Investigation of Some Gaseous and Trace Metal Emissions With Their Emission Factors From Various Brands of Mosquito Coils Used in Nigeria

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ABSTRACT: Mosquito coils of various brands are frequently burnt in indoor environments to drive away mosquitoes—the vector for malaria parasite in regions where the disease is endemic. Emissions from the coils could be a source of indoor air pollution. In this study, various brands of mosquito coils obtained from retail shops in Lagos, Nigeria were burnt in an environmental test box with a view to characterizing carbon monoxide (CO), nitric oxide (NO), and nitrogen dioxide (NO_2) in the gaseous emissions as well as elemental concentrations of the ash. Emission characterization achieved with the RAS1700 bio-gas analyzer while AAS was adopted for elemental analysis of the mosquito coil ashes. The emission factor of CO, NO and NO_2 from the coil samples ranged between 0.00138 to 0.26277 $\mu g/m^3$, 0.0002 to 0.00454 $\mu g/m^3$, and 0.000074 to 0.00714 $\mu g/m^3$, respectively. These values were found to be lower than permissible indoor levels recommended by NIOSH. The range of concentrations of Pb, Zn, Cd, Cr, Cu, As, Hg, Fe in the coil ashes from all the brands were 0.02 to 0.04 mg/g, 0.011 to 0.02 mg/g, 0.001 to 0.003 mg/g, 0.004 to 0.008 mg/g, 0.004 to 0.006 mg/g, 0.0001 to 0.0004 mg/g, 0.001 to 0.003 mg/g, and 0.124 to 0.14 mg/g, respectively. Although, the concentrations of the pollutants obtained in this study are within the recommended limits, prolong exposure could trigger chronic disease conditions. Adequate ventilation of indoor environments or utilization of mosquito nets in place of coils could be considered.

KEYWORDS: Characterization, emission factor, mosquito coils, indoor air

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Introduction

Air pollution is one of the leading causes of human mortality in the world. Within a space of 1 year, 396 000 deaths arising from indoor air pollution (IAP) in sub-Sahara Africa was reported in 2006[1] Besides the loss of human lives, public health challenges such as pneumonia in children, asthma, tuberculosis, upper airway cancer, and cataract are caused or aggravated by IAP. Indoor air pollution sources are ubiquitous and account for several cases of disease burden worldwide with household combustion processes for energy generation being the chief sources.[2-4]

Evidences in the literature point to strong association between exposure to smoke from fuels and acute respiratory disease, chronic pulmonary disease and long cancer.[4-6] Common air pollutants found in indoor environments include carbon monoxide (CO), oxides of nitrogen (NOx), particulate matter (PM), volatile organic compounds, and carcinogenic contaminants (benzene and 1,3- butadiene) and polycyclic aromatic hydrocarbons. Apart from energy sources, paints and vanishes from furniture and building also constitute sources of indoor air pollution.[7] The indoor environment could also be a sink for outdoor pollution via diffusion and infiltration.[8]

The degree at which these emissions are arising from the use of less clean fuel such as kerosene, firewood, wood charcoal, and other biomasses as domestic energy sources makes the situation more worrisome in Nigeria[9,10] and this has been receiving tremendous research attention among the researchers and the government. There are other sources of indoor air pollution on which there is still dearth of information. Such includes the burning of burning of mosquito coils as a means of preventing malaria fever. According to a World Health Organization (WHO) report, there were about 229 million incidences of malaria globally in 2019 with an estimated mortality of 409 000.[11] Furthermore, children under the age of 5 years were the most vulnerable with symptoms including anemia, acidosis, respiratory and metabolic distresses, cerebral malaria and multiple failures of organs. It accounted for 67% of the global total malaria induced mortality in 2019.[11] Malaria fever incidences are still very prevalent in Nigeria and other Sub-Saharan African countries where majority of the cases of death occurred in 2019.[11]

The fever is caused a parasite of the plasmodium group (*P. falciparum or P. vivax*) with female anopheles mosquitoes being the transport vehicles.[12,13] Avoidance of mosquito bite is seen as the surest way to prevent the fever and many approaches are being adopted in Nigeria to achieve this. Popular preventive measures include; pouring kerosene in drains and stagnant water around houses to slow down breeding of mosquitoes, sleeping under mosquito net to prevent bite, indoor burning of mosquito repelling herbs among the rural dwellers and the use of mosquito sprays and coils.[14-16] The mosquito coils appear to appeal to considerable number of people because of its affordability and ease of purchase. They are easily purchased from retail sellers in the neighborhoods.

