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Carbon Monoxide Exposure during Cooking in Households: A Case of Dar es Salaam City, Tanzania

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Abstract: Exposure to CO (carbon monoxide) during cooking in households using LPG (liquefied petroleum gas), natural gas and charcoal as fuels has been conducted. The study aimed at assessing the indoor air quality in order to address potential hazards associated with CO. Carbon monoxide concentrations and flame temperature were measured at an interval of 1 min for 1 h using CO and thermometer data loggers respectively. While the CO concentration from LPG and natural gas were found below 26 ppm for 1 h, as recommended by WHO (World Health Organization) standards, the average CO concentration from charcoal exceeded the standard limit. In addition closing the kitchen door during cooking increased the CO concentration from 26-295 ppm to 92-597 ppm. According to WHO, the observed CO concentrations from charcoal stove highlights questionable life support atmosphere. It can therefore be suggested that switching to LPG or natural gas from charcoal will reduce CO exposure to persons during cooking.

Key words: Air quality, CO poisoning, indoor pollution, pollution.

1. Introduction

Exposure to elevated CO (carbon monoxide) during cooking in kitchens is a major concern in developing countries including Tanzania. Many people can be exposed to toxic risks associated with higher concentration of CO in the cooking area due to lack of awareness. Extended exposures to higher concentration of CO may cause vomiting, headache, fatigue, loss of memory, dizziness, nausea and death. Other researchers have reported to cause dysfunction of the human visual system at COHb (carboxyhemoglobin) above 18% [1]. Carbon monoxide can also cause neurological problems in mature persons, learning disabilities, developmental problems in children and can lead to miscarriage or stillbirth for women exposed during pregnancy [2].

High concentration of CO in the kitchens depends on several factors including type of fuel and ventilation. Generally, fuels with high carbon content such as charcoal emits high CO concentration in the flue gases during incomplete combustion compared to LPG (liquefied petroleum gas) and natural gas [3]. Incomplete combustion of fuels is mainly caused by insufficient oxygen around the burning appliance. This deficiency highlights the existence of poor ventilation of the particular kitchen. Poor ventilation in many residential kitchens could be due to natural ventilation employed which depends on wind direction. Additionally, a number of buildings in developing countries have only one ventilation window on a side elevation of the kitchen. In some cases, kitchen doors are also closed during cooking to prevent children accessing the burning fire. Under these conditions, air quality in the kitchen may be compromised and the need to investigate is obvious.

Although previous studies on indoor concentrations of CO have been conducted in other developing countries, in Tanzania there is limited information on CO exposure during cooking in the kitchen.

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Furthermore, awareness on potential hazards associated with CO is also not well addressed. Therefore, this study aims at assessing the CO exposure in cooking areas with poor ventilation and addresses the associated potential hazards. Three types of fuels employed in the study were LPG, NG (natural gas) and charcoal. While the latter was chosen to represent a major source of fuel in Tanzania [4], the LPG is also commonly used in households for cooking. Natural gas was chosen as a prospect fuel following discovery in the recent years. The CO exposure levels from these fuels were compared with those recommended by WHO (World Health Organization) standards and other literatures to address potential hazards.

2. Materials and Methods

The toxicity of the environment is determined by the chemical composition, concentration, physical state of the effluents and duration of exposure as described in PD 6503-1:1990 standard [5]. In this study, the chemical concentration of CO in the kitchen was determined according to Ref. [6] standard procedures. Rice (1 kg) and green vegetable (0.4 kg) were chosen as a typical food for experimentation and their total cooking time was timed at 1 h. The food was cooked in an aluminum port (2 L) using LPG, natural gas and charcoal as sources of fuel. The Nikai gas cooker (NG-842) was used for gaseous fuels while charcoal was fired in a "Jiko Poa" (top diameter = 300 mm). Prior to cooking, the CO concentration was recorded at an interval of 1 min for 15 min. Flame temperatures for all cooking tests were also measured at an interval of 1 min using YC-747UD thermometer data logger and Type K thermocouples (accuracy ± 0.1%). Similarly, the concentration of carbon monoxide was monitored using CO (EL-USB-CO, accuracy ± 6%) data logger. The sampling points in the room were located at a region representing breathing zone as shown in Fig. 1a and 1b). The breathing point was established by taking physical measurements during cooking considering the ergonomics of human body measurements [7]. The cooking tests were conducted in three cycles to monitor maximum fluctuation.

