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# A Descriptive Assessment of Household Air Pollution in Rural Kitchens in Kenya

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**Abstract:** Efforts to ensure households transition to modern fuels are expected to reduce household air pollution. However, exposure to toxic particles and gases in fuel stacking households remains under-researched. We implemented a household survey to identify household energy sources and assess exposure to particulate matter with diameter of ≤5 microns ($PM_{2.5}$), ≤10 microns ($PM_{10}$) and select polluting gases (Sulfur Dioxide ($SO_2$), Total Volatile Organic Compounds (TVOCs), Carbon Dioxide ($CO_2$), Nitrogen Dioxide ($NO_2$), Carbon Monoxide (CO)) in a rural community. Wood was the main cooking fuel in 94.2% (1615/1703) households with fuel stacking reported in 86.1% (1462/1703) of total households. Daily time-weighted average concentrations of $PM_{2.5}$ and $PM_{10}$ were beyond World Health Organization (WHO) limits in wood-using households (189.53 (Standard deviation (SD) = 268.80) μg/m$^3$ and 592.38 (SD = 623) μg/m$^3$, respectively) and Liquid Petroleum Gas (LPG) -using households (57.2 (SD = 53.6) μg/m$^3$ and 189.86 (SD = 168) μg/m$^{3,}$ respectively). Only daily average CO and TVOC concentration in wood-using households exceeded recommended levels. Household socio-economic status, education level of the head of household, use of a separate kitchen and household size influenced household energy choices. Rural households using wood as the main cooking fuel are exposed to high levels of particulate matter, carbon monoxide and total volatile organic compounds. LPG-using households may not realize health benefits if stacking with polluting fuels is practiced.

**Keywords:** household air pollution; household energy; $PM_{2.5}$; TVOCs; Kenya

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## 1. Introduction

A third of the global population relies on biomass and kerosene to meet their cooking and heating energy needs [1]. In Kenya, combined estimates indicate that 74.5% of households use biomass and kerosene for cooking, with rural areas having the highest proportion (93.4%) compared to urban areas at 44.6% [2]. This is despite growing concerns on the effect of biomass fuels and kerosene on household air quality and its associated health and non-health impacts.

The responsibility for collection, transportation and use of wood fuel largely lies on women and children. They not only bear the largest burden of exposure to risks during wood collection and transportation [3], but also endure toxic kitchen emissions associated with traditional fuels, with added implications for health including adverse pregnancy outcomes [4–8]. Most times, women and young girls are also the caretakers of young children and spend time in kitchen environments causing early life exposure to air pollutants which may influence subsequent health outcomes [9].

The combustion of biomass fuels in rudimentary stoves such as the three-stone stove commonly found in rural African homes, has been associated with high levels of pollutant emissions. Evidence from rural Kenya show that women and girls were expose to extremely high levels of particulate matter [10,11] as well as high levels of carbon monoxide [12,13]. These studies reported peaks in pollutant concentrations during cooking episodes, indicating higher personal exposure for cooks and other household members present in the kitchen environment during cooking. Similarly high levels of kitchen emissions have been documented in other countries across Africa [14–16].

This study seeks to characterize the fuel-stove mix in a rural community in Eastern Kenya, and profile fine particulate matter and gaseous pollutants in kitchens.

## 2. Materials and Methods

### *2.1. Study Design*

We use cross-sectional data from a baseline survey targeting 2000 households sampled using a two-stage approach. We implemented a household baseline survey to assess current household sources of energy and willingness to shift to cleaner options.

We purposively sampled 20 households from the survey participants based on primary cooking fuel to ensure representation of the range of fuels used in the community (Table A1). In addition, we considered equipment safety and ease of access to the households for deployment of the monitoring equipment.

The Handheld 3016 IAQ™ Airborne Particle Counter (Lighthouse Worldwide Solutions, Medford, MA, USA) uses a laser-diode light source and collection optics for particle size detection (particle size range 0.3–10 μm). Particulate matter was monitored using the Lighthouse Handheld 3016 IAQ Airborne Particle Counter set in mass concentration mode, and mass concentration logged every minute. Purging procedure was done weekly according to manufacturer instructions.

The particle counter was anchored on a Wolfpack® Modular Area Monitor as an integrated system via the respective brackets. Each instrument logged data separately and left to run for at least 12 h to cover the typical three cooking periods in a day. The Wolfpack® Modular Area Monitor had two GrayWolf DirectSense® probes plugged in and simultaneously monitoring Sulfur Dioxide ($SO_2$), Total Volatile Organic Compounds (TVOCs), Carbon Dioxide ($CO_2$), Nitrogen Dioxide ($NO_2$), Carbon Monoxide (CO), temperature and Relative Humidity. After setting up the Wolfpack unit, probes were allowed to stabilize, and data logged at one-minute intervals. All monitors were placed one meter off the ground and a similar distance from the cookstove.

