Factors predisposing women and children to indoor air pollution in Trans Nzoia County, Kenya

Gabriel O Dida (gdidah@gmail.com)
Technical University of Kenya https://orcid.org/0000-0003-2442-0352
Patrick O. Lutta
Maseno University
Paul O. Abuom
Maseno University School of Environment and Earth Sciences
Tomislav Mestrovic
Northeastern University
Douglas N. Anyona
Maseno University School of Environment and Earth Sciences

Research

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Abstract

Background: Indoor air pollution (IAP) is an increasing public health hazard in developing countries. Although fuelwood and kerosene are still heavily relied on as energy sources among households in the Sub-Saharan Africa, little information is available concerning the predisposing factors. The aim of this study was to establish the factors predisposing women and children to IAP and their health outcomes among residents of Trans Nzoia County, Kenya.

Methods: In this cross-sectional survey, a structured questionnaire was used to collect information on effects of IAP from 252 women respondents drawn from 14 villages. Households were the sampling units and the woman of the household with/or in custody of a child aged less than 5 years old selected as respondents.

Results: Mean age of respondents was 36.49 years, (95% CI [35.5, 37.5]), with most (81.3%) being able to read. Most (64.5%) houses were semi permanent, and in good condition. Up to 58.6% of households had average kitchen size of approximately 5.6 m^2, with most (84.5%) kitchens being located in separate building from main house. Majority the women (92.0%) and children (95.4%) had coughs of varying intensities during the year, while 31.5% of the women reported wheezing, and 98% experienced headaches. Wood and kerosene were the most preferred fuel types for cooking (96.8%) and lighting (97.4%), respectively. Smoke from the wood was identified as the dominant (96.8%) source of IAP. Education level, occupation, and family income were significantly associated with presence of eave spaces ($p \leq 0.05$). In addition, the indoor concentration was negatively associated with ventilation, education and semi-permanent buildings.

Conclusions: Supporting the impoverished households and increasing their level of awareness on health-effects of IAP occasioned by use of biomass fuel while cooking indoors may be the first step in implementing a programme aimed at reducing exposure among rural households in Trans Nzoia County.

Background

The World Health Organization recently ranked Indoor Air Pollution (IAP) from solid fuels among the top risk factors attributed to preventable loss of disability-adjusted life years [1, 2]. Indoor air pollution causes an estimated four million annually across the world and has an overall attributable mortality that is about 50% higher among adult women than men [3–5]. Of the approximately 1.3 billion people living in poverty, 70% are estimated to be women, many of whom live in female-headed households in rural areas [6, 7]. Sadly, Most of these women are exposed to high level of smoke pollution for more than 5 hours per day during cooking [8].

Indoor air pollution causes serious hazards and is listed as the leading environmental risk factor for female mortality, accounting for 5% of all female deaths in the developing world — even more than those caused by malaria each year [8, 9]. According to the International Energy Agency (IEA) [10], there will still be 1 billion people having no access to electricity and 2.6 billion people without access to clean cooking facilities by 2030. It is estimated that about 2.5 billion people in the world rely on biomass fuel such as dung, wood, agricultural residues and coal for cooking, heating and lighting [11, 12]. In the African region, more than half a billion people, representing 78% of the African population still rely on biomass fuel for cooking and heating [13]. In Kenya, 68% of the populations rely on biomass fuel for cooking and heating with up to 95% of the energy consumed in rural areas being in the form of wood, agriculture residue and animal waste [14]. Another study by REN21 [15], postulates that 84% of Kenyan population relies on biomass fuel for cooking.

When used in simple cooking stoves, these biomass fuels emit substantial amounts of toxic pollutants. In households with limited ventilation (as is common for many households in rural areas), exposures levels for household members, particularly women and young children who spend a substantial duration indoors, have been measured to be many times higher than the World Health Organization (WHO) guidelines and national standards [5, 16, 17]. Indoor air pollution (IAP) from domestic biomass combustion is therefore a serious cause of health problems that disproportionately affect women and young children in rural areas of low-income developing countries.

In Kenya, low-income households rely heavily on biomass fuel for cooking and heating, resulting in high levels of particulate matter and carbon monoxide (CO) emission in their houses. In some instances, unacceptably high emission levels that are up to 1,000 times higher than the acceptable EPA 1 – hour standard of 50μg/m³ have been reported [7, 18]. In many households, most of the cooking is done by women (main cooks), often in poorly ventilated houses; evidence of which is the heavy deposits of soot on the inside walls and roofs of such houses and kitchens [19, 20].