3. Results and Discussion

By means of measurements methodology the experiments were carried out. The results obtained are presented in the form of CO exposure and potential toxic hazards.

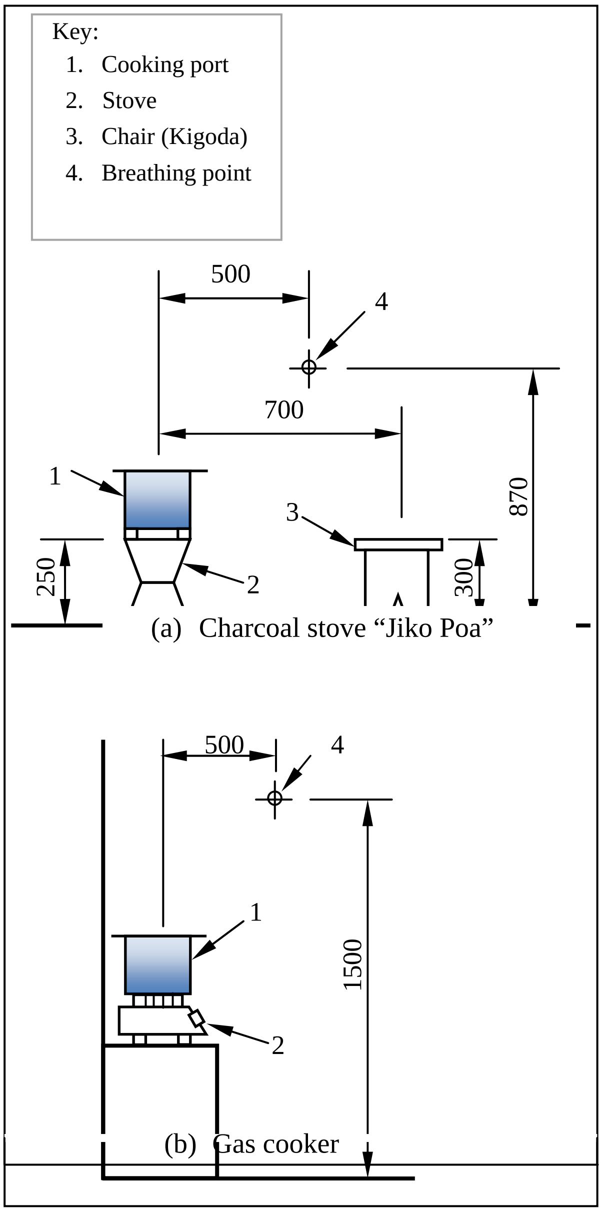

Fig. 1 Schematic diagram of the experimental layout using (a) charcoal stove "Jiko Poa"; (b) gas cooker.

3.1 CO Exposure

Fig. 2 compares the CO exposure in the kitchen from different types of fuels during cooking. It can be seen from the figure that CO exposure using charcoal as a fuel reached a maximum of 300 ppm while for LPG and natural gas were found to be below 10 ppm. The increase of CO concentration in the kitchen highlights an incomplete combustion due to insufficient oxygen. This deficiency could be attributed to the poor ventilation of the cooking area. Another possible explanation could be due to high carbon content in the charcoal compared to gaseous fuels. Further observation showed that there exist a positive correlation between CO emission and the addition of charcoal to the stove during cooking. It was observed that the CO concentration increased from 17 ppm to 215 ppm after addition of 100 g of charcoal. Therefore, adding charcoal to the stove during cooking could be another attributing factor to the increase of CO concentration in the kitchen. This is because of the non-homogeneous nature of the combustion process at this stage, where the added fuel is still in heating phase. These results compare well with those reported by Zhang et al. [3] who conducted the study in a model kitchen.