For each household, air quality monitoring was conducted every other day over a 7-day period to allow for an assessment of variation in emission levels between weekdays and weekends. This translated to four days of monitoring in a week for most households (Table A2), totalling to 71 days or 1505 h of monitoring. Monitoring ran from February to April 2021, which coincided with the end of the dry season (in mid- March) and the long rains (late March/April). It is worth noting that 2021 long rains in the area failed and the period was relatively dry.

### *2.2. Kitchen Characteristics*

Most of the households sampled for air quality monitoring had a separate kitchen (stand-alone house) which was mostly a one-roomed structure with earthen floors. A traditional three-stone stove (Figure 1a) or a variation of this with the stones covered with mud (Figure 1b) was the most common type of cooking stove in the area. In a few of the sampled homes, the kitchen was part of the main house/room.

### *2.3. Data Analysis*

Survey data was analysed using Stata software version 15.1 [17] to produce descriptive tables using the svy command, after applying sample weights. Analysis of fine particulate matter was done separately from gas pollutants. We excluded from the analysis two households that were monitored for less than three days and computed time weighted daily average concentrations of particulate matter, CO, $SO_2$, $NO_2$, $CO_2$ and TVOCs by fuel types as well as the overall average over the monitoring period for each household. Average CO concentrations were computed at 24 h, 8 h, 1 h, and 15 min intervals. The Kruskal-Wallis rank-sum test method is suitable for testing differences in particulate matter concentrations among fuel types (4 levels) because particulate matter observations are independent in each fuel type and the distribution type of $PM_{2.5}$ and $PM_{10}$ data is unknown. Kruskal-Wallis test was used to check for differences in $PM_{2.5}$ and $PM_{10}$ concentrations between different types of fuel at a significant level of 5%.

(**a**) (**b**)

**Figure 1.** (**a**) Traditional three-stone stove, (**b**) A variation of the three-stone stove.

## 3. Results

### *3.1. Household Cooking Fuels*

Table 1 presents the range of primary and secondary fuels used in the study community.

**Table 1.** Adjusted distribution of primary and secondary fuels.

| **Primary Fuels** | **Wood** | **LPG** | **Charcoal** | **Kerosene** | **Total** | |
|---|---|---|---|---|---|---|
| Percent (%) | 94.2 | 2.4 | 3 | 0.4 | | 100 |
| Frequency | 1615 | 36 | 46 | 6 | | 1703 |
| Secondary fuels * | Wood | LPG | Charcoal | Kerosene | Electricity | Ethanol |
| Percent (%) | 3.1 | 39.5 | 84.8 | 17.6 | 0.1 | 0.1 |
| Frequency | 45 | 576 | 1239 | 256 | 1 | 2 |
| | Households using secondary fuels | | | Households not using secondary fuels | | |
| Percent | | 86.1 | | 13.9 | | |
| Frequency | | 1462/1703 | | 241 | | |

* Total percent is more than 100% due to multiple responses.

Secondary fuels were used alongside the primary fuel in 1462/1703 (86.1%) households, reportedly for their ability to cook fast in 927/1703 (63.6%) households.

We present stacking behaviour in households and coin terminologies for different fuel combinations as described and shown below (Figure 2). In this paper, we use the terms "higher rung" and "lower rung" fuels to refer, respectively, to fuels that fall higher on the fuel ladder such as LPG, and those falling lower on the ladder such as firewood. Results show up-stacking (use of a "lower rung" primary fuel and a "higher rung" secondary fuel) accounting for 8.2% while down-stacking (use of a "higher rung" primary fuel and a "lower rung" secondary fuel) accounting for 2.3%. In addition, 58.7% of households used "lower rung" fuels as both primary and secondary fuels- in what we term as horizontal stacking while 30.8% of households used both "higher rung" and "lower rung" secondary fuels (we coin the term partial up-stacking for such households).

