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RELEASE OF NOXIOUS GASES DURING BURNING OF MOSQUITO COILS: A PIL STUDY

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ABSTRACT
Indoor air pollution due to combusting biomass fuels is a serious problem in developing countries and the impact to a greater extent is less known from burning mosquito coils. As malaria is a major killer in developing countries, the use of mosquito repellants would continue to be used in millions of homes across the continent of Africa. Hence this pilot study was conducted to assess emission levels of nitrogen dioxide (NO2); sulphur dioxide (SO2) and carbon monoxide (CO) during the burning of six different products of mosquito coils that are sold in Sierra Leone. One hour emission value was recorded for each product during the burning period. Result revealed that one hour SO2 concentrations range from not detected to 47 ppb and that for CO range from 16 ppm to 19 ppm for the different products. Evidence of high peak values was observed for both SO2 and CO for the different products which is clearly a public health concern. This pilot study demonstrated that burning mosquito coils in less ventilated rooms where the primary focus is to eliminate mosquitoes is an environmental health risk in Sierra Leone.

Keywords: Indoor air pollution, Nitrogen dioxide, Sulphur dioxide, Carbon monoxide, Mosquito coils, Noxious

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Contribution/ Originality

This study is the first that has provided informed information to relevant stakeholders in Sierra Leone on the dangers of combusting mosquito repellants in less ventilated areas by measuring the emission levels of gases deemed dangerous to public health.

1. INTRODUCTION

Recent estimate from the World Health Organization (WHO) approximately reported 7 million premature deaths annually-one in eight of total deaths attributed to air pollution exposure. This staggering estimate makes air pollution one of the biggest environmental health risks. Majority of the deaths from this conservative estimate emanate from combusting biomass fuels where over half of the world's population in developing countries rely on these crude fuels for several needs (Ezzati *et al.*, 2000; Taylor and Nakai, 2012c; Taylor *et al.*, 2015a; Taylor *et al.*, 2015b). The burden of diseases in developing countries is relatively high and there is no exception for malaria-a vector borne disease. The WHO recently reported that Sub-Saharan African countries shared 89% cases of global malaria burden where 90% deaths were recorded (WHO, 2015). In the wake of our global changing climate, scientists have predicted that vector borne diseases are likely to increase. Such forecast would likely increase the production and use of mosquito coils in developing countries which is considered to be an effective mosquito repellant. The insecticide of the mosquito coil will evaporate with the smoke during burning thereby inducing

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escape or preventing entry of the mosquito into the room. This burning practice eventually releases health damaging particulates and gaseous pollutants (Liu *et al.*, 2003; Lee and Wang, 2006; Salvi *et al.*, 2006; Kumar *et al.*, 2014).

In Sierra Leone, the quantity of mosquito coil consumed is unknown but it is widely believed that the use of such product is high given the high reported cases of malaria incidence in the country (WHO, 2015). The nature and type of mosquito coils that are in the country are not entirely known even with the only body charged with quality issues of products in the country (*Sierra Leone Standards Bureau-SLSB*). For instance, it was understood that two containers full of mosquito coils were imported into the country last year for which there were new products. The office of SLSB at the sea port could not determine the quality of these products by conducting emission tests of combustible gases prior to official entry into the country. Few days later, the products were allowed into the market. Considering the knowledge gap of the current scenario, it was imperative to conduct a pilot study to ascertain emission levels of combustible gases; namely nitrogen dioxide (NO_2); sulphur dioxide (SO_2) and carbon monoxide (CO) due to burning mosquito coils. It is envisaged that this pilot study would provided much needed information that would guide effective policy towards environmental health risk reduction.

2. MATERIALS AND METHOD

This pilot experimental study was conducted in December 2015 in Freetown, the capital of Sierra Leone. Freetown is a Port city that is 27 m above sea level and lie on coordinates 8.48°N and 13.23°W with a total area of 137.8 square miles (357 square kilometers) located on the western area of the country on a mountain peninsula stretching into the Atlantic Ocean which has been described in an earlier study (Taylor and Nakai, 2012b). The climate of Sierra Leone is tropical (hot and humid); with the raining season lasting from May to December and the dry season from December to April. The study location was a household situated at Hill Station which is one of the highest peak areas in Freetown roughly above 200m above sea level. An area characterized by natural ventilation and strong wind due to the landscape. The reproduction of real burning conditions is an essential determination of pollutants that are emitted from a burning source such as mosquito coils. Such an approach allow for a better control of the combustion zone realizing a smooth and constant air flow around the material to be burnt which allow well mixed conditions.