Plate 1. A typical spiral-shaped mosquito coil.

When a mosquito coil is burnt, it emits repelling incense that keeps away mosquitoes. The coil usually contains an active ingredient which may vary from one brand to another. It is commonly made into a paste that is dried and given spiral shape as shown in Plate 1. The coils are used widely in the developing countries including Nigeria to repel and kill mosquitoes most especially in the summer when hot weather aids their breeding in large quantities.[14,17] Emissions from mosquito coils have been linked with release of harmful pollutants.[14,16] This is even more worrisome and of great concern as humans are at the risk of being exposed to high toxic loads of the pollutants because they are usually released into indoor environment which in most instances have poor ventilation and the pollutants from their ashes into outdoor environment (soil and water bodies). Different brands of mosquito coils (imported or Nigerian made) are available for use in Nigerian markets. These coils are usually burnt at night in the bedrooms while household members sleep.

Emission factors employed in emission inventories have for some time been essential tools for air quality control and administration. Emission estimates are pivotal for fashioning emission control policies and strategies, deciding pertinence of permitting and control agendas, determining the impacts of sources and establishing relief measures, and various other related applications by government, researchers, organizations, specialists, and industry.[18] However, there is little or no information in the literature, as regards emission factors of emissions from mosquito coil used in Nigeria

There is dearth of information on the gaseous and trace metal emissions with their emission factors from the burning of various brands of mosquito coils in Nigeria. This information is essential in the development of air pollutant emission inventory for the varieties of mosquito coils in Nigerian market. It is also relevant in determining the human health risks associated with the use of these coils as mosquito repellants. In this study, gaseous and solid emissions from different brands of mosquito coils were characterized and their emission factors for the pollutants were determined.

Methodology

Determination of the gaseous emissions

Five brands of mosquito coils that are in use in Nigeria were obtained from the open market in Lagos and these were labeled A, B, C, D, and E for proper identification. To characterize the gaseous emissions from each of the coil brands, a burning process of each brand was initiated in an environmental test box of dimension 35.00 cm × 25.50 cm × 26.00 cm outside the laboratory in an open atmosphere while characterization was achieved with the RAS1700 biogas analyzer. The test box was closed to allow circulation of the smoke and steady burning was ensured for accurate sampling. The sample of the smoke was taken with a 5 ml hypodermic syringe and introduced into RAS1700 bio-gas analyzer to characterize and determine the initial concentrations C_o of the air pollutants inside the test box. After about 20 minutes, the window on the test box was opened to allow steady exchange of indoor air with outdoor air and another sample C_t was taken with the hypodermic syringe of 5 ml at steady burning of each coil for accuracy and characterized in a similar manner. The air exchange rate (AER) was subsequently determined with equation (1).[19] The concentrations inside and outside the test box were combined with AER to determine the pollutant emission rate (ER) as shown in equation (2).[19] The emission factor (EF) was then determined with equation (3).[18] The active ingredients of the various samples of mosquito coils used in this study are as summarized in Table 1.

$$\text{AER}=\frac{lnCo-lnCt}{t} \tag{1}$$

Where:

C_o = initial concentration of the gas (mg/m^3)

C_t = the concentration at time t (mg/m^3),

t = burning time (min)

$$ER = V \times AER\left(C_{in} - C_{out}\right) \tag{2}$$

Where:

V = the volume of the chamber (m^3)

C_{in} = pollutant concentration inside the test box (μg/m^3)

C_{out} = pollutant concentration outside the test box (μg/m^3)

$$\text{EF}=\frac{ER}{BR} \tag{3}$$

Where:

ER = Emission rate

BR = burning rate (weight reduction of the coil divided by burning time).