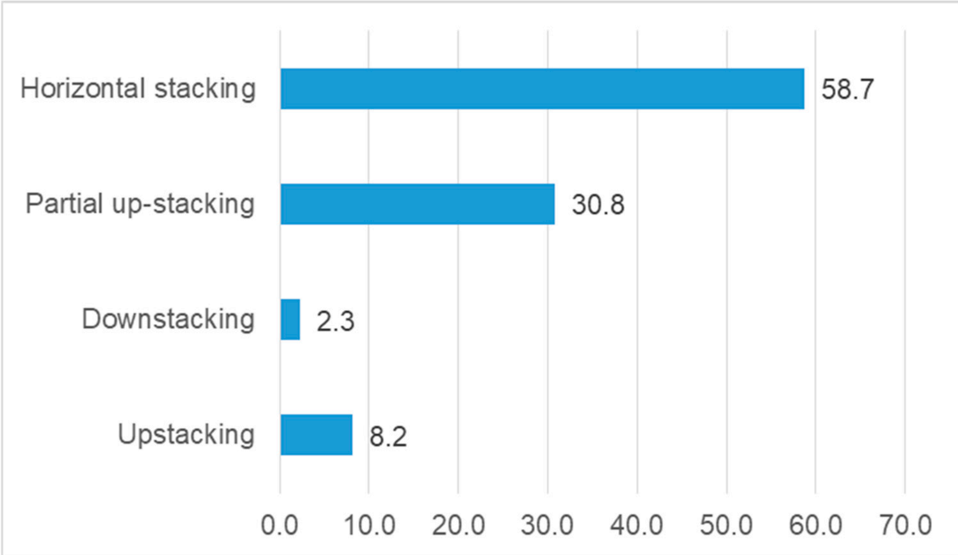


**Figure 2.** Graph showing the proportion of households using different fuel stacking levels.

### *3.2. Kitchen Emissions Levels*

The levels of particulate matter are presented in Table 2 below across the different primary cooking fuels reported. We present hourly and daily variations of $PM_{2.5}$ and $PM_{10}$ by fuel type. Emission trends of $SO_2$, $NO_2$, CO and TVOC are also shown making comparison with WHO guidelines for short-term exposure (24 h).

**Table 2.** Comparison of mean PM concentrations by fuel types.

| Fuel | Particle Size | Mean Concentration (μg/m$^3$) | | | | Four Days' Mean (SD) | *p* Value * (Wilcoxon Test) |
|---|---|---|---|---|---|---|---|
| | | Day 1 | Day 2 | Day 3 | Day 4 | | |
| LPG | $PM_{2.5}$ | 82.77 | 49.47 | 48.10 | 45.03 | 57.18 (53.6) | |
| | $PM_{10}$ | 234.10 | 182.91 | 155.47 | 186.62 | 189.86 (168) | |
| Charcoal | $PM_{2.5}$ | 15.47 | 25.35 | 15.95 | 15.74 | 18.41 (39.2) | |
| | $PM_{10}$ | 106.29 | 496.58 | 857.78 | 499.73 | 470.62 (392) | ($p < 0.001$) |
| Kerosene | $PM_{2.5}$ | 97.30 | 79.20 | 108.91 | 115.61 | 100.25 (15.7) | |
| | $PM_{10}$ | 254.37 | 221.37 | 483.32 | 351.20 | 327.56 (155) | ($p < 0.001$) |
| Wood | $PM_{2.5}$ | 200.00 | 189.42 | 246.53 | 106.67 | 189.53 (268.8) | |
| | $PM_{10}$ | 617.78 | 922.20 | 436.44 | 326.93 | 592.38 (623) | ($p < 0.001$) |

* LPG is the reference group.

Time-weighted average (TWA) daily concentrations of $PM_{2.5}$ and $PM_{10}$ was highest in wood-using households and varied significantly ($\chi^2$ (2) = 22,978, df = 3, $p < 0.001$ and $\chi^2$ (2) =8677.4, df = 3, $p < 0.001$, respectively) between different fuel types. We compare $PM_{2.5}$ and $PM_{10}$ levels in households that use LPG as their primary fuel with households using other primary cooking fuels.

$PM_{2.5}$ hourly mean concentrations were high in wood- and kerosene-using households with consistent peaks in the morning and evening hours, typical cooking time among households in the study area (Figure 3). Households using charcoal and wood had high $PM_{10}$ hourly mean concentrations with peak concentrations coinciding with morning and evening cooking times (Figure 4). $PM_{10}$ concentration in LPG-using households was low and stable. $PM_{2.5}$ and $PM_{10}$ concentration varied by day of the week and was stable in kerosene- and LPG-using households (Figures 5 and 6). In some of the days, $PM_{2.5}$ and $PM_{10}$ concentration spikes were observed in charcoal- and wood-using households. This could point to households switching between the two fuels with lower use of charcoal accompanied by increased use of wood over the weekend. This potentially points to availability of children at the end of the school week, who can accompany older females to collect more firewood for use over the weekend.

