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INDOOR SHORT-TERM EXPOSURE TO AIRBORNE PARTICULATE MATTER FROM TRADITIONAL COOKSTOVES IN RURAL AREAS OF MALAWI. A CASE OF NSABWE AND BAULENI VILLAGES

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ABSTRACT

This study was carried out to assess the short-term exposure to respirable particulate matter ($PM_{2.5}$) from biomass combustion. A total of 24 households were sampled from two rural villages in Lilongwe, viz Nsabwe and Bauleni villages. Levels of particulate matter were measured using a portable gas detector. Indoor mean concentrations of $PM_{2.5}$ ranged from 457 to 698 µg/m3, with no significant difference between the two villages, suggesting exposure to similar levels. The observed levels are far above the recommended WHO limit for indoor air, posing a great health risk, more especially to the women and children who frequently visit the cooking areas. There is therefore need to widen appropriate intervention measures to reduce the current levels of indoor air pollution in the rural areas.

Keywords: air pollution; airbourne particulate matter; Three stone stove; Biomass fuel.

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1. INTRODUCTION

Indoor air pollution from the combustion of biofuels is a significant health concern worldwide, especially in poor households in many developing countries causing nearly four million

deaths each year [1, 2]. Women and children are the most vulnerable since they are the ones that frequently visit the cooking areas [3]. The problem is further fortified by overreliance on biomass (mainly wood) for domestic activities such as cooking. Over 40% (>3 billion) people worldwide rely on biomas as the main energy source for domestic purposes [4] and the usage is higher in developing countries such as Malawi where over 90% of people use biomass fuels for cooking [5]. Pollutants produced from the use of biomass for cooking have been consistently associated with serious health implications responsible for nearly 36% of illnesses worldwide [6]. The problem is worse in developing countries with poor health facilities. Different types of diseases, such as pneumonia, respiratory tract infections, cardiac events, stroke, eye disease, tuberculosis and cancer are associated with indoor air pollution [7].

During combustion of biomass, the smoke and soot produced is composed of a complex mixture of gases and fine particles referred to as particulate matter (PM). Emissions of PM are exacerbated when using inefficient cookstoves that encourage incomplete combustion [1]. These particles can easily be inhaled deep into the lungs and accumulate in the alveoli becoming a risk factor for most illnesses associated with indoor air pollution [4]. The world health organization (WHO) recommends indoor air to have levels of $PM_{2.5}$ not exceeding 25µg/m^3 to avoid detrimental health impacts.

Malawi is a landlocked country located in the southern part of Africa. The country is among the poorest countries worldwide and among the most densely populated countries in sub Saharan Africa with over 80% of its population living in rural areas [8]. Nearly every one (>98%) in the rural areas have no access to electricity and rely on biomass for cooking and heating [9]. The country is struggling to provide electricity to its population with an energy demand increasing at an average rate of 15% likely to cause more pressure on biomass energy resources and consequently lead to more indoor air pollution [10, 11]. Cooking in the rural areas of Malawi is mostly done using the traditional three-stone stove that is fed by firewood in three spaces. Use of this type of stove is well known for its inefficiency, harnessing only 5–15% of biomass energy, requiring more firewood and produces more smoke and soot from incomplete combustion [12]. Various programs mostly run by non-governmental organizations both local and international have been rolled out in the country to disseminate

non-traditional stoves which are efficacious on fuelwood saving, an effort that could protect the rapidly declining forest resources, and combat indoor air pollution. However, despite such initiatives, adoption rates have remained disappointingly low. Most rural households do not perceive indoor air pollution as a significant health hazard, as a result they consider other basic needs as more important than spending on an improved cookstove.

This study was carried out to quantify levels of particulate matter associated with biomass combustion using the three stone stove. The results generated will provide an account of exposure levels faced each day in rural areas of Malawi.

2. EXPERIMENTAL

A total of 24 samples were collected from two villages within Lilongwe rural, viz, Nsabwe and Bauleni (Fig. 1). The households were selected by a multistage sampling method, where one house was randomly selected then a snowballing technique was used select other households. Particulate matter of dimeter less than 2.5 ($PM_{2.5}$) was considered for this study because of its association with biomass combustion [13]. The measurements were recorded while cooking a regular Malawian meal (Nsima) using a traditional three stone stove. Realtime measurements were conducted using an easy to use potable detector (DM106A) equipped with a laser sensor that operates by laser scattering principle, capable of detecting $PM_{2.5}$ concentrations between 0 – 999ug/m^3. Before the measurements the detector was calibrated according to the manufacturer's procedure outlined in the instrument's manual. To achieve a good estimate of exposure the measurements were taken at a height of about one meter from the ground and the measurements were recorded from the onset of cooking i.e. when setting up the fire, to the end. Nsima is a local staple meal prepared twice each and every day by almost everyone in the rural villages and the majority of all Malawians.