During cooking, it is common practice to find the women and the very young children together in the kitchen often strapped on their mothers' backs. In the process of staying under such conditions for long periods (e.g., hours), those in the kitchen end up inhaling the respirable suspended particles (RSP) resulting from incomplete combustion of biomass fuel. It is, therefore, likely that women and young children are particularly at a higher risk of developing ARI owing to the prolonged duration of time spent in the kitchen compared to men [21]. Moreover, children are at a higher risk due to their low immunity [22].

Given that IAP resulting from smoke is a serious cause of death among children in developing countries, efforts to tackle childhood acute lower respiratory infection (ALRI) are still falling short of target. There is evidence from previous studies that despite an increase in knowledge on causes of ARI and attitudes towards IAP and its ill effects particularly in areas where interventions have been executed, changes in behavior and practices by the community has still not been realized [21, 23]. This calls for a specific studies and actions focused at preventing further deaths from indoor air pollution [2, 24]. Cutting down on IAP will contribute to better respiratory health among the most affected as well as reduce associated health risks. A reliable source of information on the extent of IAP in rural areas of developing counties is, hence, a pivotal step for rapid intervention.

In a relatively cold region such as Trans Nzoia County in Kenya [25 26], the residents have a habit of closing windows and doors most of the time even when using firewood as a source of fuel for cooking and warming themselves. Such acts increase indoor air pollution thus increasing the exposure to household occupants more so the women and under five year old children who in most cases happen to be closest to the cooking stove. This study sought to establish the factors predisposing women and children to IAP and their health outcomes among residents of Trans Nzoia County, Kenya.

Methods

Study area

This study was conducted within Kaplamai location of Trans-Nzoia County in the western part of Kenya. Kaplamai location has 2 sub locations and 14 villages [28]. The location has a high incidence of malaria, upper respiratory diseases and diarrheal diseases in that order [28]. The location receives moderate to heavy rainfall throughout the year with a peak between March and May. The main cash crop is maize; though subsistence farming of other food crops is practiced, alongside small scale livestock rearing. Kaplamai location had a total population of 23, 100 as at 2005 [27].

Study design

This was a cross-sectional study in which 252 women respondents were randomly selected from a sample population of 23,100 household members drawn from 14 villages within Kaplamai location. Households were the sampling units and the woman of the household with/or in custody of a child aged less than 5 years old selected as respondents. A total of 18 households were selected from each of the 14 villages to make a sample size of 252 women. A structured questionnaire was used to collect data from the selected respondents

Data Analysis

The quantitative data generated was analyzed descriptively to give summaries of study variables as well as inferentially by conducting chi-square test, logistic regression test, and multivariate analysis. The Statistical Package for Social Sciences Version 20.0 (SPSS Inc., Chicago, Ill., USA) was used for data analysis purposes. P value of < 0.05 (two-sided) was considered statistically significant.

Ethical Considerations

Ethical approval to carry out this study was obtained from Maseno University Ethical Review Committee. Participation in this study was voluntary for all participants and each of them gave their written informed consent to participate in the study. The provincial administrators were briefed about the study and its objectives, procedures and the overall requirements. Thereafter, permission was sought and obtained from the Trans Nzoia County Commissioner for the study to be conducted in the area.

Results

Socio-Demographic Characteristics

The mean age of study respondents was 36.49 ± 10.86 years (± SD). The median (range) of all the people in the household was 7 (2–27), with 1 (0–7) female of 14 years and above being recorded among the households studied. Most (46.2%) households had 2 children aged below five years and another 42% had 3 children below 5 years old. Slightly over half 127 (50.6%) the respondents had attained primary school level of education, while 77 (30.7%) had attained secondary level and 10 (4.0%) tertiary level of education. However 37 (14.7%) had no formal education. The main source of income for most 164 (65.3%) households was farming, while other sources included formal employment for 45 (17.9%) households, business for 39 (15.5%) households, and other unspecified means for 3 (1.2%) households.

Type and condition of the house

Most 162 (64.5%) respondents lived in semi-permanent housing structures, 57 (22.7%) in temporary structures, and 32 (12.8%) in permanent houses. About half 125 (49.8%) of the houses were in good condition (Table 1).

Table 1
House and kitchen characteristics

Interest	Observation	N	Percentage
Main house type	Temporary	57	22.7
	Semi-permanent	162	64.5
	Permanent	32	12.7
General condition of house	Excellent	4	1.6
	Good	125	49.8
	Fair	112	44.6
	Poor	10	4.0

Kitchen size, location and state (enclosed or not)

Most 147 (58.6%) respondents had average sized (60 sqft) kitchens, 82 (32.7%) had small sized kitchens while 22 (8.8%) had large sized kitchens. Most 212 (84.5%) kitchens were located in a separate building from the main house. Most 212 (84.5%) the kitchens were enclosed (Table 2).