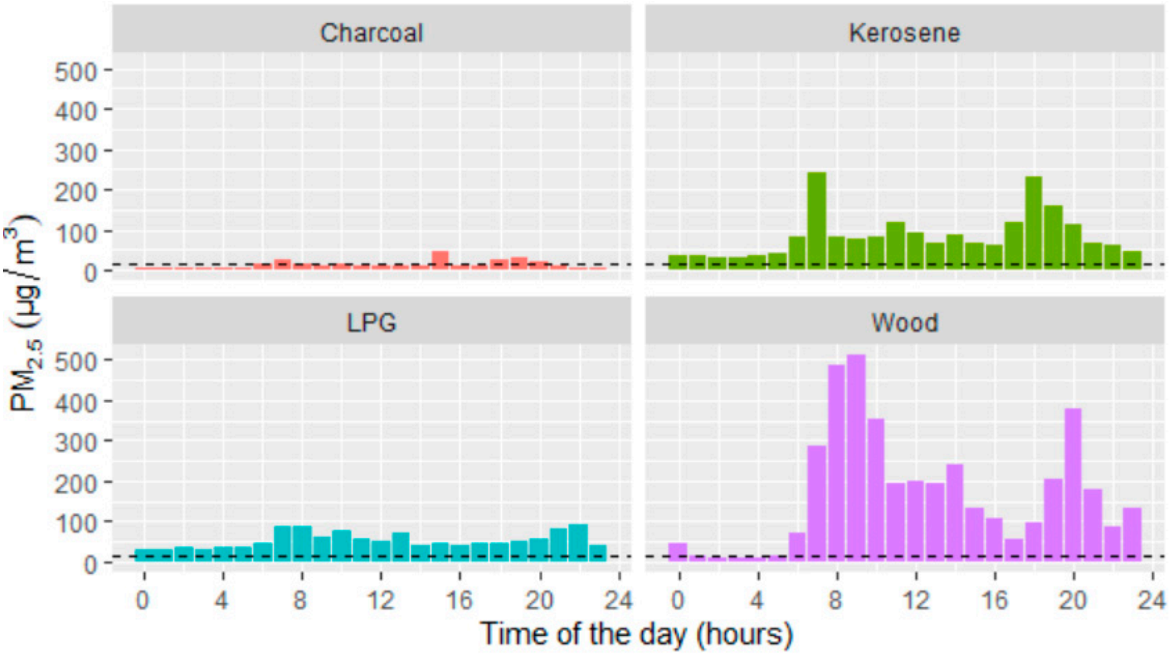


**Figure 3.** Graph showing hourly variation of $PM_{2.5}$ grouped by fuel type. Dotted line plotted at 15 µg/m$^3$, which is the mean 24 h WHO limit.

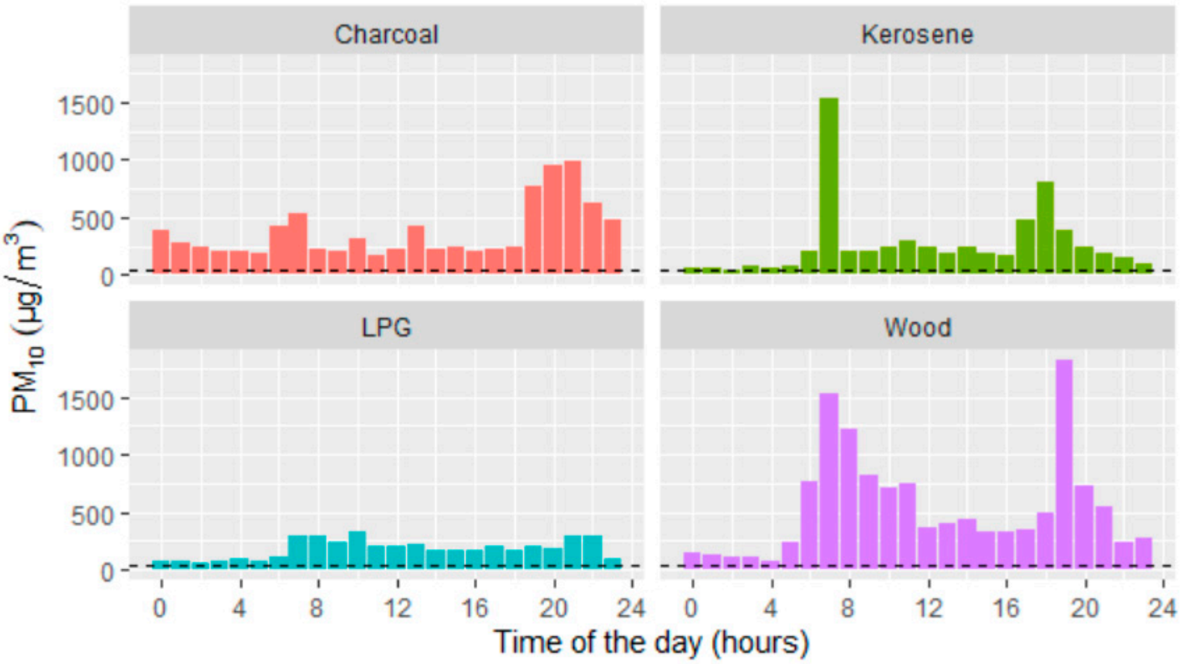


**Figure 4.** Graph showing hourly variation of $PM_{10}$ grouped by fuel type. Dotted line plotted at 45 µg/m$^3$, which is the mean 24 h WHO limit.