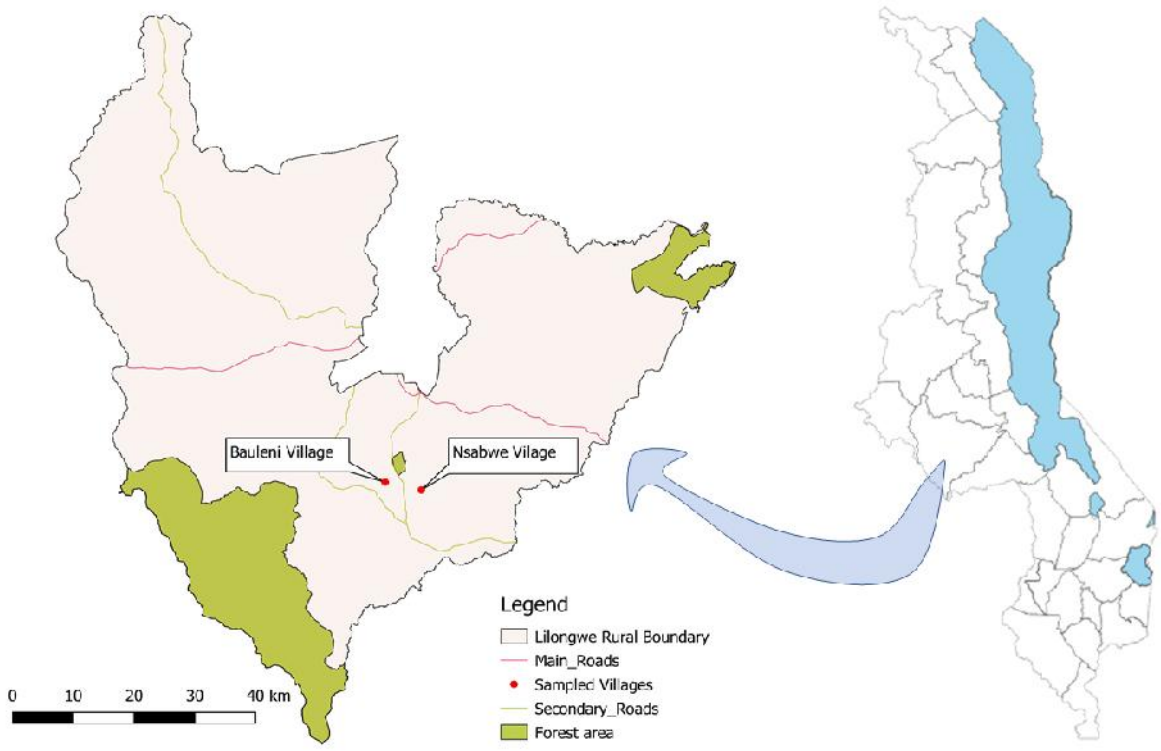

Fig.1. Map of Lilongwe rural and location of sampled villages

Three main processes are involved when preparing the meal. First water is heated to warm, and then flour (usually corn flower) is added to form a porridge. The mixture is left to boil for a few minutes then more flour is added while stirring to harden the porridge to the preferred consistency. On average, the whole process takes nearly 20 minutes.

Statistical tests and graphs were done using PAST statistical package version 3.25. Mean $PM_{2.5}$ levels were calculated from the onset of cooking to the end.

3. RESULTS AND DISCUSSION

All households visited, exclusively cooked with wood sourced from nearby forests or bought from the market or door to door wood vendors. The kitchen rooms are designed without proper ventilation (93% of the kitchens did not have windows for ventilation) constructed either with burnt or unburnt bricks, and the majority (>90%) roofed with grass. The surfaces of walls and roof were visibly covered with black deposits from soot and smoke emanating from incomplete combustion (Fig. 2). Additionally, the general unhygienic conditions of the

kitchens worsen the problems associated with indoor air pollution. Nearly all households built their kitchen rooms independently in front of the main house or at the back, to allow easy access when preparing meals. Consequently, emissions from the kitchen areas affect people in the house, including the sick and the elderly, not directly involved in the cooking process.

Fig.2. A woman preparing a meal in one of the kitchens

Twenty-four households (12 from each village) were sampled. Sampling duration was between 11:00-14:00, mean (SD) 20.1 min (4.3 min). The mean concentration of $PM_{2.5}$ from both villages was 561±368 µg/m^3. Concentrations from Nsabwe and Bauleni villages ranged from 457 to 698 µg/m^3 and 487 to 625 µg/m^3 respectively.