For each experimental run, a mosquito coil within the coil packet was lit on the metal stand and placed in the middle of sized room with dimension 12 ft by 10 ft by12 ft. Tested mosquito coils were six brands purchased from retailers along Sani Abacha Street in Freetown. Brand names were *Tigerhead*, *Allah Walli*, *Superchoice*, *Touba*, *Sweet dream* and *Hewelon*. Tigerhead, Allah Walli, Touba and Hewelon were products from China while the origin of Superchoice and Hewelon were not indicated on the coil packet. The monitoring device was placed 0.5m away from the lit coil. At the start of each experiment, the door and window were closed to simulate a typical scenario of combusting mosquito coils in Sierra Leone. Measurements or readings were taken after the coil was lit for 15 minutes and recorded values taken for 1 hour. Beyond this period, both the door and window were open to allow natural ventilation to disperse all potential gases in the room. Before the commencement of monitoring, natural ventilation was allowed for few hours until traces of the gases dispersed. The zero point accuracy of the sensors was reached by carrying out the fresh air calibration each time prior to measurement inside the experimental room. This was achieved by the 1 button calibration procedure in the experimental room after few hours of time elapse to ensure and confirm that combustible gases released from the previous experiment have been removed from the room or sufficiently diluted. Display containing the current gas concentration changes with the display OK when calibration was done indicating a successful calibration process.

The Drager X- am 5000 (*www.drager.com*) was used for the monitoring program which was obtained from Ribble -Enviro Ltd UK in August 2015. It is a small, light and easy to use which makes it very ideal for field monitoring in areas where conventional monitoring requirements are somehow restricted. It is very robust, watertight and is designed for single-handed operation in tough industrial environments. Water- and dustproof according to IP 67 and with an integrated rubber boot, the device provides optimal functionality even under harsh conditions. This monitor measures up to six gases simultaneously and for the purpose of this study, four electrochemical infrared sensors for CH_4, NO_2, SO_2 and CO were used for this study. The device has a high resolution of 0.1 ppm for both NO_2 and SO_2 and 2 ppm for CO with a very short response time of 15 seconds for both NO_2 and SO_2 and 25 seconds for CO. Five minutes average readings were recorded for an hour and data collated for further processing. Descriptive statistics were used to analyze the data.

3. RESULTS

The results presented are 1 hr average levels for the six different products of mosquito coils studied during the pilot study. There was no meaningful and consistent emission of NO_2 for all the products investigated.

3.1. Sulphur Dioxide (SO_2)

Evidence of emission of SO_2 was observed for almost all the products as illustrated in Fig 1. Tigerhead, Allawalli, Touba and Sweet dream did not reveal any considerable variation in emission of the gas based on the error bars illustration. This would suggest that emission of SO_2 for these products are relatively similar. However, there was a marked and considerable variation for Superchoice as evident in the error bars which suggest varying emission with respect to this product. This statement is further confirmed by considering the coefficient of variation for Superchoice (0.9) (defined as the ratio of standard deviation to its mean, a measure of the variability of data relative to its mean), which is the highest relative to the other products. Evidence of peak values was observed as shown in Fig 2. It's no unsurprising again that Superchoice has the highest peak value with about (200 ppb) with the other three products Tigerhead, Allah Walli, Touba and sweetdream having the similar emission peak value (100 ppb), which could be strongly attributed to the resolution of the SO_2 sensor. The one hour average values fell well within the prescribed ambient air quality guidelines for all the different products but it is somewhat contrasting for peak SO_2 values.

3.2. Carbon Monoxide (CO)

Average emission levels of CO for the different mosquito products are presented in Fig 3. It appears that all of the six investigated products released considerable levels of CO but there was no evidence of difference in emission levels for the said products as manifested in the error bars. Such a distinct observation in emission levels could have an implication for exposure response study. Nonetheless there is slight evidence of marked variation in emission levels for sweetdream product. Touba product revealed the highest peak CO value (70 ppm) with the lowest peak value observed for sweetdream (32 ppm) in Fig 4. Similar observation was made for hourly CO average which is also in conformity with ambient air quality guidelines even though instantaneous peak values appeared well above such threshold.