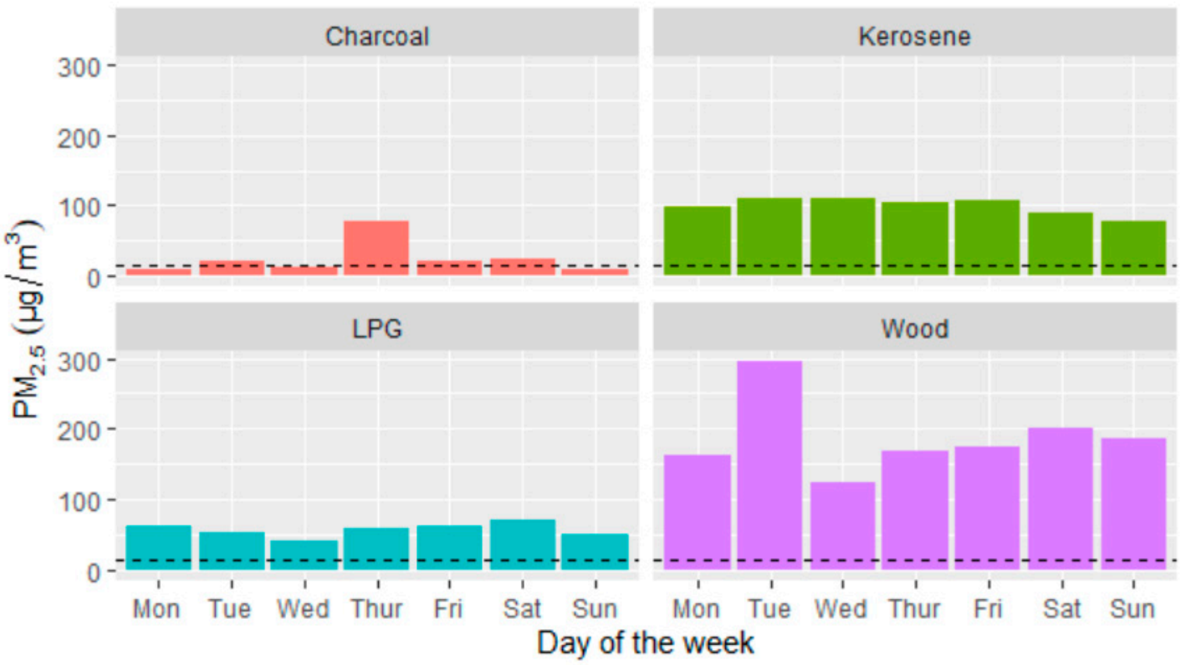


**Figure 5.** Graph showing daily variation of $PM_{2.5}$ by fuel type. Dotted line plotted at 15 µg/m$^3$, which is the mean 24 h WHO limit.