Table 1. Mean concentrations of $PM_{2.5}$ (µg/m^3)

	Household	1	2	3	4	5	6	7	8	9	10	11	12
$PM_{2.5}$ concentration	Nsabwe Village	698	565	602	516	540	469	479	457	587	562	591	546
	Bauleni Village	487	548	559	571	568	540	600	619	567	625	594	559

Concentrations of PM increased from an average of 38±27 µg/m^3 at the beggining to 947 ± 40 µg/m^3 at the end of the cooking process. There was no significant difference between levels measured from Bauleni and Nsabwe villages (p=0.41), suggesting that the villages are exposed to similar levels of the pollutants. Mean levels observed were high and exceed the WHO recommended level of 25 µg/m^3 for indoor air quality. Values observed in this study are higher than those reported in Blantyre and Chikwawa districts, south of Malawi [6]. In their study they reported a mean level of 250 µg/m^3 for both Chikwawa (rural) and Blantyre (Urban). These results were observed from a study on traditional and improved stoves. However, similar findings were reported from a study on traditional stoves in rural areas of Kenya, where the mean level was 586 µg/m^3 [14] and slightly lower than those reported in ethiopia [15]. Values above 1000 µg/m^3 have also been reported elsewhere outside Africa [16, 3]

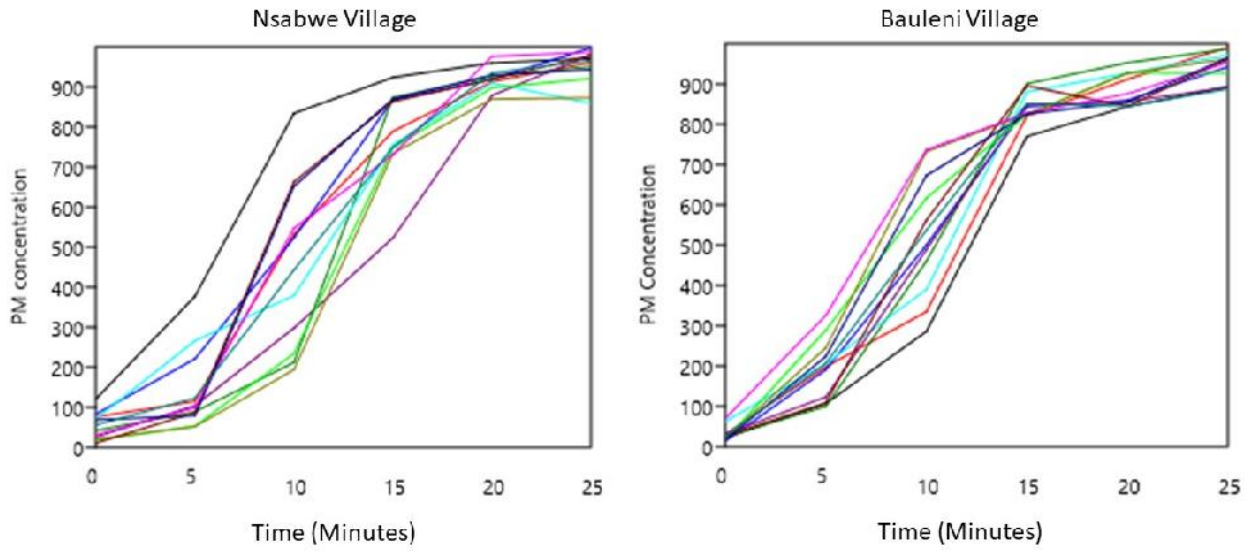

Fig.3. Average $PM_{2.5}$ concentrations (µg/m^3) fron onset of cooking to the end

Short term acute exposure to particulate matter, can cause detrimental health effects similar to chronic exposure. In a study by WHO on bio-mass energy use, women spending two hours cooking with a biomass stove inhale particulate matter equivalent to smoking 40 cigarettes in one day [17].

4. CONCLUSION

Particulate matter ($PM_{2.5}$) was studied to understand the levels of indoor air pollution in rural households using the three stone stove. The levels observed are high, twenty times greater than the recommended limit for indoor air by the World Health Organization. These levels are likely to results in adverse health implications. Furthermore, the situation is expounded by lack of ventilation in the design of the kitchens and poor hygiene practices. The study observed no significant different between the levels from the two villages. This study has conclusively studied the levels of particulate matter from the two villages, however it will be important to conduct more in-depth studies to relate the levels with health effects.

With the prevailing energy crisis in Malawi, and the cost to switch to alternative energy sources, it is obvious that biomass will continue to be the main source of energy for rural households. It is therefore important to widen up appropriate interventions to reduce intoor air polliution. Rural communities should also be educated on the need to maintain a clean air environment and to provide adequate ventilation when designing cooking areas.

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