Determination of the trace metal emissions

PerkinElmer AAnalyst 400 Atomic Asorption Spectroscopy (AAS) was calibrated and used to characterize the mosquito coil ashes. Standard sample of targeted trace metals (Pb, Zn, Cd, Cr, Cu, As, Hg, Fe) were prepared by diluting AAS standard solutions of 0.1 ml of each standard sample; the solutions were taken into 100 ml flask and made up to the mark with 2% HNO_3. The concentrations of trace elements in the ash samples were determined using the AAS method. Light from a line source of characteristic wavelength for the element being determined was allowed to pass through the flame, which is

Table 1. The brands of mosquito coils used for the study.

BRANDS	TAG	COUNTRY OF ORIGIN	WEIGHT (G)	COLOR	ACTIVE INGREDIETS
Golden Rock	A	China	14.3	Black	D-Allethrin
Rambo	B	Nigeria	10.1	Purple	0.2% Pyrethroids
Double Rabbit	C	Nigeria	13.93	Black	Meperfluthrin
Super Kill	D	Nigeria	8.57	Gray	0.05% Meperfluthrin
Swan	E	Nigeria	13.7	Black	Pyrethroid (D-Allethrin)

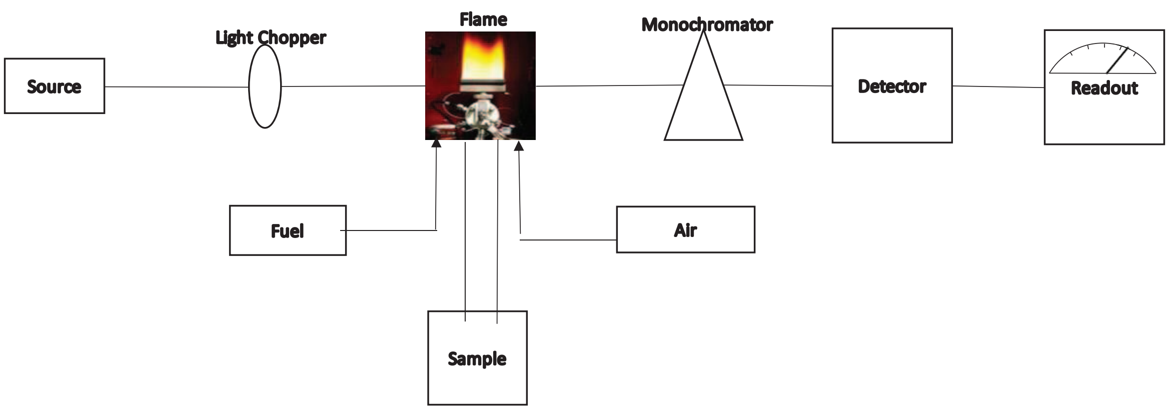

Plate 2. A typical layout of a flame AAS.

Table 2. Air exchange rates of the pollutants.

	C_O	C_T	C_O	C_T	C_O	C_T	C_O	C_T	C_O	C_T	C_O
	CO (PPM)	CO (PPM)	CO_2 (%)	CO_2 (%)	NO (PPM)	NO (PPM)	NO_2 (PPM)	NO_2 (PPM)	NO_X	NO_X	CH_4 (%)
A	55	44	1.3	0.9	13	11	3.7	3.6			13
B	81	62	1.6	1.1	11	10	3.7	3.1			13
C	78	69	10	9.3	11.3	10	6.4	6.1	3.1	0	11
D	63	60	11.1	10	12.1	11.6	6.5	6.3	3.3	3.1	10
E	79	49	9.6	8.5	12.2	11	6.3	6	4	3.8	12

typically 4 to 6 inches wide, giving a reasonably long path-length for detecting small concentrations of atoms, into which has been sprayed on the sample solution. A monochromator was used to select the region of the spectrum to be measured. The isolated spectral line fell on the photomultiplier, the detector and the output was amplified and sent to a readout-device digital meter through a computer data processing system, to a chart recorder and finally to digital display unit. The intensity of the resonance line was measured twice, once with the sample in the flame and once without. The ratio of the 2 readings is a measure of the amount of absorption, hence the amount of element in the samples. A typical layout of a flame AAS is shown in Plate 2.