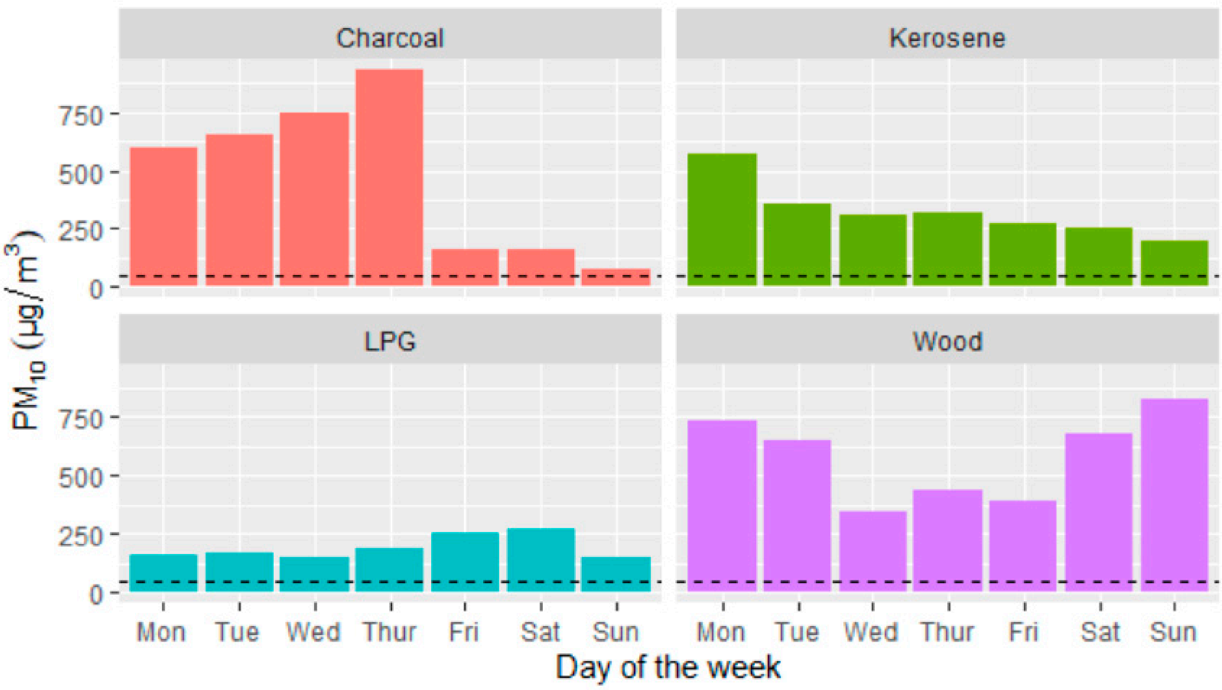


**Figure 6.** Graph showing daily variation of $PM_{10}$ by fuel type. Dotted line plotted at 45 µg/m$^3$, which is the mean 24 h WHO limit.

Daily mean $SO_2$ and $NO_2$ concentrations were below 1µg/m$^3$, which is indicative of minimal to zero traffic-related sources (Table 3). CO emissions across different cooking fuels was low and within recommended levels (Table 3).

**Table 3.** (a): Mean 24 h concentrations (μg/m$^3$) of $SO_2$, and $NO_2$. (b): Mean CO concentrations against WHO limits.

(a)

| Pollutant | Fuel Type | Mean | SD | Min | Max | WHO AQGs * |
|---|---|---|---|---|---|---|
| $SO_2$ | Wood | 0.17812 | 0.49526 | 0.00 | 8.750 | |
| | Charcoal | 0.01044 | 0.02028 | 0.00 | 0.450 | 40 μg/m$^3$ |
| | LPG | 0.03435 | 0.05445 | 0.00 | 0.550 | |
| | Kerosene | 0.21717 | 0.77785 | 0.00 | 8.130 | |
| $NO_2$ | Wood | 0.02295 | 0.12354 | 0.00 | 2.710 | |
| | Charcoal | 0.00107 | 0.00633 | 0.00 | 0.110 | 25 μg/m$^3$ |
| | LPG | 0.00250 | 0.01273 | 0.00 | 0.260 | |
| | Kerosene | 0.01216 | 0.02146 | 0.00 | 0.240 | |

(b)

| Fuel Type | Mean CO Concentration (μg/m$^3$) | | | |
|---|---|---|---|---|
| | 24 h | 8 h | 1 h | 15 min |
| Wood | 24.48 | 24.7 | 24.7 | 24.7 |
| Charcoal | 3.70 | 3.29 | 3.29 | 3.30 |
| LPG | 2.27 | 1.40 | 1.40 | 1.40 |
| Kerosene | 6.42 | 7.02 | 6.73 | 6.71 |
| WHO limit (μg/m$^3$) | 4 | 10 | 35 | 100 |

* AQGs denotes Air Quality Guidelines.

## 4. Discussion

Our study has demonstrated the dominance of wood (94.2%) as a primary source of cooking energy for households in this rural community, while also showing the high prevalence of stacking with charcoal being the most preferred secondary fuel. Recent findings from a cooking sector study showed that 86% of rural households relied on firewood for cooking [18].

We present the levels of gaseous emissions and particulate matter in households using wood, charcoal, LPG or kerosene as their primary cooking fuel. Daily average concentrations of $PM_{2.5}$ were high and beyond WHO limits in households using wood fuel, kerosene and LPG. Studies have found wood using homes to have extremely high particulate pollution, in some cases exceeding guideline levels in the order of 100 or higher [10,11,19]. This underscores the potential risk to health in an area where 94% of households rely on wood as their primary fuel. Although LPG is a more processed fuel compared to traditional cooking fuels like wood, $PM_{2.5}$ levels in LPG using households were considerably high in this setting. This is likely due to fuel stacking practices common in rural households where emissions from traditional cooking fuels compound exposure to fine particles. Similar findings were reported for urban slum households where wood, charcoal and kerosene using homes had the highest $PM_{2.5}$ levels while LPG and electricity users also had high levels [20]. In addition, most kitchens in the study community have earthen floors which when swept contribute to particulate pollution from dust.

Gaseous pollutants were below guideline levels. The low prevalence of LPG as well as the rural nature of the study community where traffic influence on indoor levels of $SO_2$ and $NO_2$ was very low explain these findings.

The spatial orientation and location of rural kitchens is a key factor to consider in characterizing collective household exposure to fine particles and toxic gases. Rural households in this community have a separate kitchen a few yards from the main house as a 'corrective strategy' to reduce exposure to other household members during cooking times, with the cook having the highest exposure. Therefore, these emission profiles provide crude estimates and are not an accurate measure of personal exposure to fine particles and toxic gases.