Table 2
Kitchen size, location and state

Interest	Observation	N	Percentage
Kitchen size	Large	22	8.8
	Average	147	58.6
	Small	82	32.7
Location of kitchen	Separate building	212	84.5
	Separate room within main house	34	13.5
	Main living area in house	5	2.0
State of the kitchen	Enclosed	210	83.7
	Semi closed	41	16.3

Ventilation type, presence of eave space and lighting in the cooking place

Cross ventilation was the most common 110 (43.8%) type of ventilation used in cooking places, with 78 (31.1%) and 63 (25.1%) of the cooking places having through and door only ventilations, respectively. Most 159 (63.3%) cooking places lacked eave spaces, with only a small proportion 31 (12.4%) of the cooking places being well lit (Table 3).

Table 3
Ventilation type, presence and size of eaves and lighting of kitchen

Interest	Observation	N	Percentage
Type of ventilation of cooking place	Cross ventilation	110	43.8
	Through ventilation	63	25.1
	Through door only	78	31.1
Presence of eaves spaces	Yes	92	36.7
	No	159	63.3
Size of the eaves spaces	None	159	63.3
	6 inches	73	29.1
	6–9 inches	15	6.0
	9–12 inches	1	0.4
	More than 12	3	1.2
Lighting of cooking place	Bright and airy	31	12.4
	Average	169	67.3
	Dark and enclosed	51	20.3

Household fuel characteristics

Various sources of indoor air pollution were identified within the house. The majority of households 243 (96.8%) relied on wood as their main source of fuel for cooking and heating with an equally high proportion 247 (98.4%) of respondents citing fire place as the major source of indoor air pollution (Table 4). Kerosene was the most 245 (97.6%) preferred household fuel for lighting while electricity was used by only 0.8% of the respondents (Table 5).

Table 4
Sources of indoor air pollution, main fuel used for cooking and its source

Interest	Reported	N	Percentage
Sources of indoor pollution	Fire place	247	98.4
	Kerosene lamps	1	0.4
	Candles	0	0.0
	Other	3	1.2
Main fuel used in Household	Wood	243	96.8
	Charcoal	1	0.4
	Residues	6	2.4
	LPG	0	0.0
	Kerosene	0	0.0
	Electricity	0	0.0
	Solar	0	0.0
	Other	1	0.4
How fuel used was obtained	Bought	84	33.5
	Gathered	167	66.5

Table 5
Main type of fuel used for lighting in the household

Interest	Reported	N	Percentage
Main fuel used for lighting	Electricity	2	0.8
	Petrol	0	0.0
	Batteries	0	0.0
	LPG	0	0.0
	Kerosene	245	97.6
	Candles	0	0.0
	Other	4	1.6
Whether fuel for lighting was bought	Yes	250	99.6
	No	1	0.4

Health Implications of Indoor Air Pollution to Women and Children

Most respondents, i.e. 231 (92.0%) of them, reported having coughs of varying intensities over a 12 month period – 106 (45.9%) of whom reported coughing in the same manner on most days, while 70 (30.3%) reported coughing in the same manner for 1 to 2 months. Almost one third 77 (33.2%) of the respondents reported coughing in a similar manner for a period of 2 years (Table 6); Fig. 1–2). Coughing was significantly associated to sources of air pollution in the households (Exact chi = 14.34, p = 0.03).

Table 6
Coughing among women

Whether respondent had a cough in previous 12 months	N	Percentage
Had a cough	231	92.0
Had no cough	20	8.0
Whether respondents coughed in a similar way on most days	N	
No	106	45.9
Yes	125	54.1
Duration in months in the past year that respondent coughed in a similar manner		
> 6	50	21.6
3–5	63	27.4
1–2	70	30.3
< 1	48	20.7
No. of years respondent had been coughing in a similar manner		
1	73	31.5
2	77	33.2
3	24	10.6
4	4	1.7
5	31	13.3
> 5	22	9.7

Coughing among children under five years associated with IAP

Most 239 (95.4%) children had a cough the previous week, with 129 (51.2%) of the coughs being associated with increased rate of breathing (Table 7). Coughing in children was significantly associated with the condition of the kitchen (enclosed or not) (Exact chi = 7.11, p = 0.02), while children under 5 years who stayed in enclosed kitchen were significantly more likely to have a cough than those in kitchens that were not enclosed (OR = 3.65, 95% CI[1.34,9.95], p = 0.01).