4. DISCUSSION

Emission of combustible gases from burning different mosquito coils was the main focus of this piece of work. Nevertheless, much information regards the materials used in the production of mosquito coils are not indicated on the boxes but previous study has revealed that most Chinese made coils were made from saw dust as the base materials while those from Malaysia were from coconut husks or shells (Liu *et al.*, 2003). From the results presented, NO_2 was not mainly captured during the monitoring period and data not reported. A previous study that investigated emission rates of combustible gases from burning candles and mosquito coils clearly indicated little or no emission factors for NO_2 (Lee and Wang, 2006). Such observation could be attributed to the non detection of NO_2 for the different products in this study. The same study reported high emission factors for CO which is in agreement with the current study given the relatively high levels of CO emissions during the burning period. An earlier study demonstrated that mosquito coils could emit high levels of CO (Lee and Wang, 2006) and we share similar viewpoint in this study given the noticeable high levels of the gas reported. Release of high levels of CO which is a byproduct of incomplete combustion is partly due to the smoldering effect (Lee and Wang, 2006; Taylor and Nakai, 2012a).

There is little evidence of SO_2 emission levels from mosquito coils in the wider literature. Nevertheless, our study has revealed considerable variation in the release of SO_2. Factors responsible for the difference in concentrations and variation of indoor air pollutants could be explained in relation to the type of material or substance burnt, burning intensity, room or enclosed area, ventilation rate, spatial distribution of pollutants, duration of the monitoring regimen *etc*, for which these factors may vary in emission release (Balakrishnan *et al.*, 2002; Smith *et al.*, 2004). For instance, Salvi *et al.* (2006) reported lower levels of CO (6.5 ppm) relative to this study when door and window were closed. The one hour average CO levels released from burning mosquito coils in the current study is lower than a recent study that looked at diurnal release from wood and charcoal fuels in western Sierra Leone (Taylor *et al.*, 2015b). Hourly average values for both sulphur dioxide and carbon monoxide were below the recommended WHO ambient air quality standards even though peak values in some cases exceeded this threshold. Generally, there is no meaningful difference in emission of CO for all the six products but this is contrary in the case of sulphur dioxide with Superchoice product recording the highest emission. Evidence of noticeable variation was observed for sulphur dioxide among the products.

Varying degree of evidence exist for different pollutants that are released during burning mosquito coils. For instance, it was reported that high levels of volatile organic compounds are released during mosquito coil burning (Liu *et al.*, 2003; Lee and Wang, 2006). Recent studies have shown the release of considerable levels of particulates with aerodynamic less than 2.5 micrometer in diameter, polycyclic aromatic hydrocarbons (Singh *et al.*, 2012; Kumar *et al.*, 2014). It has been demonstrated that the release of pollutants especially particulates is usually high during burning mosquito coils compared to before and after the burning process, an indication that exposure to these health induced pollutants is highest during the burning period; a period that characterizes repelling mosquitoes in enclosed room spaces (Kumar *et al.*, 2014).

There is strong empirical evidence that burning mosquito coils is a significant environmental risk factor and a major source of disease burden. For instance, emission of formaldehyde from burning one coil can be as high as that released from burning 51 cigarettes as documented earlier (Liu *et al.*, 2003). Evidence of human carcinogens was also quantified from PAHs release which is a concern even at low exposure levels (Liu *et al.*, 2003). There has been strong evidence of association between exposure to smoke from mosquito coils and various respiratory conditions. For example, cough was significantly associated with mosquito coil use in the stated report (Tharaphy and Chapman, 2010). Evidences of epidemiological and toxicological studies resulting from exposure to mosquito coils have been widely documented. It was calculated and reported that lifetime cancer risk from exposure to mosquito coils can be alarming (Singh *et al.*, 2012). It was also demonstrated the release of pollutants (particulates) from burning one mosquito coil is approximately the same as burning 75-137 cigarettes with a much wider implications to public health (Liu *et al.*, 2003). Another study reported a significant association between mosquito use and cough in children with or without colds suggesting further that the use of mosquito coil is an environmental risk factor for diseases (Tharaphy and Chapman, 2010).

This pilot study brought to light that mosquito coils imported to Sierra Leone is a source of indoor air exposure to combustible gases which is an environmental health concern. Given the lack of insight by the SLSB, it is hoped that the SLSB would acquaint their protocols for future emission testing as this pilot study would help guide thoughts on quality issues on all products imported to Sierra Leone. We hope that this initial result would be used to expand monitoring programs with detailed experimental design. The study again showed that vital pollution information could be done using simple but high tech scientific devices. A strong recommendation is suggested for an exposure response study so as to ascertain the disease burden from this environmental risk factor in a typical developing country in Africa on a wider scale.