Limitations

We acknowledge the following limitations in our study:

1. Emissions were not analysed separately when households switched between fuels to characterize confounding secondary fuels.
2. We present uncorrected values since we did not collect data to compute a correction factor.
3. Kitchen HAP levels estimated in this study may not reflect actual exposure to individual household members. Monitoring personal exposure to fine particles and gaseous pollutants would give more accurate exposure assessment and shed light into the effectiveness of building kitchens a few yards from the main house.
4. The study did not assess the emissions associated with the use of LPG

We are, however, confident that the findings of this study present critical evidence needed for action to improve air quality in rural kitchens and in effect protect the health of the most exposed household members i.e., women and children.

## 5. Conclusions

Rural households in this study community primarily depend on wood fuel for cooking, exposing household members to fine particulate matter and toxic gases. To reduce HAP in rural households, interventions that encourage the transition to affordable cleaner fuels need to be scaled up.

**Author Contributions:** Conceptualization, D.M. and K.M.; Methodology, K.M.; Data Analysis and Visualization, D.M.; Resources, K.M.; Writing—Original Draft Preparation, D.M.; Writing—Original draft preparation, Review & Editing, D.M. and K.M.; Supervision, K.M.; Project administration, D.M.; Funding Acquisition, K.M. All authors have read and agreed to the published version of the manuscript.

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**Institutional Review Board Statement:** The study was conducted according to the guidelines of the Declaration of Helsinki and approved by the Ethics Committee of Amref Health Africa (protocol code AMREF-ESRC P690-2019, and 24 July 2020). The National Commission for Science, Technology and Innovation granted a research permit (License No.: NACOSTI/P/20/3410 and NACOSTI/P21/8989) for the study.

**Informed Consent Statement:** Informed consent was obtained from all subjects involved in the study.

**Data Availability Statement:** The data presented in this study are available on request from the corresponding author. The data are not publicly available because the study is still ongoing. Data anonymization and upload to a public portal would only be possible after closure of the project.

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**Conflicts of Interest:** The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript; or in the decision to publish the results

## Appendix A

**Table A1.** Distribution of primary and secondary fuels in households recruited for air quality monitoring.

| Primary Fuel | Secondary Fuel | | | | | Total |
|---|---|---|---|---|---|---|
| | Wood | Charcoal | LPG | Kerosene | None | |
| Wood | | 5 | | | 3 | 8 |
| Charcoal | | | | 3 | | 3 |
| LPG | 1 | 3 | | 1 | | 2 |
| Kerosene | | 2 | | | | 5 |

**Table A2.** Hours per day when particulate matter monitoring was done in different households.

| Primary Fuel | HH No | Hours Monitored Per Day | | | | Days Monitored |
|---|---|---|---|---|---|---|
| | | Day 1 | Day 2 | Day 3 | Day 4 | |
| Wood | 4 * | 24 | | | | 1 |
| | 5 | 23 | 23 | 24 | 24 | 4 |
| | 6 | 24 | 24 | 24 | | 3 |
| | 7 | 18 | 24 | 16 | 24 | 4 |
| | 8 * | 23 | 11 | | | 2 |
| | 9 | 24 | 24 | 24 | | 3 |
| | 11 | 24 | 24 | 24 | 22 | 4 |
| | 12 | 24 | 23 | 23 | 24 | 4 |
| | 13 | 24 | 24 | 24 | 19 | 4 |
| | 20 | 24 | 24 | 24 | 24 | 4 |
| Charcoal | 14 | 21 | 24 | 24 | 24 | 4 |
| | 17 | 24 | 24 | 24 | 24 | 4 |
| | 19 | 24 | 20 | 15 | | 3 |
| LPG | 1 | 24 | 24 | 22 | 24 | 4 |
| | 2 | 22 | 24 | 24 | | 4 |
| | 10 | 24 | 24 | 20 | | 3 |
| | 15 | 22 | 24 | 24 | 20 | 4 |
| | 18 | 12 | 16 | 12 | 8 | 4 |
| Kerosene | 3 | 24 | 24 | 24 | 24 | 4 |
| | 16 | 24 | 24 | 24 | 24 | 4 |

* Denotes households that were not included in analysis due to reduced days of monitoring.