Table 7
Respiratory problems among children related to indoor air pollution

No. of children under five in the household	N	%
1	111	44.2
2	112	44.6
3	22	8.8
> 3	6	2.4
If children had a cough the previous week		
No	12	4.6
Yes	239	95.4
Condition of breathing for those who had a cough		
Normal	122	48.8
Faster	129	51.2
Other respiratory health problems experienced by under 5 year olds during time of study		
None	37	14.8
Colds	206	82.0
Others	8	3.2

Chest problems (wheezing) and sputum production among women due to IAP

Some of the respondents 79 (31.5%) reported wheezing, with a majority 63 (79.8%) of them reportedly wheezing when they had a cold. Most 28 (35%) of those who reported wheezing, reportedly produced the wheezing sound for the previous two years, 19 (24.4%) during the previous year, and 17 (21.2%) during the previous 5 years. Most 157 (62.5%) respondents produced sputum, with 55 (35%) of them experiencing it on most days. Most 56 (35.5%) of those who reportedly produced sputum mentioned that they had produced sputum in a similar fashion for more than 5 months, while 52 (33.6%) reported producing it for 2 years. Sputum production was significantly associated with house type (Exact chi = 7.29, p = 0.03).

Eye infections among women respondents resulting from indoor air pollution

Most 233 (92.8%) women respondents reported experiencing various eye problems. Over 87% reported having watery eyes, 167 (72.1%) reported eye irritation, 101 (43.3%) had red eyes, 61 (26.6%) had sore eyes, while 27 (11.2%) cited other eye problems. Eye problems among women were significantly associated to sources of air pollution in the households (Exact chi = 13.21, $p < 0.001$).

Headaches and accidents resulting from IAP

Majority of the women 246 (98.0%) reported experiencing headaches within the past 12 months, with a large proportion of those 85 (34.6%) admitting to experiencing the headaches on most days, 28.0% once a week, 2% every day and 35.4% less often. Only 12 (4.9%) of the women attributed the headaches to smoke, while 42.3% attributed it to cold (Table 8).

Table 8

Headaches and their causes among women

Headache in the previous 12 months	**N**	**%**
No	5	2.0
Yes	246	98.0
How often headaches were experienced		
Every day	5	2.0
Most days	85	34.6
Once per week	69	28.0
Less often	87	35.4
Factors attributed to the headaches		
Smoke	12	4.9
Colds	104	42.3
Other	130	52.8

Relating background factors to IAP

Over 50% of the variation in IAP was explained by the independent variables: house type, education and ventilation. The results were statistically significant, with lack of ventilation ($t = -4.62$, $p = < 0.002$), non-formal or primary level of education, ($t = -3.74$, $p = 0.004$) and semi-permanent houses ($t = 5.353$, $p = 0.001$) showing significant relationships (Table 9).

Table 9
Logistic regression on background factors influencing indoor pollution

Regression Statistics						
Multiple R	0.53257					
R Square	0.56381					
Adjusted R Square	0.43724					
Standard Error	0.5349					
Observations	251					
ANOVA						
	Df	*SS*	*MS*	*F*	*Significance F*	
Regression	3	3.100283	1.700094	14.46971	1.64E-09	
Residual	249	18.69511	0.109898			
Total	251	23.79539				
	Coefficients	*Standard Error*	*t Stat*	*p-value*	*Lower 95%*	*Upper 95%*
Intercept	0.66275	0.09353	7.085973	7.89E-12	0.478788	0.846718
Age	0.00136	0.00171	0.68580	0.493	0.00238	0.072543
Ventilation	-0.13127	0.05185	-4.61683	0.002	0.10491	0.422368
Education	-0 16256	0.12417	-3.74271	0.004	0.29513	0.374105
Semi-permanent	0.39734	0.54135	5.35359	0.001	0.17869	0.51599

Discussion

Indoor air pollution refers to chemical, biological and physical contamination of the air quality within and around buildings and structures that may result in adverse health effects for household inhabitants. This study sought to establish the factors both socio-demographic and structural that predispose women and children to indoor air pollution among rural families living within Kaplamai location in Trans NzoiaCounty. Historically, biomass fuels (wood, charcoal, sawdust, animal dung, and agricultural wastes) have been used for cooking, lighting and heating in developing countries. Duflo *et al*. [29], noted that the use of such fuels as sources of energy has constantly been about 25 percent since 1975. It is estimated that by 2030 over 2.7 billion people across the world will still be dependent on biomass fuels [30]. These energy sources, which are heavily relied upon by billions of people globally, have continued to raise health and environmental concerns and are now recognized as a significant source of potential health risks to exposed populations throughout the world [31]. It is of no wonder that the Lancet Commission on Pollution and Health endorses cleaner fuels at all levels of intervention [32].