Fig. 3 shows the average flame temperatures and structures from different sources of fuel during cooking. The flame temperatures were measured to compare the energy used from tested fuels as well as the correlation with the CO emission and cooking practice.

The flame structure was taken to observe the yellow tipping for assessing the existence of incomplete combustion. From Fig. 3, it can be seen that the flame temperature profile for charcoal as a fuel was characterised by two peaks. The first peak occurred between 15 min and 40 min while the second occurred between 40 min and 50 min of the cooking period. The occurrence of these peaks can be explained by the combustion characteristics of the charcoal. Traditionally, charcoal combustion is associated with ash formation on the particle surface which inhibit oxygen diffusion as evidenced in Fig. 4a, thus, lowering flame temperature.

For LPG and natural gas, the flame temperature peaked at the start of ignition and decreased significantly during cooking rice. This decrease was linked to the cooking practice which aimed to reduce heating rate. Moreover, a significant yellow tipping during start of the ignition was observed when using NG compared to LPG as revealed in Figs. 4b and 4c. This structure shows the existence of incomplete

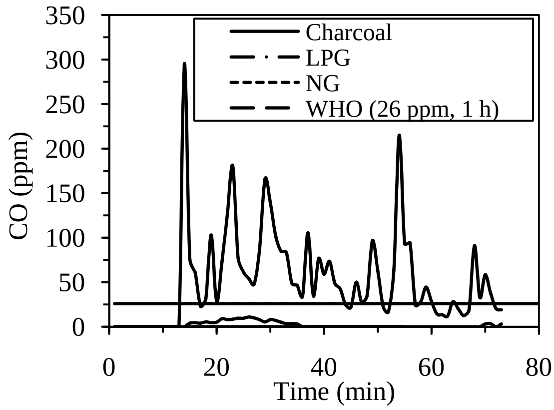

Fig. 2 CO concentration at the breathing zone from different types of fuels.

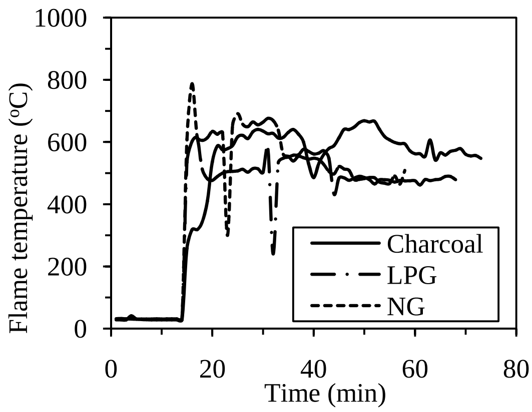

Fig. 3 Flame temperature profile of different types of fuels.

(a) Charcoal (b) LPG (c) NG

Fig. 4 Flame structures of different types of fuels.

combustion which causes CO emissions as also revealed in Fig. 2. A possible attributing factor to this characteristic could be settings of the gas cooker.

Fig. 5 compares the concentration of CO when the kitchen door was opened and closed during cooking. It can be seen from this figure that the CO concentration was higher when the door was closed than when the door was opened. The maximum concentration of CO was 295 ppm and 597 ppm for opened and closed door respectively. The increase of CO concentration could be attributed to the poor ventilation as a result of closing the door. These results indicate that families with young children practicing closing the door during cooking are exposed to higher CO levels.

Fig. 6 shows the effect of air velocity on CO concentration in the kitchen. These data were taken when the door was closed to control the air flow in the kitchen. It can be seen that the CO peaks corresponded to the decrease in air velocity. The observed peaks of CO could be due to the decreased air exchange rate as a result of decrease in air velocity.