Results and Discussion

The concentration of the pollutants in the text box at time ($t = 0$ min) and at time ($t = 20$ minutes) and the subsequent concentrations of the pollutants within and outside the test box following air exchange between the test box and the outer environment are presented in Tables 2 and 3 respectively. The concentrations of CO dropped from their initial values of 55, 81,78, 63, and 79 ppm at $t = 0$ minutes to 44, 62, 69, 60, and 49 ppm for samples A, B, C, D, and E, respectively after $t = 20$ minutes. Drops were also observed in the test box concentrations of other pollutants after 20 minutes. The data in Tables 2 and 3 were combined with the burning rates (Figure 1) of the various brands of mosquito coils to arrive at the emission

Table 3. Emission rates of the pollutants.

	C_{IN}	C_{OUT}	C_{IN}	C_{OUT}	C_{IN}	C_{OUT}	C_{IN}	C_{OUT}	C_{IN}	C_{OUT}	C_{IN}	C_{OUT}
	CO (PPM)	CO (PPM)	CO_2 (%)	CO_2 (%)	NO (PPM)	NO (PPM)	NO_2 (PPM)	NO_2 (PPM)	NO_X	NO_X	CH_4	CH_4
A	77	74	1.4	1.3	14	13	3.3	3.2			13	12
B	88	78	9.1	1.2	11.1	11	5.1	3.2	3		13	11.4
C	72	70	11.1	10.1	11.1	10	6.2	6.1	3.3	3.1	12	11
D	65	64	10.5	10.1	11.9	10.4	6.6	6.1	3.8	3.4	11.3	10
E	80	59	9	8.7	13	12.4	6.1	6	3.5	3.2	12	11

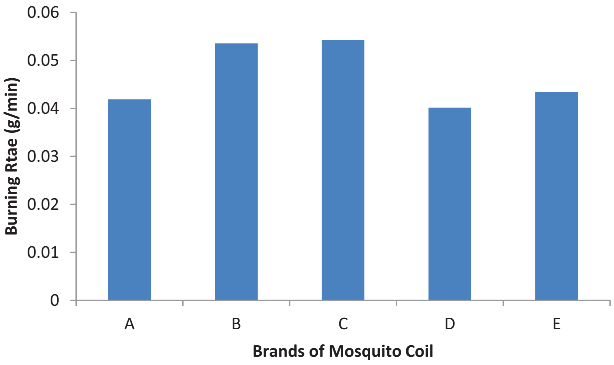

Figure 1. The burning rates of the identified mosquito coil samples.

factors. The calculated air exchange rates, pollutant emission rates and their emission factors are presented in Table 4. From Figure 1, the burning rates of the coil samples ranged between 0.04016 and 0.05428 g/minutes with D and C having the least and highest burning rate respectively.

Air exchange rate is a measure of how well ventilated an indoor environment is. An acceptable air exchange rate is required to maintain safe indoor air quality. For all the mosquito coil samples investigated in this study, the air exchange rate for CO ranged between 0.00244 and 0.02388 mg/m^3.min while those of NO and NO_2 ranged between 0.00211-0.00835 mg/m^3.min and 0.00156-0.00885 mg/m^3.min, respectively. The emission factor of CO, NO, and NO2 from all the coil samples ranged between 0.00138-0.26277, 0.0002-0.00454, and 0.000074-0.00714 µg/m^3. For the same mass of sample, the greatest emitters of CO, NO, and NO_2 were samples E, A, and B while the least emitters were D, B, and A, respectively. According to NIOSH the exposure to CO should not be more than 200 ppm for an averaging time of 15 minutes and 50 ppm for 8-hour duration. The emission rates of CO in the test box after 20 minutes ranged between 65 and 88 pm which is lower than the permissible limit. Prolong exposure could however trigger chronic respiratory effects. The concentrations of oxides of nitrogen were generally lower than the recommended permissible limits.