In the current study, information on the age of the household head, occupation, ability to read and level of education were assessed. In addition, the marital status, main source of family income and household composition by female aged above 14 years and children aged below five years were also assessed with the aim of establishing the extent to which these factors influence household vulnerability to IAP. Given that that majority of the household heads in the current study were aged between 25 and 34 years is regarded advantageous to these families, as members in this age group are likely to be much more aware of the sources of IAP and its potential health impacts on household members. Being middle aged, this group could also be considered as mature and more likely to be financially stable compared to the younger age sets or the elderly [33]. Financial stability is regarded as a critical determinant of the choice of fuel type used by a household. It also dictates the type, size and design of the family house as well as the location, size and design of the kitchen. The type of biomass fuel used greatly influences the levels of Indoor Air Pollution (IAP). All these factors are however determined by household income.

In the current study, 44.6% of women respondents were not employed, while another 20.7% worked as unskilled labourers with most (40.2%) households generating an average monthly income of between Ksh. 2001 and 5000. Consistent with the findings of this study, Kimani [34] observed that a majority of women work in the informal sector, handling small-scale businesses with meager income to even sustain their families. Insufficient household income can only allow for the most basic commodities such as food for the family forcing households to settle for the cheapest fuel sources such as plant remains and firewood that are mostly obtained for free.

Studies show that when women are overly dependent on their spouses, they are unable to make important or critical decisions especially on matters relating to the family expenditures [35]. Poverty and illiteracy remain the key barriers to adoption of cleaner fuels, with the slow pace of development in many developing countries a further indication that the use of biomass fuels will continue for many decades to come by many poor households. Akin to other studies, the use of biomass fuels among poor households in Kenya is likely to remain stable or even increase in the near future, as few rural families can afford alternative fuel that is higher on the energy ladder (such as liquefied petroleum gas and electricity, which are regarded as being cleaner but more expensive) [36]. Accordingly, the choice of fuel type used by a household becomes cleaner and more convenient, efficient and costly as people move up the energy ladder; a feat that can only be achieved through economic empowerment of women.

Studies show that households at the lower income levels tend to be at the bottom of the energy ladder; using fuel that is cheap and locally available but not very clean or efficient. According to the World Health Organization, over three billion people worldwide are at these lower rungs and depend on biomass fuels-crop waste, dung, wood, leaves and coal to meet their energy needs [37]. It is estimated that globally a majority of poor households rely on biomass fuels for everyday household energy needs, with most of those exposed being women, who are normally tasked with food preparation, and children under the age of five years who are most often with their mothers in the cooking area [38]. Consistent with the WHO [37] findings, the current study established that a large percentage (96.8%) of households relied on wood as the main source of fuel for cooking and heating with crop residues, charcoal and other sources being mentioned, albeit by less than 4% of the respondents. The second most preferred fuel for cooking and heating for a majority of households after wood was crop residues. These findings were also consistent with those of [39], who reported that approximately 3 billion people in the world use solid fuels. Precisely, 2.4 billion people use biomass (wood, charcoal, animal dung, crop wastes), and the remainder utilize coal for the majority of their household energy needs because these are relatively cheaper and thus available to a majority of the people.

Various studies [40, 41] have shown that solid fuels are extensively used for cooking and home heating in developing countries, especially in rural areas. Further, studies also show that in sub-Saharan Africa, wood fuel is acknowledged as the main source of energy in most rural communities [42], with an estimated daily fuel wood consumption of 500,000 tons per day in Africa. Sanders, [43] reported that the three-stone open fire commonly used in many developing countries is only about 10–15% efficient leaving most of the energy content of the fuel wasted. Poverty contributes highly to indoor air pollution as poor households are not able to afford alternative efficient fuel such as electricity or LPG gas and thus remain vulnerable to poor health. As such, it becomes a vicious cycle for members of the affected household as they remain trapped both in poverty and in poor health [44, 45].

Besides use of biomass fuel, several other factors at both community and household levels determine the extent of indoor air pollution among households. These factors include the design of the house, size of the kitchen and its location, availability and size of eave spaces, ventilation size and design among others. In the current study, a large proportion of respondents lived in semi permanent houses, a few others in temporary houses and only a handful in permanent houses. In terms of kitchen size, over half the households had average sized kitchen, with a small proportion (8.8%) having large sized kitchens. Kitchen size is an important contributor to indoor air pollution since burning biomass fuel indoors produces large quantities of smoke, providing a perfect avenue for human exposure to smoke especially in confined space without adequate ventilation [46].

In the current study, most (84.5%) kitchens were housed in a separate building from the main house, while 13.5% of the kitchens were located in a separate room within the main house and 2.0% were located in the main living area. Consistent with the current study findings, a similar study by Oguntoke *et al.* [47] in Odede area of South Africa also established that 25% of the respondents located their kitchens indoors (separate room within the main house); while a larger majority had their kitchen in a separate room outside the main house; but in close proximity to the main house. In the current study, most (84.5%) respondents had enclosed kitchens as opposed to 15.5% who had semi-closed kitchens. The state of the kitchen influences the levels of indoor air pollution, with enclosed kitchens likely to confine higher levels of smoke indoors than non-enclosed kitchens.