## References


1. WHO. Household Air Pollution and Health. 2021. Available online: https://www.who.int/news-room/fact-sheets/detail/household-air-pollution-and-health (accessed on 14 June 2022).
2. KNBS. 2019 Kenya Population and Housing Census Volume IV: Distribution of Population by Socio-Economic Characteristics. *Kenya National Bureau of Statistics*. 2019. Available online: https://www.knbs.or.ke/download/2019-kenya-population-and-housing-census-volume-iv-distribution-of-population-by-socio-economic-characteristics/ (accessed on 14 June 2022).
3. Parikh, J. Hardships and health impacts on women due to traditional cooking fuels: A case study of Himachal Pradesh, India. *Energy Policy* **2011**, *39*, 7587–7594.
4. Bickton, F.M.; Ndeketa, L.; Sibande, G.T.; Nkeramahame, J.; Payesa, C.; Milanzi, E.B. Household air pollution and under-five mortality in sub-Saharan Africa: An analysis of 14 demographic and health surveys. *Environ. Health Prev. Med.* **2020**, *25*, 67.
5. Njenga, M.; Gitau, J.K.; Mendum, R. Women's work is never done: Lifting the gendered burden of firewood collection and household energy use in Kenya. *Energy Res. Soc. Sci.* **2021**, *77*, 102071.
6. Okello, G.; Devereux, G.; Semple, S. Women and girls in resource poor countries experience much greater exposure to household air pollutants than men: Results from Uganda and Ethiopia. *Environ. Int.* **2018**, *119*, 429–437.
7. Owili, P.O.; Muga, M.A.; Pan, W.C.; Kuo, H.W. Cooking fuel and risk of under-five mortality in 23 Sub-Saharan African countries: A population-based study. *Int. J. Environ. Health Res.* **2017**, *27*, 191–204.

8. Roberman, J.; Emeto, T.I.; Adegboye, O.A. Adverse Birth Outcomes Due to Exposure to Household Air Pollution from Unclean Cooking Fuel among Women of Reproductive Age in Nigeria. *Int. J. Environ. Res. Public Health* **2021**, *18*, E634.
9. Po, J.Y.T.; FitzGerald, J.M.; Carlsten, C. Respiratory disease associated with solid biomass fuel exposure in rural women and children: Systematic review and meta-analysis. *Thorax* **2011**, *66*, 232–239.
10. Ezzati, M.; Saleh, H.; Kammen, D.M. The contributions of emissions and spatial microenvironments to exposure to indoor air pollution from biomass combustion in Kenya. *Environ. Health Perspect.* **2000**, *108*, 833–839.
11. Bruce, N.; Bates, E.; Nguti, R.; Gitonga, S.; Kithinji, J.; Doig, A. Reducing Indoor Air Pollution through Participatory Development in Rural Kenya. *Indoor Air* **2002**. Available online: https://www.researchgate.net/publication/248762862_Reducing_Indoor_Air_Pollution_through_Participatory_Development_in_Rural_Kenya/citation/download (accessed on 14 June 2022).
12. Ochieng, C.A.; Vardoulakis, S.; Tonne, C. Are rocket mud stoves associated with lower indoor carbon monoxide and personal exposure in rural Kenya? *Indoor Air* **2013**, *23*, 14–24.
13. Majdan, M.; Svaro, M.; Bodo, J.; Taylor, M.; Muendo, R.M. Assessment of the biomass related indoor air pollution in Kwale district in Kenya using short term monitoring. *Afr. Health Sci.* **2015**, *15*, 972–981.
14. Fullerton, D.G.; Semple, S.; Kalambo, F.; Suseno, A.; Malamba, R.; Henderson, G.; Ayres, J.G.; Gordon, S.B. Biomass fuel use and indoor air pollution in homes in Malawi. *Occup. Environ. Med.* **2009**, *66*, 777–783.
15. Dionisio, K.L.; Howie, S.; Fornace, K.M.; Chimah, O.; Adegbola, R.A.; Ezzati, M. Measuring the exposure of infants and children to indoor air pollution from biomass fuels in The Gambia. *Indoor Air* **2008**, *18*, 317–327.
16. Van Vliet, E.D.S.; Asante, K.; Jack, D.W.; Kinney, P.L.; Whyatt, R.M.; Chillrud, S.N.; Livesy, A.; Charles, Z.; Seth, O. Personal exposures to fine particulate matter and black carbon in households cooking with biomass fuels in rural Ghana. *Environ. Res.* **2013**, *127*, 40–48.
17. StataCorp. *Stata Statistical Software: Release 15*; StataCorp LLC.: College Station, TX, USA, 2017.
18. KHCSS. Publication-Kenya Household Cooking Sector Study, 2019-Energypedia. 2019. Available online: https://energypedia.info/wiki/Publication_-_Kenya_Household_Cooking_Sector_Study,_2019 (accessed on 14 June 2022).
19. Irankunda, E.; Gasore, J. Assessing the Effects of Household Wood Burning on Particulate Matter in Rwanda. *Int. J. Environ. Sustain. Dev.* **2021**, *10*, 2312–5764.
20. Muindi, K.; Kimani-Murage, E.; Egondi, T.; Rocklov, J.; Ng, N. Household Air Pollution: Sources and Exposure Levels to Fine Particulate Matter in Nairobi Slums. *Toxics* **2016**, *4*, 12.