979). "Minna Master Plan". Minna: Max Lock Nigeria Limited

Niger state statistical year book year (2011). State Bureau of Statistics Niger State Planning Commission

Ohadugha, C. B. (2018). 'Analysis of Domestic Energy Poverty and Exposure to Indoor Pollution Among Urban Households in Minna Nigeria'. An unpublished Ph.D Thesis submitted to the Fed Uni of Tech, Minna Nigeria

Sanusi, Y. A. (2008). Service Security in Gbazango Residential Area of Kubwa, FCT Abuja. URP Conf Proc 1 1: pp136 -144

Struttmann, T., Scheerer, A., Prince, T. S., Goldstein, L. A. (1998). "Unintentional carbon monoxide poisoning from an unlikely source". JABFM 11 6: pp481–4. doi:10.3122/jabfm. 11 6. 481. PMID 9876005.

White, L., & Marchant, P. (2009). An Overview of Residential Indoor Air Problems. Dept of Health, Washington.

WHO (2000). Carbon Monoxide. Chapter 5 Air Quality Guideline 2nd Edition. WHO Regional Office for Europe, Copenhagen, Denmark, Retrieved on 22/8/15 from http://www.euro.who.int/data/assets/pdf_file0020/123059/AQG2ndEd_5_5 carbonmonoxide.pdf

World Energy Outlook (2002). Energy and Poverty. Chapter 13; World Energy Outlook Series. International Energy Agency

UNDP 2016. Goal 7: Affordable and clean energy. Retrieved online from http://www.undp.org/content/undp/en/home/sdgoverview/post-2015-development-agenda/goal-7.html on 8/3/2016.