In the current study, most (63.3%) houses did not have any eave spaces in their kitchens, though for those that had, they were small sized ranging between 0 and 6 inches in size. Most (43.8%) eaves were the cross ventilation type, with another 31.1% being door ventilation type. In addition, the IAP was negatively associated with ventilation and education, while semi-permanent houses and age were positively associated with it. The reasons for these could be that with increase in education individual knew the effects of IAP. This was similar with age, and this enabled them to institute proper housing policy. House types included that of grass-thatched and most of them had small round windows or without one at all. Semi-permanent houses were those with corrugated iron sheets and most of them had spacious eves.

In a study on efficiency of eave spaces, Bruce *et al.* [39], observed a reduction in particulate levels from 2042 g/m^3 to 766 g/m^3 with a slight increase in the size of eave space. Other researchers have however argued that eave spaces alone cannot protect women and children from the effects of indoor air pollution since proximity to the fire place, duration of stay in the kitchen and length of exposure differ and these play a vital role [39].

Given that most households in the current study used biomass fuel most of which was burnt indoors on open fires or poorly functioning stoves, often with no or limited ventilation, a large numbers of women and young children within Kaplamai Division are therefore exposed to high levels of air pollution, every day of the year. Limited ventilation implies that free flow of smoke from the kitchen is inhibited thus exacerbating the effect of indoor air pollution. The WHO [48] acknowledges that the greatest global burden of air pollution exposure occurs not outdoors in the cities of the developed world, but indoors in poor rural communities. Poor ventilation coupled with incomplete combustion by most of the stoves used results in substantial emissions which in the presence of inadequate ventilation and air circulation produce very high levels of indoor pollutants [49]. Earlier studies including those of Smith *et al*. [50], Collings *et al*. [51], Martin [52] and Ellegard [53], showed that indoor concentrations of particles usually exceed set guidelines by a large margin. For instance 24-hour mean PM_{10} levels are typically in the range 300–3,000 mg/m^3 and may reach 30,000 mg/m^3 or more during periods of cooking. The United States Environmental Protection Agency's standards for 24-hour average PM_{10} and $PM_{2.5}$ concentrations are 150 mg/m^3 and 65 mg/m^3, respectively [14]. The current study however had a discrepancy as it did not measure the actual PM_{10} or $PM_{2.5}$ concentration, and it would therefore be difficult to compare them against the USEPA standards.

An individual's true exposure may vary with the size of the kitchen and an individual's proximity to the stove during periods when the stove is in use. Saksena *et al*. [54] reported concentrations of 20,000 $\mu g/m^3$ near the cooking stove and much lower concentrations in the rest of the kitchen and in other rooms within the house, while Ezzati and Kammen [55] reported peak concentrations greater than 50,000 $\mu g/m^3$ in the immediate vicinity of the cooking stove. These two studies suggest that women, children and even girls who normally seat close to cooking stoves for extended periods of time are likely to be exposed to higher levels of carbon monoxide compared to other household members. USEPA [14] estimated the mean (24-hour level) of carbon monoxide in homes using biomass fuels in developing countries to range between 2 and 50 ppm, with values ranging between 10 and 500 ppm likely to be achieved during the cooking process. This is far above the 8 hour average carbon monoxide standard of 9 ppm set by the USEPA [14].

Health outcomes of indoor air pollution

A number of poor health outcomes result from the use of biomass fuel that is normally burnt in poorly ventilated kitchens. Other factors such as duration of time that women and children spend exposed to smoke among and the habit of opening or closing windows and doors while cookingalso exacerbate the health risk. According to Begum *et al*. [56], indoor air pollution has significant influence on women and children. In the current study, over 90% of women and children experienced coughing of varying intensities over a 12 month period, with 45.9% of the women reported coughing in the same manner for several days, while 30.3% coughed in the same manner for over 1 month. Coughing was significantly associated with IAP. Inhaled particles and gases may expose women to Acute Respiratory Infection (ARI) such as pneumonia which is one of the causes of morbidity in Kenya [57]. It is, therefore, likely that among adults, women are particularly at higher risk of developing ARI because of the prolonged time they spend in the kitchen preparing meals for families compared to men. Children are also at a higher risk than adults because their airways are relatively narrower and more easily obstructed and their oxygen demand relative to body weight is higher resulting in relatively larger inhaled volumes [22, 58].