The elemental concentrations of the mosquito coil ashes after the burning process are as presented in Table 5. The range of concentrations of Pb, Zn, Cd, Cr, Cu, As, Hg, Fe in the coil ashes from all the brands were 0.02 to 0.04, 0.011 to 0.02, 0.001 to 0.003, 0.004 to 0.008, 0.004 to 0.006, 0.0001 to 0.0004, 0.001 to 0.003, and 0.124 to 0.14 mg/g, respectively. Fe and Pb were the dominant elements in the ashes of the mosquito call brands while arsenic had the least concentration in the ash. Since the ash will be disposed by pouring into the environment, the soil in the vicinity will be the recipient of the pollutants. With the exception of Zn, the concentration of other elements present in the ash were generally above the the permissible elemental soil concentrations for trace and heavy metals as presented by Dwivedi[20]. Disposal of the ash into the environment may have negative impact on the soil elemental balance.

Conclusion

Carbon monoxide, nitrogen oxide emissions, and trace metal compositions of the ash with their emission factors from burning of various brand of mosquito coils obtained from open markets in Lagos, Nigeria was investigated. The emission rates and the emission factors of CO, NO, $NO_{2.}$ Were determined. Also, the emission factors of the selected trace metal emissions: Pb, Zn, Cd, Cr, Cu, As, Hg, and Fe were also determined. Although, the gaseous emissions were generally within the limits recommended by NIOSH for indoor environment although prolong exposure could still predispose humans to chronic ill-health conditions. Adoption of other alternatives that will not produce harmful emissions are recommended as replacement for mosquito coils. The government should impose measures on the manufacturers of mosquito coils to be producing emission-free mosquito repellants. Also, electricity should be made available to poor citizens, by governments, to be able to afford electric fan and air conditioners the would make indoor environments unconducive to mosquitos.

Table 4. Air exchange rate, emission rates, and emission factors.

	CO			NO			NO_2		
	[a]AER	[b]ER	[c]EF ($X\,10^{-5}$)	AER	ER	EF($X\,10^{-5}$)	AER	ER	EF($X\,10^{-5}$)
A	0.011157	0.00076	1.818	0.00835	0.00019	0.454	0.00137	0.000003	0.0074
B	0.01337	0.00304	5.679	0.00477	0.00001	0.02	0.00885	0.00038	0.714
C	0.00613	0.00028	0.514	0.00611	0.00015	0.281	0.0024	0.0000055	0.01
D	0.00244	0.000055	0.138	0.00211	0.000072	0.179	0.00156	0.000017	0.044
E	0.02388	0.01141	2.62770	0.00518	0.000071	0.163	0.00244	0.0000055	0.013

[a]AER – mg. m^{-3} .min; [b]ER - $mg^2.m^{-3}$ .min [c]EF- mg. m^{-3}

Table 5. Elemental concentration of mosquito coil ash.

ELEMENT	A (MG/G)	B (MG/G)	C (MG/G)	D (MG/G)	E (MG/G)
Pb	0.02	0.04	0.03	0.04	0.02
Zn	0.014	0.011	0.014	0.02	0.012
Cd	0.002	0.001	0.003	0.003	0.002
Cr	0.004	0.005	0.008	0.004	0.005
Cu	0.004	0.006	0.004	0.006	0.004
As	0.0001	0.0004	0.0002	0.0002	0.0004
Hg	0.002	0.002	0.003	0.001	0.002
Fe	0.134	0.14	0.136	0.14	0.138

Author Contribution

A conceptualized the topic. A and C carried out the experimental process. B rote the manuscript. D reviewed the manuscript. A, B, C and D approved the manuscript for publication.

Data Availability Statement

The data in Table 1 were generated from the specifications written on the cartons of the identified mosquito coils which are publicly available. Figure 1 and Tables 2 to 5 were generated from the experiments and the mathematical models used in the study.

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