5. CONCLUSION

This main focus of this study was to characterize emissions of combustible gases from different mosquito coils that are sold burnt in Sierra Leone. Evidence of sulphur dioxide and carbon monoxide gases were released from burning mosquito coils but that for nitrogen dioxide was not detected in sufficient amount. There was no single mosquito coil product that showed substantial emission level for carbon monoxide but one product (*Hewelon*) showed considerable variation for sulphur dioxide. Giving the critical state of indoor air pollution in developing country, this study showed that instantaneous peak values could be critical for exposure response study given the relatively high levels of combustible gases reported in this study.

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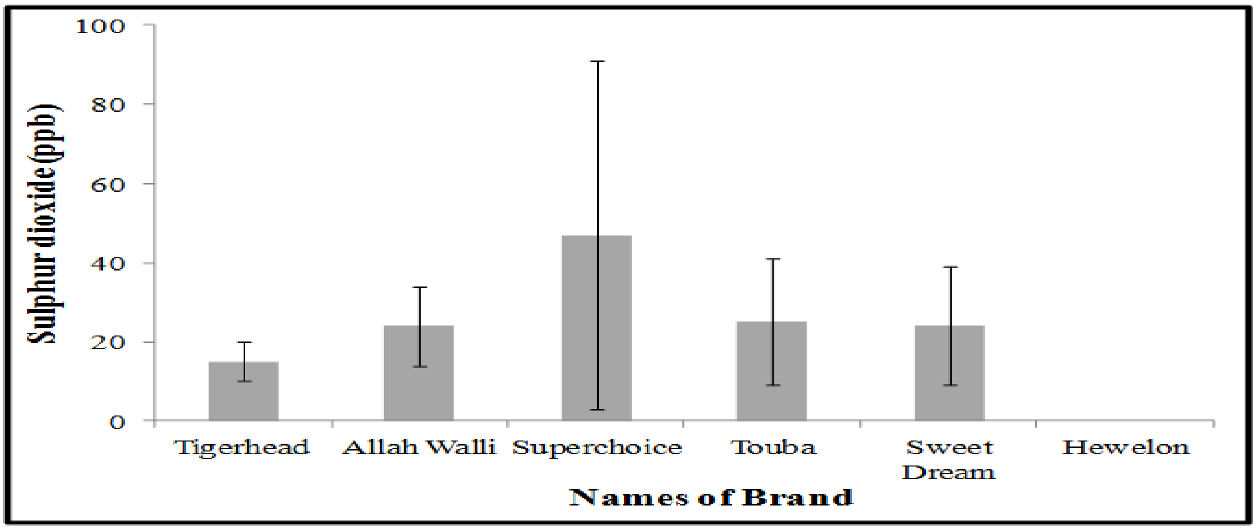

Fig-1. 1-hr average concentrations of sulphur dioxide for the different products. Error bars represent one standard deviation from the mean

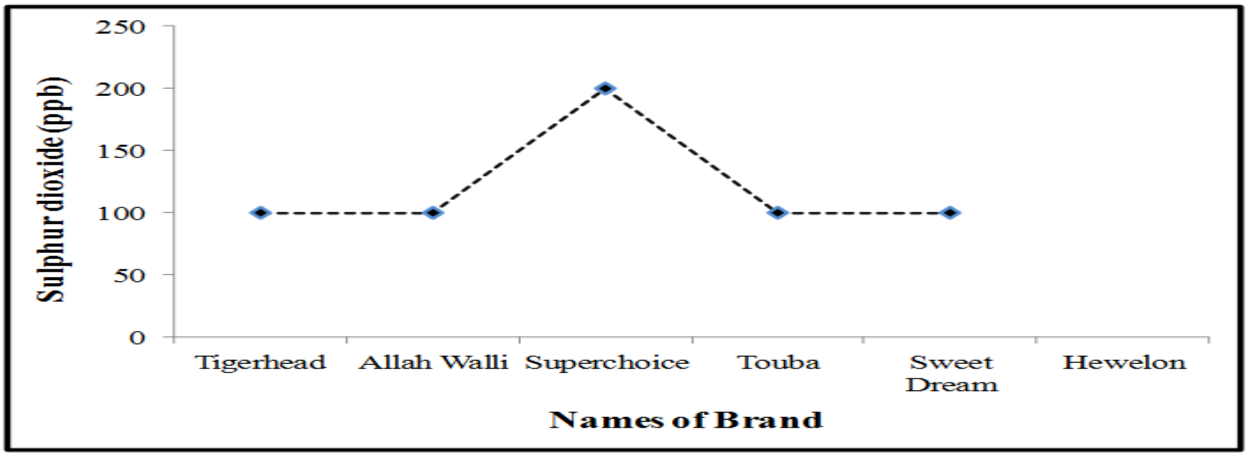

Fig-2. Peak values of sulphur dioxide recorded for the different mosquito coil products except for Hewelon