Furthermore, there is sufficient evidence linking smoke from solid fuel use with acute infection of lower respiratory tract, chronic obstructive pulmonary disease and lung cancer [59]. Shabir *et al*. [60] estimates that ARI’s are the single most important cause of mortality in children aged below 5 years, and they account for between 1.9 million and 2.2 million children deaths annually. In a study of 1532 female patients above 40 years and exposed to kitchen smoke over a span of 13 years, Mishra *et al*., [61] observed high incidence of chronic bronchitis followed by bronchial asthma, pulmonary tuberculosis and bronchiectasis. There is also evidence, mainly from China, that exposure to coal smoke in the home markedly increases the risk of lung cancer, particularly in women [62], while there is also mounting evidence that cooking with biomass substantially increases the risk of developing active tuberculosis [63, 64]. Another set of health problems associated with indoor air pollution reported in this study include sputum production, headaches and wheezing, all of which are as a result of IAP and which were confirmed by very recent studies in the field [65].

In the current study, a number of eye problems were also reported and linked to the smoke from the cooking stove. Khalequzzaman *et al*. [66] and Díaz *et al*. [67] reported that tears coming out from the eye, eye discomfort and sore eyes, redness and itching of the eye, eye irritation, muscle weakness, fatigue, sleeping problems, stomach pains, dry mouth, and blindness linked to cataracts, trachoma, and conjunctivitis are further indications of indoor air pollution within houses. The constant and continued exposure to smoke from biomass fuel continues to cause both long and short-term health threats to members of the household – hence the need to cut down on expose to IAP.

Studies show that although reducing exposure to indoor air pollution from solid fuels can be achieved through several interventions targeting emission sources through improved energy technology, well designed houses and provision of ventilations. Encouraging behavior change and time-activity budget is also a strategy that can reduce IAP. Most current studies however suggest that the main focus should be on improved (high-efficiency and low emissions) stoves and fuels, which provide more affordable options for the poor majority in developing countries as opposed to complete shift to non-solid fuels [68]. In that regard, the Clean Cooking Alliance has singled out Kenya as one of eight priority countries for clean cookstove endowment [69, 70].

However, while use of improved stoves has been proposed as being highly reliable in reducing indoor air pollution, the challenge remains on the rate of uptake of this simple technology and its usage. Experts warn that if not properly executed, these improved stoves or any other interventions for that matter might not achieve the much-desired results. A cross-sectional population-based study of 353 households in Kasarani, Kenya, has showed that higher environmental health literacy may help improve IAP-associated health outcomes among those using solid fuel stoves [71]. Finally, awareness campaigns on IAP exposure effects and interventions for reduce the use of biomass fuels are warranted in sub-Saharan Africa [72].

Conclusion

In conclusion, supporting the poor households and increasing their level of awareness on health-effects of indoor air pollution occasioned by use of biomass fuel while cooking indoors may be the first step in implementing a programme aimed at reducing exposure among rural households in Trans Nzoia County and other rural areas of Kenya as well. There is also a need to redesign the kitchens to allow adequate ventilation, while cooking points should be separated from the dwelling units to reduce negative health outcomes. In addition, keeping children out of the kitchen during cooking should be encouraged to protect them from illnesses triggered by IAP. Successful implementation of improved stoves requires active participation by those directly affected (particularly women), with cooperation from other household members and the county government though related sectors like health, energy, environment, housing and planning.

List Of Abbreviations

ALRI: Acute Lower Respiratory Infection; ARI: Acute Respiratory Infection; CO: Carbon Monoxide; DMOH; GoK: Government of Kenya; HH: Household; IAP: Indoor Air Pollution; MoH: Ministry of Health: WHO: World Health Organization

Declarations

Ethics approval and consent to participate

This study received approval from the Ethics Review Committee of Maseno University Authority to conduct the study was obtained from the County Commissioner's offices in all the areas surveyed. Area chiefs, and other stakeholders were also consulted.

Consent for publication

Not applicable.

Availability of data and materials

Datasets generated during the current study are available from the authors by written request to legitimate scientific investigators capable of using the data.

Competing interests

The authors declare that they have no competing interests

Funding

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Authors' contributions

GD, POL and DNA conceived and designed the study. GD, POL and DNA organized the fieldwork. POL and DNA collected the data. POL and DNA performed the statistical analyses. GD and POL wrote the paper. All authors revised and reviewed the manuscript critically for important intellectual content. All authors read and approved the final paper.