3.2 Potential Toxic Hazards

There are several toxic hazards associated with prolonged exposure to air containing high levels of carbon monoxide. These hazards are classified based on the concentration and exposure time. The exposure time recorded in this study was found to range between 40 min to 60 min. The exposure time was measured in order to compare with the WHO standard which recommends 9, 26, 52 and 87 ppm for 8 h, 1 h, 30 min and 15 min, respectively. From Fig. 2, it can be seen that CO exposure when using LPG and natural gas were within the limits recommended by WHO (26 ppm, 1 h).

For charcoal fuel, the CO exposure exceeded all thresholds recommended by WHO. CO concentration above 26 ppm can cause a number of hazards. For instance, at 200 ppm potential hazards include slight headache, tiredness, dizziness, nausea after 2-3 h and might be life-threatening after 3 h [2]. Another

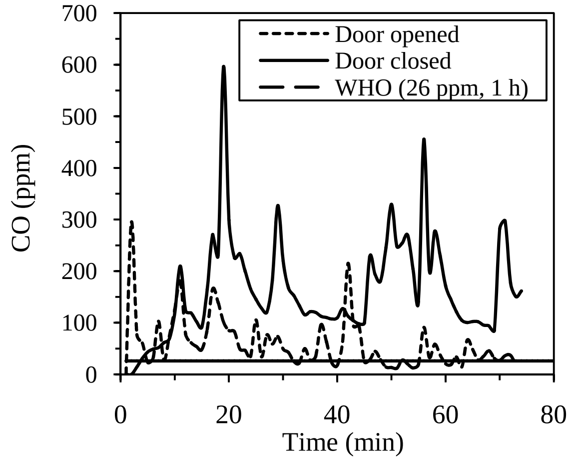

Fig. 5 The effect of closing the kitchen door on CO concentration.

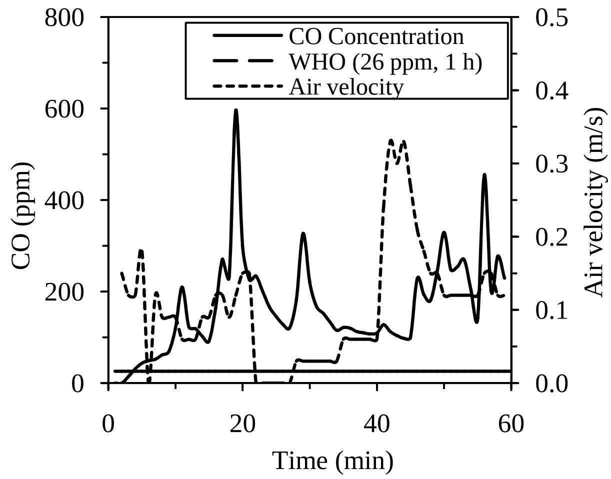

Fig. 6 Effect of air velocity on CO concentration during cooking.

laboratory study of several animal species showed a strong evidence on maternal CO exposures of 150-200 ppm (approximately 15%-25% COHb). This caused the reduction in birth weight, cardiomegaly, delays in behavioral development and disruption of cognitive function of the tested animal species [8]. In addition, isolated experiments suggested that some of these effects may occur at concentrations as low as 60-65 ppm (approximately 6%-11% COHb) maintained throughout gestation.

4. Conclusions

Experimental study on CO exposure during cooking has been conducted using charcoal, LPG and natural gas as sources of fuel. The CO exposure level using charcoal exceeded the recommended limit by WHO of 26 ppm in 1 h while LPG and NG were in the safe range. An inappropriate setting of the gas cooker is among the possible causes of CO emissions during cooking. Reducing kitchen ventilation is also a source of elevating CO levels during cooking. In general, these results suggest that cooking using charcoal may pose life threatening atmosphere compared to the gaseous fuels. The need to develop mechanism on reducing CO emissions from charcoal is required.

Acknowledgments

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