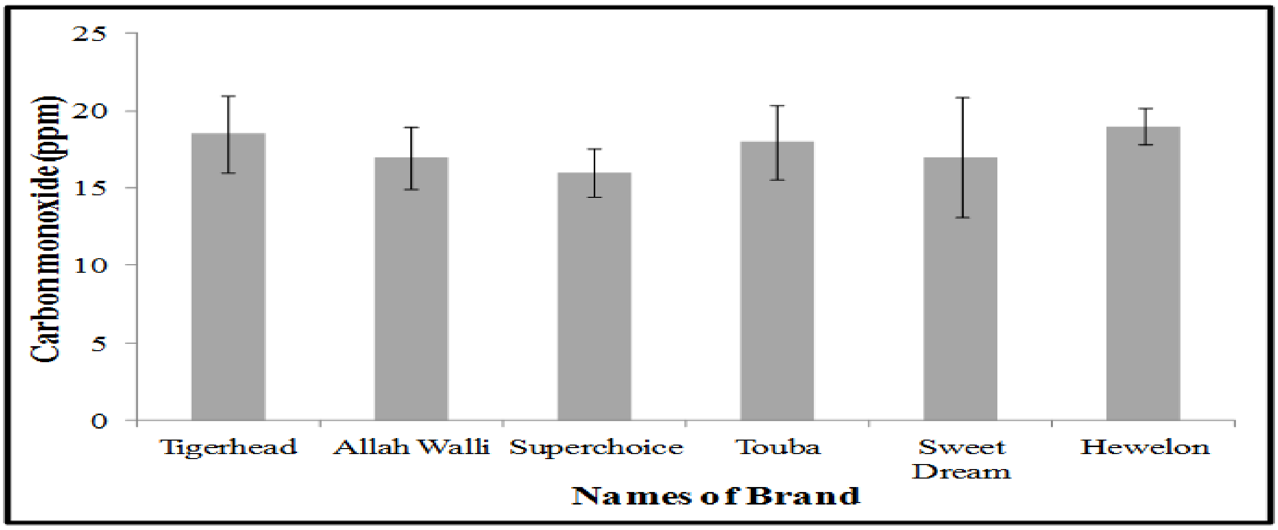

Fig-3. 1-hr average concentrations of sulphur dioxide for the different products. Error bars represent one standard deviation from the mean.

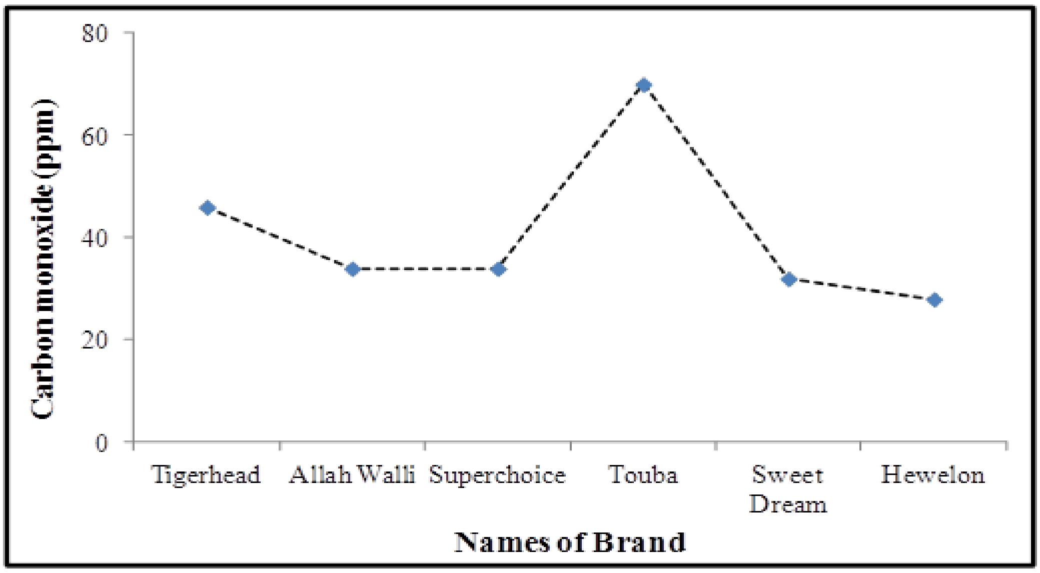

Fig-4. Peak values of carbon monoxide recorded for the different mosquito coil products