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Figures

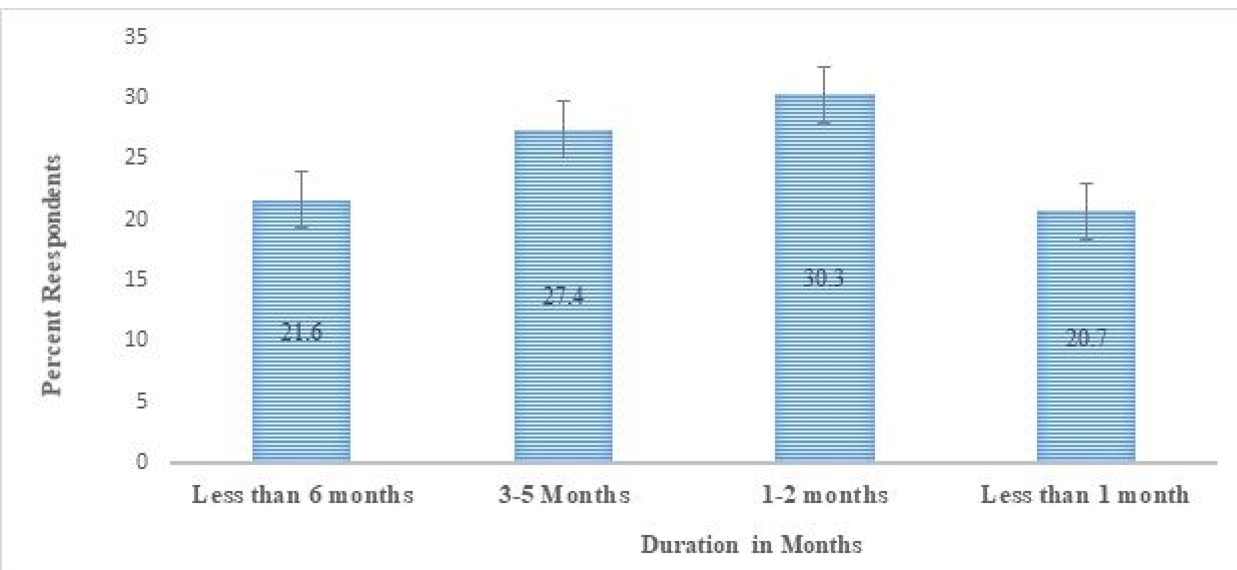

Figure 1

Duration in months in the past year that respondent coughed

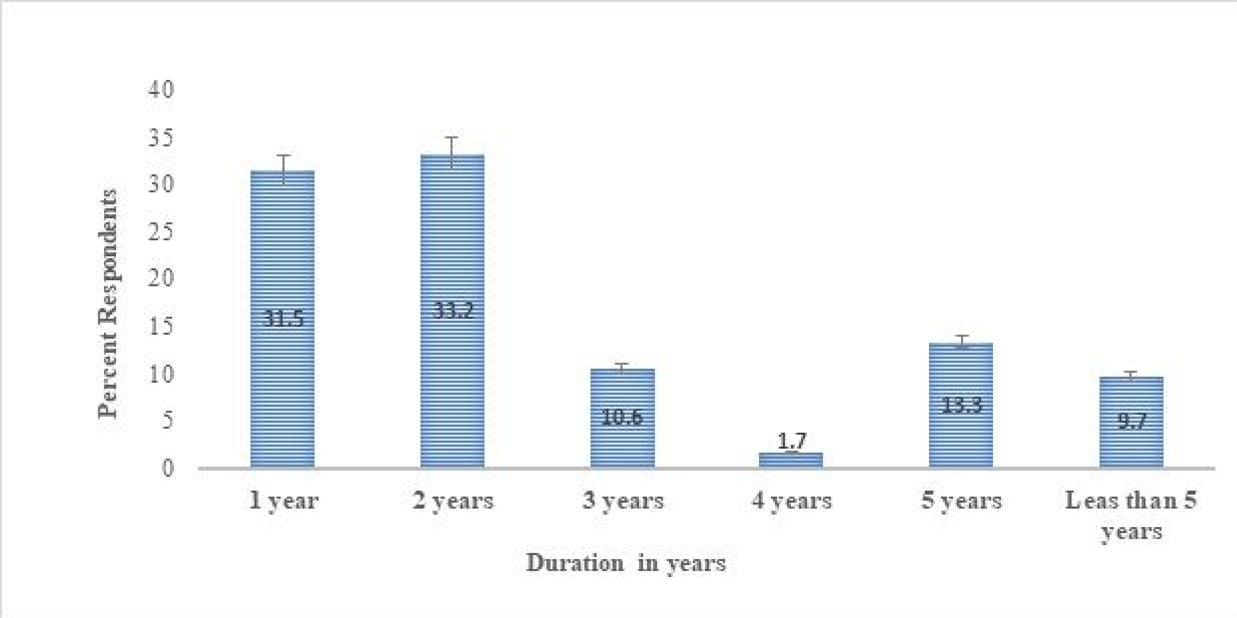

Figure 2

Number of years respondent had been cough